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TABLE OF CONTENTS

ABSTRACTS AND PAPERS

REPORTS OF SOCIETY BUSINESS

ABSTRACTS AND PAPERS

In alphabetical order by first author

Midden Mounds of Baja California: Trash Dumps with a View

Hans Bertsch

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Shells in midden mounds provide significant archaeological and anthropological information about centuries-long patterns of human use of molluscs. The original peoples of Baja California often savored their seafood while enjoying a panoramic vista.

Las Concheras de Baja California: Basureros con una Vista

Las conchas encontradas en las concheras proveen información arqueológica y antropológica significativa sobre siglos de patrones del uso humano de los moluscos. Los indígenas de Baja California frecuentemente saboreaban sus mariscos mientras gozaban una vista panorámica.

Father Kino, Abalones, and the Island of California

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Dedicated to Helen DuShane

Thirty years of explorations, missionary activities and mapping throughout Lower California and the Pimería Alta by Father Eusebio Kino, S.J., dealt the final and complete blow to the "island of California." Passages from his Historical Memoirs describe the important role that blue abalone shells played in resolving the geographic conundrum of California (see Bertsch, in press).

Literature Cited

Bertsch, Hans. In press. *Las conchas azules* (The blue shells): Father Kino, abalones, and the Island of California. The Nautilus.

El Padre Kino, Los Abulones, y la Isla de California

Luego de 30 años de exploraciones, actividades misionales y trazo de mapas a lo largo de la Baja California y de la Pinería Alta, es el Padre Eusebio Kino, S.J., quien asesta el último golpe para derribar la noción de la "Isla de California". Presentaré algunos pasajes de sus memorias para mostrar el importante papel que tuvieron las enormes conchas azules de adulón para resolver el acertijo soble la Isla o Península de California.

Description of the First Tritoniid Nudibranch Found Feeding on a Zooanthid Anthozoan, with a Preliminary Phylogeny of the Tritoniidae

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This paper describes the first tritoniid nudibranch known to feed on zooanthid anthozoans. *Tritonia papalotla* Bertsch, Valdés & Gosliner, 2009, differs from all known species of Tritoniidae in its uniform brownish color pattern, undulating mantle margins, retractile digitform respiratory organs, prominent dorsal vessels, uniseriate radula, and possession of both a receptaculum seminis and a bursa copulatrix. Owing to the extreme divergence of this species from other members of the Tritoniidae, a preliminary phylogenetic analysis was undertaken to establish its phylogenetic position relative to other members of the Tritoniidae. Despite the lack of robustness of the phylogeny, it is evident that the majority of tritoniid genera currently recognized are not monophyletic and a major systematic revision of the family is needed. *Tritonia papalotla* is included in a polytomy containing eight other tritoniid taxa in four different genera. The majority of these taxa are species currently placed in *Tritonia*. For this reason, our new species is tentatively described as a *Tritonia*, the oldest genus within the family, until a thorough revision of the family is undertaken. The majority of its unique morphological attributes are shown by the present analysis to represent autapomorphies. For this reason, it is not included in a new superspecific taxon.

Descripción del Primer Nudibranquio Tritónido Conocido que se Alimenta de Antozoos Zoantarios, con un Análisis Preliminar de Tritoniidae

En este trabajo se describe el primer nudibranquio tritónido conocido que se alimenta de antozoos zoantarios. *Tritonia papalotla* Bertsch, Valdés & Gosliner se diferencia de todas las demás especies de Tritoniidae por su patrón de color pardo (café) uniforme, la presencia de

márgenes del manto ondulados, órganos respiratorios retractiles digitiformes, venas dorsales prominentes, rádula uniseriada, y la posesión de un receptáculo seminal y una bolsa copulatriz. Debido a la divergencia extrema de esta especie con otros miembros de Tritoniidae, un análisis filogenético preeliminar ha sido llevado a cabo para establece su posición en relación a otros miembros de la familia. Pese a la falta de robustez en la filogenia, es evidente que la mayoría de los géneros de Tritoniidae que están actualmente reconocidos no son monofiléticos y una revisión más completa de la familia es necesaria. *Tritonia papalotla* está incluida en una politomía que contiene otros ocho taxones de tritónidos pertenecientes a cuatro géneros diferentes. La mayoría de estos taxones son especies actualmente incluidas en *Tritonia*. Por esta razón, nuestra nueva especie es tentativamente descrita como un miembro de *Tritonia*, hasta que se lleve a cabo una revisión de la familia. La mayoría de las peculiaridades morfológicas de *Tritonia papalotla* son, de acuerdo con el presente análisis, autoapomorfías. Por esta razón esta especie no se ha incluido en un nuevo taxón supraespecífico.

Hermaphroditism in *Pinna rugosa* at San Ignacio Lagoon

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The commercial fishery of the pen shell *Pinna rugosa* in Baja California Sur, México, is an established activity despite the lack of basic biological knowledge even about its reproductive cycle. We studied a natural population in San Ignacio Lagoon from March 2000 to April 2003 to propose some strategies to establish a sustainable fishery. Monthly samples of 15 and 7 animals belonging to one size class were measured and weighed, and then they were sub-sampled to obtain gonadic tissue for histological studies using paraffin and HE stain on 8 μm slices and resin on 1.5 μm slices, dyed with Toluidine Blue. The reproductive cycle was determined from histological observations, and oocyte sizes were measured using microscopic photos from the paraffin preparations; these were digitalized and measured using the *Image-Pro Plus 5.1* software. The pen shell is a protandric hermaphrodite. Reproduction is at the end of spring and early summer, and its gametogenic cycle begins in the early spring. We discuss the significance of hermaphroditism during their gametogenic cycle.

Mother of Pearl Shell Carving Work to Establish Family Enterprises in San Pedro México and Agua Amarga, BCS, México

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A training program to develop shell carving skills was begun in order to establish artesanal groups of women among the nonurban communities of the lower Gulf of California. The program consists of a teaching section, based on the cultural level and skills of the ladies, and a technical portion using simple regional cultural methods that can be easily used. During 2008, we contacted the two communities of Agua Amarga and San Pedro, México, in the region of Punta Arenas, Baja California Sur, and formed two groups of women, named respectively Artesanas de Agua Amarga and Estrella del Mar. We surveyed the 14 members in each group to learn their living conditions. They each average 28 years of age, with two children, a daily income of $2.40 (US) per family member (poverty level, UN criteria, 2009), live in two-roomed houses, have completed high school, and 99% of their husbands are fishermen. The participants are characterized by an enterprising spirit and an eagerness to reach a higher level of life. Traditionally in México, women are in charge of the domestic responsibilities (child rearing and their education). These ladies are especially motivated to find alternative means of producing goods or services to strengthen their financial condition. An integrated project was developed that includes a workshop and a calendar of skills learned. This was presented to the Federal Government to obtain financing and to bring it to fruition. In this work we present the plans and projects for 2009.

Madreperla Trabajada para Establecer Empresas Familiares en San Pedro México y en Agua Amarga, BCS, México

Se elaboró un programa de entrenamiento y capacitación para desarrollar habilidades para el tallado de concha y caracol, a fin de elaborar artesanías para grupos de mujeres de las comunidades ribereñas del Golfo de California. El programa comprende un apartado didáctico acorde con el nivel cultural y de conocimientos de la población objetivo y un apartado técnico con elementos de la cultura popular a fin de que el mismo pueda ser adoptado con facilidad. Durante 2008, se estableció contacto con dos comunidades de la región de Punta Arenas, las mismas son Agua Amarga y San Pedro México, en ellas formamos dos grupos de mujeres, denominados respectivamente Artesanas de Agua Amarga y Estrellas del Mar. Cada grupo está constituido por 14 miembros, a los que les fue aplicada una encuesta para conocer sus condiciones de vida. Las integrantes tienen en promedio 28 años de edad, dos hijos, un ingreso diario de $2.40 dólares americanos por miembro de su familia (situación de pobreza ONU, 2009), dos habitaciones en su vivienda, educación secundaria terminada, y el 99% de sus maridos son pescadores. Las integrantes están caracterizadas por un espíritu emprendedor y un afán de superación para alcanzar un mejor nivel de vida (ya que como en todo el país las mujeres están encargadas de los trabajos domésticos, la crianza y educación de los hijos) y siempre están motivadas para encontrar alternativas de ser productoras o protagonistas de algún bien o servicio que complemente su economía. Se elaboró un proyecto integral que comprende la construcción

de un taller de trabajo, equipado y un calendario de capacitación mismos que fueron presentados a la federación para obtener financiamiento y llevarlo acabo. En este trabajo se presentan los proyectos y las expectativas para 2009.

Molecular systematics and Phylogeography of Neustonic Aeolid Nudibranchs of the Family Glaucidae

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The evolutionary and ecological transition from a benthic (sea floor) to neustonic (pelagic ocean surface) habitat is an extraordinary leap that has occurred only a few times in history. One such instance involves the aeolid nudibranch subfamily Glaucinae, which has achieved this transition through unique and remarkable means; using specialized gastric cavities, these nudibranchs gulp air to maintain buoyancy, floating passively upside-down for their adult lives. The first goal of this research is to identify a convincing benthic sister lineage of the pelagic Glaucinae. While a number of taxonomically-proximate sister lineages have been proposed, Valdés and Angulo Campillo (2004) concluded that there was insufficient morphological or anatomical evidence at present to identify a convincing glaucinid sister lineage. Using two mt gene fragments (16S rDNA; COI) in collaboration with the Valdés lab, the initial molecular analysis places Glaucinae sister to Favorininae, which is broadly consistent with Miller's (1974) taxonomy. The second component of this research is part of a larger project examining the global phylogeography of the neustonic community. As members of the Glaucinae drift passively throughout the planet's five subtropical gyres, do continental land masses and strong equatorial currents present barriers to gene flow? What are the spatial scales and mechanisms of speciation? Molecular analysis of the cosmopolitan *Glaucus atlanticus* and Pacific-basin *G. marginatus* using mt gene fragments (16S rDNA and COI) show strikingly different patterns: *G. atlanticus* exhibited modest variation in the Pacific basin, which is contained within the variation in the North Atlantic, three gyre systems away. *G. marginatus* in the Pacific basin produced highly diverent co-occurring mt lineages in the North Pacific that may represent cryptic species.

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Fishermen and the Academy: The Search for a New Generation of Aquaculturists in Baja California, México

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Mexican fishery production has not increased much in recent years. Some factors that have affected this production include poaching and overexploitation. Thus, several fishermen considered the possibility of supporting their fishing production with aquaculture. Regasa No. 2 is a fisherman's association founded in 1994, which started its first concession catching sea urchins in Punta San Antonio of South El Rosario, Baja California. After 15 years, they have not only managed to increase sea urchin density in their area, but also to increase the population density of other species such as abalone and lobster, even though they have concessions for catching these species and other shellfish organisms such as geoduck. They also had the foresight to culture the species they catch. At the same time, CICESE has had great interest on helping producers such as fishermen and aquaculturists by transmitting fishery and aquaculture knowledge and its application. With this in mind, Regasa No. 2 started a small farm to culture abalone with the aid of CICESE. In this talk we will give more information of how the relationship between fishermen and the academy can help to increase not only fishery and aquaculture of mollusks, but also other marine organisms such as lobsters.

What is *Acmaea conus* Test, 1945?

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Ever since Avery Ransome (Grant) Test described *Acmaea conus* Test, 1945, this species has been regarded as valid and is presently known as *Lottia conus*, although it has been scarcely studied, especially compared with its supposed northern counterpart, *L. scabra* (Gould, 1846). In fact, most recent studies monitoring intertidal communities south of Pt. Conception have lumped *L. scabra* and *L. conus* because of the difficulty in their separation. In my own molecular studies of West Coast Lottiidae, I had assumed that *L. conus* was the small-bodied species I had found in southern California whose sequences revealed that it was clearly distinct but closely related to *L. scabra*. Of the about 14 *Lottia* spp. I have studied in southern California, this is the only one whose geographic range does not also extend to north of Point Conception. Even at its type locality at Pt. Fermin in San Pedro in southern California, this species is less common than *L. scabra*. Test also stated that it is relatively scarce north of La Jolla, but she considered it more

common than either *L. scabra* or *L. austrodigitalis* (as *Acmaea digitalis*) from La Jolla to the southern tip of the Baja California peninsula. This statement seemed contrary to my own experience and I decided that I needed to examine Test's type material. Because no one had yet designated a lectotype from among the 20 specimens in her "type series" for *Acmaea conus*, I requested and was fortunately granted a loan of these syntypes from the California Academy of Sciences. I was extremely surprised to discover that these were all substantially larger (13.4 to 18.7mm length; mean length = 15.4mm) than any of the specimens that I had identified as *L. conus*. For example, nine representative vouchers of what I was calling *L. conus* whose identity was confirmed by sequencing ranged from 6 to 9mm in length, with a mean length = 7.3mm. In fact, I would have identified Test's syntypes from Pt. Fermin as *L. scabra* based on their size and appearance alone, rather than what I was calling *L. conus*, even though her syntypes did have ribs that were thinner than most *L. scabra* specimens. I returned to localities around Pt. Fermin and searched without success for any thin-ribbed specimens of what I was calling *L. conus* that were as large as the *L. conus* syntypes. Instead, the limpets I saw reinforced my impression that the small species I was calling *L. conus* do not appear to get nearly as large as any of the syntypes. Ongoing studies are designed to test alternative possibilities. Perhaps I have merely missed the large *L. conus*, or they are substantially smaller now at the type locality than they were when she collected the syntypes about 70 years ago. I have found limpets somewhat resembling her syntypes further south at San Onofre (San Diego Co.). Alternatively, her syntypes are conspecific with *Lottia scabra* (Gould, 1846) and there is another small-bodied species in southern California that needs to be described.

The Zonation and Density of the Macromolluscs Living in the Mangrove Swamps of the Sand Barrier of El Mogote, La Paz, Baja California Sur, México

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On the eastern coast of Baja California Sur, mangrove forests are found in isolated strips, bush-like, with limited coverage. This region is considered one of the most arid locations in the country, with very little permanent flowing surface water due to small amounts of rainfall. We conducted a qualitative and quantitative seasonal study of the faunal community associated with the submerged roots of the red mangrove. Each sampling collected 5 roots, and the material was preserved with 10% formaldehyde solution. We selected three representative sampling areas on El Mogote (24°08'80" N, 110°8'23" W). Monthly sampling was during August 2007 to July 2008. *Laguncularia racemosa* and *Rhizophora mangle* were the dominant species on the borders of the mangrove swamp, while *Avicennia germinans* dominated the inland areas. Areal coverage by mangroves was estimated as a total area of 200 ha. The highest values of density averaged 1,937 ind.ha^{-1}, with a height average of 2.4 m and a basal area of 5.48 m^{-2} ha^{-1}. The mangroves

have complexity indices averaging 0.19 for mangroves >10 cm DBH. There were 12 species of macromolluscs (7 bivalves and 5 gastropods). The dominant species were *Crassostrea palmula* (47% and 50 ind/500 cm^2), *Anadara tuberculosa* (41% and 2.5 ind/m^2) and *Brachidontes semilaevis* (4% and 9 ind/500 cm^2). The analysis of diversity and evenness showed the highest values of the Shannon-Wiener index at Estero C with 0.49 bits/individual, and the lowest value at Estero B with 0.41 bits/individual. The most widespread impacts of human activities or natural succession on the point of the sand barrier include various forms of marinas and housing developments, widespread tourism, storm destruction and increased soil salinity. This knowledge will help us develop strategies of careful management and protection.

Management Strategies of *Argopecten ventricosus* Fisheries in Bahía Magdalena, México

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Introduction

The Pacific calico scallops fishery is an important activity in Bahía Magdalena, on the west coast of the Baja California Península, México. Its catch is notoriously variable; while during 1989 it achieved 32,000 tons, but during 1991 to 1995 landings declined to about 900 tons and, in 2005 it barely landed 15,000 tons. The fishery is based on hookah diving from outboard powered boats. Fishermen belong in cooperatives or work for private industries which obtain licenses from the federal government. Numbers of licenses are determined after density assessments by the National Fisheries Institute. As in other calico scallop fisheries in the world, the high variability of stock abundance is a consequence of climate changes and overexploitation, as well as management strategies. In México this fishery is regulated by the Official Norm 004-PESC-1993 (Diario Oficial de la Federación, 1993). In this paper we briefly summarize relevant aspects on management perspectives.

Site description

In general, scallop fisheries are characterized by a lack of planning which may jeopardize the species' stability, persistence and productivity, since demographic growth implies an increase in the number of fishermen, leading to a higher pressure on this resource. However, to prevent overfishing, which would result in higher levels of poverty among communities exploiting this resource, a better knowledge of the fishery dynamics and the species' growth and reproduction processes are required, especially those related to its potential cultivation. This work analyzes landings of *Argopecten ventricosus* living in the Bahía Magdalena region, Baja California Sur, Mexico (Figure 1).

Material and Methods

Information on biology and population dynamics of *Argopecten ventricosus* in the Mexican Pacific were reviewed, specifically those aspects related to individual growth, reproductive cycles and density distribution, commonly used to determine management measures. We also reviewed the information on catch and fishing effort and the current control procedures.

The licenses given by the federal government to commercial enterprises is in accordance with a procedure that includes information on the behavior of the fishermen and availability of the Pacific calico scallop. There are 162 licenses that include 349 boats.

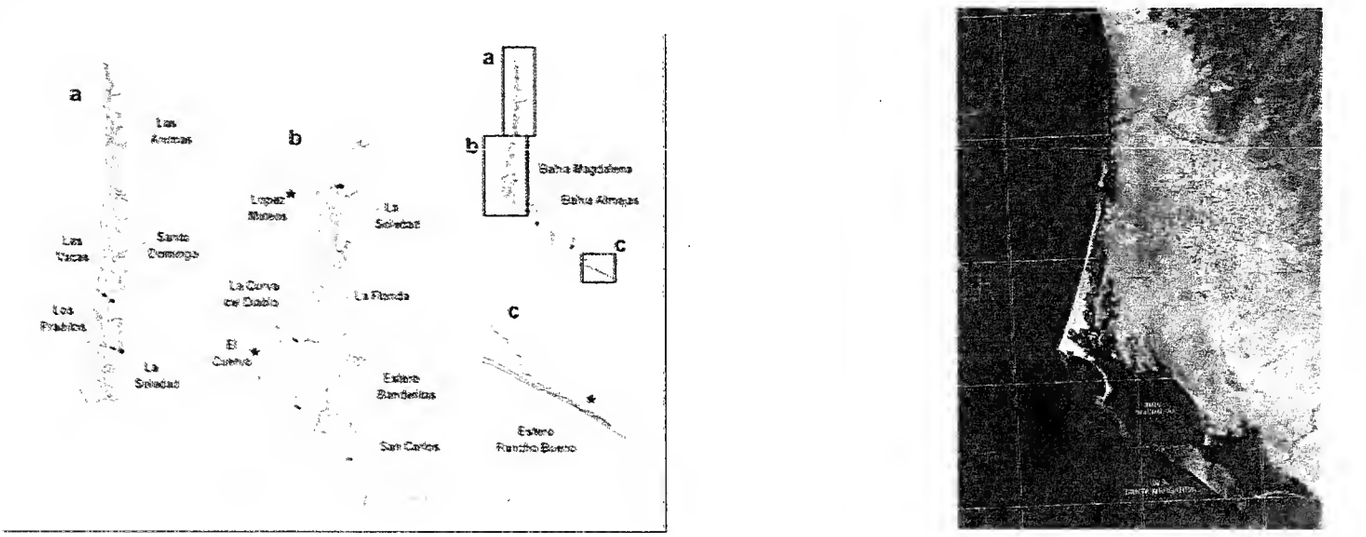

Figure 1. Location of the fisheries regions in Bahía Magdalena, Baja California Sur, México.

The ideal measurement of effort would involve some measure of diving gear or number of divers per compressor and the time of diving, e.g. catch /No. Divers h^{-1}. The catch is then reported as whole shellfish, meat, and muscle in kilograms. But usually effort data consists at best of catch boat day^{-1}.

This fishery is regulated by the Official Norm 004-PESC-1993 (Diario Oficial de la Federación). The no-catch season goes from December 15 through March 31. Minimum size is 60 mm.

Results

Since 1975 the scallop fishery in Bahía Magdalena harvests *Argopecten ventricosus,* locally called "almeja catarina." It is distributed patchily in sandy bottoms from the coast to 20 m deep (Félix Pico, 2006). According to official statistics, the total annual landings of *A. ventricosus* at the end of the 1980s averaged about 32,000 tons (Fig. 2). Usually, from June to September adults of 3 to 6 cm shell heights are found in areas 10 to 20 m deep; juveniles less than 3 cm in shell height are present in shallow waters. The main reproductive season occurred during March-April. Apparently La Niña years produce favorable conditions to an additional reproductive peak during July-August in those years, as reflected in landings from November to January. After spawning, individuals lose muscle weight, some die and others may take up to 3 months to recover to normality and reproduce again.

Fisheries management in Bahía Magdalena is based on licenses given by the federal government to commercial enterprises according to a procedure that includes information on

fishing activities and the availability of *A. ventricosus*. Actually there are 135 enterprises, 162 licenses that include 349 boats. Landings from 1998 through 2007 showed almost no catch until 2001 (average 976 tons), a rapid increment until 2005 (average = 9234 tons), a suddenly decrease in 2006 (6,435 tons) and a recuperation in 2007 (14,373 tons) (Fig. 3). Constant price value shows the same pattern; in 2007 it was estimated in US$ 5.1 million. Grossly, catch per boat varied from 1 to 2.6 tons. The administrative process used for determination of the number of licenses and extension of the fishing season is not well documented.

Catch is notoriously variable; while during 1989 it achieved 32,000 tons, during 1991 to 1995 landings declined to about 900 tons, and in 2005 it barely landed 15,000 tons.

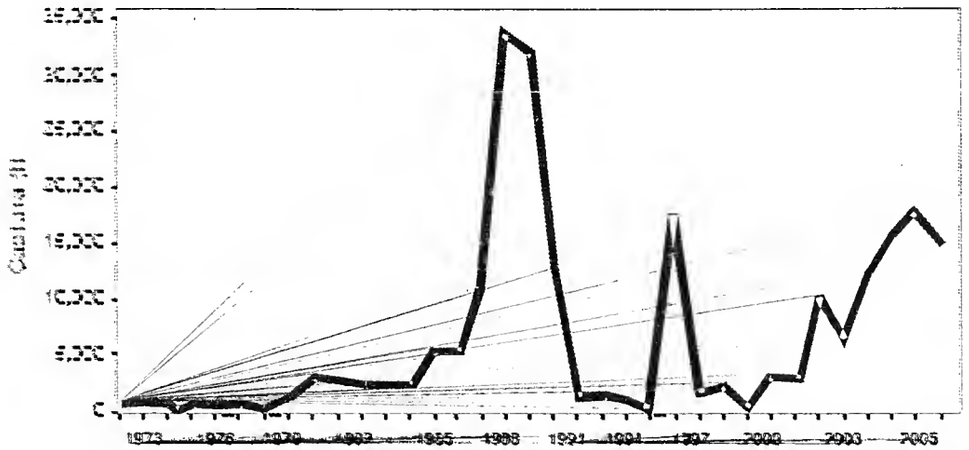

Figure 2. Historical annual catch of scallops in the Bahía Magdalena region (total fresh weight).

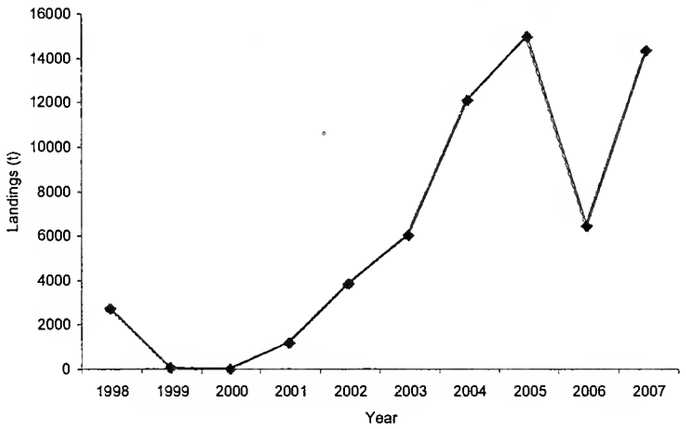

Figure 3. Landings per year of Pacific calico scallop in Bahía Magdalena, México: 1998-2007.

Discussion

Regulations

The Pacific calico scallop fishery is an important activity in Bahía Magdalena, on the west coast of the Baja California Peninsula, México. Species that have experienced a decline in range and abundance as a result of several factors (e.g. exploitation, habitat loss, and natural depredation and competition) often respond to decreased exploitation more quickly than to other management strategies. Large harvests of scallops in the late 19th and early 20th centuries are well documented (Massó Rojas, 1996, Félix Pico, 2006). Restrictive regulations that will support self-sustaining populations are essential for the protection of remnant stocks.

Current scallop regulations are much more uniform among jurisdictions and are now some of the most restrictive among the scallop species managed in Bahía Magdalena (Table 1).

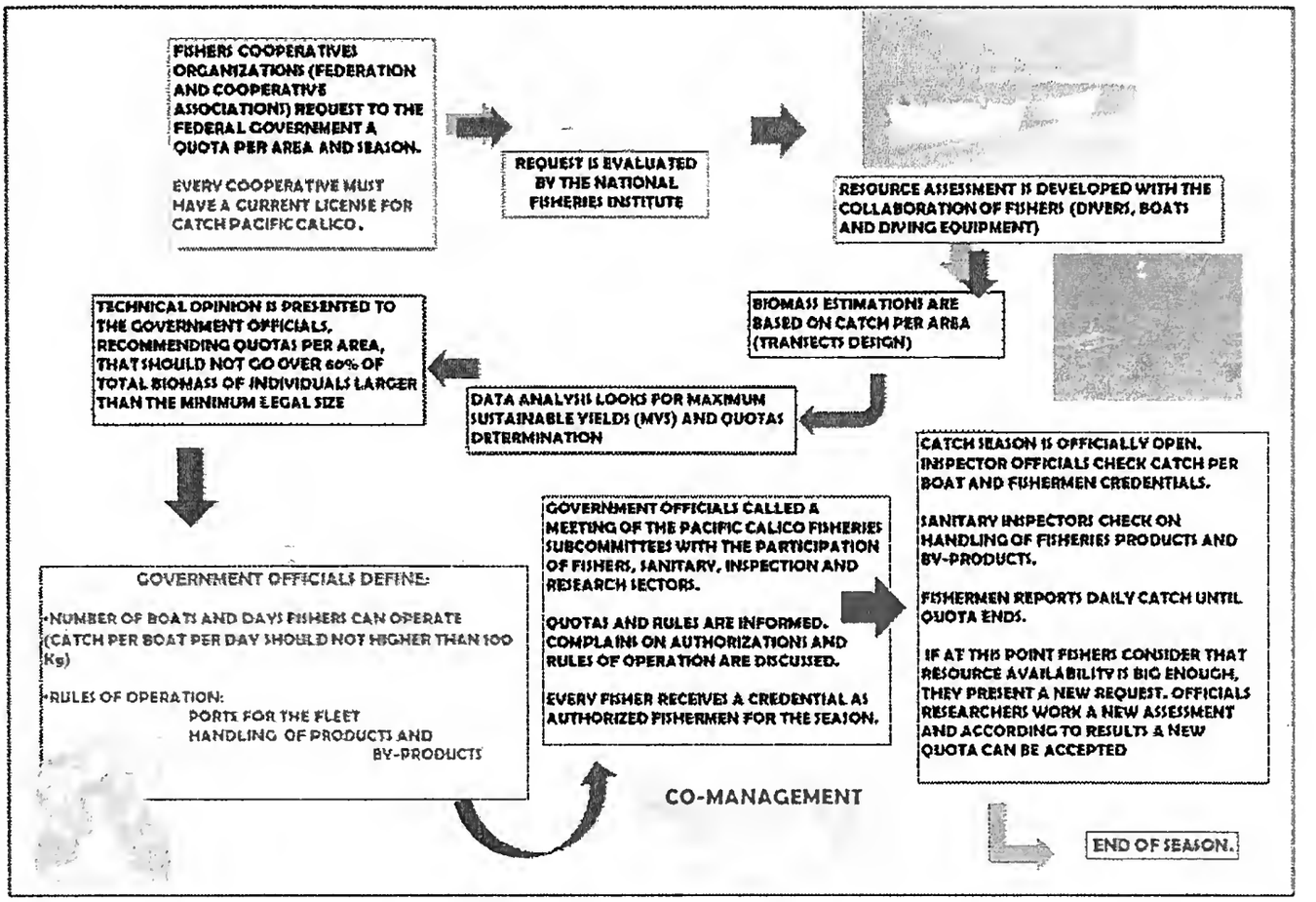

Table 1. Summary of general Bahía Magdalena fishing regulations for Pacific calico scallops.

Stocking

The stocking of Pacific calico scallop in Bahía Magdalena has occurred basin wide since the late 1960s. During most of this period, stocking provided a subsistence resource and an important commercial fishery. The estimation of stocking year densities is starting aggregate stock and then dispersed. The historical scallop producing areas of Baja California Sur, México are shown in Table 2.

During the years 2006 to 2008, the four principal stocks of the lagoon complex system of Bahía Magdalena (Fig. 4) occurred at Muelle San Carlos, Bahía Magdalena, Palma Sola and Bahía Almejas.

Table 2. Stocks and density populations exploited in the coastal lagoons of Baja California Sur, México.

YEAR	Localities	Densities of scallops per m2 February	August	October	Millions of scallops STOCKS	Authors
1975	Ensenada de La Paz	10	4	2	36	Félix-Pico 1991
1976	Ensenada de La Paz	15	6	0.5	32	Yoshida & De Alba 1977
1977	Ensenada de La Paz	13	3	1	34	Baqueiro et al 1981
1988	Bahia Concepcion	95	25	8	62	Leon-Carballo et al 1991
1989	Bahia Magdalena	159	19	2	606	Félix-Pico 1991
1990	Bahia Magdalena	26	4	0.5	321	Félix-Pico 1993
2005	Bahia Magdalena	200	32	4	186	This study
2006	Bahia Magdalena	120	26	4	421	This study
2007	Bahia Magdalena	62			230	This study

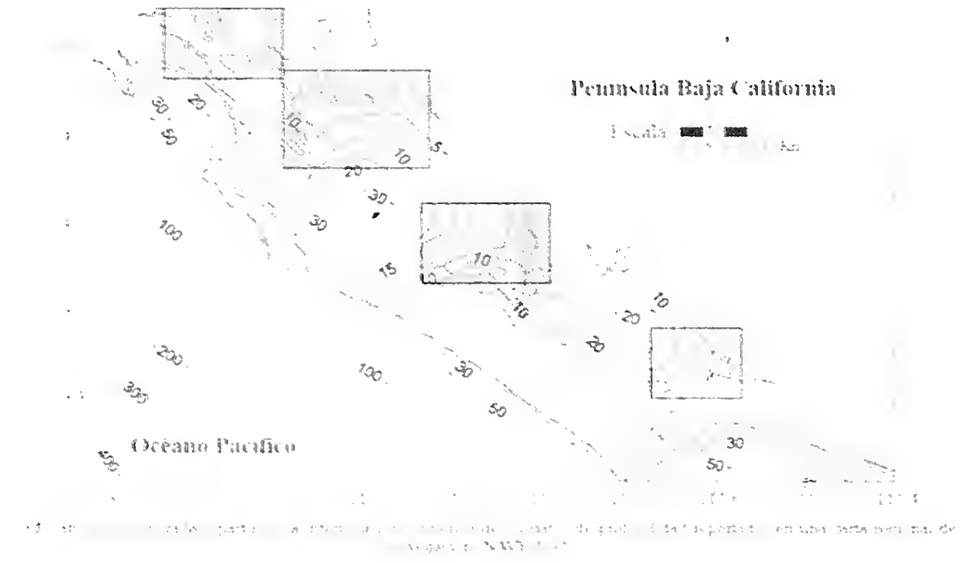

Figure 4. Location of the fisheries stocks in Bahía Magdalena.

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Morphological and Molecular Distinctions of a Specialist and a Generalist Limpet Species Living on Feather Boa Kelp Stipes in California

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To date, field observation and identification has been somewhat unreliable when making the distinction between *Lottia insessa*, a specialist species that has been known to live and graze only on the stipes of *Egregia menziesii*, and a generalist species, *L. pelta*, which can also be found on *E. menziesii* but is more normally associated with rock habitats. When found on *E. menziesii*, *L. pelta* is striking in its shell morphological similarities to *Lottia insessa*. We investigated the distribution of these two species on feather boa kelp along the shores of California and were able to correlate sequence of distinctions with morphological traits, so that now we can be relatively confident in telling them apart, even without sequencing. For identification purposes, we sequenced a portion of the mitochondrial 16S DNA gene and examined the morphology of our vouchers using light microscopes. Despite an amazing convergence in overall appearance we found consistent diagnostic features to distinguish these species: 1) The shell apex region (top 1 mm of shell) is darker than the rest of the shell only in *L. insessa*, and it often times also has white spots – this corresponds to the retained shell of the limpet when it was a juvenile; 2) the characteristic hooked apex of this earliest portion of the shell only in *L. insessa*; 3) dark tissue pigment in shell attachment region only in *L. insessa*, and this is often visible through the somewhat translucent shell; 4) the presence of fine radial sculpturing on non-eroded shells only in *L. pelta*; and 5) slight differences in the outline of the shell, *L. insessa* has somewhat more parallel lateral margins of its shell than *L. pelta*. Frequently, only the last of these distinctions is noted in available keys and this distinction is really only apparent in adults. Here, we present molecular evidence that clearly distinguishes between these two similar appearing species and shows that *L. pelta* is regionally/locally common especially along the mostly rocky shoreline of the Palos Verdes Peninsula, whereas *L. insessa* was usually the only limpet found at sites dominated by sandy beaches. We are pursuing the ecological implications of these distributional patterns and potential interactions between these limpet species.

Prehistoric Shell Middens at Punta Colonet, Baja California, México: Cultural and Environmental Significance

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Shell middens are the most conspicuous and common archaeological feature along the Baja California coast. They are very important because they hold one of the earliest evidences of human coastal mollusk exploitation for food, artifact design and trade. At Punta Colonet, most of them are very well preserved and widely distributed from the coast to many kilometers inland. Midden mollusk composition mostly agrees with the recent living fauna from the adjacent rocky or sandy shorelines, dominated by the mussel *Mytilus californianus* and the Pismo clam *Tivela stultorum* respectively. Other common rocky shoreline mollusks present are the limpets *Fissurella volcano* and *Lottia gigantea*, and the black abalone *Haliotis cracherodii*. This composition indicates intertidal collecting. Sandy shoreline mollusks are less common and diverse. In some places there is no correlation between the archaeological mollusk composition and the recent shoreline, which could be related to environmental changes due to coastal cliff retreat by wave erosion. This erosion is washing cultural remains into the sea. This natural process and the project of a megaport development are endangering the preservation of the archaeological sites, in which mollusks are clues to understanding ancient human diets, inland trade routes, environmental changes, and the peopling of America.

Population Dynamics at a Shifting Range Boundary between Sister Species of Estuarine Sea Slug: Role of the Physical Environment versus Larval Supply

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Intertidal animals that occur along linear strips of coastline are ideal models for studying the causes of range limits, and for predicting how ranges may shift due to climate change. The estuarine sea slugs *Alderia modesta* and *A. willowi* share a dynamic range boundary between Bodega Harbor and San Francisco Bay, which has likely shifted 180 km north over the last 50 years. We quantified field densities of both species along replicate transects in SF Bay, and correlated abundance with *in situ* measurements of temperature, salinity and habitat suitability. The southern species *Alderia willowi* colonizes SF Bay each September, after high temperatures kill off most *A. modesta*. Conversely, most *A. modesta* recruit in March after low salinity and possible competitive interactions eliminate *A. willowi*. Size-frequency distributions revealed two major recruitment events for each species early in their respective seasons, indicating supply-side processes are important to metapopulation dynamics of these slugs. However, the lack of subsequent recruitment refutes the hypothesis that range limits occur because the continuous

influx of maladaptive alleles from the range center inhibits adaptation to stressful edge conditions. Instead, the seasonal gradient in conditions exceeds the adaptive potential present in annual settlement cohorts, favoring first one species and then the other. These findings illuminate the biological and physical factors setting the permanent range boundary at Bodega Harbor, and may be used to predict future range shifts of estuarine animals due to increasing temperature and changing hydrology along California's coastline.

Population Structure of *Navanax* Based on Nuclear and Mitochondrial Gene Data

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Along the eastern Pacific several genera of the family Aglajidae can be found. Of particular interest are species belonging to the genus *Navanax*, which includes *N. aenigmaticus*, *N. inermis*, and *N. polyalphos*. While *N. inermis* and *N. polyalphos* are restricted to the eastern Pacific, populations of *N. aenigmaticus* are found in the eastern Pacific, western Atlantic, and eastern Atlantic. These species were described using morphological characters, such as color and the anatomy of the digestive and reproductive systems. However, members of these species exhibit wide color variation and it is not known if color forms are genetically distinct. What also remains unknown is if the three isolated populations of *N. aenigmaticus* are genetically distinct despite a similar morphology. The primary use of morphological characters to describe new species has led to questions regarding the validity of some species. New species are sometimes described solely on the basis of some color forms and fail to identify the color range within species.

To address the validity of the three species of *Navanax*, two molecular markers were employed to construct a molecular phylogeny of the genus. The mitochondrial 16S ribosomal gene has both highly conserved and highly variable regions; the variable regions are loops regions which are subject to relatively high mutation rates. The nuclear H3 histone protein-coding gene is highly conserved, but is subject to silent mutations accumulated at a much slower rate than those seen in the 16S gene. Using the molecular phylogeny, we can determine the validity, the color variation, and the geographic structure for each species. The phylogenies suggest the synonymization of two species of *Navanax* and the reinstatement of another species.

A Two-gene Phylogeny of *Chelidonura* and the Validity of Some Caribbean Species

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Several species of *Chelidonura* are known from tropical and subtropical regions. In the Caribbean a number of new species have been described during the last few years, mainly based on external morphology and coloration. Some authors have suggested that at least some of this new diversity constitute color forms of other species. The present project aims to 1) determine genetic divergence between the newly described species in order to verify how many of these are valid and 2) provide a preliminary phylogeny for *Chelidonura* based on 16S and H3 gene data, including some sequences from GenBank. The molecular phylogenies obtained support the need to synonymize most of the newly described Caribbean species, except for *Chelidonura cubana*, which is distinct. The phylogenies contain some geographic structure that appears to indicate a diversification in *Chelidonura* before the closure of the east-west main communication, as some clades contain a mixture of Atlantic and Indo-Pacific species. The pan-tropical *Chelidonura hirundinina* constitutes at least two distinct clades, likely separated by the formation of the Panama Isthmus.

Chemical Defense, Coloration and Structure in the Nudibranch Family Chromodorididae

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The secondary metabolites of nudibranchs and other opisthobranchs defend these animals from predators and have been the driving force behind their evolution (Cimino & Ghiselin, 2009). The notion that these chemicals are non-adaptive byproducts of metabolism has long since been abandoned, but skepticism with respect to their function has persisted. This is because all too often the results that have been reported in the literature have not been supported by appropriate ecological experiments or realistic quantification of the concentration of metabolites that are essential for a proper evaluation of their biological activity. Consequently the false impression has been given that certain important questions have already been answered. The work here described applies a new experimental approach to two topics having to do with the defensive function of chemicals that are associated with various color patterns and body shapes.

Metabolites were directly quantified by ^{1}H-NMR spectroscopy on crude extracts by adding a known amount of an internal standard to lipophilic extracts obtained from nudibranch tissues. This allowed us to avoid sources of error such as chemical degradation of samples that have plagued efforts at quantification based upon chromatography.

Another problem with earlier work has been the methodology of bioassays. These commonly use freshwater fishes, test toxicity rather than repugnancy, and lack statistical evaluation. In this work we have used a trophic generalist, the common marine decapod crustacean *Palaemon elegans* as an assay organism and evaluated the results statistically, following a recently-described method (Mollo *et al.*, 2008).

The first topic considered was the striking color patterns of chromodorid (and other) nudibranchs that appear to be indicative of aposematism. The alternative possibility that some of these are Batesian mimics cannot be excluded without further investigation. Ros (1976) proposed a Müllerian mimetic circle for a group of blue, white and yellow colored Mediterranean and Northeastern Atlantic species of *Hypselodoris*. Because this group is monophyletic, however, the aposematism would be preserved by selection and not be the product of convergence. One of these, *Hypselodoris fontandraui*, lacks the mantle dermal formations (repugnatorial glands) that are found in other members of this circle. It therefore seemed possible that this animal lacks chemical defense and acts like a Batesian mimic or free rider. We have experimental evidence that *H. fontandraui* is chemically defended in much the same way as its aposematic, co-occurring and blue-colored congeners within the Müllerian mimetic circle and is not a Batesian mimic. First, we found that the nudibranch contains the furanosesquiterpenoid tavacpalescenscin, most probably derived from sponges of the genus *Dysidea*, upon which it possibly feeds. The metabolite concentrations were measured from samples of the mantle rim, other external parts, and internal organs. Concentrations were about four times higher in the mantle rim than the other external parts, and more than twenty times higher in the mantle rim than the internal organs, considerably exceeding the threshold value of concentration showing the maximum dose effect as a feeding deterrent against *P. elegans*. Although histological examination failed to detect mantle dermal formations, a possible accumulation reservoir was found.

The second topic approached had to do with the functional significance of the diverse mantle morphologies within the family Chromodorididae. Measurements of metabolite levels in the mantle reservoirs of *Glossodoris atromarginata*, *Chromodoris sinensis*, *Hypselodoris infucata*, *Risbecia tryoni*, and *Ceratosoma gracillimum* reveal unpalatable concentrations of metabolites much higher than anyone had anticipated. Given that the repugnatorial glands are supplemented by what appear to be deflective color patterns and are positioned in exposed locations where they can readily deliver a high dose of metabolite to the attacking predator without suffering much damage themselves, the nudibranchs would seem to possess a highly coadapted system of defensive adaptations.

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Potential Synonymization of Two Opistobranch Mollusc Species

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Dondice is an enigmatic group of sea slugs containing only three described species. Two of these species (*Dondice occidentalis* and *Dondice parguerensis*) are found in the Caribbean while one other inhabits areas in and around Europe. A main area of interest for this study involves the difference between the distinct feeding habits of these two species and their morphological similarity to another species in a different group (*Hermissenda). Dondice parguerensis* feeds entirely on upside-down sea jellies while *Dondice occidentalis* only eats anemones. The benthic jellies are possessors of a well known venomous defense mechanism that usually protects them from potential predators. When threatened, the jelly's cnidocils are triggered and hundreds of stinging nematocysts are released into the surrounding water. This is usually enough of a deterrent to protect them from being eaten by most potential predators, but *Dondice parguerensis* has evolved a formidable counter-defense mechanism in which it is immune to the usually crippling stings of the jelly's nematocysts. Other than their distinct feeding behaviors however, these two species are strikingly similar morphologically and it is expected that they may actually be the same species occupying different ecological niches. H3 nuclear and 16S mitochondrial gene data are currently being collected to determine just how close the relationship is between these two in order to test the validity of their rank as separate species. This will provide insight into whether or not they are genetically isolated and thus capable or incapable exchanging genes between them. In addition, a comparison of molecular data from *Dondice* and its sister taxa *Hermissenda* will be explored in order to determine whether or not these should be classified as distinct groups.

Environmental Effects on Larval Development of the Sea Slug *Alderia willowi*

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Environmental cues can trigger phenotypic plasticity in a wide range of organisms. *Alderia willowi* seasonally switch developmental mode of their offspring between larger non-feeding lecithotrophic larvae in the summer and smaller feeding planktotrophic larvae in the winter. We wanted to maintain lecithotrophic development in the lab for purposes of performing multi-generation selection experiments, but past students were unable to get the slugs to maintain lecithotrophic development when raised under lab conditions. Factors that cause adult *A. willowi* to switch larval development may be temperature, seawater salinity, or growth rate. I tested the hypothesis that high temperature, high salinity, or both would cause laboratory reared slugs to express lecithotrophic development by mimicking summer conditions. I also tested for effects of

growth rate on larval development type. Combinations of high or low salinity and high or low temperature resulted in less than 15% lecithotrophic clutches. However, slugs that grew at a rate of 0.1 mm per day, compared to slugs that grew at 0.04 mm per day, resulted in greater than 90% lecithotrophic clutches. These results suggest that growth rate, rather than environmental cues, may control development mode.

Some Shield Limpets (*Lottia pelta*) Experience a Mid-life Crisis while Seaweed Limpets (*Lottia insessa*) Live Fast and Die Young

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Observations of limpet shell growth patterns can reveal a discontinuous history correlated with change in microhabitat by the limpet. We discovered a striking example of this phenomenon in the shield limpet *Lottia pelta*. This limpet has been noted to sometimes live on the stipe of the feather boa kelp, *Egregia menziesii*, displaying an amazing convergence in shell appearance to *L. insessa*, a limpet that specializes on grazing *E. menziesii*. At sites where we have noted a high proportion of *L. pelta* on feather boa kelp, notably Pt. Fermin on the Palos Verdes Peninsula in southern California, we have also found a high proportion of larger *L. pelta* individuals living under the higher intertidal rockweed *Silvetia compressa* whose shells revealed a history of habitat shift from feather boa kelp to rockweed. Specifically, their older (top) portion of the shell resembles the morphology of *L. pelta* residing on feather boa kelp and the younger (bottom) portion of the shell resembles "normal" rock morphs of *L. pelta* residing under the rockweed. Through the use of mitochondrial 16S DNA sequencing, limpets collected from both microhabitats have been confirmed in their identity. From these data and from field observations at multiple localities, we predict that the proportion of *L. pelta* versus *L. insessa* found inhabiting feather boa stipes to be greatest at sites that also have abundant rockweed nearby, and at least at Pt. Fermin, which has abundant rockweed, they are the most common limpet found on feather boa kelp. In contrast, several southern and central California sites lacking rockweed were observed to have only *L. insessa* on feather boa kelp. The implication of our study is that limpets might play an under-appreciated role affecting long-term algal abundance, especially if their habitat shifts might be related to destructive grazing of their associated algal species. Unlike *L. pelta*, the specialist grazer *L. insessa* does not appear to migrate off feather boa stipes to rocks; and has previously been reported to be an "annual" species with fast growth and reproduction. Interestingly, a conspicuous and consistent difference in the shell color (black with white spots) and profile (with a hooked apex) of tiny *L. insessa* juveniles compared with adults might have suggested that they migrate to this alga from a different microhabitat. However, we confirmed earlier reports that newly settled juveniles appear to instead settle directly on feather boa stipes, especially in abandoned adult feeding scars, so the shift in appearance must require different explanations. Perhaps the color shift to solid brown reflects an increasing incorporation of plant pigments into their shell as they feed and grow.

Collective Action, Ecological Activism, and Environmental Quality: Evidence of Native Freshwater Mussels without Invasive Bivalves, in Deep Fallen Leaf Lake, Near Invasive and Native Bivalves of Lake Tahoe, California

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Abstract

Invasive plant and animal species continue to be spread by humans, with alarming rates and consequences. Native aquatic species and waterways of California are at risk, possibly more so, as an historically arid region of the globe. Invasive *Corbicula* clams and invasive aquatic plants already are widespread, including large Lake Tahoe, in the Sierra Nevada. More invasive species, especially zebra and quagga mussels, plus New Zealand mud snails are threats, particularly at Lake Tahoe. Similar, apparently native species (Hershler *et al.* 2007) make monitoring or eradicating some of these small mollusks especially difficult.

Yet a sizable, similar lake very near Lake Tahoe, Fallen Leaf Lake, reportedly is free of invasive aquatic species. Thus, that aquatic environment may reflect historical ecological communities in such Sierra Lakes.

A network of concerned citizens, including local, long-time residents, has been able to keep their lake essentially free of invasive aquatic species, without support nor involvement of government and other agencies. They successfully established education-based policies and installed a hot-water (140-degree F = 65 degrees C) wash and inspection station at their boat launch ramp, preventing boats from moving invasive species from Lake Tahoe. Invasive milfoil plants quickly became visibly "cooked" upon contact with such water.

In Fallen Leaf Lake in May, 2009, our ecological surveys found no evidence of invasive aquatic species. We found rare evidence of native freshwater mussels, *Anodonta californiensis* without invasive bivalves, at ~40-m depths, >5 m deeper than benthic algae in this 200-m-deep Fallen Leaf Lake. Analogous surveys detected invasive *Corbicula* clams and native mussels near the Truckee River Mouth into Lake Tahoe. Our subtidal surveys down to 150 ft (~50m) depths relied on Undersea Voyager's quiet, two-person submersible, SeaMobile. Low-light cameras detected animals and plants without disturbance, with resolution and sensitivity exceeding the human eye.

We use Lubell's contractual perspective of local policy networks as public goods to explain how the Fallen Leaf Lake citizen network was able to develop and maintain its own collaborative network to govern its environmental commons, without government assistance.

Local residents were gratified to learn more about their Lake, more empowered to keep invasive aquatic species out of Fallen Leaf Lake. Their approach may be a model for other communities, to implement ecological improvements in our vulnerable environment.

Introduction

Humans have become the most important selective force on the planet (Palumbi, 2001). That tends to be bad, but perhaps we can find ways to make human's influence a GOOD one. "Sufficient evidence has emerged of stratigraphically significant change (both elapsed and imminent) for recognition of the Anthropocene [Epoch]. " (Zalasiewicz *et al.* 2008). Progress in linking ecological work and policy has become urgent, as natural resources become depleted yet use of those resources is increasing, especially in California, becoming densely populated with very mobile humans.

Environmental sustainability among dense human populations has become among the "greatest challenges to the long-term environmental quality of the nation" (National Science Foundation, 2009). A combination of solutions for conservation and environmental restoration may be necessary as soon as possible; these multidisciplinary problems of resource losses, and needs for enhanced environmental protection and management, require multidisciplinary solutions (Kitting 2007).

Our 2009 Western Society of Malacologists Environmental Management Symposium, "The Interface of Human and Molluscan Ecology," unites several practical and economic levels of importance of Mollusca, convenient to assess even from common, previously deposited shells, and often economically valuable for food, food webs, and shells themselves.

Invasive plant and animal species, including many mollusks, continue to be spread by humans, with alarming rates and consequences, environmentally and immediately economically. Native aquatic species and waterways of often dry California are at risk. As a historically arid region of the globe, with especially over-exploited water resources, California may be even more vulnerable to invasive mollusks and other organisms that may explode out of control in our California habitats, and in the absence of natural enemies, displace our natives and clog critical waterways. Trailered boats and other equipment appear to transport aquatic invasive species accidentally, such as from invaded Colorado River Reservoirs (California Department of Fish and Game, 2009); invasive *Corbicula fluminea* asian clams and invasive aquatic plants already are widespread, including large Lake Tahoe, in the Sierra Nevada. Sousa *et al.* (2008) review the ecology of *Corbicula fluminea.* More invasive species, especially zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*), plus New Zealand mud snails (*Potamopyrgus antipodarum*), are threats, particularly at Lake Tahoe.

Lake Tahoe also has established populations of invasive Curlyleaf Pondweed (*Potamogeton crispus)* and Eurasian watermilfoil (*Myriophyllum spicatum*) plants (with ecology reviewed by Eiswerth *et al.* 2002).

Yet a similar, though smaller and more isolated lake is only 2 km from Lake Tahoe (35 km long), Fallen Leaf Lake (4.6 km long), and reportedly is free of invasive aquatic species. Such an aquatic environment might reflect historical ecological communities in these Sierra Lakes. We asked how a lake so close to busy, invaded Lake Tahoe, could remain relatively free of invasive species.

Analogous questions, without clear answers, about managing growing effects of humans on natural preserves were introduced in a symposium to celebrate the centennial of Yosemite National Park, including Kitting & Echeverria (1991).

Methods

We surveyed both ends and a side of Lake Tahoe and Fallen Leaf Lake shores, with wading, snorkeling, SCUBA, and a two-person research submarine (Fig. 1), primarily throughout May, 2009 (Ramirez & Kitting, 2009) and in August, 2009. We included inspections and imaging of submerged rocks, wood, sand, and silt.

Our deepest surveys down to 150 ft (~50m) depths relied on Undersea Voyager's quiet, two-person submersible, "SeaMobile," and its 360-degree view, even at close range, on sediment and submerged wood and rock. Low-light cameras, including a Nikon D700, detected animals and algae without disturbance, with resolution and sensitivity exceeding the human eye. (A flash was impractical in the spherical glass hull.)

We also surveyed shallow Glen Alpine Creek into Fallen Leaf Lake and Taylor Creek, flowing out to Lake Tahoe, via wading, for invasive species during summer, 2009. Small, remote lakes with few humans and no roads are upstream of Fallen Leaf Lake, probably minimizing invasive species from upstream. We also exchanged mutually instructive interviews and surveyed documents with numerous human passers-by, throughout these ecological surveys.

Results

In Lake Tahoe, invasive Asian clams, *Corbicula fluminea*, and its dead shells were the most common mollusks, although patchy. The native freshwater mussel shells California floater, *Anodonta californiensis,* were common particularly near the mouth of upper Truckee River, after flowing into South Lake Tahoe.

In Fallen Leaf Lake, our ecological surveys found no evidence of invasive aquatic plants nor invertebrates, other than "signal crayfish" introduced from the Pacific Northwest *(Pacifastacus leniusculus).* We found rare evidence of native freshwater mussels, *Anodonta californiensis,* without invasive bivalves, at up to ~40-m depths, >5 m deeper than visible benthic algae in this 200-m-deep Fallen Leaf Lake. Uniquely observed in Fallen Leaf Lake, unusual colonial ciliates with symbiotic unicellular algae, together being identified as *Ophrydium versatile,* were common on shallower portions of submerged trees, near 10-meter depths.

Unlike in Lake Tahoe, no submerged aquatic plants were found in Fallen Leaf Lake. In particular, invasive Curlyleaf Pondweed (*Potamogeton crispus)* and Eurasian watermilfoil (*Myriophyllum spicatum*) evidently remain absent in Fallen Leaf Lake, a very unusual feat in California lakes. One gets the idea that this Lake probably resembles historical conditions of Sierra Lakes, more so than other lakes populated with humans.

A local network of concerned citizens, including local, long-time residents, has been able to keep their lake essentially free of invasive aquatic species, with significant effort by their "Community Area Advisory Committee." Without support nor routine involvement of government and other agencies, these cohesive local citizens successfully use community education to establish policies and install an unusual hot-water (140-degree F = 65 degrees C) wash and inspection station (Fig. 2) at their boat launch ramp, which serves many boats from a single small road, including those moving possible invasive species from Lake Tahoe. Hot water is required to wash even inside boat motors, via a clamp for the motor's cooling water intakes.

In our observations, milfoil plants adhering to a boat trailer quickly became visibly "cooked" and limp upon significant contact with such 140-degree water. (That temperature reflects temperatures of motor cooling water inside the motor, so it would not overheat a motor very quickly.)

At the other end of the lake, campers very near Lake Tahoe can carry kayaks into Fallen

Leaf Lake. That end of the lake's jurisdiction, the US Forest Service, reportedly removed the citizen's signs about required inspections and washing, as it was not the Service's policy (yet?). Discussions with the local citizens continue there.

Glen Alpine Creek into Fallen Leaf Lake and Taylor Creek, flowing out to Lake Tahoe, showed similar algae populations, with introduced crayfish, but no detectable mollusca nor invasive plants. Other valuable features of a relatively non-invaded lake appear to include native Lahontan cutthroat trout, extinct from Tahoe since the 1930s, but still remaining in Fallen Leaf Lake.

Discussion

Unlike most regions in densely populated California, Fallen Leaf Lake appears small and isolated enough to have long-term, cohesive residents, often in cabins established by their parents or grandparents, interested in long-term sustainability of their lake, rather than the usual short-term exploitation rampant in today's economy and way of life. Fallen-Leaf Lake's inter-generational view of real sustainability, to leave a suitable environment for their children and grandchildren, as they received, is analogous to other presentations in this human-molluscan interaction symposium, dealing with cooperative, inherited, family-zoned fisheries (e.g., Cáceres Martínez & Benítez Torres, 2009).

At least here at Fallen Leaf Lake, previous, broad command-and-control policies became second to community-based, less coercive, local solutions to policy problems. These networks, as Lubell *et al.* (2003) called them, form the core of largely new governing structures that are highly interdependent and involve multiple entities.

Networks that transcend traditional geographic or political jurisdictions might become increasingly important to manage environmental commons effectively, at least under conditions found around Fallen Leaf Lake.

Lubell's contractual perspective of local policy networks as public goods can explain how the Fallen Leaf Lake citizen network was able to develop and maintain its own collaborative network to govern its environmental commons, without government assistance.

In observing our research there, and hearing about our results in small and large forums, local residents were gratified to learn more about their Lakes, more empowered to keep invasive aquatic species out of Fallen Leaf Lake, and further invasive species out of Lake Tahoe. Their approach at Fallen Leaf Lake may be a model for other communities, to implement ecological improvements in our vulnerable environment.

This relatively isolated study area of Fallen Leaf Lake, and maybe analogous habitats, can serve as a living laboratory with diverse scientists, students, policy makers, and other residents working together to enhance our success in environmental management, and understanding of how interactions between humans and their ecosystem influence fates of natural environments, and subsequent, suitable policies and practices, as multidisciplinary adaptive management.

Clearly, education and other communication is important here among multiple agencies and less formal groups (after Kitting, 2007), including recreation. We are finding that suitable illustrations and metaphors assist this effective communication to diverse audiences, as formal and informal students of all ages. It will be a challenge to make this new Anthropocene Epoch a good one.

Acknowledgements

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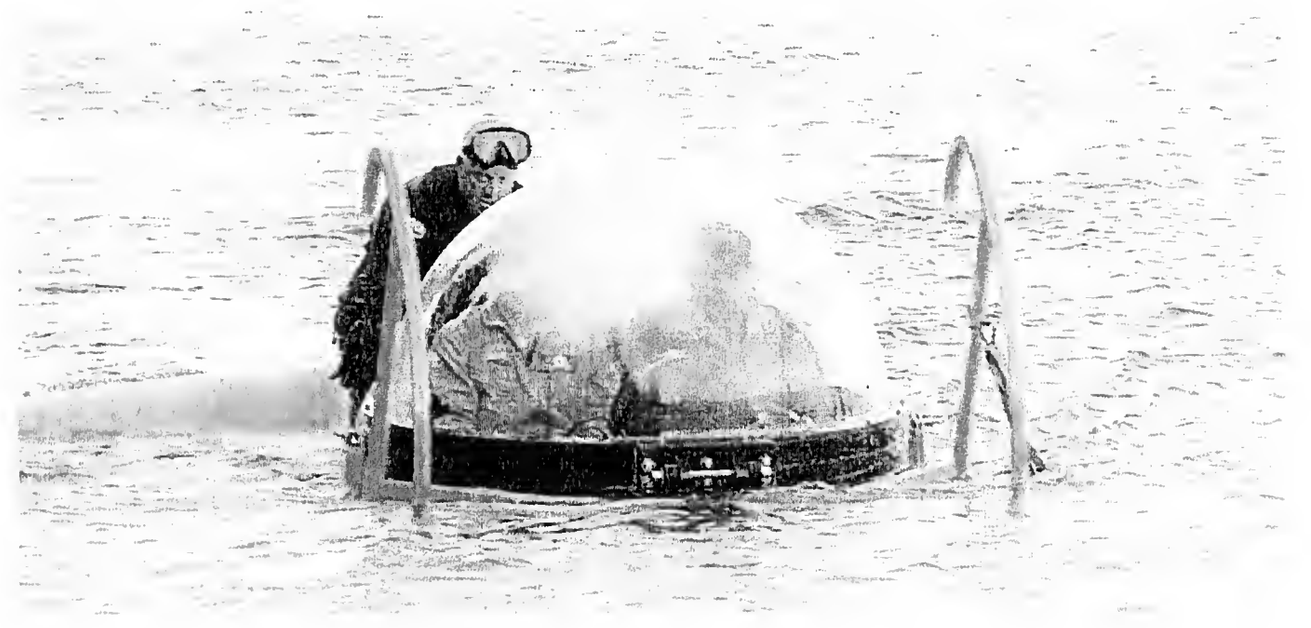

Figure 1. Undersea Voyager Project's two-person submersible with Captain Cassell and scientist Kitting, surfacing after a dive in Fallen Leaf Lake, with diver support by Tom Loomis. A fogged sphere indicates the dehumidifier was spent by the end of this dive.

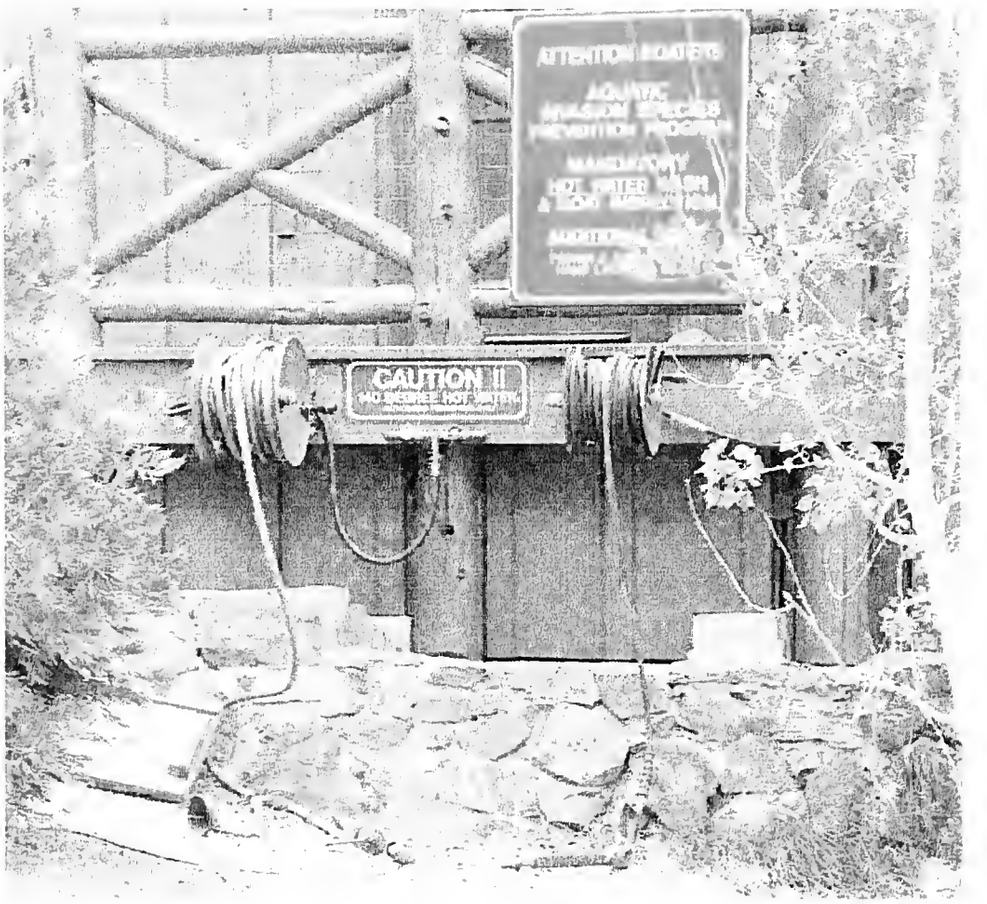

Figure 2. Unusual hot-water wash (including water intakes of motors) and inspection station required of all vessels launching in rather isolated Fallen Leaf Lake, near Lake Tahoe. Invasive plants and animals are common in Lake Tahoe, as in other California lakes. The boat ramp, adjacent, was locked until wash and inspection were passed.

Algal Host Shifts Drive Speciation and Morphological Divergence in Herbivorous Sea Slugs

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Marine taxa were traditionally thought to speciate in allopatry, but recent phylogenetic studies of diverse molluscs reveal that sister species often co-occur along a coastline or within an ocean basin. Identifying ecological mechanisms that promote isolation and divergence may lead to a new paradigm for speciation in the sea. We are reconstructing the evolutionary history of herbivorous sea slugs in the group Sacoglossa, examining how algal host fidelity has shifted among lineages and contributed to species formation. A molecular phylogeny based on four genes will be presented for the Placobranchacea, comprising the two major lineages of derived sacoglossans. Within this phylogenetic framework, Bayesian methods were used to reconstruct the ancestral host of each clade, and to identify branches on which host shifts occurred. We focus on the Placobranchoidea, a group containing all species that harbor photosynthetically active chloroplasts such as the speciose genus *Elysia*. Our analyses reveal a series of progressive host shifts among the major clades of *Elysia*, followed by radiations within basins onto diverse hosts. Allopatric sister species were also recovered, but show striking morphological stasis when both members feed on the same host alga. In contrast, host shifting is correlated with rapid diversification in external morphology and dorsal vessel venation. New hosts likely act as distinct selective environments, favoring novel characteristics as lineages adapt to differences in algal chemistry, chloroplast integrity, and cell wall composition. Ecological associations may thus drive speciation and diversification in the ocean, as in terrestrial taxa such as ectoparasites and phytophagous insects.

Slug Sex, Reproductive Interference, and Allee Effects at a Shifting Range Boundary

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At the edge of a species' range, low densities and competition from related species may result in negative Allee effects (density-dependent reduction in fitness). We studied how interactions between two marine gastropods contribute to their seasonally fluctuating range boundary in San Francisco Bay. The sister species *Alderia modesta* and *Alderia willowi* alternate in abundance throughout the year, where high recruitment of one species usually precedes local extinction of the other. We manipulated densities in lab experiments to test whether mating by hypodermic insemination allows the more common species to decrease fitness of the rarer species, by tissue damage or flooding with incompatible sperm. Within each species, higher

densities resulted in lower reproductive output due to costs of mating by hypodermic insemination. Negative interactions between the sister species were asymmetric: higher densities of *A. modesta* lowered the fitness of *A. willowi*, whereas higher densities of *A. willowi* did not affect *A. modesta.* The larger *A. modesta* inflicts substantial damage on the smaller *A. willowi* during mating, and may thus inhibit colonization or accelerate the extinction of the few *A. willowi* that survive the winter rainy season. Molecular analysis of offspring produced during lab mating trials showed no introgression of species-specific nuclear alleles, and we found no evidence of hybridization in field populations containing both species. Presence of conspecific egg masses induced greater egg production, suggesting additional Allee effects may result if pheromones that cue oviposition are not encountered when slug densities are low.

Revision of World Liotiidae, Recent and Fossil (Gastropoda: Vetigastropoda)

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The family Liotiidae, a basal group of intricately sculptured, turbiniform Vetigastropods, has long been neglected and is overdue for revision. Liotiidae are characterized by a nacreous interior, thickened final lip, lamellar micro-sculpture, and an unusual calcified operculum. The family includes a few moderately large species (maximum diameter 25 mm), some that are micro-gastropods of 2 mm in diameter, and others representing all intermediate sizes. Only a few species are common; most species have narrow distributions and some are known only from the originally described material.

The primary objective of this revision is to analyze generic level characters, and to provide a revised generic classification of living and fossil genera. The secondary objective is to describe the large number of new species that have been recognized in museum collections, many of which are from field studies and ongoing expedition programs, particularly the Tropical Deep-Sea Benthos program of the Paris Museum.

Unlike the operculum of colloniids, in which the inner side of the calcareous operculum has a paucispiral pattern, the inner side of the liotiid operculum is corneous and shows no pattern of volutions. The outer surface has a long growing edge and numerous multispiral volutions on a corneous base holding a continuous calcareous coil with pustules on the exposed surface; corneous tufts project between the volutions. Radular, epipodial, and ctenidial characters are plesiomorphic and similar to these structures in such other basal vetigastropods as the Colloniidae and some Skeneidae. Characters of the liotiid radula and external anatomy are so uniform that they are uninformative for classification and phylogeny. However, shell morphology provides an abundance of characters useful for generic and specific determination and for the provision of a working classification.

Two subfamilies are now recognized, the Liotiinae and Areneinae, which are defined on shell color, dominance of axial or spiral sculpture, other sculptural elements, complexity of the final lip, and opercular distinctions. Early records of both subfamilies are first known with

certainty from the Late Cretaceous of Europe and the Caribbean. Extinct genera and species of all sizes and with intricate sculpture are well represented in the Eocene of France and adjacent regions. Genera are grouped geographically, because their distributions and trends in shell morphology are restricted to faunal regions.

The largest subfamily and the one with the best fossil record is the Liotiinae, characterized by white shells with no color pattern, with strong primary sculpture of both axial and spiral elements, and an elaborate development of the final lip in some genera, and the surface of the operculum with pointed calcareous projections. This subfamily -- which includes nearly all of the Eocene species – is most diverse in genera and species in the Indo-West Pacific, with a smaller number of genera in temperate Australia (also including New Zealand and the Kermadec Islands), the Eastern Pacific, and the Western Atlantic. A number of the Indo-Pacific genera are characteristic of bathyal depths, unlike other regions that have little or no bathyal representation of the family. Many Indo-Pacific genera of Liotiinae have a strong periumbilical cord with deep pits on the outer side; another shell form develops a spur, a strong cord emerging from the umbilicus that connects to the outer lip. Genera of the Eastern Pacific and Western Atlantic do not develop strongly projecting terminal lips, instead usually having a clumping of axial sculpture in preterminal stages.

The less speciose subfamily is the Areneinae, usually having smaller shells with a color pattern, with spiral sculpture dominant, the operculum with oblong calcareous elements, and with the final lip less thickened than that of Liotiinae. Genera of Areneinae are best represented in the tropical Western Atlantic and Eastern Pacific, with lesser representation in southern and western Africa and even fewer genera in the Indo-Pacific.

Over the last 20 years, I have come to realize that this family is far more diverse than I had originally estimated. Illustrations have been prepared for 410 recognized species, both living and extinct, of which 260 are to be described as new. These species are to be assigned to 95 living and extinct genera, all but 18 of which are also to be described as new. Once the alpha taxonomy to be provided by this revision is in place, a phylogenetic assessment of the Liotiidae can be accomplished by future workers using the techniques of molecular genetics.

Genetic Traceability: A Feasible Tool for Mexican Abalone Products

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The authentication of canned Mexican red, *Haliotis rufescens*, and blue, *Haliotis fulgens*, abalones was determined by means of genetic traceability using a combination of the universal 16SAR/16SBR primers and another specific primer for the Haliotidae family, 16HalR. As a positive control, fresh DNA extraction of *H. rufescens* was used. The amplification of this set of primers produced fragments between 320 and 350bp for both abalone species. To determine the specificity of these primers PCR assays were performed with canned *Concholepas concholepas*, with fresh and canned giant keyhole limpet *Megathura crenulata* and with geoduck clam *Panopea* spp. Positive amplification was obtained with all non-abalone species when the universal 16SAR/16SBR primers were used. However, when the 16HalR was used with the 16SAR primer, no fragment amplification was obtained for these species. To determinate the quality of the extracted DNA, 16S PCR assays were executed using the universal set of primer 16SAR and 16SBR obtaining a fragment of about 550bp for fresh *H. rufescens*; 500bp for *Panopea* spp and 550bp for keyhole limpet. In some cases of canned abalone, a 16S fragment of 550bp corresponding to Haliotidae organisms was not amplified, probably due to damaged DNA during the canning process. A multiplex system using a mixing of universal 16S oligonucleotides and specific 16Hal (forward and reverse) primers is under evaluation. The use of the 16S region for traceability is discussed.

Biostratigraphy of the Northern Monterey Bay Section of the Purisima Formation (Late Miocene-Late Pliocene), Santa Cruz County, California

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The beautifully exposed stratigraphic section of the Purisima Formation in the sea cliffs along much of northern Monterey Bay, Santa Cruz County, and coastal central California, has been well studied and dated, but the biostratigrapy of its abundant invertebrate fauna has not been previously documented. Here we recognize the possibly late Miocene to early Pliocene La Honda biozone and the younger probable middle Pliocene Santa Cruz biozones. These shallow (< 50 m), marine biozones were previously recognized elsewhere in the Purisima Formation by

Powell (1998, USGS OFR 98-594; *http://pubs.usgs.gov/of/1998/of98-594/of98-594_2a.pdf*). They were originally described as faunas from scattered outcrops and collections made mostly in San Mateo County and north. Using 157 collections from the California Academy of Sciences, the Natural History Museum of Los Angeles County, and the University of California at Berkeley, we document mega-invertebrate fossil occurrences and recognize the aforementioned biozones in northern Monterey Bay, which will aid in correlating these outcrops to other late Miocene and Pliocene faunas in southern and central California.

The lower La Honda biozone occurs from about 70 to 140 m in the composite section along northern Monterey Bay and contains the restricted occurrences of the bivalves *Chione, Clinocardium meekianum, Lituyapecten purisimaensis, Nuttallia jamesi, Protothaca staleyi, Swiftopecten parmeleei*, and *Tresus pajaroana*. The upper Santa Cruz biozone occurs from about 140 to 248 m in the composite section and contains the restricted biozones of the bivalve *Pseudocardium densatum,* and the echinoid *Scutellaster* and possibly also by the bivalves *Nanaochalmys nutteri* and *Swiftopecten parmeleei* and gastropod *Nucella imperialis*. These taxa do not occur throughout the entire zone and are restricted only to small parts of it. Other taxa, specifically the gastropods *Beringuis stantoni, Caesia grammatus*, *Calyptraea* spp., *Demondia californicus, Lirabuccinum portolaensis,* and *Ophiodermella graciosana* occur in the upper part of the La Honda biozone and throughout the Santa Cruz biozone. The occurrence of *Lituyapecten purisimaensis* in the La Honda biozone in northern Monterey Bay supports a previous (Powell, 1998) supposition that it correlates, at least in part, with the probable early Pliocene Pilar Point biozone of Powell (1998). The deeper water Pillar Point biozone (> 100 m) is only recognized at Pillar Point in San Mateo County.

"Gastroclods": Pleistocene Remnants from Pribilof Canyon

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Located about 60 km south of St. George Island, Pribilof Canyon descends abruptly from the Bering Sea shelf break (about 160 m deep) to over 1,800 m, and is among the largest undersea canyons in the world. During exploration of Pribilof Canyon in the summer of 2007, submarine pilots observed a field of rounded, sedimentary masses lying on the silty mud seafloor at 400 meters. Ridgway collected two of the mysterious fist-sized clods by hydraulic manipulator arm. External examination revealed that the hardened sediment clods had polychaete worms, colonial bryozoa, tiny crustacea, and small *Delectopecten* sp. scallops adhering to surface grains. To illuminate potentially fragile contents, the clods were examined using mammogram-imaging technology. Resulting imagery revealed one large, intact gastropod shell in each clod. The gastropods were identified as *Neptunea heros* (Gray, 1850) and *Buccinum scalariforme* (Moller 1842). Both are extant, abundant and widely distributed in the Bering, Chukchi and Beaufort

seas.

Calcium carbonate leached from each of the thinned gastroclod shell nuclei, solidified these concreted sediment masses. The incipient concretions contained sea ice diatoms and shallow benthic microalgal taxa. These extinct microflora indicate that the samples date from the end of the last glacial (or ca. 15,000 to 25,000 BP) event in Beringia. Radiocarbon analysis of the *Buccinum* shell corroborated the more recent range of dates estimated based upon diatoms (15,380 BP).

The typical distribution of the two gastropods suggests that the "gastroclods" originated in areas shallower than the 400 m depth where collected. Perhaps they originated in shallow upper layers (0-200 m) and rolled down or were moved during a subsidence or sloughing of the canyon walls. It is also possible that they originated in shallows and were redistributed by seasonal sea ice gouging, or possibly were dislodged and swept into depths via fishing nets.

The suite of specimens collected on surfaces and within these 'gastroclod' concretions provides information about nearshore subtidal habitats and paleoclimate records at the southern extent of Beringia during the last glacial maximum. This period is critical to further our understanding of the coastal ecosystem during human migrations, a period that is conspicuously absent of archaeological evidence.

Production of Egg Masses in Enclosure Areas by Adult Milk Conch *Strombus costatus* (Gmelin) in the Contoy Island National Park, Quintana Roo, México

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In the state of Quintana Roo, the north and central zones are closed in all seasons because they were overexploited. Fishing conch in the south zone is restricted by a closed season, a fishing quota, and the prohibition of all forms of scuba diving (skin, or free, diving is allowed). Today the resource has a different recuperation strategy. In addition to the existing fishing regulations, mariculture can be used to recover the overexploited resource population.

The purpose of this study is to quantify the density-dependent structure that controls reproduction in enclosure areas with adult conchs of the species *Strombus costatus* (Gmelin). The experimental design consisted of two variables (area and male:female ratio), with areas of 20 and 40 m^2 and male:female ratios of 2:5, 2:10, and 2:15, with two replicas, yielding 12 experimental units totaling 360 m^2. In the period from May to August, the total production of the enclosure areas were 521 egg masses and approximately 102 million larvae. The sex ratio of 2:15 in the 20 m^2 area had the best results, with 145 egg masses and an estimated 27 million larvae.

Nitric Oxide Signaling Regulates Larval Metamorphosis in a Host-specialized Sea Slug

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Marine invertebrates produce planktonic larvae that settle indiscriminately at a certain age, or selectively in response to environmental cues of habitat suitability. In diverse animals, the timing of metamorphosis is regulated by nitric oxide synthase (NOS). Inhibition of NOS reduces nitric oxide (NO) and its downstream second messenger, cyclic guanosine monophosphate (cGMP), and triggers metamorphosis in species with no environmental cue. We investigated whether the NO pathway regulates metamorphosis in larvae of a host specialist, the sea slug *Alderia willowi*, which expresses an unusual dimorphism: some larvae from an egg mass spontaneously metamorphose upon hatching, while the remainder metamorphose only after encountering a cue from the adult host algae. Pharmacological reduction of NO and cGMP increased spontaneous metamorphosis among newly hatched larvae. Inhibition of NO did not trigger metamorphosis in older larvae, but potentiated their dose-response to habitat cues: larvae had increased sensitivity to the algal cue when NO signaling was suppressed. These findings also suggest a mechanism for maternal control over the proportion of spontaneous metamorphosis: regulation of the per-egg amount of L-arginine, the substrate for NOS. Under optimal conditions, mothers could decrease arginine causing a higher percentage of larvae to metamorphose without dispersing. However, a mother's ability to vary the habitat choice behavior of her offspring may be constrained because the same pathway controls spontaneous and environmentally-cued metamorphosis. Mothers that reduce the amount of spontaneous metamorphosis can adaptively increase dispersal among their offspring, but may consequently produce less choosy larvae that settle in response to weaker habitat cues.

Survival at the Edge: Ecophysiology and Range Limits of *Alderia*

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Despite the fundamental importance of range limits in ecology and evolution, little is known about the factors that set geographical limits in marine animals. The sea slugs *Alderia modesta* and *A. willowi* respectively occur north and south of San Francisco Bay, where they seasonally alternate in abundance. At this dynamic range boundary, *Alderia modesta* displaces *A. willowi* after winter rains, and *A. willowi* recolonizes after peak summer temperatures. We tested whether the sister species differ in tolerance to high temperature and low salinity across three life-history stages by simulating a series of stressful low-tide events in lab assays. Egg masses, larvae and adults of the northern species *A. modesta* survived in water down to 8 ppt. In contrast, egg masses of *A. willowi* experienced 50% mortality at 16 ppt and larvae died below 12 ppt. Survival analysis confirmed that adults differed in their physiological tolerance: *A. modesta*

survived repeated exposure to nearly fresh water (2 ppt) whereas salinities below 4 ppt were fatal to most *A. willowi*. Conversely, some *A. willowi* survived repeated exposure to 34°C, but *A. modesta* did not survive one exposure to 32°C. These thresholds are consistent with observed die-offs of *A. modesta* in the field in 2008 and 2009, when mud surface temperatures exceeded 32°C. Physiological tolerance for different environmental stressors therefore sets the range limits of *Alderia* spp., and may determine future range shifts in response to warming trends and predicted changes in estuarine hydrology.

Early to Middle Pliocene Mollusks from the Lower Part of the Towsley Formation, Wiley Canyon, Northern Santa Susana Mountains, Los Angeles County, California

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Macrofossils and microfossils are very rare in the Towsley Formation that crops out on the north side of the Santa Susana Mountains (SSM) for 20 km, from the San Fernando Pass (SFP), Los Angeles County, westward to just west of Smith Canyon, Ventura County. Based on localities described by Winterer and Durham (1962), all authors have reported that the age of this formation in this area is late Miocene to early Pliocene or early late Pliocene. These localities, however, cannot be verified as to their location, stratigraphic position, or faunal content; hence the age of the formation in the SSM is equivocal. The recent discovery by the author of a new locality in the lower part of the formation in Wiley Canyon, five km west of the SFP, therefore, is significant.

The Towsley Formation in Wiley Canyon is 780 m thick and consists of interbedded siltstone, sandstone, and conglomerate, all deposited as submarine-fan turbidites. The new locality is 262 m above the base of the formation. Fossils are exposed in a cliff face and are widely scattered along strike for 30 m in a 3-m thick channelized conglomeratic sandstone with clasts up to small boulder-size. To the east, the beds are covered by thick vegetation, and to the west, the beds are overturned and abruptly covered by slope wash in a kink-folded area on the north flank of the northeast-vergent, overturned Pico Anticline, which is coincident with the north side of the SSM.

Repeated collecting at the new locality yielded 11 gastropod and 3 bivalve species. Specimens are very weathered. Identifiable species are the gastropods *Astraea* (*Pomaulax*) *gradata* Grant & Gale, 1931, *Ficus* (*Trophosycon*) *ocoyana* (Conrad, 1835), *Calicantharus humerous* (Gabb, 1869), *Nassarius* (*Catilon*) *hamlini* (Arnold, 1907), and *Cancellaria tritonidea* Gabb, 1866, all normally shallow-marine dwellers. Although their shells obviously have been transported, the distance of post-mortem transport was not great because the shells are unabraded. Based on concurrent-range zones, these species indicate an early to middle Pliocene age. The specimens are stored at the Los Angeles County Museum of Natural History, Invertebrate Paleontology Collection.

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Deep Water Mollusk Communities in the Southern California Bight

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The City of San Diego (CSD) has a regular sampling grid of benthic stations that it monitors as part of its wastewater discharge permits for two ocean outfalls. These stations range from depths of 18 to 116m and cover an area from off northern Point Loma south to Playa Blanca in Baja California, Mexico. In general, the molluscan community found within these habitats is well-described. As part of an enhanced ocean monitoring program, CSD also annually samples randomly selected stations that extend the depth range sampled to over 200m. Additionally, CSD participates in region-wide "Bight" projects that reached a maximum depth of 1023m during the Bight '08 project begun in July 2008. Exploring these new habitats is taxonomically exciting and challenging as new suites of organisms are encountered. To examine the question of whether these new organisms were merely replacing shallow-water counterparts or if community composition undergoes more fundamental changes with depth, molluscan community structure was examined on the shelf (shallow: 10-30m, mid: 30-120m, & deep: 120-200m) and slope (upper: 200-500m, lower: 500-1000m) using sediment fines (silt and clay) of more than 35% as a proxy for similar physical habitat type. In this study, abundance and diversity decreased with increasing depth indicating factors beyond mere species substitution are at work.

Comparative Phylogeography of Caribbean Sea Slugs with Long-lived vs. Short-lived Larvae

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Predicting patterns of gene flow is important for conservation and management of marine animal populations. Biophysical coupling models have been developed for the Caribbean that use ocean currents and the lifespan of planktonic larvae to predict whether populations will be genetically connected or isolated. To test model predictions, we determined population genetic structure for the sea slugs *Elysia patina* and *E. zuleicae* which have a 30-day planktonic larval period. A portion of the mitochondrial cytochrome *c* oxidase I gene was sequenced for samples from 13 Caribbean locations. Phylogenetically distinct clades were identified by Bayesian Inference, and Analysis of Molecular Variance (AMOVA) was used to determine realized gene flow among islands. Despite its considerable potential for larval dispersal, *Elysia patina* had surprisingly high population structure; clades were up to 10% divergent, and several were

restricted to one island. In contrast, the co-occurring *E. zuleicae* had little structure, but also comprised two major clades that were 10% divergent. In contrast to published predictions from oceanographic models, there was no east-west break across the Caribbean, but there were deep barriers to gene flow among neighboring islands in the Bahamas. Larval life span is thus a poor predictor of realized dispersal, and current models do not accurately predict larval exchange for common Caribbean molluscs. Differences in larval behavior may explain why less migration has occurred among populations of *E. patina* on historical and recent time scales, compared to other *Elysia* spp.

A Molecular Phylogenetic Analysis of the Buccinidae (Mollusca: Neogastropoda) of the North West Pacific

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Marine whelks (Family Buccinidae) are one of the most diverse, commercially important, and widespread families of marine gastropods. The Pacific buccinid fauna of Japan alone includes 344 species within ten putative subfamilies. This study's aim was to use a molecular approach to further resolve the phylogenetic relationships of North Pacific Buccinidae. Taxa from North America (n=2) and Japan (n=21) were collected and sequenced for the mitochondrial gene CO1 and the nuclear gene 28s. Phylogenetic trees were constructed using maximum likelihood criteria (PhyML) and Bayesian inference (MrBayes). Combined (CO1 + 28s) and single gene analyses were performed including and excluding *Busycon* species (Melongenidea sensu Wade, 1917, and Buccinidae sensu Bouchet & Rocroi, 2005). Resulting tree topologies suggest: (1) the inclusion of *Busycon* within the Buccinidae (sensu Bouchet & Rocroi, 2005), (2) support for the Beringiiinae subfamily (Berigion + Japelion), (3) the monophyly of *Neptunea* and *Buccinum,* (4) a sister-clade relationship between subfamilies Buccininae and Beringiinae, and (5) an unresolved position of species within the genera *Microfusus*, *Kelletia*, *Nassaria*, and *Lirabuccinum*. These results will be discussed with complimentary data from larval biology, biogeography, and paleontology.

A Method for Replicating Bastropod Protoconchs for Morphological Analysis

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Protoconchs are valuable indicators of larval developmental mode that are used by malacologists in biology and paleontology. The maximum diameter and number of volutions of

the protoconch are considered especially important for inferring planktonic and non-planktonic larval lifestyles. For example, a bulbous protoconch with few volutions suggests a non-planktonic larva, while a high-spired protoconch with multiple whorls indicates a planktonic veliger. High magnification imaging (e.g. SEM, variable pressure ESEM, CT scanning) is necessary to analyze the detailed morphology of many gastropod protoconchs, but often institutional SEM machines are not equipped to accommodate these specimens (>5mm). Furthermore, practical considerations like time, effects of specimen mounting, loan permissions, access to imaging facilities, and SEM or other imaging costs, impede the microscopic study of original shell material.

Here I describe and depict a molding and casting method that conveniently, cost-effectively, and precisely replicates intact gastropod protoconchs for SEM and other analyses. The molding procedure can be done in the field, laboratory, or in museum collections, with minimal equipment. Molding material is silicone-based, quick-setting, dimensionally stable, easily portable, and harmless to most gastropod shells. Casting requires limited materials (epoxy resin and a vacuum) and can be performed at the home institution or preparatory laboratory of the researcher. The resulting casts are a convenient and practical alternative to original gastropod shells when comparing microscopic morphology of protoconchs.

Homology Between Shells of Brachiopods and Early Molluscs

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Many Cambrian (543-490 mya) fossils preserved by secondary calcium phosphate show fine-scale detail of crystal form and arrangements in the shell. The data reveal that the earliest known molluscan shells already had diverse and fairly complex microstructure (Vendrasco *et al.*, 2010). Moreover, the evidence from these fossils suggests that the shells of many Cambrian molluscs had the microstructure known as calcitic semi-nacre, revealing a striking similarity between the shells of early molluscs and calcitic brachopods, two lophotrochozoan taxa. Calcitic semi-nacre was previously unknown in molluscs, but occurs in modern brachiopods.

Additional similarities between modern brachiopod and early mollusc shells include a pore system and often loosely-ordered shell microstructures. Examination of modern molluscs reveals additional similarities with brachiopods in the nature of: the shell-secreting tissue (mantle); the organic outermost shell layer (periostracum); the complexity of the shell (layers of different types of microstructure in one shell); the high proportion of organic material embedded in the shell; and the types of shell microstructure (the major varieties of shell microstructure in brachiopods are also seen in molluscs).

There are some distinct differences between the shells of brachiopods and molluscs, such as the predominance of aragonite in molluscs versus calcite and calcium phosphate in brachiopods, as well as apparent differences in how the shell forms in early development in these two groups. However, the overall similarity between the shells of brachiopods and molluscs suggests they may have a relatively high degree of homology. Although the common ancestor of these two taxa probably lacked a mineralized shell, pre-skeletal brachiopods and molluscs may

have had a similar organic coat with homologous components that became independently co-opted for shell formation, leading to the similarities described above. Subsequently, molluscs appear to have evolved a greater ability to control mineralization and certainly ended up with a greater diversity of shell microstructures than in brachiopods. This difference may have been one of the reasons why molluscs since the end of the Paleozoic were more conspicuous, abundant, and diverse than brachiopods.

Literature Cited

Vendrasco, M.J., S.M. Porter, A.V. Kouchinsky, G. Li and C.Z. Fernandez. 2010. Shell microstructures in early mollusks. The Festivus 42(4): 43-54.

Phenotypic Plasticity in the Shell Morphology and Volume of the Surfgrass Limpet, *Lottia paleacea*

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Limpets in different microhabitats can vary dramatically in shell growth and morphology. Limpet shell geometry is simple, so it can be related to the consequences of such phenotypic plasticity. The surfgrass limpet, *Lottia paleacea*, shows a great example of phenotypic plasticity in shell morphology. This limpet is restricted to living on either of two species of intertidal surfgrass along the coast of California, *Phyllospadix torreyi* and *P. scouleri* which differ in the blade width that constrains the limpet's growth. The limpets that live on the narrower *P. torreyi* are much more compressed laterally than on the wider *P. scouleri.* This change in shell morphology can be examined using the volume of the limpets as a proxy for the change in width, length and height of the limpets. The change in volume between the limpets that live on the two different surfgrass species may impact the anatomy of the limpet as well as the life history of the limpets. We predicted that limpets that live on *P. torreyi* would have a lower total volume than those on *P. scouleri.* We tested this by directly measuring volume of water required to fill each of 30 limpet shells selected to represent observed variation throughout California. We then demonstrated that this volume could be effectively modeled as a pyramid as computed from three maximum shell dimensions, (LWH)/3, so these measurements alone would allow an approximate estimate of a surfgrass limpet's internal volume. We then estimated the volume of roughly 400 limpets from Cambria, California, found on both species of surfgrass. We found that limpets that live on *P. scouleri* had a larger total volume than those on *P. torreyi.* Our next step will be to relate estimated total volume to a calculation of each limpet's gonad volume, inferred from sectioning, in order to address the potential impact of phenotypic plasticity on life history traits such as fecundity and body volume (= age?) at first reproduction.

REPORTS OF SOCIETY BUSINESS

EXECUTIVE BOARD MEETING MINUTES

California State Polytechnic University, Pomona
January 24, 2009

- WSM President Michael Vendrasco called the afternoon meeting to order (held during the 2009 meeting of SCUM).

- Current and former WSM officers present included: Kelvin Barwick, Hans Bertsch, Doug Eernisse, George Kennedy, Charles Powell, II, and Ángel Valdés.

- Carole Hertz was proposed as member-at-large, but two people were previously elected to that position (at the 2008 annual meeting) and it was decided that a third is not needed.

- Discussion of WSM computer domain.

- Student research grant committee
    - To be headed by Danielle Zacherl, Assistant Professor of Biology at CSUF
        - She will determine the due date for grant proposals
    - Other members of the Student Grant Committee: Hans Bertsch and Nora Foster
    - It was determined that grants should be given out to students researching mollusks in Western North America. These students can be from any country and do not need to be members of WSM.
    - It was decided that the committee should aim to give out $1000 this year, in the form of either one or two grants.

- It was decided that there will be best talk and best poster awards (one each) at the 2009 Annual Meeting. Each will come with a $100 prize plus one year membership in WSM.

- Discussion of annual reports and mailing list (being compiled by Charles Powell, II).

Minutes recorded by Charles Powell, II, edited by Michael Vendrasco.

EXECUTIVE BOARD MEETING MINUTES

California State University, Fullerton
June 24, 2009

- WSM President Michael Vandrasco called the meeting to order, about 5 PM.

- Current and former WSM officers present include: Kelvin Barwick, Hans Bertsch, Carlos Cáceres Martínez, Doug Eernisse, Esteban Félix Pico, Nora Foster, Carole Hertz, George Kennedy, Charles Powell, II, Carol Skoglund, and Ángel Valdés

- Student Grant Committee (Hans Bertsch, Nora Foster, and Danielle Zacherl) suggested that the student grant award should go to Christin Slaughter from New Mexico State University.
    - Michael Vendrasco appointed Hans Bertsch, Nora Foster, and Danielle Zacherl to continue on Student Grant Committee through next year.

- Hans Bertsch motioned that Executive Board will determine how much money to give to Student Grant fund one month after annual meeting (after we know how much money is available after meeting expenses are paid). Seconded by Carol Hertz; passed unanimously.

- Hans Bertsch motioned that all funds from reprint sale and auction should be included in student grant fund. Seconded by Carole Hertz; passed with one opposition.

- Discussion of current membership list.

- Discussion of annual reports status.

- Preview of financial report for annual meeting given by Treasurer Kelvin Barwick.

- Slate of officers proposed for 2009-2010 (2010 meeting year):
    - President – George Kennedy
    - 1st Vice-President – Esteban Félix Pico
    - 2nd Vice-President – Janet Leonard (still needs to be contacted to see if she will accept nomination)
    - Treasurer – Kelvin Barwick
    - Secretary – Charles Powell
    - Members-at-Large – Hans Bertsch and Nora Foster
    - Motion made by Carole Hertz to accept slate of officers, seconded by Hans Bertsch, and passed unanimously.

- Michael Vendrasco appointed Lindsey Groves, James McLean and Ángel Valdés as auditing committee for 2009-2010

- Carole Hertz made a motion to standardize abstract format. Hans Bertsch, Nora Foster, and George Kennedy will work out the details. Seconded by Nora Foster, passed unanimously.

Minutes recorded by Charles Powell, II, edited by George Kennedy and Michael Vendrasco.

GENERAL MEMBERSHIP MEETING MINUTES

California State University at Fullerton
June 26, 2009

- WSM President Michael Vendrasco called the meeting to order at 2:55 P.M.

- Secretary's report – minutes from previous meeting in annual report (2008) distributed at meeting. Motion to accept by Hans Bertsch, seconded by Carole Hertz, passed unanimously.

- Treasurer's report – Kelvin Barwick gave brief run down on the financial health of the WSM. Approximately $19,500 balance after meeting expenses. Motion to accept by Hans Bertsch, seconded by Carole Hertz, passed unanimously.

- Student Grant Committee report – Nora Foster reported six proposals came in during the past year and the committee suggested we fund the one by Cristin Slaughter for $1,000. Motion to accept by Hans Bertsch, seconded by Carole Hertz, passed unanimously.

- Michael Vendrasco gave summary of Executive Board meeting of June 24, 2009.
  - Proceedings of auction and reprint sale to go to Student Grant Fund.
  - Standardized abstract format is being developed.
  - Changes in membership form outlined.
  - Audit committee will be developed.

- New Business
  - Discussion of new membership form.
  - Request for reprints for the Orange County Sanitation District library.

- Best Student presentation awards
  - Poster – Jann Elizabeth Vendetti "A method for replicating gastropod protoconchs for morphological analysis."
  - Paper - Dominique Gordon "Environmental Effects on Larval Development of the sea slug *Alderia willowi*."

- Slate of officers presented for 2009-2010 (2010 meeting year):
    - President – George Kennedy
    - 1st Vice-President – Esteban Félix Pico
    - 2nd Vice-President – Janet Leonard
    - Treasurer – Kelvin Barwick
    - Secretary – Charles Powell, II
    - Members-at-Large – Hans Bertsch and Nora Foster
  - Motion to elect by Carol Skoglund, seconded by Hans Bertsch, passed unanimously.

- Motion to thank current WSM officers by Hans Bertsch, seconded by Carole Hertz, passed unanimously.

- Michael Vendrasco officially stepped down as WSM president and the new president George Kennedy continued the meeting.

- George Kennedy as Historian stated that he would like materials from previous meetings donated.

- George Kennedy and Doug Eernisse gave a presentation on next meeting (2010) to be held jointly with American Malacological Society June 27-29 (dates tentative) at San Diego State University.

- Esteban Félix Pico gave a presentation on following meeting (2011) held jointly with Reunion de la Asociación Nacional de Malacologiá y Conquiliología June 9-13 at the Centro Interdisciplinario de Ciencias Marinas, La Paz, Baja California Sur, México.

- Carole Hertz made a motion to adjourn, seconded by Hans Bertsch, passed unanimously.

Minutes recorded by Charles Powell, II, edited by Michael Vendrasco.

TREASURER'S REPORT

Western Society of Malacologists

September 30, 2009

Members,

Below is an accounting of WSM funds to date.

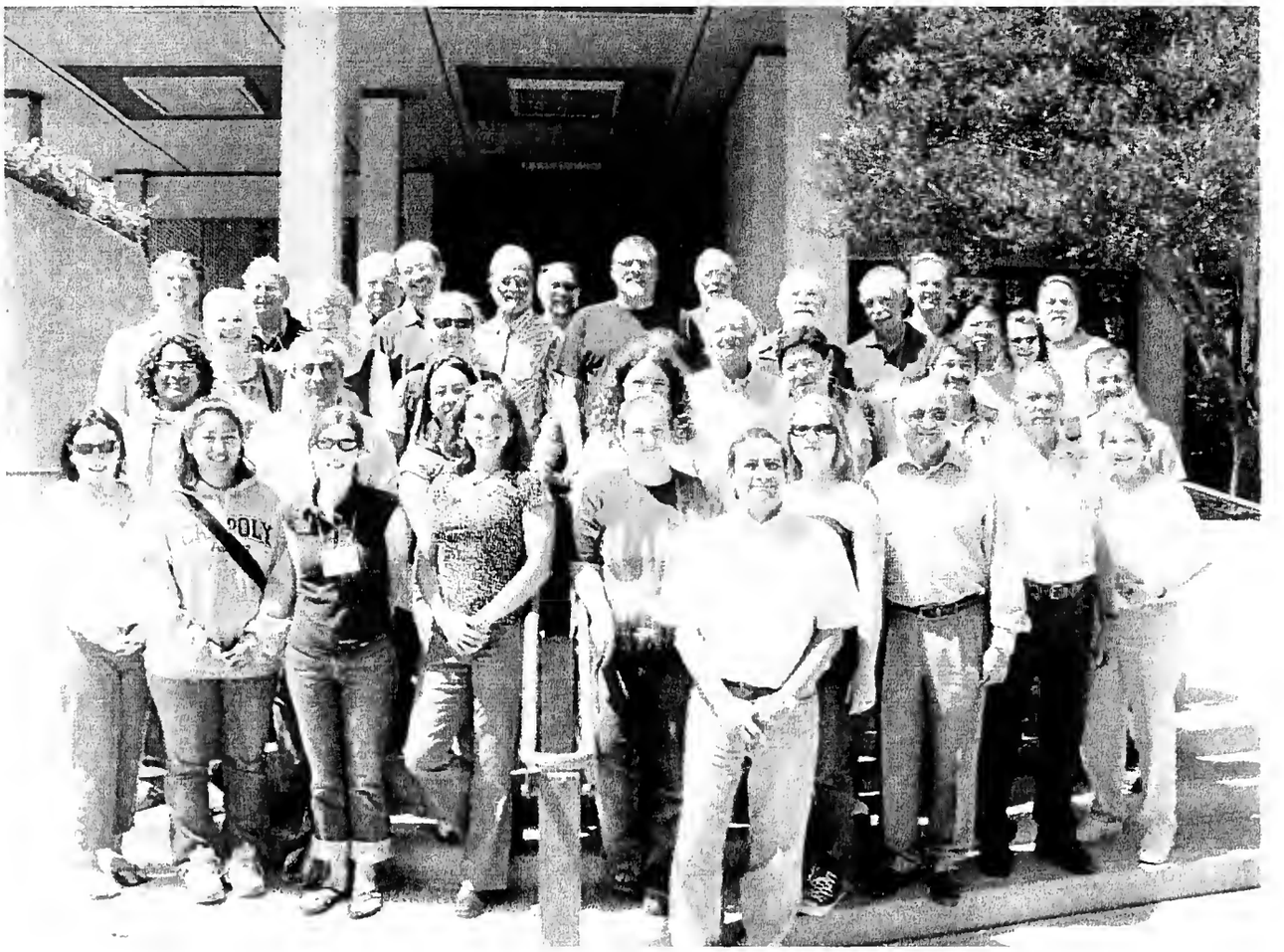
Kelvin Barwick
Treasurer

Income

	Opening balance		**$22,000.00**
Membership Dues, Individual		1,632.00	
Membership Dues, Institutional		175.00	
Student Grant Donations		936.70	
Student Grant Auction		579.00	
Student Grant Reprint Sales		123.35	
2009 Annual Conference & Fieldtrip		2,516.01	
Micro-Mollusk Workshop (materials)		1,348.80	
USGS Publication Funds Grant		1,000.00	
Interest		5.00	
	Total	8,315.86	**$8,315.86**

Expenses			
Miscellaneous		162.44	
Misc. Postage		34.14	
Bank Charges		22.50	
Student Presentation Awards		200.00	
Student Grant		1,000.00	
Annual Reports (2003 – 2008)		5,801.63	
2009 Annual Conference & Fieldtrip		2,072.21	
Micro-Mollusk Workshop (reimbursement)		1,209.66	
	Total	-10,502.47	**$-10,502.47**
		Cash Balance	**$19,813.39**

GROUP PHOTOGRAPH, 2009 WSM Annual Meeting



Front row (left to right): Deborah Roman, Elysse Gatdula, Jann Vendetti, Wendy Storm, Laney Whitlow, Carlos Cáceres Martínez, Chrystal Johnson, Esteban Félix Pico, Arturo Tripp Quezada, Rosa del Carmen Campay Villalobos.

Second row (left to right): Omar Mendoza Porras, Miguel Ángel del Río Portilla, Christine Fernandez, Celia K. C. Churchill, Carlos Figueroa Beltrán, Miguel Agustín Téllez Duarte, Ángel Valdés.

Third row (left to right): Carole Hertz, Nora Foster, Constance Gramlich, James McLean, Bob Moore, Jackson Lam, Rebecca Kowallis.

Back row (left to right): Douglas Eernisse, Jules Hertz, Roger Seapy, Michael Vendrasco, Hans Bertsch, Christopher Kitting, Kelvin Barwick, George Kennedy, Patrick LaFollette, Brenton Ferguson, Charles Powell, II.

Photograph by Dustin Harrison; photograph provided by Carole Hertz.

MEMBERSHIP LIST 2008

This is a list of current (September 30, 2009) WSM members. Please report any concerns, errors or changes to the Kelvin Barwick, Treasurer at the address below or kbarwick@ocsd.com.

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Hopkins Marine Station Miller Library
Hopkins Marine Station of Stanford University
Attn: Dr. Joe Wible
Pacific Grove USA CA 93950-3094

Museum of New Zealand
Te Aka Matua Library
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Swets Information Services Inc.
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