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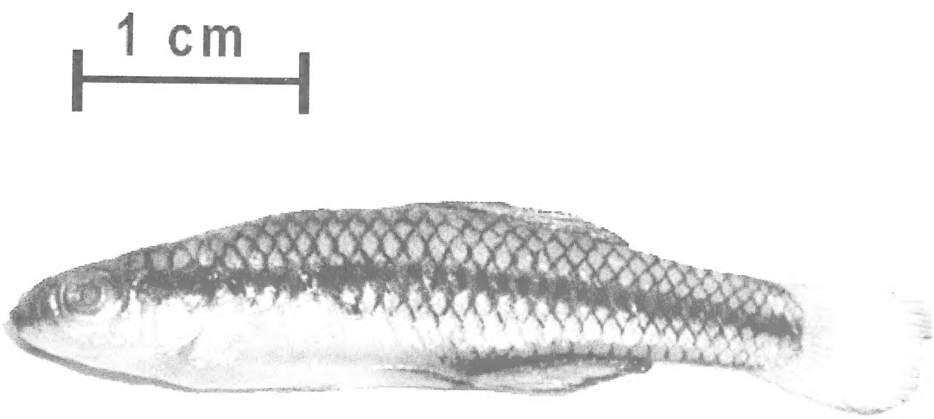

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Date of this issue 1 April 2003

∞ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

CALL FOR PAPERS

2003 ANNUAL MEETING

May 9–10, 2003

CALIFORNIA STATE UNIVERSITY

NORTHRIDGE

Details of the meeting, announcments and general instructions for pre-registration are given on the meeting web site at http://jsd.claremont.edu/sca. Pre-registration deadline is **APRIL 20, 2003**.

Planned Symposia

Friday

Changed Fish Populations, Declining Fisheries, and Marine Protected Areas: Jim Allen:
Parasites and Pathogens: Cheryl Hogue
Contributed Papers

Saturday

Reef Ecology: Dan Pondell
Habitat Restoration: Ralph Abby
Junior Academy Presentations: Gloria Takahashi
Contributed Papers

Plenary Speakers:

Friday, May 9: Dr. Brian Fagan, UCSB. "El Nino, the Little Ice Age, and the People of the Past."

Saturday, May 10: Dr. Milton Love, Marine Sci. Inst., UCSB. "Why do we Study Reef Fishes?"

Short Course

Toxicology for Educators Steve Bay (SCCWRP), Dan Schlenk (UC Riverside), and Chris Pincetich (UC Davis). 9:00 a.m.–4:00 p.m. on Saturday, May 10. This hands-on course, presented by the Southern California chapter of the Society of Environmental Toxicology and Chemistry (SoCal SETAC), will show educators and volunteer monitoring groups how to include toxicity tests into their classroom or monitoring activities. Participants in this six-hour course will receive background information on the principles of toxicology and learn how to conduct simple and sensitive toxicity tests. Experience in working with sea urchins and freshwater crustaceans will be provided. The instructors will provide examples of their own research using these methods, so that the participants can gain experience with data interpretation.

Annual Meeting, 2004

The 2004 Annual Meeting of the Southern California Academy of Sciences will be held in early May, 2004 at California State University, Long Beach. If you would like to organize a Symposia for this meeting, or have suggestions for a symposia topic, please contact either Dan Guthrie (dguthrie@jsd.claremont.edu) or David Huckaby (dhuckaby@csulb.edu).

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Commented Checklist of the Polychaetes (Annelida: Polychaeta) from Areas Adjacent to Islands of the Mexican Pacific and Gulf of California

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Abstract.—The systematic list of the benthic polychaetes from areas adjacent to the main islands of the Mexican Pacific is herein presented. A total of 1375 specimens were analyzed from 96 species and 29 families; the specimens were collected from soft bottoms around Tiburón, Del Carmen and María Madre islands, and from dead coral substrates from Socorro Island. All previous records of Annelid Polychaetes from the study area were also included; 348 species are now recorded from 36 islands in the Mexican Pacific. The highest number of species is recorded from Espíritu Santo Island (56 species) in the region of the Gulf of California and María Madre and Socorro islands (69 and 70 species) in the central Mexican Pacific.

The islands have always been considered a natural biological laboratory and have, as such, focused the attention of ecologists and evolutionists in their attempt to define if the species present are consistent with local geological records; the study of the biological processes in those isolated habitats has even been at the heart of setting forth theories such as the equilibrium theory in island biogeography (MacArthur and Wilson 1967).

In the Mexican Pacific, between latitudes 14°45′ and 32°26′ N, more than 140 islands and islets are found, but their polychaete fauna is largely unknown: the majority of the records are the product of sporadic or fortuitous collections. Research on polychaetes from these islands has been basically done by Rioja (1960, 1962) in several Pacific islands, Salazar-Vallejo et al. (1987), Góngora-Garza (1984), and Góngora-Garza and De León-González (1993) in María Madre Island and Salazar-Vallejo (1990) in Rasa Island; occasional records have been done in the vicinity of some islands by Treadwell (1914, 1929, 1937, 1941), Chamberlin (1919), Moore (1923), Hartman (1939a, b, 1940, 1941, 1944a, 1944b, 1950), Berkeley and Berkeley (1939, 1958), Steinbeck and Ricketts (1941), Rioja (1941, 1947a, 1947b, 1947c), Fauvel (1943), Fauchald (1968, 1970, 1972, 1982, 1992), Pettibone (1971), Sarti-Martínez (1984), De León-González (1985), Bastida-Zavala (1990), Holguín-Quiñones et al. (1992), Holguín-Quiñones (1994), and Bautista-Romero et al. (1994). These records together with the material obtained for this study make up for 348 species in littoral and sublittoral habitats from areas adjacent to the islands of the Mexican Pacific.

The Polychaetes are the best represented taxonomic group in the benthic communities, be it in hard or soft bottoms (Mackie and Oliver 1996), where they can reach between 36% and 70% of the total fauna, and between 25% and 65% of the species present. For this reason, their distribution patterns frequently reflect those of the whole benthic fauna (Blake 1994; Mackie et al. 1997; Glasby and Read 1998). Being such a diversified and ubiquitous group, they can increase considerably the biodiversity values of any habitat considered. In this case, the description of the communities found around the islands located in the Mexican Pacific and Gulf of California is necessary, not only because of the great number of islands present, but also because several of them have been declared priority areas by the Mexican government, so that specific strategies are being implemented for their protection and management (SEDESOL 1994), all of which is impossible without a basic knowledge of the biota present.

The purpose of this study, then, is to synthesize the results of previous records as well as to add to the knowledge of this group, with the results of the identifications of the polychaetes collected by us in Tiburón, Del Carmen, María Madre and Socorro islands. We include a systematic list with all the records made around the islands of the Mexican Pacific as well as their affinities according to their faunistic composition.

Methods

Samples were collected in March 1985 in soft bottoms in four sublittoral stations (29–102 m) from Tiburón, Del Carmen and María Madre islands, as part of the expedition "Cortes"; and in November 1997, in dead coral substrates from seven localities (0.40 to 20.5 m) in Socorro Island, Revillagigedo as part of the expedition "Surpaclipp" (Fig. 1).

The soft bottom samples were collected with a Smith-McIntyre (0.1 m^2) dredge, and those from hard bottoms manually, either directly or with SCUBA diving techniques. Fixation of the organisms was done with 10% formaldehyde followed by preservation in 70% ethanol. The polychaetes were identified and deposited in the "Colección de Poliquetos del Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México" (CP-ICML, UNAM; DFE.IN.061.0598).

The previous records herein reported are taken from the existing literature, following an exhaustive revision. Outdated terminology was corrected in favor of presently valid names, based on the publications by Reish (1968), Salazar-Vallejo (1989) and Hernández-Alcántara (1992), since these are the basic studies about polychaetes from the Gulf of California and the Mexican Pacific.

Results and Discussion

The comprehensive list of the 348 species of polychaetes so far identified from Mexican Pacific islands is shown in Table 1, which includes also the 96 species identified for this study. The species which were found to be first records for the particular areas are also indicated. In Table 2, the number of species so far recorded for all the islands (including our survey), are shown, divided by state. The taxonomic arrangement follows Rouse (2000).

For this study, 1375 specimens belonging to 96 species of 29 families were identified from the islands of Tiburón, del Carmen, María Madre and Socorro. The scant knowledge of the polychaetes living in the islands of western Mexico is evidenced by the fact that between 48% and 89% of the species identified in this survey are registered for the first time in each island (Table 1). From soft bottoms (fine and muddy sands), 752 organisms (73 species) were recorded, while

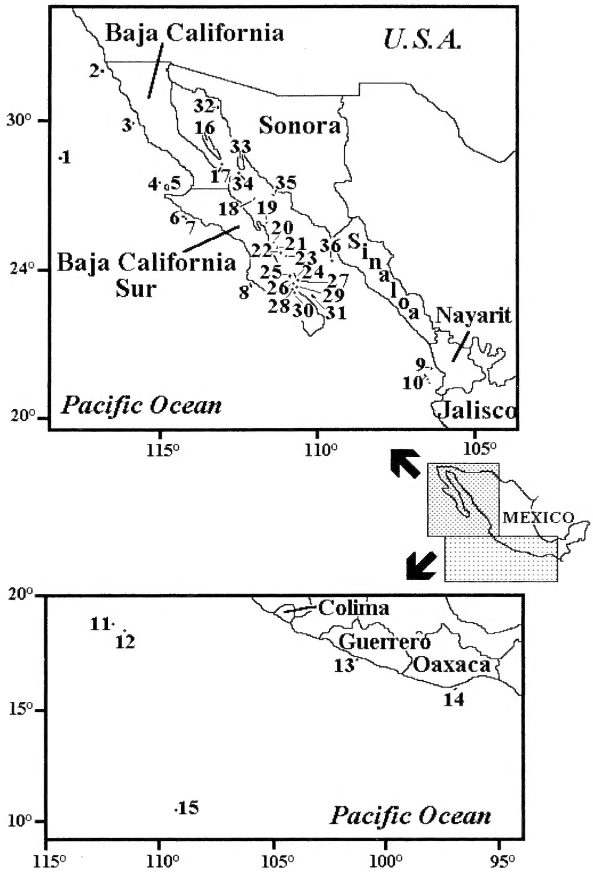

Fig. 1. Study area, including the islands where the polychaetes were reported in the literature.

623 organisms (25 species) were taken from dead coral substrates (in Socorro Island).

Comparison of the polychaete communities found in the different islands under study was limited by the sampling methodologies, often different, and by the literature records, done at different depths and types of substrates from soft to hard.

The idea that the macrofauna of the islands can be highly diversified comes from the variety of habitats present, from those due to their geological, climatic and topographic differences to those due to their location in two biogeographic provinces: the Californian province with temperate conditions and the Mexican province with tropical characteristics (Hendrickx 1992).

Albeit the variations in abundance cannot be directly compared, differences in specific composition could nevertheless be noted: in dead coral substrates, Syllids (mostly small species that are common in hard substrates of shallow waters) and Sabellariids (which live in tubes attached to hard substrates) dominate. The highest abundance there was found for *Idanthyrsus* sp. 1 and *Eurythoe complanata,* basically in intertidal localities since they both tend to decrease with depth.

On the other hand, the polychaetes collected from soft bottoms in the islands

Table 1. Systematic list of the species of the Class Polychaeta, recorded from areas adjacent to islands of the Mexican Pacific (the numbers in black indicate the distribution in a particular island and follow the same numeration of table 2; ** first records for the islands).

Annelida
Polychaeta

Scolecida

Family Maldanidae

Axiothella rubrocincta (Johnson, 1901): **10**, 20.**
Isocirrus papillatus (Berkeley and Berkeley, 1939): **28, 30.**
Sonatsa carinata (Moore, 1923): **5, 10.**

Family Capitellidae

Dasybranchus glabrus Moore, 1909: **5.**
Dasybranchus parplatyceps Kudenov, 1975: **17.**
Dasybranchus lumbricoides (Grube, 1878): **33.**
Dasybranchus sp.: **5.**
Leiocapitella glabra Hartman, 1947: **5, 29.**
Mastobranchus? variabilis Ewing, 1984: **10**.**
Notomastus americanus Day, 1973: **10**, 21**.**
Notomastus hemipodus Hartman, 1945: **21**.**
Notomastus lobatus Hartman, 1947: **29.**
Notomastus tenuis Moore, 1909: **7, 10**.**
Notomastus sp.: **2, 5.**
Scyphoproctus oculatus Reish, 1959: **17.**

Family Opheliidae

Ammotrypane gracile McIntosh, 1885: **23.**
Ophelina acuminata Örsted, 1843: **2, 17.**
Ophelina magna Treadwell, 1914: **23.**
Polyophthalmus pictus (Dujardin, 1839): **7, 28.**

Family Orbiniidae

Leitoscoloplos mexicanus (Fauchald, 1972): **21**.**
Naineris dendritica (Kinberg, 1867): **17.**
Naineris grubei (Gravier, 1909): **10**.**
Naineris laevigata (Grube, 1855): **6, 7.**
Naineris sp.: **12.**
Orbinia riseri (Pettibone, 1957); **10**, 21**.**
Scoloplos (Leodamas) chevalieri (Fauvel, 1901): **17.**
Scoloplos (Leodamas) ohlini (Ehlers, 1901): **33.**
Scoloplos (Scoloplos) acmeceps Chamberlin, 1919: **10, 33.**
Scoloplos (Scoloplos) armiger (Müller, 1776); **10**, 16.**
Scoloplos (Scoloplos capensis (Day, 1961): **10**, 33**.**
Scoloplos (Scoloplos) elongata Johnson, 1901: **20.**

Family Paraonidae

Aricidea (Acmira) simplex Day, 1963: **10**, 21**.**
Aricidea (Allia) sueccia Eliason, 1920: **17, 21**.**

Family Cossuridae

Cossura brunnea Fauchald, 1972: **10**.**

Family Scalibregmatidae

Sclerocheilus pacificus Moore, 1909: **23.**

Palpata
Aciculata

Amphinomida *sensu stricto*

Family Amphinomidae

Chloeia entypa Chamberlin, 1919: **7, 10**, 16.**
Chloeia pinnata Moore, 1911: **29.**
Chloeia viridis Schmarda, 1961: **9, 10**, 16, 18, 19, 21, 26, 27, 29, 33, 35.**
Eurythoe complanata (Pallas, 1766); **5, 6, 7, 9, 11, 12, 15, 16, 26, 28, 29.**
Eurythoe pacifica Kinberg, 1857: **11.**

Table 1. Continued.

Linopherus kristiani Salazar-Vallejo, 1987: **10**, 21.**
Notopygos ornata Grube, 1856: **12**, 16.**
Pareurythoe californica (Johnson, 1897): **5, 6.**
Pareurythoe paupera (Grube, 1856): **12.**

Family Euphrosinidae

Euphrosine bicirrata Moore, 1905: **27.**

Eunicida sensu stricto

Family Dorvilleidae

Dorvillea cerasina (Ehlers, 1901): **12, 20, 21, 29, 34.**

Family Lumbrineridae

Eranno bicirrata (Treadwell, 1929): **4.**
Lumbrinerides ? acuta (Verrill, 1875): **33.**
Lumbrineris cruzensis Hartman, 1944: **29.**
Lumbrineris inflata Moore, 1911: **27, 33.**
Lumbrineris latreilli Audouin and Milne-Edwards, 1834: **9, 21, 32, 33.**
Lumbrineris limicola Hartman, 1944: **10**, 33.**
Lumbrineris simplicis Hartman, 1959: **16.**
Lumbrineris zonata (Johnson, 1901); **12, 23.**
Ninoe sp 2: **10.**
Scoletoma crassidentata Fauchald, 1970: **10**.**
Scoletoma erecta (Moore, 1904): **3, 6, 7, 20, 29, 33, 34.**
Scoletoma platylobata Fauchald, 1970: **10**, 36.**
Scoletoma tenuis (Verrill, 1873): **16.**
Scoletoma tetraura (Schmarda, 1861): **29, 33.**

Family Oenonidae

Arabella attenuata Moore, 1907: **23.**
Arabella iricolor (Montagu, 1804): **6, 7, 12, 16, 17.**
Arabella panamensis Colbath, 1898: **12, 16.**
Arabella semimaculata (Moore, 1911); **6, 7, 33.**
Arabella sp. ?: **5.**
Drilonereis falcata Moore, 1911: **4, 10**, 21**, 29.**
Oenone fulgida (Savigny, 1818): **24, 29, 33.**

Family Eunicidae

Eunice aedificatrix (Monro, 1933): **5, 9.**
Eunice afra Peters, 1854: **16, 29.**
Eunice americana Hartman, 1944: **4, 18.**
Eunice antennata (Lamarck, 1818): **5, 9, 10, 11, 16, 20, 21, 24, 29, 33.**
Eunice aphroditois (Pallas, 1788): **29, 33, 35.**
Eunice biannulata Moore, 1904: **9, 12, 16, 20, 22, 23, 26, 28, 29.**
Eunice cariboea Grube, 1856: **7, 29, 30.**
Eunice filamentosa Grube, 1856: **6, 16, 33.**
Eunice indica Kinberg, 1865: **24.**
Eunice mexicana (Fauchald, 1970): **9.**
Eunice multipectinata Moore, 1911: **7.**
Eunice mutilata Webster, 1884: **10, 12.**
Eunice reducta Fauchald, 1970: **29.**
Eunice rubra Grube, 1856: **7.**
Eunice tridentata Ehlers, 1905: **10.**
Eunice unidentata Rioja, 1962: **6, 7.**
Eunice vittata (delle Chiaje, 1829): **12, 16, 24, 35.**
Eunice vittatopsis Fauchald, 1970: **35.**
Eunice sp.: **12.**
Lysidice collaris (Grube, 1870): **12.**
Lysidice ninetta Audouin and Milne-Edwards, 1833: **10**, 12, 35.**
Marphysa aenea (Blanchard, 1849): **29.**
Marphysa angelensis Fauchald, 1970: **16.**
Marphysa mortenseni Monro, 1928: **29.**
Marphysa sanguinea (Montagu, 1815): **15, 16, 20, 28, 29, 32.**

Table 1. Continued.

Marphysa stylobranchiata Moore, 1909: **1.**
Nematonereis hebes Verrill, 1900: **10.**
Nematonereis unicornis (Grube, 1840): **10**.**
Palola paloloides (Moore, 1909): **6, 7, 15, 21.**
Palola siciliensis (Grube, 1840): **9, 10, 15, 16, 24, 29.**

Family Onuphidae

Diopatra neotridens Hartman, 1944: **16.**
Diopatra obliqua Hartman, 1944: **10**, 21**.**
Diopatra ornata Moore, 1911: **6, 13, 16.**
Diopatra splendidissima Kinberg, 1857: **20.**
Hyalinoecia juvenalis Moore, 1911: **16, 20, 27, 29.**
Kinbergonuphis cedroensis (Fauchald, 1968): **21**.**
Kinbergonuphis pulchra (Fauchald, 1980): **10**.**
Kinbergonuphis vermillionensis (Fauchauld, 1968): **33.**
Mooreonuphis cirrata (Hartman, 1944): **16, 17.**
Mooreonuphis elsiae (De León-González, 1994): **33**.**
Mooreonuphis cf. guadalupensis (Fauchald, 1968): **10**.**
Mooreonuphis nebulosa (Moore, 1911): **7, 10**.**
Onuphis iridescens (Johnson, 1901): **23.**
Sarsonuphis parva (Moore, 1911): **21.**
Rhamphobrachium longisetosum Berkeley and Berkeley, 1938: **4.**

Family Aphroditidae

Aphrodita castanea Moore, 1910: **5.**
Aphrodita japonica Marenzeller, 1879: **27, 29.**
Aphrodita negligens Moore, 1905: **20.**
Aphrodita parva Moore, 1905: **23.**
Pontogenia laeviseta Hartman, 1939: **9, 16.**

Phyllodocida

Family Eulepethidae

Grueulepis mexicana (Berkeley and Berkeley, 1939): **13, 16.**

Family Polynoidae

Arctonoe pulchra (Johnson, 1897): **20.**
Chaetacanthus magnificus (Grube, 1875): **12, 29.**
Halosydna brevisetosa Kinberg, 1855: **5, 23, 32.**
Halosydna insignis (Baird, 1863): **23.**
Halosydna latior Chamberlin, 1919: **5, 20.**
Halosydna tuberculifer Chamberlin, 1919: **5.**
Harmothoe exanthema (Grube, 1856): **27.**
Harmothoe hirsuta Johnson, 1879: **12.**
Hololepida veleronis Hartman, 1939: **16.**
Iphione ovata Kinberg, 1855: **12, 20, 26, 28, 29.**
Lepidasthenia pulchra (Johnson, 1897): **5.**
Lepidasthenia treadwelli (Grube, 1840): **5.**
Lepidonotus purpureus Potts, 1910: **16.**
Lepidonotus hupferi Augener, 1918: **7, 9, 28, 29.**
Lepidonotus nesophilus Chamberlin, 1919: **7, 30.**
Lepidonotus squamatus (Linnaeus, 1767): **7, 12.**
Lepidonotus versicolor Ehlers, 1901: **12, 34.**
Malmgrenia nesiotes (Chamberlin, 1919): **8.**
Thormora johnstoni (Kinberg, 1855): **7, 12, 20, 27, 29.**

Family Acoetidae

Panthalis pacifica Treadwell, 1914: **23.**

Family Sigalionidae

Eupholoe philippinensis McIntosh, 1885: **29.**
Euthalanessa digitata McIntosh, 1885: **16.**
Psammolyce arenosa (Delle Chiaje, 1830): **5.**
Psammolyce fimbriata Hartman, 1939: **9.**

Table 1. Continued.

Psammolyce myops Hartman, 1993: **29.**
Sigalion lewisi Berkeley and Berkeley, 1939: **9, 29.**
Sigalion spinosus (Hartman, 1939): **9, 11, 28.**
Sthenelais articulata Kinberg, 1855: **7, 20, 29.**
Sthenelais fusca Johnson, 1897: **9.**
Sthenelais helenae Kinberg, 1855: **29.**
Sthenelais neoleanirae Hartman, 1939: **21.**
Sthenelais verruculosa Johnson, 1897: **10**, 21**.**
Sthenelanella uniformis Moore, 1910: **16.**
Sthenolepis fimbriarum (Hartman, 1939): **21, 29.**

Family Chrysopetalidae

Chrysopetalum occidentale Johnson, 1897: **12**.**

Family Glyceridae

Glycera americana Leidy, 1855: **5, 20, 23, 29.**
Glycera dibranchiata Ehlers, 1868: **33**.**
Glycera lapidum Quatrefages, 1865: **11.**
Glycera oxycephala Ehlers, 1887: **33**.**
Glycera papillosa Grube, 1857: **10**, 33**.**
Glycera profundi Chamberlin, 1919: **5.**
Glycera tesselata Grube, 1863: **9, 10**, 12, 16, 18, 23, 27, 33, 35.**

Family Goniadidae

Glycinde armigera Moore, 1911: **11.**
Glycinde multidens Muller, 1858: **23.**
Goniada aciculata Harmtan, 1940: **16, 29.**
Goniada brunnea Treadwell, 1906: **33.**

Family Phyllodocidae

Eulalia myriacyclum (Schmarda, 1861): **16, 28.**
Eumida sanguinea (Oersted, 1843): **5, 6, 7.**
Nereiphylla sp. 1: **16.**
Nereiphylla castanea (Marenzeller, 1879): **23.**
Phyllodoce (Anaitides) erythrophylla (Schmarda, 1861): **5.**
Phyllodoce (Anaitides) lamellifera (Pallas, 1788): **15.**
Phyllodoce (Anaitides) longipes (Kinberg, 1866): **10**, 16.**
Phyllodoce (Anaitides) medipapillata (Moore, 1909): **12**, 23.**
Phyllodoce (Anaitides) mucosa (Orsted, 1843): **12.**
Phyllodoce (Phyllodoce) ferruginea Moore, 1909: **23.**
Phyllodoce (Phyllodoce) fristedti Bergström, 1914: **16.**
Phyllodoce (Phyllodoce) madeirensis Langerhans, 1880: **6, 7, 10**, 16, 20.**
Phyllodoce (Phyllodoce) sp. 1: **10, 33.**

Family Hesionidae

Hesione intertexta Grube, 1878: **9, 11, 12, 18, 29.**
Hesione pantherina Risso, 1826: **24.**
Leocrates chinensis Kinberg, 1866: **11, 29.**
Ophiodromus pugettensis Johnson, 1901: **7, 28, 29.**

Family Pilargidae

Synelmis albini (Langerhans, 1881): **12**.**

Family Nephtyidae

Aglaophamus dibranchis (Grube, 1877): **5, 21, 26.**
Aglaophamus erectans Hartman, 1950: **21**.**
Aglaophamus malmgreni (Théel, 1879): **1.**
Aglaophamus verrilli (McIntosh, 1855): **16, 21, 26, 33.**
Inermonephtys inermis (Ehlers, 1887): **29.**
Nephtys caecoides Hartman, 1938: **23, 33**.**
Nephtys californiensis Hartman, 1938: **10**, 20, 21**, 33**.**
Nephtys sioni (Perkins, 1980): **9, 16, 18, 19, 27, 29, 33, 35.**
Nephtys panamensis Monro, 1928: **29.**
Nephtys picta Ehlers, 1868: **16.**

Table 1. Continued.

Nephtys squamosa Ehlers, 1887: **16, 21, 23, 29, 35.**

Family Nereididae

Ceratocephale oculata Banse, 1977: **10**, 16, 21**, 33**.**
Ceratonereis longicirrata Perkins, 1980: **10**, 21**.**
Ceratonereis singularis Treadwell, 1929: **6, 10, 12, 21.**
Ceratonereis tentaculata Kinberg, 1866: **9, 16, 20, 29.**
Leptonereis laevis Kinberg, 1866: **33.**
Namanereis riojai (Bastida-Zavala, 1990): **25.**
Neanthes arenaceodentata (Moore, 1903): **17.**
Neanthes caudata (delle Chiaje, 1828): **7, 29.**
Nereis callaona Grube, 1857: **5, 6, 7, 14, 29.**
Nereis mediator Chamberlin, 1918: **7, 14.**
Nereis paucidentata (Moore, 1903): **23.**
Nereis pelagica Linnaeus, 1761: **23.**
Nereis procera Ehlers, 1868: **23.**
Nereis rava Ehlers, 1868: **29.**
Nereis riisei Grube, 1857: **10**, 11, 12, 29.**
Nereis vexillosa Grube, 1851: **20, 23.**
Nereis zonata Malmgren, 1867: **34.**
Nicon moniloceras (Hartman, 1940): **23, 34.**
Platynereis bicanaliculata (Baird, 1863): **1, 5, 6, 7, 16, 20, 23, 29, 33.**
Platynereis dumerilii (Audouin and Milne-Edwards, 1833): **12.**
Platynereis polyscalma Chamberlin, 1919: **5, 6, 21, 28, 29.**
Rullierinereis mexicana (Treadwell, 1942): **10.**

Family Syllidae

Ambliosyllis granosa Ehlers, 1897: **10.**
Autolytus prolifera (Müller, 1788): **10, 12**.**
Autolytus sp.: **12.**
Branchiosyllis exilis (Gravier, 1900): **10, 12**.**
Branchiosyllis pacifica Rioja, 1941: **12.**
Branchiosyllis sp.: **12.**
Eoxgone (Exogone) lourei Berkeley and Berkeley, 1938: **10.**
Eoxgone (Exogone) naidinoides (Westheide, 1974): **10.**
Eoxgone (Exogone) breviantennata Hartmann-Schröder, 1959: **17.**
Eoxgone (Exogone) occidentalis Westheide, 1974: **12**.**
Haplosyllis spongicola (Grube, 1855): **10, 12.**
Haplosyllis sp.: **12.**
Odontosyllis heterodonta Góngora-Garza and De León-González, 1993: **10.**
Odontosyllis phosphorea Moore, 1909: **7, 20, 23.**
Odontosyllis polycera (Schmarda, 1861): **10.**
Odontosyllis sp.: **12.**
Opisthosyllis brunnea Langerhans, 1879: **10, 12.**
Pionosyllis cf. uraga Imajima, 1966: **10.**
Pseudosyllides mexicana Góngora-Garza and De León-González, 1993: **10.**
Pseudosyllides sp.: **12.**
Syllis gracilis Grube, 1840: **10, 12.**
Trypanosyllis gemmipara Johnson, 1901: **12.**
Trypanosyllis (Trypanedenta) taeniaeformis (Haswell, 1866): **10.**
Trypanosyllis sp.: **12.**
Typosyllis aciculata (Treadwell, 1943): **33**.**
Typosyllis adamanteus (Treadwell, 1941): **12.**
Typosyllis alternata (Moore, 1908): **12.**
Typosyllis gerlachi Hartmann-Schröder, 1960: **10.**
Typosyllis heterocirrata Rioja, 1941: **10, 17.**
Typosyllis hyalina Grube, 1865: **7, 10, 12.**
Typosyllis lutea Hartmann-Schröder, 1960: **12**.**
Typosyllis magna (Westheide, 1974): **12**.**
Typosyllis pigmentata (Chamberlin, 1919): **12.**
Typosyllis prolifera (Krohn, 1852): **10, 12**, 17, 33**.**
Typosyllis rosea (Langerhans, 1879): **12**.**

Table 1. Continued.

Canalipalpata
Spionida

Family Spionidae

Aonidella sp. 1: **33.**
Aonides cf. oxycephala (Sars, 1862): **10**.**
Apoprionospio pygmaea (Hartman, 1961): **16.**
Apoprionospio dayi Foster, 1969: **10**.**
Boccardia anophthalma (Rioja, 1962): **7.**
Boccardia sp.: **17.**
Dispio uncinata Hartman, 1951: **33**.**
Laonice cirrata (Sars, 1851): **2, 10**.**
Paraprionospio pinnata (Ehlers, 1901): **21****, 33.
Prionospio (Prionospio) heterobranchia Moore, 1907: **10**, 12**, 17,** 33**.
Prionospio (Prionospio) steenstrupi Malmgren, 1867: **16, 21****, 33**.
Scolelepis (Scolelepis) squamata (Müller, 1806): **10**.**
Spiophanes bombyx (Claparede, 1870): **7.**

Family Chaetopteridae

Mesochaetopterus minuta Potts, 1914: **15.**
Phyllochaetopterus prolifica Potts, 1914: **30.**
Spiochaetopterus costarum (Claparède, 1870): **30.**

Sabellida

Family Sabellariidae

Idanthyrsus cretus Chamberlin, 1919: **5, 12, 15.**
Idanthyrusus sp. 1: **12.**
Lygdamis nesiotes (Chamberlin, 1919): **12.**
Phragmatopoma californica (Fewkes, 1889): **7, 20.**
Phragmatopoma moerchi Kinberg, 1867: **5.**
Sabellaria cementarium Moore, 1906: **10.**

Family Sabellidae

Chone infundibuliformis Kroyer, 1865: **30.**
Chone infundibuliformis fauveli McIntosh, 1916: **29.**
Chone mollis (Bush, 1904): **29.**
Chone sp. 1: **10, 21, 33.**
Demonax medius (Bush, 1904): **5.**
Demonax rugosus (Moore, 1904): **5, 7, 33.**
Megalomma circumspectum (Moore, 1923): **10**, 30.**
Megalomma mushaensis (Gravier, 1908): **7, 20.**
Megalomma pigmentum Reish, 1963: **10**.**
Megalomma quadrioculatum Willey, 1905: **31.**
Notaulax occidentalis (Baird, 1865): **7, 29.**
Potamilla neglecta (Sars, 1851): **2.**
Sabellonga disjuncta Hartman, 1969: **5.**

Family Serpulidae

Circeis armoricana Saint Joseph, 1894: **7.**
Hydroides brachyacantha Rioja, 1941: **12.**
Hydroides dianthus (Verrill, 1873): **12.**
Simplaria pseudomilitaris Thiriot-Quiereux, 1965: **29.**
Pomatostegus stellatus (Abildgaard, 1789): **5.**
Protula atypha Bush, 1904: **23.**
Protula tubularia (Montagu, 1803): **6, 21.**
Pseudovermilia conchata ten Hove, 1975: **12.**
Pseudovermilia sp.: **12.**
Spirobranchus giganteus corniculatus (Grube, 1862): **12, 28, 29.**
Spirobranchus quadricornis Grube, 1878: **23.**
Spirorbis (Paralaeospira) racemosus Pixell, 1912: **7.**
Spirorbis spatulatus Knight-Jones, 1978: **7.**
Spirorbis tricornigerus Rioja, 1942: **12.**

Table 1. Continued.

Spirorbis variabilis Bush, 1904: **12.**
Spirorbis (Spirorbella) marioni (Caullery and Mesnil, 1879): **7, 12.**

Terebellida

Family Flabelligeridae

Flabelliderma caudata (Rioja, 1962): **7.**
Pherusa capulata (Moore, 1909): **16.**
Pherusa inflata (Treadwell, 1914): **23.**
Pherusa neopapillata (Hartman, 1961): **30.**
Pherusa papillata (Johnson, 1901): **12.**
Therochaeta sp. 1: **10.**

Family Cirratulidae

Aphelochaeta multifilis (Moore, 1909): **5.**
Caulleriella hamata (Hartman, 1948): 33.
Caulleriella pacifica Berkeley, 1929: **10**, 17,** 33**.
Chaetozone acuta Banse and Hobson 1968: **21**.**
Chaetozone sp. 1: **10.**
Cirratulus cingulatus Johnson, 1901: **29.**
Cirratulus revillagigedoensis Rioja, 1960: **12.**
Cirriformia punctata (Grube, 1859): **12.**
Cirriformia spirabrancha (Moore, 1904): **7, 12.**
Cirriformia tentaculata (Montagu, 1808): **17.**
Monticellina tesselata (Hartman, 1960): **21****, 33**.
Monticellina sp. 1: **21.**
Timarete luxuriosa (Moore, 1904): **6, 7.**

Family Ampharetidae

Amage anelicornuta Moore, 1923: **2.**
Amphicteis mucronata Moore, 1923: **2.**
Amphicteis scaphobranchiata Moore, 1906: 33**.
Asabellides lineata (Berkeley and Berkeley, 1943): 33.

Family Pectinariidae

Cistenides regalis (Verrill, 1902): **12.**
Cistenides brevicoma Johnson, 1901: **5.**
Pectinaria (Amphictene) auricoma (Müller, 1776): **28, 29.**
Pectinaria (Pectinaria) belgica (Pallas, 1766): **5, 7.**

Family Terebellidae

Artacama coniferi Moore, 1905: **5.**
Eupolymnia heterobranchia (Johnson, 1901): **50, 20.**
Lanice conchilega (Pallas, 1766): **33**.**
Loimia sp.: **12.**
Neoamphitrite robusta (Johnson, 1901): 5.
Pista elongata Moore, 1909: 7.
Polycirrus caliendrum Claparede, 1870: **12.**
Streblosoma longifilis Rioja, 1962: **7, 10**.**
Terebella sp.: 12.
Thelepus crispus (Johnson, 1901): 7, 23.
Thelepus hamatus Moore, 1905: 23.

Family Tichobranchidae

Terebellides californica Williams, 1984: **21.**
Terebellides ehlersi McIntosh, 1885: **2.**
Terebellides reishi Williams, 1984: **5.**
Terebellides sp. 1: **10, 21.**
Terebellides sp. 2: **10.**
Trichobranchus gracilis Malmgren, 1966: **10**.**

Family Sternaspidae

Sternaspis scutata (Ranzani, 1817): **5.**
Sternaspis fossor Stimpson, 1854: **2, 23.**

Table 2. Number of species from Mexican Pacific Islands.

State	Island	No. species
Pacific Ocean		
BC	1 Guadalupe	3
	2 Coronado	8
	3 San Martín	1
	4 San Benito	4
	5 Cedros	39
BCS	6 San Roque	17
	7 Asunción	45
	8 Santa Margarita	1
NAY	9 Isabela	18
	10 María Madre	69
COL	11 Clarión	9
	12 Socorro	70
GUE	13 Grande	2
OAX	14 Tangola-Tangola	2
	15 Clipperton	7
Gulf of California		
BC	16 Ángel de la Guarda	46
	17 Rasa	17
BCS	18 Tortuga	5
	19 San Ildefonso	2
	20 Coronado	25
	21 Del Carmen	37
	22 Monserrat	1
	23 Santa Catalina	32
	24 San José	6
	25 Partidito	1
	26 San Francisco	6
	27 Partida	9
	28 Ballena	13
	29 Espíritu Santo	56
	30 La Gaviota	8
	31 Cerralvo	1
SON	32 San Jorge	3
	33 Tiburón	46
	34 San Esteban	5
	35 San Pedro Nolasco	8
SIN	36 San Ignacio	1

of Tiburón, Del Carmen and María Madre islands, despite an overall wide geographical distribution, show different species composition in the different islands; moreover, the species found in this study had already been recorded from the continental shelf of the Mexican Pacific (Hernández-Alcántara and Solís-Weiss 1999). Their presence in these islands probably results from their migration from nearby coastal zones, the intensity of such migration depending on specific dispersion abilities as well as on particular oceanographic conditions surrounding these areas.

Although the sedimentary processes that determine the distribution of the organisms are still not well understood (Snelgrove and Butman 1994), the soft bottoms' environments might have less limiting factors for the settlement of species coming from nearby continental littoral and sublittoral areas. By contrast, the polychaetes living in hard bottoms might have a more restricted distribution, insofar as they need this type of substrate for settlement and, therefore, these coralline environments, surrounded by soft sediments, might be considered as real "ecological islands".

In spite of the wide distribution of the 73 species identified in soft sediments, only *Ceratocephale oculata* was found on the three sampled islands, showing that actually diverse oceanographic processes play a role in the type of substrate present which in turn determines largely the distribution of the species, so that the location of the islands in the different regions of the Gulf of California is instrumental in shaping the existing differences in the composition of their fauna.

In this respect, the highest values both in abundance (422 org) and in species richness (43), is found in the sublittoral internal coastal zone of María Madre Island, probably because its location at the southern end of the Gulf of California makes it possible for species belonging to temperate environments associated to the Californian province, as well as species related to the Mexican province, adapted to tropical and subtropical conditions to coexist (Table 1). *Caulleriella pacifica, Notomastus tenuis, Scoloplos* (*S.*) *capensis* and *Nereis riisei,* were the most abundant species there.

In Tiburón Island (23 species; 157 organisms), subjected to wide environmental variations in the islands' region, as well as in Del Carmen Island (25 species; 137 organisms) located close to the peninsular margin of the Gulf, where polychaetes do not abound (Hernández-Alcántara 2002), a lower number of species was recorded, especially those pertaining to tropical environments. The composition of their polychaete fauna also differ: *Prionospio* (*P.*) *steenstrupi* and *Aricidea* (*A.*) *simplex* are respectively the most abundant species.

Upon adding the records obtained during this survey to the species of polychaetes registered previously, we could see that these organisms have been collected only in 36 out of the more than 140 islands and islets of the Mexican Pacific (Fig. 1, Table 2). In spite of these limitations in the sampling effort, a substantial species richness is apparent in this fauna: 348 species in 40 families (Table 1) which represents approximately one third of all the species of polychaetes so far recorded from all the western coasts of Mexico (Hernández-Alcántara and Solis-Weiss 1999).

The families with the highest number of species (Table 1) are: Syllidae (35 spp.), Eunicidae (30 spp.), Nereididae (22 spp.) and Polynoidae (19 spp.). Although the available literature gives practically no information concerning the environmental particularities or habitat under which that fauna was collected, and though these families are geographically widely distributed and have been found in a broad variety of habitats, the fact that they are composed basically of mobile or discreetly mobile and mainly carnivorous species (Fauchald and Jumars 1979), could indicate that the polychaetes of the islands have been mainly collected from rocky environments, including dead coral substrates.

By contrast, the families commonly found in soft sediments, being less mobile and feeding mainly on sediments, such as the Maldanidae, Spionidae or Ampharetidae, are scantily represented in the collections of the islands of the Mexican Pacific (Table 1).

Of course, the abundance (or scarcity), and coverage (limited or not) of the species recorded, also reflects the particular objectives and sampling effort or limited possibilities of the research operations carried out in the region; as an example of this, less than 10 species have been found in 72% of the islands (Table 2). Therefore, the main limiting factor seems to be the accessibility to the sampling areas, since the majority of the islands sampled so far (21) is precisely located in the Gulf of California, the region traditionally most widely surveyed and studied in the Mexican Pacific (Fig. 1).

The islands of Tiburón (46 spp.) and Ángel de la Guarda (46 spp.) located in the center of the Gulf, in a region with such a recognized diversity high enough to be proposed as "Province of Cortes" (Briggs 1995), and the island of Espíritu Santo (56 spp.) located in front of the bay of La Paz, harbor the highest number of species, with basically tropical affinities (Fig. 1).

Elsewhere in the Mexican Pacific, María Madre and Socorro islands (in the Mexican Province), are the areas where the largest research effort has been carried out, not only in the benthic systems but in other branches of biology as well. As a result, they are now the best known islands, with the highest number of registered species of polychaetes: 69 and 70 respectively (Table 2).

The most widely distributed species appeared to be *Chloeia viridis, Eurythoe complanata, Eunice antennata, Glycera tesselata* and *Platynereis bicanaliculata,* all of them mobile species, commonly found in hard substrates.

Looking at the faunistic similarities, the islands of Espíritu Santo (29), Coronado (20) and Ángel de la Guarda (16), located in the western region of the Gulf of California, are characterized by populations where *Eunice antennata, Eunice biannulata, Platynereis bicanaliculata* and *Marphysa sanguinea* dominate; the islands of Asunción (7) and Cedros (5) of the western part of Baja California, are associated due to the presence of the Amphinomid *Eurythoe complanata*; and the islands María Madre (10), Del Carmen (21) and Tiburón (33), whose similarity results from the records brought out by this study (which basically includes soft bottom species) albeit also related by the presence of two of the widely distributed species *Chloeia viridis* and *Eunice antennata.* Socorro (12) and Santa Catalina (23) are separated from the other islands by the type of dominant fauna: in the first, a high number of species is recorded although basically associated to coralline substrates, while the second shows a mixture of species recorded both in rocky and soft bottoms.

In synthesis, the available information about the polychaetes from the islands of the Mexican Pacific shows that in spite of the high number of species recorded (mainly dependent so far on the sampling effort), there are still many regions and habitats to be studied and the high diversity displayed by this faunistic group, makes its study important in order to understand the ecology of these areas.

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Literature Cited

Bastida-Zavala, J. R. 1990. *Lycastopsis riojai,* a new species of polychaete (Polychaeta: Nereididae) from the Gulf of California. Rev. Biol. Trop., 38:415–420.

Bautista-Romero, J. J., H. Reyes-Bonilla, D. Luch-Cota, and S. Luch-Cota. 1994. Aspectos generales sobre la fauna marina. Pp. 247–275 *in* La Isla Socorro, reserva de la biosfera Archipiélago de Revillagigedo. (A. Ortega and A. Castellanos, eds.), Centro de Investigaciones Biológicas del Noreste, México, 359 pp.

Berkeley, E., and C. Berkeley. 1939. On a collection of Polychaeta, chiefly from the west coast of Mexico. Ann. Mag. Nat. Hist., ser. 11, 1:428–435.

———. 1958. Some notes on a collection of Polychaeta from the northeast Pacific South of latitude 32°N. Can. J. Zool., 36:399–407.

Blake, J. A. 1994. Introduction to the Polychaeta. Pp. 39–113 *in* Taxonomic Atlas of the benthic fauna of the Santa Maria Basin and western Santa Barbara Channel. Vol 4. (J. A. Blake and B. Hilbig, eds.), Santa Barbara Museum of Natural History, California, 377 pp.

Briggs, J. C. 1995. Global biogeography. Elsevier Science B. V., Amsterdam, 452 pp.

Chamberlin, R. V. 1919. The Annelida Polychaeta of the Albatross Tropical Pacific Expedition, 1891–1905. Mem. Mus. Comp. Zool. Harv. Univ., 48:1–514.

De León-González, J. A. 1985. Eunicidae (Polychaeta) de 10 localidades en las costas mexicanas. Tesis Profesional, Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León, 56 pp.

Fauchald, K. 1968. Onuphidae (Polychaeta) from western Mexico. Allan Hancock Monogr. Mar. Biol., 3:1–82.

———. 1970. Polychaetous annelids of the families Eunicida, Lumbrineridae, Iphitimidae, Arabellidae, Lysaretidae and Dorvilleidae from western Mexico. Allan Hancock Monogr. Mar. Biol., 5:1–135.

———. 1972. Benthic polychaetous annelids from deep water off western Mexico and adjacent areas in the eastern Pacific Ocean. Allan Hancock Monogr. Mar. Biol., 7:1–575.

———. 1982. Revision of *Onuphis, Nothria,* and *Paradiopatra* (Polychaeta: Onuphidae) based upon type material. Smithson. Contr. Zool., 356:1–109.

———. 1992. A review of the genus *Eunice* (Polychaeta: Eunicidae) based upon type material. Smithson. Contr. Zool., 523:1–422.

———, and P. A. Jumars. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanogr. Mar. Biol. Ann. Rev., 17:193–284.

Fauvel, P. 1943. Annélides polychaetes de Californie (*sic.*) recueillies par L. Diguet. Mem. Mus. Hist. nat. Paris, 18:1–32.

Glasby, C. J., and G. Read. 1998. Polychaete worms: a diverse yet poorly known group. Water & Atmosphere, 6(4):7–9.

Góngora-Garza, G. 1984. Contribución al conocimiento de los sílidos (Polychaeta: Syllidae) de la Isla María Madre, Nayarit, México. Tesis Profesional, Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León, 54 pp.

———, and J. A. De León-González. 1993. Dos nuevos sílidos (Polychaeta: Syllidae) y nuevos registros para México. Con una clave a las especies de sílidos del Pacífico Mexicano. Cah. Biol. Mar., 34:17–28.

Hartman, O. 1939a. Polychaetous Annelids, 1. Aphroditidae to Pisionidae. Allan Hancock Pac. Exped., 7:1–156.

———. 1939b. The polychaetous annelids collected on the Presidential Cruise of 1938. Smithson. Misc. Coll., 98:1–22.

———. 1940. Polychaetous Annelids, 2. Chrysopetalidae to Goniadidae. Allan Hancock Pac. Exped., 7:173–287.

———. 1941. Polychaetous Annelids, 4. Pectinariidae. Allan Hancock Pac. Exped., 7:325–345.

———. 1944a. Polychaetous Annelids, 5. Eunicea. Allan Hancock Pac. Exped., 10:1–237.

———. 1944b. Polychaetous annelids, 6. Paraonidae, Magelonidae, Longosomidae, Ctenodrillidae and Sabellaridae. Allan Hancock Pac. Exped., 10:311–389.

———. 1950. Goniadidae, Glyceridae and Nephtyidae. Allan Hancock Pac. Exped., 15:1–181.

Hendrickx, M. E. 1992. Distribution and zoogeographic affinities of decapod crustaceans of the Gulf of California, Mexico. Proc. San Diego Soc. Nat. Hist., 20:1–12.

Hernández-Alcántara, P. 1992. Los poliquetos (Annelida: Polychaeta) de la plataforma continental del

Golfo de California, México. Taxonomía, abundancia numérica y distribución geográfica. Tesis Maestría, UACPyP-CCH, Universidad Nacional Autónoma de México. 427 pp.

———. 2002. Composición y estructura de las comunidades de poliquetos (Annelida: Polychaeta) bénticos de la plataforma continental del Golfo de California. Tesis Doctoral, Facultad de Ciencias, Universidad Nacional Autónoma de México. 196 pp.

———, and V. Solís-Weiss. 1999. Systematics and distribution of the polychaetes (Annelida: Polychaeta) from the sublittoral zone in the Gulf of California. Oceánides, 13(2):25–38.

Holguín-Quiñones, O. E. 1994. Comunidades bénticas marinas. Pp. 225–245 *in* La Isla Socorro, reserva de la biosfera Archipiélago de Revillagigedo, México (A. Ortega-Rubio y A. Castellanos-Vera, eds.), Centro de Investigaciones Biológicas del Noroeste S.C., México, 359 pp.

———, S. Mille-Pagazaz, y A. Pérez-Chi. 1992. Resultado de las campañas de muestreo de 1991 para el estudio del bentos marino de Isla Socorro, Revillagigedos, Colima, México. Zool. Inf., 24:1–20.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press. Princeton.

Mackie, A. S. Y., and P. G. Oliver. 1996. Marine macrofauna: polychaetes, molluscs and crustaceans. Pp. 263–284 *in* Methods for the examination of organismal diversity in soils and sediments (G. S. Hall, ed.), CAB International, New York.

———, C. Parmiter, and L. K. Y. Tong. 1997. Distribution and diversity of Polychaeta in the southern Irish Sea. Bull. Mar. Sci., 60(2):467–481.

Moore, J. P. 1923. The polychaetous annelids dredged by the USS Albatross off the coasts of southern California in 1904, 4. Spionidae to Sabellariidae. Proc. Acad. Natur. Sci. Philadelphia, 775: 179–259.

Pettibone, M. A. 1971. Revision of some species referred to *Leptonereis, Nicon* and *Laeonereis* (Polychaeta: Nereididae). Smithson. Contr. Zool., 104:1–53.

Reish, D. J. 1968. A biological survey of Bahia de Los Angeles, Gulf of California, Mexico. II. Benthic polychaetous annelids. Trans. San Diego Soc. Nat. Hist. 15:67–106.

Rioja, E. 1941. Estudios anelidológicos III. Datos para el conocimiento de la fauna de poliquetos de las costas mexicanas del Pacífico. An. Inst. Biol., Univ. Nal. Autón. México, 12:669–746.

———. 1947a. Estudios anelidológicos XVII. Contribución al conocimiento de los anélidos poliquetos de Baja California y Mar de Cortés. An. Inst. Biol., Univ. Nal. Autón. México, 18:197–224.

———. 1947b. Estudios anelidológicos XVIII. Observaciones y datos sobre algunos anélidos poliquetos del Golfo de California y costas de Baja California. An. Inst. Biol., Univ. Nal. Autón. México, 18:517–526.

———. 1947c. Estudios anelidológicos XIX. Observaciones sobre algunos nereidos de las costas de México. An. Inst. Biol., Univ. Nal. Autón. México, 18:527–535.

———. 1960. Estudios anelidológicos XXIII. Contribución al conocimiento de los anélidos poliquetos de las Islas Revillagigedo. An. Inst. Biol., Univ. Nal. Autón. México, 30:243–259.

———. 1962. Estudios anelidológicos XXVI. Algunos anélidos poliquetos de las costas del Pacífico Mexicano. An. Inst. Biol., Univ. Nal. Autón. México, 33:131–229.

Rouse, G. W. 2000. Classification of the Annelida and Polychaeta. Class Polychaeta. Pp. 51–53 *in* Polychaetes and allies: the southern synthesis. Fauna of Australia. Vol. 4A. Polychaeta, Myzostomida, Pogonophora, Echiura, Sipuncula. (P. L. Beesley, G. J. B. Ross and C. J. Glasby, eds.), CSIRO Publishing, Melbourne.

Salazar-Vallejo, S. I. 1989. Poliquetos, bibliografía y lista de especies. Pp. 133–212 *in* Poliquetos (Annelida: Polychaeta) de México. (Salazar-Vallejo, S. I., A. De León-González y H. Salaices-Polanco, eds.). Monogr., Univ. Autón. Baja California Sur. La Paz, Baja California Sur, 212 pp.

———. 1990. Poliquetos (Annelida: Polychaeta) de fondos blandos de Isla Rasa, Golfo de California. Cienc. Mar., 16(4):75–85.

———, J. A. De León-González, G. Góngora-Garza, y H Salaices-Polanco. 1987. Nuevos registros y extensiones de ámbito de poliquetos (Annelida: Polychaeta) de México. Invest. Mar. CICIMAR, 3:29–38.

Sarti-Martínez, L. A. 1984. Estudio prospectivo de la distribución, abundancia y diversidad de los anélidos poliquetos de la zona norte del Golfo de California. Tesis Profesional, Facultad de Ciencias, Universidad Nacional Autónoma de México, 53 pp.

SEDESOL. 1994. Informe de la situación general en materia de equilibrio ecológico y protección al ambiente 1993–1994. Informe de la Secretaria de Desarrollo Social, México.

Snelgrove, P. V. R., and C. A. Butman. 1994. Animal-sediment relationships revisited: cause versus effect. Oceanogr. Mar. Biol., Ann. Rev., 32:111–177.

Steinbeck, J., and E. F. Ricketts. 1941. Sea of Cortez, a leisurely journal of travel and research. The Viking Press, New York, 598 pp.

Treadwell, A. L. 1914. Polychaetous annelids of the Pacific coast in the collections of the Zoological Museum of the University of California. Univ. Cal. Publ. Zool., 13:175–234.

———. 1929. New species of polychaetous annelids in the collections of the American Museum of Natural History from Porto Rico, Florida, Lower California and British Somaliland. Am. Mus. Novit., 392:1–13.

———. 1937. The Templeton Crocker Expedition, 8. Polychaetous annelids from the west coast of Lower California, the Gulf of California and Clarion Island. Zoologica, 22:139–160.

———. 1941. Polychaetous annelids from Lower California and the Philippine Islands in the collections of the American Museum of Natural History. Am. Mus. Novit., 1172:1–5.

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Characterization of Water Quality in the Los Angeles River

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Abstract.—The Los Angeles River is one of the most highly modified systems in the world. Dramatic modifications have successfully reduced flooding and property damage, but little of the engineered design has incorporated water quality improvements. The goal of this study was to identify sources of potential pollutants and characterize water quality along the river's seven reaches during dry weather. The three primary sources of potential pollutants included water reclamation plants (WRPs), major tributaries, and storm drain outfalls. In addition, the use of volunteers as a mechanism to collect data at large spatial scales, where tremendous labor is required over short periods of time, is evaluated.

The three WRPs discharged the majority (72%) of the volume flowing in the Los Angeles River during this study. Likewise, the three WRPs discharged the highest concentrations and greatest mass emissions of nutrients including nitrate, nitrite, ammonia, and total phosphate. In contrast, 66 flowing storm drains and 6 flowing tributaries had the highest concentrations and mass emissions of bacteria including total coliform, *E. coli,* and *enterococcus.*

Water quality in the Los Angeles River responded to inputs of potential pollutants. Levels of nutrients were generally low upstream and downstream of the WRPs (<0.1 mg/L ammonia), but were greatest in the immediate vicinity of the WRPs (approximately 6 mg/L ammonia). Concentrations of bacteria were generally high upstream and downstream of the WRPs (ca. 10^4 MPN/100 mL *E. coli*), but were lowest in the immediate vicinity of the WRPs (ca. 10^2 MPN/100 mL *E. coli*).

The Los Angeles River drains most of Los Angeles County and may be one of the most highly modified systems in the world (Brownlie and Taylor 1981). The watershed is 49% developed and is 30% impervious. Much of the channel is concrete-lined in an effort to reduce flooding and protect property. However, the successful efforts at flood control have resulted in loss of habitat and degraded water quality throughout much of the river system (LACDPW 2000; Cross et al. 1990).

The habitat and water quality degradation have prompted the Los Angeles Regional Water Quality Control Board (LARWQCB) to add much of the river

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and many of its tributaries to the State/Federal list of impaired waterbodies, the §303(d) list. The Clean Water Act stipulates that waterbodies on the §303(d) list are required to develop total maximum daily loads (TMDLs). The goal of TMDLs is to achieve water quality objectives in the receiving waterbody. As part of the TMDL process, there is a need to characterize the problem (impairment) that led to the listing, identify the sources of pollutant inputs, establish the target needed to achieve water quality standards, and conduct a linkage analysis whereby the sources are linked to receiving waterbody impairment, and finally establish waste load and load allocations for each point and nonpoint source in order to reduce the loading.

The goal of this study was to improve the problem characterization by sampling the Los Angeles River and identifying sources of pollutants found in the river. The data collection also had a secondary objective of determining if volunteer monitoring efforts can help support TMDLs, which are a regulatory mechanism.

Methods

This study was broken into two parts. The first identified and sampled the inputs to the Los Angeles River and major tributaries. The second sampled the mainstem of Los Angeles River to assess spatial distributions of water quality. The input monitoring was conducted using citizen volunteers. Monitoring the spatial distribution of water quality was conducting using professionals. Samples from both surveys were submitted to a professional, State-Certified laboratory for chemical analysis.

The Watershed

The Los Angeles River extends 54 miles from its headwaters in the San Fernando Valley past downtown Los Angeles and eventually draining to San Pedro Bay near Long Beach (Figure 1). The watershed is 834 mi^2 and is comprised of residential (35%), commercial (5%), industrial (8%), and open (51%) land uses. The river is divided into 9 reaches and seven tributary reaches. The mainstem and tributaries are listed for many constituents including nutrients (N), bacteria (fecal coliform), and trace metals (copper, lead, and zinc).

Input Sampling

Inputs to the Los Angeles River were sampled on September 10, 2000. Early September was chosen since this time period represents typical dry weather status when the watershed is closest to steady state conditions. Input sources included three water Reclamation Plants (WRP) that use tertiary treatment for municipal and industrial wastes and discharge their effluents to the River. Two of the WRP are owned the City of Los Angeles (Tillman and Glendale WRP) and one is owned by the City of Burbank, (Burbank WRP). Glendale WRP discharges directly to the Los Angeles River. Tillman WRP discharges through three outfalls; approximately 37% of the flow discharges to a recreational lake and 11% of the flow discharges to a wildlife lake, both of which ultimately discharge to the Los Angeles River. The third outfall, comprising approximately 52% of the Tillman WRP flow, discharges directly to the Los Angeles River. The Burbank WRP discharges to the Burbank-Western Channel, a major tributary, which is just upstream of its confluence with the Los Angeles River. There are numerous indus-

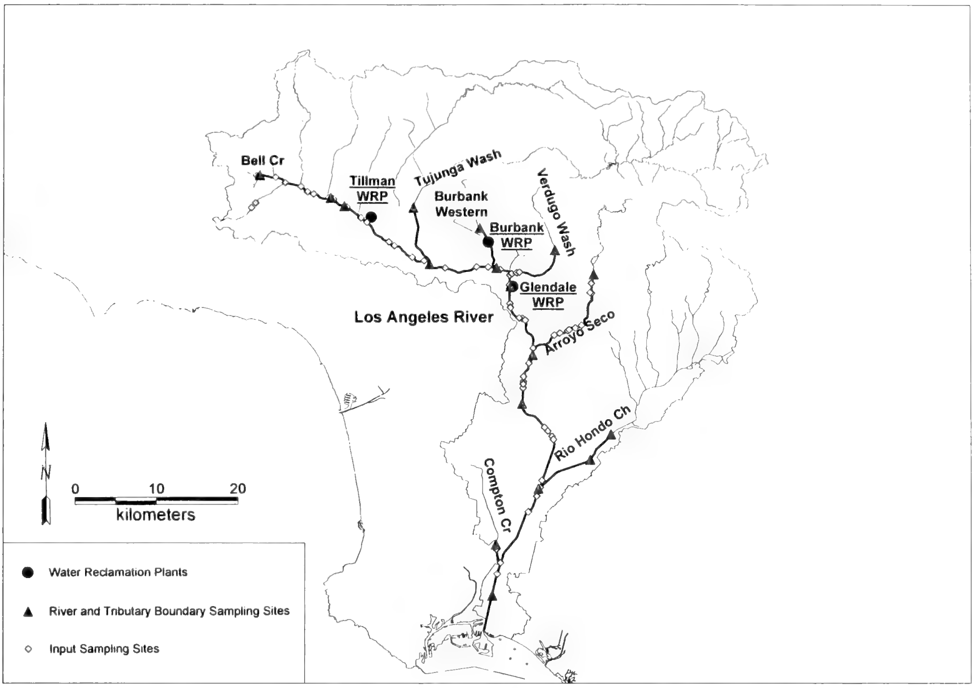

Fig. 1. Map of the Los Angeles River watershed, listed streams, and sampling locations along the mainstem, at the head of tributaries, at point sources, and at storm drain outfalls to the river.

trial facilities that can potentially discharge to the Los Angeles River, but the vast majority only discharge surface runoff during storm events.

Unlike WRP or industrial facilities, there are potentially hundreds of outfalls to the Los Angeles River from the municipal storm drainage system, which receives no treatment prior to discharge. To accomplish identifying and sampling these storm drain outfalls, citizen monitors walked all 54 miles of the River and 15 miles of tributaries, identifying, documenting and eventually sampling each flowing outfall encountered. The volunteers were trained to collect samples in accordance with standard protocols during a one-day training class.

Sampling of all inputs included visual observations of outfall size and location, flow, general characteristics such as the color, presence of foam or oily sheens, trash or algae, and water quality. Flow was measured using either timed-volumetric or depth-velocity methods. Water quality parameters included flow, total suspended solids (TSS), total organic carbon, biological oxygen demand (BOD_5), nutrients (nitrate, nitrite, ammonia, total Kjedahl nitrogen TKN, and total phosphorous), trace metals, (cadmium, chromium, copper, iron, lead, nickel, mercury, and zinc). All analyses followed protocols approved the US EPA (1983) and Standard Methods (APHA 2000).

Spatial Distribution Sampling

Sampling of eight locations along the mainstem of the Los Angeles River, and at the head of all seven tributaries, was accomplished on September 11, 2000. Each location represents each of the 303(d) listed reaches in the watershed. Sam-

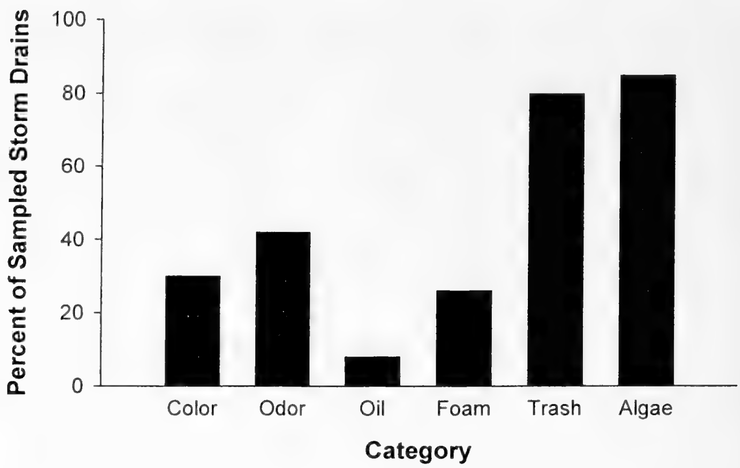

Fig. 2. Percent of storm drains that showed obvious signs of trash, algae, foam, colors, or oily sheens.

pling was conducted by collecting a single composite sample that consisted of three grab samples combined over a 10 minute period. A second composite sample was collected 20 minutes later, and a third composite collected 40 minutes after the initial composite. Existing flow gages maintained by the Los Angeles County Department of Public Works provided flow information.

Results

Our survey of the Los Angeles River identified 127 storm drain outfalls. Of these, 105 were flowing and 87 discharged sufficient volume to sample for water quality. Seventy seven percent of the outfalls discharged directly to the Los Angeles River and remainder discharged to the major tributaries.

Flow

The majority of flow on September 10 and 11, 2000 arose from treated wastewater discharges from the three WRP on the Los Angeles River. A combined 74.6 MGD comprised approximately 72% of the dry weather flow. Roughly 14.7 MGD (14%) arose from discharges out of six of the seven tributaries that discharge to the Los Angeles River. The Rio Hondo tributary was not flowing at the confluence to the Los Angeles River at the time of sampling. Roughly 13.8 MGD (13%) arose from discharges of the 66 storm drain outfalls that discharged directly to the Los Angeles River mainstem.

Visual Observations

The presence of algae and trash were consistently observed at the mouths of storm drain outfalls to the Los Angeles River (Figure 2, Table 1). The amount of trash varied from drain to drain with 23% of the outfalls categorized as having "dense" (>50% surface coverage). However, 70% of the outfalls had algae that exceeded 50% surface coverage). The presence of foam, oily sheens and odd colors were inconsistently observed.

Table 1. Spatial coverage (as % area) of trash and algae near storm drains discharging to the Los Angeles River on September 10, 2001.

<table>
<tr><th rowspan="2">Spatial coverage (% of area)</th><th colspan="2">Percent of storm drains</th></tr>
<tr><th>Algae</th><th>Trash</th></tr>
<tr><td>None (0%)</td><td rowspan="2">8</td><td>17</td></tr>
<tr><td>Light (<5%)</td><td>15</td></tr>
<tr><td>Moderate (6–10%)</td><td rowspan="2">13</td><td>14</td></tr>
<tr><td>High (11–25%)</td><td>12</td></tr>
<tr><td>Somewhat dense (26–50%)</td><td>9</td><td>16</td></tr>
<tr><td>Dense (51–75%)</td><td>21</td><td rowspan="2">23</td></tr>
<tr><td>Very dense (>75%)</td><td>49</td></tr>
<tr><td>Not recorded</td><td></td><td>3</td></tr>
</table>

Concentrations

The concentrations of inputs to the Los Angeles River differed among the three sources for general classes of constituents (Table 2). The highest concentrations of nutrients were found in WRP discharges. For example, concentrations of ammonia in WRP effluents were twice the level found in the tributaries and an order of magnitude higher than the concentrations found in storm drain discharges. In contrast, the highest concentrations of bacteria were found in discharges from storm drains. The concentration of *E. coli* was four orders of magnitude higher than WRPs, which were below method reporting levels (< 2 MPN/ 100 mL). The concentrations of trace metals were generally low from all sources; most average concentrations were below method reporting levels. The WRP effluents had higher concentrations of copper and zinc than discharges from tributaries or storm drains.

Mass Emissions

The relative contributions of potential pollutants to the Los Angeles River differed among the three sources of inputs between general classes of constituents

Table 2. Average concentrations of water quality parameters from three major sources of potential pollutants to the Los Angeles River on September 10–11, 2000.

Constituent	Units	WRPs	Tributaries	Storm drains
Bacteria				
E. coli	MPN/100mL	ND	1,307	21,199
Enterococcus	MPN/100mL	2	1,033	4,124
Total coliforms	MPN/100mL	288	76,525	79,593
Metals				
Chromium	mg/L	<0.01	<0.01	<0.01
Copper	mg/L	0.01	<0.01	<0.01
Iron	mg/L	<0.2	<0.2	0.54
Lead	mg/L	<0.01	<0.01	<0.01
Nickel	mg/L	<0.02	<0.02	<0.02
Zinc	mg/L	0.04	0.02	0.01
Nutrients				
Ammonia-N	mg/L	12	5.6	<0.2
Nitrate-N	mg/L	0.5	1.4	2.7
TKN	mg/L	14	7.9	1.5
Total phosphate-P	mg/L	1.7	0.9	0.3

Table 3. Total pollutant loads and the relative contributions among major sources to the Los Angeles River on September 10–11, 2000.

Constituent	Total mass emissions	Units	% Contribution		
			POTWs	Tributaries	Storm drains
Bacteria					
E. coli	12,022	(10^9)/day	0	11	89
Enterococcus	2,948	(10^9)/day	0	33	67
Total coliforms	113,854	(10^9)/day	1	65	35
Metals					
Copper	3.7	kg/day	73	22	6
Iron	39	kg/day	4	23	73
Lead	0.53	kg/day	0	54	46
Nickel	0.19	kg/day	0	0	100
Zinc	11	kg/day	79	17	4
Nutrients					
Ammonia-N	3,357	kg/day	85	14	0
Nitrate-N	361	kg/day	32	35	34
TKN	4,066	kg/day	82	17	2
Total phosphate-P	512	kg/day	82	15	2

(Table 3). The greatest mass emissions of nutrients were from WRPs. For example, WRPs contributed 85% of the ammonia and 82% of the total phosphate relative to tributaries and storm drains. In contrast, nearly 100% of the *Enterococcus, E. coli,* and total coliform mass emissions were from storm drain discharges and tributaries, not the WRPs. The relative mass emissions of trace metals varied among sources by metal. The WRPs accounted for 73% and 79% of the copper and zinc, respectively. On the other hand, tributaries and storm drains cumulatively accounted for 100% of the lead and nickel mass emissions to the Los Angeles River.

Spatial Distribution

The spatial distribution of water quality concentrations reflected the sources that contributed the pollutants to the Los Angeles River (Figure 3). For example, mean concentrations of ammonia were <0.1 mg/L upstream of the Tillman WRP, then increased to 6 mg/L following the three WRP discharges. The WRP had the highest concentrations and largest nutrient mass emissions. In contrast, mean concentrations of *E. coli* were near 10^3 MPN/100 mL prior to reaching the WRP, then decreased to 10^2 MPN/100 mL following the WRP discharges. Concentrations increased back to 10^3 MPN/100 mL downstream of the WRP as more storm drain discharges accumulated in the river. Storm drain discharges had the highest concentrations and mass emissions of bacteria.

Although the spatial patterns of nutrients and bacteria were dissimilar, both groups of constituents were characterized as having highly variable concentrations (Figure 3). For example, the minimum and maximum concentrations extended from 4 mg/L to more than 14 mg/L ammonia following the inputs from the Tillman WRP at river mile 38. Similarly, concentrations of *E. coli* ranged from 10^1 MPN/100 mL to 10^5 MPN/100 mL upstream of the Tillman WRP at river mile 43.

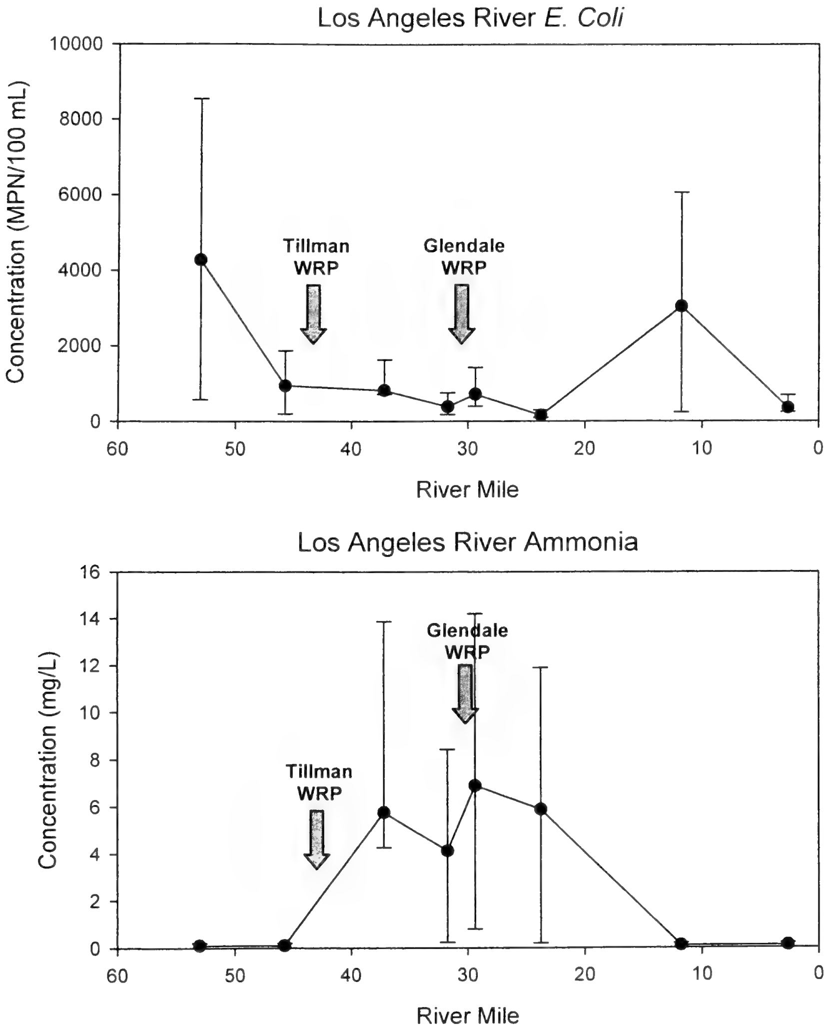

Fig. 3. Longitudinal mean concentrations (min,max) of nutrients and bacteria along the Los Angeles River. Arrows indicate input locations from water reclamation plants (WRP).

Discussion

The Los Angeles River is an effluent dominated waterbody. Nearly 70% of the volume in the Los Angeles River arose from WRPs tertiary-treated effluent discharged during this study. Although groundwater interactions exist (particularly in the Glendale Narrows and Arroyo Seco tributary), the majority of storm drain discharges are assumed to arise from urban discharges. Less than 0.1 MGD of flow was measured during dry weather months at the mouth of the Los Angeles River in 1930 when the population in the county was approximately 2 million. More than 100 MGD was measured at the mouth of the river during this study when county population estimates exceeded 9.5 million.

Storm drain discharges are known sources of bacteria in southern California (Noble et al. 2001; Schiff 1997). The City of Los Angeles (1997) has measured concentrations of 10^6 *E. coli* per 100 mL in storm drains that discharge to the Los Angeles River resulting from defecation of homeless encampments. Bacteria concentrations from WRPs, which treat municipal sewage, are low to nondetectable because the WRPs disinfect their effluents prior to discharge. As is more often the case, the bacteria sources are often diffuse and complex (Schiff and Kinney 2001). Unlike nutrients, where remedying the problem lies predominately with the WRPs, resolving bacterial water quality problems will be challenging.

Analytical reporting levels have the potential to bias mass emission results when many measurements are below detection limits. The bias occurs when scientists estimate concentrations for these truncated values. This issue is particularly important with trace metals; concentrations of most trace metals were low to nondetectable from all sources investigated. During this study we assumed all values reported as nondetectable were actually zero. However, the true concentration may be nearly as high as the reporting level. In the case of WRPs, low levels of trace metals equate to large mass emission because of the sheer volume of WRP discharges. For example, the mass emissions of lead was estimated to be 0.5 kg/day, but if the zero assigned to nondetectable values were actually as high as the reporting level, the mass emissions would have been 4.1 kg/day; an 8-fold increase. This also changes the relative contribution among sources. If nondetectable quantities were treated as zero, storm drains are considered the major (92%) source. However, if nondetectable quantities were treated as the reporting level, then the WRPs are considered the major (72%) source.

This study focused on an intensive spatial sampling design at the watershed scale, but did not have a temporal design component. We selected a dry weather sampling period when the river system was most likely to be in a steady state condition. Short term temporal variability was minimized by collecting replicate samples over a period of approximately one hour. However, our study does not account for day-to-day or week-to-week variability that may occur along the river. Monthly bacteria measurements were made at three sites along the Los Angeles River by the Los Angeles County Department of Public Works between 1987 and 1993 that can be used to examine month-to-month temporal variations (Los Angeles County Department of Public Works unpublished data). These three sites compare well to our three sites located closest to the County sites. The mean concentrations from our sites were well within the range of concentrations observed by the County monitoring program, and their median concentrations during the dry months were within the range of variability we observed within an hours time span.

The use of volunteers, if properly trained and organized, represented a powerful mechanism for accomplishing large-scale sampling tasks. In this study, we needed to cover more than 54 river miles and more than an additional 15 tributary miles in less than 5 hours. The volunteer monitoring helped us to accomplish this large-scale effort without injury or major deviations from monitoring protocols. However, this success occurred because tremendous effort was expended on logistics, preparation, and training. More than 85 volunteers ranging in age from 10 to 65 walked, biked, drove, and canoed the river. The citizen activism in this watershed is to be commended.

Acknowledgments

This study was funded by the City of Los Angeles, Los Angeles Regional Water Quality Control Board, and the Southern California Coastal Water Research Project. The authors would like to acknowledge the assistance from the Los Angeles/ San Gabriel Rivers Watershed Council and US EPA Region IX. The authors are indebted to the many volunteers that assisted in sample collection. The authors also are grateful for the assistance provided by Krista Kamer and Andrea Steinberger. The collected data can be downloaded from http://www.sccwrp.org.

Literature Cited

APHA. 2000. Standard Methods, 20th edition. American Public Health Association. Philadelphia, PA.

Brownlie, W. and B. Taylor. 1981. Sediment management for southern California mountains, coastal plains and shoreline. Part C: Coastal sediment delivery by major rivers in southern California. EQL Report No. 17-C. California Institute of Technology. Pasadena, CA.

City of Los Angeles. 1997. A study of pollutants entering storm drains from street and sidewalk washing operations in Los Angeles, CA. City of Los Angeles, Stormwater Management Division. Los Angeles, CA.

Cross, J., K. Schiff, and H. Schaefer. 1990. Mass emissions of selected constituents from the Los Angeles River. pp. 25–37, *in*: J. Cross (ed.). Southern California Coastal Water Research Project Annual Report 1989–90. Long Beach, CA.

LACDPW. 2000. Los Angeles County integrated receiving water impact report. Los Angeles County Department of Public Works, Alhambra, CA.

Noble, R.T., J.H. Dorsey, M. Leecaster, V. Orozco-Borbon, D. Reid, K. Schiff, and S.B. Weisberg. 2000. A regional survey of the microbiological water quality along the shoreline of the southern California Bight. *Environmental Monitoring and Assessment* 64:435–447.

Schiff, K. 1997. Review of existing stormwater monitoring programs for estimating bight-wide mass emissions from urban runoff. pp. 44–55 *in*: S. Weisberg, C. Francisco and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1995–96. Westminster, CA

——— and P. Kinney. 2001. Tracking sources of bacterial contamination in stormwater from Mission Bay, California. pp. 85–95 *in*: S. Weisberg, C. Francisco and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 199–2000. Westminster, CA.

US EPA. 1983. Chemical Methods for the Examination of Water and Wastes. EPA-600/4–79–020. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory. Cincinnati, OH.

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Shorebirds and Benthic Fauna of Tidal Mudflats in Estero de Punta Banda, Baja California, México

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Abstract.—We studied habitat use by shorebirds as related to tide and benthic invertebrates on three mudflats at Estero de Punta Banda, Baja California, México, between January and April, 2000. We recorded 15 shorebird species and 7974 individuals. The most abundant birds were marbled godwits (*Limosa fedoa*), small sandpipers (*Calidris alpina, C. mauri, and C. minutilla*), and willets (*Catoptrophorus semipalmatus*). The three sites were different in their shorebird assemblages, and shorebird density was significantly greater on the site closest to the mouth of the estuary. The benthic fauna in our samples included 14 polychaete and 1 cumacean families; 8 bivalve species, 7 gastropod species, 7 amphipod species, 4 decapod species, and 1 species of isopod. Benthic invertebrate abundance was significantly greater at the site closest to the mouth of the estuary in winter, and at the central site in spring. Abundance of shorebirds was clearly inverse to tide height. Shallow and deep probers responded differently to the tide cycle at two sites. The most used feeding microhabitat, among four studied, was the waterline, although benthic invertebrate abundance was not different among habitats. The benthic fauna in our samples was potential food for the shorebirds present.

Intertidal mudflats are the most important feeding habitats for shorebirds on their migratory routes (Schneider 1978; Evans et al. 1979; Gersternberg 1979; Burger et al. 1997). Far from being constant, such sites are constantly changing in response to the tide cycle. The energy gain that shorebirds derive from foraging on mudflats is influenced by temperature, wind, and rain, among other factors (Evans 1976; Burger 1984). Tides affect foraging intensity (Heppleston 1971; Connors et al. 1981), as well as the length of time and area in which shorebirds can forage (Puttick 1984). Indirectly, tides affect the distribution and activity of shorebird prey (Evans 1979; Puttick 1984). Overall, tides determine the daily patterns of activity of shorebirds (Heppleston 1971; Burger et al. 1977; Kelly and Cogswell 1979), and the number of shorebirds foraging generally reaches its highest values around low tide (Heppleston 1971; Burger et al. 1977).

Intertidal mudflats are heterogeneous in respect to the sediments that compose them, and in the distribution and abundance of benthic invertebrates (Trush et al. 1989; Trush 1991). Sediments can differ in their type (Burger et al. 1977), size

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of particles (Quammen 1982; Grant 1984; Hicklin and Smith 1984), and vary in their moistness and penetrability (Myers et al. 1987; Grant 1984; Mouritsen and Jensen 1992). Also, near the waterline, there are a number of microhabitats created by the level of water, or lack of it, and the presence of water pools in small depressions of the floor. Selection of a particular spot for feeding is the result of such characteristics, as well as of the morphology of different species (Ashmole 1970; Baker 1979). Furthermore, the distribution and abundance of birds reflects not only these physical caracteristics but also density and composition of benthic invertebrates, on which they depend during the non-breeding season (Goss-Custard et al. 1977; Bryant 1979; Hicklin and Smith 1984).

Estero de Punta Banda is one of five large coastal wetlands along the Pacific coast of the Peninsula of Baja California and is important for migrating shorebirds (Palacios et al. 1991; Massey and Palacios 1994; Page et al. 1997). Although some inventories and monitoring of shorebirds have been carried out, and the local dynamics of western sandpipers (*Calidris mauri*) has been studied (Fernández-Aceves 1996; Buenrostro et al. 1999), specific differences among sites have not been studied, nor has the relationship of this group with benthos been analyzed. The objective of this project was to obtain some insights into the use of different areas of mudflats within this coastal lagoon by shorebirds and to gather initial information on the relationship of shorebirds with benthic invertebrates.

Study Sites

Estero de Punta Banda (31°40′–31°48′ Lat N, and 116°34′–116°40′ Long W), is located within Bahía de Todos Santos, and is about 15 km south of Ensenada (Fig. 1). This coastal lagoon is a 21 km^2 water body bordered on the seaside by a 7.5 km barrier beach. Tides are semidiurnal and have a mean amplitude of 1.04 m. In winter the Estero receives occasional fresh water through arroyos San Carlos and La Grulla. The most abundant intertidal habitat in the Estero is mudflats, and for this study we selected three such sites along the inner side of the barrier beach (Fig 1). These were:

1) Tony's Camp North (TCN). This site, on the northern barrier beach and bordered by sand dunes, was subject to strong tidal currents during Spring tides. The site measured about 6.1 ha at mid-tide level (as measured on an aerial image).
2) Tony's Camp South (TCS). This site was in the central part of the barrier beach, and was bordered by pickleweed (*Salicornia* spp.) marsh. Its tidal currents were less strong than at TCN. The site measured about 10.55 ha at mid-tide level.
3) Boss Pacific (BP). This site was located in the head of the estero and was bordered by a narrow strip of pickleweed marsh, and a raised dyke with a single-lane paved road. Tidal currents were much more moderate than at other sites. The site measured about 9.7 ha at mid-tide level.

Methods

Shorebirds were monitored on eight visits between January and April 2000 (Table 1). Each visit consisted of three days, one at each site, and were carried out only on days of Spring tides. At each site we established a fixed point of observation, from where all counts were made. A total count of birds was made

Table 1. Maximum shorebird density (individuals/ha) at three mudflat sites within Estero de Punta Banda, Baja California, Mexico, between January and May 2000. Values in column "p" are the probability of type I error in Friedman's Analysis of Variance. Within a species, sites with the same letter are not different under a non-parametric Tukey test. Sites within a species are un-lettered when there were no statistical differences at $P \leq .05$.

Species	Site	17–18 Jan	2–4 Feb	16–18 Feb	2–4 Mar	16–18 Mar	30 Mar–2 Apr	12–14 Apr	29 Apr–1 May	Total	*P*	≠
Marbled godwit	TCN	16.4	18.3	19.3	19.6	21.9	25.0	21.3	11.1	153.0	0.007	a
	TCS	6.9	33.5	8.4	10.2	11.1	12.1	9.2	8.2	9.6		b
	BP	10.3	8.6	16.3	16.3	17.1	21.1	11.4	1.9	103.0		ab
Small peeps	TCN	10.1	9.3	11.9	18.0	19.5	41.6	69.6	13.1	193.1	0.004	a
	TCS	8.8	16.7	7.6	13.8	7.6	5.7	8.5	6.5	75.3		ab
	BP	5.6	11.4	7.1	7.1	4.8	3.1	0.7	0.0	5.6		b
Willet	TCN	5.7	11.8	9.8	6.5	7.2	7.4	5.9	4.1	58.4	0.004	a
	TCS	6.4	2.3	5.6	6.4	7.6	4.5	4.9	1.5	39.2		ab
	BP	1.5	2.4	2.8	2.8	1.8	2.2	1.3	0.8	15.6		b
Dowitchers	TCN	0.5	1.8	2.1	0.5	2.1	2.1	3.1	4.9	17.2	0.030	b
	TCS	7.6	4.7	6.6	1.9	2.7	3.8	4.5	6.1	38.0		a
	BP	0.8	4.7	10.1	10.1	4.9	7.7	1.2	0.0	39.7		ab
Black-bellied plover	TCN	1.3	1.5	3.3	2.6	2.9	2.5	3.3	2.6	20.0	<0.001	a
	TCS	0.6	1.3	0.9	1.6	2.0	0.8	0.9	1.2	9.4		ab
	BP	0.5	0.8	0.6	0.6	0.6	0.0	0.0	0.0	3.2		b
Ruddy turnstone	TCN	0.0	0.3	2.9	2.9	2.5	4.9	4.7	2.6	20.9	0.004	a
	TCS	0.4	1.6	0.1	2.2	0.9	0.8	0.0	0.6	6.5		ab
	BP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		b
American avocet	TCN	0.0	0.2	0.0	0.2	0.0	0.5	1.3	0.0	2.1	0.016	ab
	TCS	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.8		b
	BP	1.4	3.8	1.4	1.4	0.8	0.9	0.0	0.0	9.9		a
Long-billed curlew	TCN	1.0	0.7	0.8	0.8	0.8	0.3	0.3	0.0	4.7	0.072	
	TCS	0.4	0.3	0.4	0.3	0.5	0.5	0.1	0.2	2.6		
	BP	0.5	0.5	0.6	0.6	0.5	0.2	0.1	0.1	3.2		
Semipalmated plover	TCN	0.0	0.0	0.3	0.8	0.0	0.0	4.4	2.1	7.7	0.018	a
	TCS	0.1	0.6	0.3	0.5	0.1	0.1	0.1	1.4	3.1		ab
	BP	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.4		b

Table 1. Continued.

Species	Site	17–18 Jan	2–4 Feb	16–18 Feb	2–4 Mar	16–18 Mar	30 Mar–2 Apr	12–14 Apr	29 Apr–1 May	Total	*P*	≠
Greater yellowlegs	TCN	0.5	0.3	0.2	0.2	0.3	0.2	0.0	0.0	1.6	0.866	
	TCS	0.1	0.5	0.2	0.1	0.2	0.2	0.1	0.0	1.3		
	BP	0.2	0.1	0.3	0.3	0.2	0.1	0.3	0.0	1.5		
Whimbrel	TCN	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.0	1.6	0.093	
	TCS	0.2	0.1	0.1	0.1	0.4	0.1	0.2	0.2	1.3		
	BP	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.2	0.9		
Total	TCN	35.8	44.4	51.1	52.4	57.4	84.6	114.2	40.6	480.5	0.012	a
	TCS	31.5	61.5	30.2	37.1	33.8	28.5	28.6	25.9	277.2		ab
	BP	21.0	32.3	39.3	39.2	30.7	35.2	15.2	3.0	216.0		b

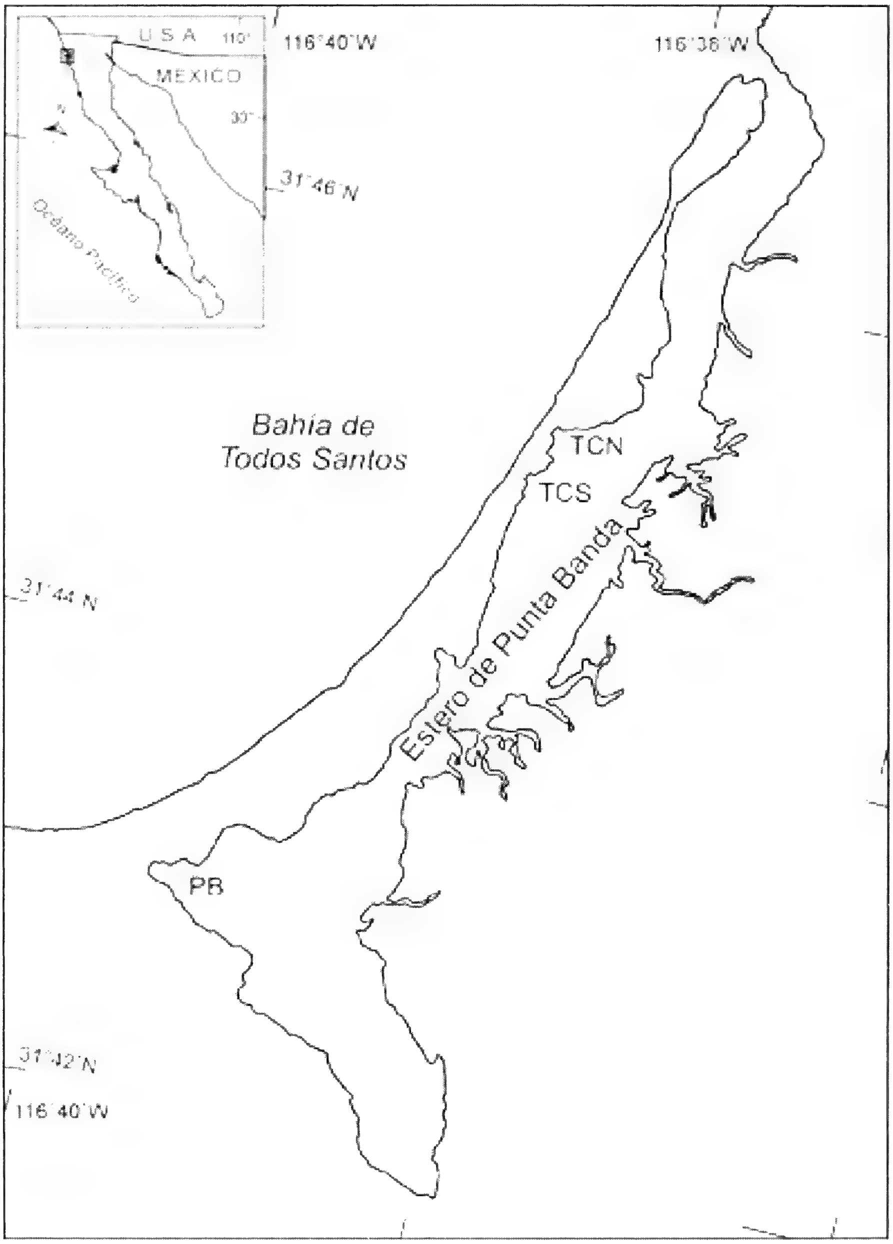

Fig. 1. Estero de Punta Banda, showing the three study localities: TCN (Tony's Camp North), TCS (Tony's Camp South), BP (Boss-Pacific). Simplified from a map by Proesteros (2000).

every 15 minutes, while numbers per species were obtained every 30 min. Every hour we noted whether the birds were feeding, resting, or were engaged in some other activity. Observations were carried out for six hours, begining 4 hours before the lowest predicted tidal level at TCN and TCS. At BP, counts were carried out from 3 hours before lowest level to 3 hours after, because before this time the mudflats remained inundated and unavailable for the birds. We considered four categories of feeding substrate: mud, tideline, shallow water (up to the tibio tarsus-tarso metatarsus joint of most birds feeding), deep water (above the tibio tarsus-tarso metatarsus joint of most birds feeding).

Counts and identification were carried out with a 15×–45× spotting scope and 7×35 binoculars. Dunlin (*Calidris alpina*), western sandpiper (*C. mauri*) and least sandpiper (*C. minutilla*) were grouped as "small peeps," and both dowitchers (*Limnodromus griseus* and *L. scolopaceus*) were not differentiated. Whenever it was possible we noted the food being consumed.

Benthic invertebrates were sampled in the winter (20 & 21 January 2000) and spring (19 & 21 March 2000) in each site, for a total of 70 samples: 10 at each site in winter, and 16 at TCN and TCS, and 8 at BP in spring. We used a 10.5 cm diameter by 15 cm high sampler (86.59 cm^2 sampling surface). All organisms retained by a 1-mm mesh were saved in a mixture of saltwater and a 10% formaldehide solution. Once fixed, they were preserved in 70% alcohol. Specimens that were complete were measured.

After testing for normality and homogeneity of variances, data were analyzed through 2-way analysis of variance and Tukey tests, or through Friedman's test (Zar 1996). We calculated Shannon's diversity index, based on the sum of the maxima for each visit, and compared the values of the three sites through pairwise comparisons, with Hutcheson's test (Zar 1996).

Results

Our maximum daily tallies summed up to 7974 individuals throughout the study, of 15 species (Table 1). The most abundant birds were marbled godwits (*Limosa fedoa,* n = 2985), small peeps (2361), willets (*Catoptrophorus semipalmatus,* 922), dowitchers (891), and black-bellied plovers (*Pluvialis squatarola,* 252). Ruddy turnstones (*Arenaria interpres*), American avocets (*Recurvirostra americana*), long-billed curlews (*Numenius americanus*), whimbrels (*N. phaeopus*), semipalmated plovers (*Charadrius semipalmatus*), and greater yellowlegs (*Tringa melanoleuca*) were rare, while snowy plovers (*Charadrius alexandrinus*) and lesser yellowlegs (*Tringa flavipes*) were sporadic. The abundance of the different species exhibited peaks on different dates.

All species were found at the three sites, except the ruddy turnstone which did not occur on BP. Overall TCN had more shorebirds than BP, while there were no differences between either of them and TCS, but individual species exhibited different uses, and the densities of some were not different among the different sites (Table 1). Whenever there were differences among the sites, TCN had the highest densities of birds. Diversity values (respectively 0.71, 0.67 and 0.65) were not significantly different among sites.

Number of shorebirds counted was clearly inverse to height of tide (Fig. 2). Maximum counts were obtained at lowest water level in TCN and BP, but 1.5 hrs before this level in TCS. Maximum counts were obtained for about 1.5 hrs. Shallow and deep probers were different in their pattern of increase and decrease with the tide at the three sites (χ^2 = 13.0, p; lt. 001; χ^2 = 6.23, p = 0.013; and χ^2 = 8.333, p = 0.004, respectively, Friedman's test).

Shorebirds exhibited differences among the four microhabitats in the three zones (Table 2). Shorebirds were mostly engaged in feeding, but we could identify only a few prey items from feeding birds. Marbled godwits included

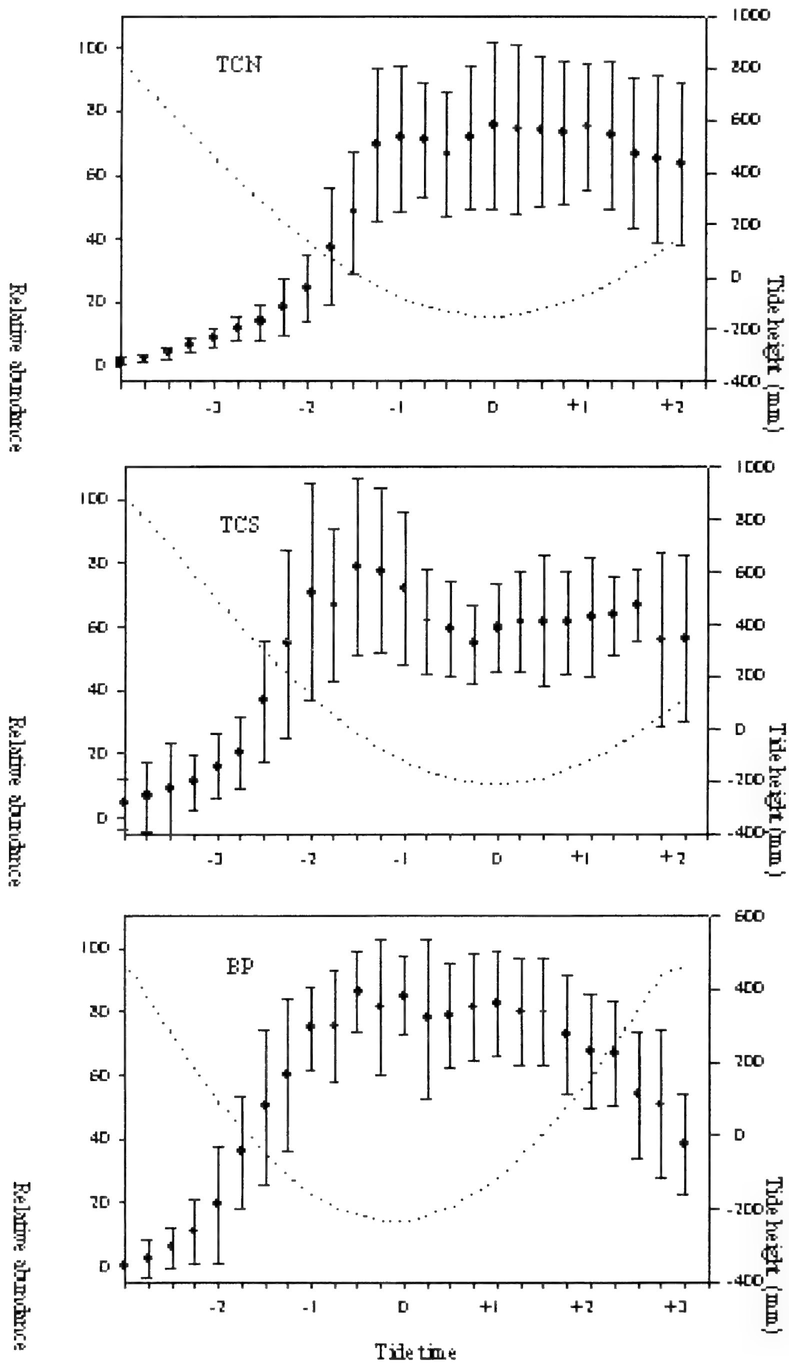

Fig. 2. Total abundance of shorebirds (+ standard deviation; dots with vertical lines) in relation with tide level (stippled line), at three sites in Estero de Punta Banda, Baja California, México, 2000. X-axis displays hours before or after the lowest tide.

Table 2. Percent of individuals of each of five shorebirds feeding in four feeding substrates on mudflats in Estero de Punta Banda, Baja California, México, January–April 2000. M = mud, WL = water line, SP = shallow ponds, and DW = deep water. Within species and sites, values with the same letter were not statistically different, according to a Tukey test ($\alpha \leq 0.05$).

		Feeding substrate			
Species	Site	M	WL	SP	DW
Marbled godwit	TCN	15.8[b]	45.7[a]	20.5[b]	18.0[b]
	TCS	13.4[b]	52.8[a]	18.4[b]	15.4[b]
	BP	10.8[c]	61.8[a]	17.5[b]	9.9[c]
Small peeps	TCN	32.5[b]	46.8[a]	17.7[c]	0.9[d]
	TCS	42.4[a]	25.7[b]	31.4[b]	0.5[c]
	BP	10.3[b]	80.9[a]	8.8[b]	0.1[b]
Semipalmated plover	TCN	34.0[a]	30.2[a]	24.3[a]	11.6[b]
	TCS	32.3[a]	26.6[a]	26.4[a]	8.7[b]
	BP	36.3[ab]	41.7[a]	16.7[bc]	5.3[c]
Dowitchers	TCN	0.2[b]	89.7[a]	9.4[b]	0.7[b]
	TCS	5.4[c]	78.5[a]	14.1[b]	1.9[c]
	BP	6.3[b]	65.4[a]	7.1[b]	1.3[b]
Black-bellied plover	TCN	94.7[a]	1.6[b]	3.7[b]	0.0[b]
	TCS	94.1[a]	2.3[b]	3.6[b]	0.0[b]
	BP	100[a]	0[b]	0[b]	0[b]

polychaetes in their diet, long billed curlews and whimbrels ate crabs, especially a fiddler crab, *Uca crenulata,* willets ate bivalves (*Macoma spp.*) and crabs, and black-bellied plover ate bivalves and gasteropods, especially *Bulla gouldiana.*

Polychaetes were by far the most abundant invertebrates in our samples (Table 3, Appendix 1). Our innermost site (BP) was devoid of crustaceans, and exhibited the lowest density of invertebrates, although in March it was not statistically different from TCN. The four feeding substrates were not statistically diferent in their abundance of invertebrates ($F = 2.743$, $df = 3$, $p = 0.058$, 2-way ANOVA).

Table 3. Total density (individuals/0.1 m^2) and relative density (in parentheses) of benthic invertebrates in mudflat sites in Estero de Punta Banda, Baja California, México, in January and March 2000. Totals with the same letter, within a sampling date are not statistically different, under a parametric Tukey test ($\alpha \leq .05$).

Group	TCN	TCS	BP
January 2000:			
Polychaeta	331 (84.2%)	194 (78.2%)	84 (88.4%)
Crustacea	27 (6.9%)	37 (14.9%)	0 (0.0%)
Gastropoda	27 (6.9%)	12 (4.8%)	5 (5.3%)
Bivalvia	8 (2.0%)	5 (2.0%)	6 (6.3%)
Total	393[a]	248[a]	95[b]
March 2000:			
Polychaeta	270 (94.4%)	333 (91.7%)	151 (92.1%)
Crustacea	8 (2.8%)	16 (4.4%)	0 (0.0%)
Gastropoda	5 (1.7%)	5 (1.4%)	7 (4.3%)
Bivalvia	3 (1.0%)	9 (2.5%)	6 (3.7%)
Total	286[ab]	383[a]	164[b]

In addition to the species in our benthic samples, there were fiddler crabs (*U. crenulata*), abundant gasteropods (especially *B. gouldiana*) and, in eelgrass (*Zostera marina*) banks at the lowest intertidal reaches, many bivalves (*Argopecten spp.*). Also, whereas our samples contained few amphipods, isopods, and carideans, these were abundant in eelgrass banks.

Discussion

With the exception of dowitchers, all species that exhibited differences in their abundance at the different sites preferred TCN over BP, while TCS was intermediate. Both small (*Calidris, Limnodromus, Arenaria, Charadrius* and *Pluvialis* spp.) and large shorebirds (*Limosa, Catoptrophorus, Recurvirostra, Numenius* and *Tringa* spp.) were about equally represented (47.5, and 52.5%, respectively). That the most abundant species was the marbled godwit, followed by the small peeps, is comparable to previous studies (Palacios et al. 1991). Despite differences in the force of water currents, and in substrate texture, there were no significant differences between TCN and TCS. The overall higher abundance of birds in TCN than in BP (Table 1) was due to different responses by individual species to differences in the habitat.

Ruddy turnstones commonly fed on bivalves asociated with eelgrass, which were absent from BP. Black-bellied plovers were more abundant at TCN and only sporadic at BP, in agreement with its preference for harder substrates (Pienkowski 1983a). Willets and the small peeps were also more abundant at TCN. This site had more non-benthic insects, which can form a substantial part of western and least sandpipers diets (Reish and Barnard 1990). On the other hand, dowitchers were more common on BP, probably because its softer substrate allowed for more efficient feeding of these species.

As shown by others (Waumann 1998; Sinicrope-Talley et al. 2000) polychaetes dominated the bethic fauna in the three zones (Table 3). TCN, in winter, and TCS, in spring had significantly more benthic fauna than the two remaining sites. Although these two areas exhibit differences in the force of tidal currents, in both areas these currents are subtantially stonger than at BP, causing better oxygenation and higher polichaete abundances (see Farreras and Villalba 1980; Wolff 1983). The reasons for seasonal differences among TCN and TCS, and between them and BP, are not clear to us. In addition to the species in our benthic samples (Table 3), eelgrass banks at the lowest intertidal reaches accounted for even further differences between TCN, TCS, and BP, since they were present only at the first two sites, where they allowed for abundant bivalves (*Argopecten spp.*), amphipods, isopods, and carideans.

By affecting the amount of exposed mudflats, tidal level was the main factor affecting the local movements of shorebirds, as has been reported elsewhere (Recher 1966). As water levels lowered, shorebirds increased, reaching their maximum numbers around the lowest water level (Fig. 2). At TCS the maximum numbers of shorebirds were reached an hour and an half before lowest tide, when the tideline reached the mid-lagoon tidal channel. Afterwards, receding tides caused the exposure of no additional habitat. However, not all species reached their maxima at the same time, as individual response varied (Burger et al. 1977). Notably, semipalmated plovers always reached their peak numbers during lowest tidal level, when exposure of eelgrass was maximized. The closer tidal curve at

BP, was caused both by its lower steepness and by the fact that we always sampled it under slightly higher tidal levels than the other two sites.

Although there were some specific microhabitat preferences by the shorebirds (Table 2), the tideline was frequently used. This is not surprising, as benthonic invertebrates are stimulated by changes in hydrostatic pressure when the tide begins to rise (Enright 1965).

Shallow water offers an alternative to the tideline. The small depressions, by maintaining pockets of water, offer a more penetrable substrate than adjacent mudflats that do not hold standing water (Grant 1984), and stimulate higher activity of benthic prey (Evans 1979; Pienkowski 1983b), reducing foraging costs of birds that feed by probing (Mouritsen and Jensen 1992). However, in our study this microhabitat was little used.

In our study we documented that some individuals of the largest species would rest on very windy days, while none of the smaller shorbirds ever did so. Also, two hours after lowest tide, marbled godwits, semipalmated sandpipers, curlews, and whimbrels rested on the shore, whereas the smaller peeps and dowitcher continued to feed. This may reflect the greater energy needs of such smaller species.

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Literature Cited

Ashmole, M.J. 1970. Feeding of western and semipalmated sandpipers in Peruvian winter quarters. Auk 87:131–135.

Baker, M.C. 1979. Morphological correlates of habitat selection in a community of shorebirds (Charadriiformes). Oikos 33:121–126.

——— and A.E.M. Baker. 1973. Niche relationships among six species of shorebirds on their wintering and breeding ranges. Ecological Monographs 43:143–212.

Buenrostro, M.A., N. Warnock, and H. de la Cueva. 1999. Wintering western sandpipers *Calidris mauri* at Estero de Punta Banda, Baja California, Mexico. Wader Study Group Bulletin 88: 59–63.

Bryant, D.M. 1979. Effects of prey density and site character on estuary usage by overwintering waders (Charadrii). Estuarine and Coastal Marine Science 9:369–384.

Burger, J. 1984. Abiotic factors affecting migrant shorebirds. pp 1–72 in: J. Burger and B.L. Olla (eds). Shorebirds: migration and foraging behavior. Behavior of Marine Animals, vol. 6. Plenum Press. New York.

———, M.A. Howe, D.C. Haan and J.Chase. 1977. Effects of tide cycles on habitat selection and habitat partitioning by migrating shorebirds. Auk 94:743–758.

———, L. Niles and K.E. Clark. 1997. Importance of beach, mudflat and marsh habitats to migrant shorebirds on Delaware Bay. Biological Conservation 79:283–292.

Connors, P.G., J.P. Myers, C.S.W.Connors and F.A. Pitelka. 1981. Interhabitat movements by sanderlings in relation to foraging profitability and the tidal cycle. Auk 98:49–64.

Enright, J.T. 1965. Entrainment of a tidal rhythm. Science 147:864–867.

Evans, P.R. 1976. Energy balance and optimal foraging strategies in shorebirds: some implications for their distributions and movements in the non-breeding season. Ardea 64:117–139.

———. 1979. Adaptations shown by foraging shorebirds to cyclical variations in the activity and availability of their intertidal invertebrate prey. Pp.357–366 in: E. Naylor and R.G. Hartnall (eds). Cyclic phenomena in marine plants and animals. Pergamon Press. Oxford, New York.

———, D.M. Herdson, P.J. Knights and M.W. Pienkoski. 1979. Short-term effects on reclamation of part of Seal Sands, Teesmouth, on wintering waders and shelduck. I. Shorebird diets, invertebrate densities, and impact of predation on the invertebrates. Oecologia 4:183–206.

Farreras, S.F. and F.A. Villalba. 1980. Evacuación de contaminantes según modelo numérico en el Estero de Punta Banda, Baja California. Geofísica Internacional 19:321–333.

Fernández-Aceves, G.J. 1996. Tasas de retorno y residencia de *Calidris mauri* (Caradriformes: Scolopacidae) en el Estero de Punta Banda (B.C., México), en la temporada invernal de 1995–1996. M.Sc. thesis. Centro de Investigación Científica y de Educación Superior de Ensenada. Ensenada, B.C. México.

Gerstenberg, R.H. 1979. Habitat utilization by wintering and migrating shorebirds on Humboldt Bay, California. Studies in Avian Biology 2:33–40.

Goss-Custard, J.D., Kay, D.G. and Blindell, R.M. 1977. The density of migratory and overwintering redshank, *Tringa tonatus* (L.) and curlew *Numenius arquata* (L.), in relation to the density of their prey in south-east England. Estuarine Coastal and Marine Science 5:497–510.

Grant, J. 1984. Sediment microtopography and shorebird foraging. Marine Ecology Progress Series 19:293–296.

Heppleston, P.B. 1971. The feeding ecology of oystercatchers (*Haematopus ostralegus* L.) in winter in northern Scotland. Journal of Animal Ecology 41:651–672.

Hicklin, P.W. and P.C. Smith. 1984. Selection of foraging sites and invertebrate prey by migrant semipalmated sandpipers, *Calidris pusilla* (Pallas), in Minas Basin, Bay of Fundy. Canadian of Journal Zoology 62:2201–2210.

Kelly, P.R. and H.L. Cogswell. 1979. Movements and habitat use by wintering populations of willets and marbled godwits. Studies in Avian Biology 2:69–82 p.

Massey, B.W. and E. Palacios. 1994. Avifauna of the wetlands of Baja California, Mexico: current status. Studies in Avian Biology 15:45–57.

Mouritsen, K.N. and K.T. Jensen. 1992. Choice of microhabitat in tactile foraging dunlins *Calidris alpina*: the importance of sediment penetrability. Marine Ecology Progress Series 85:1–8.

Myers, J.P., R.I.G. Morrison, P.Z. Antas, B.A.Harrington, T.E. Lovejoy, M. Sallaberry, S.E.Senner and A.Tarak. 1987. Conservation strategy for migratory species. American Scientist 75:19–26.

Page, W.G., E. Palacios, L. Alfaro, S. Gonzalez, L.E. Stenzel and M. Jungers. 1997. Numbers of wintering shorebirds in coastal wetlands of Baja California, México. Journal of Field Ornithologist. 68:562–574.

Palacios, E., A. Escofet and D. Loya-Salinas. 1991. El Estero de Punta Banda, B.C., México como eslabón del "Corredor del Pacífico": Abundancia de aves playeras. Ciencias Marinas 17(3): 109–131.

Pienkowski, M.W. 1983a. Changes in the foraging pattern of plovers in relation to environmental factors. Animal Behavior 31:244–264.

———. 1983b. Surface activity of some intertidal invertebrates in relation to temperature and the foraging behavior of their shorebird predators. Marine Ecology Progress Series 11:141–150.

——— and P.R. Evans. 1984. Migratory behavior of shorebirds in the western Palearctic. Pp.73–123 in: J. Burger and B.L. Olla (eds), Shorebirds: migration and foraging behavior. Behavior of Marine Animals, vol.6. Plenum Press. New York.

Puttick, G.M. 1984. Foraging and activity patterns in wintering shorebirds. Pp. 203–231 in: J. Burger and B.L. Olla (eds). Shorebirds: migration and foraging behavior. Behavior of Marine Animals. Plenum Press. New York.

Quammen, M.L. 1982. Influence of subtle substrate differences on feeding by shorebirds on intertidal mudflats. Marine Biology 71:339–343.

Recher, H.F. 1966. Some aspects of the ecology of migrant shorebirds. Ecology 47:394–407.

Reish, D.J. and J.L. Barnard. 1990. Marine invertebrates as food for the shorebirds of Bahía de San Quintín, Baja California. Proceedings of the International Marine Biology Symposium 8:1–6.

Schneider, D. 1978. Equalisation of prey number by migratory shorebirds. Nature 271:353–354.

Sinicrope-Talley, T., P.K.Dayton and S.E. Ibarra-Obando. 2000. Tidal flat macrofaunal communities and their associated environments in estuaries of southern California and northern Baja California, México. Estuaries 23:97–114.

Trush, S.F. 1991. Spatial pattern in soft-bottom communities. Trends in Ecology and Evolution 6:75–79.

———, Hewitt, J.E. and Pridmore, R.D. 1989. Patterns in the spatial arrangements of polychaetes and bivalves in intertidal sandflats. Marine Biology 102:529–535.

Waumann, D. 1998. Macrofauna béntica del Estero de Punta Banda, Ensenada, Baja California, México. M.Sc. Thesis. Universidad Autónoma de Baja California. Ensenada, B.C., México.

Wolff, W.F. 1983. Estuarine Benthos. Pp. 151–182 en: D.W. Goodall (ed), Ecosystems of the world. Estuaries and enclosed seas. Elsevier. New York.

Zar, J.H. 1996. Biostatistical analysis.2nd ed. Prentice-Hall. Englewood Cliffs, N.J. 718 pp.

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Appendix. Abundance (individuals/0.1 m^2) of benthonic invertebrates that are potential prey for shorebirds, in samples obtained at three sites on mudflats in Estero de Punta Banda, Baja California, in Winter and Spring 2000. † Represent species that were observed to be consumed by shorebirds in this study; * those reported as shorebird prey in other studies.

	TCN		TCS		BP	
	20 Jan.	20 Mar.	20 Jan.	19 Mar.	22 Jan.	19 Mar.
Polychaeta						
Magelonidae*	89	85	20	118	9	28
Capitellidae*	101	95	27	36	16	
Cirratulidae*	17	10	22	93		16
Orbiniidae*	31	41	74	60	3	
Nereidae*	55	21	16	12	49	98
Glyceridae*	10	7	12	3		
Goniadidae	8	7		7		
Opheliidae	7		20	1	1	
Lumbrineridae	1	2		2	6	9
Sabellidae	7			1		
Nephtydae*	5					
Spionidae*			3			
Onuphidae*		1				
Polynoidae		1				
Gastropoda						
Bulla gouldiana†	15	3	6	3		
*Haminoea vesícula**	8	2	3	1		
Acteocina spp.*					5	7
Nassarius tegula			1		2	
Ceratostoma spp.	1					
Cylichnella inculta			1	1		
Cerithidea californica			1			
Crepidula coei		1				
Melampus spp.*		1				
Bivalvia						
Argopecten aequisulcatus			1			
Chione californiensis				1		
Macoma nasuta†*	1			1		
Pitar spp.			1	2		
Lucina nutalli		2	1			
Tellina spp.	3	1	3		2	3
Cooperella subdiaphana	4		2	4		3
Amphipoda						
*Ampithoe polex**		2	4	2		
*Parapoxus spinosus**	7	1		1		
Podocerus spp.	2		2			
*Hyale frequens**		1	4	1		
Tethygeneia quinsana		1	4			
Monoculodes spp.			2	1		
Rudilemboides spp.	1		1			
Cumacea*						
Dyastilidae	6		7	7		
Isopoda						
Paracerceis spp.*	2	1	1	2		
Decapoda						
Rhithropanopeus spp.	2		1			
*Pachygrapsus crassipes**	1		1			
*Hemigrapsus oregonensis**		1		1		
Hyppolyte californiensis	6	1	10	1		

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Reproduction in the Baja California Rattlesnake, *Crotalus enyo* (Serpentes: Viperidae)

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The Baja California rattlesnake, *Crotalus enyo* occurs over most of the Baja peninsula from the vicinity of Cabo Colonet in the northwest, south to Cabo San Lucas, Baja California Sur and on associated islands in the Gulf of California (Beaman and Grismer 1994). Aside from data on captive breeding in *C. enyo* (Tryon and Radcliffe 1977; Armstrong and Murphy 1979), a report of "eggs" in a female collected 22 March (Klauber 1931), two clutch sizes in Klauber (1972) and time of appearance of neonates (Grismer 2002), information on reproduction in this species is unknown. The purpose of this paper is to provide information on the reproductive cycle of *C. enyo* from a histological examination of gonads from museum specimens. The reproductive cycle of this species is compared with that of other North American rattlesnakes.

Materials and Methods

A sample of 44 *C. enyo* (13 females, Mean snout-vent length, SVL = 549 mm ± 47 SD, range = 487–667 mm); 31 males, Mean SVL = 583 mm ± 79 SD, range = 470–730 mm) from Baja California was examined from the herpetology collections of the California Academy of Sciences, San Francisco, California (CAS), Natural History Museum of Los Angeles County, Los Angeles, California (LACM), Museum of Vertebrate Zoology, Berkeley, California (MVZ), San Diego Museum of Natural History, San Diego, California (SDSNH), and University of Arizona, Tucson (UAZ) (Appendix). All snakes were collected between 1919 and 1986. The left testis and vas deferens (when available) were removed from males and the left ovary was removed from females for histological examination. Tissues were embedded in paraffin, cut into 5 μm sections and stained with Harris' hematoxylin followed by eosin counterstain. Slides were then examined to determine the stage of the male cycle and for the presence of yolk deposition (secondary vitellogenesis *sensu* Aldridge 1979) in females. Histological examination was not performed on two females containing enlarged follicles (> 10 mm length), a female containing oviductal eggs and a female containing a full-term embryo. The number of specimens histologically examined were, testis (= 31), vas deferens (= 22), and ovary (= 9).

Testicular histology was similar to that reported by Goldberg and Parker (1975) for the colubrid snakes, *Masticophis taeniatus* and *Pituophis catenifer* (= *P. melanoleucus*) and the viperid snake, *Agkistrodon piscivorus* (Johnson et al. 1982). In the regressed testis, seminiferous tubules contained spermatogonia and Sertoli cells. In recrudescence, there was renewal of spermatogenic cells characterized by spermatogonial divisions and primary and secondary spermatocytes were oc-

Table 1. Monthly distribution of reproductive conditions in seasonal testicular cycle of *Crotalus enyo*. Values are the number of males exhibiting each of the three conditions.

Month	N	Regressed	Recrudescence	Spermiogenesis
March	2	1	1	0
April	4	2	2	0
May	2	1	1	0
June	3	0	1	2
July	3	0	0	3
August	2	0	0	2
September	13	0	0	13
October	2	0	0	2

casionally present. In spermiogenesis, metamorphosing spermatids and mature sperm were present.

Males undergoing spermiogenesis were collected from June through October, with regressed testes present in specimens collected from March through May and testes in recrudescence (recovery) present in specimens collected from March through June (Table 1). The smallest reproductively active male (regressed testes but sperm in the vasa deferentia from a previous spermiogenesis) measured 470 mm SVL. Sperm were present in the vasa deferentia of the following males: March 1/1 (100%); April 2/2 (100%); May 2/2 (100%); June 2/2 (100%); July 1/1 (100%); August 1/1 (100%); September 11/11 (100%); October 2/2 (100%).

The presence of males with regressed testes in spring (March–May) and spermiogenic males from June through October indicate that the timing of the testicular cycle of *C. enyo* is similar to that of other North American rattlesnakes in which sperm formation occurs summer–autumn and is stored over winter in the vasa deferentia (see Goldberg 1999a,b,c, 2000a,b,c; Goldberg and Holycross 1999; Goldberg and Rosen 2000; Holycross and Goldberg 2001). Field observations are needed to determine when mating occurs in *C. enyo*.

The seasonal ovarian cycle is summarized in Table 2. The presence of one female collected in March (SVL = 543 mm; CAS 87372) with oviductal eggs (N = 7) suggests that ovulation occurs in spring. We examined the March female (SVL = 545 mm; SDSNH 3003) described by Klauber (1931) as containing "eggs" and found it to contain four enlarged ovarian follicles (> 15 mm length)

Table 2. Monthly distribution of reproductive conditions in seasonal ovarian cycle of *Crotalus enyo*. Values are the number of females exhibiting each of the four conditions.

Month	N	Inactive	Enlarged follicles (>10 mm width)	Oviductal eggs	Full-term embryo
March	4	2	1	1	0
April	1	1	0	0	0
May	1	1	0	0	0
June	1	1	0	0	0
July	1	1	0	0	0
August	4	3	0	0	1
September	1	0	1	0	0

which would have ovulated. One female collected in August (SVL = 563 mm; CAS 101612) with a full-term embryo (SVL = 220 mm) suggests an ovarian cycle similar to that of other North American rattlesnakes in which ovulation occurs in spring with young being born in late summer (Armstrong and Murphy 1979). Grismer (2002) found newborn *C. enyo* from late July to mid-October. One female collected 26 September (SVL = 582; MVZ 189971) contained five enlarged ovarian follicles > 10 mm length. This indicates that yolk deposition begins the summer prior to ovulation. The presence of reproductively inactive females suggests that only part of the female population breeds in a particular year. This coincides with the ovarian cycle of other North American rattlesnakes (Goldberg 1999a,c; Goldberg and Holycross 1999; Holycross and Goldberg 2001).

Klauber (1972) reported litter sizes of six and nine for *Crotalus enyo.* Our finding of one female with seven oviductal eggs is within the range cited by Klauber (1972) although the March female from Klauber (1931) that would have ovulated four eggs is outside this range. It is impossible to know if the five enlarged follicles (> 10 mm length) in the September female (SVL = 582 mm; MVZ 189971) would have ovulated. The one female collected in August with a single full-term embryo indicates the minimum litter size for *C. enyo.* Small litter sizes are indicated for *C. enyo* by a female (LACM 134435) collected 12 October 1974 which gave birth in captivity to two neonates on 17 September 1977 (LACM 134431, 134432) and two more on 29 August 1979 (LACM 134433, 134434) respectively. This *C. enyo* female exhibited a biennial reproductive cycle. However, other rattlesnake species may have an annual, biennial or triennial reproductive cycle in different parts of their range: *Crotalus atrox* (Tinkle 1962; Fitch and Pisani 1993; Price 1998; Werler and Dixon 2000); *Crotalus viridis* (Rahn 1942; Diller and Wallace 1988; Macartney and Gregory 1988). Goldberg and Rosen (2000) reported that yearly percentages of gravid *Crotalus scutulatus* appeared to be related to an increase in nutritional resources. Therefore it seems plausible that during periods of prey abundance *C. enyo* could reproduce annually whereas it would reproduce less frequently when these resources are scarce.

Acknowledgments

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Literature Cited

Aldridge, R. D. 1979. Female reproductive cycles of the snakes *Arizona elegans* and *Crotalus viridis.* Herpetologica, 35:256–261.

Armstrong, B. L., and J. B. Murphy. 1979. The natural history of Mexican rattlesnakes. Univ. Kansas Mus. Nat. Hist. Spec. Publ., No. 5:1–88.

Beaman, K. R., and L. L. Grismer. 1994. *Crotalus enyo* (Cope) Baja California rattlesnake. Cat. Am. Amphib. Rept., 589:1–6.

Diller, L. V., and R. L. Wallace. 1988. Reproductive biology of the northern Pacific rattlesnake (*Crotalus viridis oreganus*) in northern Idaho. Herpetologica, 40:182–193.

Fitch, H. S., and G. R. Pisani. 1993. Life history traits of the western diamondback rattlesnake (*Crotalus atrox*) studied from roundup samples in Oklahoma. Occas. Pap. Mus. Nat. Hist. Univ. Kansas, 156:1–24.

Goldberg, S. R. 1999a. Reproduction in the tiger rattlesnake, *Crotalus tigris* (Serpentes: Viperidae). Texas. J. Sci., 51:31–36.

———. 1999b. Reproduction in the red diamond rattlesnake in California. California Fish and Game, 85:177–180.

———. 1999c. Reproduction in the blacktail rattlesnake, *Crotalus molossus* (Serpentes: Viperidae). Texas J. Sci., 51:323–328.

———. 2000a. Reproduction in the speckled rattlesnake, *Crotalus mitchellii* (Serpentes: Viperidae). Bull. So. California Acad. Sci., 99:101–104.

———. 2000b. Reproduction in the twin-spotted rattlesnake, *Crotalus pricei* (Serpentes: Viperidae). West. North Am. Nat., 60:98–100.

———. 2000c. Reproduction in the rock rattlesnake, *Crotalus lepidus* (Serpentes: Viperidae). Herpetol. Nat. Hist., 7:83–86.

———, and A. T. Holycross. 1999. Reproduction in the desert massasauga, *Sistrurus catenatus edwardsii,* in Arizona and Colorado. Southwest. Nat., 44:531–535.

———, and W. S. Parker. 1975. Seasonal testicular histology of the colubrid snakes, *Masticophis taeniatus* and *Pituophis melanoleucus.* Herpetologica, 31:317–322.

———, and P. C. Rosen. 2000. Reproduction in the Mojave rattlesnake, *Crotalus scutulatus* (Serpentes: Viperidae). Texas J. Sci., 52:101–109.

Grismer, L. L. 2002. Amphibians and reptiles of Baja California, including its Pacific islands and the islands in the Sea of Cortés. University of California Press, Berkeley, 399 pp.

Holycross, A. T., and S. R. Goldberg. 2001. Reproduction in northern populations of the ridgenose rattlesnake, *Crotalus willardi* (Serpentes: Viperidae). Copeia, 2001:473–481.

Johnson, L. F., J. S. Jacob, and P. Torrance. 1982. Annual testicular and androgenic cycles of the cottonmouth (*Agkistrodon piscivorus*) in Alabama. Herpetologica, 38:16–25.

Klauber, L. M. 1931. *Crotalus tigris* and *Crotalus enyo,* two little known rattlesnakes of the Southwest. Trans. San Diego Soc. Nat Hist., 6:353–370.

———. 1972. Rattlesnakes. Their habits, life histories, and influence on mankind. 2nd ed. Vol. 1, University of California Press, Berkeley, xlvi + 740 pp.

Macartney, J. M., and P. T. Gregory. 1988. Reproductive biology of female rattlesnakes (*Crotalus viridis*) in British Columbia. Copeia, 1988:47–57.

Price, A. H. 1998. Poisonous snakes of Texas. Texas Parks and Wildlife Press, Austin, 112 pp.

Rahn, H. 1942. The reproductive cycle of the prairie rattler. Copeia, 1942:233–240.

Tinkle, D. W. 1962. Reproductive potential and cycles in female *Crotalus atrox* from northwestern Texas. Copeia, 1962:306–313.

Tryon, B. W., and C. W. Radcliffe. 1977. Reproduction in captive Lower California rattlesnakes, *Crotalus enyo enyo* (Cope). Herpetol. Rev., 8:34–36.

Werler, J. E., and J. R. Dixon. 2000. Texas snakes. Identification, distribution and natural history. University of Texas Press, Austin, xv + 437 pp.

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Appendix: Specimens of *Crotalus enyo* examined from the herpetology collections of the California Academy of Sciences (CAS), Museum of Vertebrate Zoology (MVZ), Natural History Museum of Los Angeles County (LACM), San Diego Society of Natural History (SDSNH), and University of Arizona (UAZ).

Baja California: CAS 87372, 143987, 204090, 204094; LACM 20023, 74024, 134431–134435; MVZ 189963, 189967, 189968, 189970, 189971; SDSNH 18778, 44355, 46196, 46198.

Baja California Sur: CAS 14022, 15630, 45885, 90317, 101612, 110997, 135229, 143844, 143853, 143982, 146748, 160223, 160229; LACM 107220, 132135; MVZ 176061, 176062, 189998, 190000, 190042, 190043, 190129; SDSNH 3003, 46102, 46197; UAZ 23295, 23521, 31692, 31693.

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Research Notes

Occurrence of *Gyrodactylus perforatus* (Monogenea) on its Fish Host *Clevelandia ios* (Gobiidae) from Bodega Bay and Tomales Bay, California

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The arrow goby, *Clevelandia ios* (Gobiidae), ranges from Baja California to Rivers Inlet, British Columbia, inhabiting coastal lagoons, estuaries, and tidal sloughs (Eschmeyer and Herald 1983). This fish lives free and commensally with infaunal invertebrates (MacGinitie and MacGinitie 1949). *Clevelandia ios* is parasitized by the monogenetic trematode *Gyrodactylus perforatus* (Mizelle and Kritsky 1967). However only the population at the type locality, Bodega Bay, California, has been studied. No quantification of this host-parasite interaction exists beyond the parasite's original description, and there is no other documentation for the distribution of *G. perforatus.*

This study investigated the parasitism of *Gyrodactylus perforatus* on *Clevelandia ios* from two regions, Bodega Harbor of Bodega Bay and Tomales Bay, California. Two different host collection techniques were compared.

Host specimens were collected from the upper mudflats in Bodega Bay (Sonoma County; 39°19′23″N, 123°03′15″W) and from Tomales Bay (Marin County; 38°11′17″N, 122°54′43″W) from inside or near burrows of *Callianassa* sp. in October 2000. Using hand nets at mid to high tide, we obtained at least 12 specimens from each location. Alternately, during low tides an additional 12+ specimens from each location were collected with a manual slurp gun, also known as a yabby pump. Voucher specimens were deposited in the UCLA Ichthyology Research Collection under collection numbers W00–8 (Bodega Bay) and W00–11 (Tomales Bay). Upon capture, all fish were isolated in individual, sealed plastic bags, containing equal amounts of air and water. The bags were placed in holding tanks until the fish were processed.

We adapted Parker and Haley's (1960) procedure of removing *Gyrodactylus elegans* from goldfish to remove the parasites from the skin of host fish. Host specimens were placed in 50 ml plastic, conical centrifuge tubes with 40 ml of a solution of 1:5500 formalin:seawater for 30 minutes. A 5 cm square of 1.5 mm mesh screen was inserted approximately half way down the tube to prevent the fish from disturbing the material and parasites that accumulated at the bottom of the tube. After approximately 30 minutes the fish was removed by lifting the mesh screen out of the tube with forceps. In the event of the mesh screen failing to hold the fish off the bottom of the tube, the mesh screen was inserted into a clean centrifuge tube, and the contents of the original tube were transferred with

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Table 1. The abundance, prevalence, and mean intensity (following Bush et al. 1997) of *Gyrodactylus perforatus* infecting *Clevelandia ios* from Bodega Bay and Tomales Bay, California during October 2000.

Collection location	Abundance	Prevalence (95% confidence intervals)	Mean intensity (95% confidence intervals)
Bodega Bay	4.16	0.708 (0.489–0.874)	5.88 (3.59–8.00)
Tomales Bay	0.916	0.333 (0.156–0.553)	2.75 (1.13–4.25)

the fish being detained by the mesh screen. The original centrifuge tube was refilled to 40 ml with formalin solution and both tubes were processed for each host. Standard length measurements were taken of the host specimens.

With a pipet, supernatant fluid was removed to volumetric levels of 20 ml, 10 ml, and 5 ml with one minute of centrifuging between intervals. All removed supernatant fluid was placed into a petri dish and examined under a dissecting microscope to confirm the absence of parasites in the supernatant. The remaining 5 ml of solution was transferred to a glass spot plate and the number of parasites present was recorded at this time. Parasites were fixed in a solution of Alcohol-formol-acetic acid (Dailey 1996) and then transferred to 70% ethanol. Specimens were stained with Grenacher's alcoholic borax-carmine (Dailey 1996) and mounted on slides with Permount. Parasite specimens were deposited in the H.W. Manter Collection at the University of Nebraska (HWML 16345 through 16352).

Methods of capture were compared with no significant difference of parasites found between groups of host specimens collected with hand nets or a yabby pump ($t = -0.859$, df $= 46$, $P = 0.395$). The method of capture did not influence the number of parasites found on host fish and allowed for the two samples from each site to be combined for further analysis.

Comparison of standard lengths of host specimens taken from Bodega Bay or Tomales Bay did not reveal a statistically significant difference between the two groups ($t = 1.301$, df $= 46$, $P = 0.200$). There was no correlation between the number of parasites found versus the standard length of the host fish ($r^2 = 0.144$, $y = 0.6308x + 34.284$) at either site. This illustrates that fish hosts acquire parasites at different life stages and that life stage or size of the host fish is not a factor for parasite load.

The amount of time the host spent in the 1:5500 formalin solution and number of parasites found per host was also not correlated ($r^2 = 0.0209$, $y = 0.1148x + 31.854$). Thus, the amount of time the host fish spent in the formalin solution was determined not to be a factor in the number of parasites obtained from the host fish.

Collection methods did not differ significantly in the amount of parasites found on fish hosts. Standard length did not differ significantly between collection sites. Therefore, both can be dismissed as possible confounding variables for this study. There was a significant difference in number of parasites found on host fish from Bodega Bay and Tomales Bay (Table 1; $t = 3.035$, df $= 46$, $P = 0.004$). Fisher's exact test (Rózsa et al. 2000) for prevalence based on 2000 random permutations yielded a significant difference between the prevalence of *G. perforatus* at Bodega Bay and Tomales Bay (Table 1; $P = 0.024$). Pairwise t-tests for mean intensities based on 2000 bootstrap replications yielded a significant difference between Bodega Bay and Tomales Bay (Table 1; $P = 0.047$).

This study extended the known range of *G. perforatus* to encompass Tomales Bay, in addition to its type locality, Bodega Bay. Although our two collecting sites were only about 27 km apart, there is greater parasitism of *C. ios* by *G. perforatus* in Bodega Bay than in Tomales Bay. Some possible explanations are: (1) there was a greater density of *C. ios* in the area sampled from Bodega Bay than in the area sampled from Tomales Bay; (2) the observed greater density of host fish may allow for an increased number of *G. perforatus* to be present in this area; (3) the host fish in Bodega Bay may undergo more stresses, such as increased disturbance from boat traffic along the dredged channel, which may make them more susceptible to parasitism; (4) the host specimens sampled from Tomales Bay were taken from an area exposed to runoff from a nearby storm drain. The susceptibility of *G. perforatus* to very dilute concentrations of formalin suggests the possibility that *G. perforatus* may also be susceptible to the minor fluctuations in water composition in this sample area. Factors ranging from seasonal fluctuations of fresh water runoff to possible pollution runoff may increase mortality in *G. perforatus* at this site.

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Literature Cited

Bush, A.O., K.D. Lafferty, J.M. Lotz, and A.W. Shostak. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. J. Parasitology 83:575–583.

Dailey, M. D. 1996. Meyer, Olsen & Schmidt's Essentials of Parasitology, Wm. C. Brown Publishers, Dubuque, IA. 286 pp.

Eschmeyer, W. N., E.S. Herald, and H. Hammann. 1983. A Field Guide to Pacific Coast Fishes of North America. Houghton Mifflin Company, Boston. 336 pp.

MacGinitie, G.E. and N. MacGinitie. 1949. Natural History of Marine Animals. McGraw-Hill, New York. 473 pp.

Mizelle, J. D. and D.C. Kritsky. 1967. Studies on monogenetic trematodes. XXXIII. New species of *Gyrodactylus* and a key to the North American species. Trans. Amer. Micro. Soc. 86:390–401.

Parker, J. C. and A.J. Haley. 1960. Method for determination of the number of gyrodactylid trematodes parasitizing the skin of goldfish. J. Parasitology 46:417.

Rózsa, L., J. Reiczigel, and G. Majoros. 2000. Quantifying parasites in samples of hosts. J. Parasitology 86:228–232.

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Occurrence of the Bluefin Killifish, *Lucania goodei,* in the San Dieguito River, Southern California

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The genus *Lucania* is comprised of three species restricted to North America: *L. goodei, L. interioris,* and *L. parva.* These are small-bodied fishes (less than about 60 mm total length) of the family Fundulidae. The Cuatro Ciénegas killifish, *L. interioris,* is endemic to the freshwater Cuatro Ciénegas Basin in Coahuila, Mexico (Hubbs and Miller 1965), and is an international critically endangered species (IUCN 2000). The rainwater killifish, *L. parva,* is a native of salt marshes, bays, and lagoons from Cape Cod, Massachusetts to Tampico, Mexico (Lee et al. 1980). It is especially abundant in the southeastern portion of its range, particularly in the St. Johns River system in Florida, and the Rio Grande and Pecos Rivers in Texas and New Mexico (Hubbs and Miller 1965; Page and Burr 1991). Non-indigenous populations of *L. parva* have been established in marine and freshwater environments in New Jersey, Texas, New Mexico, Utah, Nevada, California, and Oregon (Fuller et al. 1999). In California, the rainwater killifish is found in Irving Lake and Arroyo Seco Creek near Vail Lake in southern California (McCoid and St. Amant 1980), sloughs and streams flowing into the San Francisco Bay, and Lake Merritt in Oakland (Moyle 1976). The bluefin killifish, *L. goodei,* is found in freshwater habitats in the southeastern United States. Its endemic range encompasses most of Florida, except in the panhandle where it is found only east of the Choctawhatchee River, and the Chipola River drainage in southeastern Alabama (Page and Burr 1991). It is also found sporadically along the Atlantic coast up to central North Carolina where it is possibly introduced (Loyacano 1975; Lee et al. 1980; Menhinick 1991). Fuller et al. (1999) state that nonindigenous populations of *L. goodei* are established in North Carolina and South Carolina.

All three species of *Lucania* have similar body shapes and share many traits. They are fairly slender with compressed bodies and small, upturned mouths. The origin of their dorsal fin is anterior to the origin of their anal fin. They are dusky brown to olive above, and silvery white below. Their scales have dark edges, and their anal and dorsal fins both have thin black edges. *Lucania goodei* can be distinguished from its congeners by a distinctive stripe along the midline of the body, starting from the tip of the snout and ending at a black spot at the base of the caudal fin (Page and Burr 1991). In addition, the caudal and anal fins of adult male *Lucania goodei* are bright, iridescent blue in color and have a black stripe at their bases.

On 27 July 2000, seven individuals of *L. goodei* (Fig. 1) were captured in

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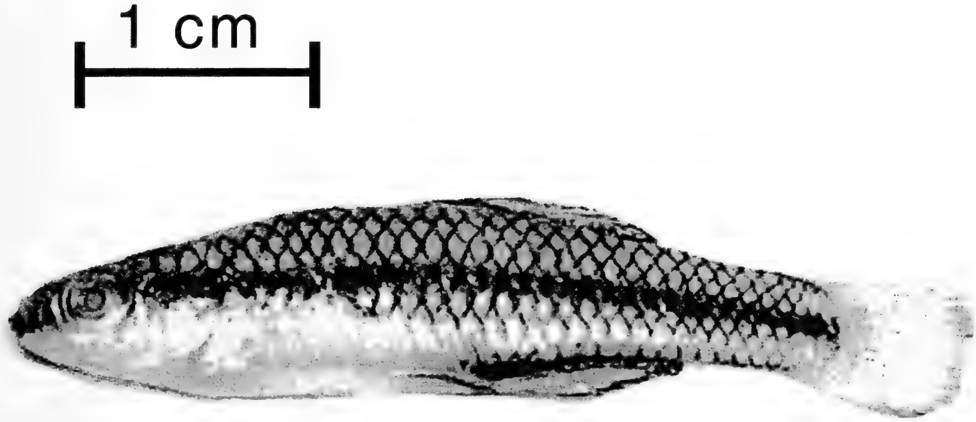

Fig. 1. Bluefin killifish, *Lucania goodei,* taken from upper San Dieguito River (SIO 01-192). Photograph by David Huang.

beach seines during annual monitoring conducted by the Marine Science Institute at the University of California, Santa Barbara of the upper San Dieguito River, San Diego County. These specimens are deposited at the Scripps Institution of Oceanography, SIO 01-192. On 23 September 2000, five more individuals were collected from the same location using dip nets. Salinity of the water at the times and locations of capture were between 15.9 and 16.2 ppt, a condition more saline than those in which they are typically found. All of the specimens had a distinct mid-lateral stripe from the tip of the snout to the base of the caudal fin, which was used to identify them as *L. goodei.* Two of the larger specimens also had the bright, iridescent blue caudal and anal fins characteristic of adult male *L. goodei.* Morphometric and meristic characters are summarized in Table 1.

Table 1. Counts and morphometric measurements of *Lucania goodei* specimens taken from upper San Dieguito River on 27 July 2000 (SIO 01-192). Morphometric measurements are in millimeters (mm).

	1	2	3	4	5	6	7
Counts:							
Dorsal fin	10	10	12	10	10	10	11
Anal fin	10	11	11	11	10	8	10
Pectoral fin	11	10	9	9	9	9	11
Lateral line scales	28	27	26	27	28	27	26
Morphometrics:							
Standard length	28.5	32.8	33.4	33.4	34.5	37.3	39.2
Total length	34.5	38.9	38.6	38.8	40.8	45.9	45.1
Head length	8.7	8.9	8.2	8.6	8.5	10.0	10.0
Snout length	1.8	2.3	2.1	2.2	2.1	3.1	3.0
Interorbital width	3.0	3.5	3.0	2.6	3.1	3.9	3.7
Orbit width	2.3	2.3	2.3	2.1	2.7	2.7	2.7
Pectoral length	4.5	4.8	4.2	4.4	5.0	4.9	4.9
Pelvic length	4.5	4.2	3.9	4.3	4.5	4.6	4.5
Caudal peduncle depth	3.6	3.8	3.2	3.4	3.9	4.5	4.0
Weight (g)	—	0.6	0.4	0.6	0.6	0.9	0.8

Many authors have speculated that *L. parva* was accidentally introduced into California as a contaminant in imported aquaculture and game fish stocks. There is circumstantial evidence indicating the populations in San Francisco Bay, California originated from eggs attached to live oysters imported from the east coast for culture (Hubbs and Miller 1965). In southern California, *L. parva* was most likely a contaminant in a shipment of game fishes such as largemouth bass (Hubbs and Miller 1965; Moyle 1976; McCoid and St. Amant 1980).

Based on differences in their natural distributions and habitats, it is unlikely *L. goodei* was introduced into California with *L. parva.* These fish are rarely collected together in their native range (Crawford and Balon 1994). The salt marsh and estuarine habitat of *L. parva* is similar to that of other temperate Cyprinodontiformes such as *Floridichthys, Fundulus,* and *Menidia* (Duggins 1980). Although *L. parva* can survive in seawater, they prefer brackish waters near a regular supply of fresh water (Jordan and Evermann 1896; Hubbs and Miller 1965). They are rarely found in completely fresh water. In contrast, *L. goodei* is almost always found in freshwater, although collections from mildly brackish water, such as in the current study, are also known.

Although the introduction of *L. goodei* with *L. parva* is unlikely, the only record of *L. goodei* in California was also the result of contaminated stocks. In late 1980, stocks of Asian milfoil (*Myriophyllum*) imported into Los Angeles from Florida were contaminated with *L. goodei* eggs, which hatched and survived several months in an outdoor pond (Swift et al. 1993). However, since that time there have been no records of this fish in any public waters in the state (Dill and Cordone 1997).

Hubbs and Miller (1965) discounted aquarium release as a source of introduction for *L. parva.* However, this now seems a likely source of *L. goodei* in the San Dieguito River. Considered to be one of the more attractive native killifish, *L. goodei* is a popular species in the aquarium trade (Schleser 1998). The introduction of new species into San Diego County by aquarium dumping is certainly not without precedent. Recently, aquarium dumping has been blamed for the threatening presence of the green alga, *Caulerpa taxifolia,* in the Agua Hedionda Lagoon as well as Huntington Harbor in Orange County, California (CWQCB 2001). The hypothesis of aquarium dumping is consistent with data taken during previous monitoring of the San Dieguito River, which shows no earlier records for *L. goodei.* This suggests that this population may have been introduced fairly recently.

Data from the 2001 San Dieguito River annual monitoring indicates the salinity at this study site has increased to 34–35 ppt, a condition considered abnormal for *L. goodei* habitat. Nonetheless, this population has persisted and become increasingly numerous (pers. obs., DH). Still, it is too early to determine the impacts of this introduction. Future monitoring will show whether *Lucania goodei* becomes permanently established in the San Dieguito River.

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Literature Cited

California Water Quality Control Board (CWQCB). 2001. A destructive seaweed threatens California. San Diego Region California Water Quality Control Board, San Diego, California.

Crawford, S. S., and E. K. Balon. 1994. Alternative life histories of the genus *Lucania*: 3. An ecomorphological explanation of altricial (*L. parva*) and precocial (*L. goodei*) species. Environ. Biol. Fish. 41(1–4):369–402.

Dill, W. A., and A. J. Cordone. 1997. History and status of introduced fishes in California, 1871–1996. State of California, Dept. of Fish and Game. Fish Bull. 178, 414 pp.

Duggins, C. F. 1980. Systematics and zoogeography of *Lucania parva, Floridichthys,* and *Menidia* (Osteichthys: Atheriniformes) in Florida, the Gulf of Mexico. Ph.D. Thesis. Florida State University. Tallahassee 168 pp.

Fuller, P. L., L. G. Nico, and J. D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publication 27, Bethesda, Maryland. 613 pp.

Hubbs, C. L., and R. R. Miller. 1965. Studies of Cyprinodont fishes. XXII. Variation in *Lucania parva,* its establishment in western United States, and description of a new species from an interior basin in Coahuila, México. Misc. Publ. Mus. Zool. Univ. Mich. 1–104.

International Union for Conservation of Nature and Natural Resources (IUCN). 2000. 2000 IUCN red list of threatened animals. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland and Cambridge, U.K.

Jordan, D. S., and B. W. Evermann. 1896. Fishes of North and Middle America. Bull. U.S. Nat. Mus. 47:1–3313.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina Museum of Natural History. 854 pp.

Loyacano, H. A., Jr. 1975. A list of freshwater fishes of South Carolina. Bull. So. Carol. Exp. Sta. 580:1–8.

McCoid, M. J., and J. A. St. Amant. 1980. Notes on the establishment of the rainwater killifish, *Lucania parva,* in California. Calif. Fish Game 66(2):124–125.

Menhinick, E. F. 1991. The Freshwater Fishes of North Carolina. North Carolina Wildlife Resources Commission. pp. 227.

Moyle, P. B. 1976. Inland Fishes of California. University of California Press, Berkeley. 405 pp.

Page, L. M., and B. M. Burr. 1991. A Field Guide to Freshwater Fishes of North America North of Mexico. The Peterson Field Guide Series, volume 42. Houghton Mifflin Company. New York. 432 pp.

Schleser, D. M. 1998. North American Native Fishes for the Home Aquarium. Barron's, Hauppage, New York and Hong Kong. 171 pp.

Swift, C. C., T. R. Haglund, M. Ruiz, and R. M. Fisher. 1993. The Status and Distribution of the Freshwater Fishes of Southern California. Bull. So. Cal. Acad. Sci. 92(3):101–167.

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McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii + 326 pp.

Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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Cover: Bluefin killifish, *Lucania goodie*. Photo by David Huang.

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2004 ANNUAL MEETING

May 2004

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FIRST CALL FOR SYMPOSIA

The Southern California Academy of Sciences will hold its 2004 annual meeting on the campus of the California State University, Long Beach. Presently planned symposium topics are Wetlands Ecology, Molecular Ecology of Southern California, Animal Movements and Dispersal, and Environmental Simulation. Additional proposed symposium topics are invited. Please contact Raymond Wilson (rwilson1@csulb.edu) or David Huckaby (dhuckaby@csulb.edu) at CSU, Long Beach, to propose additional symposia.

FIRST CALL FOR PAPERS

The Southern California Academy of Sciences will hold its 2004 annual meeting on the campus of the California State University, Long Beach. This is the first call for papers for four presently planned symposia. The symposium "Wetlands Ecology" will be devoted to studies of the biological, chemical, and geological processes of Southern California's wetlands. If you wish to participate, please contact Tonny Wijte at CSU, Long Beach (wijte@csulb.edu) or Martha Sutula at SCCWRP (marthas@sccwrp.org). The symposium "Molecular Ecology of Southern California" will be devoted broadly to ecological studies involving the use of molecular-genetic tools. If you wish to participate, please contact Raymond Wilson at CSU, Long Beach (rwilson1@csulb.edu). The symposium "Animal Movements and Dispersal" will be devoted to studies of animal migrations and dispersal, both marine and terrestrial. If you wish to participate, please contact Chris Lowe at CSU, Long Beach (clowe@csulb.edu). The symposium "Environmental Simulation" will be devoted to studies that model environmental processes. If you wish to participate, please contact Drew Ackerman at SCCWRP (drewa@sccwrp.org).

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Abundance and Importance of Fish Species from the Artisanal Fishery on the Pacific Coast of Northern Baja California

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Abstract.—The artisanal fishery from Baja California, México is conducted from small boats in nearshore waters, and from fishing camps located along the coast. This activity is important due to the volume and the number of fish species captured. In this study we describe the seasonal abundance of catches from 51 boats in 1994, and the importance of the species landed at eight sites along the northwestern coast of Baja California, from Santo Tomás to south to Punta Canoas. Sixteen fish species were identified from 2,490 individuals and with a biomass of 2,682.7 kg. The highest catches were recorded in Summer and Fall, and the lowest in Winter. The seasonal mean catch per boat was similar and lowest during Spring (42.1 fish/boat ±SE 7.9) and highest in Summer (52.1 fish/boat ±6.7), followed closely (50.3 and 50.1 fish/boat) by Fall and Winter, respectively. The most important fish species according to the Index of Community Importance were the rockfishes (*Sebastes* sp.), whitefish (*Caulolatilus princeps*), sheephead (*Semicossyphus pulcher*), and kelp bass (*Paralabrax clathratus*). All these can be considered the target species, and also important to sportfishing. San Quintín contributed 35% of the boat trips and 37.5% of the total catch.

The western coast of Baja California is a highly complex habitat with sandy bottoms, rocky reefs, beds of giant kelp or seagrasses, cold upwelling areas, inlet bodies of warm-water, and highly productive zones. These environments are important as nurseries, and spawning grounds and provide refuge for both invertebrates and small fish that act as prey for larger fish.

A high larval fish production from different species occurs along the coastal waters of Baja California (Moser *et al* 1993). This area is also important to transboundary fish species (Moser and Watson 1990), and more northern waters benefit from the egg and larval dispersion of both pelagic or demersal fishes from this area. The greatest importance of this coastal zone is that shelters a great diversity of fish species of ecological and economical interest.

The artisanal fishery of Baja California is mainly conducted with small boats (pangas; <8m long, 75 HP), and usually with hook-and-line. This fishery involves a variety of ground and pelagic species from habitats of no more than 15 fathoms depth. However, this coastal activity, in a nation-wide context, represents from 30% to 50% of the total catch with an important economic value (Hammann and Rosales-Casián 1990; SEMARNAP 1997; SEMARNAT 2000).

In Baja California, the coastal demersal fishes named the "scale" group are caught from different fishing camps located along both the Gulf of California and the Pacific coast. Their fishing products are mainly sold in Ensenada, Baja California, at the "Mercado de Mariscos del puerto de Ensenada". This market is an important source of biological information, and an annual study of the fish species taken has recently been published (Hernández-Hernández 2000).

Reports on coastal fishing of Baja California are non-existant, and very few reports on artisanal fishing have been realized, because most research has been focused on the fisheries for schooling species caught by purse seiners (tunas, sardines, anchovies) or on expensive invertebrates like abalone or lobster. A number of studies have been completed on the fish community and the biology of economic fish species in the vicinity of Bahía de Todos Santos, Ensenada, Baja California (Carrillo-Cortes 1994; Hammann and Ramirez-Gonzalez 1990; Mendoza-Carranza and Rosales-Casián 2000; Hammann and Rosales-Casián 1990; Mondragón-Rojas 1994; Pintos-Terán 1994; Rosales-Casián and Hammann 1993; Rosales-Casián 1995; Salomé-Sánchez 1993), and Bahía de San Quintín (Rosales-Casián 1996, 1997a,b).

The current study analyzes the artisanal coastal fishery data from Santo Tomas south to Punta Canoas, in Northern Baja California, during 1994. The objectives of this study are to determine 1) which fish species are taken, 2) the seasonal abundance of the catch, and 3) to analyze the importance of the fish species caught by pangas.

Methods

This study was conducted in 1994 and early 1995. Eight sites were selected from the Pacific coast of northern Baja California: Santo Tomás, Ejido Erendira, Cabo Colonett, Camalú, Bahía de San Quintín, Bahía de El Rosario, Puerto San Carlos and Punta Canoas (Fig. 1). All these sites were selected because of their importance as fishing camps.

This study began in April 1994 and continued during May, August, September, October, November, December, and January 1995. For the analysis, samples were grouped by seasons: spring (April–May), summer (August–September), fall (October–November), and winter (December and January). Each monthly sample included three to four sites, with five to seven sites per season. Sampling a site each month was difficult due to weather, movement of boats to different fishing places, outboard motor failures, lack of fishing trips due to other causes. For this reason, we analyzed the information as a whole. Because Bahía de San Quintín was visited during each trip and obtained the best data set over time, we present a specific analysis for this important locale.

The catch from the individual boats was counted, identified, measured and weighed upon arrival. The identification of the fish species followed Miller and Lea (1972). The rockfishes except for scorpionfish were unspecified and listed as *Sebastes* sp. The standard length (mm-SL) was obtained by means of a one-meter measurement board with divisions to millimeter. The total weigh was measured with an Accu-weigh spring scale of 22 kg capacity to the nearest 100 g. The type of fishing gear, length of the boats and the outboard motor power were also recorded.

Temperature (°C) was obtained from a 1994 study at the open coast of Bahía

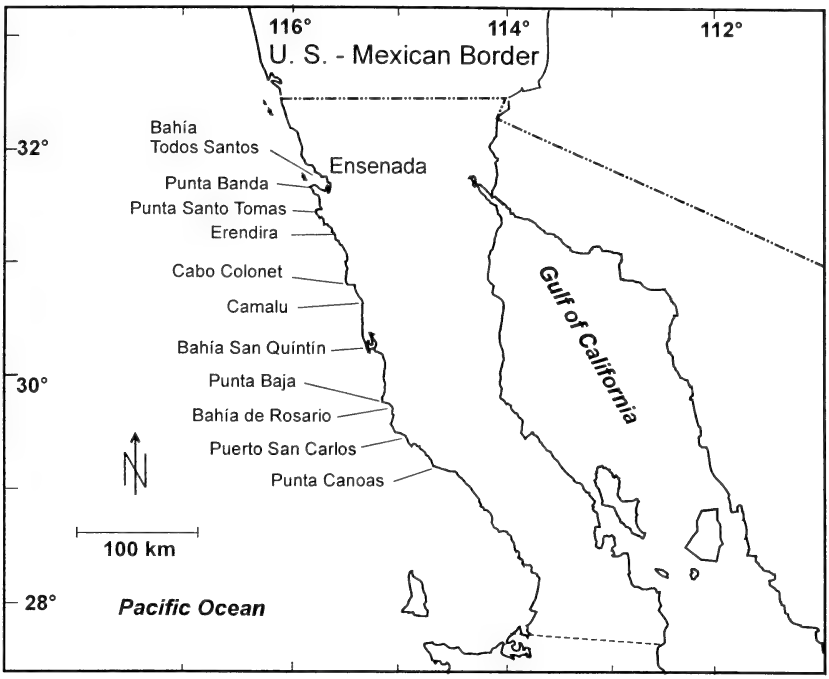

Fig. 1. Sampling sites for the artisanal fishing during 1994 and early 1995.

de San Quintín (Rosales-Casián 1997b), and was measured by four bottom replicates (10m-depth) during all monthly trips with a reversible thermometer. A Pearson correlation between bottom temperatures and fish abundance (log10[X+1] transformed) from all sites and from San Quintín was calculated to measure their association (Zar 1984).

Abundance was converted to catch per unit effort (CPUE) by dividing the number of fishes by the number of boat trips. The boat catches were first examined for assumption of normality (K-S, $d = 0.113$, $p>0.20$) and then were log10(X+1) transformed to determine seasonal differences in mean catches by an Analysis of Variance (ANOVA).

To determine the contribution of each species to the catch and which could be considered target species, the Index of Community Importance (ICI) was used (Stephens and Zerba 1981; Love *et al.* 1986; Rosales-Casián 1997a,b). The ICI was calculated by the sum of the percent of abundance and frequency-of-occurrence rankings. Species were then reranked based on these ICI values.

The standard lengths (mm) were grouped by 20 mm classes. Length-class distributions were presented for all individuals and seasonally for the three more important target fish species. Sizes were transformed to logarithms to determine seasonal differences by ANOVA, as above.

Results

The means of seasonal bottom temperatures at 10m-depth from the coast of San Quintín were 12.6, 17.2, 15.9, and 13.1°C for spring, summer, fall, and winter, respectively. The catch presented here reflects the fishes and sizes of commercial

Table 1. Sampling dates, number of sampling boats, total and relative abundance of fishes in the northwestern coast of Baja California, during 1994 and early 1995.

		No. boats		No. fishes		% Rel	
Date	Season	Monthly	Season	Monthly	Season	Monthly	Season
April 13–16, 1994	Spring	7		230		9.2	
May 24–27	Spring	5	12	275	505	11.0	20.3
August 2–5	Summer	9		487		19.6	
September 7–10	Summer	5	14	242	729	9.7	29.3
October 14–16	Fall	5		274		11.0	
November 8–12	Fall	10	15	481	755	19.3	30.3
December 14–18	Winter	6		301		12.1	
January 19, 1995	Winter	54	10	200	501	8.0	20.1
Total		51		2490		100.0	

species only. Small fish of any species are usually released alive, and are not recorded in the catch.

A total of 51 commercial fish catches were sampled from an equal number of pangas during the eight months of trips that comprised the four seasons (Table I). The total number of fishes recorded was 2,490 (Table I) with the highest catches during Summer (August, n = 487) and Fall (November, n = 481), and lowest catch in Winter (January 1995, n = 200). The total biomass of the catch during the complete study was 2,682.7 kg.

A total of 16 fish species and the group of rockfishes were identified in the catch. The most abundant fish were the rockfishes (*Sebastes* sp.) during Spring and Fall, followed by the sheephead (*Semicossyphus pulcher*) in Summer, and the whitefish (*Caulolatilus princeps*) in fall. These species contributed 30%, 25.9% and 17.6%, to the total catch, respectively (Table 2). The kelp bass, *Paralabrax clathratus,* were an important component during Summer (n = 102), and all kelp bass contributed 10.6% to the total catch.

The most important target species were the rockfishes, according to their rankings by the relative abundance and the frequency of occurrence (Index of Community Importance, ICI). By the ICI, the whitefish (*C. princeps*) occuped the second place followed by *S. pulcher* and *P. clathratus* (Table 3). The rockfishes occurred with 23.1% in the boat catches, the whitefish with 16.2%, and the sheephead and kelp bass with 13.1%, both (Table 3).

The seasonal mean catch per boat was lowest during spring (42.1 fish/boat ±SE 7.9) and highest in summer (52.1 fish/boat ±6.7), followed by close values (50.3 and 50.1 fish/boat) in fall and winter, (Fig. 2). The overall mean was 48.8 fish/boat (±2.9), and the maximum catch by a boat was 95 fish in spring, with a minimum of five fish in fall. The mean catch per boat did no differ significantly (ANOVA, p = 0.465) among seasons.

No significant correlation was found between bottom temperature (10m-depth) from the coast of San Quintín and the seasonal catch study area as a whole (r = 0.556, p = 0.254).

The lowest mean catch in the coast of San Quintín was in spring with 41.8 fish/boat (±SE 18.8) and the highest (63.2 ±SE 9.5) in fall (Fig. 4.). At this site, the overall mean was 51.8 fish/boat ±SE 5.2. The high variability of the standard

Table 2. Fish species composition of the seasonal boat catches ranked by relative abundance in the northwestern coast of Baja California, during 1994 and early 1995.

Species	Spring	Summer	Fall	Winter	Subtotal	% Rel	% Cum
Sebastes sp.	238	111	238	161	748	30.0	30.0
Semicossyphus pulcher	135	397	24	89	645	25.9	55.9
Caulolatilus princeps	75	54	262	47	438	17.6	73.5
Paralabrax clathratus	6	102	92	65	265	10.6	84.2
Paralichthys californicus	32	12	49	54	147	5.9	90.1
Seriola lalandi		31	74	6	111	4.5	94.5
Sphyraena argentea		12	6	18	36	1.4	96.0
Cheilotrema saturnum		0	0	21	21	0.8	96.8
Paralabrax nebulifer		0	0	18	18	0.7	97.6
Cynoscion parvipinnis		3	2	12	17	0.7	98.2
Ophiodon elongatus	5	0	3	8	16	0.6	98.9
Atractoscion nobilis	12	0	2	1	15	0.6	99.5
Girella nigricans	1	4	3	0	8	0.3	99.8
Stereolepis gigas		1	0	1	2	0.1	99.9
Scorpaena guttata		1	0	0	1	0.0	99.9
Coryphaena hippurus	1	0	0	0	1	0.0	100.0
Caranx hippos		1	0	0	1	0.0	100.0
Total	505	729	755	501	2490	100.0	100.0

error during spring was due to a lowest catch of eleven fishes in one boat and a high of 95 fishes in another boat. These were the minimum and maximum catch numbers in all seasons. No significant correlation was found between bottom temperature and the seasonal catch in San Quintín ($r = 0.241$, $p = 0.509$).

Thirteen species plus the rockfish group were taken off of San Quintín. The most important target species by ICI, again, were *Sebastes* sp. followed by kelp

Table 3. Fish species composition of the seasonal boat catches ranked by the Index of Community Importance in the northwestern coast of Baja California, during 1994 and early 1995.

Species	Total	% Rel	Rank	% FO	Rank	ICI
Sebastes sp.	748	30.0	1	23.14	1	2
Caulolatilus princeps	438	17.6	3	16.16	2	5
Semicossyphus pulcher	645	25.9	2	13.10	3.5	5.5
Paralabrax clathratus	265	10.6	4	13.10	3.5	7.5
Paralichthys californicus	147	5.9	5	10.04	5	10
Seriola lalandi	111	4.5	6	5.68	6	12
Sphyraena argentea	36	1.4	7	3.49	8.5	15.5
Ophiodon elongatus	16	0.6	9	4.37	7	16
Cheilotrema saturnum	21	0.8	8	0.87	11	19
Paralobrax nebulifer	18	0.7	10.5	0.87	11	21.5
Girella nigricans	8	0.3	13	3.49	8.5	21.5
Cynoscion parvipinnis	17	0.7	10.5	1.75	13.5	24
Stereolepis gigas	2	0.1	14	0.87	11	25
Atractoscion nobilis	15	0.6	12	1.75	13.5	25.5
Scorpaena guttata	1	0.0	16	0.44	16	32
Coryphaena hippurus	1	0.0	16	0.44	16	32
Caranx hippos	1	0.0	16	0.44	16	32
Total	2490	100				

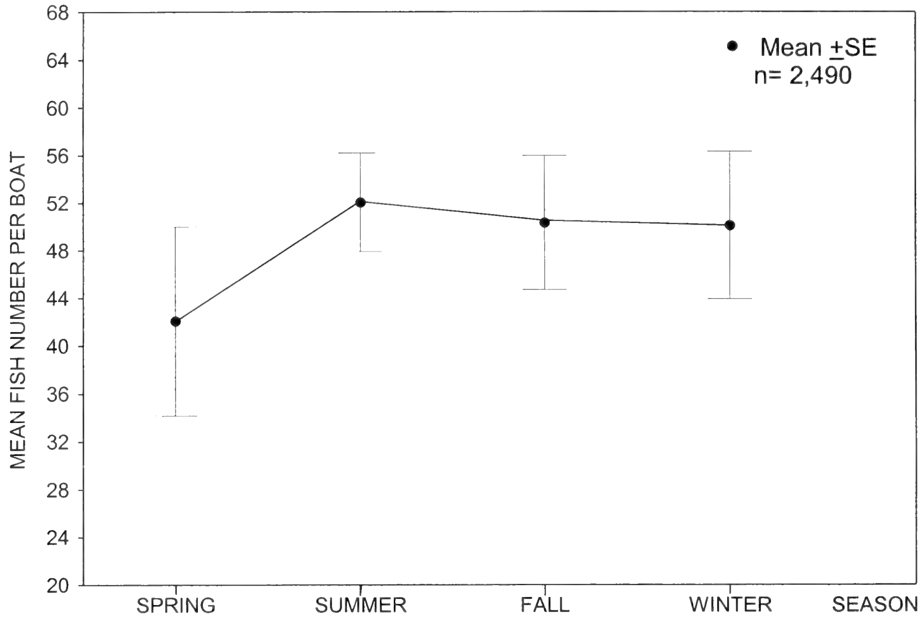

Fig. 2. Seasonality of fish catch per boat in the norwestern coast of Baja California, México, during 1994 and early 1995.

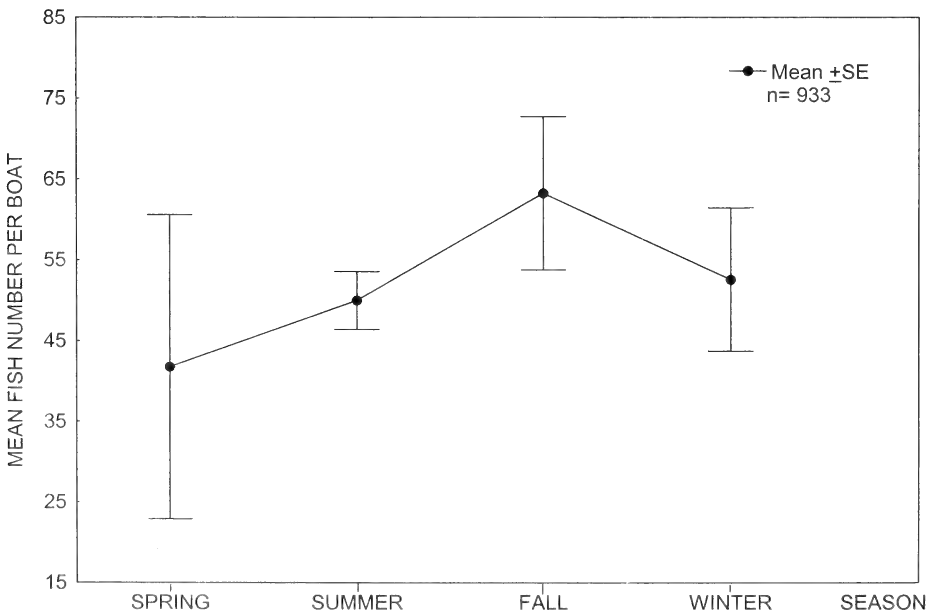

Fig. 3. Seasonality of fish catch per boat in the Coast of San Quintín, Baja California, México, during 1994 and early 1995.

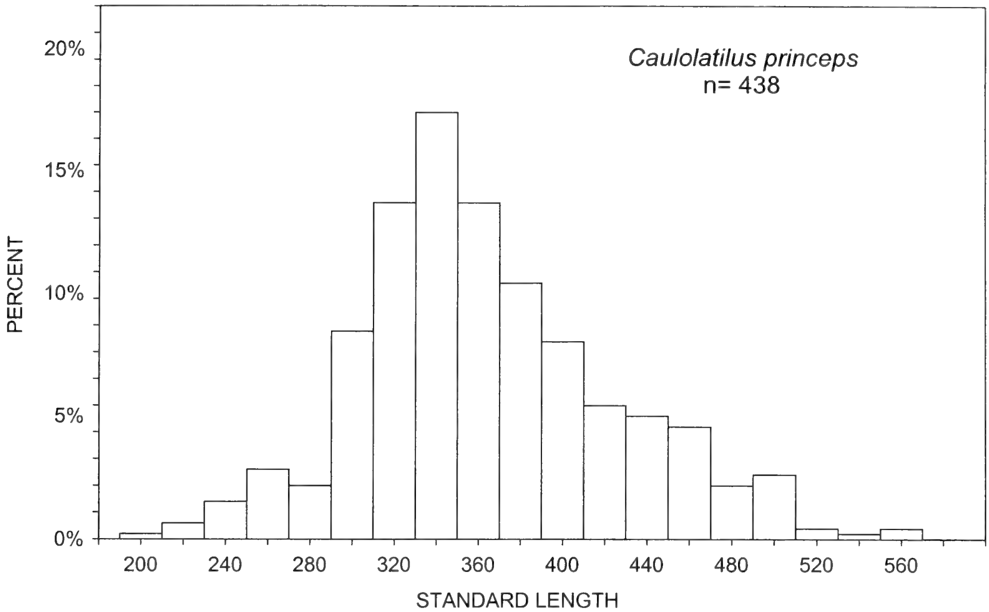

Fig. 4. Standard length (mm) distribution of *Caulolatilus princeps* in the northwestern coast of Baja California, during 1994 and early 1995.

bass, *P. clathratus* and whitefish, *C. princeps* (Table 4). *Sebastes* sp. occurred in 94.4% of the panga catches, while kelp bass and whitefish occurred in 72.2% and 66.7% of catches, respectively (Table 4).

Because rockfishes are a mix of species that were not identified, we present here the size distributions of the most important species (whitefish, California sheephead and kelp bass), only.

The standard length of the whitefish (*C. princeps*) ranged from 195 to 555 mm

Table 4. Fish species composition of the seasonal boat catches ranked by the Index of Community Importance in the coast of San Quintín, Baja California, during 1994 and early 1995.

Species	Total	% Rel	Rank	% FO	Rank	ICI
Sebastes sp.	372	39.9	1.0	94.4	1.0	2.0
Paralabrax clathratus	231	24.8	2.0	72.2	2.5	4.5
Caulolatilus princeps	114	12.2	3.0	72.2	2.5	5.5
Seriola lalandi	75	8.0	4.0	33.3	4.5	8.5
Sphyraena argentea	36	3.9	5.0	38.9	4.0	9.0
Semicossyphus pulcher	29	3.1	6.0	33.3	4.5	10.5
Paralichthys californicus	7	0.8	8.0	27.8	6.0	14.0
Cheilotrema saturnum	21	2.3	7.0	11.1	8.5	15.5
Ophiodon elongatus	11	1.2	10.0	16.7	7.0	17.0
Paralabrax nebulifer	18	1.9	8.0	11.1	10.0	18.0
Atractoscion nobilis	5	0.5	11.0	11.1	8.5	19.5
Cynoscion parvipinnis	12	1.3	9.0	5.6	11.5	20.5
Girella nigricans	1	0.1	13.0	5.6	11.5	24.5
Coryphaena hippurus	1	0.1	13.0	5.6	11.5	24.5
Total	933	100.0				

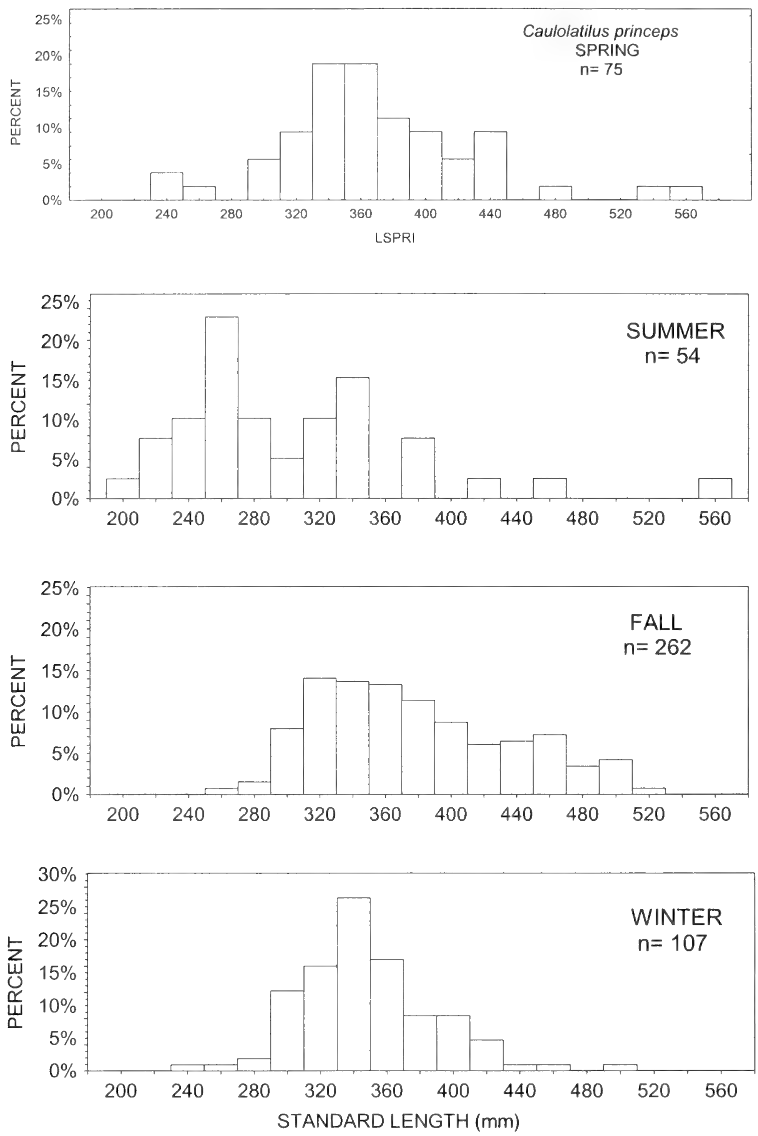

Fig. 5. Seasonal size distribution (20mm SL class) of *Caulolatilus princeps* in the northwestern coast of Baja California, during 1994 and early 1995.

with an overall mean of 354.9 mm (SD± 61.2). The length distribution for the complete study shows that 17.4% of the individuals fell into the 340 mm class (Fig. 4). Seasonally, the 340 mm size class was important during all four periods. During summer, a new cohort was incorporated representing the smallest individuals with a mode at 260 mm (Fig. 5). The standard length means showed significative differences with respect to seasons (ANOVA, F = 22.100, p = 0.000).

California sheephead (*S. pulcher*) standard lengths ranged from 194 to 628 mm, with a mean of 312.2 mm (SD± 56.8). For all individuals, modal size was at the 300 mm class, with a frequency of 17.3% (Fig. 6). By seasons, *S. pulcher* shows

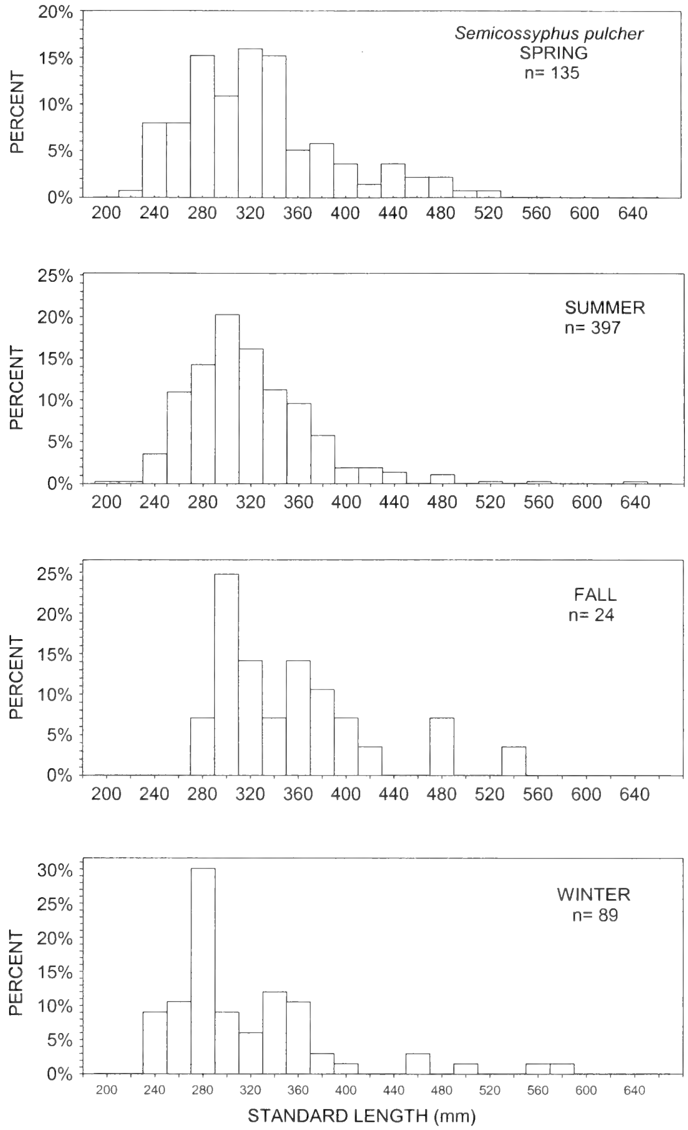

Fig. 6. Standard length (mm) distribution of *Semicossyphus pulcher* in the northwestern coast of Baja California, during 1994 and early 1995.

the main mode at the 320 mm class during spring, at 300 mm during summer and fall, and at 280 mm in winter (Fig. 7). The standard length means showed significant differences with the seasons (ANOVA, $F = 3.092$, $p = 0.027$).

With respect to the kelp bass (*P. clathratus*), we obtained some additional data for the spring months from samples in the same year at the *Macrocystis* sp. beds on the coast of San Quintín (Rosales-Casián 1995, 1997b). This increased the number for the size distribution in that period. For the complete data set, the mode was observed at the 370 mm size class which represented 18.4% of the individuals (Fig. 8). The smallest individuals represented at left of the mode con-

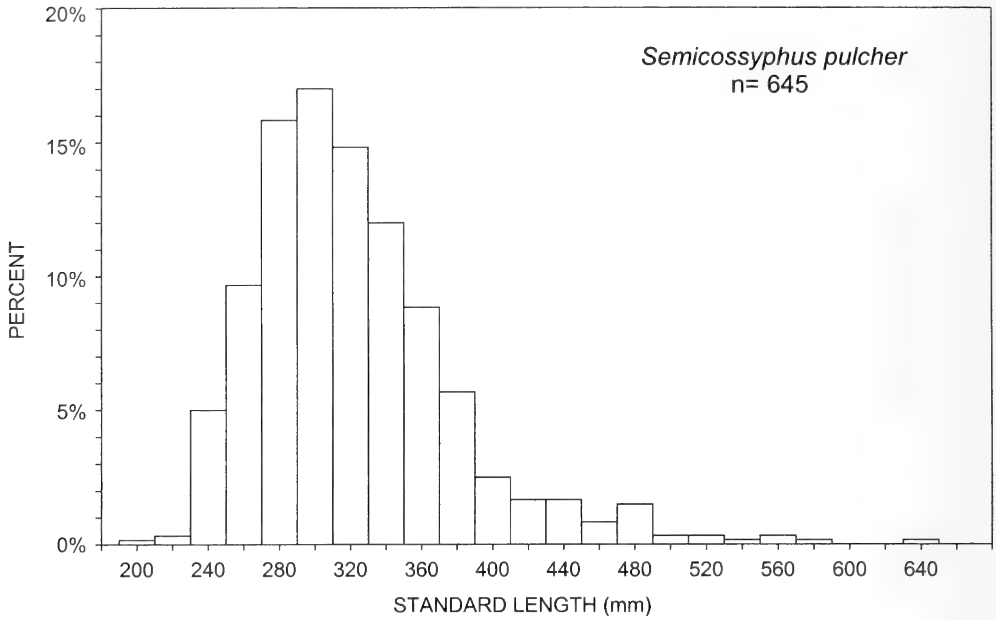

Fig. 7. Seasonal size distribution (20mm SL class) of *Semicossyphus pulcher* in the northwestern coast of Baja California, during 1994 and early 1995.

tributed 48% of the individuals. The seasonal distribution of lengths showed that 370 mm size class was important in spring and summer, while the 350 mm and 300 size classes predominated during fall and winter (Fig. 9). The analysis of variance detected significant differences in the standard length means with respect to seasons (ANOVA, $F = 11.91$, $p = 0.000$).

Discussion

This type of fishery was difficult to sample because sheer distance from Punta Santo Tomas to Punta Canoas, and rough road conditions. This and the absence or small number of fishing trips at each visit increased the difficulty. Despite these problems, we believe that the information presented here is valuable and accurately reflects the artisanal fishery on the Pacific coast of northern Baja California during 1994 and early 1995.

During the seasonal sampling in 1994–1995, all sites were important for artisanal fishing, however, the coast of San Quintín represented 35% of the 51 panga trips, followed by Punta Baja (Bahía El Rosario) with 13.7%. Furthermore, San Quintín is important because it cointains, a well protected launching ramp in the bay, where other sites are usually affected by swell. The coast of San Quintín includes San Martin Island and different shallow rocky reefs which are good sites for ground and pelagic fishes.

The seasonal totals of fishes were highest during summer ($n = 729$) and fall ($n = 755$). The fish catch per trip was lowest during spring (42 fishes), but the values in the other seasons were not much higher (50–52 fishes/trip). This non-significant difference, probably represented the market demand and was not due to the weather. Usually, boat owners do not live in the fishing camps, and have

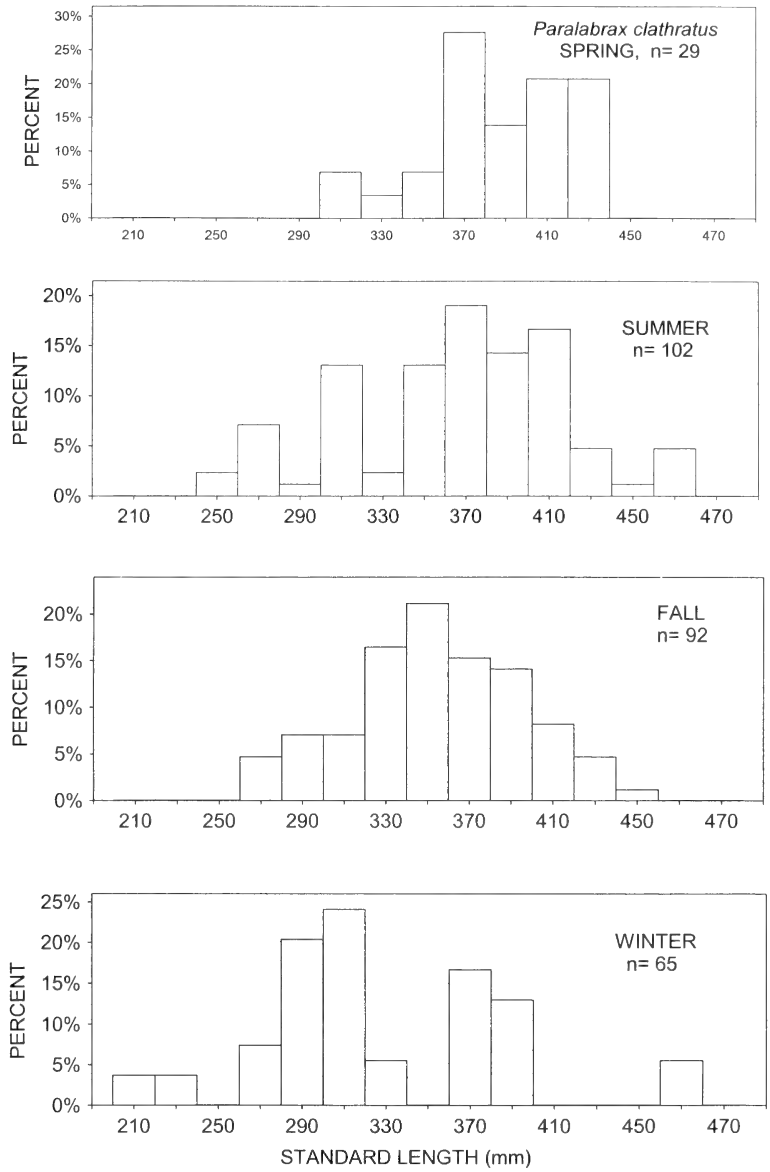

Fig. 8. Standard length (mm) distribution of *Paralabrax clathratus* in the northwestern coast of Baja California, during 1994 and early 1995.

various pangas in one or more sites. Pressure for fishing trips responds to the demand for fish. We consider the overall effort of fishing during the study as being low. Spring was represented by 12 trips, summer by 14, fall by 15, and winter by ten trips. All seasons included eight days of sampling per season, except winter which was sampled six days.

In this study, the "scale" fishery was supported by a small number of species, that together with the undetermined species of the rockfishes were the most important by the Index of Community Importance (ICI). Four species, *C. princeps,*

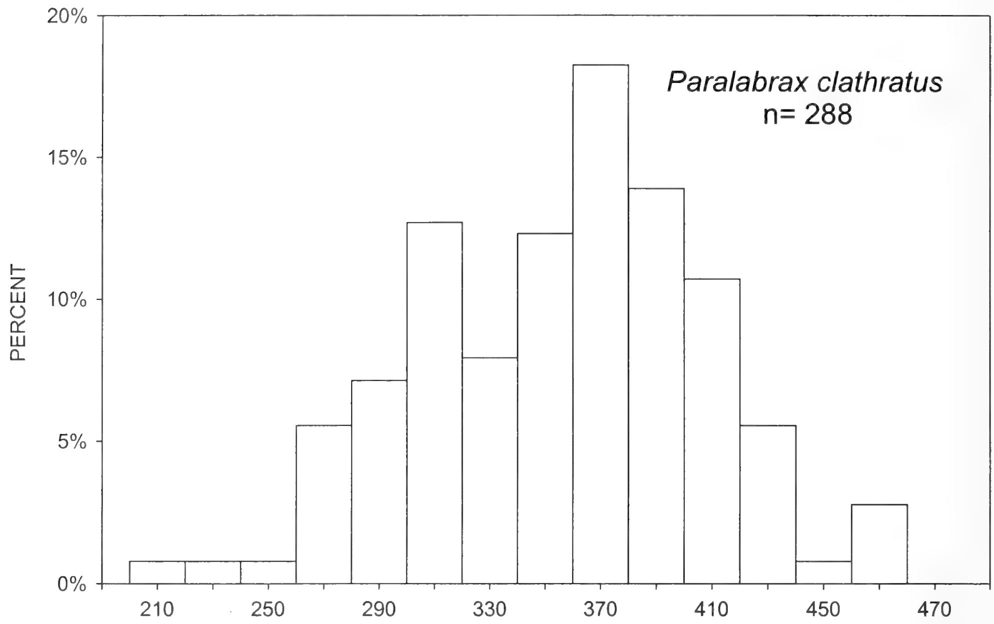

Fig. 9. Seasonal size distribution (20mm SL class) of *Paralabrax clathratus* in the northwestern coast of Baja California, during 1994 and early 1995.

S. pulcher, P. clathratus and *P. californicus* contributed with 60%, and when the rockfishes are added group summed 90% of the total catch. Because of their size, abundance and preference in the market, fishing activity is directed to these species which can be considered the target species.

The barred sand bass (*Paralabrax nebulifer*), a common constituent of the commercial fishery, was found in low numbers in the sampled period, while the kelp bass (*P. clathratus*) was relatively abundant. In a previous study during 1992–1993 El Niño event, we sampled within Estero de Punta Banda and reported that juveniles of the kelp bass, were collected in high numbers (hundreds per tow) during fall (Rosales-Casián 1995). In the present study, the white seabass (*Atractoscion nobilis*) and the shortfin corbina (*Cynoscion parvipinnis*), two important species in the commercial and sport fishery, were scarse.

In a recent study of the seafood market of Ensenada, Baja California, México during 2000–2001, 54 commercial fish species were found; the most abundant of these were the whitefish (*C. princeps,* 20.6%), the barred sand bass (*P. nebulifer,* 9.9%), the barred surfperch (*Amphistichus argenteus,* 6.6%), the Scorpaenidae (*Sebastes* sp. and *Scorpaena* sp., 6.2%), and golden spotted rock bass (*Paralabrax auroguttatus*) with 5.9% (Hernández-Hernández 2000). The golden spotted rock bass is abundant throughout the Gulf of California, and is valuable from commercial, sport fishing and ecological standpoints (Pondella et al 2001).

In a 1991 study on the sport fishing boats from Bahía de Todos Santos (Ensenada, B.C.), spotted scorpionfish (*Scorpaena guttata*), California barracuda (*Sphyraena argentea*), barred sand bass (*P. nebulifer*), sheephead (*S. pulcher*) and lingcod (*Ophiodon elongatus*) were common fish species (>80% of occurrence), while whitefish (*C. princeps*), Pacific bonito (*Sarda chilensis*), white seabass (*A.

nobilis), and kelp bass (*P. clathratus*) were classified as occasional (40–60% of occurrence), and California halibut (*Paralichthys californicus*), California corbina (*Menticirrhus undulatus*), and yellowtail (*Seriola lalandi*) as rare species with 20% of occurrence. Different species of *Sebastes* also occurred in the three classifications (Rodriguez-Medrano 1993).

The coast of San Quintín was the most visited site for fishing trips and contributed 37.5% of the total catch during our study. The most important fish species changed slightly in the next order: the rockfishes, kelp bass, whitefish, and the Pacific barracuda. All of these species are also important to recreational fishing, that is a growing activity in San Quintín. In a study of sport fishing at natural reefs and near oil platforms off Santa Barbara, California, Love and Westphal (1990) reported that the rockfishes and kelp bass were the most abundant fishes. In our study rockfishes were present at all seasons with greatest abundance at spring and fall, while kelp bass were most abundant during summer and fall.

In a review of southern California landings from recreational fishing during 1994, unspecified rockfishes were reported as the most abundant fish in the catch, but the other species change in their abundance ranking in two studies, the L. A. Times newspaper (Calif. Dept. Fish Game 1995), and the landings from commercial passenger fishing vessels reported in the CDFG logbooks (Calif. Dept. Fish Game 1996).

Because of their abundance and frequency of occurrence, the multispecies rockfish group needs to be investigated in detail in future research. Furthermore, the lack of biological information on the whitefish (*C. princeps*), and the other species needs to be addressed.

The catch of the artisanal fishery at Baja California coasts is important because it is supported by different fish species as rockfishes, whitefish, sheephead, basses and others. Although in the present study, the number of boats sampled was small, the large coastal zone represented by both the Pacific and the Gulf of California, supports a greater number boats that would increase the catch volume. This is a fishery that need to be more studied in the future.

Acknowledgments

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Literature Cited

California Department of Fish and Game (1995). Review of some California fisheries for 1994. CalCOFI Reports. 36:7–18.

———. (1996). Review of some California fisheries for 1995. CalCOFI Reports. 37:7–21.

Carrillo-Cortes, J. A. 1994. Estructura y características poblacionales del lenguado de California *Paralichthys californicus* (AYRES), en la Bahía de Todos Santos y el Estero de Punta Banda, durante los meses de abril de 1992 a marzo de 1993. Bachelor thesis, Universidad Autónoma de Baja California, Facultad de Ciencias Marinas. 52 p.

Hammann, M. G. and A. A. Ramirez-Gonzalez. 1990. California halibut, *Paralichthys californicus*, in Todos Santos Bay, Baja California, México. Calif. p. 127–144, Dept. Fish Game, Fish Bull. 174.

Hammann, G. y J. A., Rosales-Casian. 1990. Taxonomia y estructura de la comunidad de peces del Estero Punta Banda y Bahia de Todos Santos, Baja California, Mexico. Cap. 6: 153–192. En: Rosa Vélez J. de la y F. Gónzalez-Farias (eds). Temas de Ocenografia Biológica en Mexico. Ensenada. 337 pp.

Hernández-Hernández, A. 2000. Composición específica de los peces escama comercializados en el Mercado de Mariscos de Ensenada, Baja California. Bachelor thesis, Universidad Autonóma del Estado de Morelos, Facultad de Ciencias Biológicas. 60 p.

Love, M. S., J. S. Stephens, Jr., P. A. Morris, M. M. Singer, M. Sandhu and T. C. Sciarrotta. 1986. Inshore soft substrata fishes in the Southern California Bight: an overview. Calif. Coop. Oceanic Fish. Invest. Rep. 27:84–104.

——— and W. Westphal. 1990. Comparison of fishes taken by a sportfishing party vessel around oil platforms and ajacent natural reefs near Santa Barbara, California. Fish. Bull. 88:599–605.

Mendoza-Carranza, M. and J.A. Rosales-Casián. 2000. The feeding habits of spotted sand bass (*Paralabrax maculatofasciatus*) in Punta Banda estuary, Ensenada, Baja California, Mexico. CalCOFI Rep. 41, 194–200.

Miller, D.J. y R.N., Lea. 1972. Guide to the coastal marine fishes of California. Cal. Dept. Fish Game. Fish Bull. 157: 235 pp.

Mondragón-Rojas, M. 1994. Estructura poblacional de la curvina de California (*Menticirrhus undulatus*) (Girard) en la Bahía de Todos Santos y el Estero de Punta Banda, B.C., México. Bachelor thesis, Universidad Autónoma de Baja California, Facultad de Ciencias Marinas. 55 p.

Moser, H. G., R. L. Charter, P. E. Smith, D. A. Ambrose, S. R. Charter, C. A. Meyer, E. M. Sandknop, and W. Watson. 1993. Distributional atlas of fish larvae ane eggs in the California current region: Taxa with 1000 or more total, larvae 1951 through 1984. CalCOFI Atlas No. 31. 233 pp.

——— and W. Watson. 1990. Distribution and abundance of early life history stages of the California halibut, *Paralichthys californicus,* and comparison with the fantail sole, *Xystreuris liolepis.* p. 31–71, Calif. Dept. Fish Game, Fish Bull. 174.

Pintos-Terán, P. A. 1994. Estructura poblacional y crecimiento de la cabrilla de arena *Paralabrax nebulifer* (Girard) en la Bahía de Todos Santos y el Estero de Punta Banda. Bachelor Thesis. Facultad de Ciencias Marinas, Universidad Autonoma de Baja California, Ensenada. 70 pp.

Pondella, D. J., II, L. G. Allen, J. A. Rosales-Casián, and T. E. Hovey. 2001. Demographic parameters of golden spotted rock bass *Paralabrax auroguttatus* from the Northern Gulf of California. Trans. Amer. Fish. Soc. 130:686–691.

Rodriguez-Medrano, M. C. 1993. Descripción y analisis de la pesca deportiva en Bahia de Todos Santos, Ensenada, B. C. M.S. thesis, CICESE. 88 p.

Rosales-Casián, J. A. 1995. Ciclo de vida de la cabrilla sargacera (*Paralabrax clathratus* GIRARD), migración y transporte de biomasa de sus juveniles en la Bahía de Todos Santos y el Estero de Punta Banda, B.C. México. Comunicaciones Académicas, Serie Ecología. CICESE CTE-CA9501. 14p.

———. (1996). Ichthyofauna of Bahía de San Quintín, Baja California, México, and its adjacent coast. Ciencias Marinas 22(4):443–458.

———. 1997a. Inshore soft-bottom fishes of two coastal lagoons on the northern Pacific coast of Baja California. CalCOFI Rep. 38, 180–192.

———. 1997b. Estructura de la comunidad de peces y el uso de los ambientes de bahías, lagunas y costa abierta en el Pacífico norte de Baja California. PhD thesis, CICESE, Ecología Marina, CICESE. 201 p.

——— y M. G. Hammann. 1993. The Bahía de Todos Santos and Estero de de Punta Banda, Baja California, México: a BENES project for the study of coastal fishes. Report of activities and preliminary results, June 1992 to May 1993. Attachment C. In: Allen, L. G. 1993. BENES, Bay Estuarine and Nearshore Ecosystem Studies. Annual progress report for fiscal year 1992–1993. Prepared for the Calif. Dep. Fish. Game. 122 pp.

Salomé-Sanchez, J. V. 1993. Composición, estructura y aspectos biologicos de la cabrilla sargacera (*Paralabrax clathratus,* Girard) en la Bahía de Todos Santos y en el Estero de Punta Banda, B.C., México, durante mayo a octubre de 1992. Bachelor Thesis. Facultad de Ciencias Marinas, Universidad Autonoma de Baja California, Ensenada. 53 pp.

SEMARNAP. 1997. Anuario Estadistico de Pesca 1997. Secretaria de Medio Ambiente, Recursos Naturales y Pesca, México. 241 pp.

SEMARNAT. 2000. Anuario Estadístico de Pesca 2000. Secretaria del Medio Ambiente y Recursos Naturales. 372 p.

Stephens, J. S., Jr. and K.E. Zerba, 1981. Factor affecting fish diversity on a temperate reefs. Environ. Biol. Fishes. 6:111–121.

Zar, J. H. 1984. Biostatistical analysis. 2a ed. Englewood Cliffs N.J.: Prentice Hall 718 pp.

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Reliability Assessment of Season-of-Capture Determination from Archaeological Otoliths

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Abstract.—A technique involving microscopic examination of otolith growth zones has been commonly used by archaeologists along the coast of California to estimate season-of-capture of prehistoric fishes and to infer the season of site use. A test of otolith edge analysis techniques was performed on modern otoliths by estimating season-of-capture for otoliths with known dates of capture. Successful identification of season-of-capture was low, even in a best case scenario with the age-validated spotted sand bass (*Paralabrax maculatofasciatus*), emphasizing the subjectivity of this kind of analysis and inherent variability of growth zone formation in otoliths. Alteration of the otolith matrix from environmental factors further complicates the determination for archaeological otoliths, but surfperches (family Embiotocidae) hold promise for future studies. This study has called into question the validity of protocols that have not utilized age validated otolith collections and begs caution when estimating season-of-capture from otoliths.

Evaluations of site seasonality are an important component of archaeological research in North America (Monks 1981; Bettinger 1991; Kelly 1995). For areas such as California that were inhabited by hunter-gatherers, estimates of archaeological site seasonality provide critical insights into the relative mobility of foraging communities. Estimates of the seasonality of occupation have been developed from a variety of indices in California including the remains of migrating shorebirds and marine mammals (Howard 1929; Hildebrandt 1993), visual analysis of growth increments in shellfish remains (Cerreto 1992; Lyons 1978), analysis of oxygen isotopes in molluscan remains (Killingley 1981; Kennett 2003), and investigation of annual growth zones in deer teeth (O'Brien 2001; Moffitt 2002). Casteel (1976) suggested that fish otoliths might be useful in this context because of their extensive use in fishery biology and, in particular, age estimation in fishes (Huyghebaert and Nolf 1979; Nolf 1985). Periodic deposition of growth zones in otoliths has been attributed to temperature, feeding, spawning, seasonal changes and other causes (Beckman and Wilson 1995). In general, favorable growing conditions lead to the formation of an opaque growth zone and a period of poor conditions leads to a translucent growth zone (Pannella 1980), but this trend has not been firmly established for all species of marine fishes. Smith (1983) used the huge otoliths of black drum (*Pogonius cromis*) from an archaeological site in Texas to determine the season-of-capture, and in the most elaborate use of otoliths for seasonality determination to date, Higham and Horn (2000) demonstrated seasonal capture of red cod (*Pseudophycis bachus*) in New Zealand.

For numerous archaeological sites along the coast of California, a technique developed and applied by Huddleston (1981) has been used to determine season of site occupation by estimating the season-of-capture from recovered otoliths (Langenwalter et al. 1989; Salls et al. 1989; Langenwalter and Huddleston 1991; Jones et al. 1994, 1996). The basis of the technique used to determine season-of-capture, and consequently the season of occupation, involves microscopic examination of growth zones in whole otoliths when thin enough for transmitted light, or sectioned otoliths when too thick for transmitted light. In some cases, heating of the otolith was used to enhance growth zone visibility; this technique is commonly known as break-and-burn (Christensen 1964). It is hypothesized in these studies that the growth ring type (opaque or translucent) at the otolith margin can be used as an indicator of season-of-capture (Huddleston 1981, Erlandson 1994).

Although age determination of fishes using otoliths has long been an established practice in fisheries research (Chilton and Beamish 1982), it has not been established that season-of-capture determination from otolith margin observations is accurate for some studies (Gobalet 2001). Examination of the otolith margin is typically associated with a subjective form of age estimate validation, where the formation of the successive growth zones is documented over a period of time that elucidates the annual formation of growth zones (Campana 2001). Because the formation of a growth zone can be associated with a season it is possible that season-of-capture can be determined (Gobalet 1989). Determining season-of-capture for fishes using this approach, however, is subjective and can be very problematic. For freshwater fishes, seasonal changes in growth may be better defined in the otolith than for marine fishes because ocean seasons can be offset by several months (Niiler 1977) or growth may be complicated by events like upwelling or El Niño. Freshwater fishes, however, can have a broad period of growth zone formation that could confound season-of-capture determination (Thompson and Beckman 1995). In general, the timing of growth zone formation in otoliths has substantial variability at the individual, population, and species levels (Williams and Bedford 1974; Thompson and Beckman 1995).

Season-of-capture determination for archaeological otoliths is further complicated by the difficulty of species identification. While keys are available to assist with species determination from otolith shape (e.g. Smale et al. 1995; Harvey et al. 2000), some otoliths can only be identified to genus or family at best. Therefore, the application of otolith edge analyses leads to an assumption that age and growth information for one or some family members is applicable to all members. Most temperate fishes (23° to 45° north latitude) form an opaque zone during spring and summer with a peak at April to May (Beckman and Wilson 1995). There are marked exceptions, however, like the California grunion (*Leuresthes* *tenuis*) which does not grow during its spring to summer spawning period, making the timing of opaque and translucent growth zone formation completely out of phase from what is expected (Spratt 1971; Fritzsche et al. 1985). The best case scenario for determining season-of-capture from an otolith section would be for a fish known to species, for which age and growth has been described and validated.

In this study, an attempt was made to determine season-of-capture for modern and archaeological otoliths from transverse sections. The modern specimens, with known date of capture, were used to evaluate the reliability of this technique. To further describe the subjectivity of season-of-capture estimation, modern otoliths from spotted sand bass (family Serranidae, *Paralabrax maculatofasciatus*), age validated using otolith edge analysis (Allen et al. 1995; Andrews, unpublished data), were also used to qualitatively assess the difficulty of season-of-capture determination in a best case scenario. It was anticipated that the technique would prove reliable enough that estimates of season-of-capture could then be made for the archaeological specimens to provide a season of occupation estimate for the two prehistoric sites from which the specimens were collected. It was hypothesized, however, that season-of-capture estimation for archaoelogical otoliths might be complicated by problems with species identification and environmental effects on the otolith margin.

Methods and Materials

Ninteen modern otoliths from marine fishes of coastal California, identified to species with known dates of capture, were selected by Ken Gobalet from the skeletal collection in the Department of Biology, California State University, Bakersfield. Twelve archaeological otoliths collected from two prehistoric sites near San Simeon in San Luis Obispo, County, California (CA-SLO-179 and CA-SLO-267) were also used in this analysis. Excavations at these sites were directed by Terry Jones (Jones and Ferneau 2002). Otolith specimens from both the museum collection and the archaeological sites were identified by Ken Gobalet, and the otoliths, including the taxonomic designations of the museum specimens (but not the dates of death) were provided to Allen Andrews for season-of-capture estimation and evaluation of the archeological otoliths. The fisheries standard of Robins et al. (1991) was used for the taxonomic and common nomenclature.

The otoliths were mounted in casting resin and transversely sectioned using a Buehler Isomet® saw with diamond wafering blades separated by acetate spacers (0.6 mm). Sections were mounted to glass slides with Cytoseal® mounting medium. Further grinding on a Buehler® lapidary wheel (800 grit carbide wet/dry paper) was necessary for most sections to enhance the definition of growth zones.

Finished otolith sections were viewed through an Olympus® dissecting microscope using transmitted light at magnifications best suited for each section (10–25 ×). Otoliths were aged based on the assumption that growth zones were formed annually (one per year). Margin type, defined as either translucent or opaque to transmitted light, was determined for each section when possible. Reflected light was also used to attempt to clarify unclear sections. Translucent margins, typically three seasons of growth (fall through spring), were categorized in three different stages based on the thickness of the translucent zone relative to the previous translucent zone (previous years growth). When the translucent zone was thin, it was labeled "early," thicker than one half the previous years growth was labeled "late," and in between was labeled "middle." Opaque margins, typically one season of growth (summer), were usually thinner and were not broken into categories. Season-of-capture was subjectively estimated based on the margin observation described above and an appropriate literature source for age and growth information (Tables 1 and 2). In some cases, age and growth information was lacking for the species and extrapolation from other species of the same family was required.

Because the initial set of modern otoliths included a wide range of species, a larger group of specimens representing a single species was used for a second test of the reliability of season-of-capture estimation. A total of 40 spotted sand bass otoliths collected in the Gulf of California, Mexico, with known dates of capture, was available to the senior author. These otoliths were previously mounted and sectioned in the same manner stated above. Ten spotted sand bass otolith sections from each collection season (Winter = January, Spring = April, Summer = July, Fall = October) were randomly selected and the season-of-capture was estimated. Because age and growth was validated using an otolith edge analysis covering collections made during the four seasons (Andrews, unpublished data), season-of-capture was estimated for these 40 otolith sections using the same guidelines stated above.

Results and Discussion

A thorough literature search for age and growth information on each fish species, genus and family was performed to assist with proper season-of-capture estimation for the modern and archaeological otoliths. An attempt was made to obtain species level information first, followed by genus and family with similar geographical or latitudinal distribution when specific information was unavailable.

The modern otoliths represented 16 species from 8 families and edge or margin analyses could be found for only 6 species, of which 2 studies used scales (Table 1). Age was estimated for otolith sections that had clear, quantifiable growth zones. Age could not be determined for three otoliths. Margin type was determined for the remaining specimens when the thickness of the growth zones at the otolith margin permitted; six margins were opaque and nine were translucent. Two had growth zones that were too thin to determine margin type and two were estimated based on the thickness of the previous years growth. Stage was assigned for eight of the translucent margined sections. Season-of-capture was estimated for 14 of the sections, of which month to month designations were assigned when the information was available from references, and generic season (e.g. spring) was assigned when larger assumptions were necessary. Many age and growth references were researched for pertinent marginal growth zone information, but only a few had useful data for edge type relative to season (Table 1). In some cases, the season-of-capture was estimated based on very general information.

Once season of capture estimates were made, the senior author obtained actual capture dates for the specimens from Dr. Gobalet. Comparison showed that the estimated season-of-capture for the modern otoliths was within the seasonal limits for only six otoliths, well outside for eight, and five were not useful (Table 1). Of the six within the known season-of-capture, *Paralichthys californicus* was only marginally useful because of the broad estimated range, spring to summer. The

Table 1. Results from season-of-capture estimations for modern otoliths.*

Species	Margin type	Estimated age (yr)	Stage	Estimated season-of-capture	Actual death date	Estimate accurate?	Helpful reference
Merluccius productus (Pacific hake)	translucent	12	early	Sept–Nov	6/80	no	Dark (1975)
Atherinopsis californiensis (jack-smelt)	translucent	1	late	early spring?	9/15/80	no	Beckman and Wilson (1995)
Sebastes flavidus (yellowtail rock-fish)	translucent	14	mid–late	Jan–Mar	11/19/78	no	Kimura et al. (1979)
S. melanops (black rockfish)	?	12–16	n.a.	n.a.	6/15/97	n.a.	Six and Horton (1977)
S. nebulosus (china rockfish)	?	16	n.a.	n.a.	9/1/80	n.a	
S. rufus (bank rockfish)	translucent	11	?	Dec–Jan	1/11/85	yes	Watters (1993)
S. rufus (bank rockfish)	n.a.	not ageable	n.a.	n.a.	1/11/85	n.a.	
Hexagrammos decagrammus (kelp greenling)	opaque	2	—	Jul–Sept	9/2/80	yes	Ye (1993)
H. decagrammus (kelp greenling)	opaque	2	—	Jul–Sept	11/80	no	
Ophiodon elongatus (lingcod)	opaque	3	—	Jul–Sept	11/80	no	Cass and Beamish (1983)
Atractoscion nobilis (white seabass)	n.a.	not ageable	n.a.	n.a.	1/8/86	n.a.	
Seriphus politis (queenfish)	translucent	6	late	late summer–early winter	4/4/85	no	Goldberg (1976)
Embiotoca lateralis (striped surf-perch)	translucent?	8	late	Jan–Mar	3/20/94	yes	Gnose (1967)
Rhacochilus vacca (pile perch)	translucent	8	late	Jan–Mar	3/20/94	yes	Ware (1971)
Chromis puctipinnis (blacksmith)	n.a.	not ageable	n.a.	n.a.	7/3/86	n.a.	
Paralichthys californicus (California halibut)	opaque	5	—	spring–summer?	7/27/90	yes	Beckman and Wilson (1995)
Eopsetta jordani (petrale sole)	opaque	9	—	April–Oct.	3/20/94	no	Gregory and Jow (1976)
Eopsetta jordani (petrale sole)	translucent	5	late	Jan–Mar	6/16/79	no	
Psettichthys melanostictus (sand sole)	translucent	2	early	fall?	10/26/94	yes	Beckman and Wilson (1995)

* n.a. -not applicable.

Table 2. Season-of-capture estimations for archaeological otoliths recovered from SLO-179 and SLO-267

Location and taxon	Estimated age (yr)	Margin type	Stage	Estimated season-of capture
SLO-179				
Osmeridae (smelt family)	2	translucent	middle?	winter?
Osmeridae (smelt family)	<1?	translucent	early?	fall?
Osmeridae (smelt family)	<1	translucent	early?	fall?
Spirinchus starksi (night smelt)	6?	translucent	middle to late?	winter to early spring?
Spirinchus starksi (night smelt)	<1	?	n.a.	n.a.
Sebastes sp. (rockfish)	not ageable	n.a.	n.a.	n.a.
Hexagrammidae (greenling family)	2?	translucent	?	n.a.
Cymatogaster aggregata (shiner perch)	not ageable	opaque	n.a.	n.a
Embiotoca sp. (surfperch)	12	opaque?	n.a.	midsummer to winter?
SLO-267				
Sebastes sp. (rockfish)	8 to 28	?	n.a.	n.a.
Sebastes sp. (rockfish)	~20	?	n.a.	n.a.
Embiotoca sp. (surfperch)	5?	n.a.	n.a.	midsummer to winter?

n.a. -not applicable.

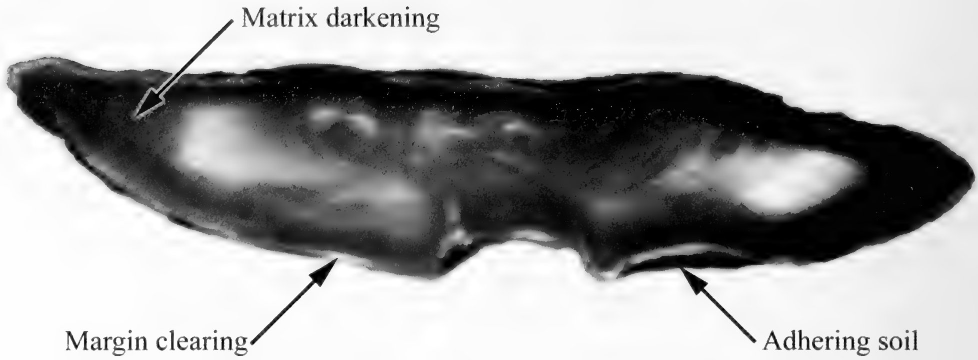

Fig. 1. A transverse cross section of an archaeological otolith, identified as a rockfish (*Sebastes* sp.), viewed with transmitted light and exhibiting the typical forms of otolith matrix alterations that can occur from environmental factors. Matrix or margin darkening and clearing, and adhering soil, can lead to a misinterpretation of the margin type for season-of-capture estimation. The symmetrical depth of the margin clearing is inconsistent with the asymmetrical growth known to occur in rockfish otoliths.

actual date of death was July 7, 1980. Consequently, the season-of-capture was accurately determined for only 32% of the specimens and 43% of those attempted.

The archaeological otoliths consisted of three specimens identified to two species, five otoliths identified to two genera, and four otoliths identified to two families from two archaeological sites (Table 2). Age was estimated for 10 otolith sections and was tenuous at best for some samples. Two were not ageable because the growth zones were poorly defined. Edge type was determined for eight sections and stage was assigned to four sections with translucent zones. Season-of-capture was tentatively estimated based on the margin type and the assumption that the available age and growth information was applicable. The appearance of some of the otolith margins, however, made the margin type subject to additional scrutiny.

Because no age and growth information could be found for the family Osmeridae (including *Spirinchus starksi*), assumptions were made based on the general seasonal growth pattern observed in otoliths (Beckman and Wilson 1995). For four of the five samples, the season-of-capture could have been from fall to early spring (Table 2), however, if the growth of osmerids are similar to California grunion (*Leuresthes tenuis*), another inshore epipelagic fish, the season-of-capture could be 6 months out of phase from the estimate (Spratt 1971; Fritzsche et al. 1985). These otolith sections exhibited what appeared to be a clearing (increased transluscence to transmitted light) of the otolith matrix at the edge.

The three otoliths identified as members of the rockfish family (family Scorpaenidae: *Sebastes* sp.) provided the least amount of marginal growth zone information (Table 2). One sample from archaeological site CA-SLO-179 did not produce a readable section, but had a strong symmetrical translucent margin (Figure 1). Because the translucent margin was symmetrical and the growth of rockfish otoliths is usually asymmetrical (Beamish 1979), it was concluded that this margin was from a clearing of the otolith matrix. Use of reflected light did not aleviate the problem and season-of-capture could not be determined. The two sections from archaeological site CA-SLO-267 produced readable sections, but this was complicated by a different kind of interference. One sample was aged at both eight years (based on grouping of fine growth increments) and twenty-eight years (based on a count of all the fine growth increments). Because the species of rockfish was unknown and many rockfish can be quite old, either estimate would have been possible (Cailliet et al. 2001). The margin type, however, could not be determined because of what appeared to be a denaturing of the otolith matrix, which made the edges appear black in transmitted light (Figure 1). The other sample was aged at about 20 years, but season-of-capture determination was not possible because the growth zones were too thin near the margin and appeared to have suffered the same denaturing problem. Use of reflected light did not alleviate the problem.

The one sample identified as a member of Hexagrammidae was tentatively aged at two years and had a translucent margin. This otolith, however, appeared to have suffered from the same otolith clearing observed in other species. While the growth zones were not well defined, as is often the case with young fish, the presence of a symmetrical translucent margin made season-of-capture estimation suspect.

Two of the three otoliths from the archaeological sites identified as members of the surfperch family (Embiotocidae) seem to have provided the most reliable season-of-capture information. The *Cymatogaster aggregata* sample was very dark to transmitted light and did not provide a readable section. The two samples identified as members of *Embiotoca* sp. produced readable sections, but determination of margin type was hindered by a darkening of the margin to transmitted light. One sample was aged at about 5 years and the margin type forming at the time of capture may have been opaque. If this is correct, the season-of-capture may have been mid-summer to winter (Gnose 1967). The other sample had an estimated age of 12 years (15 years using reflected light). This sample also had a darkened margin which interfered with season-of-capture estimation. This age estimate was greater than the maximum age of seven years reported for each *Embiotoca* species (*E. jacksoni* and *E. lateralis*; Baltz 1984). This discrepancy could be explained by a change or variation in longevity (Boehlert and Kappenman 1980; Craig 1985), misidentification of the otolith, or the existence of older individuals at the time of capture because of lower fishing pressure (Craig 1985). The margin type appears to be opaque using reflected light; therefore, the season-of-capture may be mid-summer to winter. It must be noted, however, that this determination was inferred from an age and growth study that used scales, not otoliths (Gnose 1967).

Because of the problems observed in this study with determining margin type, it is likely that some archaeological season-of-capture estimates from otolith margin type have been erroneous. Clearing or darkening of the otolith matrix can be explained by processes that occurred when the fish was utilized and during the long period of burial at the archaeological site. Altered otoliths are typically eliminated from consideration, but no study has ever documented this problem. If altered otoliths are missed and considered further, a cleared otolith margin could lead to the determination that the otolith has a translucent margin and was captured in the respective season for that species or family. Hence, loss of growth zone information from a change in the otolith matrix over time may preclude an accurate season-of-capture determination.

To help define the difficulty of determining season-of-capture, transverse otolith sections from spotted sand bass taken seasonally from the Gulf of California were studied for edge type. Note that this was an opportunistic addition to this study and that the geographical location of this species was not an issue. The motive was to demostrate the difficulty of season-of-capture determination in a best case scenario. Based on the otolith edge analysis, the opaque growth zone was narrow and formed during the summer months (Andrews, unpublished data). The translucent growth zone was broad and formed during the remainder of the year (Fall to Spring). These results were consistent with results for spotted sand bass from southern California waters (Allen et al. 1995).

Spotted sand bass otoliths were easily aged and estimated age ranged from 1 to 6 years, most being 2 to 3 years. Summer growth was easiest to identify because of the thin opaque margin. The season-of-capture was correctly identified in 9 out of 10 summer fish sections. Determining season-of-capture for fish with a translucent margin was much more difficult. Fall fish were correctly identified in only 2 out of 10 otolith sections, and the remainder were not correct (60% Winter and 20% Spring). No winter fish were identified correctly (30% Spring, 20% Summer and 50% Fall). Spring fish were second most identifiable because the translucent margin was thick relative to previous years growth (40% identified correctly). Two out of 10 were identified as summer fish because the margin type was opaque. This can be explained by the results given by Allen et al. (1995) for spotted sand bass of southern California where April was the beginning of the period for some fish to start forming an opaque margin. In addition, the specimens from the Gulf of California always had some fish forming an opaque margin in all seasons (Andrews, unpublished data). Overall, 15% were placed in a season 6 months from the actual season of capture and 37.5% (15 out of 40) were identified correctly. Hence, season-of-capture can often be inaccurate even in a best case scenario where seasonal growth patterns are known.

Based on the findings of this study it seems that season-of-capture determination from otolith sections can be problematic under any circumstances. For archaeological otoliths the determination of species can be critical, especially with marine fishes where seasonal growth patterns can be offset by a full 6 months. Even when an otolith can be identified to species, evaluation of its season of capture is further complicated by the inherent variability in otolith growth zone formation. In many cases an opaque growth zone can form at any time, but is more or less probable during certain times of the year. An examination of any otolith edge study reveals that there is always some percentage of individuals that deviate from the margin type expected; annual growth zone formation is a trend based on a majority.

To further complicate matters, environmental factors can change the otolith matrix of archaeological otoliths (Figures 1). The clearing or darkening of the otolith matrix observed here make season-of-capture determination very subjective, if not impossible, because the growth zone information was altered or lost. These changes to the otolith margin could lead to a false determination of margin type and, as a consequence, an incorrect season-of-capture determination.

Conclusions

Based on findings in this study, season-of-capture determination from otoliths of both modern and archaeological otoliths requires an adherence to specific protocol that utilizes a validated set of otoliths from the species, or perhaps family, in question. Ten genera have been recovered from middens of central California, of which, embiotocids are common nearshore species commonly found in middens (Gobalet and Jones 1995). In our study, the modern embiotocid otoliths were correctly identified to season. The combination of availability of embiotocids in the archaeological record, abundance nearshore, and the potential accuracy of season-of-capture determination makes them a strong candidate for future seasonality work; however, the high degree of subjectivity in all determinations of season-of-capture from otolith margin analyses because of the inherent variability of growth zone formation and alteration of the otolith matrix begs caution when interpreting the results. This study has called into question the validity of protocols that do not utilize age validated otolith collections.

The need to validate any age determination procedures has been stressed by numerous authors (Lagler 1969; Chilton and Beamish 1982; Beamish and McFarlane 1983; Baltz 1990; Busacker et al. 1990). Validation is having comparative sectioned otoliths from the species in question from the same locality with known dates of death for comparison. Chilton and Beamish (1982) stipulate that validation procedures should be applied to all age classes in a population of a species and to different populations of the same species. The procedures used for young members of a species may not apply to old members of the same species and each species must be independently validated. Seasonality determinations using otoliths should be no different.

Higham and Horn (2000) published the most thorough seasonality study based on otoliths recovered from an archaeological site to date. Their validation samples consisted of over 500 sectioned otoliths of red cod from the waters near the midden in New Zealand. The date of fish death of each individual fish was known for all comparative otoliths. The same rigor needs to be applied to other studies of seasonality based on growth in skeletal parts. This is daunting considering the number of possible species that may be commonly encountered and the number of locations where archaeological investigations are undertaken. In coastal central California the number of species recovered from middens exceeds 80 (Gobalet and Jones 1995). In addition, there needs to be further consideration to possible changes in the fish assemblage, fishing techniques, and fishing pressure during site occupation. Developing comparative otolith collections for particularly common species would be a starting point and the results for embiotocids in this study provide some grounds for optimism in future studies of archaeological sites in coastal California.

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Literature Cited

Allen, L. G., T. E. Hovey, M. S. Love, and J. T. Smith. 1995. The life history of the spotted sand bass (*Paralabrax maculatofasciatus*) within the southern California bight. CalCOFI Rep. 36: 193–203.

Baltz, D. M. 1984. Life history variation among female surfperches (Perciformes: Embiotocidae). Env. Bio. Fishes. 10(3): 159–171.

———. 1990. Autecology. Pp. 585–607 *in* Methods for Fish Biology. (C. B. Schreck and P. B. Moyle, Eds), American Fisheries Society, Bethesda, Maryland.

Beamish, R. J. 1979. Differences in the age of Pacific hake (*Merluccius productus*) using whole otoliths and sections of otoliths. J. Fish. Res. Board Can. 36: 141–151.

———, and G. A McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Trans. Am. Fish. Soc. 112: 735–743.

Beckman, D. W., and C. A. Wilson. 1995. Seasonal timing of opaque zone formation in fish otoliths. Pp. 27–43 *in* Recent developments in fish otolith research. (D.H. Secor, J.M. Dean and S.E. Campana), Belle W. Baruch Library in Marine Science Number 19, University of South Carolina Press.

Bettinger, R. L. 1991. Hunter-Gatherers: Archaeological and Evolutionary Theory. Plenum Press. New York. 257 pp.

Boehlert, G. W., and R. F. Kappenman. 1980. Variation of growth with latitude in two species of rockfish (*Sebastes diploproa* and *S. pinniger*) from the northeast Pacific Ocean. Mar. Ecol. Prog. Ser. 3: 1–10.

Busaker, G. P., I. R. Adelman, and E. M. Goolish. 1990. Growth. Pp. 363–387 *in* Methods for Fish Biology. (C. B. Schreck and P. B. Moyle, Eds), American Fisheries Society, Bethesda Maryland.

Cailliet, G. M., A. H. Andrews, E. J. Burton, D. L. Watters, D. E. Kline, and L. A. Ferry-Graham. 2001. Age determination and validation studies of marine fishes: do deep-dwellers live longer? Exp. Gerontology. 36: 739–764.

Campana, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol. 59: 197–242.

Casteel, R. W. 1976. Fish remains in archaeology and paleo-environmental studies. Academic Press. 180 pp.

Cerreto, R. 1992. The implications of non-periodic growth in bivalves for three seasonality methods used by southern California archaeologists. Journal of California and Great Basin Anthropololgy 14: 216–233.

Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program a the Pacific Biological Station. Canadian Special Publication of Fisheries and Aquatic Sciences 60.

Christensen, J. M. 1964. Burning of otoliths, a technique for age determination of soles and other fish. J. Cons.Int. Explor. Mer. 29: 73–81.

Craig, J. F. 1985. Aging in fish. Can. J. Zool. 63: 1–8.

Dark, T. A. 1975. Age and growth of Pacific hake, *Merluccius productus*. Fish. Bull. 73(2): 336–355.

Erlandson, J. M. 1994. Early hunter-gatherers of the California coast. Plenum Press, New York.

Fritzsche, R. A., R. H. Chamberlain, and R. A. Fisher. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—California Grunion. U.S. Fish Wildl. Serv. Biol. Rep. 82 (11.28) U.S. Army Corps of Engineers, TR EL-82–4. 12 pp.

Gnose, C. E. 1967. Ecology of the striped surfperch, *Embiotoca lateralis* in Yaquina Bay, Oregon. M.S. Thesis, Oregon State University, Corvallis. 53 pp.

Gobalet, K. W. 1989. Remains of tiny fish from a late prehistoric Pomo site near Clear Lake, California. J. Calif. Great Basin Anth. 11(2): 231–239.

———. 2001. A critique of faunal analysis; inconsistency among experts in blind tests. Journal of Archaeological Science 28: 377–386.

———, and T. L. Jones. 1995. Prehistoric Native American fisheries of the central California coast. Trans. Am. Fish. Soc. 124: 813–823.

Goldberg, S. R. 1976. Seasonal spawning cycles of the sciaenid fishes *Genyonemus lineatus* and *Seraphis politus*. Fish. Bull. 74: 983–984.

Gregory, P. A., and T. Jow. 1976. The validity of otoliths as indicators of age of petrale sole from California. Calif. Fish and Game 62: 123–140.

Harvey, J. T., T. R. Loughlin, M. A. Perez, and D. S. Oxman. 2000. Relationship between fish size and otolith length for 63 species of fishes from the eastern north Pacific Ocean. NOAA Tech. Rep. NMFS 150. 36 pp.

Higham, T. F. G., and P. L. Horn. 2000. Seasonal dating using fish otoliths: results from the Shag River mouth site, New Zealand. J. Arch. Sci. 27: 439–448.

Hildebrandt, W. R. 1993. Prehistoric hunting patterns and faunal analysis. Pp. 215–226 *in* The saunders site: MNT-391 a littoral site of the early period. (R. Cartier, ed.), Scotts Valley Historical Society, Scotts Valley, California.

Howard, H. 1929. The avifauna of Emeryville shellmound. University of California Publications in Zoology 32: 301–394.

Huddleston, R. W. 1981. Fish remains from an archaeological site (Ora-193) at Newport Bay, Orange County, California. Pacific Coast Archaeological Society Quarterly 17: 127–139.

Huyghebaert, B., and D. Nolf. 1979. An annotated bibliography of paleontological and systematic papers on fish otoliths, published since 1968. Meded. Werkgr. Tert. Geol. 16: 139–170

Jones, T. L., K. Davis, G. Farris, T. Fung, S. Grantham, and B. Rivers. 1994. Toward a Prehistory of Morro Bay: Phase II Archaeological Investigations for the Highway 41 Widening Project. Caltrans Environmental Division, Manuscript on file Caltrans, Environmental Division, San Luis Obispo, California..

———, and J. A. Ferneau. 2002. Prehistory at San Simeon reef: archaeological data recovery at CA-SLO-179 and −267, San Luis Obispo County, California. San Luis Obispo County Archaeological Society Occasional Paper 16.

———, T. Van Bueren, S. Grantham, J. Huddleson, and T. W. Fung. 1996. Archaeological Test Excavations for the State Highway 1 Widening Project near Castroville, Monterey County, Caltrans Environmental Division, Manuscript on file Caltrans, Environmental Division, San Luis Obispo, California..

Kelly, R. L. 1995. The foraging spectrum. Smithsonian Institution Press, Washington D.C. 446 pp.

Kennett, D. J. 2002. Appendix I Oxygen isotope analysis of California mussel (*Mytilus californianus*) shells from CA-MNT-521, −569B, −1227, −1233 and CA-SLO-267. Pp. 259–278 *in* Prehistoric Human Ecology of the Big Sur coast, California. (T. L. Jones, ed.). Contributions of the University of California Archaeological Facility No. 61, Berekeley.

Killingley, J. S. 1980. Seasonality of mollusk collecting determined from O-18 profiles of midden shells. American Antiquity 46: 152–158.

Kimura, D. K., R. R. Mandapat, and S. L. Oxford. 1979. Method, validity, and variability in the age determination of yellowtail rockfish (*Sebastes flavidus*) using otoliths. J. Fish. Res. Board, Can. 36: 377–383.

Lagler, K. F. 1969. Freshwater Fishery Biology. Wm. C. Brown Dubuque, Iowa. 421 pp.

Langenwalter, P.E. II, and R. W. Huddleston. 1991. Vertebrate Animal Remains from CA-MNT-129, a Late Period Coastal Abalone Processing Site on the Monterey Peninsula, California. Coyote Press Archives of California Prehistory, 33:45–60.

———, II, R. L. Reynolds, B. Bowser, and R. W. Huddleston. 1989. Vertebrate animal remains from CA-MNT-108, an Early Period Archaeological Site on the Monterey Peninsula, California. Coyote Press Archives of California Prehistory, 29:97–126.

Lyons, E. E. 1978. A statistical method of seasonality determination from *Chione undatella* (Sowerby). Pacific Coast Archaeological Society Quarterly 14(4):33–41.

Moffitt, S. A. 2002. Appendix II: Cementum annuli seasonality analysis of *Odocoileus hemionus* teeth from ten sites on the Big Sur coast. Pp. 279–285 *in* Prehistoric Human Ecology of the Big Sur coast, California. (T. L. Jones, ed.). Contributions of the University of California Archaeological Facility No. 61, Berekeley.

Monks, G. G. 1981. Seasonality studies. Pp. 177–240 *in* Advances in archaeological method and theory. (M. B. Schiffer, ed.), Vol. 4, Academic Press, New York.

Niiler, P. P. 1977. One dimensional models of the seasonal thermocline. Pp. 97–115 *in* The sea: ideas and observations on progress in the study of the seas. (E. D. Goldberg, I. N. McCave, J. J. O'Brien and J. H. Steele, eds.), Volume 6, Marine Modeling. John Wiley and Sons, New York.

Nolf, D. 1985. Otolithi piscium. *In* (H. P. Schultze ed.) Handbook of Paleoichthyology. Volume 10. Gustav Fisher Verlag, Stuttgart & New York. 145 p.

O'Brien C. J. 2001. Seasonality studies and deer teeth: an introduction to dental increment analysis in California. Society for California Archaeology Newsletter 35: 23–26.

Pannella. G. 1980. Growth patterns in fish sagittae. Pp. 519–560 *in* Skeletal growth in aquatic organisms. (Rhoades & R. A. Lutz eds.), Plenum Publishing corp.

Robins, C. R., R. M. Bailey, C. E. Bond, E. J. R. Brooker, A. Lachner, R. N. Lea, and W. B. Scott. 1991. Common and scientific names of fishes from the United States and Canada. 5th edition. American Fisheries Society Special Publication 20.

Salls, R., R. Huddleston, and D. Bleitz-Sanburg. 1989. The prehistoric fishery at Morro Creek, San Luis Obispo, California. Unpublished manuscript on file at Clay Singer and Associates, Cambria, CA.

Six, L. D., and H. F. Horton. 1977. Analysis of age determination methods for yellowtail rockfish, canary rockfish, and black rockfish off Oregon. Fish. Bull., 75:405–414.

Smale, M. J., G. Watson, and T. Hecht. 1995. Otolith atlas of southern African marine fishes. Ichthyological Monographs, number 1, J.L.B. Smith Institute of Ichthyology, Grahamstown, South Africa. 402p.

Smith, H. A. 1983. Determination of seasonality in archaeological sites through examination of fish otoliths. J. Field Arch., 10:498–500.

Spratt, J.D. 1971. The amazing grunion. Marine Resources Leaflet No. 3. Dept. of Fish and Game. 16p.

Thompson, K. R., and D. W. Beckman. 1995. Validation of age estimates from white sucker otoliths. Trans, Amer. Fish. Soc. 124:637–639.

Wares, P. G. 1971. Biology of the pile perch, *Rhacochilus vacca* in Yaquina Bay, Oregon. U.S. Fish and Wildlife Service Technical Paper 57. 21 pp.

Watters, D. L. 1993. Age determination and confirmation from otoliths of the bank rockfish, *Sebastes rufus* (Scorpaenidae). M.S. Thesis, California State University, San Jose, Moss Landing Marine Laboratories. 59 pp.

Williams, T., and B. C. Bedford. 1974. The use of otoliths for age determination. Pp 114–123 *in* The proceedings of an international symposium on ageing of fish. *Edited by* T.B. Bagenal. Unwin Brothers Limited, The Gresham Press, Old Woking, Surrey, England.

Ye, Q. 1993. A study of age and growth of greenling in coastal waters of Qingdao. J. Ocean Univ. Qingdao, Quingdao Haiyang Daxue Xeubao, 23:59–68.

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Differential Preservation of Fossil Elements in the Maricopa Brea, California

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Abstract.—Maricopa is a southern California tar seep with representative flora and fauna of the Pleistocene and Recent periods. Of the over 4000 fossil elements collected in this study, there were many that represented mammals and birds of the last 30,000 years. An analysis of the recovered skeletal remains shows a differential preservation of appendicular to axial bones. In addition, the standard 9% representation of carnivores to herbivores was not found, instead, carnivores represented 17% of that consumer class. The mechanism for these statistically significant findings is the tar seep itself. Animals would become trapped in the seep; their arms and legs buried in the tar while their spine and skull remain exposed for carnivores to consume. This resulted in more appendicular skeletal remains than axial had the entire animal been preserved. The carnivores themselves would then become trapped, attracting more carnivores, resulting in a disproportionate representation of that consumer class in the fossil matrix. Statistical analysis involve nonparametric analysis utilizing Chi-squared, G-Test and G-adjusted (Williams adjustment).

Natural tar deposits in California are known for their abundance of well-preserved fossils. Localities, such as Rancho La Brea, McKittrick, and Carpinteria have yielded extensive information about the North American faunal assemblage of the Late Pleistocene (Stock 1972; Akersten 1979; Church 1968; Merriam and Stock 1921; Schultz 1938). Maricopa is a tar seep (brea) that has received little attention in the literature and is located in the southern San Joaquin Valley southwest of Bakersfield on land owned by the Mobil Oil Company (originally the Standard Oil Company). Visitors to this site in 1952 and again in 1954 reported an active tar seep following an earthquake in 1952 (LACMNH, n.d.), and described a pool of water covered by petroleum oils which held dipterous larvae, dragon flies, dead birds and mammals. The Los Angeles County Museum of Natural History (LACMNH) collected blocks of the solidified tar on an expedition to Maricopa in 1968 and 1969 (Stuart 1968). A second expedition to the site was sponsored by California State University, Fresno (CSUF) in 1979. The latter collection is the subject of this study.

Maricopa Brea lies in the SE ¼ of Sec. 21, T11N, R23W, just 9 km north of the San Andreas Fault. The site is bordered by the San Emigdio and Tremblor mountain ranges and is on a low hillside among treeless rolling hills of grass and small shrubs. The oil-bearing Etchegoin Formation of Miocene age provides the source for the oil that seeps upward to the Quaternary-age Tulare Formation (Hall 1994). The oil originates in the diatomaceous Maricopa (Monterey) shale and migrates to the porous sandstone near the surface (Muleady 1980). The only available date from the Maricopa Brea lists a range of 36,000 ± 3900 Y.B.P. (Years Before Present) to 13, 860 ± 420 Y.B.P. (Langenwalter 1976). These findings are very similar to the dates for other California breas. Reynolds (n.d.) suggests the Maricopa activity is contemporary with Rancho La Brea, but temporally more limited.

The activity of the tar seep has varied. At times it must have been extremely active, creating mounds of asphalt many meters thick. At other periods, there has been no observable oil seepage (Macdonald 1967; Muleady 1993). When the oil seeps to the surface, the more volatile constituents evaporate and leave a black, viscous, asphaltic tar with a mirror-like surface that looks "strikingly like placid water and in this way has 'fooled' the animals" (Hanna 1924). The oil mixed with sand, gravel and alluvium washed from the foothills and this soil mixture became a key component in the entrapment of animals while the tar preserved the remains (Muleady 1980).

Materials and Methods

Two expeditions to the Maricopa study site in 1979 yielded approximately 2.5 m^3 of bone-laden asphalt blocks weighing several hundred kilograms. An area 25 m northeast and 5 m higher in elevation from the 1967–68 LACMNH expedition site was gridded and blocks averaging 0.3 m^3 were removed by California State University of Fresno (CSUF).

Fossils were removed from the matrix in 1979 and 1980. Asphalt blocks were soaked in kerosene. Dental tools, forceps, small hammers, and chisels were used to dislodge elements from the tar. Loose matrix was sifted and microsorted under a dissection scope to separate fossil elements from the asphalt flakes. All identifiable whole and fragmentary pieces that appeared to be at least 50% of the element were identified. Care was taken in the removal of elements to minimize fragmentation. Small and medium-sized elements were placed in a Bransonic ultrasonic cleaner for 15 minutes. During the cleaning process, bones were submerged in GUNK Engine Cleaner, a self-emulsifying degreaser that contains petroleum. Each batch was cleaned of matrix and dried under a heat lamp, sorted, and each fossil given a CSUF catalog number. Specimens were identified by comparison to a variety of references, including the CSUF study collection and consultation with the personnel or their collections at the George C. Page Museum.

Over 4,000 fossil elements were identified. Mammalian, herpetological, and entomological material was readily identified to species. Avian elements were more difficult and were initially separated morphologically through measurements and placed into species and species morphs. The numbers of elements per species or morph were identified. The bony elements were separated by skeletal type member. This allowed research on possible differential preservation.

Nonparametric analyses of the data for goodness of fit tests were conducted on the mammalian and avian remains. The G-test was utilized over Chi-squared due to the limitations of the expected frequency data.

The fossil assemblage was analyzed for the maximum likelihood estimation of the composition of the assemblage. Holtzman (1979) proposed that by estimating the frequency of elements divided by the number of identifiable elements in a complete individual, this would show the minimum number of individuals (MNI) in the assemblage and their relative abundance, represented by the weighted abundance of elements (WAE). Holtzman felt that WAE was less susceptible to biases arising from variations in degrees of fragmentation. WAE and MNI are percentages of relative abundance.

$$\text{WAE} = (e_i/m_i)\Big/\sum (e_i/m_i) \times 100$$

$$\text{MNI} = e_i'\Big/\sum e_i' \times 100$$

where

$$e_i = \text{number of total elements of individual (i) species}$$
$$m_i = \text{number of elements per individual}$$
$$e_i' = \text{most abundant element}$$
$$m_i = e_i/e_i'$$
$$m_i'/m_i = \text{index of differential preservation.}$$

Abundance data was used to compare the frequency ratio of consumers (carnivores to herbivores) in the observed population versus that occurring in the expected population frequency through the G-test, goodness of fit test.

Results

The Maricopa fauna from the two expeditions yielded 27 mammal species and 29 morphologically distinct avian species. Reptiles and amphibians were identified along with invertebrates and floral elements (i.e., juniper root and plant achenes). For the mammals, the 14 classes of expected skeletal elements were calculated with their expected frequency of occurrence should an entire mammal's skeletal remains be analyzed. The observed mammal skeletal remains of 1599 elements were placed as a fossil percent of total remains found as the observed frequency and placed in the appropriate skeletal category (Table 1). The expected and observed data were graphed for visual comparison (Figure 1). Because the expected frequency of many of the classes was <3, the data was collapsed into appendicular and axial skeletal classes, allowing a minimal expected frequency of >3 (Table 2). However, with degrees of freedom (df) of 1, and expected frequency of <5, the Chi-squared analysis of goodness of fit was not appropriate for this data. Therefore, a G-test was conducted. As the sample size was >200, a G-adjusted (Williams) test did not have to be completed, but was conducted for completion. The resulting analysis yielded a G-test = 9.810 with a G-adjusted = 9.8101042. The Chi-squared table (Rohlf and Sokal 1995), listed a Chi-squared critical value [0.05, 1] = 3.841, $P \gg 0.001$.

The avian skeletal elements were similarly treated (Table 3; Figure 2), with a collapse to two classes, appendicular and axial skeletal elements (Table 4). The resulting analysis yielded a G-test = 82.822. With 1320 fossil elements, a Williams correction was not necessary, but done so for completion with a resulting value of G-adjusted = 82.493. The Chi-squared critical value [0.05,1] = 3.841, $P \gg 0.001$.

Specific avian fossil elements were calculated for preservation equality. Tar-

Table 1. Maricopa mammal bone preservation.

Skeletal element	No. skeletal elements	N % of total	# of fossils	Fossil % of total
Cranium	1	0.7518797	31	1.94
Mandible	2	1.5037594	146	9.13
Vertebrae**	44	33.0827068	336	21.01
Clavicle	2	1.5037594	0	0
Scapula	2	1.5037594	25	1.56
Humerus	2	1.5037594	78	4.88
Ulna	2	1.5037594	56	3.5
Radius	2	1.5037594	41	2.56
C/T*	30	22.556391	105	6.57
Meta C/T* **	12	9.02255639	150	9.38
Sternum	1	0.7518797	0	0
Ribs	24	18.0451128	115	7.19
Innominate	2	1.5037594	115	7.19
Femur	2	1.5037594	209	13.08
Tibia	2	1.5037594	192	12.01
Fibula**	1	0.7518797	0	0
Patella**	1	0.7518797	0	0
Hyoid	1	0.7518797	0	0
	133	100	1599	100

* C/T = carpals/tarsals.
** Mean of total possible.

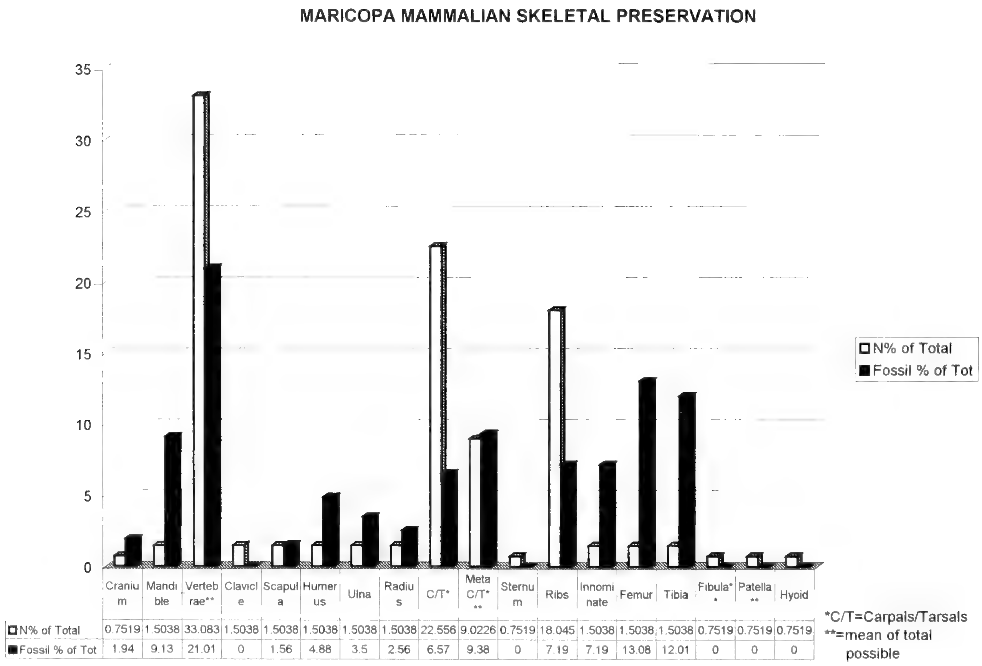

Fig. 1. Maricopa mammalian skeletal preservation.

Table 2. Maricopa mammal appendicular and axial analysis.

Skeletal element	No. skeletal elements	N % of total	# of fossils	Fossil % of tot
Axial				
Cranium	1	0.7518797	31	1.94
Mandible	2	1.5037594	146	9.13
Vertebrae**	44	33.0827068	336	21.01
Sternum	1	0.7518797	0	0
Ribs	24	18.0451128	115	7.19
Hyoid	1	0.7518797	0	0
		54.887218		39.27
Appendicular				
Clavicle	2	1.5037594	0	0
Scapula	2	1.5037594	25	1.56
Humerus	2	1.5037594	78	4.88
Ulna	2	1.5037594	56	3.5
Radius	2	1.5037594	41	2.56
C/T*	30	22.556391	105	6.57
Meta C/T* **	12	9.02255639	150	9.38
Innominate	2	1.5037594	115	7.19
Femur	2	1.5037594	209	13.08
Tibia	2	1.5037594	192	12.01
Fibula**	1	0.7518797	0	0
Patella**	1	0.7518797	0	0
		45.112782		60.73
Total	133	100	1599	100
G-test		9.81		
G adjusted		9.8101042		χ^2 critical value [0.05]

* C/T = carpals/tarsals.
** Mean of total possible.

sometatarsus elements at 195 were 3.1 times more abundant than femur elements at 62. Tarsometatarsus elements at 195 were 1.2 times more abundant than 162 coracoid elements.

The 24 Recent mammal species were represented by 3 insectivores, 16 herbivores, and 5 carnivores. Their relative observed frequency (abundance), calculated through the Holtzman equation is given in Tables 5 and Figure 3. The observed ratio of herbivores to carnivores was 6:1 = 17%. The expected ratio is 11:1 = 9% (Raven and Johnson 1999).

The expected frequency ratio of carnivores to herbivores was compared to the observed frequency ratio and subjected to the G-test goodness of fit test. The resulting G-test = 411.546 with a G-adjusted = 411.41723. The Chi-squared critical value [0.05,1] = 3.841, $P \gg 0.001$.

Discussion

Much work has been done in several of the breas of California. Maricopa has been minimally studied to date, but has revealed some surprising results. Maricopa has 97 identified vertebrate species to date, McKittrick 131 and Rancho La Brea 191. The tar at Rancho La Brea appears to be the trapping and preserving mechanism, while at Maricopa, the wet clay and mud appear to trap the animals and

Table 3. Maricopa avian bone preservation.

	N % of total	Fossil % of total
Cranium	1.3986014	1.439393939
Mandible	1.3986014	0.151515152
Vertebrae**	43.3566434	13.03030303
Coracoid	2.7972028	12.27272727
Furcula	1.3986014	0.833333333
Scapula	2.7972028	5.151515152
Sternum	1.3986014	0
Ribs	19.5804196	0
Humerus	2.7972028	12.04545455
Ulna	2.7972028	11.28787879
Radius	2.7972028	0.75757575758
Carpometacarpus	2.7972028	10.53030303
2nd phalange	2.7972028	1.818181818
Femur	2.7972028	4.696969697
Tibiotarsus	2.7972028	11.21212121
Tarsometatarsus	2.7972028	14.77272727
Fibula**	1.3986014	0
Hyoid	1.3986014	0
Patella**	0.6993007	0
	100	100

* C/T = carpals/tarsals.
** Mean of total possible.

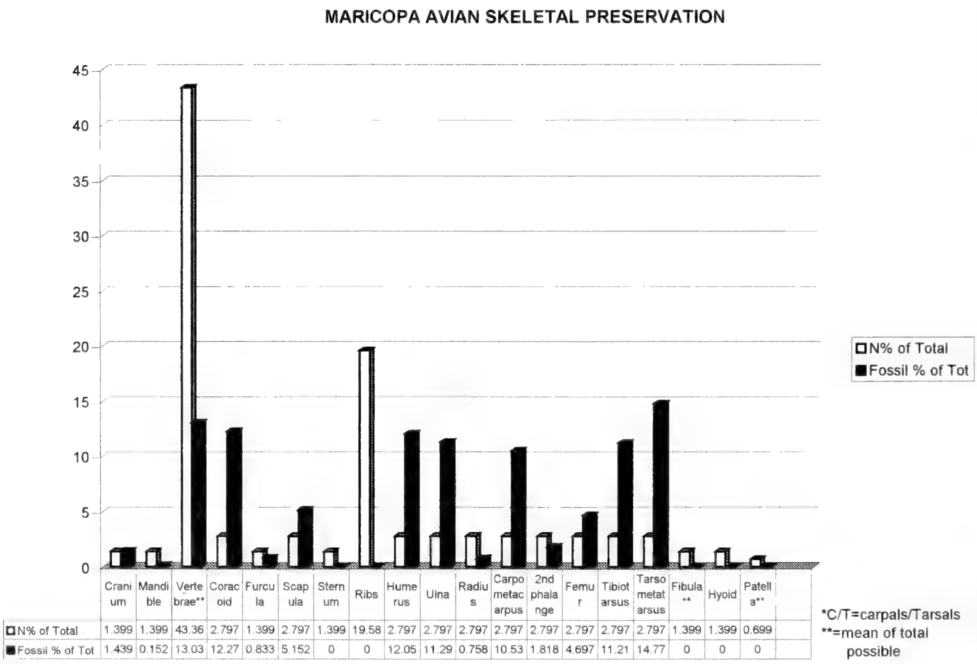

Fig. 2. Maricopa avian skeletal preservation.

Table 4. Maricopa avian appendicular and axial analysis.

Skeletal element	No. skeletal elements	N % of total	# of fossils	Fossil % of tot
Axial				
Cranium	1	1.3986014	19	1.439393939
Mandible	1	1.3986014	2	0.151515152
Vertebrae**	31	43.3566434	172	13.03030303
Sternum	1	1.3986014	0	0
Ribs	14	19.5804196	0	0
Hyoid	1	1.3986014	0	0
		68.5314685		14.62121212
Appendicular				
Coracoid	2	2.7972028	162	12.27272727
Furcula	1	1.3986014	11	0.833333333
Scapula	2	2.7972028	68	5.151515152
Humerus	2	2.7972028	159	12.04545455
Ulna	2	2.7972028	149	11.28787879
Radius	2	2.7972028	10	0.757575758
Carpometacarpus	2	2.7972028	139	10.53030303
2nd phalange	2	2.7972028	24	1.818181818
Femur	2	2.7972028	62	4.696969697
Tibiotarsus	2	2.7972028	148	11.21212121
Tarsometatarsus	2	2.7972028	195	14.77272727
Fibula**	1	1.3986014	0	0
Patella**	0.5	0.6993007	0	0
		31.4685315		85.37878788
Total	71.5	100	1320	100
G-test		82.882		
G adjusted		82.493		χ^2 critical value [0.05, 1] = 3.841

* C/T = carpals/tarsals.
** Mean of total possible.

the tar preserves the elements. This is supported by the gravel matrix found in the bones at Maricopa, absent in those from Rancho La Brea. As a result, the Maricopa skeletal elements seem more fragile. Despite this, of the 4000 fossil elements studied, 1599 were intact, identifiable mammal bones and 1320 were intact, identifiable avian bones.

The relationship of the expected preservation of the vertebrate skeletal remains was visually quite different from the observed for both mammals and birds, as seen in Graphs 1 and 2. In collapsing the skeletal classes to two, appendicular and axial and conducting the goodness of fit test, it was apparent that there was a significant differential preservation of appendicular skeletal remains compared to axial remains for both birds and mammals. The following scenario could explain this. A bird or mammal was attracted to water or the appearance of water caused by the petroleum slick on the surface. They then became trapped in the wet clay and mud, sinking by their arms and legs (appendicular skeleton). Their attempts to free themselves attracted carnivores that were then able to feed on the exposed animal's back, tail and head (axial skeleton). This would account for the abundance of appendicular skeletal remains and the paucity of axial remains in the faunal assemblage. Field observations at Maricopa in 1993 support this

Table 5. Maricopa mammalian relative abundance.

Species	C/H/I*	Abundance**
Bat	I	0.6
Sorex	I	0.6
Onychomys	I	1.2
Odocoileus	H	1.2
Antilocapra	H	2.4
Lepus	H	10.2
Sylvilagus	H	1.2
Neotoma	H	1.2
Dipodomys	H	35.5
Juv. Heteromyid	H	1.2
Thomomys	H	3
Otospermophilus	H	0.6
Sciurid 1	H	4.8
Sciurid 2	H	1.2
Cricetid. 1	H	1.8
Cricetid. 2	H	1.2
Perognathus	H	15.7
Peromyscus	H	1.8
Microtine	H	0.6
Canis latrans	C	7.8
Vulpes	C	1.8
Lynx rufux	C	0.6
Urocyon	C	3
Taxidea	C	0.6
		99.8

* I = insectivore, H = herbivore, C = carnivore.
** Abundance based on minimum # of individuals from Holtzman's equation.

concept. A barn owl (*Tyto alba*) was observed next to a kangaroo rat (*Dipodomys* sp.). Both had expired and were partially submerged in the mud and petroleum slick. While the owl had not been scavenged, the tail and part of the spine of the kangaroo rat were missing while its legs appeared to be below the surface in the drying mud.

Guthrie's (1993) taphonomic work with skeletal remains on the Channel Islands of California noted that separation of fossil elements is minimal after burial and that the pattern of preserving larger, denser bones that survive the longest needs to be assessed. Guthrie suggested (2002) that if differential preservation is occurring in avian fossil elements, tarsometatarsus elements would be preserved more than femur or coracoid elements. Indeed, at Maricopa, tarsometatarsus elements are preserved more than 3 times femur elements and 1.2 times coracoid elements.

This same scenario would also account for the abundance of carnivores greater than that expected in a normally distributed population. In continuing the above sequence of events, the carnivore that arrived to eat primarily the axial skeleton could itself become trapped. Its efforts to free itself would in turn attract another carnivore and it too would be eaten axial-first with the possibility of subsequent entrapment. This could account for the 17% carnivore population in the Maricopa faunal assemblage. This seems more likely than a resident 17% carnivore population in the Late Pleistocene and Recent periods, rather than the expected 9%.

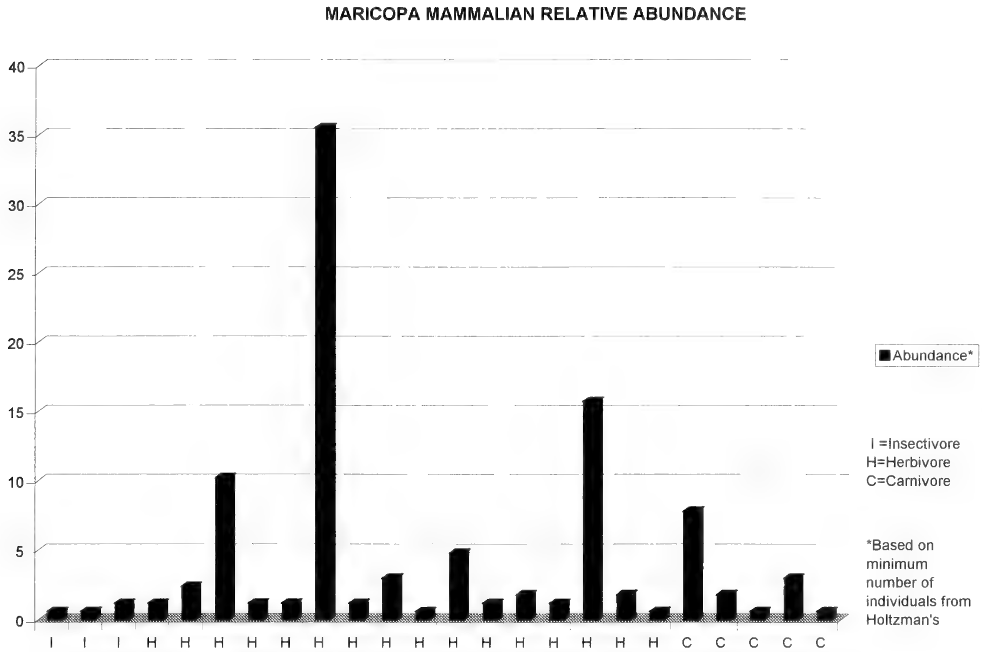

Fig. 3. Maricopa mammalian relative abundance.

The scene at Maricopa today is dry rolling hills with thick asphaltic blocks appearing intermittently on the surface. Adjacent are small seeps of water with petroleum slicks on the surface. Birds and mammals continue to be attracted to the area, possibly to be trapped and become preserved fossils of the future.

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Literature Cited

Akersten, W.A. 1979. Evidence leading to entrapment. Located at: L.A. County Museum of Natural History, Los Angeles, California.

Church, C.C. 1968. The McKittrick tar seeps paleontology papers. Located at: L.A County Museum of Natural History, Los Angeles, California.

Guthrie, D.A. 1993. Listen to the birds? The use of avian remains in Channel Islands archaeology, in Archaeology on the Northern Channel Islands of California, ed. M.A. Glassow. Coyote Press, Archives of California Prehistory, 34:153–167.

———. 2002. Personal Communication. Keck Science Center, Claremont, CA, 91711–5916.

Hall, Brook E. 1994. A Fossil Rodent Fauna From the Maricopa Tar Seep, Kern County, California. Master's Thesis, Northern Arizona University; Flagstaff, Arizona, 96pp.

Hanna, G.D. 1924. Insects in the California tar traps. Science, 59(1538):555.

Holtzman, R.C. 1979. Maximum likelihood estimation of fossil assemblage composition. Paleobiology, 5(2):77–89.

Langenwalter, P.E. 1976. Memorandum to Theodore Downs. Located at: LACMNH, Los Angeles, California.

LACMNH (Los Angeles County Museum of Natural History), n.d. Accession files. Located at LACMNH, Los Angeles, California.

Macdonald, J.R. 1967. The Maricopa Brea. Los Angeles County Museum of Natural History Quarterly, 6:21–24.

Merriam, J.C. and C. Stock, 1921. Occurrence of Pleistocene vertebrates in an asphalt deposit near McKittrick, California. Science, 54(1406):566-567.

Muleady, N.E. 1980. The Fossils of Maricopa. Master's Thesis, Department of Biology, California State University, Fresno; Fresno, California, 60pp.

———. 1993. Maricopa field notes, unpublished.

Raven, P.H. and G.B. Johnson, 1999. Biology. (Boston: McGraw Hill).

Reynolds, R.L., n.d. History of paleontologic excavations and conditions at the McKittrick asphalt deposits. Located at California State University, Fresno, Fresno, California.

Rohlf, F.J. and R.R. Sokal, 1995. Statistical Tables. (New York: W.H. Freeman and Company).

Schultz, J.R., 1938. A late quaternary mammal fauna from the tar seeps of McKittrick, California. Studies on Cenozoic Vertebrates of Western North America. Carnegie Institute of Washington Publication 487, 4:118–167.

Stock, C. 1972. Rancho La Brea. (Los Angeles: L.A. County Museum of Natural History).

Stuart, M.B. 1968. Maricopa field notes. Located at: L.A. County Museum of Natural History, Los Angeles, California.

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Invasive Aquatic Animals and Possible Effects on Native Frogs and Toads in Mediterranean Baja California[1]

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Northwestern Baja California, Mexico, shares a unique mediterranean biota with adjacent California, USA, as a result of the climatic conditions that dominate the area. Many of the vertebrates in it are restricted to this ecosystem, including most amphibians (Linsdale 1932; Mellink 2002). This ecosystem faces severe conservation problems, mostly derived from the extensive urbanization of California and northernmost Baja California. The resulting habitat modification has impacted some of the species of amphibians in southern California so strongly that the arroyo toad (*Bufo californicus;* sensu Gergus 1998) is officially considered endangered, and the red-legged frog (*Rana aurora*), threatened. In contrast with their diminished populations in southern California, these species, as well as other frogs and toads, fare much better in Baja California (Grismer 2002).

Besides knowledge of such better conditions, not much is known about the conservation status of amphibians in Baja California. There are a number of pressures that might impair the quality of their habitat, including development, land conversion, dams, sand-mining, gravel mining, roads, water extraction, refuse, chemical contamination, and invasive species (Robert E. Lovich, pers. comm.).

One potentially serious threat is the presence of invasive animals, as such species have impacted native taxa in other aquatic habitats of western North America (Bury and Luckenbach 1976; Dudley and Collins 1995). Alien fishes have been widely introduced to Mexico, including to Baja California (Contreras-B. and Escalante-C. 1984; Follett 1961; Mellink and Ferreira-Bartrina 2000). However, not enough information is available to judge the risks to amphibian conservation derived from invasive aquatic animals in the Mediterranean of Baja California. Here we report on field work carried out in order to obtain a first impression of such risks.

Methods

Between 3 March 1998 and 30 August 2001 we visited 24 sites with standing or running water within the mediterranean region of Baja California, from Arroyo El Rosario to the U.S. boundary (Table 1). Some of the sites were visited once; others, on multiple occasions. At most sites we visually searched for amphibians and captured them by hand or with hand-nets. Specimens were identified on the spot and, if captured, released. At most sites we also captured fishes with a 1 ×

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Table 1. Sites and dates on which amphibians were surveyed in northwestern Baja California, 1998–2001.

Arroyo El Rosario	April 1999
Arroyo Santo Domingo	July 2000, August 2001
Arroyo San Telmo	April 1999
Sierra San Pedro Mátrir:	
Arroyo de Los Alamitos at the Estación Forestal	June 1998
Vallecitos	June 1998
La Grulla	September 1999
Arroyo La Encinosa at Santa Cruz	August 2001
Arroyo Valladares at El Potrero	August 2001
Arroyo San José at Rancho Meling	April 2000, August 2001
Arroyo San Rafael, near Colonet	May 2000
Arroyo Santo Tomás	April 1998
Uruapan (a 4 × 4 m pool)	April 1998
Agua Caliente at Cañón de San Carlos	July 2001
Arroyo Ensenada, above and below the Ensenada dam	October 1998, April 1999, and several unrecorded dates all years
El Sauzal–ephemeral pools	March 1998, January 1999
Arroyo San Antonio, from Cañón del Carmen near San Miguel and San Antonio de las Minas East to 1 km above Rancho La Fortuna	several days in March, June, August, September, and October 1999, March 2000
Cañón Salsipuedes at Saldamando	February 2000
La Misión	September and October 1998, April 1999
Cañada El Morro at El Descanso, near La Viña	April 1999, February 2000
Rio Las Palmas	March 1998
El Florido	March 2000
Presa de Tijuana by Centro Recreativo Azteca	April 1999

10-m beach seine with 3/16″ mesh, and with a hand-net. The fishes were brought to the laboratory, in 70% ethyl alcohol, for identification. We examined the stomach contents of the larger specimens.

Results

We recorded seven species of native anurans, two native reptiles, and three native fishes (Table 2). Except for the red-spotted toad and the western spadefoot, which because of their preference of drier habitats were not sampled adequately, the anurans were widespread and common. We recorded 10 invasive aquatic animals (Table 3), which were more common in the northern half of the survey area. This, however, might be an artifact of sampling higher-elevation locations in the southern part of the study area.

Discussion

Aquatic amphibians and reptiles are well distributed in northwestern Baja California. However, many of the remaining low altitude waterbodies, especially in the north, are heavily populated with invasive animals. Some of these are potentially threatening to native anurans although, conversely, some invasive species, or some of their developmental stages, serve as food for the natives.

In terms of their potential negative impacts, some of these invasive aquatic animals have been documented as predators of anurans. For example, crayfish pose high environmental risks, as they are omnivores that feed on aquatic plants and algae, invertebrates, frogs, and even some fish, and in some places have eliminated most aquatic invertebrates (Dudley and Collins 1995; Hobbs et al.

Table 2. Native-species found in freshwater wetlands in northwestern Baja California, 1998–2001.

	Amphibians									Reptile		Fish		
	Unidentified toad (*Bufo* sp.)	Western toad (*Bufo boreas*)	Arroyo toad (*Bufo californicus*)	Red-spotted toad (*Bufo punctatus*)	Unidentified treefrog (*Pseudacrys* sp.)	California treefrog (*Pseudacrys cadaverinia*)	Pacific treefrog (*Pseudacrys regilla*)	Red-legged frog (*Rana aurora*)	Western spadefoot (*Spea hammondii*)	Western pond turtles (*Clemmys marmorata*)	Two-striped garter snakes (*Thamnophis hammondi*)	Striped mullet (*Fundulus parvipinnis*)	California killifish (*Gillichthys mirabilis*)	Longjaw mudsucker (*Mugil cephalus*)
Arroyo El Rosario			X				X							
Arroyo Santo Domingo			X					X		X				
Arroyo San Telmo		X					X							
Arroyo La Encinosa (Santa Cruz)					X					X	X			
Arroyo Valladares (El Potrero)								X						
Arroyo San José (de Meling)						X	X	X			X			
Arroyo de los Alamitos (estación forstal)		?												
La Grulla							X							
Vallecitos				X										
Arroyo San Rafael			X					X						
Arroyo Santo Tomás	X	X				X	X							
Uruapan, stagnant 4 × 4 m pool						X	X	X						
Agua Caliente (Cañón de San Carlos)	X					X	X	X						
Arroyo Ensenada (presa)		X				X	X						X	
El Sauzal (ephemeral pools)		X					X							

Table 2. Continued.

	Amphibians									Reptile		Fish		
	Unidentified toad (*Bufo* sp.)	Western toad (*Bufo boreas*)	Arroyo toad (*Bufo californicus*)	Red-spotted toad (*Bufo punctatus*)	Unidentified treefrog (*Pseudacrys* sp.)	California treefrog (*Pseudacrys cadaverinia*)	Pacific treefrog (*Pseudacrys regilla*)	Red-legged frog (*Rana aurora*)	Western spadefoot (*Spea hammondii*)	Western pond turtles (*Clemmys marmorata*)	Two-striped garter snakes (*Thamnophis hammondi*)	Striped mullet (*Fundulus parvipinnis*)	California killifish (*Gillichthys mirabilis*)	Longjaw mudsucker (*Mugil cephalus*)
Arroyo San Antonio–Rancho La Fortuna		X	X			X	X	X	X	X	X			
Cañón Salsipuedes (Saldamando)						X		X						
Arroyo La Misión				X			X	X				X	X	X
Cañada El Morro (El Descanso)		X	X				X	X			X			
Río Las Palmas (a tributary arroyo)									X					
El Florido		X						X						
Presa de Tijuana (Centro Recreativeo Azteca)														

Table 3. Invasive species found in freshwater wetlands in northwestern Baja California, 1998–2001.

	Invertebrate	Amphibian		Fish						
	Crayfish (*Procambarus* sp.)	Bullfrog (*Rana catesbeiana*)	African clawed frog (*Xenopus laevis*)	Threadfin shad (*Dorsoma petense*)	Mosquitofish (*Gambusia affinis*)	Channel catfish (*Ictalurus punctatus*)	Unidentified sunfish (*Lepomis* sp.)	Green sunfish (*Lepomis cyanellus*)	Bluegill sunfish (*Lepomis macrochirus*)	Spotted bass (*Micropterus punctatus*)
Arroyo El Rosario										
Arroyo Santo Domingo					X					
Arroyo San Telmo					X					
Arroyo La Encinosa (Santa Cruz)										
Arroyo Valladares (El Potrero)										
Arroyo San José (de Meling)										
Arroyo de los Alamito (estación forestal)										
La Grulla										
Vallecitos										
Arroyo San Rafael										
Arroyo Santo Tomás	X					X				
Uruapan, stagnant 4 × 4 m pool	X			X						
Agua Caliente (Cañón de San Carlos)	X			X						
Arroyo Ensenada (dam)	X	?					X	X	X	
El Sauzal (ephemeral ponds)										
Arroyo San Antonio–Rancho La Fortuna	X	?						X	X	
Cañón Salsipuedes (Saldamando)										
Arroyo La Misión	X	X			X			X		
Cañada El Morro (El Descanso)										
Río Las Palmas (a tributary arroyo)										
El Florido				X						
Presa de Tijuana (Centro Recreativo Azteca)			X			X			X	X

1989). Conversely, crayfish have been found to be an important food item for one species of garter snake (*Thamnophis marcianus*) and other vertebrates.

Mosquitofish, a very adaptable fish introduced around the world because of its larviferous reputation, can predate on eggs and larvae of amphibians. We documented mosquitofish attacking treefrogs in masse, and the stomachs of two mosquitofish from Uruapan contained unidentifiable tadpoles in addition to insects. This is coincident with findings in the Santa Monica Mountains, Calif., where mosquitofish preyed heavily upon Pacific treefrog (Goodsell and Kats 1999). Sunfish (*Lepomys* spp.) have often been considered a threat to native fish where introduced outside their range, especially through competition. In one of three stomachs of green sunfish from San Antonio that we examined there were remains of unidentifiable tadpoles, in addition to remains of insects. Juveniles of the spotted bass feed on crustaceans and aquatic insects, but may also have been involved in the decline of amphibians in California.

Bullfrogs tadpoles can have a significant impact upon benthic algae, while adults may be responsible for significant levels of predation on native anurans and other aquatic herpetofauna, such as snakes and turtles (Bury and Luckenbach 1976; Clarkson and De Vos 1986; Dudley and Collins 1995; Hammerson 1982; Moyle 1973). African clawed frogs may be a threat to native aquatic species as documented in southern California (Bury and Luckenbach 1976; Dudley and Collins 1995).

To summarize, several alien species that occur in Baja California Mediterranean wetlands are suspected of causing declines in the populations of native species. However, at this point it is not clear whether in northwestern Baja California native species are less common on sites with invasive species, or that any lower densities or absences are the results of such introductions, rather than due to differences in the characteristics of the sites. It seems highly possible that at least in some types of wetland, invasive species could negatively impact native species. Although evidence on the affects of invasive species on native amphibians is not available for Mediterranean Baja California, it seems that prevention of their colonization of areas that are currently free of them would be a wise conservation strategy. To this end, at least a monitoring program should be launched.

Acknowledgments

We are grateful to Lee Grismer, Robert E. Lovich, and Dan Guthrie for their editorial comments.

Literature Cited

Bury, R. B. and R. A. Luckenbach. 1976. Introduced amphibians and reptiles in California. Biol. Conservation 10:1–14.

Clarkson, R. W. and J. C. DeVos. 1986. The bullfrog, *Rana catesbeana* Shaw, in the Lower Rio Colorado, Arizona-California. Herpetology 20:42–49.

Contreras-B., S. and M. A. Escalante-C. 1984. Distribution of known impacts of exotic fishes in Mexico. Pp. 103–130 in W.R Courtney and J.R. Stauffer (eds). Distribution, biology, and management of exotic fishes. John Hopkins.

Dudley, T. and B. Collins. 1995. Biological invasions in California wetlands. Pacific Institute for Studies in Development, Environment and Security. Oakland, California. 62 pp.

Follett, W. I. 1961. The fresh-water fishes; their origin and affinities (*in* Symposium on the biogeography of Baja California and adjacent seas). Sys. Zool. 9:212–232.

Gergus, E. W. A. 1998: Systematics of the Bufo microscaphus complex: allozyme evidence. Herpetologica 54:317–325.

Goodsell, J. A. and L. B. Kats. 1999. Effect of introduced mosquitofish on Pacific treefrogs and the role of alternate prey. Cons. Bio. 13:921–924.

Grismer, L. L. 2002. Amphibians and Reptiles of Baja California, Including Its Pacific Islands and the Islands in the Sea of Cortés. University of California.

Hammerson, G. A. 1982. Bullfrog eliminating leopard frogs in Colorado? Herpetological Review 13: 115–116.

Hobbs III, H. H., J. P. Jass and J. V. Huner. 1989. A review of global crayfish introductions with particular emphasis on two north american species (Decapoda, Cambaridae). Crustaceana 56: 299–316.

Linsdale, J. M. 1932. Amphibians and reptiles from Lower California. U. Calif. Publ. Zool. 38:345–386.

Mellink, E. 2002. El límite sur de la región mediterránea de Baja California, con base en sus tetrápodos endémicos. Acta Zoológica Mexicana 85:11–23.

———. and V. Ferreira-Bartrina. 2000. On the wildlife of wetlands of the Mexican portion of the Rio Colorado delta. Bull. So. Calif. Acad. Sci. 99:115–127.

Moyle, P. B. 1973. Effects of introduced bullfrgogs, *Rana catesbeiana,* on the native frogs of the San Joaquin Valley, California. Copeia 1973:18–22.

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Distribution and Morphotypes of the Federally Endangered Land Snail *Helminthoglypta* (*Charodotes*) *walkeriana* (Hemphill, 1911)

Michael Walgren

California Department of Parks and Recreation, State Park Rd., Morro Bay, California 93442

The Morro shoulderband snail, *Helminthoglypta walkeriana* (Hemphill 1911), a terrestrial snail found in San Luis Obispo County, California, is listed as endangered under the U.S. Endangered Species Act. Surveys conducted by the California Department of Parks and Recreation have resulted in range clarifications, identification of new habitat associations, and evaluation of various morphological types. These results have important economic and political implications due to the protections afforded to federally listed species.

At the time of federal listing the entire recognized range of this species was thought to cover the community of Los Osos and adjacent California State Parks property (USFWS 1998). Historically, the species was found alive inland near the city of San Luis Obispo and north near the coastal town of Cayucos (Pilsbry 1939). The populations at San Luis Obispo and Cayucos have been described as *H. walkeriana morroensis* (Hemphill 1911) but are regarded as a likely extinct infrasubspecific variant by Roth (1985). The diagnostic features of the *morroensis* type are strong papillation and absence of incised spiral grooves. Habitat associations of the typical type of *H. walkeriana* (type *walkeriana*) have been limited to coastal dune and coastal sage scrub communities, primarily in association with older wind deposited sands with an organic component known as Baywood fine sands. Thus, the range reduction, limited habitat associations, and possible extinction of a subspecies resulted in federal listing in 1994.

To determine the extent of snail presence within State Park property, surveys were conducted between January 2001 and April 2003 for *H. walkeriana* throughout the larger historic range. Samples of 50 shells were collected from each of seven populations, and 11 other populations were examined in the field in order to evaluate the status of the *morroensis* type. In determining types, the following features were examined: density and extent of shell papillation, pronouncement and continuity of incised spiral grooves, whorl number, percent umbilicus occlusion, height (H), and diameter (D).

Live specimens were found throughout the historic range, from the coast at Cayucos, inland to the City of San Luis Obispo. Because live snails were readily found at multiple locations, a range restricted to a few locations is not indicated, but rather a larger continuous range similar to the historic range is predicted (Fig. 1).

The northernmost population was rediscovered along coastal bluffs south of the town of Cayucos. Inland populations were found near the City of San Luis Obispo at 162 m elevation. The southern coastal extent of surveys found live snails at Spooner's Cove within Montana de Oro State Park.

The type *morroensis* has been rediscovered inland near the City of San Luis

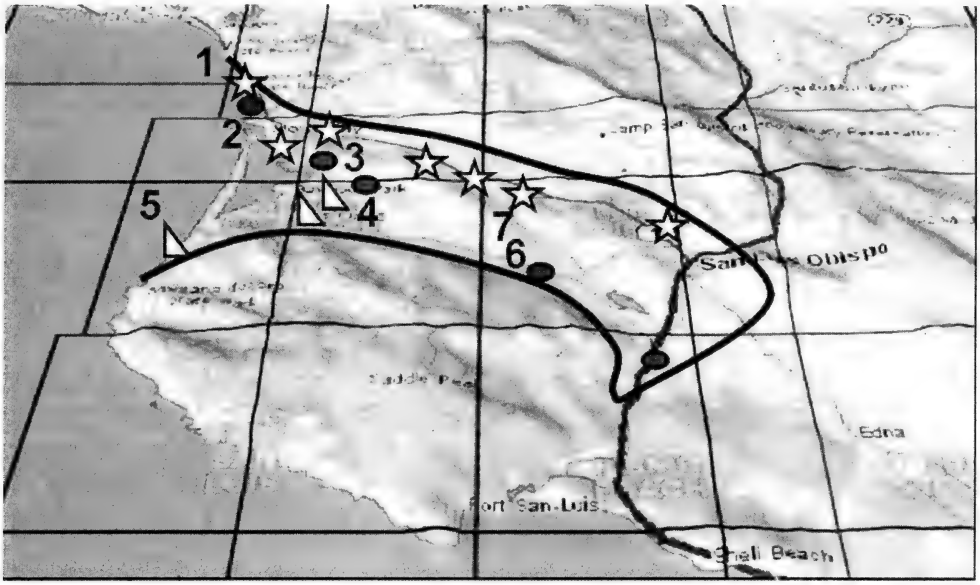

Fig. 1. The overall predicted range of *H. walkeriana* is outlined. Circles represent locations of intermediate types; triangles represent locations of type *walkeriana* south of Morro Bay; stars represent locations of type *morroensis* along the Chorro Valley. Site numbers correlate to site numbers in Table 1.

Obispo, along the coast near Cayucos, and at several points along the Chorro Valley. One population of type *morroensis* is abundant on an artificial peninsula created in the Morro Bay estuary circa 1950. Populations found in the center of the overall revised range, as well as at three outlier locations, present unique types featuring characteristics of both type *walkeriana* and type *morroensis.*

Examination of shell morphometrics revealed varying degrees of papillation, incised spiral grooves, umbilicus occlusion, whorl number, and size at sexual maturity. This variation appears to follow a geographical gradient that reflects microclimate shifts following a mesic gradient primarily south to north (wetter to drier) along the coast, and west (coastal) to east (inland). This gradient progresses from globose nonpapillated *walkeriana* type with well-defined incised spiral grooves, large size at sexual maturity, a more occluded umbilicus, and higher whorl number, to intermediate populations, and eventually to type *morroensis* with small size at sexual maturity, coarse profuse papillation, open umbilicus, lower whorl number, and reduced pronouncement of incised spiral grooves (Table 1). Size gradients have also been observed in Helminthoglyptid snails on north versus south facing slopes and on moist versus dry sides of California islands (F. G. Hochberg, pers. comm.).

Intermediate populations include one population within the City of Morro Bay that appears similar to type *walkeriana,* yet reaches sexual maturity at a reduced size (Table 1). Several populations similar to type *walkeriana* exhibit widespread fine papillations not seen on the *walkeriana* type. One population found in the Los Osos Valley is similar to type *morroensis* (Table 1), yet reaches a larger maximum size (D 30.3 mm, H 19.4 mm) that is close to type *walkeriana* (D 31.5, H 23.2 mm).

Table 1. Mean values of adult shell features by site numbers as presented in Figure 1. Degree of papillation (Pap) and pronouncement of spiral grooves (Grooves) were measured using a qualitative scall of 1-4, 4 being the strongest pronouncement. Percent umbilicus occlusion (Umb) was estimated as a percentage by ocular inspection. Wh = number of whorls, n = sample number of subsequent features, H/D = ratio of height divided by diameter.

Site	Location	n	H (mm)	D (mm)	H/D	n	Gr	Pap	n	Umb	n	Wh
1	35°25′N 120°52′W	20	13.40	21.30	0.6282	19	2.10	3.95	18	0.32	19	5.33
2	35°22′N 120°51′W	20	15.30	21.70	0.7040	19	3.90	1.11	15	0.53	15	5.62
3	35°20′N 120°49′W	20	17.10	24.40	0.7036	19	2.42	3.42	18	0.47	19	5.78
4	35°19′N 120°49′W	20	20.00	25.80	0.7778	18	3.83	1.33	17	0.67	17	5.97
5	35°19′N 120°52′W	20	21.00	28.70	0.7415	20	3.80	1.30	8	0.51	10	5.83
6	35°16′N 120°43′W	20	16.40	25.40	0.6442	15	3.60	2.87	10	0.35	13	5.75
7	35°19′N 120°43′W	20	14.40	21.90	0.6584	18	2.00	3.83	18	0.41	9	5.44

Habitat associations of type *walkeriana* have been expanded, according to Sawyer and Keeler-Wolf (1995), to include coast live oak woodland, California annual grassland, dune lupine-goldenbush, introduced perennial grassland, and European beachgrass series communities at 3–46 m elevations on soils of Baywood fine sands, active dune sands, and clay. Type *morroensis* has been found in sand verbena-beach bursage, coyote brush, coast live oak woodland, nodding needlegrass, European beachgrass, California annual grassland, iceplant, and dune lupine-goldenbush series communities at 4–162 m elevations on soils of clay and active dune sand.

Types *walkeriana* and *morroensis* appear to represent valid subspecies based on unique shell morphology, ecology, and geographically isolated ranges. Further research should focus on collection of live specimens for analysis of soft tissue anatomy and DNA to address the taxonomic status of various types.

Identification of all samples from outlier populations was confirmed by Dr. Barry Roth, Research Associate, Santa Barbara Museum of Natural History, and one or both of the federally permitted biologists Mr. Jeff Tupen and Mr. Vincent Cicero. Voucher specimens are deposited in the malacology collection of the Natural History Museum of Los Angeles County (LACM 153235–153244).

Literature Cited

Hemphill, H. 1911. Descriptions of some varieties of shells, with short notes on the geographical range and means of distribution of land shells. Trans. San Diego Soc. Nat. Hist., 1:99–108.

Pilsbry, H.A. 1939. Land Mollusca of North America (north of Mexico). Acad. Nat. Sci. Philadelphia, Monog. 3, 1(1):1–573.

Roth, B. 1985. Status survey of the banded dune snail, *Helminthoglypta walkeriana*. Report to United States Fish and Wildlife Service, Sacramento Endangered Species Office. 27 pp.

United States Fish and Wildlife Service. 1998. Recovery plan for the Morro shoulderband snail and four plants from Western San Luis Obispo County, California. USFWS, Portland, Oregon. vi + 75 pp.

Sawyer, J., & T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society. Sacramento, California. 471 pp.

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The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with **an emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

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The author should submit *at least two additional copies with the original,* on 8½ × 11 opaque, nonerasable paper, double spacing the entire manuscript. *Do not break words at right-hand margin anywhere in the manuscript.* Footnotes should be avoided. **Manuscripts which do not conform to the style of the BULLETIN will be returned to the author.**

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McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii + 326 pp.

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Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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Research Notes

Cover: Sexually mature typical *H. walkeriana* from coastal Montana de Oro State Park on left; sexually mature *H. walkeriana* from "morroensis" from inland Camp San Luis Obispo on right. Specimens represent average sizes for their lots. M. Walgren.

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SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

Volume 102 **Supplement to Number 2**

ABSTRACTS OF PAPERS

2003 Annual Meeting
California State University
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May 9–10, 2003

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Research Training Program

Abstracts 90 to 103 represent the final product of the high school Research Training Program for 2002–03.

The following students were selected to receive an honorary membership in the American Association for the Advancement of Sciences: Ved Chirayath, Anuj Chaudhary, Edward Smetak and Genevieve Y. Williams.

Based on their oral presentation and research paper, the following students were invited to present their work at the American Junior Association of Science meeting, held in conjuction with the A.A.A.S. meeting in February, 2004 in Seattle, Washington: Ved Chirayath, Anuj Chaudhary, Jason Bae, Su Fey Ong, Edward Smetak, Genevieve Y. Williams, Vijay Yanamadala, James Bok Lee and Michael Hong.

We would like to acknowledge the Harbor Association of Industry and Commerce for generously supporting our Research Training Program.

STUDENT AWARD WINNERS AT 2003 ANNUAL MEETING

At the 2003 Annual Meeting, held May 9–10 at California State University, Northridge, the following students papers and posters won awards.

Awarded by the Southern California Academy of Sciences

Best Paper, Ecology/Evolution

Kelly S. Andrews. Department of Biology, San Diego State Univ., San Diego, CA 92182

HABITAT-DEPENDENT RECRUITMENT OF TWO TEMPERATE REEF FISHES AT MULTIPLE SCALES

M. Patrick Griffith. Department of Botany, Claremont Graduate University, Claremont, CA 91711

WHAT DID THE FIRST CACTUS LOOK LIKE? EVIDENCE FROM NEW MOLECULAR DATA

Best Poster, Ecology/Evolution

Lisa Gilbane and S. Murray. 800 N. State College, California State University, Fullerton, Department of Biological Sciences, Fullerton, CA 92093-0208

ANALYSES OF CARBON (^{13}C) AND NITROGEN (^{15}N) STABLE ISOTOPE SIGNATURES OF INPUTS INTO BENTHIC FOOD WEBS ON SOUTHERN CALIFORNIA ROCKY SHORES

Best Paper, Molecular Biology

Donovan P. German, M.H. Horn, and A. Gawlicka. Department of Biological Science, California State University, Fullerton, Fullerton, CA 92834

DIGESTIVE ENZYME ACTIVITIES IN THE OMNIVOROUS *PHYTICHTHYS CHIRUS* (STICHAEIDAE): EVIDENCE FOR MEMBERSHIP IN AN HERBIVOROUS CLADE OF PRICKLEBACK FISHES

Best Poster, Molecular Biology

Danielle L. Neumann and K. Dickson. California State University of Fullerton, Department of Biological Science, Fullerton, CA 92831-3599

A COMPARATIVE STUDY OF THE DIGESTIVE ENZYME ACTIVITY OF TUNAS, MACKERELS AND BONITOS

Best Paper, Geology

Kevin S. Rivera and V. Pedone. Department of Geological Sciences, California State University, Northridge, CA 91330-8266

GROUNDWATER DISCHARGE DEPOSITS IN THE MOJAVE DESERT, CALIFORNIA

Best Paper, Physical Sciences

Jennifer McAdam and J. Landry. Loyola Marymount University, Department of Natural Science, Los Angeles, CA 90045

TRACE METAL ANALYSIS OF THE CALIFORNIA HORN SNAIL (*CERITHIDEA CALIFORNIA*) IN THE BALLONA WETLANDS

Awarded by the American Institute of Fishery Research Biologists

Best Paper

Matthew E. Neilson and R.R. Wilson, Jr. Department of Biological Sciences, California State University, Long Beach

MITOCHONDRIAL DNA GENETICS OF AN INVASIVE POPULATION OF YELLOWFIN GOBY *ACANTHOGOBIUS FLAVIMANUS* IN CALIFORNIA

Runner-up Best Paper

Jeremy J. Vaudo, C. G. Lowe, and G. J. Moss. California State University, Long Beach, Department of Biological Sciences, Long Beach, CA 90840

MOVEMENTS AND SITE FIDELITY OF THE ROUND STINGRAY, *UROBATIS HALLERI,* AT SEAL BEACH, CALIFORNIA: A PRELIMINARY REPORT

Best Poster

Kim Carpenter, J. Flannery, R. Pommerening, T. Speer, and K. Martin. Department of Biology, Pepperdine University, Malibu, CA 90263-4321

DOES BEACH GROOMING HARM GRUNION EGGS?

Southern California Academy of Sciences 2003 Session Schedule

Friday, May 9, 2003
Location: Santa Clarita Room

Session: Changing Fish Populations Relative to the Environment, Fisheries, and Management

Chair: M. James Allen, SCCWRP

1. 8:40 **TEMPORAL TRENDS IN SHALLOW NEARSHORE AND DEEPER CONTINENTAL SHELF FISHES SINCE 1977; DO SIMILAR RESPONSES SUGGEST A COMMON MECHANISM BEHIND OBSERVED DECLINES? A. J. Brooks**[1], H. Lenihan[2], S. Lester[3], S.J. Holbrook[3], and R.J. Schmitt[3]. [1]Marine Science Institute, University of California, Santa Barbara, CA 93106; [2]Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106; [3]Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106.
2. 9:00 **DECLINES IN ABUNDANCE OF THREE NEARSHORE SURFPERCHES OFF HUNTINGTON BEACH, CALIFORNIA, 1972–2001. D.S. Beck**[1] and K.T. Herbinson[2]. [1]MBC Applied Environmental Sciences, Costa Mesa, CA, 92626, and [2]Southern California Edison Company, Rosemead, CA, 91770.
3. 9:20 **EFFECTS OF CHANGING OCEAN CONDITIONS ON THE FUNCTIONAL ORGANIZATION OF SOUTHERN CALIFORNIA DEMERSAL FISH COMMUNITIES. M. James Allen**. Southern California Coastal Water Research Project, Westminster, CA 92683.
4. 9:40 **TEMPORAL TRENDS IN SOUTHERN CALIFORNIA NEARSHORE FISH POPULATIONS RELATIVE TO ENVIRONMENTAL INFLUENCES. M. J. Allen**[1], R. W. Smith[2], E. T. Jarvis[1], V. Raco-Rands[1], B. Bernstein[3], and K. Herbinson[4]. [1]Southern California Coastal Water Research Project, Westminster, CA 92683; [2]Ojai, CA 93024; [3]Ojai, CA 93024; [4]Southern California Edison Co., Rosemead, CA 91770.
5. 10:00 **SOUTHERN CALIFORNIA TRENDS IN RECREATIONAL FISH CATCH. E.T. Jarvis**. Southern California Coastal Water Research Project, Fish Group, Westminster, CA, 92683.
6. 10:20 **ENVIRONMENTAL INFLUENCES ON CALIFORNIA COMMERCIAL FISH AND INVERTEBRATE LANDINGS. J. G. Norton** and Janet E. Mason. Pacific Fisheries Environmental Laboratory/SWFSC, 1352 Lighthouse Avenue, Pacific Grove, CA, 93950.

10:40 **Break**

11:00 **Plenary Talk: Dr. Brian Fagan, UCSB. "El Nino, the Little Ice Age and People of the Past."**

12:00 **Lunch**

7. 1:20 **CONSERVATION MANAGEMENT OF UNDERSIZED BYCATCH IN THE GROUPER-SNAPPER FISHERY OF THE EASTERN GULF OF MEXICO. R. R. Wilson, Jr.** and Karen M. Burns[1]. Department of Biological Sciences, California State University, Long Beach, CA; [1]Fisheries Biology Program, Mote Marine Laboratory, Sarasota, FL.
8. 1:40 **BIOLOGY AND POPULATION DYNAMICS OF COWCOD ROCKFISH (*SEBASTES LEVIS*) IN THE SOUTHERN CALIFORNIA BIGHT. J. L. Butler**[1], L. D. Jacobson[2], J. T. Barnes[3], and H. G. Moser[1]. [1]National Marine Fisheries Service, Southwest Fisheries Science Center, P.O. Box 271, La Jolla, California 92038; [2]National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street Woods Hole, Massachusetts 02543; [3]California Department of Fish and Game, Southwest Fisheries Science Center, P.O. Box 271, La Jolla, California 92038.
9. 2:00 **GOOD NEWS AND BAD NEWS FROM LONG-TERM FISH MONITORING. D. J. Pondella, II**. Vantuna Research Group, Department of Biology, Moore Laboratory of Zoology, Occidental College, Los Angeles, CA, 90041.
10. 2:20 **DOCUMENTING THE RETURN OF A FISHERY? DISTRIBUTION AND ABUNDANCE OF JUVENILE WHITE SEABASS (*ATRACTOSCION NOBILIS*) IN THE SHALLOW NEARSHORE WATERS OF THE SOUTHERN CALIFORNIA BIGHT, 1995–2002. L. G. Allen**[1], D. J. Pondella II[2], M. Shane[3], and R. F. Ford[3]. [1]California State University, Northridge, CA 91330-8303; [2]Occidental College, Los Angeles, CA 90041; [3]San Diego State University, San Diego, CA 92182.

11. 2:40 **CALIFORNIA'S FISHERIES: LANDINGS INCREASE, BUT VALUE DECLINES.** **J. Mason**. Pacific Fisheries Environmental Lab, DOC/NOAA/NMFS/SWFSC, 1352 Lighthouse Ave, Pacific Grove, CA 93950.
3:00 **Break**

Friday, May 9, 2003
Location: Santa Clarita Room

Session: Contributed Papers in Fish Biology

Chair: Dr. Ralph G. Apply, Port of Los Angeles

12. 3:20 **GROWTH BIOMARKERS IN FISH: IGFBPs (insulin-like growth factor-binding proteins).** **K.M. Kelley**, M.M. Galima, J.A. Reyes, K. Sak, K. Goldman, D. Topping and C.G. Lowe (2003). Endocrine Laboratory, Department Biological Sciences, California State University, Long Beach, Long Beach, CA 90840.

13. 3:40 **BEHAVIORAL RESPONSES AND SURVIVORSHIP OF CALIFORNIA SHEEPHEAD TO POST-RELEASE ANGLING STRESS.** **K.J. Goldman**, D.T. Topping, M.M. Galima, K.M. Kelley and C.G. Lowe. California State University Long Beach, Department of Biological Sciences, 1250 Bellflower Blvd., Long Beach, CA 90840.

14. F 4:00 **ENDOCRINE ALTERATIONS IN RESPONSE TO CATCHING STRESS IN CALIFORNIA SHEEPHEAD: METABOLIC AND GROWTH IMPACTS.** **M.M. Galima**, D.T. Topping, K.J. Goldman, C.G. Lowe, and K.M. Kelley. Department of Biological Sciences, California State University Long Beach, Long Beach, CA 90840.

15. 4:20 **DOWNSTREAM MIGRATION OF STEELHEAD TROUT AND RESIDENCE IN A LOWER MAINSTEM AT 35° N.** **A.P. Spina**[1], M.A. Allen[2] and M.V. Clarke[3]. [1]National Marine Fisheries Service, Long Beach, CA 90802; [2]Thomas R. Payne & Associates, Arcata, CA 95518; [3]City of San Luis Obispo, San Luis Obispo, CA 93401.

16. 4:40 **MEASURING BARRIERS TO FISH PASSAGE IN THE SANTA MONICA MOUNTAINS.** **S.L. Drill**. University of California Cooperative Extension, 2 Coral Recovery Coalition, P.O. Box 91034, Santa Barbara, CA 93190.

Friday, May 9, 2003
Location: Pasadena Room

Session: Geology

Chairs: Vicki A. Pedone and Peter W. Weigand, CSU Northridge

17. P 1:20 **GEOCHEMICAL AND MINERALOGICAL ANALYSIS OF THE "BLUE DRAGON" FLOW IN CRATERS OF THE MOON NATIONAL MONUMENT, IDAHO.** **T. Collins**. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

18. P 1:40 **A GEOCHEMICAL AND PETROLOGIC STUDY OF POWAY CLASTS IN SAN DIEGO AND THE CHANNEL ISLANDS, CALIFORNIA.** **L. G. Field** and P.W. Weigand. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

19. P 2:00 **ANIMATION OF THE RECENT GEOLOGIC EVOLUTION OF SOUTHERN CALIFORNIA.** **G. A. Briscoe**, A. E. Fritsche, and P. W. Weigand. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

20. P 2:20 **A FIELD AND PETROGRAPHIC ASSESSMENT OF A PORTION OF THE KERN PLATEAU SHEAR ZONE, TULARE COUNTY, CALIFORNIA.** **K. Mahr Hill** and G. Dunne. Department of Geological Sciences, California State University, Northridge, CA 91330.

21. P 2:40 **EVALUATION OF SAND AND PEBBLE PROVENANCE FOR CONSTRAINING RATES OF STREAM CHANNEL OFFSET BY THE SAN ANDREAS FAULT ON THE CARRIZO PLAIN, CALIFORNIA.** **R. J. O'Neil**. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

3:00 **Break**

22. P 3:20 **SEISMIC HAZARD ANALYSIS OF THE SAN FERNANDO VALLEY USING THE FRISKSP COMPUTER PROGRAM. R. J. Medina**. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

23. P 3:40 **DETERMINING THE DEPOSITIONAL AGE OF PEAT: IMPLICATIONS FOR DATING PALEOEARTHQUAKES AT THE BURRO FLATS PALEOSEISMIC SITE NEAR BANNING, CALIFORNIA. C. L. Howland** and J. Douglas Yule. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

24. P 4:00 **GROUNDWATER DISCHARGE DEPOSITS IN THE MOJAVE DESERT, CALIFORNIA. K. S. Rivera** and V. Pedone. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

25. P 4:20 **SUBAQUEOUS SPRING DEPOSTS IN LIMESTONE FROM THE MIDDLE MIOCENE BARSTOW FORMATION, MOJAVE DESERT, CALIFORNIA. B. C. Sill**. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

26. P 4:40 **CHAROPHYTE MOUNDS IN THE MIDDLE MIOCENE BARSTOW FORMATION, MUD HILLS, CALIFORNIA. C. Caceres** and V. Pedone. Department of Geological Sciences, California State University, Northridge, CA 91330-8266.

Friday, May 9, 2003
Location: Flintridge

Session: Teacher Education in Science

Chair: Virginia Vandergon, CSU Northridge

27. 3:20 **STUDENT RESEARCH IN K-12 CLASSES MENTORED BY TEACHERS TRAINED IN UNIVERSITY RESEARCH LABS. S. B. Oppenheimer**. Center for Cancer and Developmental Biology, California State University, Northridge, Northridge, CA 91330-8303.

28. 3:40 **RESEARCH EXPERIENCES FOR TEACHERS OPENS THE DOOR FOR RESEARCH EXPERIENCES FOR K–12 STUDENTS. A MEASURE OF CLASSROOM IMPLEMENTATION SUCCESS. C. A. Coyle-Thompson**. California State University, Northridge, Department of Biology, Northridge, CA 91330.

29. 4:00 **CALIFORNIA STATE UNIVERSITY NORTHRIDGE RESEARCH FELLOWSHIPS FOR TEACHERS. N. Herr**. California State University, Northridge, Department of Secondary Education, Northridge, CA 91330-2580.

30. 4:20 **TOMORROW'S SCIENTIST, USING A SERVICE LEARNING MODEL WITH PRE-SERVICE TEACHERS TO RUN AN AFTER-SCHOOL SCIENCE PROGRAM FOR MIDDLE SCHOOLERS. V. Oberholzer Vandergon**. California State University, Northridge, Department of Biology, Northridge, CA 91330-8303.

31. 4:40 **ENHANCEMENTS OF SCIENCE CONTENT KNOWLEDGE THROUGH THE SCIENCE LEADERSHIP INITIATIVE–A SUPERFUNDED PROJECT. G. Simila**, Virginia Oberholzer Vandergon and Steven Oppenheimer. California State University, Northridge, Department of Geological Sciences, Northridge, CA 91330-8266.

Friday, May 9, 2003
Location: Thousand Oaks

Session: Contributed Papers

Chair: Dr. Judith Doino Lemus, Sea Grant Program, USC

32. P 9:00 **TRACE METAL ANALYSIS OF THE CALIFORNIA HORN SNAIL (*CERITHIDEA CALIFORNIA*) IN THE BALLONA WETLANDS. J. McAdam** and J. Landry. Loyola Marymount University, Department of Natural Science, Los Angeles, CA, 90045.

33. P 9:20 **STUDIES DIRECTED TOWARD THE TOTAL SYNTHESIS OF ERGOLINE ALKALOIDS. A. Schultz** and T. Oh. California State University Northridge, Department of Chemistry, Northridge, CA 91330.

34. P 9:40 **SYNTHESIS OF 2-(1,1′-BINAPHTHYL) CHIRAL AUXILIARIES. T. Tasu** and T. Oh. California State University Northridge, Department of Chemistry, Northridge, CA, 91330-8262.

35. M 10:00 **MOLECULAR AND MORPHOMETRIC ANALYSIS OF THE ENDANGERED YELLOW POND TURTLE (*MAUREMYS MUTICA*). J.J. Fong** and R.L. Carter. Department of Natural Sciences, Loma Linda University, Loma Linda, CA 92350.

36. 10:20 **THE MOLECULAR EVOLUTION OF THE *MYB* GENE FAMILY IN BAMBOO AND SORGHUM. A. Norris** and V. Oberholzer Vandergon. Calif. State Univ., Northridge, Department of Biology, Northridge, CA 91330.

10:40 **Break**

11:00 **Plenary Talk: Dr. Brian Fagan, UCSB. "El Nino, the Little Ice Age and People of the past."**

12:00 **Lunch**

Friday, May 9, 2003
Location: Thousand Oaks

Session: Contributed Papers (Continued)

Chair: John Roberts, CSU Dominguez Hills

37. E 1:20 **AN OIL POLLUTION MODEL USING SOUTHERN CALIFORNIA WILLOWS. K. Williams**, J. Torres, C.M. Vadheim, and **J.W. Roberts***. The Applied Environmental Plant Physiology Laboratory, CSU Dominguez Hills, Department of Biology, Carson, CA 90747.

38. E 1:40 **CHANGING MACROPHYTE ABUNDANCES AND PRIMARY PRODUCTIVITY OF A SOUTHERN CALIFORNIA SHORE. A. M. Bullard** and S. N. Murray. California State University, Fullerton, Department of Biological Science, Fullerton, CA 92834-6850.

39. E 2:00 **POSSIBLE "EVIL TWIN" EFFECT THROUGH COMPETITION OF ARROYO WILLOW CLONES. M. Drexler**, C.M. Vadheim and **J.W. Roberts***. The Applied Environmental Plant Physiology Laboratory, CSU Dominguez Hills, Department of Biology, Carson, CA 90747.

40. E 2:20 **THE USE OF *BRASSICA NIGRA* AS AN ADJUNCT GENETIC MODEL FOR THE STUDY OF SALT TOLERANCE. Candice Groat**, Richard Kuromoto and John Roberts. CSUDH Department of Biology, Applied Plant Physiology Laboratory, Carson, CA 90747.

41. E 2:40 **THE EFFECTS OF LONG-TERM COPPER EXPOSURE ON TWO SPECIES OF *SALIX*, CALIFORNIA WILLOW. L.M. Peters**, R. Resendiz, C.M. Vadheim and **J.W. Roberts***. The Applied Environmental Plant Physiology Laboratory, CSU Dominguez Hills, Department of Biology, Carson, CA 90747.

3:00 **Break**

42. E 3:20 **A *BOLD* VISION: ENHANCING WETLAND EDUCATION AND RESTORATION THROUGH THE BALLONA OUTDOOR LEARNING & DISCOVERY (BOLD) AREA. K. Sueda**, P. M. Drennen, J. H. Dorsey, J. M. Landry, J. McAdams, T. D. McShurley, L. Roberts, and W. Scheidegger. Loyola Marymount University, Department of Natural Sciences, One LMU Drive, Los Angeles, CA 90045.

43. E 3:40 **MITOCHONDRIAL DNA GENETICS OF AN INVASIVE POPULATION OF YELLOWFIN GOBY *ACANTHOGOBIUS FLAVIMANUS* IN CALIFORNIA. M.E. Neilson** and R.R. Wilson, Jr. Department of Biological Sciences, California State University, Long Beach.

44. E 4:00 **ARE COASTAL WETLANDS IN SOUTHERN CALIFORNIA SOURCES OR SINKS FOR FECAL INDICATOR BACTERIA? M. Evanson** and R. F. Ambrose. Environmental Science and Engineering Program, School of Public Health, UCLA, Los Angeles, CA 90095.

45. 4:20 **FIRST YEAR SURVEY RESULTS OF THE LOS ANGELES CONTAMINATED SEDIMENTS TASK FORCE, CONFINED AQUATIC DISPOSAL SITE LONG-TERM MONITORING PROGRAM.** **S. C. Johnson** and Tim Mikel. Aquatic Bioassay and Consulting Laboratories, Inc., Ventura, CA 93001.

46. F 4:40 **EFFECTS OF CONTAMINANTS ON THE GROWTH PATTERNS OF PACIFIC SANDDAB (*CITHARICHTHYS SORDIDUS*) FROM SANTA MONICA BAY AND DANA POINT, CALIFORNIA.** **B.A. Swig** and C.C. Hogue. California State University Northridge, Department of Biology, Northridge, CA 91330.

Friday, May 9, 2003
Location: Grand Salon

Session: Poster Session and Wine and Cheese Social

47. E **ARTHROPOD SPECIES DIVERSITY IN RESTORED AND UNDISTURBED COASTAL SAGE SCRUB.** **J. Blodgett**, B. Stimmler, and C. Swift. Department of Biology, Whittier College, Whittier, CA 90608.

48. **DIGENEAN ENDOPARASITE COMMUNITIES OF FISHES OF THE SERRANID GENUS *PARALABRAX*.** **D.G. Buth**[1], D.J. Pondella II[2], and P. Frost[3]. [1]Dept. of Organismic Biology, Ecology, and Evolution, UCLA, Los Angeles, CA 90095-1606; [2]Vantuna Research Group, Occidental College, Dept. of Biology, Los Angeles, CA 90041; [3]Dept. of Psychiatry and Behavioral Sciences, Neuropsychiatric Institute and Brain Research Institute, UCLA School of Medicine, Los Angeles, CA 90095-1761.

49. F **DOES BEACH GROOMING HARM GRUNION EGGS?** **K. Carpenter**, J. Flannery, R. Pommerening, T. Speer, and K. Martin. Department of Biology, Pepperdine University, Malibu, CA 90263-4321.

50. E **RELATIONSHIPS BETWEEN FOOD CHOICE AND TOTAL ASSIMILATION EFFICIENCY IN THE HERBIVOROUS MARINE SNAIL *LITHOPOMA UNDOSUM* (TURBINIDAE).** **E. Cox** and S. Murray. California State University, Fullerton, CA 92834-6850.

51. E **ANALYSES OF CARBON (^{13}C) AND NITROGEN (^{15}N) STABLE ISOTOPE SIGNATURES OF INPUTS INTO BENTHIC FOOD WEBS ON SOUTHERN CALIFORNIA ROCKY SHORES.** **L. Gilbane** and S. Murray. 800 N. State College, California State University, Fullerton, Department of Biological Sciences, Fullerton, CA 92093-0208.

52. **SUCCESSFUL REINTRODUCTION OF A TIDEWATER GOBY (*EUCYCLOGOBIUS NEWBERRYI*) POPULATION AT SAN MATEO LAGOON, USMC CAMP J. PENDLETON, CALIFORNIA.** **A.T. Gutierrez**, M.A. Booker, and C.C. Swift, Dr. Merkel & Associates, Inc., San Diego, CA 92123.

53. M **A COMPARATIVE STUDY OF THE DIGESTIVE ENZYME ACTIVITY OF TUNAS, MACKERELS AND BONITOS.** **D.L. Neumann** and K. Dickson. California State University of Fullerton, Department of Biological Science, Fullerton, CA 92831-3599.

54. M **MITOCHONDRIAL DENSITIES IN THE LOCOMOTOR MUSCLE OF ECTOTHERMIC AND ENDOTHERMIC SCOMBRID FISHES.** **C.M. Porcu** and K. Dickson. Cal State University College, Department of Biology, Fullerton, CA 92831.

55. **PRELIMINARY STUDIES ON A NEW APPROACH TO DEVELOPMENT OF CELL TYPE SPECIFIC ANTI-CANCER DRUGS.** **E.L. Heinrich**, A. Contreras, M. Khurrum, O. Badali, L. Banner and S. Oppenheimer. Department of Biology and Center for Cancer and Developmental Biology, California State University, Northridge, CA 91330-8303.

56. **BEAD ANALYSIS OF HUMAN COLON CANCER CELL SURFACES.** **M.R. Khurrum**, O. Badali, A. Contreras, L.Y. Welty, E. Heinrich, M. Barajas, G.C. Zem, and S.B. Oppenheimer. Department of Biology and Center for Cancer and Developmental Biology, California State University Northridge, Northridge, CA 91330-8303.

57. F **INITIAL PROTOCOLS FOR THE CAPTIVE BREEDING AND REARING OF SPOTTED SAND BASS (*PARALABRAX MACULATOFASCIATUS*) IN SOUTHERN CALIFORNIA.** **E.F. Miller**. Nearshore Marine Fish Research Program, California State University, Northridge, Department of Biology, Northridge, CA 91330-8303.

58. **SOUTHERN CALIFORNIA STEELHEAD: RESTORING A LIVING LEGACY. D. Pritchett**, Southern California Steelhead Coalition, P. O. Box 91034, Santa Barbara, CA 93190 dapritch@cox.net; and Sabrina Drill, University of California Cooperative Extension, 2 Coral Circle, Bldg. B Floor 2, Monterey Park, CA 91755-7425 sldrill@ucdavis.edu

59. P **ASYMMETRIC SYNTHESIS OF 1,1′-BINAPHTHYL-2, 2′-DIAMINE. M. Sina-Kahdiv**, M. Thaman, and T. Oh. California State University Northridge, Department of Chemistry, Northridge, CA 91330-8262.

60. **SCIENTIFIC INVESTIGATIONS AND STUDENT ENGAGEMENT IN OSMOSIS AND DIFFUSION LAB ACTIVITIES: AN ANALYSIS OF TEN LABORATORY MANUALS. M.E. Tweedy** and W.J. Hoese. California State University Fullerton, Department of Biological Science, Fullerton, CA 92834.

61. **SURFACE ANALYSIS OF HUMAN COLON CANCER AND NON-CANCER CELL LINES. L.Y. Welty**, M. Khurrum, H. Hekmatjou, I. Livshin, J. Calderon, S. Sajadi, L. Baresi, and S. Oppenheimer. Department of Biology and Center for Cancer and Developmental Biology, California State University Northridge, Northridge, CA 91330-8303.

62. E **THE EFFECTS OF AN INVASIVE PLANT COMMUNITY ON THE COASTAL SAGE SCRUB SOIL MICROBIAL COMMUNITY. M. Winters** and D. Lipson. San Diego State University, Department of Biology, San Diego, CA 92182.

63. E **SOIL NITROGEN STORAGE IN AREAS OF VARYING ANTHROPOGENIC NITROGEN DEPOSITION IN SOUTHERN CALIFORNIA. G. Zorba** and G. Vourlitis. California State University, San Marcos, Department of Biological Sciences, San Marcos, CA 92078.

64. M **PCR BASED SECONDARY SCREENING OF CLONED DNA USED FOR SEQUENCING DECISION MAKING. J. A. Sonnentag**, S. Yamamoto, and R. L. Carter. Loma Linda University, Natural Sciences Department, Loma Linda, CA 92350.

Saturday, May 10, 2003
Location: Santa Clarita Room

Session: Reef Ecology

Chairs: Daniel Pondella II. Vantuna Research Group, Occidental College
Robert Grove, Southern California Edison

8:50 **INTRODUCTION.** Dan Pondella and Robert Grove

65. E 9:00 **SPAWNING BEHAVIOR OF THE KELP BASS, *PARALABRAX CLATHRATUS*, FROM SANTA CATALINA ISLAND, CALIFORNIA. B.E. Erisman**. Nearshore Marine Fish Research Program, California State University, Department of Biology, 18111 Nordhoff Street, Northridge, CA 91330-8303.

66. 9:20 **OBSERVATIONS OF COURTSHIP AND SPAWNING BEHAVIOR IN THE CALIFORNIA SHEEPHEAD, *SEMICOSSYPHUS PULCHER*. M.S. Adreani**[1]. [1]University, Northridge, CA 91330; [2]Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106.

67. E 9:40 **THE SPAWNING ACTIVITY AND ASSOCIATED SOUND PRODUCTION OF WHITE SEABASS, *ATRACTOSCION NOBILIS*, AROUND SANTA CATALINA ISLAND. S.A. Aalbers**. CSU Fullerton, Department of Biology, Fullerton, CA 92834.

68. 10:00 **WHEELER NORTH'S "TAMPICO MARU": RE-DISCOVERING BAJA CALIFORNIA'S "EXXON VALDEZ." Alan J. Mearns**. Senior Staff Scientist Hazardous Materials Reponse Division National Oceanic and Atmospheric Administration Seattle, Washington 98115.

69. 10:20 **THERE AND BACK*, THE RESPONSE AND RECOVERY OF SOUTHERN CALIFORNIA KELP BEDS FROM THE 1997–1998 EL NINO SUMMARY 1997–2002. M. D. Curtis** and Wheeler J. North (Professor Emeritus—deceased). MBC Applied Environmental Sciences Costa Mesa, and CalTech Kerchkoff Marine Laboratory.

10:40 **Break**

11:00 **Memorial in Honor of Wheeler J. North. Remarks by Charles T. Mitchell, MBC Applied Environmental Science**

11:15 **Plenary Talk: Dr. Milton Love, Marine Science Institute, UCSB "Why do we Study Reef Fishes?"**

12:00 **Lunch**

70. E 1:40 **PATTERNS OF HABITAT AND ABUNDANCE IN THE LA JOLLA KELP BED. Ed Parnell**. Scripps Institute of Oceanography, UCSD.

71. E 2:00 **LONG-TERM VARIATION IN A SOUTHERN CALIFORNIA KELP FOREST. L. Honma**, AMEC Earth & Environmental, 5510 Morehouse Dr., San Diego, CA 92121. M. Foster, Moss Landing Marine Labs, Moss Landing, CA 95039.

72. E 2:20 **EVALUATION OF EELGRASS MITIGATION AND FISHERY ENHANCEMENT STRUCTURES IN SAN DIEGO BAY. D.J. Pondella, II**[1], L. G. Allen[2], J. R. Cobb[1], M. T. Craig[3] and B. Gintert[1]. [1]Vantuna Research Group, Department of Biology, Moore Laboratory of Zoology, Occidental College, Los Angeles, CA 90041; [2]Department of Biology, California State University, Northridge; [3]Scripps Institution of Oceanography.

73. E 2:40 **HABITAT-DEPENDENT RECRUITMENT OF TWO TEMPERATE REEF FISHES AT MULITPLE SCALES. K.S. Andrews**. Department of Biology, San Diego State University, San Diego, CA 92182.

3:00 **Break**

74. E 3:20 **POPULATION DYNAMICS AND PRODUCTIVITY OF CRYPTIC FISHES. Jana Cobb**. Dept of Biology, California State Univ. Northridge.

75. 3:40 **A COMPARISON OF REEF FISH ASSEMBLAGES BETWEEN SANTA CATALINA ISLAND AND THE OUTER LOS ANGELES FEDERAL BREAKWALL. J.T. Froeschke**. Nearshore Marine Fish Research Program, California State University, Northridge, Department of Biology, 18111 Nordhoff St. Northridge CA, 91330.

Saturday, May 10, 2003
Location: Thousand Oaks Room

Session: Contributed Papers in Fish Biology

Chair: Erica Jarvis, SCCWRP

76. E 9:00 **RELATIONSHIP OF MORPHOLOGY, DIET, AND FEEDING GUILD STRUCTURE IN THE INTERTIDAL FISH ASSEMBLAGE OF CENTRAL CALIFORNIA. K. S. Boyle** and M. H. Horn. Department of Biological Science, California State University, Fullerton, CA 92834-6850.

77. M 9:20 **DIGESTIVE ENZYME ACTIVITIES IN THE OMNIVOROUS *PHYTICHTHYS CHIRUS* (STICHAEIDAE): EVIDENCE FOR MEMBERSHIP IN AN HERBIVOROUS CLADE OF PRICKLEBACK FISHES. D.P. German**, M.H. Horn, and A. Gawlicka. Department of Biological Science, California State University, Fullerton, Fullerton, CA 92834.

78. E 9:40 **ONTOGENY OF DIET, TROPHIC POSITION, AND FEEDING GUILD MEMBERSHIP IN HERBIVOROUS AND CARNIVOROUS PRICKLEBACK FISHES (STICHAEIDAE): DIETARY AND STABLE ISOTOPE ANALYSIS. Michael V. Saba** and M. H. Horn. California State University, Fullerton, Department of Biological Science, Fullerton, CA 92834.

79. E 10:00 **MOVEMENTS AND SITE FIDELITY OF THE ROUND STINGRAY, *UROBATIS HALLERI,* AT SEAL BEACH, CALIFORNIA: A PRELIMINARY REPORT. J. J. Vaudo**, C. G. Lowe, and G. J. Moss. California State University, Long Beach, Department of Biological Sciences, Long Beach, CA 90840.

80. 10:20 **DISTRIBUTION AND ABUNDANCE OF THE ROUND STINGRAY, *UROLOPHUS HALLERI,* NEAR A THERMAL OUTFALL AT SEAL BEACH, CALIFORNIA. G. Hoisington** and C.G. Lowe. Department of Biological Sciences, California State University, Long Beach, CA 90840-3702.

10:40 **Break**

11:00 **Memorial in Honor of Wheeler J. North. Remarks by Charles T. Mitchell, MBC Applied Environmental Science**

11:15 **Plenary Talk: Dr. Milton Love, Marine Science Institute, UCSB "Why do we Study Reef Fishes?"**

12:00 **Lunch**

Saturday, May 10, 2003
Location: Thousand Oaks Room

Session: Contributed Papers

Chair: Cheryl Hogue, CSU Northridge

81. F 1:40 **CAPTIVE SPAWNING BEHAVIOR OF THE SPOTTED SAND BASS (*PARALABRAX MACULATOFASCIATUS*). E. F. Miller**. Nearshore Marine Fish Research Program, California State University, Northridge, Department of Biology, Northridge, CA 91330-8303.

82. 2:00 **ARE JUVENILE TOPSMELT REALLY BEACH FISH? A. Jahn**. Port of Oakland, Oakland, CA 94607.

83. 2:20 **GRUNION GREETERS: VOLUNTEERS MONITORING GRUNION RUNS IN SAN DIEGO. K. Martin**, T. Speer, R. Pommerening, J. Flannery, and K. Carpenter. Department of Biology, Pepperdine University, Malibu, CA 90263-4321.

84. 2:40 **AGGREGATION RESPONSE TO CHEMICAL ATTRACTANTS RELEASED BY *TEGULA* SPECIES. G.K. Nishiyama** and C.A. Kay-Nishiyama. College of the Canyons, Department of Biology, Santa Clarita, CA 91350.

3:00 Break

85. P 3:20 **CLIMATIC AND LITHOLOGIC INFLUENCES ON QUATERNARY TERRACE FORMATION BASED ON PRELIMINARY SOIL INDICES, SANTA ANA MOUNTAINS, CALIFORNIA. O. F. Figueroa**, N. A. Ikeda, C. M. Irwin, R. A. Perez, A. M. Stein and J.R. Knott. Department of Geological Sciences, California State University Fullerton, Fullerton, California 92834-6850.

86. 3:40 **DIETARY SHIFTS OF ELEGANT TERNS AND CASPIAN TERNS AT TWO SOUTHERN CALIFORNIA NESTING COLONIES: RESPONSES TO CHANGES IN OCEAN CLIMATE AND PREY POPULATIONS. I. Chlup**[1] and M. H. Horn[2]. California State University, Fullerton, [1]Environmental Studies Program and [2]Department of Biological Science Fullerton, CA 92834-6850.

87. E 4:00 **A VASCULAR FLORA OF THE OWENS PEAK EASTERN WATERSHED. N. S. Fraga**. Department of Botany, Claremont Graduate University, Rancho Santa Ana Botanic Garden, 1500 N. College Ave. Claremont, CA 91711.

88. E 4:20 **WHAT DID THE FIRST CACTUS LOOK LIKE? EVIDENCE FROM NEW MOLECULAR DATA. M. P. Griffith**. Department of Botany, Claremont Graduate University, Claremont, CA 91711.

89. E 4:40 **MARIANO AND MANUEL'S MILPA: SUBSISTENCE FARMING IN THE SOCONUSCO REGION OF CHIAPAS. S. Alves**. California State University Dominguez Hills, Anthropology Department, Carson, CA.

Saturday, May 10, 2003
Location: West Valley

Session: Research Training Program

Chair: Martha and Richard Schwartz,
LA Co. Office of Ed. and Torrance High School

92. 9:40 **PHOTOMETRIC DETECTION OF AN EXTRA-SOLAR PLANETARY TRANSIT ACROSS THE SUN-LIKE STAR HD 209458. V. Chirayath**[1]. [1]Southern California Academy of Sciences & The California Academy of Math and Science, 1000 E. Victoria St. #8002, Dominguez Hills, CA 90747.

93. 10:00 **COMPARATIVE STUDY OF PLANKTON DENSITIES IN THE UPPER AND LOWER NEWPORT BAY AND THE FACTORS THAT AFFECT IT. A. Chaudhary**. Oxford Academy High School, Cypress, CA 90630.

94. 10:20 **CONVERSION OF A-AMINO ACIDS INTO NITRILES USING TRICHLOROISOCYANURIC ACID (TCICA). J. Bae**[1] and Gene Hiegel[2]. [1]Cypress High School, Cypress, CA 90630; [2]Department of Chemistry and Biochemistry, California State University Fullerton, Fullerton, CA 92834-6866.

10:40 **Break**

11:00 **Memorial in Honor of Wheeler J. North. Remarks by Charles T. Mitchell, MBC Applied Environmental Science**

11:15 **Plenary Talk: Dr. Milton Love, Marine Science Institute, UCSB "Why do we Study Reef Fishes?"**

12:00 **Lunch**

96. 2:00 ***AUREOCOCCUS ANOPHAGEFFERENS* IN COASTAL WATERS: PREVENTION CONTROL AND MITIGATION. S. Kadakia**. University of Southern California, Department of Biology, Cabrillo Marine Aquarium.

97. 2:20 **A TWO-YEAR STUDY: SAND CRABS, SAND PIPERS & POLLUTION: FACTORS EFFECTING SAND CRAB AND SAND PIPER POPULATIONS AT SITES IN THE SANTA MONICA BAY AND LOS ANGELES HARBOR. K. Nakaba**. Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90274.

98. 2:40 **GLOBAL WARMING: CAN BACTERIA REALLY HELP STOP IT? S.F. Ong**. California Academy of Mathematics and Science, Carson 90747.

3:00 **Break**

99. 3:20 **DISTRIBUTION OF OXIDATIVE AND GLYCOLYTIC ENZYMES IN ELECTROCYTES OF PHYLOGENTICALLY DIVERSE SPECIES OF FISH. E. Smetak, Jr.**, La Habra High School, La Habra Hts, CA, 90631; and G.H. Kageyama, California State Polytechnic University, Pomona, Dept. of Biological Sciences, Pomona, CA 91768.

100. 3:40 **DISTRIBUTION OF ARGENTINE ANTS ON THE PALOS VERDES PENINSULA: EFFECTS OF ABIOTIC FACTORS AND HUMAN DISTURBANCE. G. Y. Williams**. Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90275.

101. 4:00 **RECLAIMING THE ECOSYSTEM: EUTROPHICATION CONTROL WITH CALCIUM CARBONATE (PHOSPHATE-BINDING ION-EXCHANGE) FILTERS AND DENITRIFICATION IN FRESH WATER LAKES. V. Yanamadala**. Palos Verdes High School.

102. 4:20 **THE RELATIONSHIP BETWEEN THE PATTERNS OF PALEOMAGNETIC INTENSITY VARIATIONS IN EAST ASIA VERSUS THE PATTERNS OF INTENSITY ON OTHER PARTS OF THE WORLD.** S. Lund and **J. Lee**. University of Southern California, Department of Earth Sciences, 3651 Trousdale Pkway, Los Angeles, CA 90089.

103. 4:40 **CLONING THE C-TERMINUS OF *ATCDPPIV* IN TO A BACTERIAL EXPRESSION VECTOR. M. Hong**, B. Thorson and J. Brusslan. Dept. of Biological Sciences, California State University, Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840.

ABSTRACTS

1 **TEMPORAL TRENDS IN SHALLOW NEARSHORE AND DEEPER CONTINENTAL SHELF FISHES SINCE 1977; DO SIMILAR RESPONSES SUGGEST A COMMON MECHANISM BEHIND OBSERVED DECLINES?**

A. J. Brooks[1], H. Lenihan[2], S. Lester[3], S.J. Holbrook[3], and R.J. Schmitt[3]. [1]Marine Science Institute, University of California, Santa Barbara, CA 93106; [2]Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106; [3]Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, CA 93106

Populations of many shallow water (< 30m), coastal fish species within the southern California Bight have undergone dramatic declines over the past twenty-five years. Previous analyses of abundance data by us and others have demonstrated that the magnitudes of these declines were similar for all species regardless of trophic level, mode of reproduction, longevity, or habitat association. These patterns are consistent with the explanation that the observed regional decline in productivity associated with warmer ocean temperatures and decreased levels of upwelling since 1977 may have negatively affected larval production and/or larval survivorship leading to regional level declines in populations of nearshore fishes. We now extend these analyses to data collected by the National Marine Fisheries Service since 1977 on the abundance of deeper water (> 50m) groundfishes occurring over the outer Pacific coast continental shelf.

2 **DECLINES IN ABUNDANCE OF THREE NEARSHORE SURFPERCHES OFF HUNTINGTON BEACH, CALIFORNIA, 1972–2001**

D.S. Beck[1] and K.T. Herbinson[2]. [1]MBC Applied Environmental Sciences, Costa Mesa, CA 92626; [2]Southern California Edison Company, Rosemead, CA 91770

Fish populations offshore most of southern California's coastal generating stations have been routinely monitored by 1) demersal fish surveys by otter trawl, 2) in-plant fish impingement surveys, or 3) both methods. Nearshore demersal fish surveys have been conducted offshore the Huntington Beach Generating Station since 1972. Fish impingement studies at the generating station have also been conducted routinely since the early 1970s to quantify fish loss resulting from the operation of the cooling water intake system. For the most part, composition of the fish community sampled by trawl and assessed in-plant has remained somewhat similar through time, dominated by queenfish (*Seriphus politus*), white croaker (*Genyonemus lineatus*), and northern anchovy (*Engraulis mordax*). However, three surfperches (family Embiotocidae) that were highly abundant during the onset of trawl and impingement studies in the early- to mid-1970s declined steeply in the late-1970s and early-1980s, and their abundance has remained low. These species are walleye surfperch (*Hyperprosopon argenteum*), white seaperch (*Phanerodon furcatus*), and shiner perch (*Cymatogaster aggregata*). Trawl-caught numbers of these three species declined by 99–100% between 1979 and 1984, and the numbers impinged at the generating station declined by 97% or more during the same period. Abundance of these species has remained relatively low since 1984. Simultaneous surveys at other locations in the Southern California Bight suggest region-wide declines for some species, and these declines coincided with several consecutive years of warming ocean temperatures in southern California.

3 **EFFECTS OF CHANGING OCEAN CONDITIONS ON THE FUNCTIONAL ORGANIZATION OF SOUTHERN CALIFORNIA DEMERSAL FISH COMMUNITIES**

M. James Allen. Southern California Coastal Water Research Project, Westminster, CA 92683

Changing ocean conditions during the past 30 years have caused noticeable effects on fish populations in the Southern California Bight. Most effects have been observed in populations of pelagic or nearshore fishes. This study describes effects of changing ocean conditions on the organization of demersal fish communities on the continental shelf. The study is based on three large-scale studies of the demersal fish fauna of the southern California shelf at depths of 10 to 200 m conducted in 1972–1973 (cold regime), 1994 (warm regime), and 1998 (El Niño). The 1994 and 1998 studies are compared to a baseline model of the functional organization the communities developed by the author using 1972–1973 data, that described the occurrence of 18 foraging guilds and their distribution across

the southern California shelf at depths of 10 to 200 m. The order of depth displacing species within a given guild relative to depth generally did not change but the relative area occupied by a guild dominant often did change. Changes in depth displacement patterns between cold- and warm-regimes, and the El Niño varied by guild. El Niño effects included expansions or contractions of depth ranges of guild members, retreats of some guilds to deeper water, and intrusions of new dominant guild members from the south. Warm and cold regime changes were less pronounced but some gradual declines in deeper species were apparent. Examination of depth displacement patterns within foraging guilds provides a unique perspective to effects of changing ocean conditions on demersal fish communities.

4 TEMPORAL TRENDS IN SOUTHERN CALIFORNIA NEARSHORE FISH POPULATIONS RELATIVE TO ENVIRONMENTAL INFLUENCES

M. J. Allen[1], R. W. Smith[2], Erica T. Jarvis[1], V. Raco-Rands[1], B. Bernstein[3], and K. Herbinson[4]. [1]Southern California Coastal Water Research Project, Westminster, CA 92683; [2]Ojai, CA 93024; [3]Ojai, CA 93024; [4]Southern California Edison Co., Rosemead, CA 91770

Changes in the abundance of southern California fish populations during the past three decades have raised concern that these populations are at risk. These changes have been attributed to changes in oceanic conditions, overfishing, pollution, and habitat alteration. The objective of this study is to assess the relative importance of natural and environmental influences on population changes in southern California nearshore fishes. This study compares trends found in a number of long-term fish and environmental databases. Fish databases included power generating station fish impingement and trawl monitoring, recreational fishing, and publicly owned treatment plant (POTW) trawl monitoring. Combined, these databases provided information on 300 species of fish. Environmental databases included oceanographic data, shoreline temperature, stormwater runoff, and contaminant concentrations in POTW effluents. Relationships of fish and environmental trends were determined using multiple regression analysis, ordination, cluster analysis, and recurrent group analysis. Environmental variables generally showed distinctly different patterns over the 30 year period, with Pacific decadal oscillation and annual surface runoff trends being most similar. The Pacific decadal oscillation was the dominant influence for the most species in these databases, with upwelling off southern California and Baja California playing an important role for others. The influence of surface runoff and contamination on fish population trends was less important than natural changes in the oceanic environment. The reduced abundance of cold-water species during the regime shift at the end of the 1970s was compensated only in part by increased abundances of warm-water species.

5 SOUTHERN CALIFORNIA TRENDS IN RECREATIONAL FISH CATCH

E.T. Jarvis. Southern California Coastal Water Research Project, Fish Group, Westminster, CA 92683

Dramatic declines in southern California fish populations have caused heightened concern in recent years. While these declines have been mainly attributed to years of sustained and increased fishing pressure, recreational fish data have rarely been analyzed in terms of life history characteristics or compared to temporal changes in oceanographic conditions. This paper attempts to bring us up to date on the following questions: How have catch rates of recreational fish species changed over time? How do trends in recreational fishing data compare with trends in fishery-independent data? Do species of specific life history categories and/or families show any obvious temporal patterns? Finally, are the patterns, if any, related to trends in large-scale oceanographic conditions, years of El Niño events, and/or sport fishing regulations? Boat and shore sample data (catch rates) collected by the Marine Recreational Statistical Survey (MRFSS) from 1980 to 2000 were obtained for time series comparison with local oceanographic data and fish impingement rates from several southern California power generating stations. This paper will describe trends in southern California recreational fish catch with the hopes of achieving a better understanding of the dynamics of our coastal recreational fisheries and realizing the importance of maintaining historic time series.

6 ENVIRONMENTAL INFLUENCES ON CALIFORNIA COMMERCIAL FISH AND INVERTEBRATE LANDINGS

Jerrold G. Norton and Janet E. Mason. Pacific Fisheries Environmental Laboratory/SWFSC, 1352 Lighthouse Avenue, Pacific Grove, CA 93950

In this analysis of 71-year time series from the California commercial fishery landings data (CACom), market groups comprising more than 85% of the total landings weight are examined for possible influences of environmental variability. Taking multi-species ensembles of market groups in empirical orthogonal function (EOF) analyses, reduces ambiguity in data grouping and archival. The CACom data have two distinct patterns of variation in relative species abundance that explain more than 45% of the variance through the 1930–2000 period. These patterns, defined by EOF1 and EOF2, appear robust to changes in CACom species combination. Association of trends in the fisheries variables to trends in EOF1 and EOF2 time variation (C1 and C2) during parts of the record suggests that the fishery, alert to profitable opportunities, readily altered the relative species abundance of its landings. Flexibility of the fishery together with changing environments produced continued change in relative species abundance in the California commercial landings. Trends in C1 and C2 match trends in physical environmental variables more closely than they match trends in fisheries variables, suggesting that the changes found in relative species abundance begin as changes in the physical environment. Larger-scale, longer lasting environmental events in 1957–1962, 1973–1982 and 1998–2000 are clearly evident in relative CACom species abundance. Generally, the relative species abundance varies gradually and continuously, with trends lasting from six to 36 years. This persistence is the result of the varying life histories of the fishes harvested and capital investment in harvest and processing equipment.

7 CONSERVATION MANAGEMENT OF UNDERSIZED BYCATCH IN THE GROUPER-SNAPPER FISHERY OF THE EASTERN GULF OF MEXICO

Raymond R. Wilson, Jr. Department of Biological Sciences, California State University, Long Beach, CA and Karen M. Burns, Fisheries Biology Program, Mote Marine Laboratory, Sarasota, FL

Groupers and snappers are heavily exploited fisheries of the eastern Gulf of Mexico. Conservation measures adopted in 1990 imposed *inter alia* new minimum legal sizes. Minimum sizes have encouraged release of undersized bycatch with the clear intent to permit further growth and reproduction before harvest. Factors thought to negatively affect post-release survival are hook injuries and barotraumas from swimbladder rupture. Experiments have shown that red grouper *Epinephelus morio* could potentially survive barotraumas at high rates (>90%) when captured shallower than 50 m and released. In practice, however, released fish must usually overcome buoyancy to re-descend quickly. Thus, venting has become widely practiced. We assessed the efficacy of venting using tag-recapture data from a long-term tag and release program. Data from thousands of tagged fish caught shallower than 31 m found tag-return rates for vented red grouper and red snapper *Lutjanus campechanus* to be significantly lower ($p < 0.005$) than those for non-vented fish (6.6% v. 10.1%) and (6.2% v. 10.0%), respectively, but were significantly higher ($p < 0.005$) for vented gag *Mycteroperca microlepis* (10.8% v. 8.1%). At capture depths below 31 m return rates were significantly higher for vented red grouper and gag, but significantly lower for vented red snapper. Experiments in progress will ascertain how hook injuries separately affect survival in red snapper experiencing barotraumas. Regarding possible conservation effects, the trend in landings for red grouper and gag continued downward between 1990 and 1997/98, but has been rising since 1998; the same appears true for red snapper.

8 BIOLOGY AND POPULATION DYNAMICS OF COWCOD ROCKFISH (*SEBASTES LEVIS*) IN THE SOUTHERN CALIFORNIA BIGHT

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The cowcod, *Sebastes levis,* is common off southern and central California. Adult cowcod may live to more than 50 years and are usually associated with rocky outcrops at depths of 152–244 m. Cowcod have been a target of both recreational and commercial fishers off Southern California since World War II. Recreational landings peaked in 1976 at 140 metric tons (MT) in the then declined to 3.5 MT

1998. Commercial landings for cowcod peaked in 1984 at 141 MT. The population dynamics of cowcod were analyzed using both fishery independent and dependent data. Biomass was linked to larval production that has been monitored by CalCOFI plankton surveys since 1951. Recruitment was linked to sanitation district otter trawl surveys conducted since 1972. Commercial passenger fishing vessel logbook data provided angler success rates since 1964. Landings data and all indices of abundance showed declines since the 1960s. High exploitation rates during a prolonged period of low recruitment have reduced the cowcod biomass to about 7% of the 1951 level. In response to this overfished condition, the Pacific Marine Fishery Council prohibit the take of cowcod and established a Cowcod Conservation Area of 4300 sq. mi. in the Southern California Bight in 2001. Because of slow population growth, rebuildling time for cowcod will be 95 y with an initial quota of 2.4 MT. Additional protection for cowcod was afforded by new regulations for rockfish in 2003 which prohibit most bottom fishing in depths from 20–150 fms.

9 GOOD NEWS AND BAD NEWS FROM LONG-TERM FISH MONITORING

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In this paper I will discuss the effectiveness and necessity of using long-term monitoring data to understanding two critical processes in our marine environment: productivity and harvest refugia. The Vantuna Research Group (VRG) at Occidental College has continually monitored the nearshore ichthyofauna of the southern California bight since 1974. Various components of this fish community-recruitment, survivorship, larval and adult abundances-demonstrate a long-term decline in nearshore productivity over the past three decades. This decline in nearshore productivity is both regional and consistent with trends in other Californian marine systems. That's the bad news.

Starting 1995, the VRG began the White Seabass Monitoring program for the Ocean Resource Enhancement Hatchery Project for the Department of Fish and Game. This program has been conducted continually in conjunction with the Nearshore Marine Fish Research Project directed by Larry Allen at California State University Northridge. Data from this monitoring program indicates that large predatory fishes including white seabass, black seabass, leopard sharks and soupfin sharks are increasing dramatically in abundance despite this regional decline in productivity. The only hypothesis consistent with these cross-taxonomic increasing trends is the release of fishing pressure on these stocks from the removal of gill nets in our nearshore environment beginning in 1992. This data indicates that changes in harvest in our nearshore environment can have dramatic effects on these stocks. For large predatory and mobile fishes a harvest refugia of the entire southern California bight is of significant scale to result in an increase in abundance of these fishes. That's the good news.

10 DOCUMENTING THE RETURN OF A FISHERY? DISTRIBUTION AND ABUNDANCE OF JUVENILE WHITE SEABASS (*ATRACTOSCION NOBILIS*) IN THE SHALLOW NEARSHORE WATERS OF THE SOUTHERN CALIFORNIA BIGHT, 1995–2002

L. G. Allen[1], D. J. Pondella II[2], M. Shane[3], and R.F. Ford[3]. [1]California State University, Northridge, CA 91330-8303; [2]Occidental College, Los Angeles, CA 90041; [3]San Diego State University, San Diego, CA 92182

As part of the Ocean Resources Enhancement and Hatchery Program (OREHP), nearshore coastal and embayment areas off southern California were sampled to determine the distribution and abundance of young white seabass in the shallow (5–10 m) nearshore waters throughout the Southern California Bight. This sampling program further serves to monitor white seabass that are cultured, tagged, and released by OREHP. A total of nineteen stations, 13 in nearshore coastal waters and 6 in embayments, were surveyed over in April, June, August, and October using 50 m variable mesh, monofilament gill nets. In the eight-year period of sampling, a total of 8,164 juvenile white seabass have been captured. CPUE has increased significantly over time from April 1995 to June 2002 ($r^2 = 0.471$; $p < 0.0001$) at a rate of 0.05 fish/net/year. Of the white seabass caught since April 1995, 537 (6.6%) were hatchery-reared fish. Tag returns have also increased significantly over time at a rate of 0.002 tagged fish/net/year ($r^2 = 0.17$; $p = 0.02$*). This increase was strongly influenced by increasing numbers of tagged fish being recovered from embayments ($r^2 = 0.20$; $p = 0.03$*) where they are often released. The relatively high catch rates of non-hatchery fish, along with significant and nearly significant increases in commercial and recreational catches over the same period, indicate that the natural populations of white seabass may be in recovery. The ban of nearshore commercial gill net fishing by Proposition 132 in 1992 probably made the greatest contribution to this increase.

11 CALIFORNIA'S FISHERIES: LANDINGS INCREASE, BUT VALUE DECLINES

Janet Mason. Pacific Fisheries Environmental Lab, DOC/NOAA/NMFS/SWFSC, 1352 Lighthouse Ave, Pacific Grove, CA 93950

California's fisheries may look healthy from the total landings; landings in 2000 were the highest in 20 years. However the economic value of the fisheries has been steadily falling for the last 5 years as species with lower market value, squid and sardine, constitute more of the landings and valuable sea urchins, salmon, swordfish and groundfish contribute less. Total landings have increased nearly 50% since their low in 1992, but the value has decreased 42%.

Over the last 74 years, California's commercial fisheries changed from primarily small pelagic species (sardines, anchovy and mackerels) to include more tunas, groundfish and invertebrates. The value increased from these species and from landings of salmon and swordfish. The high value of sea urchins contributed to the peak value in the late 1980s. However total value began to drop, and from 1988 to 2001, values in Monterey and all Southern California regions dropped about 50% and northern California regions dropped 75%.

Various factors are involved in the decline in value of the total landings: increased landings of lower value sardine and squid; restrictions on landings of groundfish to prevent overfishing; serial depletion of many valuable stocks; decreases in price from competition with imports; decreases in price for exports to Japan. California fisheries are in economic trouble despite their increased landings.

12 GROWTH BIOMARKERS IN FISH: IGFBPs (insulin-like growth factor-binding proteins)

K.M. Kelley, M.M. Galima, J.A. Reyes, K. Sak, K. Goldman, D. Topping and C.G. Lowe (2003). Endocrine Laboratory, Department Biological Sciences, California State University at Long Beach, Long Beach, CA 90840

Essential to somatic growth and a host of anabolic processes in fishes, and in all vertebrates, are the actions of insulin-like growth factors (IGFs). All vertebrate cells express IGF-I and/or IGF-II, and these peptides are responsible for directly stimulating mitogenic and differentiative functions in cells and tissues. Growth hormone, on the other hand, has mostly indirect growth actions, via stimulating expression of IGF-I. In biological fluids, IGF peptides are bound to high-affinity IGFBPs, of which there are six known members (IGFBPs 1–6). IGFBPs are a group of dynamic and centrally-positioned 'integrators' of the endocrine growth-regulatory apparatus, as they dictate the distribution and bioavailability of IGF peptides in the cellular/physiological environments. IGFBPs also exhibit an array of specialized properties derived from their complex evolutionary history [e.g., cell membrane association] and they are regulated by a diversity of "outside" factors [e.g., other hormones, metabolic status, stress]. In fishes and in all vertebrates in which it has been assessed, physiological shifts toward catabolism (e.g., with food deprivation) are consistently associated with elevations in serum levels of an IGFBP of $\leq$31 kDa. In mammals, 30-kDa IGFBP-1 is substantially up-regulated under catabolic circumstances, and it plays a key physiological role by sequestering IGFs to inhibit energy-expensive growth until conditions are more favorable (e.g., with resumed feeding). Similarly in fishes, it has been shown that when the IGFBP is elevated in serum, somatic growth is inhibited. This paper will address the cellular actions of IGFBPs and will compare three different experimentally-induced catabolic states in fishes: fasting, insulin-dependent diabetes mellitus (IDDM), and stress. The relationship between elevated serum cortisol concentrations and the presence of IGFBPs in each case is noted, and the utility of serum IGFBP measurement to serve as an effective indicator (biomarker) of catabolic growth inhibition in fishes will be considered. [Funded by CA Sea Grant College Program NOAA NA06RG042 2002–03, project # R/F-192, and NSF g.]

13 BEHAVIORAL RESPONSES AND SURVIVORSHIP OF CALIFORNIA SHEEPHEAD TO POST-RELEASE ANGLING STRESS

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The California sheephead, *Semicossyphus pulcher* (Labridae), is a highly sought member of the temperate, rocky-reef/kelp-bed fish community by both recreational and commercial fishers. The marked decline in numbers of this species along its range has recently prompted action to be taken to effectively manage its fishery. Bag limits and size restrictions can be effective tools in fisheries management, however, size restrictions dictate that many fish will be released after capture and the ultimate fate (survival or mortality) of these fish is unknown and of serious concern to fisheries manages and fishermen alike. Research on the behavioral and physiological responses of California sheephead to the effects of stress induced by the capture and release process is starting to shed light on post-release survival. Fish that have been physiologically stressed from being caught hook and line and having long-term (~1 yr) coded acoustic transmitters surgically implanted in their abdomens, have exhibited high site fidelity and had a 100% survival rate. Preliminary indications are that there may be some difference between stressed and unstressed animals in home range size, rate of movement (ROM) and total distance moved during the first 24-hour period. However these differences appear to be quite subtle as stressed fish show very similar movement patterns and similar time of day peak ROM within and after the first 24-hour period. Additionally, blood hormone stress indicators, such as cortisol, from stressed fish that have been released and later recaptured show a return to baseline within an 18-hour period. [Support by CA Sea Grant College Program NOAA NA06RG042 2001–02, project # R/F-192].

14 ENDOCRINE ALTERATIONS IN RESPONSE TO CATCHING STRESS IN CALIFORNIA SHEEPHEAD: METABOLIC AND GROWTH IMPACTS

M.M. Galima, D.T. Topping, K.J. Goldman, C.G. Lowe, and K.M. Kelley. Department of Biological Sciences, California State University Long Beach, Long Beach, CA 90840

Harvest control measures (size limit ≤30.5 cm TL) have been implemented by the State of California in the marine teleost fish, the California sheephead (*Semicossyphus pulcher*), with the objective at reducing impacts of fishing pressure on this economically important species. While these policies are currently in place, it has not yet been established whether the stress associated with catch-and-release practices in this fish has subsequent negative physiological effects. We have thus examined the impacts of line-catching associated stressors on the physiology of sheephead, with an emphasis on its effect on the endocrine regulation of somatic growth. Sheephead were caught offshore near Catalina Island by angling and blood was sampled immediately after capture (≤ 3 min), or after 5, 10, and 20 min of fight times, or after different recovery times in tanks after line-catching (30 min, 1 hr, 2 hr, 1 d, 3 d, 5 d, 8 d). Variation in plasma levels of cortisol, glucose, lactate, insulin-like growth factor-I (IGF-I), and IGF-binding proteins (IGFBP) were then quantified. As compared with controls, fish in the treatment groups exhibited more than 2–4-fold elevations in serum glucose and lactate concentrations and up to 100-fold elevations in the stress hormone, cortisol. Although no changes in serum IGF-I levels were observed, preliminary serum profiles of the growth-regulatory IGFBPs exhibited changes reflective of a growth-inhibited state in stressed sheephead. Our data thus far indicate that California sheephead experience a significant physiological response to line-catching that may impact somatic growth. Comparisons among different fishing techniques will be discussed. [Support by CA Sea Grant College Program NOAA NA06RG042 2001–02, project # R/F-192].

15 DOWNSTREAM MIGRATION OF STEELHEAD TROUT AND RESIDENCE IN A LOWER MAINSTEM AT 35°N

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The function of stream reaches a short distance from the ocean (lower mainstem) in the ecology of parr steelhead trout *Oncorhynchus mykiss* is poorly understood, as is the characteristics of the downstream migration and the migrants near the southern extent of the species' range. Three years of monitoring downstream migration and abundance of steelhead in a south-central California stream indicated juveniles reside in the lower mainstem during summer and fall. Characteristics of the migration and the migrants were generally similar to those reported for steelhead in northerly areas of the species' range. The findings illustrate the lower mainstem is more than simply a migration corridor for steelhead, and have implications for the regulatory community.

16 MEASURING BARRIERS TO FISH PASSAGE IN THE SANTA MONICA MOUNTAINS

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The Southern California Evolutionarily Significant Unit of steelhead (*Onchorynchus mykiss*), found in coastal watersheds from the Santa Maria River to the Mexican border, was listed as endangered in 1997. Man-made barriers to passage, including dams, culverts, road crossings, and channelized reaches, are the leading cause of decline of this anadramous fish, and removal or modification of these barriers will be vital for steelhead recovery. In order to develop recovery plans, a systematic assessment of these barriers is needed. We will begin conducting an inventory of barriers in the 23 coastal watersheds in the Santa Monica Mountains. This project will expand upon work conducted in the Santa Ynez mountains, and will result in development of a GIS database that can be used to evaluate those barriers which, if addressed, hold the highest promise for recovery. We will review the science behind barrier assessment and describe the methodology to be used in the Santa Monica range.

17 GEOCHEMICAL AND MINERALOGICAL ANALYSIS OF THE "BLUE DRAGON" FLOW IN CRATERS OF THE MOON NATIONAL MONUMENT

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Craters of the Moon National Monument is located in the Snake River Plain in south-central Idaho along a 45-km segment of the northern part of the Great Rift. A distinctive lava flow in the Monument exhibits a stunning surface that reflects various shades of blue. The flow, named the "Blue Dragon", covers an area of approximately 280 km^2, has a volume of 3.4 km^3 and is approximately 2076 $\pm$ 45 radiocarbon years old. In 1973, Faye and Miller proposed that the coloring of the blue material of the "Blue Dragon" flow is a result of electron-transfer between $Fe^{2+} \rightarrow Fe^{3+}$ and $Fe^{2+} \rightarrow Ti^{4+}$. The objective of this project is to further investigate this unusual surface color. Approaches will include making microscopic examination of thin sections, comparing whole-rock geochemical and microprobe analyses of surface and interior samples, and performing transmission and reflective spectral studies by colleagues at California Institute of Technology.

18 A GEOCHEMICAL AND PETROLOGIC STUDY OF POWAY CLASTS IN SAN DIEGO AND THE CHANNEL ISLANDS, CALIFORNIA

L. G. Field and P.W. Weigand. Department of Geological Sciences, California State University, Northridge, CA 91330-8266

A geochemical and petrologic study was conducted to investigate Poway clasts (PC), distinctive porphyritic meta-rhyolite clasts of Jurassic age that were deposited in several Eocene conglomerates in southern California. Poway clasts were collected from San Diego (Poway and Stadium Conglomerates), Santa Cruz Island (Jolla Vieja and Vaqueros Formations), San Miguel Island (Cañada Formation), and San Nicolas Island.

The mineralogical composition and textural characteristics of the six clast sets are very similar. Quartz phenocryst (6 to 19 volume %) are frequently embayed with little pitting or vacuolization. Plagioclase and potassium feldspar phenocrysts (22 to 40%) are usually pitted or vacuolized with frequent regions of calcite replacement. Biotite is usually altered to sericite, piemontite, or another colorless mica with abundant opaque grains. Common opaque crystals are mostly hematite and magnetite with minor iron sulfides. Low-Mn piemontite is infrequently seen in Santa Cruz Island, San Miguel Island, and San Diego clasts. Groundmass (42 to 61%) is variably recrystallized; the presence of remnant shards indicates their tuff origin.

Geochemical analysis shows complete overlap of the six Poway clast collection sites. Most clasts are classified as rhyolite and belong to the calc-alkaline magma series. All are slightly enriched in light REE, with a small Eu anomaly. Negative spikes for Ba, Nb, Sr, P and Ti are exhibited on Spider diagrams by all samples.

This study confirms that PC clast sets, are in fact, extremely similar with respect to mineralogy and geochemistry and that their use in paleogeographic models is justified.

19 ANIMATION OF THE RECENT GEOLOGIC EVOLUTION SOUTHERN CALIFORNIA

G.A. Briscoe, A.E. Fritsche, and P.W. Weigand. Department of Geological Sciences, California State University, Northridge, CA 91330-8266

Previous animations of the geologic and tectonic evolution of southern California have included little actual geologic detail. This presentation uses existing paleotectonic, paleogeographic, paleomagnetic, and paleoreconstruction constraints to create a Flash computer animation that illustrates southern California's dynamic and dramatic evolution over the past 30 million years. A likely scenario of the potential geologic and tectonic future of southern California is also portrayed in the animation. Previous research is correlated to create a "best-fit" scenario that most accurately depicts the geologic and tectonic past and is presented in a ten-minute animation that graphically shows this scenario. Highlights of this modeling include a visual demonstration of the way that the western Transverse Ranges block has rotated over time. Evidence for this rotation has been well documented through paleomagnetic and paleotectonic data as well as by the correlation of a distinctive volcanic rock that originated in Mexico and is now found in sedimentary rocks located in San Diego and on the northern Channel Islands off the coast of California. Planned for Web publication, this project uses the most recent advances in Web technology to allow for the widest dissemination of this information. The authors intend for this presentation to enlighten both the general public and the scientific community while sparking greater interest in the dramatic geologic developments that have taken place in southern California.

20 A FIELD AND PETROGRAPHIC ASSESSMENT OF A PORTION OF THE KERN PLATEAU SHEAR ZONE, TULARE COUNTY, CALIFORNIA

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I report here results of a study of the field and petrographic characteristics of two variably deformed granitoid plutons—Rockhouse granite (~230 Ma) and Long Valley pluton (~148 Ma)—that are part of the Kern Plateau shear zone, a Mesozoic-age ductile fault zone in the southern Sierra Nevada. These granitoids crop out adjacent to out-of-place Paleozoic oceanic rocks in the Kennedy Meadows roof pendant, but it has not been clear as to whether these plutons intruded into or were faulted against the pendant strata. Key findings of my study are as follows: (1) the intensity of deformation in the granitoids increases as one approaches the Kennedy Meadows roof pendant; (2) one or more phases of mylonitization occurred between intrusion of the intensely deformed Rockhouse granite and commonly undeformed Long Valley pluton that intrudes it; (3) the Rockhouse granite has intruded into the pendant, demonstrating that it is in place with respect to the pendant rather than being transported within the fault zone; (4) sense of shear in intensely folded pendant strata that lie alongside the plutons is consistently left-lateral; (5) petrographic characteristics of minerals in the mylonites indicate that deformation occurred under temperature and pressure conditions consistent with the greenschist facies.

21 EVALUATION OF SAND AND PEBBLE PROVENANCE FOR CONSTRAINING RATES OF STREAM CHANNEL OFFSET BY THE SAN ANDREAS FAULT, ON THE CARRIZO PLAIN

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The San Andreas fault (SAF) is an active transform fault. Offset stream channels are one of the most obvious geomorphic tectonic landforms apparent in the Carrizo Plain segment of the SAF. These channels have been displaced right-laterally by SAF movement. Geological determination of late Holocene slip-rates, dates of paleoseismic earthquakes, and estimates of slip per rupture have created models of recurrence intervals along segments of the San Andreas fault.

In this study, I test the feasibility of using sand and pebble provenance to determine rates of stream offset along the Carrizo Plain segment of the SAF. Stream channels extend upstream above the SAF scarp the Temblor Range. Tertiary marine deposits of the Temblor, Vaqueros, Santa Margarita Formations, and the Monterey, Bitterwater creek Shales, crop out within the Temblor Range source area. Numerous ephemeral streams deliver sediments from the Temblor Range to the Carrizo Plain. Stream samples were collected east of the SAF on the North American Plate between the Temblor Range and

the SAF. Thin sections made from these samples reflect changes in lithology along strike of the fault. Some samples are dominated by calcareous mudstone fragments with minor quartz and feldspar grains; others are dominated by plutonic clasts composed of quartz and feldspar. These contrasting compositional fingerprints could help constrain stream channel offset history in the Carrizo Plain.

22 SEISMIC HAZARD ANALYSIS OF THE SAN FERNANDO VALLEY USING THE FRISKSP COMPUTER PROGRAM

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The 6.7 magnitude Northridge earthquake that occurred in 1994 caused major damage in the San Fernando Valley and surrounding regions. A blind thrust fault located 19 km beneath the surface caused this earthquake and emphasizes the seismic hazard associated with blind thrust faults. Seismic ground motion accelerations recorded by the USGS during the earthquake were compared to accelerations calculated using the FRISKSP program, which generates the probability of future ground accelerations. FRISKSP uses recorded fault-rupture-area data, earthquake magnitude, distance to source, and recurrence interval to calculate peak horizontal ground acceleration resulting from a given fault. The recurrence interval of an earthquake is directly proportional to the slip rate of the fault(s) associated with a particular earthquake. The intensity of ground shaking at a given location depends primarily upon the earthquake's magnitude, the site's distance from the epicenter, and the site-response characteristics. Site response is dependent on subsurface and soil characteristics. Probabilities of theoretical accelerations for two earthquake scenarios were calculated using FRISKSP. The two earthquakes used for this study were the 1857 ($M = 7.9$) rupture of the San Andreas Fault and the 1994 ($M = 6.8$) Northridge earthquake. The results show a 4% probability of 0.25 g accelerations being experienced by CSUN from the San Andreas rupture, whereas there is an 11% probability that this same site will experience the same acceleration value from the Northridge blind thrust fault.

23 DETERMINING THE DEPOSITIONAL AGE OF PEAT: IMPLICATIONS FOR DATING PALEOEARTHQUAKES AT THE BURRO FLATS PALEOSEISMIC SITE NEAR BANNING, CA

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Determining the age of paleoearthquakes hinges upon acquiring age data that accurately reflects the age of the ground surface at the time of past ruptures. Peat deposited shortly before and shortly after ground rupture provides an opportunity to precisely constrain the timing of paleoearthquakes. However, the peat layers consist of a variety of organic material that both predates and post-dates the age of deposition. Components that predate the depositional age include detrital charcoal, wood fragments, seeds, and organic soil. Components that post-date the depositional age primarily consist of roots. Radiocarbon dating of a bulk peat sample will therefore yield a mixing age that may not reflect the depositional age of the deposit. Peats also contain layer-parallel fibers interpreted to represent annual reeds and/or grasses that die and are buried parallel to the ground surface. At the Burro Flats site, each sample was examined under a microscope, and various components including charcoal, wood, seeds, roots, and plant fibers were hand-separated. All but the roots were dated showing a range in radiocarbon ages as great as 300 years. The detrital components, bulk samples, and layer-parallel fibers consistently yielded the oldest, intermediate, and youngest ages, respectively. Relying upon radioarbon data from bulk peat and/or detrital charcoal to constrain the timing of paleoearthquakes can result in ages that are too old. We consider the radiocarbon ages of layer-parallel fibers to best represent of depositional age of the unit. These fiber ages can therefore provide robust constraints on the timing of paleoearthquakes.

24 GROUNDWATER DISCHARGE DEPOSITS IN THE MOJAVE DESERT, CALIFORNIA

K.S. Rivera and V. Pedone. California State University Northridge, Department of Geological Sciences, Northridge, CA 91330

A number of laterally limited and stratigraphically thin carbonate deposits are exposed at the surface in the Mojave Desert. The deposits overlie and/or are interbedded with unconsolidated silty sand to

gravel and are presumed to be Pleistocene in age. The origin of these deposits is uncertain, and the purpose of this study is to determine the hydrologic system from which they formed: 1) a lacustrine system dominated by surface runoff, 2) a pedogenic system dominated by meteoric infiltration, or 3) a wetland dominated by groundwater flow and discharge. The initial results of the overall study, which will synthesize field, petrographic, and isotopic characteristics of the carbonates and their associated clastic deposits, has defined the geomorphology, areal distribution, stratigraphy, and paleontology of one deposit located along a broad alluvial fan surface near the intersection of two major drainage areas defined by the Bristol, Old Dad, Granite, Marble, Old Woman, Providence, New York, and Piute Mountains. The study site contains an approximately 1-km-wide irregular band of poorly exposed carbonate deposits, which form subtle, resistant topographic highs. Carbonates are white to light-brown, fine-grained, and porous and contain about 20% clastic sand and silt. Beds range in thickness from 3 to 35 cm and grade vertically above and below into moderately resistant, fine-grained, calcareous sand. Carbonate beds locally contain abundant molluscan fauna and commonly exhibit root casts within their gradational contacts. The gastropod assemblage, *Fossaria sp.*, *Gyraulus sp.*, and *Pupillidae,* are typical of those found in wetlands dominated by groundwater flow and discharge.

25 SUBAQUEOUS SPRING DEPOSTS IN LIMESTONE FROM THE MIDDLE MIOCENE BARSTOW FORMATION, MOJAVE DESERT, CALIFORNIA

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Localized subaqueous-spring tufa mounds occur in a coarse-grained siliciclastic tongue near the base of the Middle Member of the Barstow Formation on the south limb of the Barstow syncline near Owl Campground, about 12 km north of Barstow, California. The initial results of the study, which will synthesize field, petrologic, and carbon and oxygen stable-isotope data, focuses on the field relationships and petrology. The mounds are typically 1.5-m-thick and 3.5-m-diameter. They overlie pebbly, coarse-grained sandstone in which there are vertical pipes of carbonate-cemented gravel. Similar pipes, up to 20 cm in diameter, form the interiors of the carbonate mounds. Some portions of the mounds, including the pipes in the gravel, consist of crudely and broadly banded microbialite, where different zones are best defined by changes in color. Other portions consist of well defined, alternating thin bands of prismatic calcite and micrite. The prismatic calcite bands are approximately 300 to 500 microns thick and the micrite bands are 10 microns thick. The distinctly banded tufa is overlain by and sometimes laterally grades into porous, crudely laminated microbialite. The localized development and internal pipe structure of the mounds suggests that they were formed where subaqueous springs of groundwater discharge entered the lake.

26 CHAROPHYTE MOUNDS IN THE MIDDLE MIOCENE BARSTOW FORMATION, MUD HILLS, CALIFORNIA

C. Caceres and V. Pedone. California State University Northridge, Department of Geological Sciences, Northridge, CA 91330

Charophyte mounds at the base of the Middle Member of the Barstow Formation in the Mud Hills have been investigated using field, petrographic, and geochemical/isotopic studies. Although over- and underlain by coarse-grained sandstone and conglomerates, the carbonate rocks of the mound unit contain little siliciclastic material. The mounds formed by extracellular calcification of the green alga *Chara* and are 1 to 3 m thick and 3 to 5 m in diameter. Primary calcification of the *Chara* consists of alternating bands of dull-orange luminescent prismatic calcite and bright-orange luminescent micrite. The calcite has moderate levels of Mn (mean 1400 ppm) and low levels of Fe (mean 470 ppm). The $\delta^{18}O$ of the charophyte fabric ranges from -4.5 to -9 permil (VPDB), and $\delta^{13}C$ ranges from $+1.7$ to -2.5 permil (VPDB). Based on calcite $\delta^{18}O$ and an estimated precipitation temperature of $\sim$20°C, lake water $\delta^{18}O$ ranged from -4.3 to -8.3 permil (SMOW). Synthesis of all data suggests that charophyte mounds formed in a shallow, nearshore lake environment where synsedimentary faulting temporarily disrupted clastic input, allowing carbonate deposition to occur. Calcite cements have significantly higher values of Mn and Fe, compared to framework components, indicating that later diagenetic fluids were strongly reduced. The wide range of $\delta^{18}O$ indicates that cements formed from meteoric water, slightly evaporated meteoric water, and geothermal water. Low $\delta^{13}C$ values indicate the addition of organic carbon to all fluids. Meteoric water and geothermal fluid most likely become isotopically light by interaction with organically derived CO_2 in the vadose (soil) zone.

27 STUDENT RESEARCH IN K–12 CLASSES MENTORED BY TEACHERS TRAINED IN UNIVERSITY RESEARCH LABS

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For nearly a decade teachers have received research experiences in the laboratories of faculty at Cal State Northridge, UCLA, Caltech and other institutions under fellowships supported by grants from the National Science Foundation, Eisenhower Program and the Improving Teacher Quality State Grant Program. Some of the teachers have spent many years in our research labs, receiving continuing fellowships. After completing research projects mentored by university scientists, the teachers train the students in their K–12 classes to do research. Assessment of the program's success is based on student work: publication of student research abstracts in the Journal of Student Research Abstracts, Pearson Education, Boston, and student poster presentations at our annual student poster symposium. The 2003 issue of the journal (Library of Congress Number ISBN 0-536-68038-8) includes 131 abstracts co-authored by 594 K–12 students.

We feel that the success of the program is based on two key factors: (1) some teachers spend years working with university scientists on a year round basis (not just summer only) leading to high quality classroom research, and (2) the bottom line is always assessment of student work (published abstracts and presented posters). The research experiences component is part of a Super-Funded Science Leader Initiative where many of the teachers also receive content and leadership training funded by the Eisenhower Program, the Improving Teacher Quality State Grant Program and the California Science Project (Supported by NSF grant ESI 9729391, Eisenhower/Improving Teacher Quality Grant 1101 and the California Science Project).

28 RESEARCH EXPERIENCES FOR TEACHERS OPENS THE DOOR FOR RESEARCH EXPERIENCES FOR K–12 STUDENTS. A MEASURE OF CLASSROOM IMPLEMENTATION SUCCESS

Catherine A. Coyle-Thompson. California State University, Northridge, Department of Biology, Northridge, CA 91330-8303

K–12 Teachers completed research projects using *Collembola* (springtails) during the past four years as part of the NSF Science Scholar and Eisenhower programs directed by Dr. Steven B. Oppenheimer. Each teacher learned the methods and developed lesson plans and research projects incorporating the new California State Science Standards. In addition, several teachers have continued to develop additional projects for further study as part of the program.

Each of the teachers has been implementing the *Collembola* projects in the classroom. In addition, they are getting support from their principals, parents of students and fellow teachers. They have received additional microscopes and supplies for their students to use. The parents of the students have helped to assemble *Collembola* collecting kits. The support our teachers are getting is really helping them to work with *Collembola*.

The students have also expressed interest. Many of these students have continued to study *Collembola* as members of Science Clubs and for Science Fair projects. As quoted from Joe Moche and Terry Miller, "Any science project that can get middle students to come to school and work before class starts and to stay late after school is over to observe and study the organism, has captured their interest." Several of these aspects of the *Collembola* project will be discussed.

29 CALIFORNIA STATE UNIVERSITY NORTHRIDGE RESEARCH FELLOWSHIPS FOR TEACHERS

Norman Herr. California State University, Northridge, Department of Secondary Education, Northridge, CA 91330-2580

The CSUN Research Fellowships for Teachers program (now in its fifth year) has been funded by the National Science Foundation and the Dwight D. Eisenhower Professional Development State Grant Program of the California Post Secondary Education Commission. The objective of this program is to provide teachers with scientific research experiences so they are better prepared to develop inquiry experiences in their secondary school classrooms. Participants spend 120 hours in the laboratory of a scientist engaged in scientific research. Teachers who successfully complete the research program are awarded a stipend of $1800 and are given the opportunity to obtain university credit. Teachers implement research projects in their classes, provide reports on their research projects, engage in follow-up meetings and enrichment activities, and submit abstracts of their students' research projects for publication in the Journal of Student Research Abstracts. In addition, their students make poster presentations of their own work at the Student Research Symposium held each spring on the CSUN campus. Teachers may be invited to continue their research fellowships after successful classroom implementation. Current research and implementation areas include: microbiology, developmental biology, ecology, biochemistry, plant physiology, neuroboioiogy, animal behavior, cell biology, marine biology, molecular genetics, genetics, molecular biology, seismology, geology, and high energy physics.

30 TOMORROW'S SCIENTIST, USING A SERVICE LEARNING MODEL WITH PRE-SERVICE TEACHERS TO RUN AN AFTER-SCHOOL SCIENCE PROGRAM FOR MIDDLE SCHOOLERS

Virginia Oberholzer Vandergon. California State University, Northridge, Department of Biology, Northridge, CA 91330-8303

Using a service-leaning model the introductory biology course (Biological Concepts BIOL102) consisting of students in the Integrated Teacher Education Program (ITEP) created an after-school program for under-served middle schoolers called "Tomorrow's Scientist". A major goal for this program was to familiarize ITEP students with the California Science Standards by exposing them to the science concepts and give them early experience in hands-on science teaching. The middle-schoolers were brought to campus with the goal to get them excited about science through providing a science enrichment program. The program ran for twelve weeks in which the ITEP students implemented fun, experimental based activities using topics from the Life Science portions of the State Science Standards. Attitudinal and knowledge-based research assessed the value of two semesters of the "Tomorrow's Scientists" service-learning program to both undergraduate future teachers and the 7th grade students they taught. Both groups improved in science content knowledge and subject enjoyment, while the future teachers also showed increased confidence in knowledge and teaching ability, and the middle schoolers abandoned some negative stereotypes about science and scientists. Overall the Tomorrow's Scientists after-school program appeared effective for increased science content knowledge and demonstrating effective pedagogy.

31 ENHANCEMENTS OF SCIENCE CONTENT KNOWLEDGE THROUGH THE SCIENCE LEADERSHIP INITIATIVE–A SUPERFUNDED PROJECT

Gerry Simila, Virginia Oberholzer Vandergon and Steven Oppenheimer. California State University, Northridge, Department of Geological Sciences, Northridge, CA 91330-8266

The California State University Northridge (CSUN) San Fernando Valley Science Project (SFVSP) has served school districts including the Los Angeles Unified School District (LAUSD) in the San Fernando Valley and Los Angeles region since summer 2000. The project was designed to provide leadership development institutes for teachers in middle school and high school geology, life science, chemistry and physical science based on the California State Science Standards. The workshops also focused on ways of teaching English Language Learners in middle school and high school classrooms along with ways to use state mandated materials to enhance the workshop participants teaching and improve the content level of their students. Progress in teacher development was surveyed with pre and post content testing and evaluation of teacher produced written lesson plans and their oral presentations to project staff and their colleagues and by classroom visitations. The SFVSP provided teacher training to middle and high school teachers from low performing schools (API = 1–4) of LAUSD in intensive 3 week summer workshops with monthly academic-year follow-up activities and classroom visitations.

32 **TRACE METAL ANALYSIS OF THE CALIFORNIA HORN SNAIL (*CERITHIDEA CALIFORNIA*) IN THE BALLONA WETLANDS**

J. McAdam and J. Landry. Loyola Marymount University, Department of Natural Science, Los Angeles, CA 90045

The Ballona Wetlands is a 340 acre degraded urban salt-water marsh located adjacent to the new Playa Vista development and Marina del Rey. The wetlands includes a substantial population of *Cerithidea california,* the California Horn Snail. Although highly degraded, Ballona will undergo restoration in the future with the design to improve the overall health of the wetlands. *Cerithidea california* will be used as an indicator of the health in the Ballona Wetlands just as the National Oceanic & Atmospheric Administration (NOAA) has used Mussel Watch to measure the health of coastal waters. An analytical method was developed in which snails are collected from nine distinct sites in the wetlands, soft tissues extracted and digested, then analyzed by Atomic Absorption Spectroscopy (AAS) for Cd, Zn, Pb, Cr, Cu, and Ni. The resulting accuracy and precision data for the method will be presented. Heavy metal levels in the snails at the sites will be discussed along with maps illustrating heavy metal level trends present throughout the Ballona Wetlands.

33 **STUDIES DIRECTED TOWARD THE TOTAL SYNTHESIS OF ERGOLINE ALKALOIDS**

Alexander Schultz and **Taeboem Oh**. California State University Northridge, Department of Chemistry, Northridge, CA 91330-8262

A new synthetic approach to the total synthesis of lysergic acid has been explored. Following the iodination of gramine the tertiary amine is smoothly converted to first a nitrile and then an aldehyde before successfully employing an imino Diels-Alder reaction to produce the 2,3-dihydro pyridone moiety. Methyl, benzyl and butyl substituents were incorporated at the 1-pyridone positions for different analogues. Numerous one-step attempts at closing the final ergoline ring have been summarized. Enolate generating studies were carried out, after synthesizing nearly identical model compounds, that suggest the more complicated indolyl pyridones are resistant to deprotonation in the 3-pyridone position when compared to pyridones lacking an indolyl system.

34 **SYNTHESIS OF 2-(1,1′-BINAPHTHYL) CHIRAL AUXILIARIES**

Tania Tasu and Taeboem Oh. California State University Northridge, Department of Chemistry, Northridge, CA 91330-8262

New method for the synthesis of handedness in molecules is important in many aspects of chemistry. These methods are also needed to form chiral nonracemic drugs. Our approach is to explore the use of axis of symmetry in 2-(1,1′-binaphthyl) as chiral auxiliaries for asymmetric reactions. In this talk, the approach in the synthesis of 2-(1,1′-binaphthyl) chiral auxiliaries and how it will be used to synthesize chiral molecules will be presented.

35 **MOLECULAR AND MORPHOMETRIC ANALYSIS OF THE ENDANGERED YELLOW POND TURTLE (*MAUREMYS MUTICA*)**

J.J. Fong and R.L. Carter. Department of Natural Sciences, Loma Linda University, Loma Linda, CA 92350

Due to the food, medicine, and pet trade, as well as destruction of natural habitat, turtles in Asia are rapidly disappearing from the wild. This has resulted in the recognition of endangered status of many species by international conservation groups such as CITES and IUCN. One such species is the Yellow Pond Turtle, *Mauremys mutica.* This wide-ranging species is rare in the wild but prevalent in the food markets across China due to captive breeding efforts in turtle farms. Previous studies have hinted at *M. mutica* being a complex of species due to the tremendous variation in color, morphology and mitochondrial DNA throughout its range. In our study, the species status of *M. mutica* is examined through the use of molecular and morphometric analyses.

36 **THE MOLECULAR EVOLUTION OF THE *MYB* GENE FAMILY IN BAMBOO AND SORGHUM**

Andrew Norris and Virginia Oberholzer Vandergon. Calif. State Univ., Northridge, Department of Biology, Northridge, CA 91330

The sequencing and comparison of gene families can be a major factor in elucidating the evolution of a plant species. Of particular interest is the *myb* gene family. Their genomic sequences have been shown to retain highly conserved sequences in the DNA binding domain, with high levels of variability at the C-terminal end. My hypothesis is that the *myb* gene sequences from Bamboo and Sorghum will have very few changes in the DNA binding domain, and will express a wide variety of changes at the C-terminal end. Screening of genomic libraries with PCR amplified myb-like sequences has yielded two possible candidate genes from both Bamboo and Sorghum. These candidate genes have been sequenced, analyzed, and compared to known sequences of *myb* genes from classical plant models. The search for any striking differences or similarities will help to illuminate the reasons behind the evolutionary process and in particular how it has occurred in plant genomes.

37 **AN OIL POLLUTION MODEL USING SOUTHERN CALIFORNIA WILLOWS**

K. Williams, J. Torres, C.M. Vadheim, and **J.W. Roberts***. The Applied Environmental Plant Physiology Laboratory, CSU Dominguez Hills, Department of Biology, Carson, CA 90747

Used motor oil from street water runoff is a major pollutant in Southern California. Estimates from previous studies suggest that the concentration of petroleum hydrocarbons in runoff ranges from 0.7 to 6.6 mg/l. Motor oil pollution can have adverse effects on plants thereby effecting entire ecosystems, as well as polluting drinking water and contaminating fisheries. We exposed two species of native S. California willows (*Salix lasiolepis,* Arroyo Willow; *Salix laevigata,* Red Willow) to various levels of used motor oil diluted with water as a model for street water runoff (levels ranging from 0.0 to 8.0 mg/l). The willow cuttings were collected from a site with petroleum exposure (both oil wells and street runoff). Preliminary results on both Salix species show moderate tolerance to the motor oil at all treatment levels. Leaf and shoot growth was not decreased compared to controls in either species, with Red Willow possibly more tolerant at higher treatment levels than Arroyo Willow. Root mass was increased at higher doses, possibly as a result of oil-induced hypoxia. We are currently conducting studies to better define the LD-50 level and the physiologic effects of motor oil on cuttings of these two species. We are also exploring a contaminated soils model to further characterize the effects of oil on Salix.

38 **CHANGING MACROPHYTE ABUNDANCES AND PRIMARY PRODUCTIVITY OF A SOUTHERN CALIFORNIA SHORE**

A. M. Bullard and S. N. Murray. California State University, Fullerton, Department of Biological Science, Fullerton, CA 92834-6850

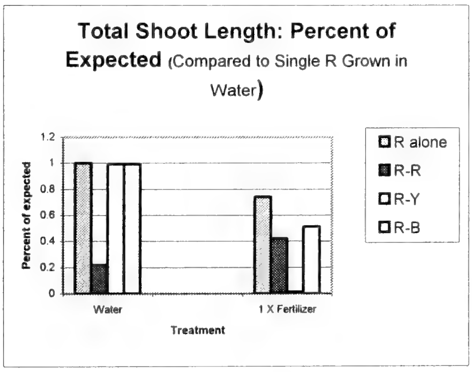
Cover and light-saturated net photosynthetic rates of rocky intertidal macrophytes were measured at Little Corona del Mar, California between January and March 2003. Overall macrophyte cover was low (75.4%), with the greatest contributions by smaller, turf, and crustose algal species that provide little habitat structure: *Corallina pinnatifolia* (22.9%), *Caulacanthus ustulatus* (8.1%), and Crustose Corallinaceae (7.9%). The cover of larger, frondose seaweeds was very low (<5%). Of the 15 rocky intertidal macrophytes used in our photosynthesis experiments, the highest light-saturated rates were mostly obtained for species with low cover, while the lowest rates were measured for species contributing high cover values. We estimated the light-saturated, net community productivity for Little Corona del Mar using the photosynthetic rates (calculated as mg C m^{-2} h^{-1}) and percent cover values of the most abundant populations. This value was compared with prior estimates of macrophyte community productivity obtained from southern California sites in the mid-1970s using similar methods. Analyses of past records indicate that low-producing, crustose and coralline algae have become increasingly abundant while higher-producing, frondose algae have declined on many southern California shores. Our abundance and photosynthetic studies for Little Corona del Mar indicate that this site is characterized by low macrophyte cover and productivity, and underscore the degree to which changing macrophyte abundances can affect the primary productivity of intertidal communities.

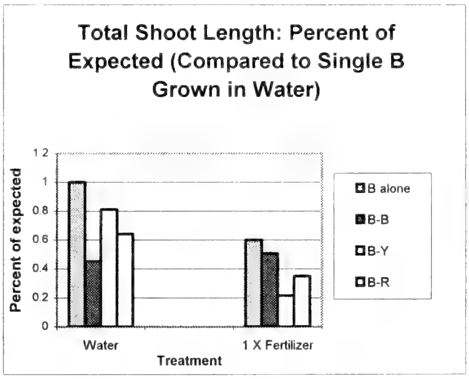
39 POSSIBLE "EVIL TWIN" EFFECT THROUGH COMPETITION OF ARROYO WILLOW CLONES

M. Drexler, C.M. Vadheim and **J.W. Roberts***. The Applied Environmental Plant Physiology Laboratory, CSU Dominguez Hills, Department of Biology, Carson, CA 90747

Studies of interactions between individuals, especially between male and female plants in dioecious species, raise interesting questions about the role of gender in intra-specific plant competition. *Salix* (willow) species provide a useful model for such interactions; yet little research has been conducted using willows. We observed possible competition between willow shoots in an uncontrolled fertilizer study in which shoots were rooted in pairs. The current study focused on three clones of a native California willow, *Salix lasiolepis* (Arroyo Willow): two female clones (R and B) and one male (Y). Shoots were planted two to a pot either with themselves or with one of the other clones. Half of the paired shoots were treated with liquid fertilizer, the other half with water only. Singly-planted shoots served as controls for each clone. As seen below, shoot length is reduced when female shoots are planted in intra-clonal pairs and treated with water (the "evil twin" effect).

Growth is reduced less (or not at all) when water-treated shoots are planted in inter-clonal pairs. The situation in fertilizer-treated pairs is more complex. Growth response to fertilizer appears to differ between the clones. In addition, the male (Y) clone exerted a greater effect on the other clones with fertilizer treatment. We are conducting a follow-up study to confirm and expand these findings.





40 THE USE OF *BRASSICA NIGRA* AS AN ADJUNCT GENETIC MODEL FOR THE STUDY OF SALT TOLERANCE

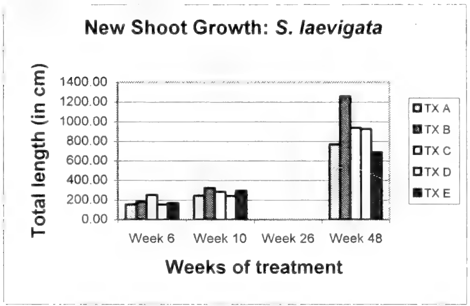
Candice Groat, Richard Kuromoto, John Roberts. CSUDH Department of Biology, Applied Plant Physiology Laboratory, Carson, CA 90747

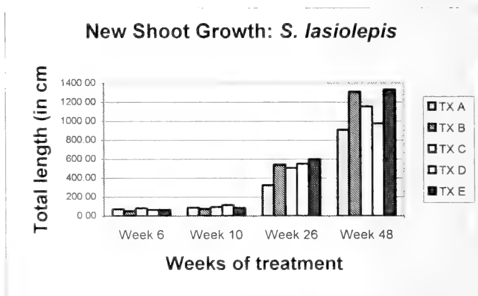
Commonly found among the California Coastal Flora, and widely distributed throughout the United States, *Brassica nigra* can inhabit ecosystems with wide gradients of abiotic factors. *Brassica nigra* is closely related to *Arabidopsis thaliana* and may be a valuable adjunct genetic model for the study of salt tolerance. Previous studies of ecotypes done by C.B. Osmond have shown that ecotypes of *Atriplex* differed in their tolerances to NaCI salinity. Similarly, in this research study, we hypothysized that ecotypes of *Brassica nigra* from a beach site (33°43.759′N, 118°21.166′W) and an inland site(34°08.830′N, 118°45.573′W) possess different tolerances to NaCI salinity. Experiments conducted over several years at CSUDH provide evidence that *Brassica nigra* is a facultative halophyte capable of adaptive radiation into habitats with a wide range of salinities. These experiments included germinations, dry and wet weight measurements, time to first flowers, number of siliques and seeds produced per silique after early and late treatments with NaCI in both distilled and tap water. Significant differences between dry weights of ecotypes were found at the 0.1 M NaCI and 0.2 M NaCl levels of treatment ($P < 0.05$ and $P < 0.001$ respectively). Ecotype differences also existed with regard to germinations, flowering times, and production of seeds and siliques.

41 THE EFFECTS OF LONG-TERM COPPER EXPOSURE ON TWO SPECIES OF *SALIX*, CALIFORNIA WILLOW

L.M. Peters, R. Resendiz, C.M. Vadheim and **J.W. Roberts***. The Applied Environmental Plant Physiology Laboratory, CSU Dominguez Hills, Department of Biology, Carson, CA 90747

Copper has become a common contaminant in S. California waters. Our laboratory is studying the ability of several native willows to tolerate and extract copper from soil and water (phytoremediation). If successful, such willows will be useful for both revegetation and remediation purposes. The current study investigates the long-term viability of *Salix lasiolepis* (Arroyo willow) and *Salix laevigata* (Red willow) upon exposure to moderate levels of dissolved copper (0 mg, 0.15 mg, 0.3 mg, 0.7 mg, 1 mg $CuSO_4 \cdot 5H_2O$/L, respectively). The copper treatments began when the cuttings were sixteen weeks of age and the experiment was terminated after approximately one year of treatment. This initial experiment revealed two novel results regarding new shoot growth: 1) In the several weeks after copper treatments began *S. laevigata* showed noticeably more growth than *S. lasiolepis*; 2) *S. lasiolepis* however, outgrew S. *laevigata* by week 48, especially treatment group E (1 mg $CuSO_4 \cdot 5H_2O$/L). The Applied Environmental Plant Physiology lab is presently conducting further tests to determine the LD-50 level for copper in these plants.





42 A *BOLD* VISION: ENHANCING WETLAND EDUCATION AND RESTORATION THROUGH THE BALLONA OUTDOOR LEARNING & DISCOVERY (BOLD) AREA

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Under contract to the Ballona Wetlands Foundation, a team of Loyola Marymount University (LMU) students and faculty designed the Ballona Outdoor Learning & Discovery (BOLD) area, an out-door learning facility with a mission to educate students and the public on the value of wetlands, restore habitats in a portion of the Ballona Wetlands, one of Los Angeles' largest remaining salt marsh, and to conduct research on restoration techniques and processes.

The BOLD area will be located in the southwest corner of the Ballona Wetlands. This area presently consists of degraded upland habitat dominated by non-native plants. Portions of the area will be reshaped to restore four habitats—tidal channels, intertidal mud banks, salt marsh, and coastal sage. Educational information will be available to students and the public over a network of trails on which signs and kiosks will be strategically positioned. The first phase of construction will entail grading the area's eastern portion to construct a channel and intertidal mudflat, and construction of paths, an irrigation system for the coastal sage and upland habitats, fencing, and planting the various habitats with native species. Phase 2 will occur when the Wetlands are restored with mixed tidal flows so BOLD's tidal channel can be extended further to the west.

43 MITOCHONDRIAL DNA GENETICS OF AN INVASIVE POPULATION OF YELLOWFIN GOBY *ACANTHOGOBIUS FLAVIMANUS* IN CALIFORNIA

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Recent genetic bottlenecks can produce short-term effects on genetic diversity, yet our ability to detect them using traditional indices is marginal. A survey of population genetic studies utilizing mitochondrial DNA (mtDNA) sequence data of marine fishes has shown from regression analysis that the number of singleton haplotypes in populations ostensibly at mutation-drift equilibrium is in constant proportion to the total haplotypes discovered. A significant reduction in the ratio of singleton haplotypes to total haplotypes in a population might indicate transitory non-equilibrium following a recent genetic bottleneck. We estimated this singleton ratio and calculated the traditional haplotype diversity, *h,* from mtDNA sequence data from two yearly samples from a population of the yellowfin goby, an invasive estuarine fish in California with a documented colonization, in the San Francisco Bay estuary system. We found 32 distinct haplotypes, of which 20 were singletons, in 63 individuals in the 2001 sample, and 21 haplotypes (18 singletons) in 29 individuals in the 2002 sample; however, sequencing of individuals is incomplete. The number of singletons is significantly lower than expected from the constant ratio (t = 10.23, $P < 0.001$) in the 2001 sample, but not in the 2002 sample. When combined, the number of singletons is significantly lower than expected (t = 11.92, $P < 0.001$). This evident loss of rare mtDNA alleles in this population is concordant with a recent bottleneck following the invasion of yellowfin goby, even though traditional indices did not indicate such ($h > 0.94$ for each years).

44 ARE COASTAL WETLANDS IN SOUTHERN CALIFORNIA SOURCES OR SINKS FOR FECAL INDICATOR BACTERIA?

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By acting as natural filtering systems, wetlands perform an important service by improving water quality. Although constructed freshwater wetlands have been shown to remove fecal indicator bacteria (FIB) with high efficiency, little is known about the fate of FIB in estuaries. By filtering particles to which FIB are adsorbed, estuaries could reduce FIB inputs. On the other hand, recent studies have indicated that the large numbers of birds attracted to estuaries could provide a significant source of FIB.

A study was carried out to identify wetland processes that may spatially and/or temporally mediate, the input of FIB into coastal adjacent waters. Wetland characteristics such as extent of tidal flushing, benthic grazer density and vegetative cover did not appear to be correlated with higher FIB levels. However, the occurrence of algal mats may have contributed to elevated sediment FIB by providing protection from desiccation and UV exposure. Temporally, sediment and water FIB concentrations both became extremely high after rain events. Levels of sediment FIB, however, persisted for several days compared to water levels, which decreased rapidly. FIB concentrations were also high on some vegetation types, including *Spartina foliosa* (cordgrass) and algal mats, although not on *Salicornia virginica* (pickleweed). These data indicate that wetland sediment and vegetation are temporary sinks for FIB, however, further work is needed to ascertain their contribution of FIB to coastal waters.

45 FIRST YEAR SURVEY RESULTS OF THE LOS ANGELES CONTAMINATED SEDIMENTS TASK FORCE, CONFINED AQUATIC DISPOSAL SITE LONG-TERM MONITORING PROGRAM

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The Los Angeles Basin Contaminated Sediments Task Force (CSTF) currently is evaluating several treatment and disposal alternatives for contaminated dredged material. One of these options is confined aquatic disposal (CAD), where dredged material is placed in a pit and capped with clean sediments. In August 2001, approximately 100,000 cubic meters of contaminated sediment was dredged from the Los Angeles River Estuary (LARE) then deposited into the North Energy Island Borrow Pit (NEIBP) in Long Beach Harbor. Clean cap material was dredged from a second borrow pit and used to cover the LARE material with a 1.0 to 1.5 m cap layer. In October, 2002 the first year of monitoring was conducted on the NEIBP CAD site. Monitoring included bathymetric and video studies of the cap's integrity, the potential migration of contaminants through the cap and the measurement of biological recolonization of the cap. Results of the multibeam bathymetric survey provided detailed resolution of the NEIBP and indicated that the cap was intact. Video survey results showed that there are an estimated 92,000 (±20%) holes >2 cm in diameter on the cap. Further work is necessary to determine if some of these holes are caused by burrowing organisms that could transport contaminated sediments from beneath the cap to surface sediments. Chemical analysis of core samples indicated that the cap was acting to confine heavy metals and PAH's. After only eight months, biological recolonization of the cap appears to be occurring at a rapid pace.

46 EFFECTS OF CONTAMINANTS ON THE GROWTH PATTERNS OF PACIFIC SANDDAB (*CITHARICHTHYS SORDIDUS*) FROM SANTA MONICA BAY AND DANA POINT, CALIFORNIA

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Santa Monica Bay is a heavily contaminated ecosystem that also provides an ideal habitat for bottom dwelling fish like flatfish. Previous studies suggest that contaminants affect the growth patterns of some species of fish adjacent to the bay in Palos Verdes. However, little information exists on effects of contaminants on longevity and growth rates of Pacific Sanddab (*Citharichthys sordidus*), which is a common flatfish of the bay. The age and growth rates of Pacific sanddab from both contaminated and noncontaminated sites from within the Santa Monica Bay and Dana Point are described. Fish were collected from all of the sites using a standard otter trawl from November 1999 to March 2002. Fish were aged using otoliths and counting annual annuli. Significant differences were found in age, standard length, and weight of Pacific sanddab based upon site; however there were no significant differences between gender. Furthermore, no significant differences were found in the length-weight relationships of Pacific sanddab between Santa Monica Bay and Dana Point.

47 ARTHROPOD SPECIES DIVERSITY IN RESTORED AND UNDISTURBED COASTAL SAGE SCRUB

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Habitat restoration as a means of mitigating habitat loss is a controversial practice. Most of the controversy centers on whether restored coastal sage scrub is viable habitat for the species that depend on resources provided by this plant community. Although most monitoring centers on the extent of native plant cover, the effectiveness of restoration as a means of increasing habitat depends on the ability of the plants to support animal species characteristic of the community. We compared arthropod diversity in undisturbed coastal sage scrub with restored coastal sage scrub and invasive annuals. Plant community cover and diversity was sampled along 30 meter transects. Arthropods were sampled by taking 60 sweeps along each 30 meter transect, and by establishing pit fall traps along a sub sample of the 30 meter transects at 10 meter intervals. About twice as many orders of arthropods were collected along transects dominated by invasive annuals as along transects dominated by native shrubs in undisturbed areas. More orders were collected along transects in the restored coastal sage scrub, but diversity was not as great in the restored area as in the undisturbed area even when plant cover was similar. These results are consistent with published studies that show lower arthropod diversity in restored coastal sage scrub; however, the increased diversity in the restored coastal sage scrub suggests that restoration, while not a cure for habitat loss, does increase habitat for arthropods.

48 DIGENEAN ENDOPARASITE COMMUNITIES OF FISHES OF THE SERRANID GENUS *PARALABRAX*

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The digenean endoparasite communities of six northeastern Pacific species of the serranid genus *Paralabrax* (*P. clathratus, P. nebulifer, P. maculatofaciatus, P. loro, P. auroguttatus,* and *P. albomaculatus*) were compared. Six species of digenetic trematodes were identified as parasites of the six fish hosts. The prevalence of five of the parasites was quite low and only two parasite species were shared among species of hosts. *Paralabrax clathratus* hosted the most digenean species, the highest prevalences of parasites, and different assemblages of parasites at different geographic locations. These parasite assemblages hold minimal information for phylogenetic application (e.g. Hennig's Parasito-

logical Method) but may, at least in the case of *P. clathratus,* be useful in identifying and tracking isolated stocks of the hosts.

49 DOES BEACH GROOMING HARM GRUNION EGGS?

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Grunion (*Leuresthes tenuis*) eggs incubate in damp sand of southern California beaches, fully out of water for two weeks. These fish spawn on some of the most heavily used urban beaches on this coast. Because of numerous human visitors, urban beaches are groomed regularly to remove trash, kelp, and other debris. During grunion season in 2002, San Diego beach maintenance staff followed the Grunion Grooming Protocol (GGP), remaining in dry sand above the high tide mark. The tide mark was set at the highest semilunar tides. On four city beaches, the beach maintenance staff followed this GGP most of the time. All grunion eggs we found were in the intertidal zone, below the high tide mark. Thus the GGP keeps the grooming machines away from the eggs. There is no negative impact on grunion eggs by grooming above the high tide mark. To discover whether grooming directly over the eggs is harmful, we identified areas where grunion spawned, and sampled them to determine the population of incubating eggs. Then, the beach maintenance staff groomed over these experimental areas. Afterwards, we sampled the sand to measure the population of eggs again. Even when little or no kelp is present, beach grooming directly over spawning sites consistently results in a significant loss of eggs. After removal of debris, nearly all the eggs are destroyed. We encourage other beach cities to follow the lead of San Diego and implement a Grunion Grooming Protocol to protect the vulnerable eggs of this unique natural treasure.

50 RELATIONSHIPS BETWEEN FOOD CHOICE AND TOTAL ASSIMILATION EFFICIENCY IN THE HERBIVOROUS MARINE SNAIL *LITHOPOMA UNDOSUM* (TURBINIDAE)

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Numerous studies have identified the preferred food items of herbivorous marine snails and have made attempts to correlate factors such as macrophyte morphology, the presence of deterrent chemicals, and nutritional content with these choices. However, few studies have attempted to examine the degree to which the assimilation efficiency of a food item corresponds with its position in a preference hierarchy. *Lithopoma undosum,* is one of the largest herbivorous snails in southern California, where it occurs from the low intertidal zone to depths up to 21 m. Previous field studies have shown that *L. undosum* feeds on a wide variety of macrophyte foods and that certain foods are consumed more often than others. Through a series of two-choice laboratory experiments, we established clear preference rankings for eleven macrophytes known to occur in *L. undosum's* field diet. *Lithopoma undosum* chose three kelp species (*Egregia menziesii, Eisenia arborea* and *Macrocystis pyrifera*) over all other tested macrophytes; but also showed secondary preferences for the red alga *Pterocladiella capillacea,* followed by the calcified coralline *Lithothrix aspergillum.* These species were chosen over five other macroalgae and the seagrass, *Phyllospadix torreyii.* Using an ash-marker technique, we determined total assimilation efficiencies for the kelp *Egregia menziesii* and five other macrophytes in *L. undosum's* established preference hierarchy. These results failed to show a clear relationship between total assimilation efficiency and food choice in this marine herbivore.

51 ANALYSES OF CARBON (^{13}C) AND NITROGEN (^{15}N) STABLE ISOTOPE SIGNATURES OF INPUTS INTO BENTHIC FOOD WEBS ON SOUTHERN CALIFORNIA ROCKY SHORES

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Rocky intertidal ecosystems are open systems that receive carbon inputs from multiple sources. Benthic consumers directly or indirectly obtain carbon derived from phytoplankton and benthic macrophytes (algae and seagrasses), whose abundances change spatially and temporally with ocean conditions. On urban coasts, however, many other carbon sources are available to benthic intertidal organisms, including estuarine and terrestrial plants and other organic materials that enter coastal oceans in runoff and storm drainage. Carbon (^{13}C) and nitrogen (^{15}N) stable isotopes have been successfully

used to differentiate and track sources of production through coastal food webs, particularly in salt marsh and estuarine habitats and in pristine, colder seas characterized by large algal beds. A stable isotope approach can overcome difficulties working with food webs characterized by multiple inputs because consumers develop isotope compositions that reflect only the ingested materials incorporated into their tissues. However, stable isotopes have rarely been used to analyze benthic food webs in urban coastal habitats lacking extensive offshore algal beds, a condition occurring along much of southern California. The ultimate goal of this study is to analyze the ^{13}C and ^{15}N stable isotope compositions of suspension feeding mussels across a gradient of benthic macrophyte production. Here we report ^{13}C and ^{15}N values for phytoplankton, macrophyte, estuarine/terrestrial plants, and other potential sources of organic material consumed by mussels along the urban southern California mainland. We plan to use these ^{13}C and ^{15}N stable isotope signatures to investigate inputs into mussel populations on southern California shores.

52 SUCCESSFUL REINTRODUCTION OF A TIDEWATER GOBY (*EUCYCLOGOBIUS NEWBERRYI*) POPULATION AT SAN MATEO LAGOON, USMC CAMP J. PENDLETON, CALIFORNIA

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San Mateo Lagoon has intermittently supported a population of the federally endangered Tidewater Goby (*Eucyclogobius newberryi*) that has been extirpated at various times in the past two decades. In February 1998, a severe storm coupled with emergency San Mateo Creek Trestle Bridge repair work apparently extirpated the San Mateo Creek Tidewater Goby population. A reintroduction of the Tidewater Goby at San Mateo Lagoon was implemented as a component of San Mateo Creek Trestle Bridge repair mitigation in January 2000. Seining was utilized for exotic predator removal prior to Tidewater Goby reintroduction. Tidewater Goby collection occurred at San Onofre Lagoon and consisted of 44 random seine hauls. A total of 520 gobies were transported in three ice chests to San Mateo Lagoon and released at three locations in the northwestern portion of the lagoon. Monitoring surveys revealed the continued presence of Tidewater Gobies within San Mateo Lagoon, with captures or observations ranging from 3 individuals to thousands. Breeding activity was detected as early as 5 months after reintroduction, confirmed by the presence of multiple age classes and the capture of gravid females. Exotic species removal has taken place in conjunction with goby monitoring and included the extirpation of Largemouth Bass (*Micropterus salmoides*) from San Mateo Lagoon. Water quality, lagoon profiling, and habitat mapping were monitored as parameters that would potentially effect the success of reintroduced gobies. Results showed reintroduction accompanied by predator control as an important management tool for Tidewater Gobies. Genetics studies being conducted simultaneously should be used to help make determinations about effective reintroduction population size.

53 A COMPARATIVE STUDY OF THE DIGESTIVE ENZYME ACTIVITY OF TUNAS, MACKERELS AND BONITOS

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Tunas are the only teleost fishes known to elevate the temperature of their aerobic locomotor muscle, and some tuna species can also maintain elevated visceral temperatures (they are regional endotherms). Tunas are effective predators, swim continuously, undertake trans-oceanic migrations, and have high metabolic rates. Their diet consists primarily of fishes, crustaceans, and cephalopods, and thus they ingest large quantities of protein and lipids. In tunas, the largest visceral organ is the caecal mass, composed of many branched pyloric caeca, which are thought to increase the surface area for digestion and absorption. It has been hypothesized that the caecal mass of tunas provides a region to which partially digested food from the stomach can be moved for more complete digestion, leaving the stomach empty in the event that another opportunity to feed arises. This study is a comparison of digestive enzyme activities in tunas and their close relatives that are not endothermic, to test the hypothesis that enzyme activities are greater in the endothermic tunas. Three tuna species [skipjack tuna (*Katsuwonus pelamis*), a species that warms its muscle but not its viscera, Pacific northern bluefin tuna (*Thunnus orientalis*) and albacore tuna (*Thunnus alalunga*), species that warm both the muscle and viscera] were compared with the ectothermic chub mackerel (*Scomber japonicus*) and eastern Pacific bonito (*Sarda chiliensis*). The specific activities of three digestive enzymes (trypsin, lipase and pepsin) in the stomach, intestine and caecal mass were measured at 20°C and 25°C. Pepsin activity was detected in the stomach, and trypsin and lipase activities were detected in the caecal mass and intestine. No significant interspecific differences have been detected in any of the digestive enzyme activities measured at either 20°C or 25°C.

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54 MITOCHONDRIAL DENSITIES IN THE LOCOMOTOR MUSCLE OF ECTOTHERMIC AND ENDOTHERMIC SCOMBRID FISHES

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Tunas are unique among scombrid fishes because they can conserve metabolic heat to maintain the temperature of the slow, oxidative myotomal muscle (red muscle) elevated above water temperature (i.e., they are regional endotherms). Other scombrid fishes, including mackerels and bonitos, are ectothermic species. Red muscle, a major source of heat used for endothermy, is a highly vascularized, aerobic tissue with a high density of mitochondria to support aerobic muscle contraction. Recent studies have shown that tunas have a higher standard metabolic rate (SMR) than mackerel and bonito do. This study tests the hypothesis that tunas also have a greater muscle mitochondrial density than is found in mackerel and bonito. Chub mackerel (Scomber japonicus), eastern Pacific bonito (Sarda chiliensis), and albacore tuna (Thunnus alalunga) were obtained off the coast of southern California. Samples of slow, oxidative and fast, glycolytic myotomal muscle fibers were prepared via standard procedures for analysis with a transmission electron microscope (TEM). Individual whole muscle fiber cross-sections were photographed at low magnification (1,000–2,000×) on the TEM and the negatives were scanned into a computer and overlaid with a grid. Using the Scion Image program, the muscle fiber area composed of mitochondria was calculated for each fiber via the point-contact method. Preliminary results indicate that red muscle fiber mitochondrial densities of the chub mackerel are greater than those of tuna. [Supported by NIH grant # R25GM56820

55 PRELIMINARY STUDIES ON A NEW APPROACH TO DEVELOPMENT OF CELL TYPE SPECIFIC ANTI-CANCER DRUGS

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Using an assay developed in this laboratory to examine the binding of various human cell lines to agarose beads derivatized with about 50 different compounds, we found that specific tumor cell lines displayed statistically significant binding differences to specific derivatized beads, versus a non-tumor cell line of the same tissue. Of the many differences observed, the colon cancer cell line, CCL-220, bound more consistently to beads derivatized with 5 lectins: *Phaseolus vulgaris, Lens culinaris, Triticum vulgaris, Arachis hypogaea* and *Artocarpus integrifolia* than did a non-cancer colon cell line, CRL-1459. We are now undertaking studies to ascertain if the observed binding differences between the colon cancer cell line and the non-cancer colon cell line to the various lectin derivatized beads also result in differential toxicity of the lectins to these cell lines in culture. Thus, we wish to know whether or not consistent cancer cell binding to specific lectins also results in increased toxicity of these lectins to cells in culture. This is possibly a new approach, based on differential binding, to the development of anti-cancer drugs that may be better targeted to specific cancer cells.

(Supported by NIH RISE, ONR RISE and Joseph Drown Foundation)

56 BEAD ANALYSIS OF HUMAN COLON CANCER CELL SURFACES

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Two human colon cancer cell lines (CCL-220, tumorigenic in nude mice; CCL-255, non-tumorigenic in nude mice), a non-cancerous human colon cell line (CRL-1459) and a human lung carcinoma cell line (HTB-171) were tested for their ability to bind to agarose beads derivatized with 51 different molecules. The 2 colon cancer cell lines bound to more beads than the non-malignant colon cell line and the lung carcinoma cell line. The closely related colon cancer cell lines bound differently to beads derivatized with histamine, isomaltose, and L-tyrosine, while only the lung cancer cell line bound to para-aminophenyl-beta-D-glucopyranoside derivatized beads. The 4 cell lines showed distinctly different binding properties to beads derivatized with various lectins. All results were statistically significant based on p-values calculated using SPSS Fischer exact tests. Experiments using a hapten inhibition approach with free compounds suggested that, in many cases, cell-bead binding was specific. This assay is a good first step in the analysis of new cell surface properties that may be related to cellular malignant potential (supported by NIH RISE, ONR RISE, NSF ESIE, Eisenhower program and the Joseph Drown Foundation).

57 INITIAL PROTOCOLS FOR THE CAPTIVE BREEDING AND REARING OF SPOTTED SAND BASS (*PARALABRAX MACULATOFASCIATUS*) IN SOUTHERN CALIFORNIA

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A pilot hatchery for the locally common serranid is currently under development in Redondo Beach, CA. A captive broodstock of 36 adult individuals began voluntary spawning on May 19, 2002. Adult spotted sand bass were captured via hook and line from San Diego Bay, San Diego, CA. Eggs were collected continuously throughout the Summer into Fall 2002 until spawning ended in early December. Water temperature ranged from 18.5–22.5°C during that same timeframe. Spawning, and corresponding behavior, was documented in the evening hours (1700–2100hrs). Eggs were hatched from random spawns based on tank availability. Hatching rates in excess of 90% were routinely achieved, with hatching occurring 18–26 hrs after spawning. Large hatches (>200 individuals) of larvae were successfully developed up to 24 days after hatch (dah) with oldest larvae reaching 35 dah. Settlement was found to initiate after 25 dah in limited observations.

58 SOUTHERN CALIFORNIA STEELHEAD: RESTORING A LIVING LEGACY

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The poster depicts with maps and photos a variety of conservation issues for endangered steelhead trout (Salmonidae: *Oncorhynchus mykiss*) in southern California. Thirty-three projects or plans throughout southern California are highlighted, involving fish passage barrier removals, large dam deconstructions, Corps of Engineers feasibility studies, watershed plans, and population monitoring. The poster was developed jointly by Southern California Steelhead Coalition, University of California Cooperative Extension, and California Department of Fish and Game. Posters (24 × 36 inches) are available for purchase at $75 each to cover the large-format plotting, laminating, and mailing. The poster also is available as a free downloadable PDF file at the Steelhead Coalition web site (www.socalsteelhead.org).

59 ASYMMETRIC SYNTHESIS OF 1,1′-BINAPHTHYL-2, 2′-DIAMINE

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Chiral BINOL and its derivatives have become very important as ligands for asymmetric synthesis. Many of these derivatives are also natural products with biological activity. The unique axis of chirality exists due to the rotational barriers of the naphthyl groups. Asymmetric syntheses of these compounds have been successful through copper catalyzed coupling reactions. However, the amine analog has resisted a practical asymmetric synthesis. We have approached the asymmetric synthesis of binaphthyl diamine synthesis via benzidine rearrangement. Benzidine rearrangements traditionally have been promoted by bronsted acids. Our approach has been to use both chiral bronsted acids as well as chiral Lewis acids. We will present our efforts in the asymmetric synthesis of the 1,1′-binaphthyl-2,2′-diamine.

60 SCIENTIFIC INVESTIGATIONS AND STUDENT ENGAGEMENT IN OSMOSIS AND DIFFUSION LAB ACTIVITIES: AN ANALYSIS OF TEN LABORATORY MANUALS

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In order to assist student understanding of scientific concepts and the nature of scientific inquiry, the National Science Education Standards recommend that laboratory activities engage students in all steps of a scientific investigation, from forming questions to drawing conclusions and applying the results to new examples. This study used a modified version of the Laboratory Structure and Task Analysis Instrument (LAI) to evaluate 63 exercises from ten college laboratory manuals to assess the degree of student involvement in each. All exercises focused on the concepts of osmosis and diffusion. This instrument assesses 1) the presence of a pre-laboratory activity, 2) the students' role in the planning of the experiment, 3) student performance during the activity, 4) the amount of analysis and interpretation required, and 5) the application of knowledge. The most common pre-laboratory activity was a selected reading (76.2%). Students' involvement in planning exercises was limited to identifying a hypothesis in 17.5% of the exercises, the independent variable in 9.5% and predicting results in 23.8%. Most often students performed the exercise according to a given set of instructions (76.2%) or observed an instructor demonstration (20.6%). Questions often guide students to draw conclusions (60.3%) but rarely asked them to provide evidence (14.3%) or apply the results to a practical object (14.3%). We recommend revising exercises to encourage students to learn concepts through the use of scientific inquiry, which increases student involvement in a scientific investigation and teaches the student to investigate the world as scientists.

61 SURFACE ANALYSIS OF HUMAN COLON CANCER AND NON-CANCER CELL LINES

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This laboratory has developed an assay to examine the surfaces of cells by assessing the binding properties of various cell lines to agarose beads derivatized with about 50 different compounds. Human colon cancer cell lines and non-cancer colon cell lines have been examined using this assay. The results showed statistically significant binding differences between the colon cancer cell lines and normal cell lines to various derivatized beads. In the present study, we focus on colon cancer cell line, CCL-220 and a non-cancer colon cell line, CRL-1459. The results indicate that of the many observed bead binding differences of these cell types, the cancer cell line more consistently bound to beads derivatized with 5 lectins: *Phaseolus vulgaris, Lens culinaris, Triticum vulgaris, Arachis hypogaea and Artocarpus integrifolia.* We are now undertaking studies to examine the surfaces of these two cell lines via micro gel electrophoresis and labeled lectins to ascertain whether cell-type specific surface components can be identified that would account for the observed lectin bead-cell binding differences. These studies may help lead to a useful approach in the development of anti-cancer drugs, based on differential binding of toxic compounds to cancer cells versus normal cells of the same tissue type. Presently this laboratory is beginning to explore this possibility in tissue culture studies (Supported by NIH RISE, ONR RISE, and Joseph Drown Foundation).

62 THE EFFECTS OF AN INVASIVE PLANT COMMUNITY ON THE COASTAL SAGE SCRUB SOIL MICROBIAL COMMUNITY7

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Previous studies suggest the division between grassland and shrubland has several causes involving herbivory, allelopathic responses, and climate (Mooney 1988). The differences between grassland soils and coastal sage scrub (CSS) soils from this study indicate that the soil microbial community may have a role as well. In this study, soils were tested from sites covered with the predominant coastal sage scrub shrub, *Artemisia californica* with varying levels of invasive non-native grasses. Different enzyme analyses (cellulase, ligninase, protease) and substrate-induced respiration (SIR) analyses of different substrates (glycine, glucose, salicylate) were used to elucidate a difference in the structure of the microbial community. An analysis of soil characteristics (pH, soil moisture content, organic

matter, and microbial biomass) was made to determine how the amount of invasive plants directly affects the soil. A higher pH was found under bare ground and non-native grasses than under *A. californica.* With increases in invasive non-native grasses, a decrease in soil moisture content and organic matter was observed. Results of the enzyme and SIR analyses concur with a difference in microbial community structure between grassland and shrubland communities. These findings indicate changes in the structure of the CSS soil microbial community with increasing levels of invasive grasses.

63 SOIL NITROGEN STORAGE IN AREAS OF VARYING ANTHROPOGENIC NITROGEN-DEPOSITION IN SOUTHERN CALIFORNIA

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Southern California's expanding population and geography have caused an increasing amount of atmospheric nitrogen (N) pollution to be deposited into semi-arid shrubland ecosystems. The effects of anthropogenic nitrogen deposition on temperate coniferous-forest ecosystems have been previously studied in Europe and the northeast and western United States. However, the effects of N deposition on semi-arid shrublands of Southern California are still poorly known, and therefore, need to be addressed. This research investigated soil nitrogen storage in several areas of Southern California, which received different levels of exposure to atmospheric nitrogen pollution. Soil samples from four sites of varying atmospheric deposition were analyzed for available nitrogen, total nitrogen and pH. Preliminary results indicate that sites with higher pollution exposure had higher total N and extractable N, lower pH, and lower C:N ratios than sites with lower pollution exposure. The increases in soil N suggest that atmospheric N deposition can significantly increase soil N content in southern California shrublands.

64 PCR BASED SECONDARY SCREENING OF CLONED DNA USED FOR SEQUENCING DECISION MAKING

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Following cloning of restricted DNA into pUC19 plasmids and selection of positive colonies of *E. coli* (based upon blue/white screening) a secondary screening procedure was performed in order to further characterize cloned DNA prior to sequencing. Additional information obtained from PCR based screening included fragment length and, if present, location of repeat units within the fragment. Based upon this supplemental information, total cost of sequencing for laboratory projects was significantly reduced. 100% of sequenced inserts in plasmids contained sought after microsatellite repeats.

65 SPAWNING BEHAVIOR OF THE KELP BASS, *PARALABRAX CLATHRATUS*, FROM SANTA CATALINA ISLAND, CALIFORNIA

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The spawning behavior of the kelp bass, *Paralabrax clathratus,* was studied on Santa Catalina Island, California from 2000 to 2002. Behavioral observations were conducted at several sites near the marine reserve adjacent to the USC Wrigley Marine Science Center. In addition, an aggregation of 108 individuals was observed in a 700 m^3 outdoor, floating net-pen for more detailed descriptions of spawning behavior. Approximately 250 spawning events were observed over the entire study period. Adults formed aggregations that ranged in size from 30 to 200+ individuals. However, spawning occurred within smaller subgroups of 3 to 20+ individuals. Spawning groups consisted of a single, gravid female and several males. Adults were sexually dichromatic during the spawning season, with ripe males adopting bright orange snouts. Males and females also exhibited ephemeral color changes during courtship and spawning periods. Spawning occurred between 1900–2130 hours and the onset was highly correlated with sunset. Both males and females were capable of spawning multiple times during a single evening. Spawning occurred on a daily basis from June through August 2002 and showed no significant relationship with the lunar cycle. The behavior patterns observed in the field

were virtually identical to those observed in the captivity study. In general, the spawning behavior of kelp bass was consistent with other gonochoric, group-spawning serranids.

66 OBSERVATIONS OF COURTSHIP AND SPAWNING BEHAVIOR IN THE CALIFORNIA SHEEPHEAD, *SEMICOSSYPHUS PULCHER*

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The courtship and spawning behaviors of a protogynous fish, the California sheephead (*Semicossyphus pulcher*), were recorded weekly throughout their spawning season (late June–early September). Behaviors were recorded while on SCUBA using slates and digital video at Bird Rock, Santa Catalina Island, CA. Additional observations were made at the Monterey Bay Aquarium and confirmed the details of behavior seen in the field. Large males held spawning territories in which females congregated approximately one hour before sunset. Courtship commenced shortly before sunset and involved the male approaching each female, making lateral contact and leading her in a circular pattern. Large males engaged in an average of 11.8 spawns during observation periods, which averaged 34 minutes. Smaller males attempted to court females within the territories, prompting aggressive chases by the large males, even at the expense of aborted spawns. Females were not faithful to a particular territory throughout the day or spawning season, indicating that they are not part of a strict harem. Both field and aquarium observations confirm that the mating system can be successfully predicted from the size advantage model. Current regulations on the sheephead fishery allow the removal of large, rare males and consideration of the mating systems of protogynous fishes could lead to better fishery management strategies.

67 THE SPAWNING ACTIVITY AND ASSOCIATED SOUND PRODUCTION OF WHITE SEABASS, *ATRACTOSCION NOBILIS,* AROUND SANTA CATALINA ISLAND

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White seabass, *Atractoscion nobilis* (Sciaenidae), supported economically important recreational and commercial fisheries throughout California prior to a population collapse. Although white seabass stocks are currently recovering, management efforts are compromised by insufficient information on fish spawning activity and sound production. During 2001 and 2002, the spawning behavior and periodicity of 61 white seabass (15 male, 46 female) were observed within a 525 m^3 net pen. In addition, underwater audio recordings were taken to determine diel sound patterns and sound production during spawning events. Calibrated sound recordings were spectrally analyzed to determine the rate and frequency range (Hz) of individual calls. Spawning was observed on 49 occasions, and 148 spawning events were documented through regular sampling for eggs within the net pen. Consistent spawning activity was observed between April and June, 2001, and between February and July, 2002, within a temperature range of 12.3–19.3°C. Peak spawning activity occurred from one hour before sunset to three hours after sunset. There was no correlation between spawning activity and lunar phase. Sound production was recorded during 37 spawning events. Male white seabass produce a unique and discernible sound coinciding with the release of gametes. Additional fieldwork is in progress to identify the source level (dB re 1 μPa at 1 m) of white seabass sounds and to locate white seabass spawning aggregations around Santa Catalina Island through the detection of spawning sounds. This research provides essential information that can be used by fishery managers to design regulations that protect white seabass spawning stocks.

68 WHEELER NORTH'S "TAMPICO MARU": RE-DISCOVERING BAJA CALIFORNIA'S "EXXON VALDEZ"

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There is great need for preserving and using historical information about our coastal ecosystems. In March, 1957, the Tanker Vessel Tampico Maru ran aground 60 km south of Ensenada, releasing over 800,000 gallons of black diesel. Within a month the late Dr. Wheeler North, then at Scripps Institution of Oceanography, lead an expedition to observe the plight of marine life. This was followed by about

20 site visits over the next 22 years, involving many of California's leading marine scientists. However, only data from the first several years was actually published: the remaining information remained with Dr. North for many decades. In 1997 Dr. North became aware of our interest in longterm recovery from oil spills and happily agreed to mobilize the old data. As time and health permitted, Dr. North resurrected photos and data and began to write a new manuscript on the incident. In addition, I subjected available information to analysis using our current oil fate and trajectory models. The incident changes our thinking about the effect of oil spills on subtidal ecosystems: although the spill was highly toxic to intertidal and subtidal marine life over a large area, kelp beds quickly recovered and canopy covered much larger area than had previously existed, apparently due to prolonged lack of grazing and protection from waves by the vessel's hull. Over the longterm, Dr. North and many associates recorded the arrival of various plants and animals. Wheeler North passed away in December, 2002, while completing work on resurrecting the Tampico Maru story. In February, 2003, I was privileged to provide a briefing of this incident to Mexican and California spill responders at a recent joint spill response workshop (MEXUSPAC). Western Mexico now has its own "Exxon Valdez" and all of us have access to information about recovery from the largest diesel spill in history along the west coast.

69 THERE AND BACK*, THE RESPONSE AND RECOVERY OF SOUTHERN CALIFORNIA KELP BEDS FROM THE 1997–1998 EL NINO SUMMARY 1997–2002

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In 1997, we went to the brink as kelp beds were decimated in San Diego and Orange Counties leaving kelp resources at their lowest ebb recorded during the century. In 1999, we began a slow but steady march back from that brink to a substantial recovery of the resource. Although all the beds lost biomass, not all of the beds recovered as rapidly or completely. By looking at the long-term record, we explore herein the reasons for these incongruities. A database to assess these changes was available as quarterly kelp bed aerial surveys are a requirement, since 1983, of discharge permits into the offshore waters under the jurisdiction of the San Diego Regional Water Quality Control Board. By means of aerial infrared photography, the 24 distinct beds that occur offshore of Orange and San Diego Counties were recorded as best as possible at the maximum areal extent of any canopies during the year. Although the intention was that a synoptoic survey of the beds would allow a determination of the potential effects of waste water (both heated effluent and sanitary) on the kelp beds, insight is provided, through the medium of aerial photographs, the kelp beds response to and the aftermath of the El Niño.

Based on these data, a synopsis of the health of each of the kelp beds and the effects of these environmental perturbations, as it compares with the other kelp beds in the region, can be determined. Although it is not possible to determine the cause of a decline or decrease in a single kelp bed by aerial photographs, it does determine whether the bed in question is responding to an area wide event, or if it is atypical of the beds in the region. Atypical beds can then be categorized according to their distance from other beds, substrate depth, and potential biological factors. Looking at these factors then offer some insight as to the cause and effect of the differences noted.

*With apologies to B. Baggins

70 PATTERNS OF HABITAT AND ABUNDANCE IN THE LA JOLLA KELP BED

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Surveys of habitat, algae, fish and invertebrates were conducted throughout the La Jolla kelp bed during spring, summer, and early fall of 2002. The work was part of an effort to (1) determine the effectiveness of the relatively small San Diego-La Jolla Ecological Reserve (established in 1971), (2) to provide data that would be useful for the design of a new reserve or redesign of the present reserve, and (3) to serve as a baseline of fish and invertebrate abundance patterns for future studies. The patterns of habitat and the association of fishes and invertebrates with these habitats will be presented.

71 LONG-TERM VARIATION IN A SOUTHERN CALIFORNIA KELP FOREST

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Variation in large kelps and invertebrates in a giant kelp forest near San Onofre, CA was assessed over 22 years (1978–2000) based on abundance estimates of large kelps and invertebrates in six stations within the forest. Giant kelp (*Macrocystis pyrifera*) density was cyclic, with large peaks in

1981 and 1992. Recruitment occurred approximately every three years. The understory kelp *Pterygophora californica* and red and purple sea urchins (*Strongylocentrotus* spp.) were abundant at the beginning of the study, but declined to near extinction at most stations in 1980–85. *Pterygophora* abundance increased beginning in 1986, but declined to near zero by 1997. *Strongylocentrotus* spp. abundance began to increase in 1990, and has remained high but variable since 1996. Bat stars (*Asterina miniata*) declined to near extinction by 1983 and have remained rare. The white sea urchin (*Lytechinus anamesus*), increased in 1982–4 and then declined to near zero by 1990. Dramatic declines in giant kelp abundance were associated with warm water/low nutrients in 1981–4 and 1997–8, and increases with cooler water in 1990. Variation in kelp abundance among stations appears to be negatively associated with sand cover and sea urchin abundance. These data and historical records indicating that entire kelp forests in the San Onofre region can be buried by sand suggest that temporal variation in this kelp forest is largely driven by variation in the physical environment.

72 EVALUATION OF EELGRASS MITIGATION AND FISHERY ENHANCEMENT STRUCTURES IN SAN DIEGO BAY

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From September 1997–August 2002 the Vantuna Research Group at Occidental College monitored the fish populations of an eelgrass mitigation site in San Diego Bay for the U.S. Navy. This mitigation area was located in outer San Diego Bay proximate to North Island. During this period, this enhancement effort was surveyed 34 times in a standardized fashion. With the planting of eelgrass the density of fishes quickly reached the densities observed in the reference eelgrass habitat. The eelgrass persisted throughout the scope of the study and fish utilization of the transplant area continued to be high at the termination of this study. There was not a significant difference between the densities of fishes in the transplant area when compared to a reference eelgrass bed.

In addition to the eelgrass transplant area four replicated artificial reefs were placed proximate to the new habitat on the slope of the channel of San Diego Bay. These reefs were designed to increase fishery productivity. The four reefs contained both concrete and rock replicates in a paired design. For fish density there was not a significant difference between rock and concrete reefs. For the three major fishery species observed by divers there was differential utilization of this newly created habitat. Spotted bay bass (*Paralabrax maculatofasciatus*) utilized this reef area in the winter when fish production in San Diego Bay is low, and were generally absent from the reefs during their spawning season. For kelp bass (*Paralabrax clathratus*), a more open coast species, they were found to utilize this habitat by all life stages. Similarly for barred sand bass (*Paralabrax nebulifer*), young-of-year, subadult and adult fishes were present on the reefs throughout the study period. The density of each year class of barred sand bass was positively correlated with the successive year class throughout the life history of this species. This is an indication of the ability of these reefs to enhance the fishery productivity of this region. Overall, the enhancement effort was successful in terms of fish abundance.

73 HABITAT-DEPENDENT RECRUITMENT OF TWO TEMPERATE REEF FISHES AT MULTIPLE SCALES

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The distribution and abundance of reef fishes often has been attributed to several processes that result in a measure of recruitment success. We employ a large-scale experimental reef system to examine patterns of recruitment of two rocky reef fishes, the California sheephead (*Semicossyphus pulcher*) and the blackeye goby (*Rhinogobiops nicholsii*). We quantified recruitment on twenty-one experimental reefs (each 1600 m^2) that represented low, medium, or high treatments of habitat coverage in 2001 and 2002. Recruitment of California sheephead was higher on reefs of medium coverage than on other coverages, while the blackeye goby exhibited lower recruitment on reefs of low coverage than on other coverages. Within reefs, recruitment to "edge" habitat was lower than "inside" the reef for each species. At the smallest scale, several measures of habitat structure were quantified within 1-m^2 quadrats to identify potentially important microhabitat characteristics. Rugosity was important in predicting the presence of recruits for each species at this small scale.

The densities of recruits of California sheephead corresponded to the densities of age 1+ individuals the following year, suggesting that spatial patterns of abundance may be established early in life, and the abundance of predators does not appear to influence the patterns observed. Low densities of recruits for each species may have led to the habitat-dependent patterns of recruitment through habitat selection at settlement and density-independent mortality because of the low densities of recruits observed. Longer temporal studies with variable recruitment are needed to determine the importance of habitat structure relative to other processes.

74 POPULATION DYNAMICS AND PRODUCTIVITY OF CRYPTIC FISHES

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This study was designed to characterize cryptic fish populations by 1) productivity 2) composition and principal species 3) diversity and seasonal dynamics with comparisons to conspicuous fishes and 4) microhabitat and spatial variation. Two reefs (KH06-shallow and KH12-deep) within King Harbor, Redondo Beach, California, were sampled from January 2000 to September 2002, with monthly samples taken from July to November of 2000 for productivity estimates. Fishes were collected from random 1 m^2 replicates using quinaldine. Fifty meter visual transects were used to assess composition and density of conspicuous fish populations in the same locations. Collections were also made at Palos Verdes Peninsula and Catalina Island to address questions of spatial variation.

Annual production of cryptic fishes in King Harbor was 14.4 g WW/m^2. *Paraclinus integripinnis* contributed to 74.3% to total production followed by *Gibbonsia elegans* (14.3%) and *Hypsoblennius jenkinsi* (11.5%). The annual production was higher at KH06 than KH12. *P. integripinnis* contributed to most of the total production for both reefs (86.5% KH06, 56.8% KH12). The top 5 species accounted for 97% of the total numbers of individuals and 88% of the total biomass. One species, *P. integripinnis* predominated in both numbers (82.0%) and biomass (52.8%). This dominance lead to low overall H′ diversity (0.34), but KH12 was more diverse than KH06. Species richness, H′ diversity, number of individuals and biomass were all greatest in the summer and early fall. Numerical density of conspicuous fishes was significantly lower than that of the cryptics on the same reef, while their diversity was greater. There were multiple correlations between species and microhabitat preferences, and great spatial variation on a larger scale was also found. The Palos Verdes collections were dominated by cottids while the Catalina Island collections were predominately composed of gobies.

75 A COMPARISON OF REEF FISH ASSEMBLAGES BETWEEN SANTA CATALINA ISLAND AND THE OUTER LOS ANGELES FEDERAL BREAKWALL

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The fish assemblage of the rocky reef kelp forest habitat of Santa Catalina Island, California was compared to the outside of Los Angeles Federal breakwater, a mature artificial reef. Two sites along the breakwall as well as four sites at Catalina (two inside and two outside of a marine reserve) were sampled approximately bimonthly using visual census on SCUBA at depths of six and 12 meters. Cryptic fishes were sampled at the breakwall and at Catalina outside the reserve using mesh bags and anesthetic in one meter square collections at each site. Preliminary data suggests significant differences in both density and species composition of fishes between the mainland and island sites. Densities of recreationally important species, *Paralabrax clathratus* and *Semicossyphus pulcher* were significantly higher at Catalina within the marine reserve. Densities of cold water fishes including scorpaeniformes and embiotocids were significantly higher at mainland sites. Clustering analysis by species and sites resulted in primarily mainland and island groups. Inclusion of cryptic fishes significantly increased both densities and species richness at both island and mainland locations. Preliminary results of this study suggest that there are more significant differences between the island and mainland reef fish assemblages than would be predicted with only 40 kilometers separating the two locations.

76 RELATIONSHIP OF MORPHOLOGY, DIET, AND FEEDING GUILD STRUCTURE IN THE INTERTIDAL FISH ASSEMBLAGE OF CENTRAL CALIFORNIA

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The intertidal fish assemblage of central California comprises four feeding guilds: (1) a carnivore guild, (2) a microcarnivore guild, (3) a guild of polychaete feeders, and (4) an omnivore guild. The relationship between morphology, diet, and guild membership was examined for the 14 most abundant species of this assemblage. The purpose of the study was to determine whether: (1) dietary similarity parallels morphological similarity; (2) any morphological features are associated with the consumption of a particular type of prey, and (3) unique morphological configurations are associated with a particular feeding guild. Twelve morphological measurements potentially related to feeding were made and involved the head, mouth, gill rakers, and gut. Linear regression revealed no assemblage-wide relationship between dietary similarity and morphological similarity, but a significant relationship was found between taxonomic relatedness and morphological similarity. A significant positive relationship was found between mouth height and the amount of amphipods consumed. In addition, a significant positive relationship was found between the amount of algae consumed and both mouth angle and gut length. A significant negative relationship was found between mouth angle and the amount of gastropods consumed. Principal components analysis revealed considerable overlap in morphology between the four feeding guilds. The microcarnivore guild contained the widest array of morphologies, and the carnivore guild was the least diverse in morphology. The morphological variation of the central Californian intertidal fish assemblage is correlated more closely with taxonomic affiliation than with specific types of prey.

77 DIGESTIVE ENZYME ACTIVITIES IN THE OMNIVOROUS *PHYTICHTHYS CHIRUS* (STICHAEIDAE): EVIDENCE FOR MEMBERSHIP IN AN HERBIVOROUS CLADE OF PRICKLEBACK FISHES

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We measured the activities of proteases, carbohydrases, and a lipase in *Phytichthys chirus* to determine whether this fish exhibits digestive enzyme activities supporting its current position in a clade of largely herbivorous pricklebacks (Stichaeidae) or in an adjacent clade of carnivorous species. Activity profiles of digestive enzymes in three members of the herbivorous clade, *Cebidichthys violaceus, Xiphister atropurpureus,* and *X. mucosus,* reveal a profile expected in plant-eating fishes, i.e., high carbohydrase and lipase but low protease activities, whereas *Anoplarchus purpurescens,* a member of the carnivorous clade, exhibits the opposite pattern. The previous work showed that the carnivorous *X. atropurpureus* displays an activity profile most similar to its sister taxon, the herbivorous *X. mucosus,* suggesting that phylogeny influences digestive enzyme activities. The current study examined further the possible constraints of phylogeny on digestive enzyme activity. We measured the activities of eight digestive enzymes in *P. chirus,* the omnivorous taxon sister to the two species of *Xiphister.* Univariate and multivariate analyses indicated that *P. chirus* exhibits activities of amylase, maltase, isomaltase, aminopeptidase, and lipase similar to other members of the herbivorous clade. The results showed that all four members now studied of the herbivorous clade are similar to each other with respect to the overall suite of digestive enzyme activities but different from the suite displayed by *A. purpurescens.* These outcomes support the phylogenetic relationships of pricklebacks hypothesized earlier based on morphological characters and also challenge the current paradigm that diet is more important than phylogeny in affecting digestive enzyme activity.

78 ONTOGENY OF DIET AND TROPHIC POSITION IN HERBIVOROUS AND CARNIVOROUS PRICKLEBACK FISHES (STICHAEIDAE): DIETARY AND STABLE ISOTOPE ANALYSES

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We compared gut contents and stable isotope signatures (in progress) of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) of four phylogenetically-related, wild-caught, and experimentally-fed (high-protein animal diet) prickleback fishes. $\delta^{13}C$ and $\delta^{15}N$ signatures (in progress) of invertebrate, algae, and a seagrass from the prickleback habitat also were assessed to determine food origins and ontogenetic changes in trophic positions of these fishes as they grow. Two of the pricklebacks, *Cebidichthys violaceus* and *Xiphister mucosus,* begin life as carnivores, then become herbivores at sizes >44 mm SL, whereas *X. atropurpureus* and *Anoplarchus purpurescens* are carnivores throughout life. We hypothesized that, consistent with the dietary analyses, stable isotope values will show that: (1) Wild-caught *C. violaceus* and *X. mucosus* shift to an algal diet and decrease in trophic position with increasing size; (2) Wild-caught *X. atropurpureus* and *A. purpurescens* shift their diet to somewhat larger animal prey and show a

slight increase in trophic position with increasing size; and (3) On the animal diet, the two carnivores exhibit greater $\delta^{15}N$ enrichment than the two herbivores. Results obtained to date show that trophic position based on $\delta^{15}N$ signatures of the pricklebacks on natural diets reflect phylogeny more than diet in that the three members of the largely herbivorous clade, *C. violaceus, X. atropurpureus,* and *X. mucosus,* were all nearly one trophic level lower than *A. purpurescens,* in an adjacent carnivorous clade. Nevertheless, trophic positions of the four species on the animal diet were similar, the fishes thus appearing to show a plastic response to diet.

79 MOVEMENTS AND SITE FIDELITY OF THE ROUND STINGRAY, *UROBATIS HALLERI*, AT SEAL BEACH, CALIFORNIA: A PRELIMINARY REPORT

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The round stingray, *Urobatis halleri,* is a common nearshore elasmobranch in southern California waters. At Seal Beach, CA, round stingrays are found in high densities and are responsible for over 300 injuries to humans each year. Little, however, is known about their movement patterns or residence time in the Seal Beach area. Fine-scale movements and site fidelity of round stingrays at Seal Beach are being determined using acoustic telemetry. To date, six rays have been manually tracked continuously for up to 90.5 h, and 14 rays have been monitored using automated acoustic monitors for up to 176 d. Manually tracked rays exhibited limited daily movement, with a median rate of movement of 32.0 m h^{-1}, which varied with tidal stage. Rate of movement was lower during periods of incoming tide (19.2 m h^{-1}, median) than high slack tide (38.6 m h^{-1}, median) and outgoing tide (44.4 m h^{-1}, median). Acoustically monitored rays typically remained off Seal Beach for weeks after they were tagged and two rays were detected at Seal Beach approximately six months after being tagged. During this time, rays were most often recorded at the mouth of San Gabriel River at the west end of Seal Beach. During the 176-d period, six rays were observed to move to neighboring beaches between 1 and 2.5 km away and five of these rays later returned to Seal Beach. So far, rays monitored have showed periods of little movement followed by movement out of the area.

80 DISTRIBUTION AND ABUNDANCE OF THE ROUND STINGRAY, *UROLOPHUS HALLERI*, NEAR A THERMAL OUTFALL AT SEAL BEACH, CALIFORNIA

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Large numbers of round stingrays, *Urolophus halleri,* are known to inhabit nearshore areas at Seal Beach, California. It has been hypothesized that *U. halleri* are attracted to thermal effluent discharged into the intertidal zone by power-generating stations at Seal Beach; however, nearshore distribution and abundance of *U. halleri* are unknown. Distribution and abundance of *U. halleri* are being compared between two sites at Seal Beach (outfall sites) and one site at Surfside Beach (reference site) using beach seines and diving surveys. Stingray abundance obtained during monthly beach seines from July 2002 through the present is higher and more variable at Seal Beach compared to Surfside Beach. Intermittent diving surveys from August–October 2002 indicate higher densities within 30 m of the surfzone, but densities decrease markedly 31–60 m from the surfzone at all sites. Sea floor water temperatures are also higher and more variable at Seal Beach than at Surfside. Additionally, sea floor temperatures are also higher within 30 m of the surfzone than 31–60 m of the surfzone. Preliminary analyses of environmental parameters indicate that water temperature and swell height explain up to 76% the variation in nearshore stingray abundance at Seal Beach.

81 CAPTIVE SPAWNING BEHAVIOR OF THE SPOTTED SAND BASS (*PARALABRAX MACULATOFASCIATUS*)

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The reproductive biology of *Paralabrax maculatofasciatus* has received close scrutiny. In contrast, the spawning behavior of this diandric protogynous hermaphrodite has received far less attention. During the development of a pilot hatchery for the species, observations were made of the courtship and spawning of the captive broodstock. Most observations were made twice weekly from June–

August 2002 during the hours of 1600–2000 via digital videotape. Two tanks housed a cumulative total of thirty-six adults, ten and twenty-six fish, respectively. Each tank contained a minimum of three males, determined by secondary sex characteristics. The predominant gender in each tank was female, to maximize egg output for the hatchery effort. Each tank represented a spawning aggregation density hypothesized for a diandric protogynous reproductive strategy. A low density tank of ten fish showed spawning activity dominated by a single male, who actively courted and pair-spawned with females, while intimidating subordinate males. The high density tank of twenty-six fish showed no male dominance and three major spawning types; pair spawning, sneak spawning and group spawning. Significant color modification was found within each sex and sexual dichromatism during spawning events. Females took on a overall darker green punctuated with dark vertical bars while males showed dark vertical bars with very light, off-white, background. The males were able to modify their color based on interaction intensity and type. Aggressive behavior was more prevalently during spawning periods, both male to male and male to female. Courtship and subsequent spawning occurred almost daily during the period of observation.

82 ARE JUVENILE TOPSMELT REALLY BEACH FISH?

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To explore habitat associations and abundance of an important prey item of the endangered California least tern, *Sterna antillarum browni,* we sampled age-0 jacksmelt, *Atherinopsis californiensis,* and topsmelt, *Atherinops affinis,* in eastern San Francisco Bay. We used beach seines and a surface-skimming (neuston) net in waters near Alameda Point during the tern nesting season. About 85% of all silversides identified were topsmelt. Day-time neuston tows took mainly larval silversides, and all size classes studied were more abundant in beach seine samples. Analysis of habitat associations was made difficult by differential tide height restrictions at some sites. Beach seine capture frequency of fish >15 mm total length (TL) was significantly greater at tide heights >60 cm than at lower tides. During higher tides, when juvenile silversides are available to the beach seine, the seineable area constitutes less than 4% of the available shallow water habitat in the study area. Nighttime neuston tows in protected open water took larger catches per unit effort of the size class of interest (15–50 mm TL) than did day-time beach seines on average.

83 GRUNION GREETERS: VOLUNTEERS MONITORING GRUNION RUNS IN SAN DIEGO

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Grunion (*Leuresthes tenuis*), the only marine fish that spawn completely out of water, are restricted to a narrow, long distribution in coastal California and Baja California. The populations are difficult to assess because grunion are not caught in trawls and are difficult to locate except during spawning runs. Over 200 volunteers were trained during two workshops at the Birch Aquarium, Scripps Institution of Oceanography in February and April of 2002. They then were assigned to monitor grunion appearances at ten sites on four city beaches. Within 24 hours after each scheduled run, they reported data by telephone and by an interactive web questionnaire. The scientific team verified the spawning sites in the field by finding the eggs on shore and recording locations with GPS coordinates. Data on numbers of grunion, spawning areas on the beach, and other conditions were collected from twenty nights for ten runs beginning March 1 and ending July 13, 2002. We found that San Diego is home to a very strong spawning population of grunion. Grunion appeared at the earliest predicted run date, March 1, and spawning continued into July. Extensive runs were seen at many locations on all four city beaches. Heaviest runs occurred at the end of April and at the end of May, on Ocean Beach, Pacific Beach, Mission Beach, and La Jolla Shores. We are continuing to work with volunteers to monitor grunion populations in 2003.

84 AGGREGATION RESPONSE TO CHEMICAL ATTRACTANTS RELEASED BY *TEGULA* SPECIES

G.K. Nishiyama and C.A. Kay-Nishiyama. College of the Canyons, Department of Biology, Santa Clarita, CA 91355

Spatial partitioning was observed between *Tegula funebralis* and *Tegula gallina* in a survey conducted in the rocky intertidal zones at both White's Point and Dana Point, CA. Although niche overlap was evident, mono-specific aggregations were commonly observed. An aggregating behavior has been proposed as a mechanism to reduce inter-specific competition. A preliminary study was conducted to determine the factors responsible for the maintenance of the dispersions and distributions observed. In a series of preference experiments conducted, it was determined that a chemical attractant released by *Tegula funebralis* was responsible, in part, for the aggregation behavior. The test apparatus consisted of an acrylic maze which presented centrally located test snails with various potential attractants or deterrents at the ends of the maze. In particular, test snails were presented with either aggregates of the same species, water conditioned by those aggregates, or aggregates of other species as well as empty shell and seawater controls. The *T. funebralis* test snails had a preference for *T. funebralis* aggregates and water conditioned by those aggregates. In many instances, when test snails located an aggregate, their searching behavior ceased. An attraction by the test snails to water conditioned by aggregates of the same species suggested that a chemical attractant may be involved in the initial formation of clusters of *Tegula*. Although metabolites have been isolated from conditioned water samples, the active metabolite has not yet been ascertained. This work provides some preliminary information on a potential mechanism by which spatial partitioning between similar species can be maintained.

85 CLIMATIC AND LITHOLOGIC INFLUENCES ON QUATERNARY TERRACE FORMATION BASED ON PRELIMINARY SOIL INDICES, SANTA ANA MOUNTAINS, CALIFORNIA

Otto F. Figueroa, Nancy A. Ikeda, Christine M. Irwin, Rene A. Perez, Andrea M. Stein and Jeffrey R. Knott. Department of Geological Sciences, California State University Fullerton, Fullerton, California 92834-6850

We made field observations and calculated Harden soils indices for three terraces (Qoa 1–3, oldest to youngest) near the confluence of Silverado and Santiago Creeks of Santa Ana Mountains. We compared these indices to other dated southern California soil chronosequences to elucidate the age and geomorphic factors contributing to terrace formation.

Prominent terraces are found in the last 3 km reach of Silverado Canyon downstream from where the resistant Baker Canyon Conglomerate yields to more erosive lithologies. The erosive character is expressed by increasing valley floor width to height ratios (0.26 upstream; 7.6 at the confluence).

Qoa1 has a profile index of 233 and thickness of 676 cm which correlates to an age of 300,000–700,000 yr B.P. Qoa2 has a profile index of 32 and a 152 cm thick soil, which correlates to 22,700–63,000 yr B.P. Qoa3 has a profile index of 18 and is 76 cm thick, which correlates to 5,900–11,500 yr B.P. Metasedimentary/plutonic clasts comprise 10% and 66% of Qoa1 and Qoa3, respectively.

We infer that terraces formed here in response to decreased precipitation during the change to interglacial climates and lower stream power in the less resistant lithology. Qoa2 and Qoa3 formed at the oxygen isotope stage 4/3 and Holocene-Pleistocene transitions, respectively. The correlated age of Qoa1 is too broad to infer a specific oxygen isotope stage. We interpret the clast composition change from Qoa1 to Qoa3 as headward erosion of streams into metasedimentary rock found to the northeast, possibly caused by uplift along the Elsinore fault.

86 DIETARY SHIFTS OF ELEGANT TERNS AND CASPIAN TERNS AT TWO SOUTHERN CALIFORNIA NESTING COLONIES: RESPONSES TO CHANGES IN OCEAN CLIMATE AND PREY POPULATIONS

Ingrid Chlup[1] and Michael H. Horn[2]. California State University, Fullerton, [1]Environmental Studies Program and [2]Department of Biological Science Fullerton, CA 92834-6850

We reported previously on the diets of Elegant Terns and Caspian Terns nesting at the Bolsa Chica Ecological Reserve from 1993 to 1999 and extended the work through 2002 and included the Los Angeles Harbor colony. Our now 10-year analysis of fish prey delivered to the colonies by parental birds is based on identifying fish dropped or regurgitated at the nests. For the diets of each tern species, we report here (1) the proportion of each prey taxon including the two main species, northern anchovy and Pacific sardine, (2) the ratio of anchovies to sardines, and (3) the composition of dropped vs. regurgitated samples, to assess the foraging responses of the terns to changing ocean temperature and food supply. The proportions of anchovy and sardine in the diet were plotted against ENSO ratings (reflecting sea surface temperatures) and estimated biomass of the two prey species for 1993–2002. The results to date indicate that (1) dropped fish are an adequate measure of the proportions of anchovies and sardines in regurgitated samples, (2) Elegant Terns appear to prefer anchovies while

Caspian Terns appear to prefer sardines, and (3) the proportions of anchovy and sardine in the ocean and in the terns' diets appear to cycle out of phase with each other, anchovies increasing during cold ENSO (La Nina) episodes and sardines increasing during warmer ENSO (El Nino) episodes. This cyclic pattern appears to result in the rather consistent annual availability of lipid-rich prey for terns in southern California coastal waters.

87 A VASCULAR FLORA OF THE OWENS PEAK EASTERN WATERSHED

Naomi S. Fraga. Department of Botany, Claremont Graduate University, Rancho Santa Ana Botanic Garden, 1500 N. College Ave., Claremont, CA 91711

A thorough understanding of a region's botany must begin with a basic flora. The importance of phytogeography is demonstrated in our continued discovery of new plant species, range extensions and rediscoveries of species previously thought to be extinct. Owens Peak and its eastern watershed lie at the southern end of the Sierra Nevada within the Owens Peak Wilderness Area in Kern County. Owens Peak itself is the highest in the Southern Sierra rising to more than 2,600 meters. The location's floristic composition is unusual, possessing elements of the southern Sierra Nevada, the Great Basin, and the Mojave Desert. The flora of this area has been poorly documented in the past, therefore a flora treatment of this region is of pivotal importance, both systematically, to catalogue the location's diverse flora and ecologically, allowing analysis of the impacts and interactions of these floristic elements in a relatively confined area. The aim of this project is to produce a comprehensive flora of the Owens Peak eastern watershed.

88 WHAT DID THE FIRST CACTUS LOOK LIKE? EVIDENCE FROM NEW MOLECULAR DATA

M. P. Griffith. Department of Botany, Claremont Graduate University, Claremont, CA 91711

Early systematic treatments considered the most relictual members of the cactus family (Cactaceae) to be woody broadleaved trees of the genus *Pereskia,* as they resemble 'typical' dicot morphology more closely than any other cacti. One treatment in particular (Britton and Rose, 1919) has greatly influenced subsequent work, which advances the widely accepted view that stem-succulence and habit reduction represent derived character states within the Cactaceae, which evolved from a *Pereskia*-like ancestor. Recent independent phylogenetic papers, although explicitly or implicitly advancing this traditional view, often present evidence that does not support this hypothesis. One subfamily of Cactaceae, the Opuntioideae, is seriously underrepresented in recent work, and is absolutely critical to our understanding of early cactus evolution. The current study investigates deep, early-diverging lineages within Cactaceae using phylogenies inferred via Bayesian and parsimony analyses of nuclear (ITS) and chloroplast (trnL-F) DNA sequence data, emphasizing the relationships among the subfamily Opuntioideae, and interprets those results in the context of other phylogenetic work. The following hypotheses are supported: the relationships among the subfamilies of Cactaceae are not clear; the Opuntioideae may be sister to all other cacti; plants of the geophytic, leafless genera *Maihueniopsis* and *Puna* are sister to all other opuntioids; geophytism, leaflessness, and architectural simplicity seem plesiomorphic in Opuntioideae. In context with other recent work and the outgroups of the Opuntioideae and Cactaceae, this suggests the possibility that early cacti were not leafy *Pereskia*-like shrubs, but instead may have been diminutive, succulent geophytes.

89 MARIANO AND MANUEL'S MILPA: SUBSISTENCE FARMING IN THE SOCONUSCO REGION OF CHIAPAS

S. Alves. California State University Dominguez Hills, Anthropology Department, Carson, CA

The Soconusco region of the Southern Mexican State of Chiapas is a lush tropical lowland environment. As in many tropical regions of the world, the forests are disappearing to agribusiness and land extensive swidden farming practices. Population pressure and run off from agricultural chemicals have affected the quality of life for the indigenous population. Subsistence farming and traditional life ways closely tied to the forest are undergoing drastic changes. It is vital that the ethnoecological knowledge that the people of this region posses be preserved before it and the forests are forgotten. In June of 2002, I went to Chiapas as a member of an ethnobotany field class to do an ethnographic study of subsistence farmers and to explore the extent to which modern pesticides, herbicides and

fertilizers are used in their corn cultivation. Finally, the use of agricultural chemicals among subsistence farmers is a recent phenomenon and recording of the types of chemicals and quantities used will provide a way to project future contamination of the environment and the impact on local plant, animal and human populations.

92 PHOTOMETRIC DETECTION OF AN EXTRA-SOLAR PLANETARY TRANSIT ACROSS THE SUN-LIKE STAR HD 209458

Ved Chirayath[1]. [1]Southern California Academy of Sciences & The California Academy of Math and Science, 1000 E. Victoria St. #8002, Dominguez Hills, CA 90747

Sponsored in part by a grant from the Southern California Academy of Sciences and cooperation from Meade Instruments Inc.

I report photometric measurements of HD 209458, an extra-solar planetary system known by radial velocity measurements to have an orbiting planetoid of Jupiter mass. The star has been observed with a 10″ Meade Schmidt-Newtonian LXD 55 telescope and a Nikon Coolpix 995 CCD. I detect two full transits at projected transit times defined by radial velocity measurements (Mazeh et al.). An accuracy of ±0.01 stellar magnitudes has been achieved. The photometric dimming measured, attributed to the transit of a planet across the stellar disk, is consistent with past photometric measurements made by considerably large observatories (Hubble, Keck I). Also presented are derived values for the diameter of the planetary disk.

93 COMPARATIVE STUDY OF PLANKTON DENSITIES IN THE UPPER AND LOWER NEWPORT BAY AND THE FACTORS THAT AFFECT IT

Anuj Chaudhary. Oxford Academy High School, Cypress, CA 90630

Plankton densities were measured in upper and lower Newport Bay, an estuary in Southern California. Samples were taken at the mouth of the bay, and just above the Pacific Coast Highway Bridge, which represents the division between upper and lower bay, a distance of about 4.5 miles. Plankton's primary food source is phytoplankton, small producers that are at the bottom of the ocean food web. Phytoplankton growth is known to be affected by phosphates and nitrogen, both of which were measured, along with other water quality data. Density was generally much higher in the upper bay as compared to the lower bay.

94 CONVERSION OF A-AMINO ACIDS INTO NITRILES USING TRICHLOROISOCYANURIC ACID (TCICA)

Jason Bae[1] and Gene Hiegel[2]. [1]Cypress High School, Cypress, CA 90630; [2]Department of Chemistry and Biochemistry, California State University Fullerton, Fullerton, CA 92834-6866

α-Amino acids were converted into nitriles by reaction with trichloroisocyanuric acid (TCICA) in methanol or water. The reaction proceeded rapidly at room temperature with the evolution of carbon dioxide to give high purity nitriles in yields of 41–77%. Nitriles were purified by distillation or column chromatography and characterized by infrared spectroscopy, nuclear magnetic resonance, and gas chromatography. Phenylalanine ($C_6H_5CH_2CH(NH_2)CO_2H$) gave phenylacetonitrile ($C_6H_5CH_2CN$) in 77% yield and 99.0% purity. Valine ($(CH_3)_2CHCH(NH_2)CO_2H$) gave isobutyronitirile ($(CH_3)_2CHCN$) in 41% yield and 97.1% purity. Leucine ($(CH_3)_2CHCH_2CH(NH_2)CO_2H$) gave isovaleronitrile ($(CH_3)_2CHCH_2CN$) in 49% yield and 97.4% purity. Isoleucine ($CH_3CH_2CH(CH_3)CH(NH_2)CO_2H$) gave 2-methylbutyronitrile ($CH_3CH_2CH(CH_3)CN$) in 40% yield and 96.8% purity.

96 *AUREOCOCCUS ANOPHAGEFFERENS* IN COASTAL WATERS: PREVENTION CONTROL AND MITIGATION

Saloni Kadakia. University of Southern California, Department of Biology, Cabrillo Marine Aquarium

Aureococcus anophageferen is a toxic species of algal bloom that has been shown to have devastating impacts on the local coastal resources. This brown tide has had a severe impact on the eel grass populations which in turn effects scallops. This experiment deduced the grazing rates of protozoan communities, the isolation and culturing of the protozoan, and the usage of mescocosm experiments to measure the effect and manipulation of nutrient forms and concentrations. From these experiment a new method of culturing and treating these blooms was found that reduced the grazing rates of this toxic species to nearly ¼ the original bloom and created an environment around the algea that prevented the blooms from further progressing as quickly as they usually would in the ocean thus preventing the algae's toxic product to enter the gills of water species.

97 A TWO-YEAR STUDY: SAND CRABS, SAND PIPERS & POLLUTION: FACTORS EFFECTING SAND CRAB AND SAND PIPER POPULATIONS AT SITES IN THE SANTA MONICA BAY AND LOS ANGELES HARBOR

Katherine Nakaba. Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90274

The dominant species in the swash zone is the Hippid sand crab, *Emerita analoga.* A study was conducted to determine if water temperature, salinity, barometric pressure, precipitation and/or pollution factors effect sand crab population density. I hypothesized that sand crabs would have a smaller population where higher levels of ocean pollution were found. The first year, after measuring the abiotic factors, the number and size of sand crabs were recorded at one location. After these results, the trials were expanded to include a second location. Both locations were chosen based on ocean bacteria counts (*enterococcus,* total and fecal *coliforms*)—that indicate pollution from numerous sources including fecal waste. The second year, I chose to analyze the difference in substrate as an additional abiotic factor, to corroborate previous results, and to determine if lower sand crab population numbers had a corresponding lower number of sandpipers. The study continued to measure bacterial levels, salinity, barometric pressure, precipitation, and water temperature and increased the number of sites from two to four, expanding from the Santa Monica Bay to the LA Harbor. At one site (Pico-Kenter) the storm drain run-off is now being cleaned through a SMURFF facility. Previous and current bacteria and sand crab data were compared. While the abiotic factors remained constant at all locations, the bacteria count was significantly different. The results obtained support the hypothesis that the population density of sand crabs and sandpipers is effected by bacterial pollution. There is minor variation in substrate that will generate further study.

98 GLOBAL WARMING: CAN BACTERIA REALLY HELP STOP IT?

S.F. Ong. California Academy of Mathematics and Science, Carson 90747

Trichodesmium is a form of oceanic cyanobacteria, a type of bacteria known for its photosynthesizing and nitrogen fixing ability. They are one of the very few organisms that can convert atmospheric nitrogen into an organic form that can be used by plants. The importance of *Trichodesmium* as a major contributor to the oceanic ecosystems and cutting down on global warming is becoming known in the scientific world. Very little is known about these microscopic wonders. This experiment was conducted into order to study its optimal irradiance level for nitrogen fixation. It was also conducted to determine if phosphorous is a limiting factor in the nitrogen fixation rates of *Trichodesmium.* It was found that *Trichodesmium* grown in 5 μM phosphorous concentrations had an optimal irradiance level of 105 Quanta/sec/cm^2 and *Trichodesmium* grown in 50 μM phosphorous concentrations had an optimal irradiance level of 80 Quanta/sec/cm^2 in respect to nitrogen fixation ability. It was also concluded that, in this experiment, phosphorous was a limiting factor. These data will lay the vital foundation for future researchers and scientists to build upon.

99 DISTRIBUTION OF OXIDATIVE AND GLYCOLYTIC ENZYMES IN ELECTROCYTES OF PHYLOGENTICALLY DIVERSE SPECIES OF FISH

Edward Smetak, Jr., La Habra High School, La Habra Hts, CA 90631; and G.H. Kageyama, California State Polytechnic University, Pomona, Dept. of Biological Sciences, Pomona, CA 91768

Electric fish generate energy for, and produce an electric current from electrocytes which are derived from muscle tissue, or in some cases nervous tissue. The type of energy metabolism that creates the needed high amounts of ATP in the electrocytes can vary, possibly depending on the type of muscle the electrocyte has evolved from, either fast or slow. The goal of this research is to determine how various electric fish generate ATP in their electric organs, either through oxidative respiration or glycolysis. Cytochrome oxidase histochemistry was used to localize oxidative metabolic activity and lactate dehy-

drogenase histochemistry was used to localize glycolytic enzymes in the muscle derived electrocytes of the weakly electric fish *Gnathonemus,* commonly known as the elephant-nosed fish. These findings were then compared to *Apteronotus albifrons,* whose electrocytes originates from nervous tissue. By examining the differential distribution of metabolic enzymes in both species, it can be determined if electrocytes utilize one or both, oxidative respiration and/or glycolysis, in the production of ATP.

100 DISTRIBUTION OF ARGENTINE ANTS ON THE PALOS VERDES PENINSULA: EFFECTS OF ABIOTIC FACTORS AND HUMAN DISTURBANCE

G. Y. Williams. Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90275

The Argentine ant, *Linepithema humile,* has spread worldwide, often decimating native ant species and other arthropod species. Numerous investigations have shown biotic aspects that contribute to the Argentine's success, such as its ability to exploit resources, but fewer and somewhat contradictory studies have been made of abiotic or non-biological conditions that limit the Argentine's distribution. This study investigated the abiotic factors-light, temperature, relative humidity, soil moisture, and soil temperature in three habitat areas on the Palos Verdes Peninsula, non-developed, semi-developed, and fully-developed. Measurements of the factors where Argentines were established suggest that the Argentine prefers cooler air and soil temperatures and dry soils with high relative humidity. Disturbance, especially in the form of human-installed water sources, nonnative plants, human activity, and human litter appear to attract the Argentine. The most popular habitat area was the semi-developed, possessing human-installed water sources, nonnative plants, moderate human activity, and dryer soil moisture.

101 RECLAIMING THE ECOSYSTEM: EUTROPHICATION CONTROL WITH CALCIUM CARBONATE (PHOSPHATE-BINDING ION-EXCHANGE) FILTERS AND DENITRIFICATION IN FRESH WATER LAKES

Vijay Yanamadala. Palos Verdes Peninsula High School, 27118 Silver Spur Road, Rolling Hills Estates, CA 90274

Eutrophication, the process by which a lake becomes rich in dissolved nutrients due to various pollutants, mainly phosphates and nitrates, is a major cause of the loss of natural lake ecosystems throughout the world. This process occurs naturally in all lakes, but phosphate-rich nutrient runoff from storm drains and agricultural runoff is a major human cause. Especially in Madrona Marsh, one of the last remaining vernal marshes in the Greater Los Angeles Area, cultural eutrophication has become a major problem. In this experiment, calcium carbonate was found to be an excellent phosphate binder, reducing up to 70% of the phosphates in a given sample of water, and it posed relatively negligent ecological repercussions. This project involved the testing of this principle in both the laboratory and in the real ecosystem. A calcium carbonate lacing procedure was first carried out in order to determine its efficacy in Madrona Marsh. Ammonia was found to interfere with the solubility of calcium carbonate and therefore is a hindrance to the reduction of phosphate. Therefore, various approaches for reduction of ammonia were tested including aeration, use of bacteria growth medium, and plants, mainly in an attempt to increase population of *Nitrobacter* and *Nitrosomonas.* All were successful in moderately reducing ammonia levels. The effect of phosphate and ammonia reduction on the populations of pathogenic bacteria was an important focus of this experiment. There was a strong correlation between phosphate concentrations and bacterial populations: a 66% decrease in phosphate resulted in a 35% reduction in bacterial populations and a 45% reduction in enteropathogenic populations. Likewise, a strong correlation was shown between calcium carbonate concentrations greater than that which can be attributed to the phosphate reduction alone. This was followed by the construction of various phosphate binding calcium carbonate filters, which utilized the ion exchange principle. The experiment was extremely successful in designing a working phosphate binding and ammonia reducing filter, and a large-scale filter is currently being constructed in Madrona Marsh; this filter will reduce phosphate and ammonia levels substantially in the following years.

102 THE RELATIONSHIP BETWEEN THE PATTERNS OF PALEOMAGNETIC INTENSITY VARIATIONS IN EAST ASIA VERSUS THE PATTERNS OF INTENSITY ON OTHER PARTS OF THE WORLD

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The earth's magnetic field variation during times of stable polarity, termed secular variation, has a wide range of space-time variability. Although secular variation denotes both directional and intensity variability, in this study the emphasis will be on the intensity variation of the magnetic field. Such intensity variability can be determined in sediment sequences by measuring the natural remnant magnetization (NRM) and then dividing the NRM by some sediment magnetic parameter which estimates the amount of magnetic material present. We have compiled such sediment paleointensity records from Lake Barrine and Eacham of Austrailia, and from Lake Baikal of Siberia. Other intensity variability can be determined by measuring the NRM in archaeological materials. The data was compiled from three regions of China and one region of Japan. The results show that the data gathered from each region closely correlate with each other even across broad geographical distances. In all the regions, there are two distinct peaks in magnetic intensity at approximately 300 A.D. and 1300 B.C., as well as various other smaller correlating features at dates of 1300 A.D., 2800 B.C., and 4500 B.C. It thus appears that East Asia has varied in intensity in a systematic manner for the last 8000 years. This pattern is significantly different from the intensity variability in Europe and North America in the same time interval.

103 CLONING THE C-TERMINUS OF *ATCDPPIV* IN TO A BACTERIAL EXPRESSION VECTOR

M. Hong[1], B. Thorson[2] and J. Brusslan[2]. [1]Torrance High School, Torrance, CA 90501; [2]Dept. of Biological Sciences, California State University, Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840

We studied the plant *Arabidopsis thaliana* in order to isolate the *AtcDPPIV* gene. The fact that the genome of *A. thaliana* has been completely sequenced makes this angiosperm the ideal plant to study. After running a PSI-BLAST search on the *AtcDPPIV* gene, we suspected that the gene codes for a serine protease. This is of interest to us because a serine protease has never before been observed in a plant naturally. To produce an antibody that would recognize this protein, we used a method of gene cloning. We cloned the *AtcDPPIV* insert into a pET32b vector; the clones were sent to UC Davis to be sequenced. We achieved only one perfect construct. We expressed the gene with IPTG, and purified the protein. In the future the purified protein will be injected into rabbits for antibody production.

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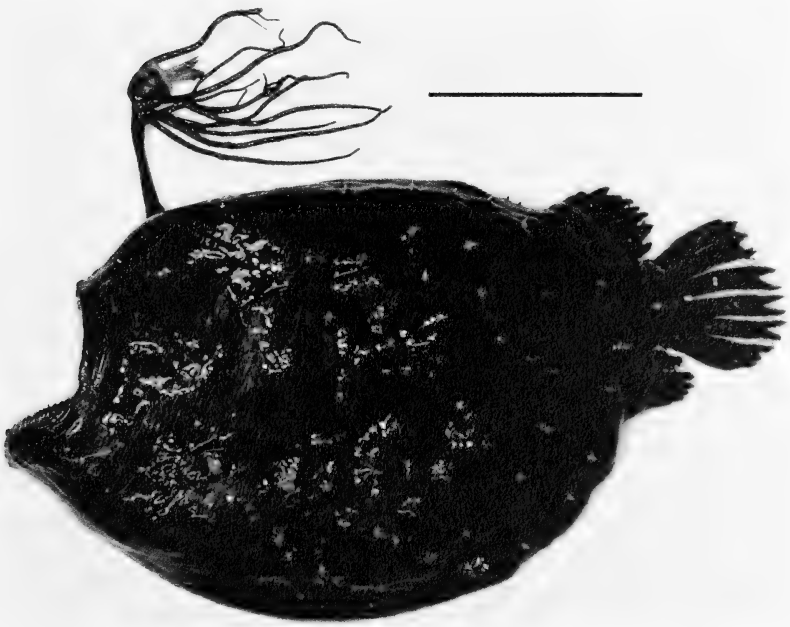

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CALL FOR SYMPOSIA & PAPERS

2004 ANNUAL MEETING

May 7–8, 2004

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FIRST CALL FOR SYMPOSIA
Annual Meeting of the Southern California Academy of Sciences
California State University, Long Beach
May 7–8 2004

The Southern California Academy of Sciences will hold its 2004 annual meeting on the campus of the California State University, Long Beach. Presently planned symposium topics are listed below. Additional proposed symposium topics are invited. Please contact Raymond Wilson (*rwilson1@csulb.edu*) or David Huckaby (*dhuckaby@csulb.edu*) at CSU, Long Beach to propose additional symposia.

Proposed Symposia

"Wetlands Ecology" will be devoted to studies of the biological, chemical, and geological processes of Southern California's wetlands. If you wish to participate please contact Tonny Wijte at CSU, Long Beach (*wijte@csulb.edu*) or Martha Sutula at SCCWRP (*marthas@sccwrp.org*).

"Molecular Ecology of Southern California" will be broadly devoted to ecological studies involving the use of molecular-genetic tools. If you wish to participate please contact Raymond Wilson at CSU, Long Beach (*rwilson1@csulb.edu*).

"Biological and Management Perspectives on Stress Responses in Fish: 'Catch & Release' and Other Human-derived Impacts." is being co-organized by Kevin Kelley (*kmkelley@csulb.edu*) and Chris Lowe (*clowe@csulb.edu*).

"Environmental Simulation" will be devoted to studies that model environmental processes. If you wish to participate please contact Drew Ackerman at SCCWRP (*drewa@sccwrp.org*).

"Safe in the Surf?: Advances in Microbial Testing" will be devoted to techniques in pollution monitoring in the nearshore. If you wish to participate, contact (*jdorsey@lmu.edu*, or call at (310) 338-7817).

"Reef Ecology" is a continuing symposium on the ecology of rocky substrates. If you wish to participate, contact Dan Pondella (*pondella@oxy.edu*) or Robert Grove (*grovers@sce.com*).

"Ecology of Soft Bottom Fishes and Invertebrates" is being organized by Jim Allen (*jima@sccwrp.org*) who should be contacted if you are interested in participating.

"Paleontology and Archeology of Southern California" will be devoted to recent discoveries on the prehistory of our area. Contact Mark Roeder (*mroeder1@earthlink.net*) if you wish to participate.

There will be additional sessions of Invited Papers and Posters and of papers by Junior Academy members.

Abstracts of presented papers and posters will be published in the August issue of the Bulletin.

Student Awards: Students who elect to participate are eligible for best paper or poster awards in the following categories. Biology: ecology and evolution, biology: genetics and physiology, physical science. A paper by any combination of student and professional co-authors will be considered eligible provided that it represents work done principally by student(s). In the case of an award to a co-authored paper, the monetary award and a one year student membership to the Academy will be made to the first author only.

For further information on posters, abstracts, registration and deadlines, see the Southern California Academy of Science web page at: www.lam.mus.ca.us/~scas/

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Pacific Footballfish, *Himantolophus sagamius* (Tanaka) (Teleostei: Himantolophidae), Found in the Surf-zone at Del Mar, San Diego County, California, with Notes on its Morphology

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Abstract.—On 15 December 2001, a moribund adult female *Himantolophus sagamius* (Tanaka 1918) was found in the surf at Del Mar, San Diego County, California. This poorly known but widespread Pacific Ocean species has been previously reported off Chile and Ecuador, off Hawaii, off northwest New Guinea, off California and from the surf-zone in Japan. Examination of the visceral anatomy revealed a surprisingly long digestive tract (combined length of the stomach and intestine 5.6 times the standard length).

The ceratioid anglerfishes of the family Himantolophidae are most frequently caught at depths of 200–800 m (Bertelsen and Krefft 1988), mainly in tropical and subtropical waters. Specimens of the genus *Himantolophus* have been found down to a depth of 1800 m; the known distribution in the Atlantic is as far north as about 65°N and in the Pacific from about 40°N (Kharin 1984; Bertelsen and Krefft 1988) southward to about 55°S (Meléndez and Kong 1997). On 15 December 2001, a 380 mm standard length (SL) moribund adult female *Himantolophus* (Fig. 1) was found in the surf-zone at Del Mar, San Diego County, California (32°57.5′N, 117°15.9′W), by Mark Grundler of Carlsbad, California. Mr. Grundler placed the specimen on ice and notified the Marine Vertebrates Collection at Scripps Institution of Oceanography (SIO) where the specimen has been catalogued as SIO 02-2. Other institutional abbreviations are as given by Leviton et al. (1985).

The specimen is in excellent condition. Only the skin over the dermal spines was abraded, due in all probability to rolling about in the surf. There are no cuts, bites, tears, or other outward signs of damage. The internal organs show no signs of damage (though there was a heavy nematode infestation external to the stomach), and there is no indication of the cause of death or how the specimen made its way to shore.

External Morphology

Meristics and illicial characters agree closely with the *H. groenlandicus*-group of Bertelsen and Krefft (1988). The specimen was identified as *H. sagamius* (Tanaka 1918), with all meristics and measurements falling within the ranges given by Bertelsen and Krefft (1988). Fin-ray counts of SIO 02-2 are dorsal 5; anal 4; pectoral 14,14. The membranes between the dorsal, anal and caudal rays are distinctly white, and the membranes between the pectoral rays are black. The body and fin rays are uniformly black. There are 48 dermal spines on the left

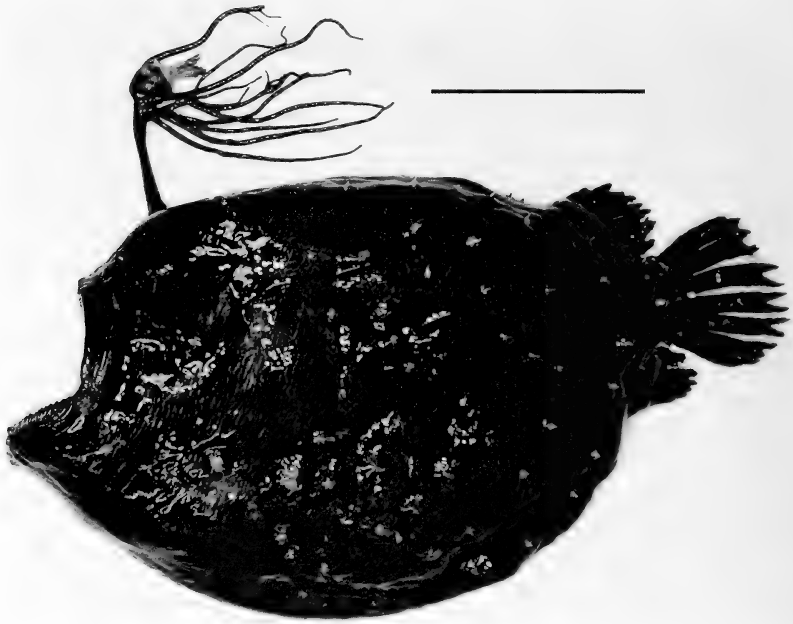

Fig. 1. *Himantolophus sagamius,* SIO 02-2, 380 mm SL. Scale bar = 15 cm.

side of the body (from the posterior part of the head to the caudal peduncle) and 44 on the right, with 3–4 spines on each pectoral peduncle.

The esca (Fig. 2A, B) has the light-guiding distal appendage (DA) divided at the base; each main branch has a bifurcated tip and two tiny papilliform side-branches; the base is surrounded by four escal lobes of about equal size, each with a slightly roundish tip; length of the DA is 24 mm (6.3% SL). The unpaired anterior escal appendage (AA) is simple with two short side-branches near the tip; its length is 91 mm (23.9% SL). The unpaired posterior escal appendage (PA) is bifurcated; one branch is simple and the other branch has three short side-branches near the tip; its length is 147 mm (40.8% SL). There are three pairs of illicial appendages (IA) near the base of the escal bulb; both distal appendages are bifurcated and both proximal appendages are simple; no side-branches are present on any pair; the length of the longest is 172 mm (45.3% SL). All escal appendages and side-branches are black with bright silvery tips. The illicium and esca of *H. sagamius* has also been illustrated in Lea (1988) and Bertelsen and Krefft (1988).

Himantolophus sagamius can be readily distinguished from the four other members of the *groenlandicus*-group. *Himantolophus sagamius* has an anterior escal appendage (AA), absent in both *H. paucifilosus* Bertelsen and Krefft 1998 and *H. crinitus* Bertelsen and Krefft 1988. It has longer distal appendages (DA) (6.3% SL versus 3.8–4.2% SL for specimens greater than 325 mm SL), and a longer posterior appendage (PA) (40.8% SL versus 24–33% SL for specimens greater than 325 mm SL) than *H. groenlandicus* Reinhardt 1837. *Himantolophus sagamius* has bright silvery tips on all escal appendages and side-branches, with the escal lobes rounded, whereas *H. danae* has pigmented tips on its escal appendages

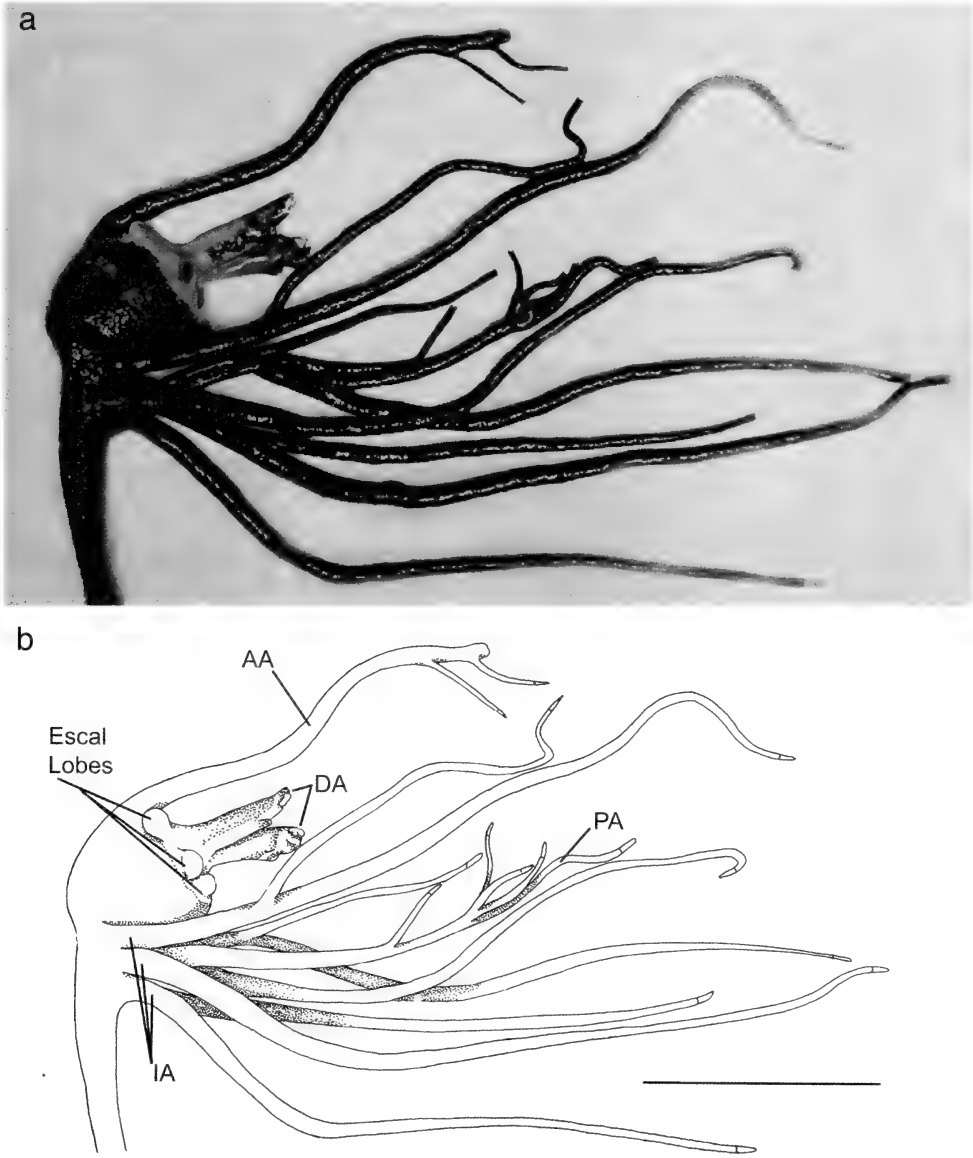

Fig. 2. Esca of *Himantolophus sagamius,* SIO 02-2. Scale bar = 5 cm. (A) Photograph and (B) line drawing: AA = anterior escal appendage, DA = light-guiding distal appendage, PA = posterior escal appendage, and IA = illicial appendages.

(except the third pair of IA), and the distal lobes pointed, with the anterior pair prolonged into filaments.

Visceral Anatomy

The visceral anatomy of antennaroids has been described and figured by Suyehiro (1942) and Le Danois (1974), but only sketchy information is available for ceratioids (Bertelsen 1951; Pietsch 1976; Bertelsen and Krefft 1988).

In SIO 02-2, the broad esophagus merges ventrally into the stout-walled stom-

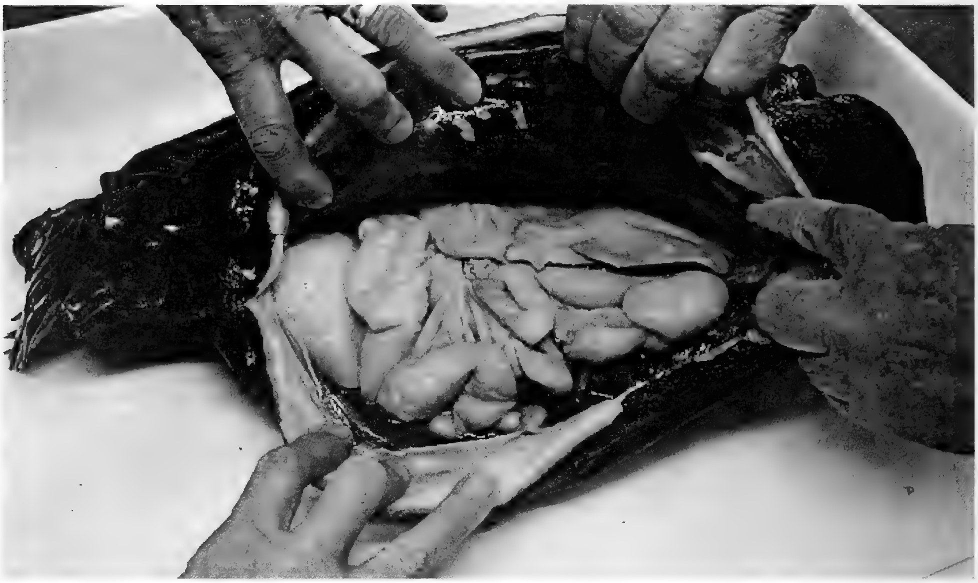

Fig. 3. Internal organs *in situ.*

ach, which has a rounded posterior extension. The internal wall of the broad esophagus is gathered into a series of accordian-like pleats (Figs. 3, 4), so that it may be very distensible. At the point where it enters the stomach, the esophagus is 6 cm in diameter. The stomach projects anteriorly and posteriorly to the esophagus. The wall of the stomach, which is empty, is, like that of the esophagus, deeply folded internally. The anterior portion tapers to a well-developed and muscular pylorus. The stomach is 11 cm from posterior end to the pylorus. The thick-walled tubular intestine runs anteriorly for 5 cm then abruptly turns posterodorsally, passes on the right side of the esophagus, then runs posteriorly to the level of the rear of the stomach, where it begins a series of loops as a tapering tube. The intestine ultimately enters a broad, thinner-walled, posteriormost section, 15 cm in length, which extends below the fused portion of the ovaries to the vent. The length of the intestine from the pylorus to the vent is 200 cm. Thus the total digestive tract length (stomach plus intestine) is 5.6 times the SL. The internal organs are suspended on stout mesenteries strengthened by connective tissue cords. A well-developed spleen, 1.5 cm in length, is suspended in the mesentery above the intestine. The liver is bilobed, with the left lobe much the larger. The gall bladder (Fig. 4) is about 50 mm long and 35 mm wide. It is filled with clear fluid, with no trace of bile pigment. The ovaries are thick walled, nearly circular in outline in lateral view, and laterally compressed (Fig. 5). They are broadly fused posteriorly to form a stout common oviduct. The medial wall of each is lined with villus-like ovarian lamellae about 1 cm long (Fig. 6) with non-vitellogenic oocytes. The lateral walls of the ovaries are smooth.

Discussion

Himantolophus sagamius is known from wide-ranging collections in the Pacific Ocean (Bertelsen and Krefft 1988). In the western Pacific, it has been reported

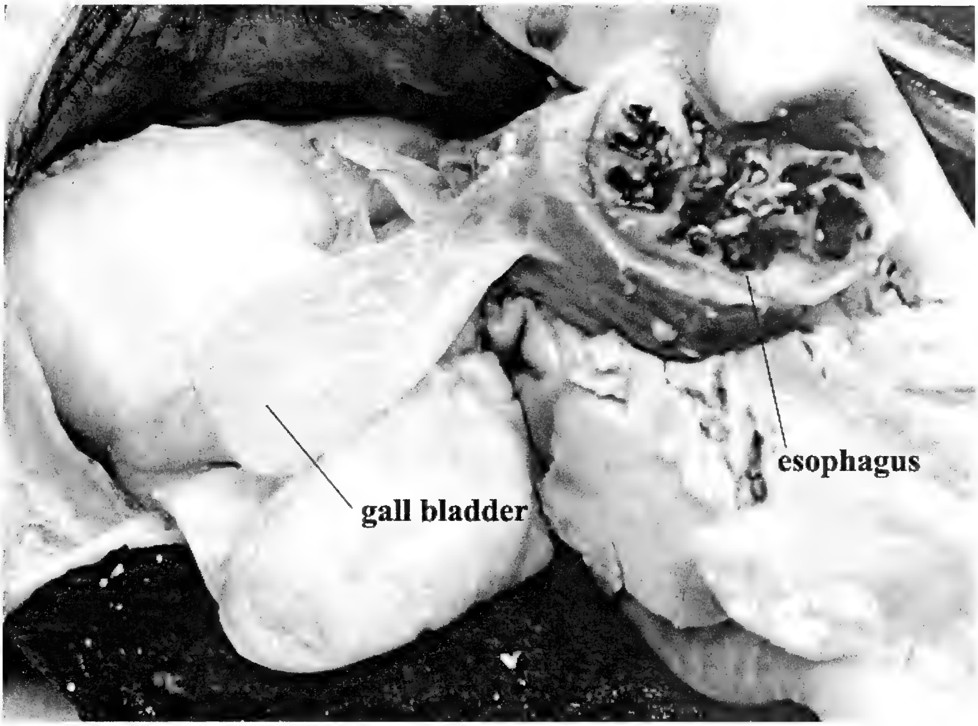

Fig. 4. Dorsal view of gall bladder, and cross-section of esophagus showing accordian-like pleats.

Fig. 5. Internal organs removed from body cavity showing lateral view of right ovary.

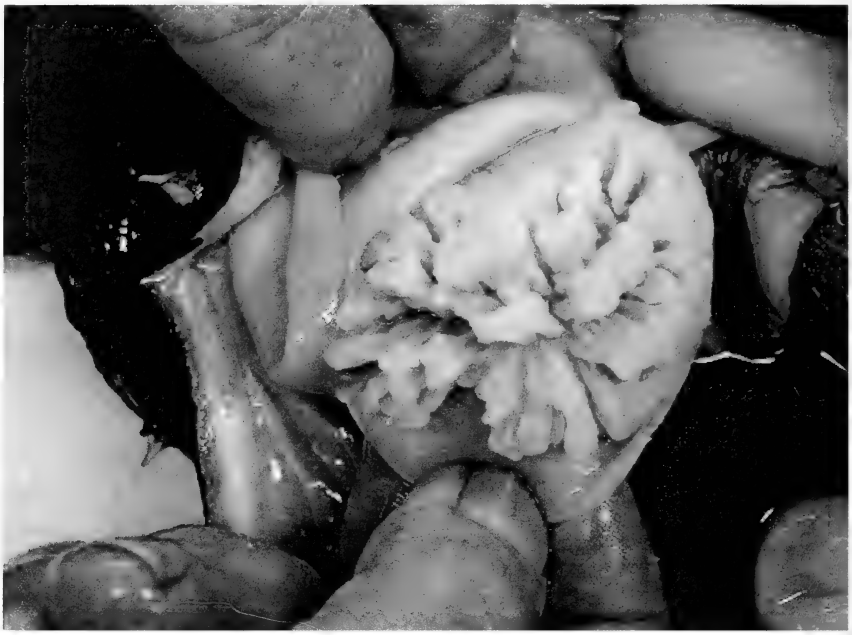

Fig. 6. Internal view of right ovary showing medial surface lined with villus-like ovarian lamellae.

from off Japan and off New Guinea, and in the central Pacific it has been collected off the Hawaiian Islands. In the eastern Pacific, its occurence off California has previously been reported by Lea (1988) as *Himantolophus* sp. Bertelsen and Krefft (1988) later identified the two specimens (LACM 43760-1 and CAS 57639) as *H. sagamius.* Meléndez and Kong (1977) reported on a specimen of *H. sagamius* from off Coquimbo, Chile (MNHNC P.6848), and there are two additional eastern Pacific records from off Ecuador, both from the stomachs of sperm whales (ISH 18/55a,b; Bertelsen and Krefft 1988).

SIO 02-2 is the largest known specimen of *H. sagamius.* At present there are 12 known adults (32–380 mm SL) and three juveniles (32–40 mm SL).

The occurrence of this specimen of *H. sagamius* in the surf-zone with no significant damage or signs of predation is remarkable. The inshore terminus of the La Jolla Submarine Canyon, which seems a possible route inshore from deeper waters, is about five miles south of where the specimen was found. Haneda (1968) reported on a specimen of *Himantolophus* (356 mm TL) found "as it floated along the beach at the tidal mark." It was initially identified as *H. groenlandicus,* but Bertelsen and Krefft (1988) re-identified it as *H. sagamius* based on Haneda's (1968) description and photographs (the specimen was not preserved). In photographs of Haneda's specimen, the esca is similar to that of SIO 02-2 except for the presence of white reflective tissue on the proximal areas of various appendages. Why either female moved, or was driven, inshore remains a mystery.

The digestive tract of this specimen of *H. sagamius* is surprisingly long, with the combined length of the stomach and intestine being approximately 5.6 times the SL. Although ceratioids are carnivorous, the digestive tract of carnivores is typically less than the SL, while that of omnivores ranges from 1.3 to 4.2 times the SL; that of herbivores ranges from 2 to 20 times the SL (Horn, 1989; Helfman et al. 1997). Montgomery (1977) cautioned against uncritical comparisons of relative gut lengths in fishes of radically different body forms. Nonetheless, even considering the relatively short, deep body typical of ceratioids, the gut of this specimen of *H. sagamius* is much longer than would be expected for a carnivorous fish. The stomach was empty and the intestine contained a fine chyme that was otherwise unidentifiable. Perhaps the relatively long digestive tract slows the passage of food items and permits maximum breakdown of prey items and absorption of nutrients.

The ovaries do not correspond exactly to the available descriptions of ceratioid gonads (Bertelsen 1951; Pietsch 1976; Bertelsen and Krefft 1988). The ovarian lamellae are in the form of a series of villiform projections, united at the base. Pietsch (1972:24–25) reported "villi-like projections of the epithelium" in *Centrophryne spinulosa* but did not specify their arrangement. In *C. spinulosa,* the ovarian lumen is described as being "filled with villi-like projections" whereas in our specimen the villi are restricted to the medial wall of the ovary. Details of ovarian anatomy of other ceratioid genera are unknown. In contrast to *C. spinulosa,* which has a single ovary (Pietsch 1972:24, fig. 5), *H. sagamius* has paired ovaries, united posteriorly. This is the condition reported by Bertelsen (1951) for other ceratioids.

As reported for most ceratioid females, the ova of SIO 92-2 are represented by small oocytes, although the individual is large enough to be sexually mature. The phenomenon of large females with undeveloped eggs has been attributed to expatriation, lack of an attached male (Bertelsen 1951), or as evidence of recent spawning. However, we suggest that maturation of ova in female ceratioids may be dependent on the presence of a suitable large prey item to provide the material for oögenesis.

Acknowledgments

We thank Mark Grundler for collecting the specimen and for bringing it to our attention, H.J. Walker, Jr. (SIO) for curatorial assistance, and two anonymous reviewers for helpful suggestions.

Literature Cited

Bertelsen, E. 1951. The ceratioid fishes. Ontogeny, taxonomy, distribution and biology. Dana Report 39:1–276.

———, and Krefft, G. 1988. The ceratioid family Himantolophidae (Pisces, Lophiiformes). Steenstrupia 14:9–89.

Haneda, Y. 1968. Observations on the luminescence of the deep sea luminous angler fish, *Himantolophus groenlandicus.* Sci. Rept. Yokosuka City Mus. 14:1–6.

Helfman, G. S., Collette, B. B., and Facey, D. E. 1997. The diversity of fishes. Blackwell Science, Malden, Mass.

Horn, M. H. 1989. Biology of herbivorous fishes. Oceanogr. Mar. Biol. Ann. Rev. 27:167–272.

Kharin, V. E. 1984. Two new species of deep water anglerfishes (Ceratioidei: Himantolophidae, Gigantactidae) from the North Pacific. J. Ichthyol. 24:112–117.

Lea, R. N. 1988. Family Himantolophidae added to the ichthyofauna of the temperate eastern North Pacific. Calif. Fish Game 74:180–182.

Le Danois, Y. 1974. Étude ostéo-myologique et révision systématique de la famille des Lophiidae (Pédiculates Haploptérygiens). Mem. Mus. Natl. Hist. Nat., n.s., Sér. A, Zool., 91:1–127.

Leviton, A. E., Gibbs, R. H., Jr., Heal, E., and Dawson, C. E. 1985. Standards in herpetology and ichthyology. Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia 1985:802–832.

Meléndez, R., and Kong, I. 1997. Himantolophid fishes from Chile (Pisces: Lophiiformes). Rev. Biol. Marina y Oceanogr. 32:11–15.

Montgomery, W. L. 1977. Diet and gut morphology in fishes, with special reference to the monkeyface prickleback, *Cebidichthys violaceous* (Stichaeidae: Blennioidei). Copeia 1977:178–182.

Pietsch, T. W. 1972. A review of the monotypic deep-sea anglerfish family Centrophrynidae: taxonomy, distribution and osteology. Copeia 1972:17–47.

———. 1976. Dimorphism, parasitism and sex: reproductive strategies among deepsea ceratioid anglerfishes. Copeia 1976:781–793.

Suyehiro, Y. 1942. A study on the digestive system and feeding habits of fish. Japan. J. Zool. 10:1–303.

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Decapod Crustaceans from the Puente Formation (Late Middle to Early Late Miocene), California: A Possible Mass Death

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Abstract.—Decapod crustaceans are reported for the first time from the late middle to early late Miocene Puente Formation, Riverside County, California. A single specimen of penaeid shrimp and numerous cancrid crabs, referred to *Metacarcinus danai* Nations, were collected in association with a mixed assemblage of terrestrial plants, a few bivalves, marine mammals, and numerous taxa of microfossils. Living species of *Metacarcinus* are found in temperate, normal-marine conditions in water depths up to about 100 m. Thus, an inner shelf, shallow-water environment of deposition is postulated for this part of the Puente Formation. The accumulation of many articulated fossils suggests rapid killing and burial of many individuals, suggestive of a mass death.

Thirteen samples of siltstone bearing fossil decapod crustaceans from the Miocene Puente Formation, Riverside County, California, form the basis for this study. The samples were examined in the context of the Eagle Glen paleontologic resource impact mitigation program conducted by Paleo Environmental Associates, Inc., and L & L Environmental, Inc., during grading associated with development of the Corona Country Club Estates in the city of Corona, California (Lander 2002). The fossils have been identified, and their biostratigraphic and paleoecologic significance has been evaluated. It appears that the fossils accumulated in a nearshore, marine environment, possibly as a result of a mass-mortality event.

Location and Stratigraphic Position

The studied fossils were collected from rocks assigned by Gray (1961) to the undifferentiated Puente Formation of Eldridge and Arnold (1907) at a locality situated on the north slope of Bedford Canyon, Riverside County, California, at latitude 33°48′21″N, longitude 117°32′17″W, in section 19, T4S, R6W, of the Corona South 7.5′ Quadrangle (Figure 1). The stratigraphic section for the upper part of the rock sequence in this general area (Figure 2) spans an interval of over 700 feet (213 m) of Miocene and post-Miocene sedimentary rock. The lower 170 feet (52 m) of this section is composed of fossiliferous siltstone and claystone that are lithologically similar to those identified as the Puente Formation by Gray (1961) approximately 11 km (7 mi) to the north and northwest of the Bedford Canyon locality in the Corona North and Prado Dam 7.5′ quadrangles. In the northern part of his study area, Gray (1961) recognized four members of the Puente Formation. In ascending order these are the La Vida, Soquel, Yorba, and

Sycamore Canyon members. He established the age of the undifferentiated formation as middle to late Miocene, based upon benthic foraminiferans.

Some confusion about the naming of the Puente Formation has arisen recently by the assignment of the La Vida, Yorba, and Soquel members to the Monterey Formation and the elevation of the Sycamore Canyon Member to formational rank (Dibblee 1999a). However, Dibblee (1999b) and Dibblee and Ehrenspeck (2000) continued to use the name Puente Formation for subsurface rocks north of the Palos Verdes Hills, approximately 80 km (50 mi) west from Corona. Subsequently, Dibblee (2000) and Dibblee and Ehrenspeck (2001) applied the terms Monterey Formation and Sycamore Canyon Formation as far east as the Prado Dam Quadrangle. However, the terminology of Dibblee (1999a and b) has not been used in the area of the Corona South Quadrangle, and the rocks in that area have not been assigned to a specific member within the Puente Formation. Thus, the most prudent course of action is to retain the name Puente Formation in an undifferentiated sense for the purposes of this study.

Vertebrate and invertebrate megafossils as well as foraminiferans and diatoms previously have been reported from the Puente Formation. In describing the geology of the formation, Gray (1961, p. 35) listed 27 species of foraminiferans in nine genera and one species of diatom, based on the identifications of P. B. Smith. Gray made no mention of megafossils. Although Rigby and Albi (1996) described a new species of hexactinellid sponge from the Puente Formation in Orange County and noted that pelecypods as well as fish were present in the unit, Schoellhamer et al. (1981) do not show any Puente Formation in that area. Although this accounting is not exhaustive, I know of no previous references to decapods in the formation. Schweitzer and Feldmann (2002) described several new decapod fossils from southern California and summarized known occurrences of Cretaceous through Pliocene decapods in the state. None was noted in the Puente Formation. During the present paleontological resource evaluation, a wide range of micro- and mega-invertebrates, vertebrates, and plants were collected. Those relevant to the present study will be noted below and are listed in the Appendix.

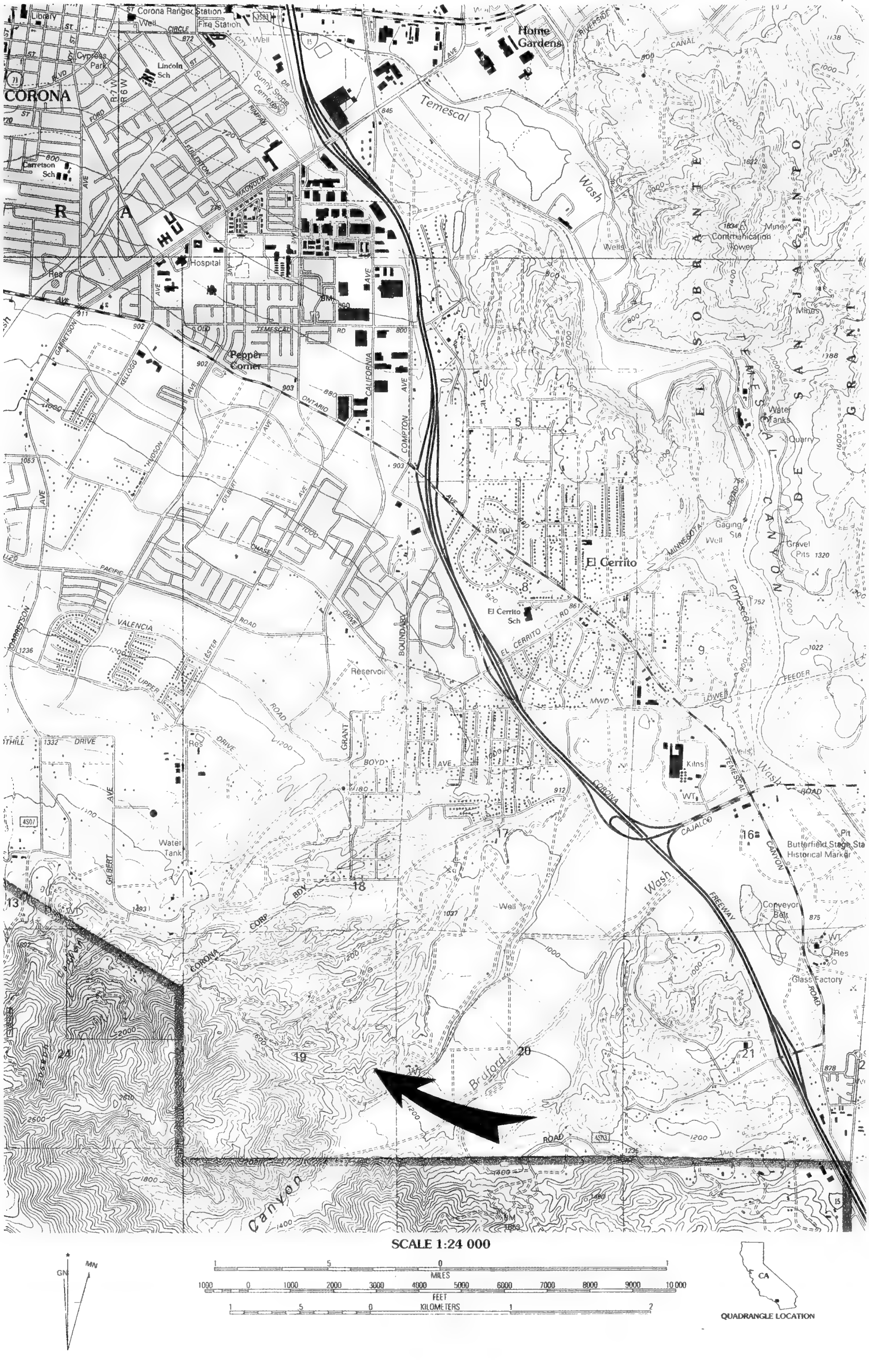
Age of the Puente Formation

Based upon the enclosed benthic foraminiferans, Gray (1961, p. 35) placed a late Miocene (upper Mohnian) and possibly middle Miocene (Luisian) age on the Puente Formation. However, benthic foraminiferan ages in the Cenozoic rocks of the Pacific coast of North America have been shown to be unreliable because they are time transgressive, relative to ages derived from planktonic microfossils (Prothero 2001: 389). Foraminiferans, diatoms, and radiometric dates determined as part of the Eagle Glen paleontologic resource impact mitigation program confirm that age (Lander 2002). Specifically, $^{40}Ar/^{40}K$ dates were determined on ash beds 3 and 4 (Figure 2) by Geochron Laboratories. The dates of 12.6±0.4 MA

→

Fig. 1. Location map showing the position, south from Corona, Riverside County, California, from which fossil decapods were collected.

CORONA SOUTH QUADRANGLE
CALIFORNIA
7.5-MINUTE SERIES (TOPOGRAPHIC)



for ash bed 3 and 12.4±0.4 MA for ash bed 4 are statistically indistinguishable. These radiometric ages place the ash deposits at a late middle Miocene age. However, the diatoms are assignable to early late Miocene Subzone D of the *Denticulopsis hustedtii–D. lanta* Zone (Lander 2002). Because both ash beds and diatoms occur within the part of the formation in which the crabs in the present study were collected, the age of the decapods is reasonably well defined as late middle to early late Miocene.

Metacarcinus spp. range from Oligocene to Recent (Schweitzer and Feldmann 2000) with certainty. A single chela from the Centinela Formation, Santa Cruz Province, Argentina, probably is referable to the genus (Schweitzer and Feldmann 2000), and this would extend the range back to the Eocene. The genus appeared in the Oligocene of Alaska and, by the Miocene, had dispersed along the west coast of North America and into Japan. That same geographic range is observed in the Pliocene. Recent occurrences of the genus are known from the northeast, southeast, and southwest Pacific Ocean basin and from the North Atlantic. Thus, the late middle to early late Miocene age based upon radiometric dating and the enclosed microfossils is well within the temporal and geographic range of the genus. The type locality of *M. danai* is in the middle Miocene Briones Formation, based upon a single specimen at a single locality (Nations 1975). The occurrence of this species in the Puente Formation reinforces that age.

Systematic Paleontology

Order **Decapoda** Latreille, 1802
Suborder **Dendrobranchiata** Bate, 1888
Superfamily **Penaeoidea** Rafinesque, 1815
Family **Penaeidae** Rafinesque, 1815

Remarks.—The sole specimen under consideration, LACMIP 6945, bears most of the characteristics of the superfamily Penaeoidea and family Penaeidae. The carapace is preserved in lateral aspect, which suggests that it was originally laterally compressed and that the sternal region was very narrow. There is no evidence of a well developed groove pattern. The rostrum is well developed and is spinose, at least on the dorsal surface. The ventral surface of the rostrum is obscured. Although the pereiopods are not well-represented, one of the anterior-most, possibly the first, is relatively long. The abdomen is well-developed, curving ventrally and then anteriorly, and the telson and uropods are well developed. Unfortunately the detail of the pleura of the second abdominal somite is lacking. Penaeidea are characterized by having a second pleuron that does not overlap the pleuron of the first somite whereas the Caridea includes taxa in which the second pleuron overlaps the pleura of the first and third somite. One aspect of the morphology that confirms that the specimen is not an oddly preserved crab is that a segment of the antenna is preserved. That segment is longer than the carapace and is folded back over the top of the carapace. This is characteristic of the shrimps and quite unlike the brachyurans, or true crabs. The antennae on crabs tend to be very short. Thus, although the specimen is crushed and incompletely preserved, placement in the Penaeidea is likely; however, the Caridea cannot be entirely ruled out.

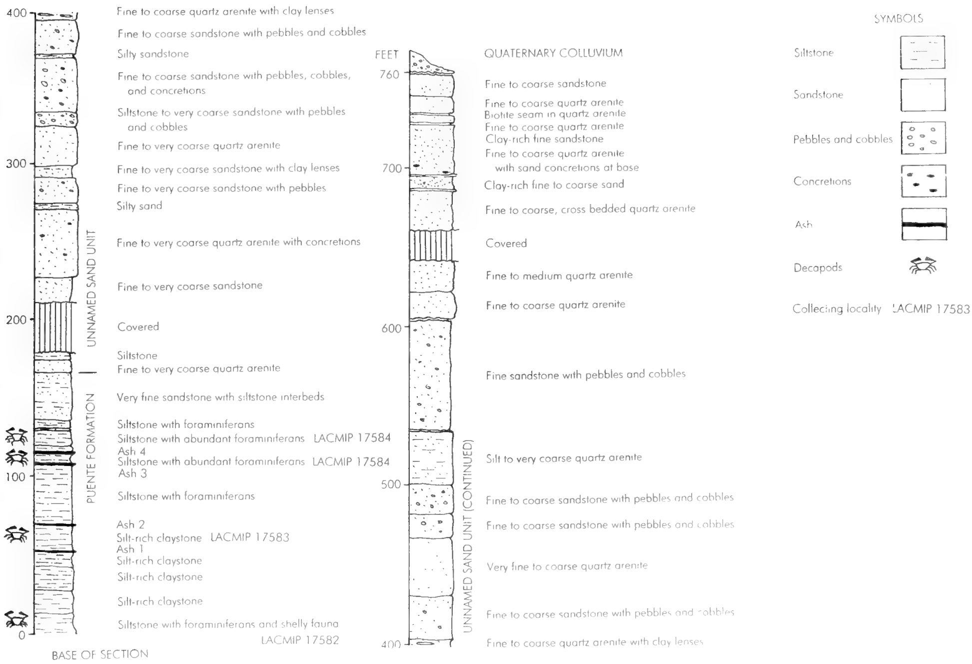


Fig. 2. Stratigraphic section through the Puente Formation in Bedford Canyon, Riverside County, California, showing the horizons from which fossil decapods were collected and ash samples were collected for radiometric dating.

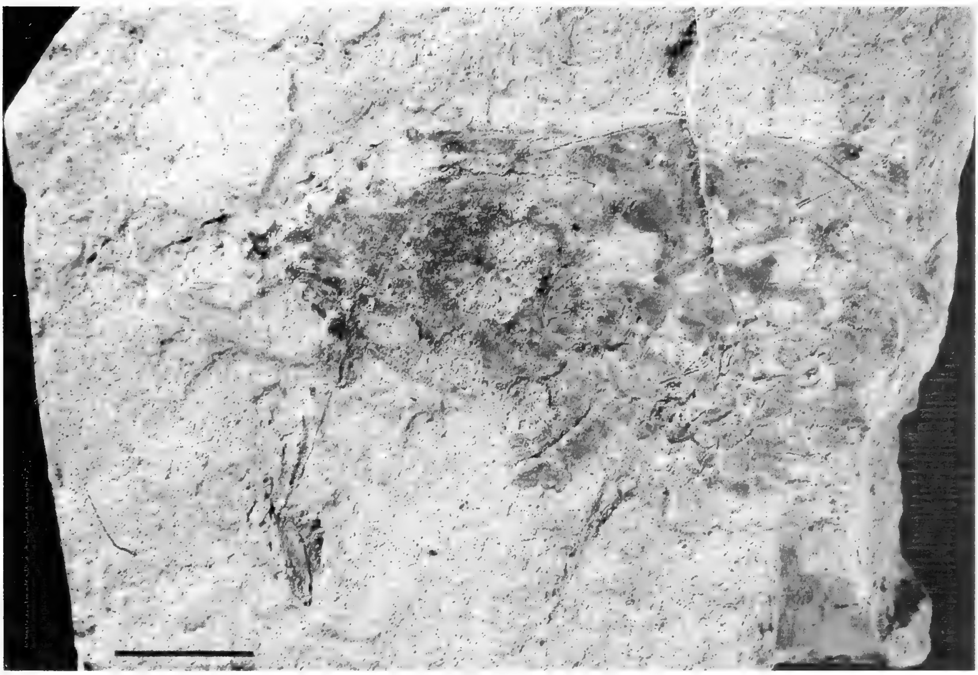


Fig. 3. LACMIP 6945, penaeid shrimp (Family Penaeidae, Genus and species indet.) from Locality LACMIP 17583 in the Puente Formation of Bedford Canyon.

Genus and Species Indeterminate
Figure 3

Discussion.—The single specimen, LACMIP 6945, appears to bear no resemblance to any of the other decapods collected in the Puente Formation, all of which are crabs. It is an elongate form with a smooth carapace and curved abdomen. A long, slender, chelate appendage extends downward from near the anterior end of the specimen. Although segmentation appears to be present on the abdomen, details necessary to confirm the generic placement are not discernable.

Although it might be anticipated that crabs and shrimps would be preserved together, it rarely happens, perhaps because the conditions for preservation of the benthic crabs is different from that of the pelagic shrimp. Glaessner (1969) noted that preservation of the fragile remains of shrimp is favored in acidic conditions. Such conditions would not enhance preservation potential of the more strongly calcified crabs. Both groups occupy normal marine habitats and both could be found in coastal areas. However, because the identification of this single specimen is tentative, no paleoecological conclusions will be based upon its occurrence.

Infraorder **Brachyura** Latreille, 1802
Superfamily **Cancroidea** Latreille, 1802
Family **Cancridae** Latreille, 1802
Genus **Metacarcinus** A. Milne Edwards, 1862

Diagnosis.—The diagnosis of the genus *Metacarcinus,* with reference to the carapace only, is, "Carapace ovate, about two-thirds wider than long. Front with five spines including inner-orbital spine, inner three spines closely spaced; front usually not produced beyond orbits. Fronto-orbital width about 0.26–0.34 maximum carapace width; orbits shallow, directed forward. Anterolateral margin with nine or ten spines; anterolateral spines variable in form; small, sharp, and separated to bases or small, sharp and fissured; spine margins simple, serrate, or granular. Posterolateral margins rimmed, sometimes with one spine; carapace regions poorly developed, smooth or ornamented with fine granules " (Schweitzer and Feldmann, 2000, p. 235).

Discussion.—Nations (1975) studied the genus *Cancer* and subdivided that genus into four subgenera: *Cancer (Cancer)* Linnaeus, 1758; *C. (Gelbocarcinus)* Nations, 1975; *C. (Romaleon)* Gistl, 1848; and *C. (Metacarcinus)* A. Milne Edwards, 1862. The genus *Cancer* subsequently has been demonstrated to be comprised of several clusters of species, and Schweitzer and Feldmann (2000) elevated the subgenera described by Nations to generic level, reevaluated the placement of species within those genera and, in so doing, revised the entire family Cancridae. Although none of the specimens at hand is preserved well enough to exhibit all the above-mentioned characteristics, each of the specimens exhibits some of the diagnostic features. Therefore, nearly all the characteristics can be recognized. Thus, the generic identity of the crabs from the Puente Formation is certain.

Fig. 4. LACMIP 6946, *Metacarcinus danai* from Locality LACMIP 17584 in the Puente Formation of Bedford Canyon.

Metacarcinus danai Nations, 1975
Figure 4

Discussion.—Of the 24 specimens of decapods from the Puente Formation that can be identified with any confidence, all but the one referred to the Penaeidae are referable to *Metacarcinus danai* (Nations 1975). *Cancer danai* Nations, 1975, was referred to the subgenus *Cancer (Metacarcinus)* by Nations (1975, p. 53). He noted its close similarity to *Cancer (Metacarcinus) magister* Dana, 1852. Examination of the description and illustration of *Cancer danai* (Nations 1975, p. 53, fig. 34–4) confirms that the Puente Formation material can confidently be referred to that species. The frontal region on all the preserved carapace material is very poorly preserved, but the texture of the dorsal surface; the size, shape, and serration pattern on the teeth on the anterolateral margin; and the nature of the posterolateral margin conform closely to the type description. Nations (1975) based this taxon, known only from the middle Miocene Briones Formation, Contra Costa County, northern California, on a single specimen with a carapace width of 54.2 mm. This is slightly larger than the largest specimen that could be measured in the Puente Formation, which was over 40 mm wide. Most specimens are too fragmentary to measure. That difference in size suggests that the specimens at hand may be juvenile forms. Certainly, the size difference is not extraordinary.

Paleoecology

The occurrence of decapod crustaceans collected in the Puente Formation is atypical in that they were found in association with a wide variety of vertebrate and invertebrate megafossils and terrestrial plants (see Appendix). Microfossils were reported from one of the sites, LACMIP 17582; however, at the other two localities they were absent. This absence is unusual for the Puente Formation, which is dominated by microfossils elsewhere. For example, the microfossils of the formation were first detailed by Smith (1960), and subsequently Gray (1961) presented a list of 27 species of foraminiferans, identified by Smith, from the formation in the Corona South Quadrangle. Despite the fact that four of the species identified by Smith, *Buliminella curta* Cushman, 1925; *B. subfusiformis* Cushman, 1925; *Epistominella subperuviana* (Cushman, 1926); and *Uvigerina subperegrina* Cushman and Kleinpell, 1934, are considered indices of outer shelf and bathyal depths (Finger, 1990), Gray interpreted the Puente Formation in his study area as having been deposited in a nearshore, shallow water environment. He made no mention of a megafauna. Schoellhamer et al. (1981) also noted the dominance of microfossils in the formation, in an area west from the current site of interest, but noted the presence of bivalves and fish scales as well.

Interpretation of the paleoecological setting in which the crabs lived, and presumably died, will be drawn from three independent lines of evidence. First, the ecology of living representatives of *Metacarcinus* will be used to define the modern ecological and biogeographic setting of the genus. Second, the association of the crabs with the other elements of the biota will be discussed. Third, the nature of the occurrence of the crabs will be considered.

The ecological setting of four extant species of *Metacarcinus* was summarized by Rathbun (1930). The species presumably most closely related to *M. danai, M. magister* (Dana, 1852), has been collected from low water to 50 fathoms (100 m) and is known to live on a wide range of substrates from mud to gravel and bare rock. The species ranges from Alaska to Monterey Bay, California. Another species, *M. anthonyi* (Rathbun, 1897), ranges from 6–50 fathoms (12–100 m) in water temperatures from 13–19.5 degrees C. This species is known from Monterey Bay to Baja California, Mexico. *Metacarcinus gracilis* (Dana, 1852) lives from low water to 56 fathoms (112 m) and has been collected from Alaska to Baja California, Mexico. In what is probably a good example of a disjunct, amphitropical generic distribution, *M. edwardsii* (Bell, 1853) ranges from Ecuador to Chile. Garth (1957) recorded a depth range for the species of 0–45 m. All species of the Cancridae living today are restricted to temperate and subpolar temperatures of 1.3–25 degrees C (Williams and Wigley, 1977, *in* Williams, 1984). There are no strictly tropical or subtropical occurrences of cancrids except in very deep, offshore habitats where the animals live in cool water below the thermocline. No restricted, brackish water occurrences have been noted. Thus, presuming that the ecological requirements have not changed substantially since the Miocene, *Metacarcinus danai* probably lived in temperate waters at oceanic salinity, and in water depths ranging somewhere from low water to about 100 m; that is to say, it lived somewhere within the typical continental shelf depths in the temperate zone.

Consideration of the biotic associations of *Metacarcinus danai* may further help to define its ecological habitat. The associated fossils in the Puente Formation (Appendix) suggest mixing of marine and non-marine elements. Presence of several types of plant material, including algae, conifers, and dicotyledonous plants, indicates mixing of terrestrial and marine elements, a condition that would be anticipated in inshore habitats and would not be nearly as likely in offshore, outer shelf settings. Presence of bivalves and marine mammals is consistent with this interpretation, and, although the precise identity of the mammals and the algae is not known, they may suggest a kelp forest or other euphotic area in which attached plants flourished. The light-colored sediments enclosing the crab fossils suggests a well-aerated, oxidizing sedimentary environment.

Finally, the mode of occurrence of the fossil crabs is unusual and provides evidence suggesting that they may have been victims of a mass-kill event, conceivably a toxic algal bloom. Because of the fragmentary nature of the crab specimens, it is not possible to determine with confidence whether the specimens represent molted remains or corpses. The carapaces are extremely thin and, in some cases, folded and distorted. This suggests that the animals might have been in the molt condition. Typically, the carapaces of cancrid crabs are quite thick and strong. However, molted remains are often typified either by complete separation of the legs from the carapace or by partial separation and rotation of the legs (Glaessner 1969; Feldmann and Tshudy 1987). A sufficient number of specimens exhibit the legs in living position, relative to the carapace, to suggest that at least some individuals were corpses. Partial dissolution of the carapace would account for the fragile nature of the preserved remains.

Examination of the systematic literature and personal observations indicate that the "typical" mode of occurrence of fossil decapod crustaceans is as single individuals. The individuals can be relatively abundant in a rock unit and can be preserved in concretionary structures or on bedding plane surfaces. In either case, individuals generally are not confined to a single stratigraphic horizon but may be found throughout the sedimentary sequence. Examination of the specimens in the collection at hand indicates that at least two horizons within the Puente Formation were sites of accumulation of numerous individuals that died suddenly enough to come to rest on single bedding horizons and were buried very rapidly. This type of mass mortality was recently documented in a Turonian decapod assemblage from Colombia (Feldmann et al. 1999). The preservational style in the Colombian rocks is quite similar to that in the Puente Formation; both display a very large number of specimens arrayed on discrete bedding planes, and, in both cases, the cuticular material is extremely thin and delicate. It is possible that in both cases the calcareous material in the cuticle was leached out during diagenesis. Event beds such as this are relatively rare in the fossil record of crabs and, for this reason alone, the occurrence is noteworthy.

In summary, it is likely that the crabs were killed during a brief interval of time, possibly as victims of an algal bloom, and that they were buried and preserved very near their living site. The composite of information regarding paleoecology suggests a normal marine, inshore habitat that was biologically rich. Water depth was probably very shallow, much less than the projected maximum depth of 1000 meters, and water temperature was temperate.

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Literature Cited

Bate, C. S. 1888. Report on the Crustacea Macrura collected by H.M.S. Challenger during the years 1873–76. *Report on the scientific results of the voyage of H.M.S. Challenger, Zoology* 24: 942 pp., pls. 1–150.

Bell, T. 1853. *A History of the British Stalk-eyed Crustacea.* London: John van Voorst, 386 p.

Boettcher, R. S., and S. A. Kling. 2001. Biostratigraphic report, Paleo Environmental Associates, Inc., Eagle Glen Project—Phase III, Puente Formation, southern California. *Micropaleo Consultants, Inc., job #21–101(A2). Prepared for Paleo Environmental Associates, Inc.*

Cushman, J. A. 1925. Some Textulariidae from the Miocene of California. Contributions from the Cushman Laboratory for Foraminiferal Research. Research Contributions, 1:29–34.

———. 1926. Foraminifera of the typical Monterey of California. Contributions from the Cushman Laboratory for Foraminiferal Research. Research Contributions, 2:53–66.

———, and R. M. Kleinpell. 1934. New and unrecorded Foraminifera from the California Miocene. Contributions from the Cushman Laboratory for Foraminiferal Research. Research Contributions, 10:1–23.

Dana, J. D. 1852. Crustacea. In *U. S. Exploring expedition during the years 1838, 1839, 1840, 1842, under the command of Charles Wilkes, U.S.N., Volume 13,* 390–400. Philadelphia: C. Sherman.

Dibblee, T. W., Jr. 1999a. *Geologic map of the El Monte and Baldwin Park Quadrangles, Los Angeles County, California.* Dibblee Geological Foundation map DF-69 (not seen).

———. 1999b. *Geologic map of the Palos Verdes Peninsula and vicinity, Redondo Beach, Torrance, and San Pedro quadrangles, Los Angeles County, California.* Dibblee Geological Foundation map DF-70 (not seen).

———. 2001. *Geologic map of the Yorba Linda and Prado Dam Quadrangles (eastern Puente Hills), Los Angeles, Orange, San Bernadino, and Riverside counties, California.* Dibblee Geological Foundation map DF-75 (not seen).

———, and H. Ehrenspeck. 2000. Geology of the Palos Verdes Hills, California. *Amer. Assoc. Pet. Geol. Bull.* 84: 865.

———, and ———. 2001. New geologic maps of the Puente Hills, Southern California. *Amer. Assoc. Pet. Geol. Bull.* 85:1119–1120.

Eldridge, G. H., and R. Arnold. 1907. The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California. *U. S. Geol. Surv. Bull.* 309:103–106.

Feldmann, R. M., and D. Tshudy. 1987. Ultrastructure in cuticle from *Hoploparia stokesi* (Decapoda: Nephropidae) from the Lopez de Bertodano Formation (Late Cretaceous-Paleocene) of Seymour Island, Antarctica. *J. Paleontology* 61: 1194–1203

———, T. Villamil, and E. G. Kauffman. 1999. Decapod and stomatopod crustaceans from mass mortality lagerstatten: Turonian (Cretaceous) of Colombia. *J. Paleontology* 73:91–101.

Finger, K. L. 1990. Atlas of California Neogene Foraminifera. *Cushman Foundation for Foraminiferal Research Special Publication* 28:1–271.

Gabb, W. M. 1869. Cretaceous and Tertiary fossils. *California Geological Survey, Paleontology* 2:1–229.

Garth, J. S. 1957. Reports of the Lund University Chile Expedition 1948–49. 29. The Crustacea Decapoda Brachyura of Chile. *Lunds Universitets Årsskrift. N. F. Avd 2. Bd 53. Nr. 7,* 130 p., 4 pls.

Gistl, J. von N. F. X. 1848. Naturgeschichte des Thierreichs fur Höhre Schulen. Hoffman'sche Verlags-Buchhandlung, Stuttgart, 216 p.

Glaessner, M. F. 1969. Decapoda, p. R399-R651. *In Treatise on Invertebrate Paleontology, Pt. R, Arthropoda 4,* ed. R. C. Moore, R339-R651.

Gray, C. H., Jr. 1961. Geology of the Corona South Quadrangle and the Santa Ana Narrows area, Riverside, Orange, and San Bernardino counties, California. *California Division of Mines Bulletin* 178: 5–58.

Lander, E. M. 2002. Corona Country Club Estates Phases 1 and 2 (Eagle Glen Specific Plan Amendments 1 and 2), Corona, Riverside County, California—Paleontologic resource impact mitigation program final technical report of results and findings—Addendum—Phase 3. *Paleo Environmental Associates, Inc., project 2000–23. Prepared for L&L Environmental, Inc.*

Latreille, P. A. 1802–1803. *Histoire naturelle, générale et particulière, des crustacés et des insectes, Volume 3.* F. Dufart, Paris (not seen).

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Edition 10, 1:1–824.

Milne Edwards, A. 1862–1865. Monographie des crustacés de la famille cancériens. *Annals des Sciences Naturelles, Zoologie* Series 4, 18 (1862): 31–85; 20 (1863): 273–324; Series 5, 1 (1864): 31–88; 3 (1864): 297–351.

Nations, J. D. 1975. The genus *Cancer* (Crustacea: Brachyura): Systematics, biogeography and fossil record. *Nat. Hist. Mus. Los Angeles Co., Sci. Bull.* 23: 1–104.

Prothero, D. R. 2001. Chronostratigraphic calibration of the Pacific coast Cenozoic: A summary. In *Magnetic Stratigraphy of the Pacific Coast Cenozoic,* ed. D. R. Prothero, 377–394. Pacific Section SEPM, Book 91.

Rafinesque, C. S. 1815. *Analyse de la nature, ou tableau de l'Universe et des corps organisée.* Palermo, Italy, not seen.

Rathbun, M. J. 1897. Description of a new species of *Cancer* from Lower California, and additional note on *Sesarma. Proc. Biol. Soc. Wash.* 11:111–112..

———. 1930. The cancroid crabs of America of the families Euryalidae, Portunidae, Atelecyclidae, Cancridae, and Xanthidae. *U. S. Nat. Mus. Bull.* 152:1–609.

Rigby, J. K., and Y. Albi. 1996. An upper Miocene hexactinellid sponge from the Puente Shale, Orange County, California. *J. Paleontology* 70:908–913.

Schoellhamer, J. E., J. G. Vedder, R. F Yerkes, and D. M. Kinney. 1981. Geology of the northern Santa Ana Mountains, California. *U. S. Geol. Surv. Prof. Paper* 420-D:D1-D109.

Schweitzer, C. E., and R. M. Feldmann. 2000. Re-evaluation of the Cancridae Latreille, 1802 (Decapoda: Brachyura) including three new genera and three new species. *Cont. to Zoology* 69: 223–250.

———, and ———. 2002. New Eocene decapods (Thalassinidea and Brachyura) from southern California. J. Crustacean Biology, 22(4):938–967.

Smith, P. B. 1960. Foraminifera of the Monterey Shale and Puente Formation, Santa Ana Mountains and San Juan Capistrano area, California. *U. S. Geol. Surv. Prof. Paper* 294-M:463–495, pls. 57–59.

Williams, A. B. 1984. *Shrimps, Lobsters, and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida.* Washington, D. C.: Smithsonian Institution Press, 550 pp.

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Appendix

Stratigraphic Array of Samples

Locality LACMIP 17582

Sample JDC 010208–3—part of left lateral margin with anterolateral teeth like those of *Metacarcinus.*
Associated organisms: pollen, fungal spores, silicoflagellates, dinocysts, foraminiferans, diatoms, leaves, bivalves, fish

Locality LACMIP 17583

Sample MHS 010130.1—good claw specimen and possibly a telson

Sample MHS 010130.3—possible penaeid shrimp, LACMIP Hypotype 6945—antennae very long, curving abdomen exhibiting some metamerism, pleurae vague (Figure 3)

Sample MHS 010130.6—numerous specimens, two with anterolateral margins lobed with denticles posteriorly becoming simple anteriorly—typical of *Metacarcinus danai*

Sample MHS 010130.7–42 mm wide carapace with good anterolateral margin and claw with small, domed denticles

Sample MHS 010130.8—Large sample with fragments of carapace—small sample with claw or walking leg fragments

Associated organisms: ebredians, silicoflagellates, diatoms, whale bone

Locality LACMIP 17584

Sample KMS 010109.1—part and counterpart of large sample with as many as eight complete specimens, some of which exhibit well preserved margins, LACMIP Hypotype 6946 (Figure 4)

Sample MHS 001228.1—venter with legs, possibly a sternum, possibly a male; good carapace wider than long, with orbits, sulcate front, and weakly developed axial regions

Sample NLJ*001227.1—crushed venter of? female

Sample NLJ 001228.8—pair of claws; venter with buccal frame, antennal fragment

Sample NLJ 001228.9—fragment of dorsal carapace

Sample NLJ 001228.11—walking legs with lanceolate dactyl

Sample NLJ 001228.12—venter of male? with some pereiopods

Associated organisms: plants, bivalves, fish

* Note that NLJ, as denoted here and on the specimens, appears to correspond to NHJ on the Eagle Glen Phase III—master list.

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Soil Compaction and Moisture Status from Large Mammal Trampling in *Coleogyne* (Blackbrush) Shrublands of Southern Nevada

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Abstract.—Soil compaction from large mammal trampling was quantitatively investigated in *Coleogyne ramosissima* (blackbrush) shrublands of the Red Rock Canyon National Conservation Area (RRCNCA) in southern Nevada. Fecal density decreased significantly when moving away from water sources, and was negatively correlated with increasing distance from water courses. Path analysis revealed that trampling severity was a significant positive predictor of soil compaction and soil bulk density, and was a negative predictor of the presence of macropores. Soil compaction was a significant positive predictor of soil bulk density, and was a negative predictor of the presence of macropores. Significant interaction was detected between trampling severity and geomorphic surface for area of water spread (surface water runoff). Significant differences were observed in trampling severity and geomorphic surface for all measured soil moisture variables. The degree of soil compaction through large mammal trampling was a function of distance from water in *Coleogyne* shrublands of the RRCNCA in southern Nevada.

The Red Rock Canyon National Conservation Area (RRCNCA) may seem rugged and desolate at first glance, but a closer look reveals an area teeming with wildlife (BLM 1999). A variety of wild mammal species live within the boundaries of *Coleogyne ramosissima* (blackbrush) shrublands, a major mid-elevation vegetation zone in the RRCNCA. During the peak of dry summer seasons, most large mammals prefer to be active from dusk to dawn hours where air temperatures are cooler compared to midday hours. These typical nocturnal mammals include *Urocyon cineroargenteus* (gray foxes), *Vulpes macrotis* (desert kit foxes), *Canis latrans* (coyotes), *Lynx rufus* (bobcats), *Odocoileus hemionus* (mule deer), and *Felis concolor* (mountain lion) (Eifert and Eifert 2000). *Ovis canadensis nelsoni* (desert bighorn sheep) and *Equus asinus* (burro) are active during the day (Eifert and Eifert 2000). Although *Felis* and *Ovis* inhabit high cliffs and canyons, they can be found occasionally in the *Coleogyne* shrublands. *Equus asinus* and *E. caballus* (wild horses) are often seen in the vicinity of Bonnie Springs and Spring Mountain Ranch State Park, the southernmost part of the RRCNCA. *Equus caballus* are also active during the day (BLM 1994).

Large mammals derive some moisture from their food but require drinking water periodically. *Ovia c. nelsoni* will not live more than two miles from a water source. They may expand their range after rains fill more potholes, but such expansions are only temporary (BLM 1999). *Equus asinus* are frequently seen on roadsides begging for food (Lei, personal observation 2001). Approximately 50

E. asinus and 70 *Ovis* live within the Conservation Area (Eifert and Eifert 2000). *Odocoileus hemionus* prefer foothills with low scrub growth or thickets along washes. By late evening, *Odocoileus* leave their daytime hiding places to search for water in seeps and springs (BLM 1999).

Many mammal species are faithful to their home ranges, although home ranges tend to be larger in fall and winter than in summer and spring (Douglas and Haitt 1987; Douglas and Hurst 1993). Home ranges are smallest during dry summer seasons because the proximity to a water source is crucial to survival. Cool winter air temperatures permit a greater dispersal of large mammals from water sources (Norment and Douglas 1977).

Since large, heavy mammals follow many paths over the ground surface, severe soil compaction may occur, especially near water sources. Soil compaction has been defined by Lull (1959) as the packing together of soil particles by instantaneous forces exerted at the soil surface. These forces (animal, human foot or vehicle traffic) can increase soil bulk density and reduce macropore space. The loss of macropores reduces water infiltration and water movement through the soil, thus increasing surface water run-off and fluvial erosion (Scholl 1989). A significant increase in bulk density has been the most common means of expressing soil compaction problems. Both penetrometer and bulk density are used to assess compaction effects of vehicles, humans, and animals in the Mojave Desert of southern California (Webb et al. 1986).

Studies of cattle trampling under semiarid conditions have shown detrimental effects on various soil properties (Reed and Peterson 1961; Orr 1975; Warren et al. 1986; Stephenson and Veigel 1987; and Van Havern 1983). Yet, soil compaction from large, heavy mammal trampling under arid conditions of southern Nevada have not been documented. The objective of this study is to quantitatively evaluate changes in soil attributes (compaction, bulk density, macropore, and moisture status) resulting from mammal trampling in *Coleogyne* shrublands of the RRCNCA.

Methods

Study Site

Southern Nevada is in the Basin and Range physiographic province, a region characterized by annual weather extremes and a sparse vegetation cover (Brittingham and Walker 2000). Most precipitation in southern Nevada occurs in the winter, while summer storms are highly localized and unpredictable (Brittingham and Walker 2000).

Red Rock Canyon National Conservation Area (roughly 36°05′N, 115°15′W) of the Spring Mountains, Nevada, was chosen because it supports well-established, nearly monospecific *Coleogyne* shrublands, ranging from approximately 1,450 to 1,775 m in elevation. *Coleogyne* shrublands support at least nine relatively large mammal species (Table 1) as indicated by large numbers of dung, paw and hoof prints, and grazed vegetation. Blue Diamond Wash, Willow Spring, Pine Creek, Oak Creek, Calico Hills, First Creek, Lost Creek Canyon, and Ice Box Canyon are some of the major areas within the RRCNCA that can provide ample water for large mammals throughout much of the year. Water can be replenished with melting snow from adjacent high mountains in the spring, erratic

Table 1. Nine large mammal species found within the boundaries of *Coleogyne* shrublands in the Red Rock Canyon National Conservation Area (Eifert and Eifert 2000). These mammal species are arranged by weight, from heaviest to lightest.

Common name	Species name	Mean weight (kg)	Type of track
Horse	*Equus caballus*	409.1	Hoof
Burro	*Equus asinus*	181.8	Hoof
Desert bighorn sheep	*Ovis canadensis nelsoni*	105.0	Hoof
Mule deer	*Odocoileus hemionus*	90.9	Hoof
Mountain lion	*Felis concolor*	63.6	Paw
Coyote	*Canis latrans*	13.6	Paw
Bobcat	*Lynx rufus*	9.8	Paw
Gray fox	*Urocyon cineroargenteus*	4.5	Paw
Desert kit fox	*Vulpes macrotis*	2.1	Paw

precipitation during fall and winter, as well as with occasional monsoon thunderstorms in the summer. Summer thunderstorms often cause locally intense rainfall where intermittent washes throughout the RRCNCA can rapidly collect excess running surface water during and shortly after major storm events. Prolonged cloudbursts in the summer can create major flash floods in wash and depression areas.

Large, heavy mammals directly trample and turn up the fragile desert soil. Sandstone and limestone are both rock types that have shallow soils in which *Coleogyne* and other associated woody species grow well (Callison and Brotherson 1983; West 1983). Within *Coleogyne* vegetation zones, many common herbaceous species are members of the Asteraceae, Brassicaceae, Fabaceae, and Poaceae families.

Field Design and Sampling

Field studies were conducted in animal trails during Summer 2000 in the RRCNCA. A total of 49, 1-ha plots containing paw and hoof prints and fecal material was established within 7 km of intermittent springs and streams. Because animal trails were not conspicuous, sampled plots were randomly selected at each distance (1 to 7 km) from water courses, and individual piles of fecal material (fresh and dried) were counted.

Within each kilometer (1, 2, and 6) of water in the same plots, 60 soil samples containing clearly defined paw and hoof prints were randomly collected. Adjacent reference soils were collected beyond 7 km of water, with no clear evidence of paw or hoof prints, dung, and grazed vegetation. Soil samples were excavated approximately 10 cm in diameter to depths of 15 cm. Soil compaction was obtained in the field using a penetrometer inserted into the soil after removing the stony surface (Lei and Walker 1997; Lei 1999; Lei 2000). The compaction readings were taken at the point where the cone base reached the soil surface (point depth = 3.7 cm). Soil samples were sifted through a 2-mm mesh to remove plants roots and rocks > 2 mm in diameter. Soil bulk density measurements were performed on sifted soils that were oven-dried at 65°C for 72 h.

For each sampled plot, soil surface characteristics of bare ground, gravel (2–

64 mm in diameter), cobble (65–256 mm), and boulder (> 256 mm) were visually quantified using 10% increments.

Soil moisture characteristics were stratified by trampling severity (control, light, moderate, and heavy) and geomorphic surfaces (terrace and slope sites). Water infiltration rates were measured by using PVC pipe, 5.5 cm in diameter and 9.5 cm tall. This pipe was open at both ends and was gently tamped into the trampled and non-trampled soils to a depth of 2 cm to prevent leakage, and then 50 mL of water was poured into the pipe. Time taken for the water to soak completely into the soil was recorded with a stop-watch.

Approximately 1.5 L of water, acting as an artificial rain, was manually poured through a perforated 13-cm disk, with perforations being evenly spaced on a 0.1-cm grid. The disk was placed at 1.0 m aboveground. Total delivery time was 1 min for the water to be dispensed on the soil surface and to create precipitation at a cloudburst level (Brotherson and Rushforth 1983). A sudden heavy precipitation is significant due to its impact on surface-water runoff and fluvial erosion. Depth of water penetration was measured once the water had disappeared completely into the soil surface.

Surface-water runoff was measured by recording the downslope and across-slope spread of water that was artificially rained onto study sites (Brotherson and Rushforth 1983). The shape of surface-water runoff resembled an ellipse, thus was computed using the following formula: (πab) where a and b are radii of an ellipse (Larson et al. 1994). Since surface water runoff did not form a perfect elliptical shape, measured areas were likely to be overestimates.

Soil movement was assessed by estimating the amount of soil moved through fluvial erosion during a measured rain. The following index was used: 1 = no appreciable movement; 2 = moderate movement, up to 10 % of soil particles being displaced; and 3 = heavy movement, between 10 % and 20 % of soil particles being displaced (Brotherson and Rushforth 1983).

Laboratory and Statistical Analyses

A set of soil cores of known volume was carefully removed from the field. Fresh soil cores were oven-dried at 65°C until they reached constant mass. Soil bulk density was estimated by dividing dry mass by known volume. Average pore space was determined using the equation: per space (%) = $100 - (D_b/D_p * 100)$, where D_b is bulk density of the soil and D_p is average particle density, usually about 2.65 g cc^{-1} (Hausenbuiller 1972; Davidson and Fox 1974).

One-way analysis of variance (ANOVA; Analytical Software 1994) was used to determine if fecal densities differed with respect to distance from water, and to compare physical property differences between trampled and adjacent reference soils. Tukey and Scheffe's multiple comparison tests (Analytical Software 1994) were then performed to compare site means when a significant trampling effect was detected. Linear regression analysis was performed to correlate fecal density with increasing distance from water courses.

Path analysis and Pearson's correlation analysis (Analytical Software 1994) were conducted to correlate trampling severity with soil compaction, soil bulk density, and macropore, as well as to intercorrelate among these three soil properties. Path analysis was used to examine proposed causal links between trampling and soil moisture attributes, and among the three soil physical properties.

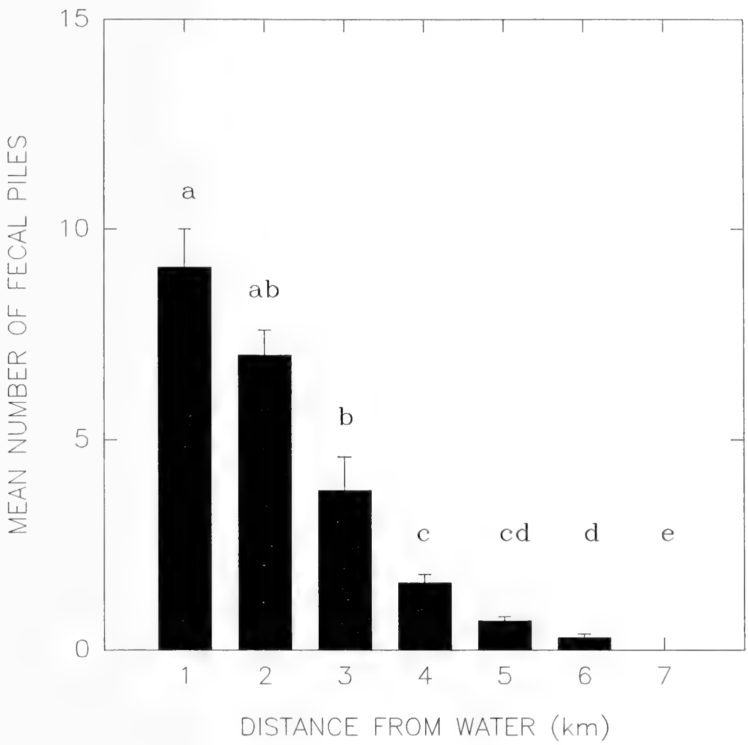

Fig. 1. Fecal density (mean + SE; n = 60 per distance from water) of large mammals sampled in 1-ha plots locating at various distances from water in *Coleogyne* shrublands. Narrow vertical bars denote standard errors, and letters at column tops indicate significant differences at $p \leq 0.05$.

Multivariate Analysis of Covariance (MANCOVA; Analytical Software 1994) was conducted on six soil moisture attributes, with trampling severity and geomorphic surface (terrace and slope) as main variables, and with rock size (gravel, cobble, and boulder) and rock abundance (percent rock cover) as covariate variables. Percent ground cover of gravel, cobble, and boulder was visually quantified using 10 % increments. Tukey and Scheffe's multiple comparison tests were then performed to compare site means when significant effects of trampling severity and geomorphic surface were detected. The presence of abundant rocks on the soil surface would influence various soil moisture regimes. Mean values were presented with standard errors, and statistical significance was determined at $p \leq 0.05$.

Results

Fecal density decreased significantly ($p \leq 0.001$; Fig. 1) when moving away from water sources, and was negatively correlated ($R^2 = -0.88$; $p \leq 0.001$) with increasing distance from water courses in the RRCNCA.

Moderate to heavy mammal trampling had a significantly lower macropore (percent pore space), and higher soil compaction and soil bulk density compared to light or no trampling ($p \leq 0.01$; Table 2). However, significant differences were not detected ($p > 0.05$; Table 2) in soil compaction, soil bulk density, and percent pore space between moderate and heavy trampling, as well as between light and

Table 2. Physical characteristics (mean ± SE; $n = 60$ per treatment per characteristic) of non-trampled (reference) and various levels of trampled soils in *Coleogyne* shrublands. Heavily, moderately, and lightly trampled soils are located within 1, 2, and 6 km of water, respectively. Mean values in rows followed by different letters are significantly different at $p \leq 0.05$.

Soil property	Control	Trampling severity		
		Light	Moderate	Heavy
Compaction (kg/cm^2)	6.1 ± 0.4 a	6.3 ± 0.7 a	7.0 ± 0.5 b	7.3 ± 0.5 b
Bulk density (g/cm^3)	1.24 ± 0.04 a	1.29 ± 0.05 a	1.41 ± 0.07 b	1.43 ± 0.06 b
Pore space (%)	53.2 ± 2.4 a	51.3 ± 2.5 a	46.8 ± 2.3 b	44.9 ± 2.2 b

no trampling. Path analysis revealed that trampling severity was a significant positive predictor of macropore, soil compaction, and soil bulk density (Fig. 2). Soil compaction was a significant positive predictor of bulk density, and a negative predictor of macropore (Fig. 2).

Significant interaction ($p \leq 0.05$; Tables 4 and 5) was detected between trampling severity and geomorphic surface for area of water spread (surface water runoff) only. Significant differences were observed in trampling severity and geomorphic surface for all measured soil moisture variables.

Discussion

Excessive trampling by large mammals significantly altered a number of soil properties and moisture characteristics in *Coleogyne* shrublands of the RRCNCA. Location of water was a main factor in large mammal movement. The extent of trampling disturbances was a function of their distance from water sources. In this study, fecal density increased significantly when approaching water sources.

Dry summer seasons are the time of greatest soil disturbance as large herbivores congregate in large numbers near water to graze upon shrubs, perennial forbs and grasses. In summer, approximately 60 % of the entire *E. asinus* populations is found within a 2-km radius of water, and about 98 % of the *E. asinus* are restricted to within 4 km of water (Douglas and Hurst 1993). In contrast, about 80 % are seen at distances greater than 6 km of water in winter (Douglas and Hurst 1993).

Because mammal trails radiate in all directions from springs, soil disturbance is substantially greater near a spring in Death Valley of southern California (White

Table 3. Relationship between mammal trampling severity and three soil physical attributes and relationship among these three soil attributes in *Coleogyne* shrublands. The direct causal effect of each pairing of variables is the standard partial regression coefficient (path coefficient). Total causal influence (Pearson's r-value) sums all direct and indirect pathways. Heavily, moderately, and lightly trampled soils are located within 1, 2, and 6 km of water, respectively. All computed values are statistically significant at $p \leq 0.001$.

Pairing of variables	Direct causal	Indirect causal	Total causal
Compaction × trampling severity	0.85	0.10	0.95
Bulk density × trampling severity	0.88	0.09	0.97
Macropore × trampling severity	−0.88	−0.09	−0.97
Bulk density × compaction	0.94	0.05	0.99
Macropore × compaction	−0.94	−0.05	−0.99
Macropore × bulk density	−0.98	−0.01	−0.99

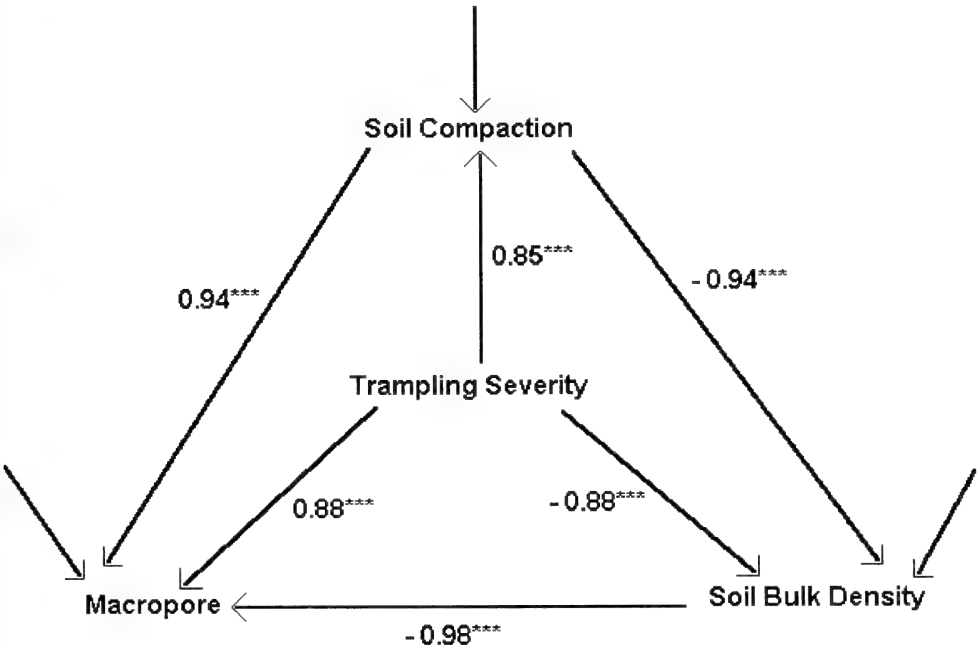

Fig. 2. Path diagram showing predictor variables influencing three soil physical properties. Path coefficients quantify direct causal influences of severity of large mammal trampling on macropore, soil compaction, and soil bulk density. All pathways are statistically significant at $p \leq 0.05$.

1980). Within 0.5 km of a spring in the Lake Mead National Recreation Area, the number of converging trails contributes to severe soil compaction (O'Farrell 1978). Animals have caused a moderate to severe soil compaction within 0.8 km of major water courses in the Las Vegas valley (Woodward 1976). Nevertheless, ecological impacts on soil and vegetation beyond 0.8 km of the spring has been minor in southern California (Woodward 1976).

Path analysis indicated that percent pore space, soil compaction, and soil bulk density were significantly directly influenced by the severity of mammal trampling. Percent pore space and bulk density were also significantly directly affected by the severity of soil compaction. Short, unlabeled (residual) arrows shown in the path diagram (Fig. 2) indicated that these variables are also subject to additional biotic influences, which include small animal and human trampling (recreational) activities. After all, the RRCNCA is a popular place for year-round, outdoor recreational activities. Humans and their motor vehicles go off-trails periodically.

Significant increases in soil compaction and bulk density can lead to a significant decrease in the percentage of macropores in heavily trampled compared to lightly or non-trampled soils. Pore space consists of macropores that allow the ready movement of air and water (Davidson and Fox 1974). The increase in soil compaction, along with the subsequent increase in soil bulk density and decrease in macropore space in heavily trampled soils, reduces the amount of water that the soil can hold and the rate at which water can flow through the soil.

Furthermore, soil compaction resulting from heavy paw and hoof impacts sig-

Table 4. Moisture characteristics (mean ± SE; n = 60 per treatment per characteristic) of nontrampled soils and various levels of trampling in *Colegyne* shrublands. Heavily, moderately, and lightly trampled soils were located within 1, 2, and 6 km radius of water, respectively.

		Trampling severity		
Moisture parameter	Control	Light	Moderate	Heavy
Infiltration (seconds)				
Terrace	181.2 ± 17.2	197.3 ± 14.7	236.7 ± 13.4	270.6 ± 16.4
Slope	202.2 ± 12.4	220.2 ± 15.1	253.3 ± 12.1	287.6 ± 13.9
Depth of water penetration (cm)				
Terrace	4.0 ± 0.01	3.5 ± 0.02	2.4 ± 0.01	2.1 ± 0.01
Slope	3.6 ± 0.02	3.2 ± 0.02	2.3 ± 0.01	1.9 ± 0.01
Downslope spread (cm)				
Terrace	69.0 ± 4.6	80.1 ± 4.9	90.8 ± 5.4	98.2 ± 5.8
Slope	94.4 ± 5.4	10.3 ± 5.2	108.2 ± 5.7	119.6 ± 6.2
Across slope spread (cm)				
Terrace	60.5 ± 3.9	68.4 ± 4.9	84.2 ± 5.8	96.1 ± 5.9
Slope	85.1 ± 4.1	94.4 ± 5.2	110.4 ± 5.8	123.5 ± 6.7
Area of spread (cm^2)				
Terrace	3276.9 ± 498.1	4295.5 ± 455.7	6001.6 ± 612.7	7392.9 ± 659.1
Slope	6306.3 ± 523.4	7432.6 ± 701.2	9377.0 ± 689.4	11594.9 ± 750.3
Soil movement				
Terrace	1.1 ± 0.01	1.2 ± 0.01	1.3 ± 0.01	1.4 ± 0.01
Slope	1.3 ± 0.01	1.4 ± 0.01	1.5 ± 0.01	1.6 ± 0.01

Table 5. Summary from two-way ANOVA with trampling severity, geomorphic surface, and their interactions on various soil moisture characteristics. *df* = 1 for geomorphic surface; *df* = 3 for trampling severity and for the trampling severity × geomorphic surface combination.

	Trampling severity		Geomorphic surface		Trampling × surface	
Moisture parameter	F	P	F	P	F	P
Water infiltration	56.23	0.0000	26.23	0.0014	0.65	0.6092
Depth of water penetr.	254.77	0.0000	15.93	0.0052	1.38	0.3317
Downslope water spread	10.03	0.0063	31.49	0.0008	0.13	0.9359
Across-slope water spread	35.02	0.0001	78.32	0.0000	0.05	0.9861
Area of water spread	999.79	0.0000	275.16	0.0000	6.42	0.0022
Soil movement	6.22	0.0219	16.80	0.0046	0.62	0.6193

nificantly reduced water infiltration and water movement into the soil, and increased surface-water runoff in *Coleogyne* shrublands. Soil compaction greatly reduces water infiltration in alluvial soils of the Mojave Desert in southeastern California (Webb and Wilshire 1980; Vasek et al. 1975). Severely compacted animal trails are nearly impervious to penetration by water so that heavy precipitation tends to run-off compacted soils, leading to fluvial erosion and resistance to plant colonization (Carothers 1976).

A high percentage of rock cover was observed on the soil surfaces throughout much of the study site. By far, gravel was the most common type of rock compared to cobbles and boulders. In New Mexico, rock size and abundance may influence a variety of other soil attributes including infiltration, porosity, water-holding capacity, and erodibility (Carlson and Whitford 1991). Fluvial erosion and surface water runoff were significantly greater for slope than terrace site. At some slope sites, a small movement of soil particles occurred when water traveled rapidly downslope during a cloudburst, perhaps due to a lack of abundant rocks on the soil surface to reduce fluvial erosion and surface water runoff.

Excessive trampling by large mammals significantly altered a number of edaphic attributes where *Coleogyne* and associated woody taxa exist. Research plots containing heavily trampled soils included countless visible, overlapping paw and hoof prints on the soil surface. Some of the trampling herbivore (prey) species were a much more important source of soil compaction than others. Among the five large mammal species, *E. asinus* were most frequently seen during the course of study. In this study, wild *E. caballus,* by far, were the heaviest in weight, averaging 409 kg. *Equus asinus* and *Ovis* were the second and third heaviest mammals, weighing 182 and 105 kg, respectively (Table 1). Although *Canis, Lynx, Urocyon,* and *Vulpes* are considered as light-weighted mammals, having a high traffic volume contributed to the overall water infiltration rate, as well as to the overall severity of soil compaction and surface-water runoff. The predators, however, would have a minimal impact on soil compaction because they were smaller and considerably less abundant compared to those large prey species.

Soil compaction is an aspect of land degradation associated with excessive foot traffic from large animals. Heavily compacted soils through animal trampling can alter the composition of *Coleogyne* shrublands through time, favoring weedy, pioneer plant species. Proximity to water courses, along with preference for abundant food supply during dry seasons, appear to be the driving force in producing massive soil disturbance. *Equus asinus, E. caballus,* and *Ovis* are large, heavy opportunistic herbivores. Their generalized feeding behavior provide them with the ability to exploit and degrade many aspects of desert woody vegetation zones in southern Nevada and the southwestern United States.

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Literature Cited

Analytical Software 1994. Statistix 4.1, an interactive statistical program for microcomputers. Analytical Software, St. Paul, Minnesota.

Brittingham S.B. and L.R. Walker 2000. Facilitation of *Yucca brevifolia* recruitment by Mojave Desert shrubs. Western N. Amer. Nat. 60:374–383.

Brotherson, J.D. and S.R. Rushforth. 1983. Influence of cryptogamic crusts on moisture relationships of soils in Navajo National Monument, Arizona. Great Basin Nat. 43:73–78.

Bureau of Land Management. 1994. Southern Nevada Times: Las Vegas Territory, Volume I. Bureau of Land Management, Red Rock Canyon National Conservation Area, Las Vegas, Nevada.

———. 1999. Mammals. U.S. Department of the Interior, Bureau of Land Management, Red Rock Canyon National Conservation Area, Las Vegas, Nevada.

Callison, J. and J. Brotherson. 1985. Habitat relationship of the blackbrush community of southern Utah. Great Basin Naturalist 45:321–326.

Carlson, S.R. and W.G. Whitford. 1991. Ant mound influence on vegetation and soils in a semiarid mountain ecosystem. Amer. Mid. Nat. 126:139–159.

Carothers, S.W. 1976. An ecological survey of the riparian zone of the Colorado River between the Grand Wash Cliffs, Arizona. Report on file at National Park Service in Death Valley National Monument.

Davidson, E. and M. Fox. 1974. Effects of off-road motor cycle activity on Mojave Desert vegetation and soil. Madrono 22:381–390.

Douglas, C.L. and H.D. Haitt. 1987. Food habits of feral burros in Death Valley, California. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada, Las Vegas.

——— and T. Hurst. 1993. Review and annotated bibliography of feral burro literature. Cooperative National Park Resources Studies Unit, University of Nevada, Las Vegas, Nevada.

Eifert, L.E. and N.C. Eifert. 2000. Red Rock Canyon Nature Guide. The Red Rock Canyon Interpretation Association, Las Vegas, Nevada.

Hausenbuiller, R.L. 1972. Soil science. William C. Brown Company Publishers, Dubuque, Iowa.

Larson, R.E., R.P. Hostletler, and B.H. Edwards. 1994. Calculus, 5th edition. D.C. Health and Company, Lexington, Massachusettes. 1256 pp.

Lei, S.A. 1999. Postfire woody vegetation recovery and soil properties in blackbrush (*Coleogyne ramosissima* Torr.) shrubland ecotones. J. of the Arizona-Nevada Acad. Sci. 32:105–115.

——— 2000. Ecological impacts of seed harvester ants on soil attributes in a *Larrea*-dominated shrubland. Western N. Amer. Nat. 60:439–444.

——— and L.R. Walker. 1997. Biotic and abiotic factors influencing the distribution of *Coleogyne* communities in southern Nevada. Great Basin Nat. 57:163–171.

Lull, H.W. 1959. Soil compaction on forest and rangelands. U.S. Department of Agriculture, Forest Service, Misc. Publ. No. 768.

Norment, C. and C.L. Douglas. 1977. Ecological studies of feral burros in Death Valley. National Park Service, Contribution No. 17, University of Nevada, Las Vegas, Nevada.

O'Farrell, M.J. 1978. An assessment of impact of feral burros on natural ecosystems of the Lake Mead

National Recreation Area, Arizona-Nevada. National Park Service, Cooperative National Park Research Studies Unit, University of Nevada, Las Vegas, Nevada.

Orr, H.T. 1975. Recovery form soil compaction on bluegrass range in the Black Hills: Trans. Amer. Soc. Agricultural Engineers 18:1076–1081.

Reed, M.J. and R.A. Peterson. 1961. Vegetation, soil, and cattle responses to grazing on northern Great Plains range. U.S. Department of Agriculture, Technical Bulletin 1252.

Scholl, D.G. 1989. Soil compaction from cattle trampling on a semiarid watershed in northwest New Mexico. New Mexico J. Sci. 29:105–112.

Stephenson, G.R. and A. Veigel. 1987. Recovery of compacted soil on pastures used for winter cattle feeding. J. Range Management 40:46–48.

Van Haveren, B.P. 1983. Soil bulk density as influenced by grazing intensity and soil type on a shortgrass prairie site. J. Range Management 36:586–588.

Vasek, F.C., H.B. Johnson, and D.H. Eslinger. 1975. Effects of pipieline construction on creosote bush scrub vegetation of the Mojave Desert. Madrono 23:1–13.

Warren, S.D., W.H. Blackburn, and C.A. Taylor. 1986. Effects of season and stage of rotation cycle on hydrologic condition of rangeland under intensive rotation grazing. J. Range Management 39:486–491.

Webb, R.H. and H.G. Wilshire. 1980. Recovery of soils and vegetation in a Mojave Desert ghost town, Nevada, USA. J. Arid Environ. 3: 291–303.

Webb, R.H., J.W. Steiger, and H.G. Wilshire. 1986. Recovery of compacted soils in Mojave Desert ghost towns. Soil Science Soc. Amer. Jour. 50: 1341–1344.

West, N.E. 1983. Ecosystems of the world, Volume 5. Temperate deserts and semi-deserts. Department of Range Science and the Ecology Center, Utah State University, Logan, Utah.

White, L. 1980. A study of feral burros in Butte Valley, Death Valley National Monument. National Park Service, Cooperative National Park Resources Studies Unit, University of Nevada, Las Vegas, Nevada.

Woodward, S.L. 1976. Feral burros of the Chemehuevi Mountains, California: the biogeography of a feral exotic. Doctoral Dissertation, University of California, Los Angeles.

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An Inexpensive Method to Identify the Elevation of Tidally Inundated Habitat in Coastal Wetlands

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Abstract.—We explored the use of an inexpensive "vial" method to measure the elevations reached by a series of high tides, which included the highest tides of the year, at sites in four southern California wetlands, examined variation in the distribution and abundance of marsh, transition, and upland vegetation as a function of elevation, and assessed whether our measure of height of tidal inundation correlated with the distribution of these plants, permitting the use of vegetation boundaries as a proxy for the height of tidal inundation. The potential effects of factors unrelated to tidal inundation render elevational boundaries of native marsh plants unattractive as a general criterion for defining the upper edge of tidally influenced habitat. By contrast, both the upper limit of tidal inundation as measured by the vial method and the lower elevational limit of exotic grasses, such as *Parapholis incurva,* appears to be useful in delineating the upper edge of tidally influenced habitat. This elevation coincided with the highest spring tides and varied among sites in association with the extent of tidal muting. The vial method is a useful technique to identify sites of comparable tidal influence in restored and reference wetlands and can provide an early indication of tidal muting in restored wetlands.

The performance of restoration projects in tidal wetlands has been assessed using several methods (reviewed in Kentula 2000). One approach is to compare the degree of similarity of the restored site, in terms of selected physical and biological criteria, to natural reference wetlands. For tidal wetlands, a definition of "tidally-influenced" habitat may first be needed to delineate the general area for comparison across sites. Physical criteria used to define "tidally influenced" habitat are ambiguous, but may include that the "substrate is at least irregularly exposed and flooded by oceanic tides" (Ferren et al. 1996abc). Tidal wetland soils are characterized by low permeability and halophytic vegetation (e.g., *Salicornia, Spartina*) may be present.

Unfortunately, these definitions are subject to interpretation. Tidal influence can be defined statistically as a greater than zero probability of inundation by tidal waters. In practice, such a definition could include habitats that are inundated by tidal waters much less frequently than even once per year (e.g., once every five or ten years). Such a definition does not consider that ecological functioning may vary greatly as a function of inundation frequency; habitat at the upper end of the tidal gradient may function differently relative to habitats lower (e.g., be more susceptible to invasion by exotic species). Similar problems occur when using the presence of hydric soils or halophytic plants to define tidally influenced habitat, since both can occur in seasonal wetlands far removed from tidal influence (Ferren et al. 1996a).

In addition, the biological structure and function of the restored site may be compared to those characteristics in control or reference sites in "equivalent" tidally influenced habitats. Elevation *per se* is only an approximate measure of tidal influence or the frequency of tidal inundation because local hydrology and soil characteristics may influence the relationship between these variables (Van Der Molen 1997). To permit comparisons of habitats characterized by similar inundation regimes, it is necessary to examine the relationship between elevation and inundation in wetlands. Unfortunately, this comparison can require use of expensive instruments, thereby limiting the number of sites that can be simultaneously measured.

The distribution and abundance of plant species may also be used to characterize "equivalent" habitats. The distribution and abundance of marsh plants and the lower limits of transition and upland plants vary as a function of elevation and, by inference, frequency of tidal inundation (e.g., Zedler 1977; Callaway et al. 1990; Bertness 1991ab; Pennings and Callaway 1992; Zedler et al. 1999). Despite the existence of numerous studies on the distribution of plants in salt marshes, however, little published information is available on how plant distributions may be related to the height of tidal inundation; information that could prove useful in the development of criteria to define "tidally influenced" habitat and in choosing "equivalent" habitats for comparisons across restored and reference wetlands. Previous work has suggested that the elevational limits of marsh plants may vary among estuaries even within the same region (Frenkel et al. 1981).

In this study, we explored the use of an inexpensive technique to measure the elevations reached by a series of high tides, which included the highest tides of the year, at sites in four southern California wetlands. We examined whether our measure of height of tidal inundation correlated with the distribution and abundance of marsh, transition, and upland vegetation, thus permitting the use of vegetation boundaries as a proxy for the height of tidal inundation.

Materials and Methods

Study Sites

To examine relationships between elevation, the height of tidal inundation, and the distribution and abundance of vegetation, we collected data along transects at

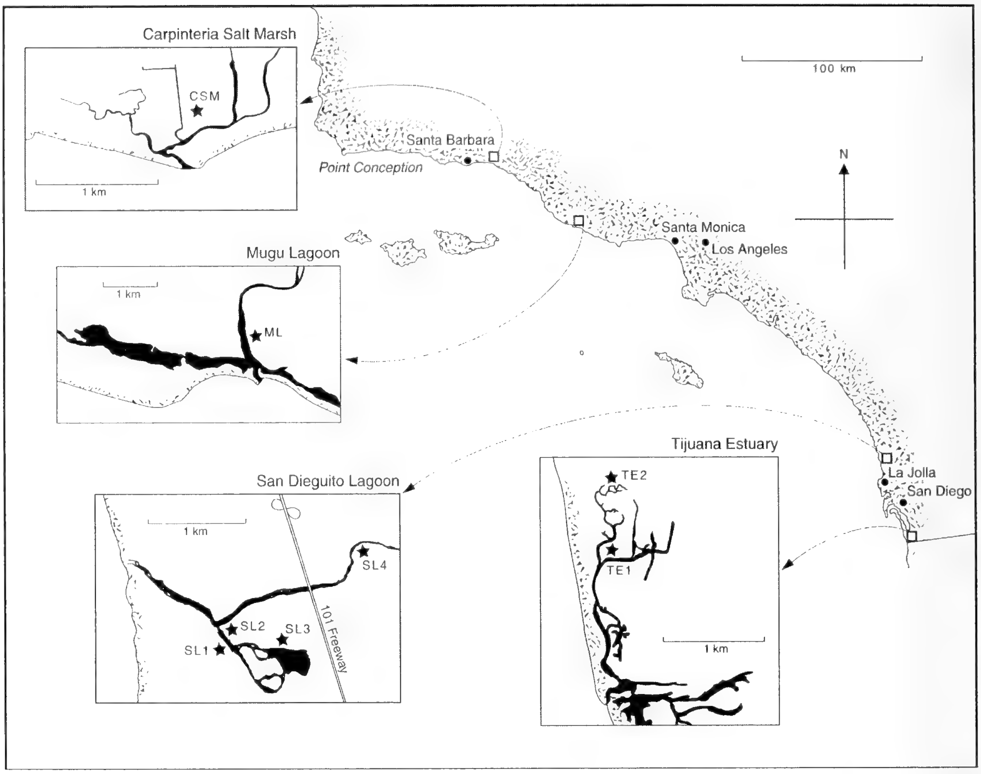

Fig. 1. Map showing location of study sites at San Dieguito Lagoon, Carpinteria Salt Marsh, Tijuana Estuary, and Mugu Lagoon. Tide data from the open coast measured at Santa Monica and La Jolla and reported by the National Oceanic and Atmospheric Administration (see text). Inset maps modified from Ferren (1985), Onuf (1987), SAIC (2000), and Zedler et al. (1992).

8 sites distributed among 4 wetlands (San Dieguito Lagoon, Tijuana Estuary, Carpinteria Salt Marsh, and Mugu Lagoon) that incorporated a range of inundation regimes. Four sites were located at varying distances from the ocean inlet in San Dieguito Lagoon (32°58′N, −117°08′W) (Fig. 1). This wetland, located at the northern edge of the City of Del Mar, consists of ~61 ha of estuarine habitat, including 25 ha of tidal salt marsh (SAIC 2000) (Fig. 1). The western portion of the estuary consists of salt marsh with tidal channels 15 m to 30 m wide and one 28 ha basin. The eastern portion of the estuary consists of the San Dieguito River channel with a narrow strip of salt marsh along the southern border of the river. Three sites (SL1, SL2, SL3) were located in the western portion of the estuary at distances of ~1.4, 1.3, and 1.9 km, respectively from the inlet. One site (SL4) was located in the eastern portion ~2.6 km from the inlet. Two transects spaced ~2 m apart were established at each site perpendicular to tidal channels (SL1, SL2, SL4) or a basin (SL3).

Tidal exchange in San Dieguito Lagoon occurs through an inlet to the Pacific Ocean. Sand accretion can block the inlet preventing tidal exchange. For example, between March 1992 and May 1993 the inlet was closed (MEC 1993). However, the inlet was estimated to have been open 90% of the time from October 1994 through September 1997 (Boland 1998).

Two sites (TE1, TE2) were sampled in Tijuana Estuary (32°33′N, −117°05′W), located in the southwestern corner of San Diego County. Tijuana Estuary encompasses ~712 ha of wetland habitat, including ~249 ha of tidal salt marsh. The ocean inlet is generally open but is relatively shallow, which could reduce tidal exchange in this estuary (Zedler et al. 1992). One transect was established at each site, which extended perpendicular to the edge of 1 to 2 m wide tidal creeks located ~1.6 km (TE1) and 2.2 km (TE2) from the inlet (Fig. 1).

One site (CM) was located in the eastern portion of Carpinteria Salt Marsh (34°24′N−119°31′W). This marsh contains ~93 ha of wetland habitat, including ~54 ha of tidal salt marsh (Ferren 1985; Page et al. 1995). Tidal exchange occurs year round through the inlet that is flanked by rock revetments. However, total tidal range and the tidal prism are reduced due to a cobble sill at the inlet (Hubbard 1996). One transect was established perpendicular to the edge of a small (1 m wide) tidal creek ~0.9 km from the inlet (Fig. 1).

The last site (ML) was located east of the central basin at Mugu Lagoon (34°06′N−119°05′W). Mugu Lagoon contains ~597 ha of wetland habitat, including ~382 ha of tidal salt marsh (Onuf 1987). The lagoon consists of a western arm, an eastern arm, and a central basin section. The inlet/barrier beach varies dynamically with fluvial and nearshore processes, but the inlet is continuously open to tidal exchange. One transect was run perpendicularly from the edge of a 5 m wide tidal channel approximately 1.0 km from the inlet (Fig. 1).

Transects extended from the nonvegetated waters edge into upland vegetation. Consequently, transect length varied depending on the elevational slope at each site (i.e. <30 m at SL1 and SL4 to >200 m at ML, CM, and TE1). Measurements of elevation, plant species composition and percent cover were taken at stations located at uniform distances along each transect. Stations along the transects were generally spaced 10 m apart except at sites SL1 and SL4, where stations were spaced 2 m apart because of the relatively short length of these transects. It should be noted that data on elevation, tidal inundation, and vegetation from our study sites were collected for the purpose of examining relationships among these variables rather than to fully characterize these variables for each wetland.

Measurements of Tidal Elevation and Height of Tidal Inundation

Elevations were determined at every station along each transect using a differential GPS system (Sokkia RTK Receiver System) in October 1998. To determine the repeatability of these measurements, the elevation of 25 stations at San Dieguito Lagoon were remeasured in January 1999. Measurements of elevation in January were similar to those determined in October, differing on average by 2.1 cm (range 0 to 4.8 cm) from the previous measurements. All elevations are expressed relative to NGVD (National Geodetic Vertical Datum = Mean Sea Level in 1929). Current mean sea level (MSL) is 0.017 m NGVD.

We explored the use of an inexpensive "vial" method to measure the elevations reached by a series of high tides between November 1997 and March 1998 at each site. This series included the highest tides of the year. We placed a vertical stake at or near the beginning of each transect at a known elevation. Glass 20 ml vials were attached to each stake at 3 cm intervals. The elevation reached by a given high tide in the marsh was measured by noting the elevation of the highest vial on the stake that was filled with seawater. Vials were emptied prior to each measured high tide. Our measurements presumably correlated with inundation frequency and submersion time for a given elevation and thus provided a comparative measure of the inundation environment at each site.

Using the vial measurements, we determined the degree of muting of the high tides at the study sites relative to tides on the coast. High tides in San Dieguito Lagoon and Tijuana Estuary were compared with the same high tides at La Jolla (Scripps Pier), as reported by the National Oceanic and Atmospheric Administration (NOAA). San Dieguito Lagoon and Tijuana Estuary are located 11 km south and 37 km north of La Jolla, respectively (Fig. 1). The elevations reached by high tides at Mugu Lagoon and Carpinteria Salt Marsh were compared with the same high tides observed at Santa Monica (NOAA). Mugu Lagoon and Carpinteria Salt Marsh are located 60 km and 120 km north of Santa Monica, respectively (Fig. 1).

Vegetation Sampling

We identified and measured the percent cover of plant species along the transects at each site. Percent cover was determined using point-contact sampling. A 4 mm diameter rod was dropped through 25 randomly placed holes in a sampling table situated above a 0.5 m $\times$ 0.5 m quadrat at each station along the transect lines. All species touching the rod were recorded and the percent cover of each plant species was determined by multiplying the number of contacts by four. Because more than one species could contact the rod, the total cover can exceed 100%. Following quantitative sampling, each quadrat was searched and any additional species encountered were recorded as covering <4%. Although we collected data on all marsh plant species, here we present only data on the most ubiquitous species (the native succulents *Salicornia virginica* and *Arthrocnemum subterminale,* the invasive grass, *Parapholis incurva,* and a grouping of transition/upland species that included the native rush, *Juncus bufonius,* non-native grasses *Polypogon monspeliensis, Lolium multiflorum, Bromus diandrus,* and *B. hordeaceus,* the native shrubs *Isocoma mensiezii, Lycium californicum, Rhus integrifolia,* and the weeds *Brassica* sp. and *Gnathophalium* sp).

Data Analyses

All statistical analyses were done using Systat Version 8.0 (SPSS Inc. 1998). Linear regressions of the elevation reached by high tides on the stakes against the elevations reached by high tides on the coast were compared among sites using Analysis of Covariance (ANCOVA) to determine whether the degree of muting varied among sites. In this analysis, site was the categorical variable with elevation as the covariate. We used multiple regression analysis to evaluate relationships between the lower elevational limits of *Arthrocnemum subterminale, Parapholis incurva,* and grouped transition/upland species, and the independent variables of tidal muting and marsh slope. The upper limits of distribution of these plants were not considered in this analysis because these species occur in non-tidal habitats. Tidal muting at the lower limits of plant species was calculated from the regression equation that described the relationship between the elevations reached by high tides at each site and along the open coast at La Jolla or Santa Monica. Slope was calculated as the average change in elevation over a distance of 10 m (the typical distance between stations) from the lower limit for each plant group towards the creek, channel or basin.

Results

Site Elevations and Marsh Topography

Elevation and marsh topography varied among sites (Fig. 2). As expected, elevation was highly correlated with distance from tidal creek, channel, or basin for all transects ($P < 0.001$ for SL1, 3, 4, ML, CM, TE1, TE2; $P < 0.01$ for SL2). However, the marsh plain (*sensu* Zedler et al. 1999) occurred at higher elevations (>0.75 m NGVD) at SL1, 2, 3, 4, and ML compared with CM, TE1 and TE2. The marsh plain at CM and ML had a uniform, gradual slope while the elevation of TE1 varied primarily at distances of 160 to 240 m from the channel. TE2 crossed irregular topography that included a low nonvegetated area 60 m from the channel. The elevations of SL1, 2, and 4 varied primarily at the channel and upland ends of the transects. Much of SL3 covered elevations >1.5 m with abrupt changes in elevation at the basin and upland ends of the transect.

Elevation of High Tides

As expected, there was a linear relationship between the elevation reached by high tides at each site and high tides measured along the open coast (Fig. 3). However, vial measurements of tidal inundation indicated that high tides were muted at 7 of the 8 sites. Within San Dieguito Lagoon, high tides were from 0.06 to 0.09 m lower at SL1, 2, and 3 compared with those measured on the open coast. Because there was no difference between these sites ($P > 0.05$, ANCOVA), the data are grouped in Figure 3. In contrast, high tides at SL4, the most landward site, reached higher elevations than those measured on the open coast. This "run-up" effect appeared to increase with height of the high tide. For example, from the regression equation for SL4, a high tide of 1.8 m on the open coast would yield a tide of 2.0 m at this site (Fig. 3). High tides were also from 0.06 to 0.09 m lower at ML compared with those measured on the open coast. Because there was no difference between ML and SL1, 2, and 3 ($P > 0.05$, ANCOVA), the data from ML are grouped with the latter sites in Figure 3.

The greatest muting of tides occurred at CM, TE1, and TE2; high tides at these sites were ~0.3 m lower than the same tides along the open coast. There was no difference in tidal muting between CM, TE1, and TE2 ($P > 0.05$, ANCOVA) and the data from these sites are grouped in Figure 3.

Plant Species Distributions and Elevation

There was broad overlap in the distribution of *Salicornia virginica* and *Arthrocnemum subterminale*. However, as expected (Zedler et al. 1992; Pennings and Callaway 1992), the highest cover of these species occurred at different elevations; highest cover of *S. virginica,* occurred consistently at lower elevations than the highest cover of *A. subterminale* (Fig. 4). However, across sites, the highest cover of these species generally varied with the degree of tidal muting (Fig. 4). For example, highest cover of *S. virginica* (to 100%) occurred at elevations of >0.60 m NGVD at the least muted sites (SL1, 2, 3, and ML), but was virtually absent at elevations of >0.60 m NGVD at the most muted sites (CM, TE1, and TE2). Similarly, highest cover of *A. subterminale* occurred at elevations occupied by transition/upland plants at the most muted sites (Figs. 4, 5). At the site of tidal "run-up" (SL4), *S. virginica* also occurred at elevations of >0.60 m

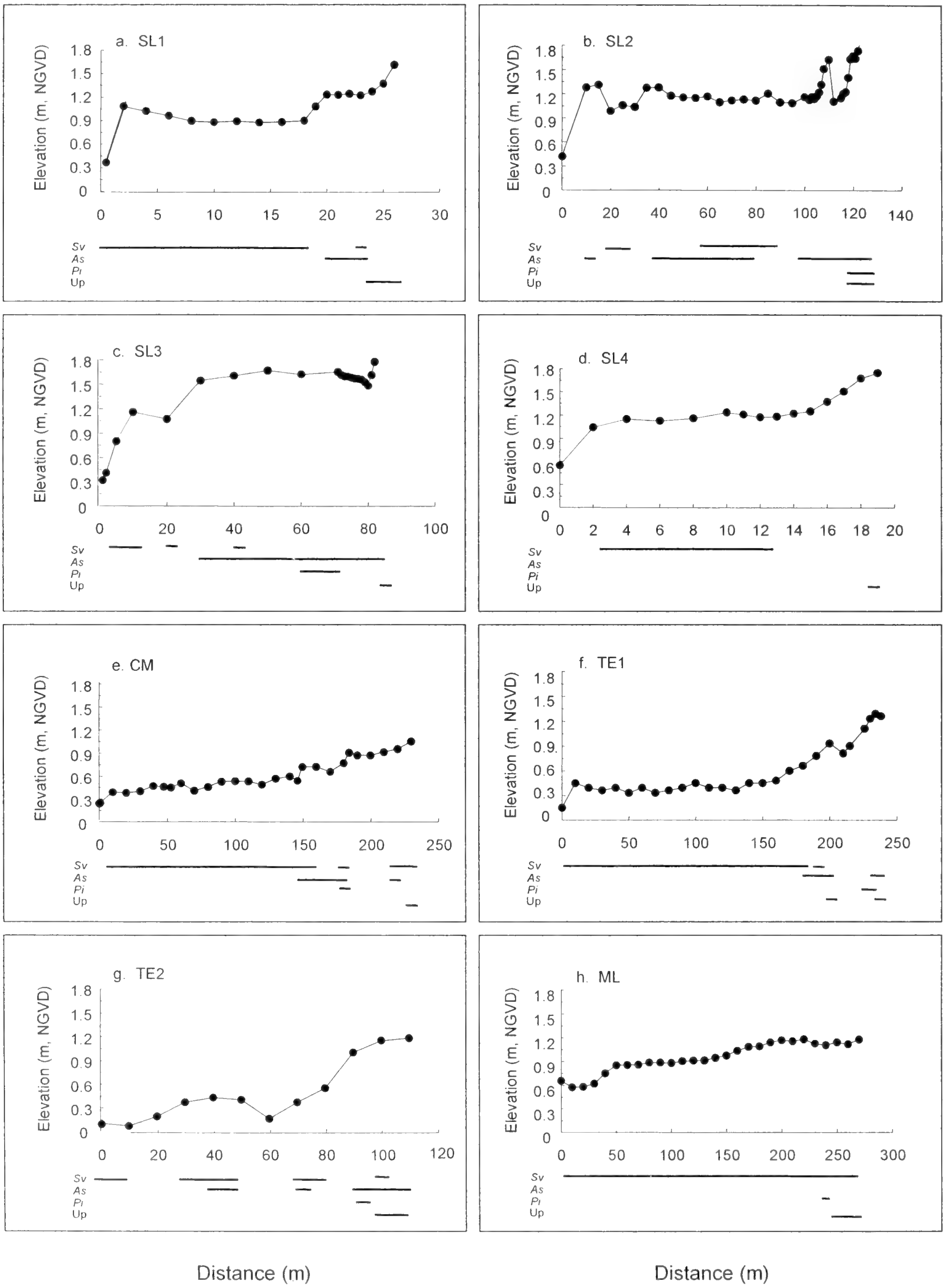

Fig. 2. Profiles of elevation (m, NGVD) versus distance from channel/basin at sites in San Dieguito Lagoon (SL1, 2, 3, 4), Carpinteria Salt Marsh (CM), Tijuana Estuary (TE1, 2), and Mugu Lagoon (ML), and the distribution of *Salicornia virginica, Arthrocnemum subterminale, Parapholis incurva,* and grouped upland plants along transects. Values from means of two transects at SL1, 2, 3, and 4 and from one transect at CM, TE1, 2, and ML. Note that the scale of the x-axis varies among sites. Plant abbreviations: *Sv—Salicornia virginica, As—Arthrocnemum subterminale, Pi—Parapholis incurva,* Up—transition/upland group.

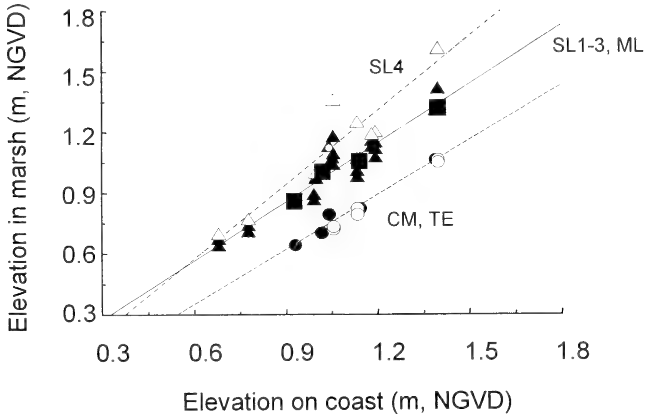

Fig. 3. Linear regressions of the elevation of high tides measured at the wetland study sites against the elevation of high tides measured on the open coast on the same date. Elevations at San Dieguito Lagoon (SL) and Tijuana Estuary (TE) are compared with elevations at Scripps Pier. Elevations at Carpinteria Salt Marsh (CM) and Mugu Lagoon (ML) are compared with elevations at Santa Monica. Each point represents one high tide. Common regression line ——— computed for SL1-3 (▲) and ML (■): $y = 0.97x - 0.06$, $r^2 = 0.89$, $n = 27$; SL4 –·–·– (Δ): $y = 1.22x - 0.52$, $r^2 = 0.88$, $n = 8$. Common regression line – – – for CM (●) and TE (○): $y = 0.91x - 0.70$, $r^2 = 0.98$, $n = 12$.

NGVD, but was not abundant (cover <20%) and *A. subterminale* was absent. *Jaumea carnosa* was the most abundant plant at this site (unpubl. data). At two sites (SL2, SL3), *A. subterminale* occurred at elevations (1.95 m NGVD) above the highest observed water level reported along the coast (1.5 m NGVD, August 8, 1983) (Fig. 4).

There were also differences in the lower limits of distribution of transitional and upland species among sites having different degrees of tidal muting. For example, the lower limit of the invasive grass, *Parapholis incurva,* occurred on average ~0.54 m lower at the sites of greatest tidal muting (CM, TE1, and TE2) (Fig. 5). The lower limit of plants grouped in the transition/upland category occurred 0.75 m lower at CM compared with SL4. These species were present in high cover (70–100%) at CM, TE1, and TE2 at elevations (0.90–1.20 m NGVD) occupied entirely by marsh plants at SL1, 2, 3 and 4. The lower limits of *Parapholis incurva* and transition/upland plants at the different sites were significantly correlated with the elevation reached by the highest high tide measured in this study (3 December 1998, third highest tide of 1998 at La Jolla with an observed high of 1.41 m, *P. incurva,* $P < 0.01$, $r = 0.95$, $df = 4$; transition/upland: $P < 0.001$, $r = 0.95$, $df = 6$: Fig. 6).

Relationship between the Lower Limit of Vegetation, Tidal Muting, and Marsh Slope

Tidal muting explained a significant amount of variation in the lower limits of *Parapholis incurva* and the transition/upland group, but not in *Arthrocnemum subterminale* (Table 1). In contrast, marsh slope did not explain any significant variation in the lower limits of any of the species studied.

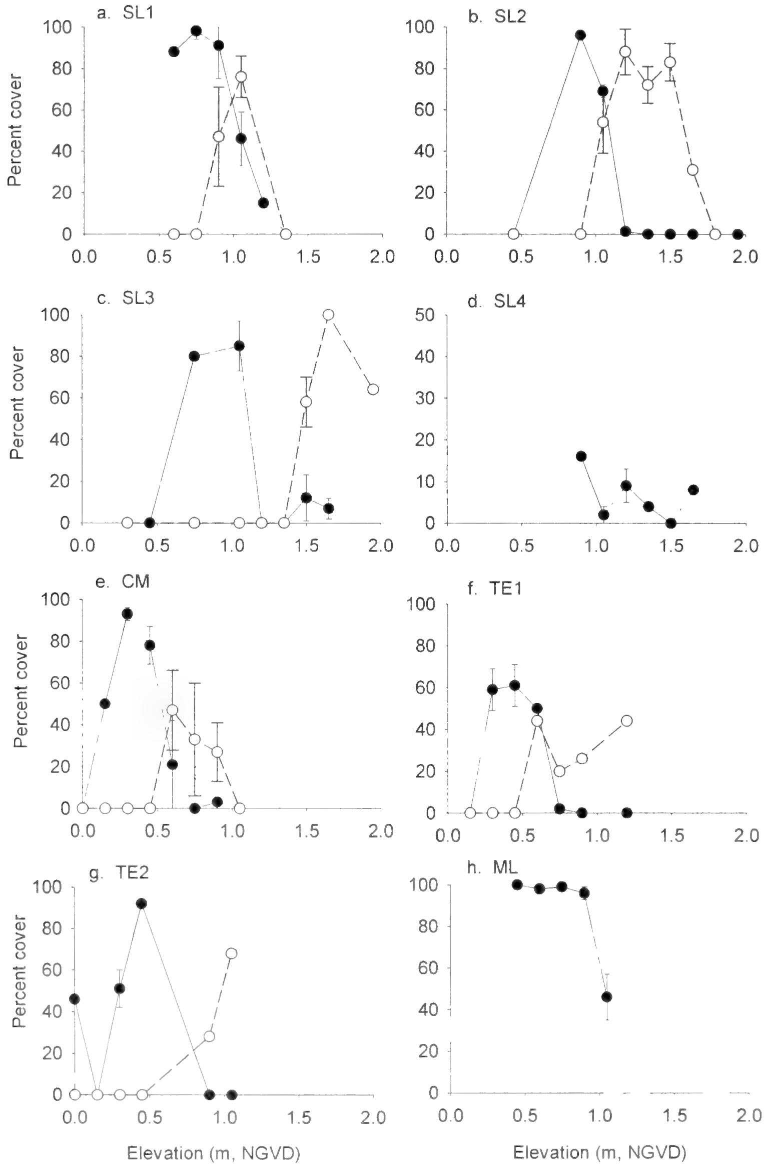

Fig. 4. Percent cover versus elevation (m, NGVD) for *Salicornia virginica* (●) and *Arthrocnemum subterminale* (○). Data grouped in 0.15 m elevation classes. Mean values ±1SE. Standard errors are shown only when number of quadrats >2. Note that the y-axis of (d) extends only to 50% cover. *A. subterminale* absent from SL4 (d) and ML (h).

Discussion

Our study was motivated by the desire to identify similar tidally influenced habitats at different wetland sites on the basis of elevation, height of inundation, and/or vegetation. We used an inexpensive vial method to characterize sites in terms of height of tidal inundation and examined whether plant distribution and cover were similar for equivalent heights of inundation.

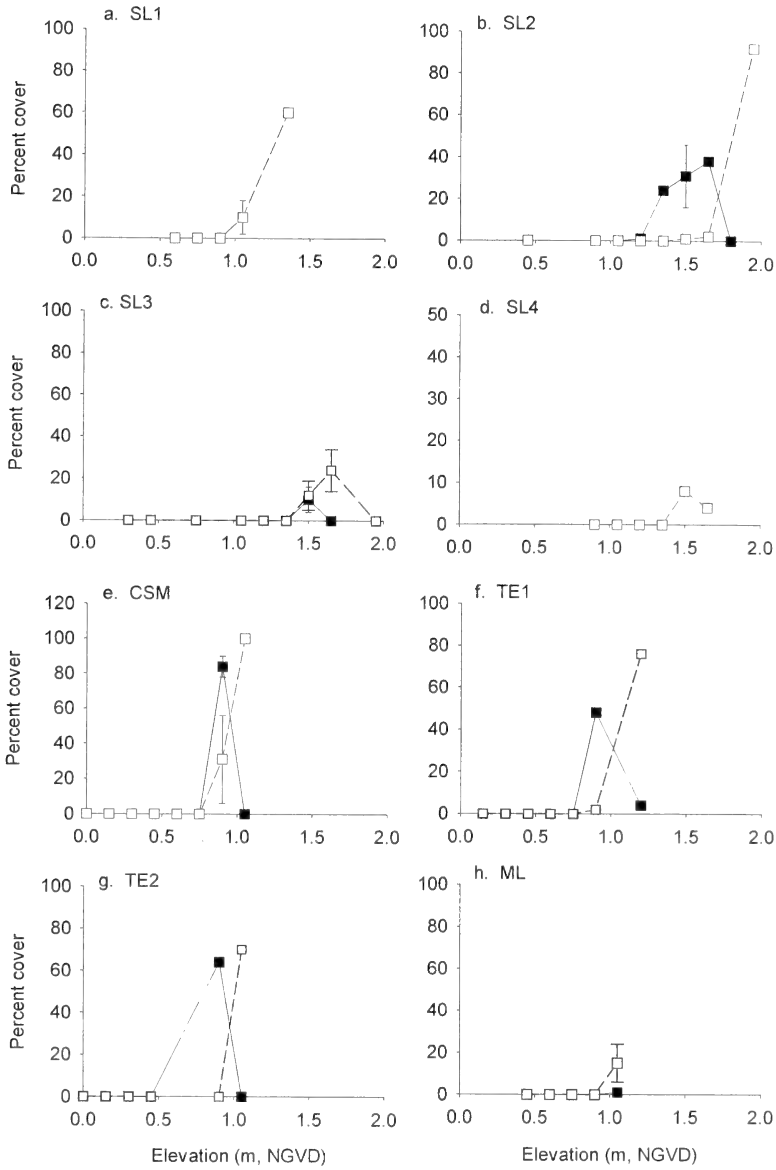

Fig. 5. Percent cover versus elevation (m, NGVD) for *Parapholis incurva* (■) and grouped transitional/upland plants (□). Data grouped in 0.15 m elevation classes. Mean values ±1SE. Standard errors are shown only when number of quadrats >2. Note that the y-axis of (d) extends only to 50% cover. *P incurva* absent from SL1 (a) and SL 4 (d).

The relationship between elevation and height of tidal inundation varied among sites making elevation *per se* unattractive as a general criterion for delineating "tidally influenced" habitat. High tides were muted relative to coastal high tides at all but one site (SL4). The specific reasons for the differences in tidal muting among sites are not known, but channel morphology may be a contributing factor (e.g., Van der Molen 1997). Transects at Tijuana Estuary and Carpinteria Salt Marsh ran perpendicular to small tidal creeks (<1 m wide) while transects at

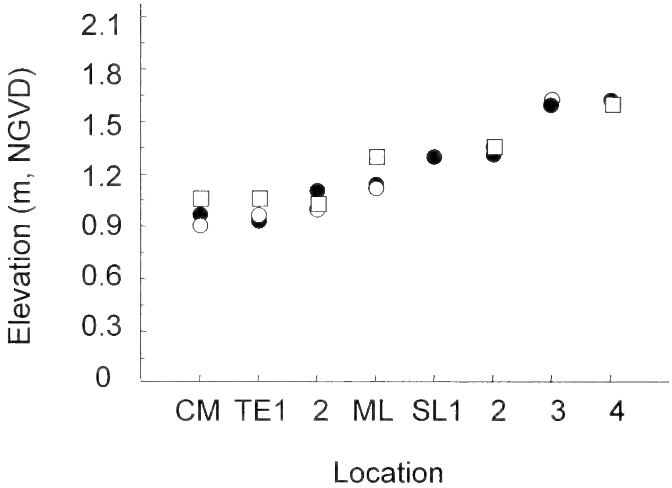

Fig. 6. Lower limit of *Parapholis incurva* (○) and grouped transition/upland plants (●) at study sites. *P. incurva* not present at SL1 and 4. Species grouped in the transition/upland category given in text. Elevation reached by the highest high tide measured during this study (3 December 1998) also plotted (□). No tidal height data are available from SL1 and SL3 on this date.

Mugu and San Dieguito Lagoons originated off wider, deeper channels (>5 m wide) (or a basin).

The elevational range of distribution of *Salicornia virginica, Arthrocnemum subterminale* (absent at SL4 and ML), *Parapholis incurva,* and transition/upland species generally reflected the degree of tidal muting across sites. Indeed, marsh plants at the least muted sites (SL1, 2, 3, 4, ML) occurred in high cover at elevations occupied only by transition/upland plants at the most muted sites (CM, TE1, TE2). As expected, the upper limit of distribution of native marsh plants was not useful in defining tidally influenced habitat; *A. subterminale* occurred at or above (SL3, Fig. 4, Page, unpublished data) the highest observed tidal water level of 2.3 m NGVD measured at Scripp's Pier on 8 August 1983 (MEC, 1993). *A. subterminale, S. virginica,* and other marsh plants may be found in nontidal habitats (seasonal marsh) if soil salinities and moisture conditions are suitable (e.g., Ferren 1985; Ferren et al. 1996c).

Results of multiple regression analysis also indicated that variation in the lower

Table 1. Summary of the results of multiple regression analysis evaluating the relationship between the lower elevation limit of *Arthrocnemum subterminale, Parapholis incurva,* a grouping of transition/upland plant, and marsh slope and tidal muting.

	Arthrocnemum subterminale (n = 6)				*Parapholis incurva* (n = 5)				Transition/upland plants (n = 8)			
Effect	Coeff	Std error	t	P	Coeff	Std error	t	P	Coeff	Std error	t	P
Constant	0.83	0.24	3.51	0.039	1.73	0.09	19.11	0.003	1.40	0.08	17.67	<0.001
Slope	3.84	2.02	1.90	0.154	0.51	0.23	2.27	0.151	0.17	0.39	0.43	0.685
Muting	0.28	0.30	0.93	0.423	2.53	0.11	6.91	0.020	0.39	0.12	3.69	0.014

limit of *Arthrocnemum subterminale* could not be accounted for simply in terms of tidal muting and marsh slope (Table 1). Biological interactions (Pennings and Callaway 1992) and disturbance (Callaway and Pennings 1998) may obscure relationships between tidal muting and the lower limit of this species. For example, competition between *A. subterminale* and *Salicornia virginica* can affect the location of the boundary of both species (Pennings and Callaway 1992). *A. subterminale* has a greater tolerance of high soil salinity, allowing this species to exist high in the marsh while *S. virginica* has a greater tolerance of inundation, allowing this species to exist lower in the marsh. In areas where both species overlap, small differences in soil salinity and moisture over short distances may modify the outcome of competitive interactions between these species (Pennings and Callaway 1992).

The lower elevational limits of *Parapholis incurva* and transition/upland species were correlated with variation in the degree of tidal muting across sites (Table 1) and with the elevation reached by the highest tide (1.4 m NGVD at La Jolla). *P. incurva* and other transition or upland plants are sensitive to elevated soil salinities, which probably limits these species from occurring at lower elevations (Callaway and Sabraw 1994; Kuhn and Zedler 1997; Callaway and Zedler 1998).

Exotic grasses such as *Parapholis incurva* and *Polypogon monspeliensis* are not desirable in restored marshes because they occupy space, preclude the establishment of native species, and may not provide the functions (e.g., food, shelter, nesting habitat) of native plants (Zedler 1996). Results from this study show that the lower elevational limit of such species may prove to be a useful proxy for delineating the upper edge of tidally influenced habitat. Below the lower limit of exotic grasses, the vial method is an effective and inexpensive technique that can be used to identify sites of comparable tidal influence in restored and reference wetlands.

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Literature Cited

Bertness, M. D. 1991a. Interspecific interactions among high marsh perennials in a New England salt marsh. Ecology, 72: 125–137.

———. 1991b. Zonation of *Spartina patens* and *Spartina alterniflora* in a New England salt marsh. Ecology, 72: 138–148.

Boland, J. M. 1998. Water quality monitoring of San Dieguito Lagoon. Final Report. California Coastal Commission, San Diego, California.

Callaway, J. C., and J. B. Zedler. 1998. Interactions between a salt marsh native perennial (*Salicornia virginica*) and an exotic annual (*Polypogon monspeliensis*) under varied salinity and hydroperiod. Wetland Ecology and Management, 5: 179–194.

Callaway, R. M., and S. C. Pennings. 1998. Impact of a parasitic plant on the zonation of two salt marsh perennials. Oecologia, 114: 100–105.

———, and C. Sabraw. 1994. Effects of variable precipitation on the structure and diversity of a California salt marsh community. J. Veg. Sci., 5: 433–438.
———, S. Jones, W. R. Ferren, and A. Parikh. 1990. Ecology of a mediterranean-climate estuarine wetland at Carpinteria, California: plant distributions and soil salinity in the upper marsh. Can. J. Bot., 68: 1139–1146.
Ferren, W. R., Jr. 1985. Carpinteria salt marsh: environment, history, and botanical resources of a southern California estuary. The Herbarium, Department of Biological Sciences, University of California, Santa Barbara, CA. Publication No. 4.
Ferren, W. R., Jr., P. L. Fielder, and R. A. Leidy. 1996a. History of wetland classification. Madroño, 43: 105–124.
———, K. D. Lafferty, and L. A. K. Mertes. 1996b. Classification and description of wetlands of the central and southern California coast and coastal watersheds. Madroño, 43: 125–182.
———. 1996c. Key and catalogue of wetlands of the central and southern California coast and coastal watersheds. Madroño, 43: 183–233.
Frenkel, R. E., H. P. Eilers, and C. A. Jefferson. 1981. Oregon coastal salt marsh upper limits and tidal datums. Estuaries, 4: 198–205.
Hubbard, D. M., 1996. Tidal cycle distortion in Carpinteria Salt Marsh, California. Bull. So. Cal. Acad. Sci., 95: 88–98.
Kentula, M. E. 2000. Perspectives on setting success criteria for wetland restoration. Ecological Engineering, 15: 199–209.
Kuhn, N. L., and J. B. Zedler. 1997. Differential effects of salinity and soil saturation on native and exotic plants of a coastal salt marsh. Estuaries, 20: 391–403.
MEC Analytical Systems. 1993. San Dieguito Lagoon Restoration Project Biological Baseline Study March 1992–May 1993. Volume 1. Prepared for Southern California Edison.
Onuf, C. P. 1987. The ecology of Mugu Lagoon, California: An estuarine profile. U.S. Fish and Wildlife Report 85, 122 p.
Page, H. M., R. L. Petty, and D. E. Meade. 1995. Influence of watershed runoff on nutrient dynamics in a southern California salt marsh. Est. Coastal Shelf Sci., 41: 163–180.
Pennings, S. C., and R. M. Callaway. 1992. Salt marsh plant zonation: The relative importance of competition and physical factors. Ecology, 73: 681–690.
SAIC. 2000. Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the San Dieguito Wetland Restoration Project. Draft Report prepared for the U.S. Fish and Wildlife (USFWS) and the San Dieguito River Park Joint Powers Authority (JPA), 646 pp.
Van Der Molen, J. 1997. Tidal distortion and spatial differences in surface flooding characteristics in a salt marsh: implications for sea-level reconstruction. Est. Coastal Shelf Sci. 45: 221–233.
Zelder, J. 1977. Salt marsh community structure in the Tijuana estuary, California. Est. Coastal Marine Sci. 5: 39–53.
———. Principal Author. 1996. Tidal Wetland Restoration: A Scientific Perspective and Southern California Focus. California Sea Grant College System, University of California, La Jolla. Report No. T-038.
———, C. S. Nordby, and B. E. Kus. 1992. The ecology of Tijuana Estuary, California: a national estuarine research reserve. NOAA Office of Coastal Resource Management, Sanctuaries and Reserves Division, Washington, D. C.
———, J. C. Callaway, J. S. Desmond, G. Vivian-Smith, G. D. Williams, G. Sullivan, A. E. Brewster, and B. K. Bradshaw. 1999. Californian salt-marsh vegetation: an improved model of spatial pattern. Ecosystems, 2: 19–35.

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Research Notes

Gastrointestinal Helminths of the Black-tailed Brush Lizard, *Urosaurus nigricaudus* (Phrynosomatidae), from Baja California Sur, Mexico

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The black-tailed brush lizard, *Urosaurus nigricaudus* (Cope, 1864), is found in a variety of habitats along the eastern side of the Peninsular Ranges from San Diego County, California, southward to the Cape Region of Baja California (Grismer 2002). This note constitutes the first report of helminths from *U. nigricaudus.*

Forty-two adult *U. nigricaudus,* (mean snout–vent length (SVL) = 44.6 mm ± 3.1 SD, range = 38–51 mm), collected 1977–1978 in the vicinity of La Paz, (24°10′N, 110°20′W) Baja California Sur, Mexico, were examined (Appendix). The sample consisted of 28 males (mean SVL = 45.5 mm ± 2.8 SD, range = 39–51 mm) and 18 females (mean SVL = 42.7 ± 3.0 SD, range = 38–48 mm). Adult males are typically larger than females as was the case in this sample (unpaired t test, $t = 2.99$, $P = 0.005$, $df = 40$). Specimens were fixed in 10% formalin and preserved in 70% ethanol. The digestive tracts were removed, opened longitudinally and the contents of the esophagus, stomach, small and large intestines were searched *in situ* for helminths using a dissecting scope in July 2002. Helminths were placed on microscope slides, cleared in a drop of concentrated glycerol under a coverslip, and identified with a compound microscope.

Gravid individuals of two species of Nematoda, *Strongyluris similis* Caballero, 1938, *Thubunaea iguanae* Telford, 1965 and one cystacanth of a species of oligacanthorhynchid Acanthocephala were found. Two male *U. nigricaudus* harbored 1 male *Strongyluris similis* each (one in the stomach, one in the large intestine); 3 male *U. nigricaudus* harbored 7 female *Thubunaea iguanae,* 1, 1, 5, respectively (all in stomachs); 1 male *U. nigricaudus* harbored 1 oligacanthorhynchid cystacanth (in the body cavity). No host had a dual infection. Prevalence (number of infected lizards divided by sample size) was 5%, 7%, and 2%, respectively. Mean intensity ± 1 SD (mean number of helminths per infected lizard) was 1 ± 0, 2 ± 2 SD, and 1 ± 0, respectively. Helminths were placed in vials of 70% ethanol and deposited in the United States National Parasite Collection, (USNPC), Beltsville, Maryland: *Strongyluris similis* 92433; *Thubunaea iguanae* 92434; acanthocephalan cystacanth 92435.

Thubunaea iguanae was previously found in the Isla Cerralvo spiny lizard, *Sceloporus grandaevus,* from Cerralvo Island, Baja California Sur (Goldberg et al. 2002) and from unidentified lizards from Baja California (Telford 1965). Other North American lizard hosts include *Callisaurus draconoides, Cnemidophorus hyperythrus, C. tigris, Coleonyx variegatus, Gambelia wislizenii, Sceloporus magister, S. orcutti, Uma exsul,* and *Uta stansburiana* (Baker 1987). *Urosaurus nigricaudus* represents a new host record for *Thubunaea iguanae.*

Strongyluris similis was originally described by Caballero (1938) from *Sceloporus torquatus* collected in the Districto Federal, Mexico. It was reported from *Sceloporus jarrovii* collected from eight other Mexican states (Goldberg et al. 1996) as well as in *Sceloporus nelsoni* from Nayarit (Mayén-Peña and Salgado-Maldonado 1998), *Sceloporus formosus* from Oaxaca, and *Sceloporus mucronatus* from the Mexican states of Hidalgo and Mexico (Goldberg et al. 2003). It also occurs in sceloporine lizards from Arizona (*Sceloporus jarrovii,* Goldberg et al. 1995a) and Texas (*Sceloporus grammicus, S. merriami, S. olivaceus, S. serrifer, S. undulatus, S. variabilis* Goldberg et al. 1995b). The Goldberg et al. (1999) record of *Strongyluris rubra* in *Urosaurus microscutatus* should be corrected as *Strongyluris similis. Strongyluris similis* appears to occur primarily in Mexico, reaching its northern distributional limit in the southwestern United States. *Urosaurus nigricaudus* represents a new host record for *Strongyluris similis* and Baja California Sur is a new locality record.

Moravec et al. (1990) reviewed North and Central American species of *Strongyluris* (*S. rubra* Harwood, 1935; *S. similis; S. ranae* Reiber, Byrd and Parker, 1940; *S. acaudata* Caballero, 1941; *S. riversidensis* Edgerley, 1952; and *S. readi* Rothmann, 1954) and suggested that these species were identical based upon morphological similarity, host type, and geographical distribution. However, using caudal papillae patterns, spicule lengths and other morphological differences, Bursey et al. (2003) considered them to be valid species.

Acanthocephalan cystacanths have been reported from *Ctenosaura pectinata, Phyllodactylus lanei, Sceloporus jarrovii* and *S. merriami* collected in Mexico (Guajardo-Martínez 1984; Goldberg et al. 1996; Mayén-Peña and Salgado-Maldonado 1998) and from *Cnemidophorus dixoni, C. gularis, C. neomexicanus, C. septemvittatus, C. sonorae, C. tigris, C. uniparens, Cophosaurus texanus, Eumeces gilberti, Sceloporus jarrovii, S. magister,* and *S. merriami* from the southwestern United States (Telford 1970; Benes 1985; Goldberg and Bursey 1990; McAllister 1990a,b, 1992; Goldberg et al. 1995b; McAllister et al. 1991, 1995). Species of acanthocephalans require an arthropod host (Schmidt 1985), and because cystacanths are frequently found in cysts, the possibility of lizards as paratenic hosts must be considered. This is the first report of cystacanths in the genus *Urosaurus.*

Urosaurus nigricaudus is the fourth species within the genus to be examined for helminths (Table 1). It is apparent that the helminth fauna, while varying

Table 1. Helminths from species of *Urosaurus* in North America.

Lizard species	Helminth	Locality	Reference
Urosaurus graciosus	*Mesocestoides* sp.	California	Telford 1970
		California	Mankau and Widmer 1977
	Oochoristica sp.	California	Goldberg et al. 1993a
	Oochoristica scelopori	California	Telford 1970
	Physaloptera sp. (3rd stage larvae)	California	Goldberg et al. 1993a
Urosaurus microscutatus	*Oochoristica* sp.	California	Goldberg et al. 1999
	Spauligodon giganticus	California	Goldberg et al. 1999
	*Strongyluris similis**	California	Goldberg et al. 1999
Urosaurus nigricaudus	*Strongyluris similis*	Baja California Sur	this paper
	Thubunaea iguanae	Baja California Sur	this paper
	acanthocephalan cystacanths	Baja California Sur	this paper
Urosaurus ornatus	*Mesocestoides* sp.	Arizona	Benes 1985
		New Mexico	Goldberg et al. 1993b
	Oochoristica sp.	New Mexico	Goldberg et al. 1993b
	Parathelandros texanus	Texas	Specian and Ubelaker 1974
	Pharyngodon sp.	Arizona	Benes 1985
	Pharyngodon warneri	Arizona	Walker and Matthias 1973
	Spauligodon giganticus	Arizona, New Mexico	Goldberg et al. 1993b
	Physaloptera sp. (3rd stage larvae)	New Mexico	Goldberg et al. 1993b

* Originally identified as *Strongyluris rubra*.

between species, is depauperate. The reasons for low helminth diversity in North American species of *Urosaurus* are yet to be determined.

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Literature Cited

Baker, M. R. 1987. Synopsis of the Nematoda parasitic in amphibians and reptiles. *Memorial Univ. Newfoundland, Occas. Pap. Biol.,* 11:1–325.

Benes, E. S. 1985. Helminth parasitism in some central Arizona lizards. *Southwest. Nat.,* 30:467–473.

Bursey, C. R., S. R. Goldberg, and S. R. Telford, Jr. 2003. *Strongyluris panamaensis* n. sp. (Nematoda: Heterakidae) and other helminths from the lizard, *Anolis biporcatus* (Sauria: Polychrotidae), from Panama. *J. Parasitol.,* 89:118–123.

Caballero, E. 1938. Nematodes of the reptiles of Mexico.–II. *Ann. Trop. Med. Parasitol.,* 32:225–229.

Goldberg, S. R., and C. R. Bursey. 1990. Gastrointestinal helminths of the Yarrow spiny lizard, *Sceloporus jarrovii jarrovii* Cope. *Am. Midl. Nat.,* 124:360–365.

———, ———, and K. R. Beaman. 2002. Gastrointestinal nematodes of the Isla Cerralvo spiny lizard, *Sceloporus grandaevus* (Phrynosomatidae) from Baja California Sur, Mexico. *Bull. So. Calif. Acad. Sci.,* 101:142–143.

———, ———, and R. L. Bezy. 1995a. Helminths of isolated montane populations of Yarrow's spiny lizard, *Sceloporus jarrovii* (Phrynosomatidae). *Southwest. Nat.,* 40:330–333.

———, ———, and ———. 1996. Gastrointestinal helminths of Yarrow's spiny lizard, *Sceloporus jarrovii* (Phrynosomatidae) in Mexico. *Am. Midl. Nat.,* 135:299–309.

———, ———, and J. L. Camarillo-Rangel. 2003. Gastrointestinal helminths of seven species of sceloporine lizards from Mexico. *Southwest. Nat.,* (in press).

———, ———, and H. Cheam. 1999. *Urosaurus microscutatus* (Small-scaled lizard). Endoparasites. *Herpetol. Rev.,* 30:98–99.

———, ———, and C. T. McAllister. 1995b. Gastrointestinal helminths of nine species of *Sceloporus* lizards (Phrynosomatidae) from Texas. *J. Helminthol. Soc. Wash.,* 62:188–196.

———, ——— and R. Tawil, 1993a. Gastrointestinal helminths of the western brush lizard, *Urosaurus graciosus graciosus* (Phrynosomatidae). *Bull. So. Calif. Acad. Sci.,* 92:43–51.

———, ———, and N. Zucker. 1993b. Gastrointestinal helminths of the tree lizard, *Urosaurus ornatus* (Phrynosomatidae). *J. Helminthol. Soc. Wash.,* 60:118–121.

Grismer, L. L. 2002. Amphibians and reptiles of Baja California, including its Pacific islands and the islands in the Sea of Cortés. Univ. Calif. Press, Berkeley, 399 pp.

Guajardo-Martínez, G. 1984. Preliminary survey of parasites of Cuatro Ciénegas, Coahuila, México. *J. Arizona-Nevada Acad. Sci.,* 19:81–83.

Mankau, S. K. and E. A. Widmer. 1977. Prevalence of *Mesocestoides* (Eucestoda: Mesocestoididea) tetrathyridia in southern California reptiles with notes on the pathology in the Crotalidae. *Jap. J. Parasitol.,* 26:256–259.

McAllister, C. T. 1990a. Helminth parasites of unisexual and bisexual whiptail lizards (Teiidae) in North America. IV. The Texas spotted whiptail (*Cnemidophorus gularis*). *Texas J. Sci.,* 42:381–388.

———. 1990b. Helminth parasites of unisexual and bisexual whiptail lizards (Teiidae) in North America. II. The New Mexico whiptail (*Cnemidophorus neomexicanus*). *J. Wildl. Dis.,* 26:403–406.

———. 1992. Helminth parasites of unisexual and bisexual whiptail lizards (Teiidae) in North America. VIII. The Gila spotted whiptail (*Cnemidophorus flagellicaudus*), Sonoran spotted whiptail (*Cnemidophorus sonorae*), and plateau striped whiptail (*Cnemidophorus velox*). *Texas J. Sci.,* 44:233–239.

———, J. E. Cordes, and James M. Walker. 1991. Helminth parasites of unisexual and bisexual whiptail lizards (Teiidae) in North America. VI. The gray-checkered whiptail (*Cnemidophorus dixoni*). *Texas J. Sci.,* 43: 309–314.

———, ———, and ———. 1995. Helminth parasites of unisexual and bisexual whiptail lizards

(Teiidae) in North America. IX. The plateau spotted whiptail (*Cnemidophorus gularis septemvittatus*). *Texas J. Sci.*, 47:83–88

Mayén-Peña, E., and G. Salgado-Maldonado. 1998. Helminths of four lizards from Nayarit, México: *Anolis nebulosus* (Polychrotidae), *Ctenosaura pectinata* (Iguanidae), *Phyllodactylus lanei* (Gekkonidae), and *Sceloporus nelsoni* (Phrynosomatidae). *J. Helminthol. Soc. Wash.*, 65:108–111.

Moravec, F., A. Coy Otero, and V. Baruš. 1990. Two remarkable nematodes from *Leiocephalus* sp. (Sauria: Iguanidae) from Bahamas. *Helminthologia*, 27:225–232.

Schmidt, G. D. 1985. Development and life cycles. Pp. 273–305 *in* Biology of the Acanthocephala. (D. W. T. Crompton and B. B. Nickol, eds.), Cambridge University Press, Cambridge, UK., 519 pp.

Specian, R. D., and J. E. Ubelaker. 1974. *Parathelandros texanus* n. sp. (Nematoda: Oxyuridae) from lizards in west Texas. *Trans. Am. Microscop. Soc.*, 93:413–415.

Telford, S. R., Jr. 1965. A new species of *Thubunaea* (Nematoda: Spiruroidea) from California lizards. *Jap. J. Exp. Med.*, 35:111–114.

———. 1970. A comparative study of endoparasitism among some southern California lizard populations. *Am. Midl. Nat.*, 83:516–554.

Walker, K. A., and D. V. Matthias. 1973. Helminths of some northern Arizona lizards. *Proc. Helminthol. Soc. Wash.*, 40:168–169.

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Appendix

Specimens of *Urosaurus nigricaudus* examined from the herpetology collection of the Natural History Museum of Los Angeles County (LACM): 126101, 126103, 126104, 126105, 126107–126111, 126117, 126118, 126121–126123, 126125, 128182, 128183, 128185–128198, 128200–128202, 128204, 128205, 128213–128215, 128220, 128224, 128232

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Department:
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Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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