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The Marine Biological Laboratory at Terminal Island, Los Angeles Harbor

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Abstract.—In 1891, Professor William E. Ritter of the biology department at the University of California began searching for a location along the California coast for a biological field station. After operating summer field stations from tents in Pacific Grove on Monterey Bay, Avalon on Catalina Island and San Pedro, California, Ritter selected Terminal Island in Los Angeles Harbor as the home for what he originally hoped would be a permanent station. The station opened in June 1901. Ritter's goal was to catalog the rich fauna of San Pedro Bay, Santa Catalina Island and San Diego Bay. The laboratory also provided an educational opportunity for secondary school teachers in the field of marine zoology. Ritter sought help from prominent Los Angeles citizens and the Southern California Academy of Sciences to financially support the laboratory and the laboratory remained in operation for the summers of 1901 and 1902. The Marine Biological Laboratory of Terminal Island represented the first outpost of the University of California in Southern California and the true beginning for the study of marine science within the Los Angeles region. Scientific research in the Los Angeles region prior to this time gave little attention to marine life. It was during the laboratory's first year of operation in 1901 that the first red tide off Southern California was recorded. This paper chronicles the history of the two summers of operation at the Terminal Island laboratory focusing on the challenges to establish, furnish and raise funds for the continuation of the laboratory in Los Angeles. Ultimately, Los Angeles found itself outcompeted by a focused fundraising campaign organized in San Diego and Ritter moved the laboratory to San Diego in 1903. In making the move, Ritter speculated that Los Angeles Harbor might become commercially significant reducing its appeal as a place for collecting and studying marine life. Ritter's San Diego laboratory ultimately became the Scripps Institution of Oceanography. Yet its humble beginning in an old bathhouse on Terminal Island is often overlooked.

The establishment of seaside laboratories for the study of marine biology in Southern California began with the establishment of summer camps and marine biological field stations in the late 19th century by University of California professor William E. Ritter. Ritter had first considered sites in Northern California, at Pacific Grove on Monterey Bay and at San Francisco Bay. But the efforts underway by Stanford University to develop the Hopkins Marine Laboratory in Pacific Grove and the perilous collecting conditions for marine organisms in San Francisco Bay caused Ritter to shift his focus to Southern California. Ritter's quest for a marine station in Southern California ultimately culminated in the establishment of the Scripps Oceanographic Institution in San Diego in 1903. Little is known, however, about the laboratory Ritter established prior to his move to San Diego. In 1901 and 1902, Ritter operated a marine station in the community of East San Pedro, on Terminal Island, in Los Angeles Harbor, even declaring, at one point, that he was certain this would be the place for the permanent marine laboratory of the University of California. Yet the operation of the laboratory on Terminal Island is often overlooked as a formative step in the development of Scripps as well as the history of the development of marine research in the Los Angeles region as well as the history of Los Angeles Harbor. It was in Los Angeles where Ritter honed his skills as a fundraiser. Los Angeles boosters supported the operation of the Terminal Island laboratory and formed a committee to secure its future but were outcompeted by a more organized and focused campaign by those championing San Diego. Doubtless, it was the harbor's prospects as a burgeoning commercial enterprise at the beginning of the twentieth century that seemed to portend it a less desirable collecting ground for marine specimens.

While the Terminal Island laboratory was short-lived, it was significant in advancing interest in marine biological research in the Los Angeles area. After California achieved statehood in 1850, east coast scientists sought information and specimens new to science from the west, although the primary focus was on terrestrial plants and animals, minerals, and Indian antiquities. Prior to the opening of the Terminal Island laboratory, there was little marine research emanating from Southern California (Splitter 1956). Many of the early scientific reports from the Los Angeles region focused on mollusks. This research was often aided by local conchologists, many of them women collectors (Williamson 1894). The laboratory Ritter established on Terminal Island in Los Angeles Harbor should be recognized as the beginning of marine biology research and education in the Los Angeles region. The Terminal Island laboratory was the first in the Los Angeles region that educated secondary school teachers in marine zoology while research conducted at the laboratory produced a number of scientific publications. This paper will document the little known details of the establishment and operation of the Terminal Island marine laboratory.

The Search for a Marine Station Site

In 1891, Professor William Ritter from the University of California began to investigate possible locations for a laboratory field station for the study of marine science. At that time, he was an Instructor in Biology and had assumed the position of scientific director in the newly inaugurated sub-department of biology. Recognizing that the field of marine zoology was in its infancy on the U.S. west coast and thus, a prime opportunity for significant scientific research, Ritter made the focus of his department's research the marine life of the Pacific Ocean. Ritter's priority for a laboratory was for a seaside location from which a comprehensive survey of the Pacific Coast fauna could be conducted (Ritter 1912).

As the University of California only had schools in the San Francisco Bay area at this time, Ritter looked first to San Francisco Bay for a laboratory site. But he sought to study oceanic organisms that were typically only found at the entrance to the Bay, an area he perceived as too dangerous for field work from small craft. Therefore, in 1892, Ritter erected a canvas and wood tent structure at Pacific Grove on Monterey Bay. The cost was $200 and instrumentation was borrowed from the main campus. All water had to be carried to the laboratory in a bucket. About a dozen students and teachers collected specimens but no research results were recorded from this effort. Ritter called the laboratory a "sorry spectacle" compared to the building constructed nearby that same year to house the Hopkins marine laboratory (Ritter 1912).

In 1893, Ritter relocated his tent laboratory to Avalon, Santa Catalina Island. It was while traveling to Catalina Island that Ritter and other University of California faculty had the opportunity to observe what Los Angeles Harbor might have to offer as a potential location for a seaside laboratory. So, for several weeks in 1895, a small party of researchers set up a laboratory facility with a dormitory, essentially a tent and a cottage at Timms point in San Pedro along the Port of Los Angeles's main channel.

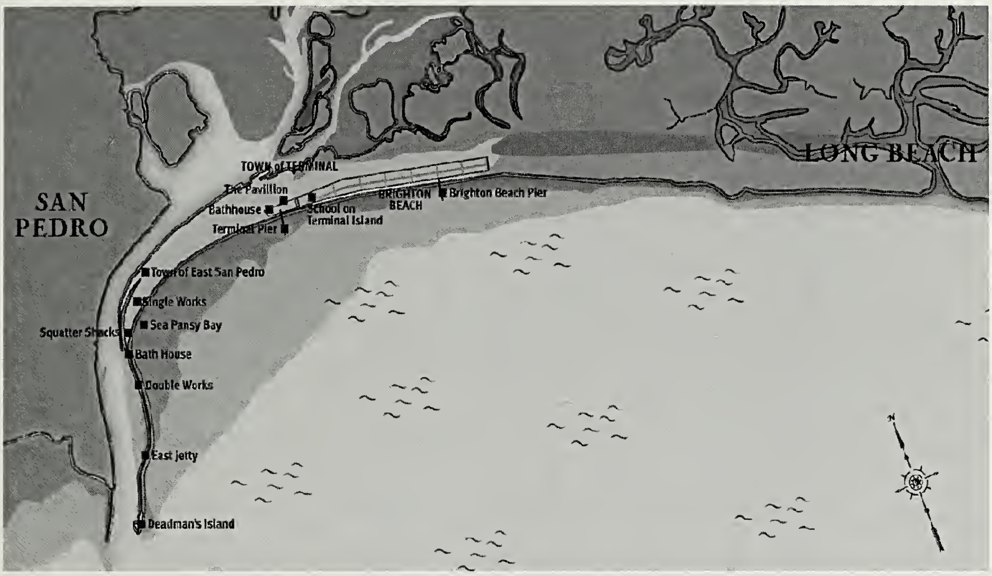


Fig. 1. Los Angeles Harbor, circa 1900, showing the split of land called Terminal Island and its points of interest including the town of East San Pedro where the marine laboratory was located. A breakwater built by the U.S. Army Corps of Engineers from 1871 through 1881 extends from the tip of the island to a small rock promontory called Deadman's Island, another site considered for the marine laboratory. Source: Hirahara and Knatz, Terminal Island, Los Communities of Los Angeles Harbor.

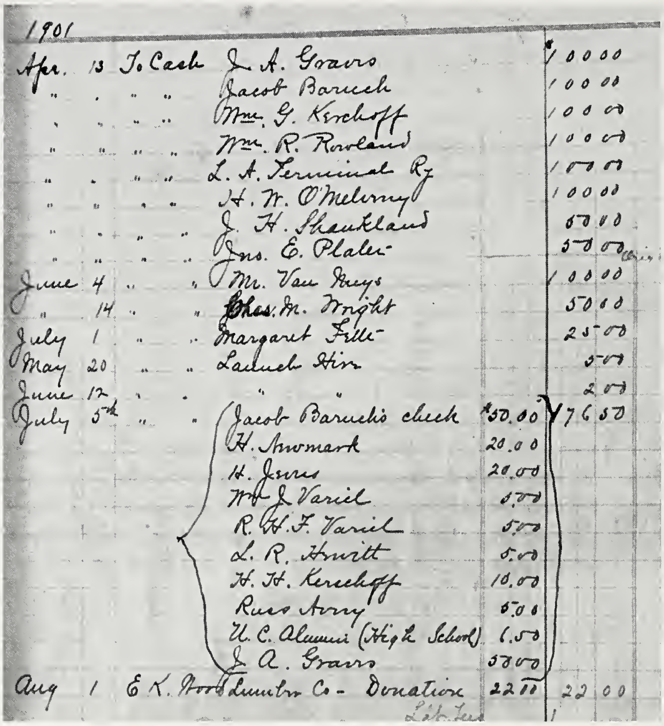
Ritter's quest for a permanent laboratory location was deferred for several years due to his travels. In 1894-1895, Ritter visited the *Stazione Zoologica* founded in 1874 in Naples, Italy by Anton Dohrn, a trip that likely helped formulate his views about the value of a seaside laboratory. During the period 1896 through 1900, occasional collections were made along the entire Pacific Coast of North America by University of California faculty, including Ritter's participation in the Harriman Alaska Expedition. During these years, consensus was reached among the University of California researchers that a permanent location in Los Angeles Harbor should be established.

Benson (2001) suggests that there were three types of models for marine biological field stations during the late 19th and early 20th centuries: an international center, like the Naples, Italy station; a summer camp like the one that ultimately became the marine biological laboratory at Woods Hole; or, an outpost of an established university. On the west coast, the marine laboratories being established fell into this latter category, with Ritter's laboratory an outpost of the University of California.

Establishing the Field Station in Los Angeles Harbor

In 1901, Ritter established the marine laboratory in Los Angeles Harbor.[1] Although it is referred to as the San Pedro laboratory, the laboratory was located on unincorporated land under the jurisdiction of Los Angeles County. It was situated across the harbor's main channel from San Pedro on Terminal Island in a community known as East San Pedro (Fig. 1). The location could be reached by ferry from San Pedro or from Los Angeles and Long Beach by the Terminal Island Railway (Hirahara and Knatz 2015). Ritter was able to secure funding in the amount of

[1] At the time Ritter established the laboratory, Los Angeles had not yet annexed the harbor communities. The area where the laboratory was located eventually became part of the Port of Los Angeles.



1901					
Apr.	13	To Cash	J. A. Graves		100 00
"	"	" "	Jacob Baruch		100 00
"	"	" "	Wm. G. Kerckhoff		100 00
"	"	" "	Wm. R. Rowland		100 00
"	"	" "	L. A. Terminal Ry		100 00
"	"	" "	H. W. O'Melveny		100 00
"	"	" "	J. H. Shankland		50 00
"	"	" "	Jno. E. Plater		50 00
June	4	" "	Wm. Van Nuys		100 00
"	14	" "	Chas. M. Wright		50 00
July	1	" "	Margaret Fette		25 00
May	20	" "	Ladies' [illegible]		5 00
June	12	" "	" "		2 00
July	5th	" "	Jacob Baruch's check	$50.00	176 50
			H. Newmark	20.00	
			H. Jevne	20.00	
			Wm J. Variel	5.00	
			R. H. F. Variel	5.00	
			L. R. Hewitt	5.00	
			H. W. Kerckhoff	10.00	
			Russ Avery	5.00	
			U. C. Alumni (High School)	1.50	
			J. A. Graves	50.00	
Aug	1		E. K. Wood Lumber Co - Donation	22.00	22 00

Fig. 2. William Ritter's ledger detailing donations acquired to support establishment of the marine biological laboratory on Terminal Island. Courtesy of the Scripps Institution of Oceanography Archives.

$2000 to establish the laboratory. Most of the funding was secured from noted Los Angeles businessmen (Fig. 2).

Critical to the success of the laboratory were three individuals from the University of California: 1) Dr. Charles A. Kofoid, appointed to the department of zoology in the year 1900; 2) Dr. Harry Beal Torrey, who began at the University as an assistant in Zoology in 1895; and 3) Dr. Frank Watts Bancroft, a physiologist. Kofoid was already doing marine research and Torrey had spent 12 days at the Timms Point collecting site in 1895 which kindled his research on Cnidarians (Calder 2013). The laboratory faculty also included J.W. Raymond, Assistant Professor of Physics, Hydrography and Conchology. Two staff were assigned to the laboratory, Miss Alice Robertson who was in charge of collections and Mr. Calvin O. Esterly. Ritter's diary referred to Esterley as the "boy Esterley" although he would have been 22 years old at the time he worked at the laboratory.[2] There were also seven investigators who undertook independent studies working from the laboratory, four men and three women. The men were Russian diatomist, W. C. Adler-Mereschkowsky, entomologist T.D.A. Cockerell from New Mexico, zoologist S. J. Holmes from the University of Michigan and zoologist W.R. Coe from Yale. The women were Miss Sarah P. Monks, instructor in zoology from the Los Angeles State Normal School, Miss G. R. Crocker, a graduate student and Mrs. Ida Oldroyd from Long Beach, California (Ritter, 1902a).

Ritter deliberated on the role the laboratory would have in research and education and in the laboratory's first year made teaching of marine science an integral part of the field station

[2] William E. Ritter papers, carton 9 diaries, Summer_1901, San Pedro, Bancroft Library, Berkeley, CA.

Fig. 3. The marine laboratory was located amid squatter homes and businesses located on the East Jetty which extended from Terminal Island to Deadman's Island.

activities. The fees charged to students would help cover the expenses for the faculty who had to travel to Los Angeles Harbor.

Laboratory Facilities

The laboratory facility was located on a portion of the East Jetty or "old breakwater" as it was often called. Constructed by the U.S. Army Corps of Engineers between 1871 and 1881, the East Jetty stretched from the tip of Rattlesnake Island (now Terminal Island) to Deadman's Island and protected the inner harbor from heavy waves (Hirahara and Knatz 2015). Over time, sand accreted along the jetty and a community of squatters had taken up residence, most living in shanties built on stilts or pilings (Fig. 3). The laboratory itself was a squatter because it was situated on land where ownership was hotly debated between residents and local officials.

The laboratory consisted of two buildings on the breakwater, one an old bathhouse that was constructed by Michael Duffy (Fig. 4). Duffy operated the ferry service from San Pedro to Terminal Island and had constructed the bathhouse on Terminal Island in 1891 to promote use of his ferry operation. By 1901, the attractive resort communities of Terminal Beach and Brighton Beach developed further east on Terminal Island attracted most of the ocean bathers. The resorts had a much grander bathhouse and other amenities so it is likely the Duffy bathhouse had limited use for its intended purpose and was available for lease to the University. The bathhouse's seven rooms were assigned to the researchers with one being reserved as a library and a larger room for the use of the classes (Figure 5). The classroom was equipped with long tables that were set near each of the nine windows (Williamson 1902).

The other building which was larger than the bath house was used for classrooms, storage and for some of the investigators who did not have a private room (Ritter 1912). The facility could

Fig. 4. The two buildings of the marine biological laboratory on Terminal Island, 1902. Courtesy of Scripps Institution of Oceanography Archives.

Fig. 5. A glimpse inside the classroom building of the laboratory shows how the laboratory was fitted out for use by the students. This image is a copy from the July 7, 1901 Herald Examiner and was titled *Classifying Sea Things.*

Fig. 6. The Duffy ferry boat *Elsie* which was used as a research vessel in 1901, near the marine biological laboratory. Courtesy of the Scripps Institution of Oceanography Archives.

accommodate 15 students. On one occasion, a lady on the island provided the use of her summer cottage for an evening lecture (Williamson 1901).

Historical records do not indicate where the students were housed during the classes. Fourteen men and women were enrolled as students in the 1901 summer session, with thirteen of them paying fees. Given that course instruction was normally six days a week, with the daytime devoted to field work and evening lectures twice a week, it is likely that the students stayed in the immediate vicinity and there were numerous boarding houses on the island that could have been used. Yet Ritter's diary noted the difficulty that Calvin Esterly had in securing lodging. Ledger records for the laboratory indicate that Ritter stayed at the Colonial Hotel in San Pedro.[3]

Most of the classroom instruction was informal without textbooks at late 19^{th} and early 20^{th} century field stations. Collections from the field provided the material for instruction and the teaching technique was observation. In that way, students would learn how to collect, describe and identify organisms (Benson 2001).

Along with the bath house, Duffy leased one of his ferry boats, the *Elsie*, to Ritter to use as a research vessel. Duffy had named each of his boats after his children and he likely had his children helping with the ferry business.[4] Ledger records from the Scripps Oceanography Institution Archives indicate that E. Duffy received a payment of $140 per month for the launch and labor. The *Elsie* was 40 feet in length with a 17 horse power engine (Ritter 1902a). It was easily adapted to scientific research because its limited canopy provided open space for working with sampling gear (Fig. 6).

[3] Scripps Institution of Oceanography Minutes of Meetings of the San Diego Marine Biological Association and the Scripps Institution of Marine Biology. The books were accessioned under 81-40 dated 1903-1911 and 81-41 dated 1912-1918. 81-41 include accounts of San Pedro Laboratory, May 15 to August 15, 1901.

[4] Period news reports indicate Duffy's daughter Elsie had graduated from High School in 1901 and that she traveled to Berkeley to enter University of California in fall, 1901. She likely spent time at the laboratory and could be the one student who did not pay fees. Her time at the laboratory may have influenced her decision to attend the University of California in fall 2001. It is not clear if she assisted in operating the *Elsie* which was owned by her brother Edward.

The hoisting gear was located in the middle of the boat and the rear of the vessel was used for receiving and sorting samples from the dredge. In order to slow the boat sufficiently for trawling, the scientists would cast out an anchor for drag or turn off the gasoline engine and switch to a battery. Four men were needed to operate the hand winch. Laboratory funding limited the dredging and trawling to depths of less than 100 fathoms and the plankton net to 300 fathoms. Hydrographic soundings were made using ordinary 12 and 20 pound weights on galvanized steel wire. The scientists were not equipped to measure anything other than temperature and specific gravity of the water and their attempts to measure salinity were unsuccessful (Ritter 1902a).

Ritter also took advantage of knowledge from local fisherman. On August 6, 1901, Ritter reports in his diary that an Italian fisherman Louis Mascalo who had been in San Pedro since 1884 and interested in natural history would be their guide on one of their longer treks out in the launch. Mascalo was one of the squatters living on the East Jetty in East San Pedro (Hirahara and Knatz 2015).

The formal opening of the lab was on June 25th when the library, reagent room and largest laboratory room was ready.[5] Three other lab rooms were still being worked on by carpenters. Three days later, Ritter's diary indicated he sent a letter to UC President Wheeler asking that he convene representatives of the Los Angeles region for a conference about a permanent laboratory as in his mind *there was no longer any doubt that this is the place for a headquarters for any marine investigations we may be able to carry on.*

Research Conducted in 1901

Ritter's intention was to conduct a faunal survey with as much accuracy and coverage as resources and equipment would permit. Eighty-five sampling stations were located along a thirty mile stretch of the coastline from the Redondo Beach pier in Los Angeles County south to Newport Bay, in Orange County. In San Diego County, sampling stations ranged from the coastal community of La Jolla south to the Los Coronado's Islands, off the coast of Baja, Mexico. Stations were also established at Catalina Island. Stations were visited multiple times during the period May 15 through August 15, 1901. Ritter summarized the scientific work of the first summer in an article in Science in 1902. He discounted the hydrographic data as insufficient but felt that his additional observations on the geology of Catalina Island corroborating his previous published views that the island had undergone recent subsidence. Most of the laboratory's accomplishments in its opening year were the result of the biological survey work which documented the discovery of new species and extended the range of known species. Other behavior and life cycle observations were made. For example Ritter notes in his diary on June 24, 1901, that *a long string of yellow eggs were deposited by an Aplysia last night. This settles the egg question for this species.* J.W. Raymond and Mrs. Oldroyd were the resident conchologists and both were able to add extensively to their collections with Oldroyd's local collection passing 500 hundred species (Ritter 1902a).

On July 7, 1901 a red streak was noted in the waters at the entrance to the harbor (Torrey 1902). By July 16th red patches had approached the shore and in the evening hours, phosphorescence in the ocean waters off the laboratory was noted. The organism was identified by Harry Beal Torrey as the Peridinium *Gonyaulax*. This was the first documented red tide along the west coast of the United States. Torrey notes that a similar occurrence happened in Tomales Bay in

[5] William E. Ritter papers, carton 9 diaries, Summer_1901, San Pedro, Bancroft Library, Berkeley, CA.

Northern California in the 1870's but none of the older residents living in the San Pedro area in 1901 had ever seen such a phenomenon in the local vicinity.

The phosphorescence increased in intensity through July and into August (Williamson 1901). It was also reported in other coastal communities from San Diego to Santa Barbara (Torrey 1902). By the end of July, numerous dead fish had washed ashore. The red tide served as a mechanism of discovery for the scientists. For example, the blind fish *Typhlogobius californiensis* had not been reported north of San Diego until it washed ashore during the red tide.

The coming and going of various visitors to the laboratory were reported in the local press along with scientific results. In August 1901, Professor William H. Dall of the Smithsonian Institute visited the laboratory for a month and lectured to the students. Ritter considered the press reports a way to raise awareness of the laboratory which might eventually aid his fundraising efforts.

Interactions with the Southern California Academy of Sciences (SCAS)

As part of his efforts to promote the laboratory, Ritter reached out to the Southern California Academy of Sciences and met with its President, William Henry Knight. He made arrangements to attend the Academy's June 19th 1901 meeting to lecture about the laboratory. Ritter diary indicated he hoped that many of their wealthy men could attend. At the end of the first year of operation, Knight wrote to the President of the University of California, Benjamin Wheeler, to support the effort to make the laboratory permanent and pledged the active support of the Academy. The full text of UC President Wheeler's response to the Academy was published in the Los Angeles Herald on August 18, 1901. Wheeler's response was fairly blunt, suggesting that a wealthy Los Angeles man could provide the $5000 annual cost to operate the laboratory. In Wheeler's words *if the opportunity was not speedily embraced, I fear Southern California will lose it. Whatever happens there can be no reasonable doubt that in some way or other, this biological work will go on. Whether at San Pedro or San Diego, a station will be permanently established.*

When Ritter met with James Foshay, Superintendent of Los Angeles city schools, and his deputy regarding the permanent laboratory, he was cautioned to seek a steady stream of funding rather than associating his funding requests directly with a laboratory. Ritter suggested that a monument could be created for University of California Professor Joseph Le Conte who had died on July, 6, 1901.[6] But Foshay told Ritter that most people in Los Angeles did not know who LeConte was. Foshay's deputy told Ritter *if our people give the money for the undertaking they might rather want to manage it themselves*. Ritter diary following this exchange noted the care that the SCAS has taken not to mention the University in connection with the program the Academy was holding in Long Beach at which Mr. Torrey was to lecture.[7] Ritter notes *it is clear they are afraid of us. Is this due to the wish that the Academy is in front or to hostility to the University? The former I am very sure.*[8]

[6] Le Conte was a University of California faculty member who was a physician, geologist, and a conservationist who founded the Sierra Club with John Muir.

[7] Note that at this time, the University of California only had campuses in Berkeley and San Francisco and none yet in Southern California until the Los Angeles Normal School became part of the UC system as the Southern branch in 1919, becoming the University of California at Los Angeles in 1927.

[8] Ritter diary entry for July 16, 1901. Note the fundraising strategy developed by Los Angeles businessman as discussed in Ritter's diary entry for June 27th, 1902 also might indicate an intentional sentiment to mask the fact that the fundraising was for a University of California facility.

The event Ritter refers to is a two day Chautauqua meeting[9] held in Long Beach on July 18 and 19, 1901. Day two of the meeting was under the direction of the SCAS and consisted of a musical prelude followed by lectures on agriculture, geology, astronomy, agriculture and other scientific topics. A detailed description of the program for the meeting was published by the Los Angeles Herald and the Los Angeles Times on July 19, 1901.[10] Ritter apparently took offense at Torrey being referred to as "recently from Columbia" rather than a University of California faculty member. Torrey had held academic positions with the University of California since 1895 (Calder 2013). He did, however, earn his Ph.D. in Zoology from Columbia in 1903 which could explain the reference to Columbia. Torrey's speech, which was titled *That Sea Phosphorescence,* explained in layman terms the current red tide experienced along the coastline. It was printed in its entirety in the Los Angeles Times on July 20, 1901. Torrey clearly indicated his association with the University of California while making his presentation. Other than the July 16, 1902 diary entry where Ritter speculates that that SCAS might deem that it is the appropriate organization to be the lead on a laboratory in Southern California rather than the University of California, there was no other evidence found to indicate that the Academy was other than supportive of the establishment of the laboratory by the University.

Fundraising Challenges

Ritter's diaries are replete with comments about the meager funding provided by the University to support the field laboratory. In July 4 1901, he had to appeal directly to UC President Wheeler to get bills paid for fuel and labor; *otherwise the summer field work would be halted.*[11] Ritter took advantage of the opportunity to approach Los Angeles businessmen while they were vacationing at their summer homes on Terminal Island at Brighton Beach. Ritter also solicited funds from port businesses located on Terminal Island such as Mr. James Schultz of E.K Wood Lumber Company and L.W. Blinn of the Blinn Lumber company. University President Wheeler asked Los Angeles attorney and a laboratory patron Henry O'Melveny if he would convene a meeting of Los Angeles businessmen to hear a proposal for the laboratory from Ritter.

Fundraising for operations in 1902 was not as successful as the prior year. Therefore Ritter decided that the laboratory would operate for the summer with both research and teaching but no investigations conducted at sea. Instead that year, Ritter personally committed significant time to fundraising. In June his diary indicates he had a number of meetings with Los Angeles businessmen generally with the help of O'Melveny and his law partner Jackson Graves. At a June 23rd 1902 meeting, Graves agreed to chair a fundraising committee. Ritter had determined that an amount of \$25,000 was necessary for new buildings, \$10,000 for a research vessel and \$5000 annually for operations (Ritter 1902b). Plans were underway to raise funds to provide a new laboratory in close proximity to the existing laboratory. Graves vowed to raise the \$25,000 needed for the laboratory, drawing up a subscription agreement and a list of about 65 businessmen, mostly from Los Angeles that would be approached. Graves's secured 13 pledges of 500 dollars each but the pledges were contingent upon the entire amount being raised. Ritter was concerned that the Graves fundraising strategy was to promote a business arrangement but not associated with the specific work of the laboratory.[12]

[9] Chautauqua was a non-denominational education movement of the late 19th and early 20th centuries that brought education and culture to rural areas of America typically through camp meetings with lectures.

[10] Los Angeles Herald, 19 July 1901—Socialists in full charge, have their day at Long Beach, Miss Dromgoole lectures on southern folk lore, academy of sciences has full charge of the Chautauqua exercises today.

[11] Ritter diary entry for July 4, 1901.

[12] Ritter diary entry for June 27, 1902.

The 1902 summer session closed, with every anticipation that the laboratory would be back the following year and renewed vigor on the part of Ritter and Los Angeles business interests to support a permanent laboratory in Los Angeles Harbor. But only one third of the necessary amount was raised (Ritter 1912). The strategy employed by Ritter's Los Angeles patrons to de-emphasize the specific nature of the marine research as a fundraising tactic might have doomed the fundraising efforts in Los Angeles. A benefactor's natural desire to understand how their donation can be used to better the world or society often helps to solidify the financial commitment.

Deadman's Island as a Potential Laboratory Site

Amid fundraising efforts Ritter spent time seeking other locations in Los Angeles Harbor for a permanent laboratory. He was aware that the ownership of the land where the current laboratory buildings were located had been contested. The Army Corps of Engineers was reticent to allow further building construction on the East Jetty. Captain J. Meyler of the U.S. Army Corps did announce publically that he had supported the approval given to Ritter to construct a laboratory for scientific purposes.[13] Ritter also met with Los Angeles city attorney Carr to inquire about the city owned property and the land ownership issue. Ritter, nevertheless, investigated other locations in the area for a permanent laboratory. Jackson Graves's who owned a home on the Island at Brighton Beach, took Ritter and others on his sailboat, the *Pasquilito*, to observe the coastline for promising locations. At one point, Deadman's Island was considered a potential laboratory site.[14] Ritter took several trips to Deadman's Island, one time rowing over with Kofoid and other times with his faculty and his Los Angeles donors. Ritter became quite enthusiastic about the potential of the research facility moving to Deadman's Island (Fig. 7). It was convenient to the landing site in San Pedro, the water quality was high and it was easy to drag boats onto the island. He noted its commanding position and beauty. But his diary shows that he also had questions about the viability of this site, its isolation, the potential for storm damage and the need for freshwater.

The Loss of the Laboratory to San Diego

In July 1901, Kofoid took the launch for a three week trip to San Diego and became enthusiastic about that area as a potential laboratory site. Kofoid met Dr. Fred Baker on that trip, which triggered Baker's active campaign to move the laboratory to San Diego. Baker was an avid shell collector who sought out every biologist who came to San Diego. Baker had previously met Ritter and his wife while they were on their honeymoon in San Diego in 1891 (Shor 1981). Kofoid's research trip made the local press and Baker invited him to address an influential business group while he was still there (Spiess 2003). A letter from Kofoid to Dr. Baker dated May 24, 1902 indicates that Kofoid desired to see the laboratory move to San Diego for the summer session of 1902 but that a decision had been made to keep the laboratory in San Pedro. *Our plant at San Pedro cannot be given up without considerable loss of plumbing and woodwork, etc.*, Kofoid writes.[15]

Baker did not give up, pressing Ritter on the advantages of the San Diego location (Shor 1981). When Baker secured a boat house to use for the 1903 summer session along with funding, the deal was clinched (Ritter 1912). Los Angeles had lost the laboratory to San Diego where

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[13] Los Angeles Herald, July 31, 1901.

[14] Deadman's Island was a rock promontory located at the entrance to Los Angeles harbor. Serving as a burial ground and home to mid-19th century coast whaling stations, and then a WWI location, the island was blasted away in 1928 to widen the main channel into Los Angeles Harbor.

[15] Charles Atwood Kofoid Papers, Papers 1902-1940 Collection 82-71, Box 1, Folder 2, Scripps Institution of Oceanography Archives.

Fig. 7. 1908 Photo of Deadman's Island from album belonging to one of the researchers at the marine laboratory, Miss Sarah P. Monks. Courtesy of San Pedro Bay Historical Society.

a better funded and better orchestrated support group had developed. The San Diego laboratory would eventually become the Scripps Institution of Oceanography (see Raitt and Moulton 1967, for a complete history of the development of Scripps).

The Significance of the Marine Biological Laboratory in Los Angeles Harbor

Even without the meeting between Kofoid and Dr. Fred Baker on the 1901 expedition to San Diego, it is likely that Ritter would still have moved the laboratory outside of Los Angeles Harbor. Construction by the Army Corps of Engineers of a major breakwater to protect San Pedro Bay from heavy surf had begun in 1899. This infrastructure investment would lead to further industrialization and set the harbor on a course of increasing commercial importance.

Ritter anticipated that the harbor would grow in commercial significance along with the population and he feared that industrial and sewage pollution would lead to *the inevitable destruction of some of the best collecting grounds in and about the harbor.* These factors weighted on his mind as he considered other locations (Ritter 1912).

Although the laboratory on Terminal Island only existed for two years, it was significant for several reasons. First, it solidified Ritter's resolve that the laboratory be located someplace in Southern California. In Ritter's view, Southern California was the optimum location to undertake detailed continuous long term observations because of the weather and because the deep ocean could be reached only 6 miles from the coastline unlike the east coast where one has to travel 50 to 100 miles off the coast to reach similar depths (Ritter 1902b). It also was the first outpost of the University of California in Southern California, made at a time when there was considerable debate among the leadership of Los Angeles about lack of investment by the University of California in the southern part of the state (Dickson 1955).[16] Second, the station

[16] Los Angeles lobbied the state legislature for years to secure a University of California campus in Southern California and were successful in 1919 when Assembly Bill 626 was approved which turned the Los Angeles State Normal School into what would become the University of California at Los Angeles.

received considerable press exposure, partly due to the preeminence of its visiting scientists and partly due to the red tide, a previous unknown phenomenon that aroused public interest. The press exposure aided Ritter's fundraising process. A critical error was made, however in the fundraising strategy undertaken by his Los Angeles patrons that Ritter would not repeat in San Diego. In addition to positive press, visiting scientists brought their own research techniques that were shared with the local scientists. This laboratory, as well as other summer stations, did much to help shape the way biological research developed in America (Benson 2001).

The laboratory and its research activities were the true beginning of marine biological research in the Los Angeles region. It was a teaching laboratory and provided an opportunity for local teachers to learn marine biology and to pass that knowledge on to their own students. Class instruction was eliminated at the San Diego station due to the researchers desires to focus on their own research and because student fees were no longer necessary to support the operation (Ritter 1912). As a teaching laboratory, the Terminal Island facility was more likely to attract women who enrolled as students or became associated with the laboratory to carry out their own independent research. Please see the companion paper to this one on the early women scientists who were associated with the Terminal Island laboratory, 115(2).

The Terminal Island laboratory operated during the time that marine science in Los Angeles region was still in its "descriptive" phase, focusing on whole organisms (Dailey et al. 1994). The Los Angeles region lagged other parts of the country which had begun, in the late 19th century, the transition from descriptive marine science to more analytical research. Ritter's premonition that the commercial development of Los Angeles Harbor would doom its viability as a collecting ground came true. Industrial discharges after WWII virtually eliminated nearly all life within the Los Angeles inner harbor and severely reduced species diversity in the outer harbor. This trend began to be reversed as regulatory controls over discharges were put in place beginning in the 1960's (Reish 1971). Despite becoming a major commercial seaport, however, Los Angeles Harbor continued to be the subject of biological research. By virtue of its development, the harbor became a prime location for analytical marine research that examined the impacts of coastal development and contaminant inputs on coastal waters (Dailey et al. 1994).

The presence of the marine biological laboratory on Terminal Island in Los Angeles Harbor is a part of the history of the development of the marine sciences in Los Angeles and the history of the Scripps Institution of Oceanography that is not well known. The ledgers for 1901 operation of the laboratory are filed under the records for the San Diego Marine Biological Association, 1903-1911, which further obscures its existence. The author is indebted to former Scripps archivist Peter Brueggeman who assisted me in locating these records.

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Early Women Scientists of Los Angeles Harbor

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Abstract.—Los Angeles Harbor, in San Pedro Bay, has long drawn scientific researchers, from its days as a 19th century muddy tide flat to today's industrial complex of man-made channels and wharves. A marine biological laboratory was established on Terminal Island as an outpost of the University of California and operating for the summers of 1901 and 1902. As it was a teaching laboratory, it attracted women students and researchers. Two Los Angeles women associated with the laboratory and who made contributions to the advancement of biology were Sarah P. Monks, an instructor at the Los Angeles Normal School and Martha Burton Williamson, a self-taught conchologist. These women were born in the 1840's and grew up at a time when scientific pursuits were not the norm for the proper Victorian women. Both had done research in Los Angeles Harbor before the laboratory on Terminal Island was opened and both continued their independent research in the harbor after the laboratory was relocated to San Diego. Both women had cottages on Terminal Island from where they collected and conducted their research. Monks named her cottage Phataria after a sea star, whose asexual reproduction and autonomy was the subject of her research. Williamson amassed a significant collection of shells, corresponding extensively with malacologists from around the world. Williamson's most significant publication was her 1892 Smithsonian paper on the shells of San Pedro Bay, possibly the first paper published devoted exclusively to the biota of San Pedro Bay and certainly, the first written by a woman. Both faced setbacks in their careers, Monks by not being recognized as author of her anatomy textbook and Williamson for her inability to join the California Academy of Sciences. They both survived residing, at least part-time, within the inhospitable environment of the Terminal Island district of Los Angeles Harbor. They serve as role models for any women who face the prospect of going where few women go in their quest for scientific knowledge.

Marine field stations and laboratories established around the country in the late 19th and early 20th centuries represented an opportunity to equip local teachers with knowledge of the marine environment to take back to their own classrooms. Teachers were a significant part of the student enrollment in the courses taught at these field stations. Early records from the west coast stations such as Stanford University's Hopkins Marine Station, the University of Washington's Friday Harbor Marine Station and the various field stations established by William E. Ritter of the University of California in Southern California indicate that women were studying at these laboratories (Benson 2001).

One of the University of California marine laboratories was established in the community of East San Pedro on Terminal Island in Los Angeles Harbor in 1901 (Fig. 1). Four women scientists have been documented as being associated with this laboratory. They are Sarah P. Monks, Martha Burton Williamson, Alice Robertson, and Ida Shepard Oldroyd. This paper focuses on the two lesser-known women scientists that were residents of Los Angeles, Martha Burton Williamson and Sarah P. Monks. Both should be acknowledged as part of the history of science in Los Angeles and, in particular, for their association with the science of Los Angeles Harbor.

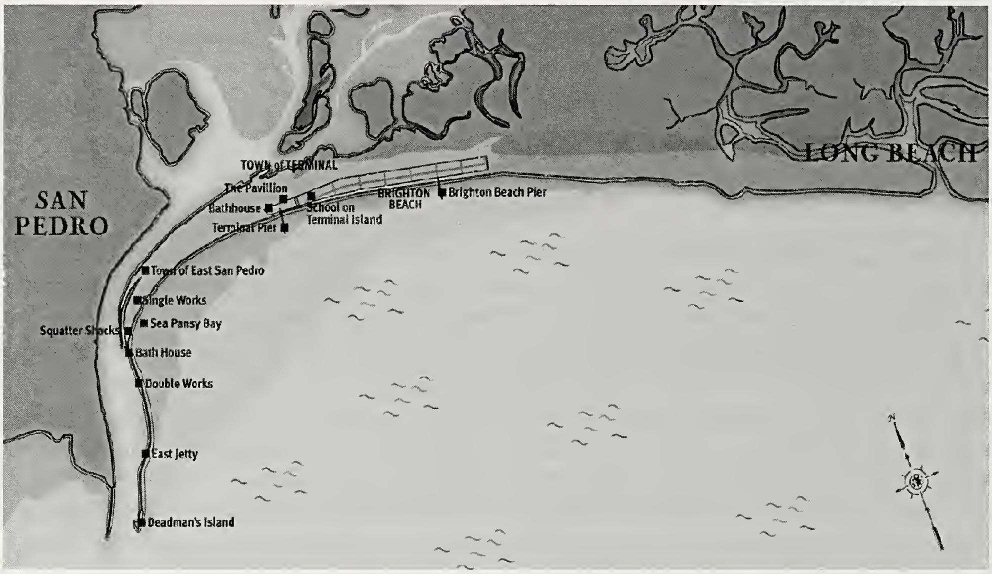

Fig. 1. Los Angeles Harbor, circa 1900, showing the town of East San Pedro in Terminal Island where the marine laboratory was located. Source: Hirahara and Knatz, Terminal Island, Los Communities of Los Angeles Harbor.

Monks was a teacher at the Los Angeles Normal School and an independent researcher associated with the Ritter's laboratory. Williamson was enrolled as a student at the laboratory in 1901. Both women were involved in marine biological investigations in Los Angeles Harbor before the laboratory opened and both continued their independent research in the harbor after the laboratory was relocated to San Diego.[1]

The other two women who were at the Terminal Island laboratory, Alice Robertson and Ida Shepard Oldroyd pursued their scientific careers outside of Southern California. Robertson was part of the University of California laboratory staff and responsible for the specimens collected during field work. She became an authority on Bryozoans and published a series of papers on the Entoprocta and Bryozoa of the Pacific Coast of North America. Robertson left California in 1906 when she realized there was little opportunity for her at the University of California and took a teaching position at Wellesley College. She returned to the University of California when Charles Kofoid offered her a position in 1921 (Sears and Woollacott 2008). Her return was brief as she died the following year. Her contributions to science are covered by Sears and Woollacott (2008) along with a listing of the new genera and species she described.

Oldroyd was a shell collector who, along with her husband Tom, lived in Long Beach and then Signal Hill, California. According to the diary kept by Ritter of the activities at the Terminal Island laboratory, Oldroyd was at the laboratory in 1901 and offered her shell collection to him for $1000.[2] Ritter, facing funding challenges to keep the laboratory operating, was unable to purchase it. Oldroyd eventually sold her collection to Stanford University for $8000. In lieu of payment, Stanford hired Oldroyd as curator. Oldroyd stayed at Stanford until she passed away at age 84 in 1940. Coan and Kellogg (1990) report on her contributions to science in Veliger. In addition to her collection, which was transferred to the California Academy of

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[1] See the companion paper titled *The Marine Biological Laboratory at Terminal Island*, for more information on the establishing of this laboratory 115(2).

[2] William E. Ritter papers, carton 9 diaries, Summer 1901, San Pedro, Bancroft Library, Berkeley.

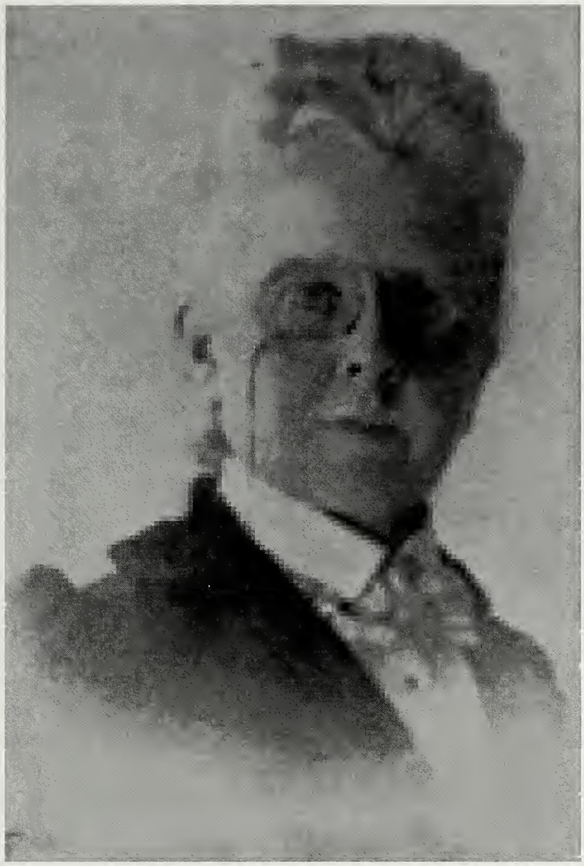

Fig. 2. Sarah P. Monks, circa 1907. Photo from The Los Angeles State Normal School, a Quarter Centennial History, 1882–1907 available on the Internet Archive.

Sciences in 1977, she is known for her publications on mollusks including *The Marine Shells of West Coast of North America* (Oldroyd 1924-27).

Burek and Biggs (2007) noted early female scientists were characterized as having a pioneering spirit. Often born into influential families, they had the means to pursue an interest or work as a volunteer without a formal position or salary. Monks (Fig. 2) and Williamson were middle class white women who were educated but by no means wealthy. Monks never married and had to support herself. Williamson's correspondence with her husband often focused on financial needs and his ability to find a good paying job. They often lived apart as he traveled to find work and her letters indicate a desire for the family to be together. Williamson would occasionally come into money, likely from her writing, happily reporting to her husband that she would be able to pay the rent on time or buy something for her children.[3] Both women were self-sufficient and confident enough to ignore Victorian values of decorum prevalent during the mid-to late 19th century. The west and Los Angeles, in particular, provided an environment where women, like Monks and Williamson, could be different.

[3] Martha Burton Woodhead Williamson Papers, 1849-1922, SIA acc. 06-121, Smithsonian Archives, Washington, D.C.

Monks and Williamson took up residence, in separate cottages, as part of the squatter community that developed on the East Jetty, a federal civil works project constructed by the U.S. Army Corps of Engineers in Los Angeles Harbor. The jetty was built from the tip of Rattlesnake Island (now Terminal Island) to Deadman's Island during the period 1871-1881. As sand built up along the jetty, squatters built primitive wooden structures, homesteading on this newly-created land they considered free for the taking. Most of the homes built on the jetty were constructed of driftwood. They were simple wood structures, often with porches, elevated on stilts or pilings to avoid flooding. The sanitation system was high tide. Most of these shacks or cottages were furnished with the flotsam and jetsam that washed up on harbor shores (Hirahara and Knatz 2015).

Despite Monks having a home in San Pedro and Williamson in Los Angeles and Monks in San Pedro, they both spent a considerable amount of time in their harbor cottages. The presence of these educated women creates an incongruous image among the hermits, fisherman and bohemians that made up the rough and tumble community of East San Pedro.

Sarah P. Monks was born in Cold Springs, New York in 1841.[4] She attended Vassar College and received her A. B. degree in 1871 and her masters in 1876. In 1876, she was elected to Phi Beta Kappa. She attended the women's medical college in Philadelphia to study anatomy and microbiology. She went to work for the Academy of Natural Sciences in Philadelphia classifying birds in their collections while independently studying herpetology. From 1878 to 1891 she published papers on salamanders, lizards and turtles in the American Naturalist and the Proceedings of the American Philosophical Society. She moved to California and spent one year teaching at the College of Santa Barbara before taking a post at the Los Angeles Normal School where she taught from 1884 to 1906.[5] She taught courses in botany, physiology, zoology, chemistry, and drawing. In addition to teaching, Monks was a collector and researcher. As curator of the museum of the State Normal School, it is likely she used her collections for her teaching and to add to the school's museum. Monks research interests for many years focused on regeneration in sea stars but she also published on diatoms and spiders (Monks 1887, 1920).

The first annual report for the corporation known as the Marine Biological Laboratory (MBL) of Woods Hole, Massachusetts, published in 1888, lists Monks as a member.[6] In 1894 at a meeting of the MBL, the Biological Association was created and Monks became a founding member.[7] This annual meeting was described as a convention of teachers, students and researchers who came together to support the establishment of a marine station. It is likely that Monks attended the meeting in person since she was enrolled in a botany course at the Marine Biological Laboratory at Woods Hole the same summer (Fig. 3).

Several profiles have been published about Monks life and work.[8] The Los Angeles Times dubbed Monks the "genius of the old government breakwater" in a profile published in 1907.[9] Monks' was described with *white fluffy hair and pink cheeks*. Her home, at 223 15th Street in San Pedro, could have been described as a cabinet of curiosities, walls lined with shelves filled with biological and geological specimens. Human skulls were perched on the

[4] U.S. Federal Census for New York, 1880.

[5] Interesting Westerners, Sarah P. Monks, Sunset, the Pacific Monthly, 44(1):54.

[6] The Marine Biological Laboratory, Annual Reports for the years 1888-95, Volumes 1-8, Boston.

[7] The marine biological laboratory, Third Annual Report for the year 1890, Boston.

[8] Hail Women as Marvel, Los Angeles Times December 8, 1918 and Sunset, The Pacific Monthly, 1920, 44(1):54.

[9] Mighty Borer is in Danger, San Pedro's women scientist seeks Teredo's end. Los Angeles Times, February 10, 1907, page II-8.

Fig. 3. Sarah P. Monks (second from left leaning against the wall with spectacles) in the botany class at the Marine Biological Laboratory at Woods Hole, 1894.

risers to her second floor. Her colleagues describe her unseen tender side although her public persona was often brusque and characterized by frankness that could be considered cold if she came in contact with what she called *a stupid or unreceptive mind.* She was equally conversant in biology, zoology and geology. Her profiles credit her as in the discoverer of regeneration in sea stars.

Monks retired from teaching at the Los Angeles Normal School in 1906 but continued her scientific pursuits. After her studies of regeneration, she focused her research on the destructive wood borer *Teredo*, hoping to find a solution to the destruction of the harbor pilings which supported her waterfront laboratory.[10] Although Monk's was a long term educator, her views on the pursuit of naturalistic study are revealed in her quote published in the Pacific Rural Press on November 17, 1877:

> *When a person had the ability and range of experience for the correct investigation of nature, it is a waste of time and talent that he must, for bread-and-butter reason, drudge in the college, or university, or the ordinary routine of professional service.*

Sarah Preston Monks died in July 1926 in San Pedro and her passing made the headlines in the San Pedro Daily News.

Martha Burton Woodhouse (Fig. 4) was born in 1843 in England, moving to Cincinnati with her parents as an infant. She was educated in private school and with private instructors, took college level courses but never graduated from college.[11] In 1866 she married Charles

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[10] Mighty borer is in danger, San Pedro's Women Scientist seeks Teredo's End, Los Angeles Times, February 10, 1907.

[11] Holographic Autobiography of Williamson at the Santa Barbara Museum of Natural History. S. S. Berry archives.

Fig. 4. Martha Burton Williamson, from an insert included in the reprint of her publication *Ladies Clubs and Societies in Los Angeles in 1892.*

Williamson in Burlington, Iowa. The U.S. Census for 1870 indicates that Williamson lived next door to her father and both her father and husband were carpenters. Charles and Martha had three daughters.

Williamson began publishing in 1877. She was a special correspondent for the Garfield Presidential campaign. She wrote articles for various newspapers in Indiana and Kansas City.[12] In 1882, she became an editor for the *Enterprise*, a newspaper from Terre Haute, Indiana (Coan 1989). Her personal correspondence indicates that she often pursued work for newspapers and would encourage publishers to create a women's news bureau. In the late 1880's, the family moved to Los Angeles for her husband's work opportunities.

It was in Los Angeles where Williamson turned to science, particularly the collection of shells. In 1890, she was a founding member of the short-lived organization called the American Association of Conchologists. From 1893-1898, she served as secretary of the Issac Lea Conchologist Association of the Agassiz Association (Coan 1989). Williamson's most significant

[12] Holographic Autobiography of Martha Burton Williamson, Santa Barbara Museum of Natural history.

scientific publication was *An Annotated List of the Shells of San Pedro Bay and Vicinity* published by the Smithsonian Institution (Williamson 1892a). She also wrote a paper on the abalone shells of the California Coast and after noting their decline due to overfishing, advocating for their conservation, and noting the inadequacy of the then-current preservation laws (Williamson 1894a, 1907).

Williamson carried on extensive correspondence and specimen exchanges with malacologists from around the world, such as Robert E. Stearns of the Smithsonian, Charles Hedley of the Australian museum in Sydney, M. J. Elrod from University of Montana and Charles W. Johnson of the Boston Society of Natural History. Her most interesting correspondence is the letters with James G. Cooper, noted ornithologist and an early member of the California Academy of Sciences (Emerson 1899). Cooper had helped Williamson with some of the identifications of her shells from San Pedro Bay. The correspondence reveals the Academy's inability to publish Williamson's work because she was not a member. Given how Williamson actively joined numerous scientific organizations, it would seem likely that she would want to become a member of the academy. Her lack of a college degree might have prevented her membership. Cooper's letters to Williamson were somewhat patronizing. He told her to be careful when collecting from San Pedro because a shell might have been thrown off a ship.[13] Cooper often requested she send specimens to him. It is possible that Williamson asked that these species be named for her, for in a letter dated February 10, 1890, Cooper tells her that *Williamsonae is just too long.*[14]

She was a prolific writer publishing on scientific, historical and women's topics, including a three part series of articles titled *Some American Women in Science* (Williamson 1898-99). She was active in women's organizations as a charter member of the Friday Morning Club and a member of the Ruskin Art Club. She was the second president of the Southern California Press club.[15] She was often a speaker at these club meetings, entertaining her audiences with her shells and jars of specimens including an octopus from Rattlesnake Island.[16] She often made the society news in the Los Angeles papers. As a journalist she published her work under the *nom de plume* Virginia Burton while her scientific publications were all published under her own name as *M. Burton Williamson.*[17] It does not appear she was trying to disguise her sex. Her extensive correspondence with scientists around the world indicates they knew she was female.

Williamson was an active member of the Historical Society of Southern California, joining in 1891 after being asked by Dr. Ira More, principal of the Los Angeles State Normal School. There were only two other women members when she joined, Dona Coronel, the wife of former Mayor of Los Angeles Antonio F. Coronel, and Tessa L. Kelso, the Los Angeles City Librarian (Williamson 1919). It was her involvement in the Historical Society that brought her in contact with many of the Society founders and pioneers in the development of Los Angeles. She was an active member for 30 years and published numerous papers in the Society's Annual Bulletin including papers on the history of Catalina Island, Deadman's Island and University Park, the area around the University of Southern California, as well as the Mission Indians of the San Jacinto Reservation.

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[13] January 28, 1891 Letter from James G. Cooper to Mrs. Williamson, Smithsonian Archives.

[14] February 10, 1990 Letter from James G. Cooper to Mrs. Williamson, Smithsonian Archives.

[15] The Friday Morning Club founded in 1891 was an all-women's organization devoted to personal and civic betterment.

[16] Conchological Lore, Los Angeles Herald June 27, 1892, page 3.

[17] Holographic Autobiography of Martha Burton Williamson, Santa Barbara Museum of Natural History, S. S. Berry archives.

Her involvement with the Historical Society prompted her to suggest that a special meeting be organized to record the history of all the women's organization and societies in Los Angeles. The meeting, held at the mansion of Don and Dona Coronel in Los Angeles, on March 28, 1892, was significant enough to have been noted in Harris Newmark's *60 Years in Southern California* (Newmark 1916). Williamson compiled the information and proposed that the Historical Society publish it. Unfortunately, the Historical Society did not have the funds to create more than a few copies of the 172 page compiled work titled *Ladies Clubs and Societies in Los Angeles in 1892.* When the Society President, Frank J. Polley, resigned in the middle of his term in 1896 to take on the chairmanship of the history department at Stanford University, Williamson assumed the role for the remainder of his term. She notes in her 1919 article, *Glancing Backwards*, that her name was not listed as the Society president in the 1896 Annual and that the oversight was repeated again in a later article listing the former presidents, although she was listed as a Vice-President from 1895 through 1913 (Hall 1916).

She was widowed in 1891. Williamson applied for a civil war widow's pension under the Widow's Pension Act of April 19, 1908.[18] She began receiving twelve dollars a month beginning in June 1908, the amount being increased to twenty dollars a month in 1916 when she hit the age of 70. She died on March 18, 1922. A 13 page brochure was produced for her funeral service.[19] She was described as a writer, scientist, and philanthropist but first of all, a homemaker. Honorary pallbearers included notables such as Dr. Millbank (sic) Johnson, of Alhambra, Dr. Laird Stabler of University of Southern California, and notable Los Angeles resident Charles Lummis.

At the Marine Biological Station in Los Angeles Harbor

Monk's experience at the field station at Woods Hole likely attracted her to the marine laboratory established by Ritter in Los Angeles Harbor. She was neither a student nor an instructor but an independent researcher working out of the laboratory. Ritter (1902) reports that her scientific work on the sea star *Phataria* concluded that there is much variability in the number of rays but that the throwing off of rays is not accidental but an intentional means of asexual reproduction. Studies conducted at the laboratory hypothesized but did not conclusively prove that a severed ray can regenerate an entire organism including the disk (Ritter 1902). Monks however proved this point in follow-on research (Monks 1903, 1904).

Ritter, who kept detailed diaries rarely mentioned any of the students or independent researchers however he made one interesting comment about Monks. On August 3, 1901, Kofoid took the research vessel *Elsie* on a collecting trip to Whites Point, off the Palos Verdes Peninsula. Monks went along and Ritter's diary entry states *Miss Monks gets about 40 specimens of the Phataria, all as disregardful of the law as ever.*[20] Was Ritter complaining that Monks was taking too many specimens and violating a law of nature, potentially impacting the population? He never made any other similar comments about the other researchers despite often listing the numerous numbers of specimens collected.

Williamson was the only student at the laboratory that Ritter mentioned in his 1902 paper in *Science*, reporting on her discovery that two species of *Pecten* were hermaphroditic. Williamson, however, was already a noted authority on mollusks when she enrolled as a student at the laboratory. When William Dall, the curator of mollusks at the Smithsonian Institution

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[18] Marriage certificate included with Williamson's civil war widow's pension application, National Archives and Records Administration.

[19] Smithsonian archives, SIA Acc.06-121 Martha Burton Woodhead Williamson Papers 1843-1922, Box 1.

[20] William E. Ritter papers, carton 9 diaries, Summer 1901, San Pedro, Bancroft Library, Berkeley, CA.

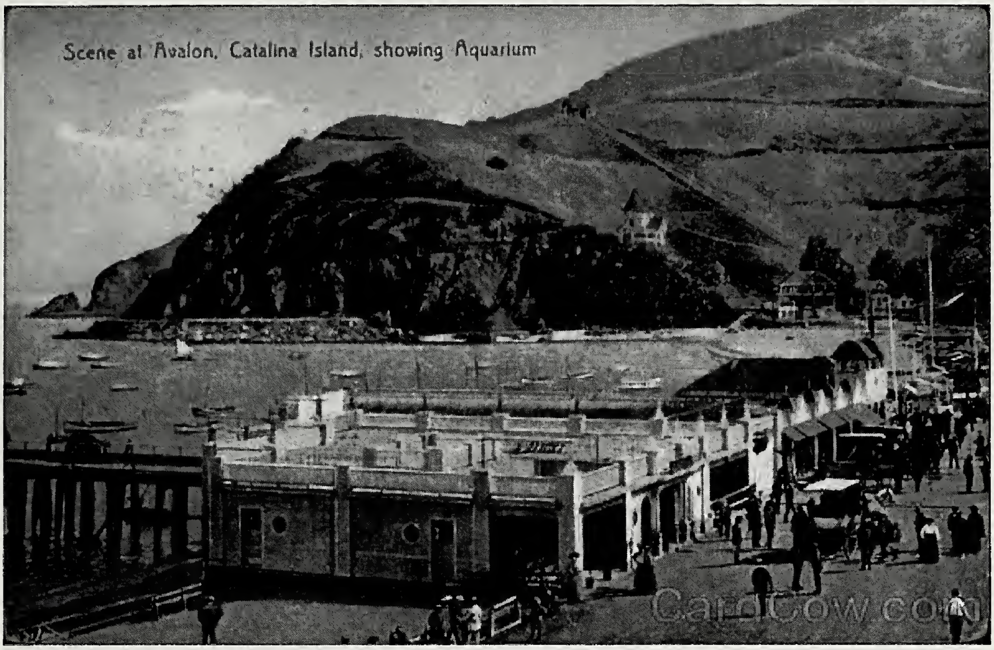

Fig. 5. Aquarium at Avalon, Santa Catalina Island, Circa 1908.

came to the harbor laboratory to speak in 1901, he and Williamson were already well acquainted. Nearly a decade earlier, Dall had named the species *Vitrinella williamsoni* Dall for Williamson, intentionally using the male genitive ending *i* because Williamson's name was *inherently masculine*. Dall's description is included in Williamson's 1892 paper so she apparently took no issue with how he named the species (Williamson 1892a). Williamson also published *The Marine Biological Laboratory at San Pedro* in the 1901 Annual of the Historical Society of Southern California.[21] Williamson continued her study of biology at the University of Southern California in 1904.[22]

Monks and Williamson knew each other before the Terminal Island laboratory opened. Nearly a decade before, Williamson acknowledged Monks for use of her shell collection for her 1892 publication. She also acknowledged Ida Shepard (prior to her marriage to Tom Oldroyd) and other women shell collectors in the same publication. In August 1899, a group of scientists that included both Monks and Williamson visited the aquarium established by Charles Frederick Holder in Avalon on Santa Catalina Island (Fig. 5). Holder envisioned the aquarium as a tourist attraction as well as a zoological station similar to the Zoological Station at Naples, Italy (Holder 1899). Monks and Williamson went to study the behavior of his aquarium inhabitants and to obtain specimens.[23] Despite knowing of each other work, Williamson did not mention Monks as one of the American women in science in her three part series published in 1898-99 although her series notes that some women scientists were also teachers and illustrators, as Monks was.

[21] This paper is how the author discovered the laboratory existed in Los Angeles Harbor as none of the published harbor histories had mentioned it.

[22] Holographic Autobiography of Martha Burton Williamson, Santa Barbara Museum of Natural History, S. S. Berry archives.

[23] Scientists at Avalon studying Life by land and sea for useful purposes, Los Angeles Herald Examiner, August 4, 1899.

Fig. 6. Sea Pansy Bay along the East Jetty, Terminal Island. Courtesy of San Pedro Historical Society.

Monks and Burton Williamson's Cottages in Los Angeles Harbor

Monk's cottage on the breakwater was in an area known as Sea Pansy Bay where the Army Corps of Engineers had constructed rock groins perpendicular to the jetty to stabilize it, creating a small bay (Fig. 6). Monk's neighbor was noted Los Angeles citizen, Charles Fletcher Lummis, the founder of the Southwest Museum and the librarian at the Los Angeles public library.[24] Lummis kept a daily diary of his days down at his cottage and would often report Monks was visiting in the evening to enjoy music.[25]

Monks named her cottage Phataria after the sea star which was the subject of her research (Fig. 7). She conducted experiments on regeneration in her waterside laboratory, keeping *Phataria* in tanks of water that required changing every day. The daily trek over to Phataria from San Pedro involved a ferry ride followed by a trek along a broken boardwalk over water and jagged rocks, using a wire for support. The chair on Monk's porch was fashioned out of an old ships rudder and her stove and lamp were brought from the wreck of the vessel *Portland* (Fig. 8).

No photograph was found of Williamson's cottage. She laid claim to a squatter lot in 1901 during a land rush of prospective squatters that materialized in East San Pedro after word got out that a prominent Los Angeles man had taken a lot (Hirahara and Knatz 2015).[26] It is not clear whether Monks and Williamson bought existing cottages or built their own. However, Williamson sought permission from the Army Corps of Engineers to make modifications to her cottage, and included a hand-drawn map of her location in her correspondence to the Corps.[27]

As the concern intensified over legal right of the residents of East San Pedro to continue living on the Army Corps jetty and the land that accreted around it, both Monks and Williamson corresponded with the Corps of Engineers to solidify their claims to their lots. Monks in her letter to Colonel Fries of the Los Angeles District of the Army Corps

[24] A blueprint plot plan is available at the Port of Los Angeles which shows the names of the residents and building on the East Jetty. It is believes this drawing was made approximately 1912 prior to the City's eviction of the residents.

[25] Diary of Charles Fletcher Lummis, Braun Library, Autry Museum.

[26] Squatters evicted at East San Pedro, lots may not be staked, Los Angeles Herald, July 31, 1901, page 4. I suspect this prominent citizen was Charles F. Lummis.

[27] Letter to Secretary of War and Captain C. H. McKinistry, Corps of Engineers from M. Burton Williamson, both dated May 39, 1904, National Archives at Riverside, Record Group 77, File W-10e

Fig. 7. Cyanotype photograph taken in 1906 of Monk's cottage on the East Jetty where she conducted her biological research. White letters on the fence show part of the name Phataria. Photo courtesy of Huntington Library.

called her cottage a *place of study* and emphasized her efforts to study the destructive wood borers Teredo.[28] She tells Fries that the she does not know anyone in Washington D. C., then proceeds to name the curators at the Smithsonian. Fries was sympathetic in his response. Nevertheless, he informed her that her cottage rested on disputed territory he called *no man's land.*[29]

In 1912, the City of Los Angeles began eviction actions against the squatters (Hirahara and Knatz 2015). Like the rest of the squatters who clung to their waterside cottages like barnacles to the rocks, Monks' and Williamson's efforts to secure permanent rights to save their cottages were unsuccessful.

The Legacy Left by Sarah P. Monks and Martha Burton Williamson

When Monks was still living, she was best known for a 300 page textbook used at the Los Angeles Normal School titled *Anatomy Physiology Hygiene.*[30] Unfortunately, she is not listed as the author. The text was compiled under the direction of the State Board of Education. Monks

[28] Letter to Captain Amos A. Fries from Monks, dated December 23, 1907, National Archives at Riverside, U.S. Army Corps Records, File W-10e

[29] Letter to Monks from Captain Fries dated February, 7,1908, National Archives at Riverside, U.S. Army Corps of Engineers Record Group 77, File W-10e.

[30] *Anatomy Physiology Hygiene* was printed by the State Printing office without a date. Google books cited the year of publication as circa 1891.

Fig. 8. Sarah P. Monks, on left at Phataria. The group is looking toward San Pedro across the main channel of the Port of Los Angeles from Terminal Island. Courtesy of the San Pedro Historical Society.

was given credit inside the book for all its original drawings. Monks is mentioned in Creese's American and British Women of Science for her work in herpetology (Monks 1878, 1881). Monks donated her library, consisting mostly of Proceedings of the National Museum and the Philadelphia Academy of Sciences to to the Los Angeles Museum of History, Science and Art in 1915.[31] It is believed that the gastropod *Fusinus monksae* was named for her by William Dall in 1915.[32]

Although she lived alone, many researchers made a path to her doorway. She fell in love with the sea and expressed those feelings in her poetry as illustrated in this last stanza of her poem *The Islands of the Sun*:

Mayhap my ships that outward went
And never came to me again
Mayhap my winged hours misspent
And dreams and fancies passion pent
Have found some port of sweet content
In Islands of the Sun

Williamson donated her shells to the Los Angeles Museum of History Science and Art in 1912.[33] Although no complete inventory of her collection currently exists, letters in the collection file at the Los Angeles County Museum of Natural History indicate her collection numbered about 3000 specimens. Some of her specimens were traded with other institutions.[34] Her extensive correspondence with malacologists around the world is in the Smithsonian

[31] Los Angeles County Museum of Natural History, Accession Catalogue, Number 372.

[32] Conchology, Inc., Biography of S. Monks, http://www.conchology.be/?t=9001&id=25225.

[33] Los Angeles County Museum of Natural History, Accession Catalogue, Number 52.

[34] Personal Communication, Lindsey Groves, Mollusks Collections Manager, Los Angeles County Museum of Natural History.

archives except for one box which was donated to Stanford University.[35] The Stanford box contains material associated with the American Association of Conchologists including a letter its President John Campbell sent to Williamson, dated May 5, 1890, welcoming her as the first lady member of the association (Keen 1981).

Williamson's daughters Lillian and Estella worked to ensure their mother's legacy. They were dismayed to find, upon a visit to the museum in 1927 that their mother's collection was not on display. Their written inquiry to the museum emphasized that the donation was made with the understanding that the items were to be on display. Their letter triggered acting museum director John Comstock's request to the museum Board of Governors to go on record opposing donations that come with restrictions. Comstock found no evidence supporting the Williamson's daughters claim, and assured them that such a valuable collection, like their mother's, had to be preserved for research purposes.[36] In 1925, Williamson's daughters also printed her report *Ladies Clubs and Societies in Los Angeles in 1892*. It is frequently cited by historians in the field of women's studies.

One of Williamson's most delightful publications was published in Popular Science News in 1891, *A Midwinter Trip in Search of Shells*.[37] It provides a rare first-hand glimpse of a collecting trip to Deadman's Island and Rattlesnake Island, two locations that no longer exist in Los Angeles Harbor. Williamson published a summary of conchological research in San Pedro Bay (Williamson 1894b) noting that the collection of shells and biological specimens from San Pedro bay occurred as far back as the 1850's and by James G. Cooper in 1867 and William Dall in 1873.[38] However, her 1892 Smithsonian paper on the shells of San Pedro Bay may be one of the first biological papers published specifically on the fauna of San Pedro Bay and is most certainly, the first written by a woman. Over her career, Williamson identified 11 new species of which two *Crepidula* are valid (Coan 1989).

Monks and Williamson represent a unique breed of women who led unconventional lives that were dedicated to the pursuit of knowledge and science. Both women worked to share the knowledge they gained through their studies. Although Williamson never became a teacher like Monks, she was an avid public speaker on scientific topics to women's groups and published scientific pieces in magazines available to the general public.

Los Angeles Harbor of the late 19^{th} and early 20^{th} century was not a hospitable environment for a woman. Yet, Monks and Williamson carved out an existence there, becoming well-known members of an eclectic community that began to disappear in 1912 with the progress of harbor commercialization. Whether it is Monks making the daily trek to her waterside laboratory to change the seawater in her aquaria or Williamson collecting on Deadman's Island, the image of these two women wearing Victorian dress navigating the rocks in the pursuit of science is one that should be imagined and not forgotten. These women can serve as role models for any budding scientist who might feel intimidated by the daunting massive industrial complex of today's Los Angeles harbor, yet sees it as an environment worthy of biological research and discovery.

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[35] M.B. Williamson Papers 1887-1927, Stanford University Library.

[36] October 11, 1927 Letter to the Board of Governors of the Los Angeles Museum, Statement concerning the E. (sic) Burton Williamson collection by Acting Director John A. Comstock, Los Angeles County Museum of Natural History.

[37] Popular Science News, 1891, XXV(9):132.

[38] The Conchologists: Searching for Seashells in 19th Century America, Library of Congress June 22, 2015 by Jennifer Harbster, Library of Congress blog, https://blogs.loc.gov/inside_adams/2015/06/the-conchologists-searching-for-seashells-in-19th-century-america.

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Significance of Bulb Polarity in Survival of Transplanted Mitigation Bulbs

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Abstract.—Our experimental design was formulated to determine whether or not bulb polarity (orientation) at the time of replanting of bulbs to salvage plants of *Calochortus weedii* A. W. Wood (Liliaceae) or Weed's Mariposa Lily affected the success of the mitigation transplant effort. Polarity of bulbs at planting clearly did influence subsequent growth, most notably in the tip-down (D) treatment. Among these bulbs, 75% failed to emerge from dormancy and only four (20%) actually set mature fruit. This was in sharp contrast to the other three treatments where 100% of the bulbs successfully emerged in this season and between 80% (S) and 95% (UG and UN) set mature fruit. The data from this study do indicate that: 1) bulb planting orientation does influence survival and growth, and 2) proper bulb planting polarity (orientation) should be an important consideration in any transplantation of this or any sensitive bulb producing plant species for mitigation purposes.

In general, when planted, bulb polarity is important and bulbs should be planted with the apex up and the root base down (Hitchmough and Fieldhouse 2003). However, if bulbs are inadvertently planted sideways or upside-down how significant is that to bulb survival and/or subsequent reproductive productivity? Such knowledge becomes especially important when the manipulated bulbiferous plant is a rare and endangered species and the bulbs are being salvaged and transplanted as part of a mitigation process. It is in this context that the current study was conceived. This study was initiated at the request of the U. S. Fish and Wildlife Service Agency. Specifically, the question under consideration is: "In Weed's Mariposa Lily, *Calochortus weedii* var. *intermedius*, does the tip orientation (polarity) of bulbs have a significant effect on subsequent survival and reproduction?" Results are intended to assist future mitigation efforts when applied to this and perhaps other rare and endangered bulbiferous species.

Calochortus weedii var. *intermedius* (hereafter - CWI) is a single-leaved herbaceous perennial that develops from a small bulb (Fig. 1). Bulbs were defined as the swollen basal portion after the thinner elongated portion, made up of the dried senescent portions of the inflorescence and associated leaf bases, was removed. It is distinguished from the three other varieties by anther shape, flower color, and petal shape (Ownbey 1940; Wiggins 1980; Hickman 1993; Fielder 1996). It is included in the CNPS Inventory of Rare and Endangered Plants on list 1B.2 (*rare, threatened, or endangered in CA and elsewhere*) (Tibor 2001; California Native Plant Society 2013). CWI bulbs generally follow the *Calochortus* life history or pattern of development described by Fiedler (1987) in her study of five primarily Central California species. After fall rains, the small bulbs emerge from late summer/fall dormancy, producing the single basal leaf. Following several months of leaf elongation, an inflorescence stalk develops. Flowers

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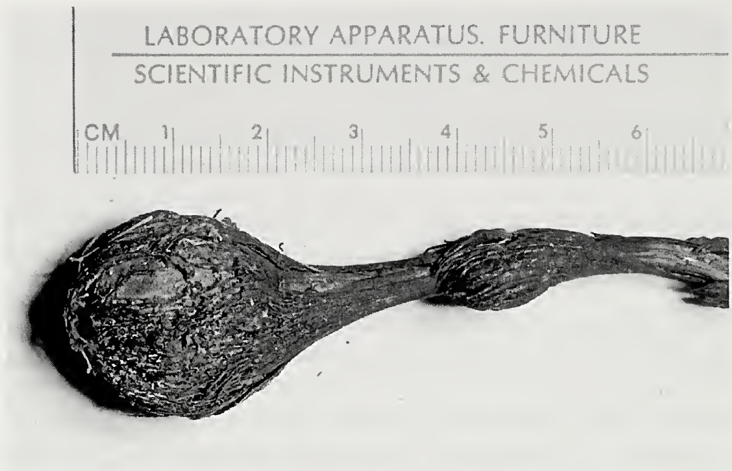

Fig. 1. Typical bulb of CWI. Bulb includes area from left side of figure to the 3 cm position on the ruler.

appear in mid-spring and by July-August fruit capsules mature, seeds disperse, flower stalks dry down, and the bulbs once again become dormant.

Materials and Methods

CWI bulbs used in this study originated in Los Trancos Canyon, Orange County, California just inland from northern portions of Crystal Cove State Park, at the east end of the San Joaquin Hills. To examine if orientation had any affect on bulb transplantation success, we used four bulb planting orientation treatments encoded UN, UG, S, and D as follows: 1) UN, tip (bulb apex) up, in native soil (used as a control for comparison to treatments in which the soil was a standard greenhouse mix, see below for details); 2) (UG) tip up, in greenhouse soil; 3) (S) tip to the side; i.e., parallel to the soil surface, in greenhouse soil; and 4) (D) tip down, in greenhouse soil. The two tip-up groups (UN and UG) served as controls. Twenty bulbs were selected for each treatment.

Square plastic pots (2.6 liter) were utilized and bulbs were planted in the center of the pot at a 5 cm depth. Native soil for the UN treatment was provided by LSA Associates, Inc., Irvine, California, (hereafter LSA). All other treatment pots were filled with a greenhouse soil mix, which included one part native soil (for possible mycorrhizal considerations) to three parts standard greenhouse soil by volume. This latter greenhouse soil was a mix of an organic fraction (50%) that included peat moss (6 parts by volume) and forest humus (9 parts by volume) plus an inorganic fraction (50%) that included washed plaster sand (6 parts by volume) and pumice (9 parts by volume). Sierrablen (Everiss International) time-released fertilizer (NPK 18N:7P:10K + Fe) was added at the rate of 4oz/10 gallons soil mix and dolomite (Ca & $MgCo_3$) at 5oz/10 gallons of soil mix.

Pots were randomly placed on outdoor benches in the California State University, Fullerton (CSUF) Biology Greenhouse Complex where they were subject to natural environmental temperatures (Fig. 2). The pots on the bench were surrounded by cement blocks in order to provide the outer pots with a heat load similar to that experienced by other pots on the bench. During both two-year studies (2003-05 and 2005-07) supplemental water was provided when the pot soil was dry to a 2.5 cm depth. All watering (natural or artificial) had ceased by mid-July when fruit capsules were ripening, the flower stalks were withering, and the bulbs had entered summer dormancy.

Fig. 2. Benches used in study. Located in the California State University, Fullerton, California, Biology Greenhouse Complex.

Experiment 1, using wild-collected bulbs (2003-05).—Two batches of newly-dug CWI bulbs were provided by LSA, one each on October 16 and 18, 2003. To minimize possible bulb size effects, larger bulbs weighing at least 3g, as determined using a Mettler AE163 balance, were selected and placed in numbered coin envelopes (No. 1 coin envelopes – 2.25 X 3.5 in.) forming a pool of 160 bulbs for potential study. Bulbs were selected for the various treatments with the use of a Random Number Table (Zar 1974). Selected bulbs ranged in weight from 3.8 to 7.9g with a mean weight of 4.8g. Planting occurred on October 19, 2003 and the resulting plants were followed through 2005 until the bulbs were harvested on September 30, 2005. Harvested bulbs were subsequently individually weighed and returned to LSA.

Experiment 2, using propagated bulbs (2005-07).—Bulbs for the second two-year study were descended from the original field collection of October 2003, but these bulbs had been propagated by the Tree of Life Nursery in San Juan Capistrano, California and were then provided to us by LSA in October 2005. Individual bulbs were selected for this study using the same methods described for the first two-year study; however, these bulbs were significantly smaller ($t=222.0$, $df=79$, $P>0.001$), so a minimum weight to be included was established at 1.5g. Selected bulbs ranged in weight from 1.7g to 5.6g with a mean weight of 2.6g. Planting of these bulbs occurred on October 21, 2005 and the resulting plants were followed through 2007 until the bulbs were harvested on September 28, 2007, individually weighed. All recovered bulbs were returned to LSA upon completion of the study and the submission of the final report.

Where appropriate, data were analyzed using a Student's t-test, analysis of variance (ANOVA) in JMP, version 5.0 or an analysis of covariance (ANCOVA) or a logistical regression in JMP version 5.0. Homogeneity of variance and normality were examined by looking at residuals and normal probability plots of residuals.

Results

Maximum and minimum temperatures were recorded during both two-year studies (2003-2005 and 2005-2007). There were six weeks with average temperatures at or above 30°C in

2003-04, two such weeks during 2004-05, seven such weeks in 2005-06, and four such weeks in 2006-07. However, overall the weekly pattern of temperatures was similar over the four-year study.

Experiment 1, Year 1.—During the 2003-04 growing season, all twenty newly planted bulbs in the UN, UG, and S treatments ultimately produced leaves; however, only five of the tip-down (D) did so. One hundred percent leaf emergence occurred two weeks earlier (Week 14, mid-January) in the native-soil control bulbs (UN) than in the greenhouse-soil controls (UG) and side-planted (S) bulbs (Week 16, early February). Maximum emergence (25%) of D (tip-down) bulbs was registered even later in Week 20 (early March).

Experiment 1, Year 2.—In the 2004-05 growing season, 100% of the previously side planted bulbs produced leaves, whereas 95%, 90%, and 65% of the UG, UN, and D bulbs, respectively, did so. More than 85% of the UN, UG, and S bulbs had produced a leaf by the end of the Week 11, whereas only 10% of the D bulbs had done so by that same time. (Note that leaf emergence proceeded faster during the 2004-05 season than it did during the 2003-04 season).

Experiment 2, Year 1.—During the 2005-06 growing season, eighteen of the newly planted S and UG bulbs, as well as 19 of the UN and only 9 of the D bulbs ultimately produced leaves. Furthermore, leaf emergence did not proceed at the same rate in the treatments during that year. Leaf emergence occurred in UN (bulbs in native soil) plants much more rapidly than any of the other treatments.

Experiment 2, Year 2.—In the 2006-07 growing season, many fewer previously planted bulbs experienced leaf emergence. Fourteen of the UN, 15 of the UG, 18 of the S, and only 8 of the D bubs produced a leaf.

Inflorescence initiation.—Once the basal leaf has reached maturity and the plant begins to put forth an inflorescence, the basal leaf rapidly begins to wither away and is replaced by an inflorescence stalk. In the 2003-04 growing season, development of inflorescence stalks was first noted in the two tip-up control groups (UN and UG) during the second week of February (Week 16). Side-planted bulbs (S series) began exhibiting developing flower stalks two weeks later (Week 18, late February), followed two weeks later (Week 20, early March), in the tip-down group (D treatment). Development of inflorescence stalks during the 2004-05 growing season was first noted in the two tip-up control groups (UN and UG) in the last week of January (Week 16) during the 2004-05 growing season. Side-planted bulbs (S) began exhibiting developing flower stalks in that same week (Week 16), followed two weeks later (Week 18, early February) by inflorescence development in the tip-down group (D).

During the 2005-06 growing season, development of inflorescence stalks in the newly planted bulbs was first noted in the two tip-up control groups (UN and UG) during the second week of January (Week 12). Side-planted bulbs (S) began exhibiting developing flower stalks during that same week (Week 12), followed six weeks later (Week 18, early February) by inflorescence development in the tip-down group (D).

Development of inflorescence stalks during the 2006-07 growing season was first noted in the previously planted tip-up control group, grown in native soil (UN), during the second week of January (Week 14). The other tip-up control group (UG), began to develop inflorescences during the first week in February (Week 17). Side-planted bulbs (S) began exhibiting developing flower stalks during the third week of February (Week 19), followed three weeks later (Week 22, second week in March) when the first instances of inflorescence development appeared in the tip-down group (D).

When mean times of inflorescence initiation during the 2003-04 growing season are considered by treatment, values of the UN, UG, and S group are approximately equivalent (19.7, 20.2, and 20.4 weeks, respectively) with the D group average differing at 22.5 weeks after planting.

These variations were not statistically different. An analysis (ANOVA) of the data for the 2004-05 growing season also showed no significant differences among all four treatments.

Not all plants formed inflorescences during either of these first two seasons. In each group at least one plant remained in the vegetative state with the basal leaf rapidly withering. These plants were categorized as "dead or dormant" (d/d). During the 2003-04 growing season in the S treatment, three plants out of 20 failed to form inflorescences, whereas in the UN and UG controls, it was one plant out of 20 and in the D treatment, of the five plants that had a basal leaf, only four formed inflorescences. During the 2004-05 growing season only 7 of the 20 UN bulbs planted in 2003 produced an inflorescence, whereas 10 of the S bulbs, 12 of the D bulbs, and 13 of the UG bulbs did so. Similarly, during the second two-year study (2005-06 and 2006-07) not all plants formed inflorescences during either of these second two seasons. In each group at least one plant remained in the vegetative state with the basal leaf rapidly withering. These plants were also categorized as "dead or dormant" (d/d). During the 2005-06 growing season, in the S treatment, three plants out of 17 that produced a basal leaf failed to go on to form inflorescences, whereas in both the UN and UG controls, four bulbs out of 19 and 18 respectively that produced a basal leaf failed to produce an inflorescence. In the D treatment, of the nine plants that had a basal leaf, only six formed inflorescences. Inflorescences were produced in fewer of the tip-down (D) bulbs than any of the other treatments. The other three treatments were all very similar.

During the 2006-07 growing season, only 7 of the 14 UN bulbs that had produced a basal leaf went on to produce an inflorescence, whereas 12 of 18 of the S bulbs, 5 of the 8 D bulbs, and 9 of the 15 UG bulbs that developed a basal leaf actually produced an inflorescence. Inflorescences were produced later in the tip-down (D) bulbs than in any of the other three treatments during this fourth year of study. However, side-planted (S) and those bulbs planted with the tip-up in greenhouse soil (UG) were not different from one another but they both different from the D and UN treatments. Those bulbs planted with the tip-up in native soil produced inflorescences earlier in the season than any of the other treatments.

Initiation of floral buds.—In contrast to the developmental aspects discussed above, floral bud formation occurred synchronously in all treatments during both years (2003-04 and 2004-05) of the first study: Week 24 (beginning in late March) of 2004 and during Weeks 26 and 27 (again beginning in March) of 2005. Floral bud formation also occurred synchronously in all treatments during both years (2005-06 and 2006-07) of the second two-year study, with 2006-07 showing the most spread. However, bud initiation for neither of these two years was notably different from bud formation during the first two years of study (2003-04 and 2004-05). Buds began to form in Weeks 25 to 27 (beginning in late March) of 2006 and during Weeks 23 to 27 (again beginning in March) of 2007.

Appearance of open flowers.—As with floral buds, open flowers appeared synchronously in all treatments during both growing seasons of the first two-year study. This occurred in mid-May or Weeks 29 to 30 of 2004 and in Weeks 30 to 32 of 2005. A similar pattern was observed during the second two-year study with flowers appearing in Weeks 29 to 32 of 2006 and in Weeks 29 to 31 of 2007.

Initiation of fruit set.—Again, this process was observed to be synchronous in all treatments during the first two-year study and was coincident with the appearance of open flowers during Week 30 and 32, mid-May of 2004 and during Weeks 33 to 35 of 2005. A similar pattern of fruit production was seen in the second two-year study with fruits appearing in Weeks 31 to 33 in both 2006 and 2007. However, fruit set began slightly earlier in 2003-04 than in the following years.

Table 1. Summary of data relative to growth in CWI for the four treatments and the overall average for all four treatments in the 2003-2004 study. Infl.=Inflorescence; Ave.=average; SD=standard deviation.

Trait	UN	SD	UG	SD	S	SD	D	SD	Overall average
Infl (N)	19		18		17		4		14.5
Ave. Infl. Height (mm)	745.5	51.4	851.9	58.2	817.5	54.6	818.3	50.7	808.3
Ave No. Branches	3.4	0.2	4.3	0.3	4.0	0.3	2.8	0.2	3.6
Ave No. Fruits	5.0	0.4	7.6	0.6	7.1	0.5	5.0	0.3	6.2

Number of mature fruit produced.—The four treatments fell into essentially two groups in terms of mean fruit production during the 2003-04 growing season (Table 1). The tip-down treatment (D) and the native-soil control plants (UN) were essentially equivalent, producing an average of 5.0 (D) and 5.1 (UN) mature capsules, respectively, per plant. Fruit production for the side-planted (S) and the greenhouse-soil controls (UG) was approximately 30% higher, with mean values of 7.1 and 7.7, respectively. An analysis of variance (ANOVA) showed significant differences among the four groups ($P<0.05$), with UN being significantly different from UG and S, but not from D. All other treatments were not significantly different from one another.

Fruit production during the 2004-05 season (Table 2) was only significant different between the two controls (UN and UG). Fruit production during the 2005-06 season showed some significant differences among the four treatments ($P<0.05$) using an analysis of variance (ANOVA), with only the tip-down (D) bulbs being significantly different from the side-planted (S) bulbs, but neither of those were significantly different from either of the controls (UN or UG planted bulbs). Fruit production during the 2006-07 season showed significant differences among the four treatments ($P<0.05$) using an analysis of variance (ANOVA), with the tip-down (D) bulbs being significantly different from the up-greenhouse bulbs (UG control), but neither of those was significantly different from either of the controls (UN or S planted bulbs).

Summaries of reproductive information.—The following tables summarize the data relative to reproduction for this species during the four growing seasons: 2003-04 (Table 1); 2004-05 (Table 2); 2005-06; (Table 3); and 2006-07; (Table 4). In nearly all cases (except inflorescences produced per plant in the down treatment in 2004-05 and the average number of fruits produced per inflorescence in the 2006-07), reproductive output as measured by inflorescence characteristics and fruit production was lower in the year following the initial planting season (2004-05 versus 2003-04 and also in 2006-07 versus the 2005-06 season). Reproductive fitness was severely limited by the tip-down orientation of bulb planting during all four seasons. Only four of the tip-down CWI bulbs produced flowers and fruits during the 2003-04 and 2004-05

Table 2. Summary of data relative to growth in CWI for the four treatments in the 2004-2005 study with percentage similarity to 2003-2004 for comparison.

Trait	UN	%	SD	UG	%	SD	S	%	SD	D	%	SD	Overall average
Infl (N)	6	32		8	44		10	59		4	100		6
Ave. Infl. Height (mm)	534.2	72	41.8	432.3	51	29	451.8	55	31.3	393.3	48	28.5	452.3
Ave No. Branches	2.2	65	0.1	1.0	16	0.1	1.9	27	0.1	1.5	30	0.1	1.8
Ave No. Fruits	2.7	43	0.2	1.3	17	0.3	1.8	26	0.2	1.5	30	0.2	1.8

Table 3. Summary of data relative to growth in CWI for the four treatments and the overall average for all four treatments in the 2005-2006 study.

Trait	UN	SD	UG	SD	S	SD	D	SD	Overall average
Infl (N)	16		14		15		6		12.8
Ave Infl Height (mm)	652.1	48.1	826.4	56.3	785.9	52.1	625.7	46.5	722.5
Ave No. Branches	5.3	0.3	5.4	0.4	5.6	0.4	3.2	0.2	4.9
Ave No. Fruits	3.9	0.2	4.4	0.2	5.5	0.3	2.8	0.1	4.2

growing seasons and only six and five tip-down CWI bulbs respectively produced flowers and fruits during the 2005-06 and 2006-07 growing seasons.

Initial bulb weight as a predictor of reproductive success – first experiment (2003-05).— An analysis of covariance (ANCOVA) showed that initial bulb weight was not related to stalk size ($P=0.2115$), the number of side branches on a flowering stalk ($P=0.7647$), or the number of fruit produced ($P=0.5009$) for the 2003-04 growing season. Further, a logistical regression showed that the initial bulb weight could not be used to predict if a bulb would produce a flowering stalk ($P=0.3033$). Lack of any correlation between initial bulb weight and reproductive success further indicates that the method of bulb selection used for this study did not result in any bias in the experimental results. Since initial bulb weight was not a significant predictor of reproductive success, this analysis was not completed for the second experiment (2005-07).

Bulb sprouting pattern.—As the bulbs were removed from the pots at the end of the 2004-05 season, we were particularly interested in examining bulbs that had been planted oriented parallel to the soil surface (S-bulbs, i.e., planted on their side) and bulbs that had been planted upside-down (D-bulbs). We had noted that the plants developing from these bulbs arose at the edges of the pots rather than from the center of the pot where the bulb had been initially planted. It appeared as if the bulbs sprouted and elongated until hitting a surface – in this case the pot wall – and then turned and grew upward until finally emerging from the soil surface. Upon digging up the bulbs, we verified that this was indeed the situation. In contrast, bulbs planted upside down (Fig. 3) seem to have grown downward until hitting the base of the pot, then grew obliquely until apparently hitting the side wall of the pot, and then finally completed an upward growth toward the soil surface. In these cases, no bulb reorientation to gravity occurred within the pots.

Harvest bulb weights – Experiment 1 (2003-05).—Bulb weights were not significantly different among treatments when first planted in 2003 ($P>0.05$). However, bulb weight among treatments when the bulbs were harvested in 2005 did differ in that the control Up–Native (UN) and Up–Greenhouse (UG) bulbs as a group were significantly smaller than the Side–Greenhouse (SG) and Down–Greenhouse (DG) treatment bulbs ($P<0.05$). Note also that average bulb weights in the Up–Greenhouse and Up–Native control groups were significantly less (t-test, $P<0.05$) when harvested in 2005 than those originally planted in 2003, whereas there were no significant differences in such bulb weights for the SG or the DG treatments ($P>0.05$, Table 5). Bulb weights tended to decrease in the UN and UG controls, whereas they generally increased slightly in the SG and DG treatments. Weight loss between seasons averaged more than 35% in the Up-Native (UN) and Up-Greenhouse (UG) controls, whereas weight gain averaged more than 5.5% in the SG and DG treatments.

Harvest bulb weights – Experiment 2 (2005-07).—Bulb weights were not significantly different among treatments ($P>0.05$) when first planted in 2005 and were also not significantly different among treatments when these bulbs were harvested in 2007 ($P<0.05$). However, it

Table 4. Summary of data relative to growth in CWI for the four treatments in the 2006-2007 study with percentage similarity to 2005-2006 for comparison.

Trait	UN	% 03-04	SD	UG	% 03-04	SD	S	% 03-04	SD	D	% 03-04	SD	Overall average	% 03-04
Infl (N)	7	44		9	64		12	80		5	83		8.3	65
Ave. Infl Height (mm)	417.4	64	33.8	654.4	79	29.6	685.0	87	41.5	553.0	88	38	577.5	80
Ave No. Branches	1.7	32	0.2	2.1	34	0.4	1.9	34	0.3	1.4	44	0.1	1.8	37
Ave No. Fruits	5.0	128	0.3	4.3	98	0.3	3.6	65	0.4	2.4	86	0.1	3.6	86

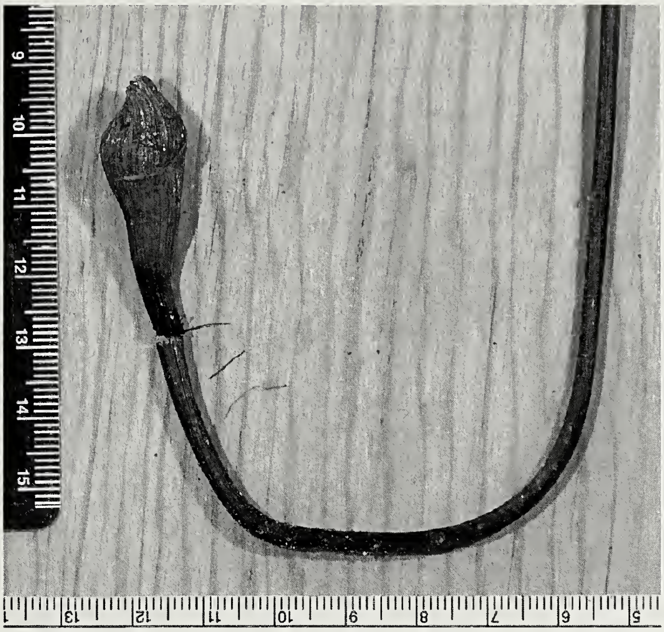

Fig. 3. Growth pattern in bulbs planted upside-down.

is interesting to note that the average weight of the bulbs planted in 2003 was significantly greater than those planted in 2005 (t=126.21, df=78, P<0.0001). The average bulb weight in 2003 was 4.82g, whereas the average bulb weight in 2005 was 2.61g (Table 6).

Reproductive success by treatment during the first two-year study (2003-05).—A comparison of sexual reproductive success between the two growing seasons can be seen in Tables 7 and 8. Note that most bulbs, with the exception of the D treatment, reproduced successfully during the 2003-04 growing season, but there was a substantial reduction in reproductive success in all treatments, with the exception of the D treatment during the 2004-05 growing season.

Discussion

The energetics of plant growth and reproduction is discussed by several authors including Fiedler (1987), Philippi and Seger (1989), and Fenner (1998), Miller, et al. 2004), and Marques and Draper (2012). In our study, CWI bulb orientation at planting in CWI clearly did influence the energy input that affected subsequent growth and reproduction, most notably in the tip-down

Table 5. Comparison of bulb weights for each treatment when bulbs were planted and harvested in 2005 and 2007.

Group	N	Ave. lf. width	SD	Leaf only	Flower stalk	flowers	Mature Fruit	D/D	% Repro
UN	20	12.7	0.1	1	-	-	19	-	95
UG	20	13.2	0.1	1	-	-	19	-	95
S	20	15.5	0.2	3	-	-	17	-	85
D	5	15.2	0.3	3	-	-	4	15	20
Overall Ave. %	81.25	14.2	0.2	7.5	0	0	73.7	18.8	73.75

Table 6. Comparison of the maximum stage attained for growth and reproductive success by treatment for 2003-2005.

Bulb orientation	2005 sample size (N)	Ave. bulb wt. 2005 (g)	SD	Ave. bulb wt. 2007 (g)	SD	2007 sample size (N)	Ave. wt. loss or gain	SD	Range of wt. loss or gain
UN	20	2.43	0.5	3.37	0.9	14	+39%	0.8	−3 to +124%
UG	20	2.67	0.2	2.95	0.4	15	+10%	1.9	−41 to +317%
SG	20	2.69	0.8	3.21	2.1	20	+19%	1.7	−87 to +175%
DG	20	2.66	1.1	2.72	2.3	7	+2%	2.0	−69 to +250%

(D) treatment. Fruit-set for the D treatment was uniformly low, 20% for both years of experiment 1 and 25% for both years of experiment 2.

When all bulbs were removed from the pots at the end of experiment 2 and weighed, it was apparent that the values for the control bulbs (UN and UG) were, in nearly all cases, noticeably lighter in weight than those recorded for the original bulbs planted in 2003. In contrast, over half of the bulbs surviving from the other two treatments (S and D) weighed more than the original bulbs. This may mean that the successful growth and fruit-set in UN and UG bulbs during the first year required substantial energy and resulted in the subsequent formation of smaller bulbs (possessing less stored energy) and in fewer bulbs setting mature fruit during the second season. Bulb weight (as an indicator of stored reserves) and, therefore, reproductive success, thus may partially explain the episodic reproductive success that has been recorded for several species of *Calochortus* (Fiedler 1987; Miller and Douglas 2001); Miller et al. 2004). That is, the bulb dormancy that often follows years of substantial reproduction may be explained, at least in part, by the formation of insufficient energetic reserves to allow for successful reproduction in consecutive years (Fenner 1998; Marques and Draper 2012). However, other factors may also play a significant role in reported cases of apparent synchronized bulb dormancy (dormancy across sites within the species geographic distribution), as has been suggested by Miller et al. (2004).

When bulbs were examined and weighed at the end of experiment 2, the weights were not significantly different from one another. In all treatments including the tip-down (D) bulbs, bulb weight at harvest in 2007 did increase somewhat although not significantly over the weight of the bulbs when initially planted in 2005. Harvested bulb weights in 2007 were similar for the two control treatment bulbs (UG and UN). However, the increases in harvested bulb weights for the tip-down (D) and side-planted bulbs (S) were greater at the end of 2005, than they were in those bulbs harvested at the end of 2007. In contrast to the pattern of bulb weights observed at the end of experiment 1 (2003-05) in which the control plants (UN and UG) decreased an average of over 40% (range +8 to −79%) in their bulb weight, the bulb weights of these two control treatments actually showed an average increase over initial bulb weight of about 25% (range −3 to +317%) during experiment 2 (2005-07). The decreased bulb weight during 2003-05 was in

Table 7. Comparison of the maximum stage attained for growth and reproductive success by treatment for 2005-2007.

Bulb orientation	2005 sample size (N)	Ave. bulb wt. 2005 (g)	SD	Ave. bulb wt. 2007 (g)	SD	2007 sample size (N)	Ave. wt. loss or gain	SD	Range of wt. loss or gain
UN	18	9.6	0.1	10	1	-	7	2	35
UG	19	8.1	0.2	9	2	1	7	1	35
S	20	9.3	0.1	7	4	1	8	-	40
D	13	9.9	0.3	6	3	-	4	7	20
Overall Ave. %	87.5	9.2	0.2	40	12.5	2.5	32.5	12.5	32.5

Table 8. Comparison of the maximum stage attained for growth and reproductive success by treatment for 2005-2007.

Group	N	Ave. lf. width	Leaf only	Flower stalk	Flowers	Mature fruit	D/D	% Repro
UN	18	9.6	10	1	-	7	2	35
UG	19	8.1	9	2	1	7	1	35
S	20	9.3	7	4	1	8	-	40
D	13	9.9	6	3	-	4	7	20
Overall Ave. %	87.5	9.2	40	12.5	2.5	32.5	12.5	32.5

sharp contrast to the manipulated bulbs (S and D), which did not have the reproductive success of the two controls during (2003) the first growing season (95% for both controls -- UN and UG, 85% for S and 20 % for D), but also did not suffer nearly the subsequent bulb weight decrease of the controls (in fact, manipulated bulbs experienced an average bulb weight gain of between 5.7% (D) and 9.5% (S) during the first two years of that study – 2003-05). Even the difference in final bulb weights between these two treatments may be the result of their relative expenditure of energy during the two years of the study for growth and reproduction. An examination of the growth patterns of these two treatments during the first two-years of this study (2003-05) would seem to support this conclusion since the amount of growth required to break the soil surface and establish an initial basal leaf (required for photosynthetic activity) by the D bulbs versus the S bulbs appeared to be substantial.

During experiment 2 (2005-07) bulb weights of the two control treatments (UN and UG), as well as the two manipulated treatments (S and D), actually showed an increase in average bulb weight (of about 17%) with UN showing the largest average weight gain of 39%, compared to 10% for UG, 19% for S, and 2% for D. It may be that the planting of smaller bulbs in 2005 at the beginning of the second two-year study produced a greater tendency for these smaller bulbs to put less energy into reproduction and more into carbohydrate storage in the bulb (Fielder, 1987). It would appear that the growth patterns exhibited by these two treatments (S and D) would necessitate a greater energy expenditure just to break the soil surface and begin to produce energy by photosynthetic activity in the basal leaf. However, during both two-year studies (2003-05 and 2005-07), the greatest average weight increase in S and D bulbs at harvest was 2% in D bulbs in 2007 and 19% in S bulbs in that same year.

Sexual reproductive success during experiment 1 (2003-05), as measured by the percentage of bulbs forming mature fruit, dropped off substantially for most plants during the second season (2005) with values of 30% for UN bulbs, and 40% for UG and S bulbs. Only the D bulbs were able to maintain the same, albeit low, level of reproductive output (20%) during the two years. A similar pattern of reproductive success was observed for experiment 2 (2005-07) in which 45% of the UG bulbs, 60% of the S bulbs and 25% of the D and UN bulbs produced fruit. Only the D bulbs maintained the same level of reproductive output between the two years even though the number of successfully reproducing plants was much smaller than that found in the other three treatments. All other treatments showed a decline in reproductive output.

Implications for management strategies indicate that bulb death and/or dormancy are far greater in the D treatment (upside down polarity) during both experiments than in the controls (UN and UG) or the S treatment, although this condition also did appear to increase in the UN bulbs during the 2007 of experiment 2. However, the treatment bulbs that did survive (both S and D) were able during both studies, on average, to store up a greater mass of photosynthate than did either of the control groups. This latter unexpected observation may possibly result in greater long-term survival and establishment of bulbs planted with these orientations in new populations in the mitigation areas, but this clearly requires examination over a longer study period before recommendations can be made. A consistent pattern of reduced survival of all treatment bulbs became apparent in the second year of each of the two sets of replicated studies. It may be that *Calochortus* bulbs do not do well when kept longer than one year in pots under controlled conditions.

A number of aspects of this study would seem to warrant further examination. For example, D bulbs that did emerge from dormancy during both years of the first two-year study began doing so between one and two months after the tip-up controls (UN and UG) and 2-3 weeks after the side-planted group. Maximum emergence of D bulbs was five plants in 2003-04 and 13 in 2004-05. During the second two-year study (2005-07), D bulbs seemed to emerge from dormancy faster than in the first two-year study (2003-04).

Tip-up controls planted in native soil (UN) presented the most complex patterns of response. Reproductive success, as measured by fruit-set, varied among treatments during the four years of study. Fruit-set in plants from UN bulbs was low in first year of each experiment (2003-04 and 2005-06), but improved in 2004-05 and 2006-07 when UN plants produced the highest number of fruits per flowering stalk. Fruit-set in plants from D bulbs was usually among the lowest in each of the four years of this study (2003-04, 2004-05, 2005-06, and 2006-07). Plants from UG and S bulbs varied noticeably in reproductive output, but did have the highest reproductive output in first year of each two-year study (2003-04 and 2005-06).

As previously noted, low fruit-set in plants from D bulbs makes sense from an energetic standpoint, since more energy would have to be devoted to the growth of the stem from the bulb to the soil surface than in the other three treatments. This energetic constraint seems to be corroborated by the low survival rate of the D bulbs at the end of each two-year study (in 2005 and 2007), when their survival rate was between 35% and 65% of that of the other three groups (UN, UG, and S bulbs). However, the variation in fruit-set in the other three treatments is more difficult to explain and requires further investigation. Further, at present, the reasons for the various differences in fruit-set with time in the ground (first and third years versus the second and fourth years of this four-year study) for the plants derived from UN and D bulbs needs further examination.

From the above summaries, it can be seen that bulb orientation at planting did have an influence on both qualitative and quantitative aspects of growth, i.e., on the timing of some processes and on the size and/or numbers produced by these processes, but the pattern that emerged in each experiment during the second year (2004-05 and 2006-07) was dissimilar in many ways from that found during the first growing season (2003-04 and 2005-06). The only consistent pattern to emerge was that many fewer bulbs planted in the upside down (D) orientation survived and/or set mature fruit each year than in the other treatments. Therefore, care should be given to ensure that bulb orientation during replanting of salvaged mitigation bulbs is accomplished with the bulbs planted in the proper polarity (growing tip upright). For the other parameters (e.g., bud formation, flower opening, and fruit set), planting orientation did not appear to be the major factor influencing the timing of the process (ambient/soil temperatures, soil moisture levels, and/or photoperiod would seem to be more likely cues).

Several of the quantitative effects may also be a consequence of carbohydrate availability limitations reflected in the limited number of D bulbs that emerged during the first season as compared to the second season (5 versus 13 in 2003-04 versus 2004-05). As stated above, the D treatment experienced the largest bulb mortality of all treatments during the course of each of the two-year studies. It is interesting to note, however, that surviving D bulbs actually registered an average weight increase of 5.7% in the second year bulbs during the first two-year study (end of 2005), which was second only to the 9.5% weight increase seen in comparable S bulbs. However, although the surviving D bulbs did experience an average weight gain of 2% during the second two-year study (when the bulbs were harvested in 2007), all three other treatments experienced a greater average bulb weight gain (UN=39%, UG=10%, and

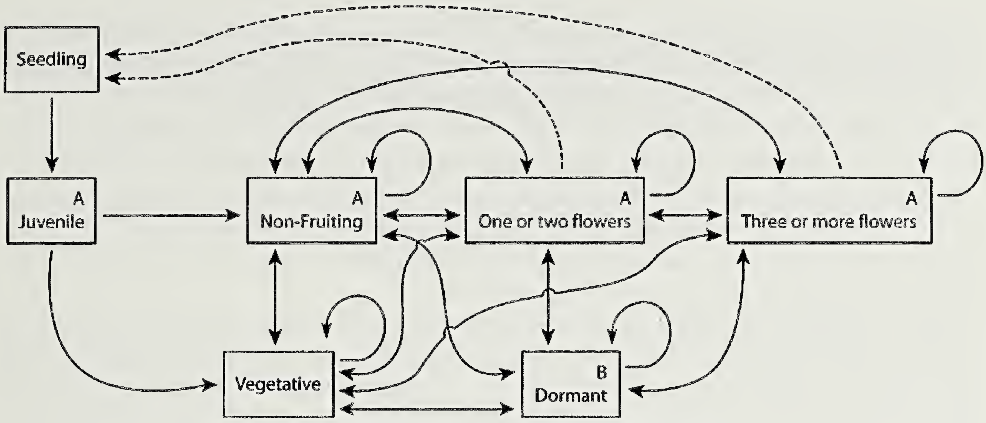

Fig. 4. Model for growth and development in CWI.

S = 19%). It is unknown why the results for bulb weights at the end of each of the two-year studies is so different, but it may be related to the differences in average bulb weights at initial planting during 2003 and 2005 of each study. The significantly smaller size of bulbs utilized during the second two-year study (starting in 2005) may have contributed to this difference, since smaller bulbs tend to devote much of their photosynthate production to increasing bulb reserves to a point that ensures a greater probability of a successful reproduction event (Fiedler 1987; Philippi and Seger 1989; Fenner 1998; Worley and Harder 1999).

Judging from the current data, it is quite possible that bulb orientation at planting may not be a significant factor in the long-term survival of individual bulbs. However, from the standpoint of bulb population mortality rate, it would be better to plant the bulbs in either an upright or, at least, a sideways orientation and avoid, if possible, an up-side-down orientation. An additional aspect of interest arising from our four-years of study (2003-07) was the degree of dormancy seen in bulbs that were initially planted in the up-side-down orientation. It would seem that this increased dormancy could create problems when trying to assess the effectiveness of bulb transplantation as part of the mitigation process, in that bulb survival could potentially be greatly underestimated if monitoring of the project to determine transplantation success rate is limited to one year. It is additionally apparent from our study and from the literature (see Fiedler 1987 and Miller et al. 2004 as examples) that population densities of naturally occurring geophytes, such as CWI, may be greatly underestimated due to dormancy episodes that can last a single year or more. It is currently unknown which internal or external factors may induce such dormancy in natural populations, although Miller et al. (2004) found that such episodes were apparently synchronized across sites within the geographic distribution of a given species.

As an aid to further investigative efforts, the data collected in this study and data from the final report to LSA Associates 2008 for vegetative data not reported here were used to develop a preliminary model for growth and development in CWI (Fig. 4). Plants producing greater than three flowers are much more likely to set mature fruit than are ones with fewer flowers. This is probably related to the availability of greater photosynthate reserves stored in the bulbs from which the former plants normally arise. If the photosynthate reserves are reduced for any reason, the bulbs may produce a smaller plant that: 1) has only one or two flowers; 2) may be non-fruiting; 3) may be strictly vegetative; or 4) may even go dormant for one or more years. Bulbs may produce new smaller bulbs asexually if an external stimulus, such as some type of stress, initiates the process (Fiedler 1987). Some bulbs may even have a genetic predisposition toward this type of cloning. Each stage may remain in that condition for a year or more (Fiedler 1987).

Conclusions

The data from this study do indicate that: 1) bulb planting orientation does influence survival, growth, and reproduction and 2) proper bulb planting polarity (orientation) should be an important consideration in any transplantation of this or any sensitive bulb producing plant species for mitigation purposes. Based on our results, we predict negative effects if the shoot apical meristems of salvaged bulbs are not carefully planted in a normal tip-up orientation during transplantation. We predict that negative effects would include one or more of the following: 1) abnormal bulb dormancy or death; 2) abnormal energy-wasting subterranean growth patterns; and 3) suppressed sexual reproduction, at least in the short term.

Figure 3 illustrates what happens when D or S bulbs turn upward after coming in contact with the pots. It appears there may be a lack of negative gravitropism in this species. We recommend future studies should investigate this possibility by planting D and S bulbs in the ground and following what then occurs. One would expect negative gravitropism to affect the growth of the shoot, but it may take longer to occur and further deplete the energy reserves of the bulb reducing the survival and reproductive output of these bulbs. As an aid to further investigative efforts, the data collected in this study were used to develop a preliminary model for growth and development in bulb producing plants.

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A Baseline Investigation into the Population Structure of White Seabass, *Atractoscion nobilis*, in California and Mexican Waters Using Microsatellite DNA Analysis

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Abstract.—The white seabass, *Atractoscion nobilis*, is a commercially important member of the Sciaenidae that has experienced historic exploitation by fisheries off the coast of southern California. For the present study, we sought to determine the levels of population connectivity among localities distributed throughout the species' range using nuclear microsatellite markers. Data from the present study have revealed distinct genetic breaks between the Southern California Bight, Pacific Baja California, and the Peninsula of Baja California.

The white seabass, *Atractoscion nobilis*, is the largest species of croaker (Sciaenidae) occurring off the coast of southern California (Miller and Lea 1972) and has been highly prized historically by commercial and recreational fisheries. Declines in catches of white seabass have occurred historically to the point that population numbers had dropped to critically low levels (Pondella and Allen 2008). These declines have been followed by increases in commercial catches due to management strategies such as the prohibition of gill-nets along the southern California coast (Allen et al. 2007; Pondella and Allen 2008). Despite the economic importance of the white seabass and its history of over-exploitation and rebound, information on population structure life history has been limited.

What is known of the life history of the white seabass is that the species is a broadcast spawner, with males fertilizing eggs that females release into the water column. In regards to larval abundance, larvae are generally observed most frequently south of the Southern California Bight (SCB) (the faunal region of ocean extending from mid Baja California northward to Point Conception, CA) in the areas around Sebastian Viscaino and San Juanico bays off the coast of Baja California. (Moser et al. 1983). Donohoe (1990) and Franklin (1991) studied the abundance, distribution, age and growth, and food habits of young seabass from different regions of the SCB (the mainland coast between Point Conception to the Mexico border, and along the coastlines of four of the Channel Islands) and determined that the portion of the species' range that occurs within the SCB may be the northern extreme of the area where spawning can occur. It also appears that this portion of the SCB may support lower than expected successful settlement of seabass larvae. Allen and Franklin (1992) examined the settlement success of young seabass in this region and determined that recruitment success depends on larval availability as opposed to environmental factors (e.g., bottom water temperature, pH, lunar periodicity, etc.). In recent years, valuable information on spawning activity, sound production, and adult movements have been the subject of numerous studies (Aalbers 2008; Aalbers and Drawbridge 2008; Aalbers and Sepulveda 2012, 2015).

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The white seabass is distributed throughout the northeastern Pacific from Alaska to the tip of the Baja California peninsula and into the Gulf of California (Miller and Lea 1972; Eschmeyer et al. 1993). Numerous biogeographic and phylogeographic barriers have been described within the distribution of the white seabass (Rawson et al. 1999; Stepien et al. 2000; Dawson 2001; Dawson et al. 2001; Jacobs et al. 2004; Dawson et al. 2006; Robertson and Cramer 2009) with the most prominent being the San Quintín upwelling zone (Selkoe et al. 2007; Paterson et al. 2015) and the Peninsula of Baja California (Bernardi et al. 2003). As data indicate that the northernmost range of the white seabass along the Pacific coast of North America may be within the SCB and that the majority of breeding and recruitment within this region occurs off of the coast of Pacific Baja California, population substructure may exist within this species due to the effect of these barriers on population connectivity resulting in different stocks that may need to be managed separately. Recently, Romo-Curiel et al. (2016) used otolith isotope analyses to investigate the existence of distinct subpopulations of white seabass along the California and Pacific Baja California coastlines. Two distinct subpopulations of white seabass were observed and these authors suggested that the likely break occurs in the vicinity of Punta Eugenia (Romo-Curiel et al. 2016). Based on the distribution of the white seabass spanning several biogeographic barriers and the observation of two putative subpopulations by Romo-Curiel et al. (2016), the objective of this project was to use nuclear microsatellite loci, genetic markers with relatively high mutation rates and a bi-parental mode of transmission that makes them ideal for testing gene flow among populations (Avise 2004; Wang 2010), to establish a baseline estimate of the population connectivity within and among white seabass localities from throughout the range of this economically important species.

Materials and Methods

Tissue samples of white seabass (gill filaments or fin clips) were obtained by gillnets, spear, and hook-and-line from the three putative regions spanning the distribution of the species within the northeastern Pacific: two groups of localities within Southern California (SC) north of the San Quintín upwelling zone including the California Channel Islands (Anacapa Island, Santa Cruz Island, Santa Rosa Island, Santa Barbara Island, Santa Catalina Island, and San Clemente Island; $n = 69$) and along the California mainland coast (Santa Barbara, Ventura, Hermosa Beach, Long Beach, Newport Bay, and Mission Bay; $n = 57$), along the mainland coast south of the San Quintín upwelling zone (Pacific Baja California; $n = 16$), and within the northern Gulf of California (GC) (San Felipe, Baja California and the Midriff Islands; $n = 17$) (Fig. 1) between the summers of 1990 and 1993. All samples were preserved in NET* (2.5 M NaCl, 0.25 M EDTA, 0.25 M Tris base, pH 8.5) and placed on wet ice in the field followed by long-term storage at −20°C at the California State University, Northridge.

Nuclear DNA was isolated by phenol-chloroform-isoamyl alcohol extraction followed by cold ethanol/ammonium acetate precipitation (Sambrook et al. 1989). Five species-specific microsatellite loci, ATRNOB-D, ATRNOB-E, ATRNOB-F, ATRNOB-K, and ATRNOB-R (Appendix 1), were used to genotype white seabass individuals following the protocols of Franklin (1997). Departures from Hardy-Weinberg Equilibrium (HWE), observed heterozygosity (H_O), and expected heterozygosity (H_E) were estimated for each sample locality in GENEPOP 4.0 (Raymond and Rousset 1995; Rousset 2008). Linkage disequilibrium (LD) was tested in FSTAT 2.9.3.2 (Goudet 2003). FSTAT was also used to determine the total number of alleles and to estimate average allelic richness (A_R). STRUCTURE 2.3.3 (Pritchard et al. 2000; Falush et al. 2003; Falush et al. 2007) was used to assign individuals to putative clusters/subpopulations (K) of white seabass that minimize linkage disequilibrium and deviations from Hardy Weinberg equilibrium. Number of subpopulations was estimated with

Fig. 1. Locations where genetic samples of *Atractoscion nobilis* were obtained within the three general regions (Southern California – SC; Pacific Baja California – PB; and Gulf of California – GC) of the Northeast Pacific Ocean.

20 independent runs of K = 1-10 with each run consisting of 10^6 MCMC repetitions and a burn-in of 10^5 steps under the admixture model with correlated allele frequencies. The optimal number of subpopulations was estimated using ΔK of Evanno et al. (2005) as implemented in STRUCTURE HARVESTER (Earl and vonHoldt 2012). Similarity among STRUCTURE replicates was assessed using CLUMPP 1.1.2 (Jakobsson and Rosenberg 2007) utilizing the greedy algorithm.

Global population structure was estimated by Analysis of Molecular Variance (AMOVA) (Excoffier et al. 1992) as implemented in GENALEX 6.501 (Peakall and Smouse 2006). To determine the effect of the San Quintín upwelling zone and the Peninsula of Baja California in restricting population connectivity, a hierarchical AMOVA based on three regions corresponding to areas adjacent to either side of these potential barriers (Mainland/Channel Islands — Pacific Baja California — Gulf of California) was performed in GENALEX. Pairwise population estimates of F_{ST} were generated for all pairs of sample localities in GENALEX. F_{ST} is commonly used to assess population subdivision, however, due to the high mutation rate of microsatellites resulting in elevated heterozygosities, F_{ST} may underestimate population subdivision (Rousset 1996). Therefore, Hedrick's G''_{ST} (Hedrick 2005; Meirmans and Hedrick 2011) and Jost's D (Jost 2008) were estimated in GENALEX. Both estimators produce values between

Table 1. Summary microsatellite statistics for *Atractoscion nobilis*. *N*, number of individuals, H_O avg. observed heterozygosity; H_E avg. expected heterozygosity; *A*, number of alleles; A_R, avg. allelic richness; *PA*, private alleles.

Locality	N	H_O	H_E	A	A_R	PA
Overall	159	0.719	0.733	69	-	-
Mainland	57	0.686	0.738	58	7.12	3
Channel Islands	69	0.739	0.743	65	7.39	5
Pacific Baja	16	0.713	0.582	18	3.43	3
Gulf of California	17	0.882	0.636	27	4.97	14

0 and 1 with 0 indicating complete panmixia and 1 being indicative of a lack of migration. All estimates of divergence were tested non-parametrically (9,999 bootstrapped replicates) and significance was tested via permutation and corrected for multiple testing by the sequential Bonferroni correction. Statistical power of the microsatellite loci used in the present study to detect genetic divergence and to reject the null hypothesis of panmixia among sampled white seabass localities was determined by power simulations conducted in POWSIM 4.1 (Ryman & Palm 2006). Settings for simulations were a minimum F_{ST} of 0.05, a value indicated by Balloux and Lugon-Moulin (2002) to be the upper threshold of weak divergence for microsatellite loci, 500 replicates, and sample sizes from populations after the simulated drift process equal to those of the present study.

Results

White seabass loci were all in Hardy-Weinberg equilibrium for each sample locality and did not demonstrate any evidence of linkage disequilibrium. All loci were polymorphic for all localities with the number of alleles ranging between 18 and 65 (69 overall) (Table 1), observed and expected heterozygosities ranged between 0.686-0.882 (0.719 overall) and 0.582-0.743 (0.733 overall) (Table 1), respectively. When taking into account sample size, allelic richness ranged between 3.43-7.39 (Table 1) with Pacific Baja California demonstrating the lowest allelic richness and Channel Islands the highest. Private alleles were observed in all localities with the Gulf of California possessing the greatest number (Table 1).

Based on results from both the log-likelihood and Evanno methods, a *K* of two had the greatest posterior support from the STRUCTURE analysis and a break was evident at Pacific Baja California between the Southern California (Mainland/Channel Islands) and the Gulf of California (Fig. 2). Significant genetic divergence was observed globally among all four localities (Table 2; $F_{ST} = 0.04, p < 0.005$). Results of the hierarchical AMOVA also revealed significant divergence between Mainland/Channel Islands — Pacific Baja California — Gulf of California (Table 3; $F_{CT} = 0.09, p < 0.0001$). Similarly, pairwise estimates of divergence also demonstrated two significant disjunctions in population connectivity corresponding to the breaks recovered by the hierarchical AMOVA (Table 4).

Discussion

Data from the present study of the white seabass demonstrate subpopulation structuring indicating three main sub-groups/populations within the northeastern Pacific: one in the north including the Southern California Bight, another in the south including Pacific Baja, and the last subgroup consisting of the members from the Gulf of California. This pattern of diversity has been supported by the STRUCTURE analysis (Fig. 1) and divergence estimates based on allele frequencies (Table 2) and pairwise comparisons of sample localities (Table 3). A note on the STRUCTURE analysis, although STRUCTURE is generally used to assign individuals to

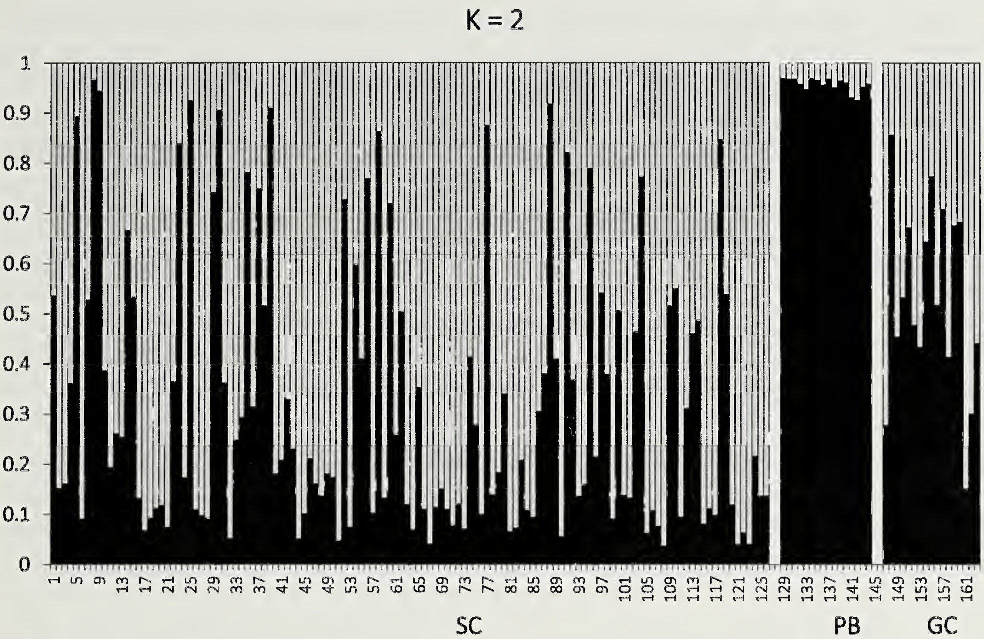

Fig. 2. STRUCTURE analysis of *Atractoscion nobilis*. Localities (Mainland (MD), Channel Islands (CI), Pacific Baja California (PB), and Gulf of California (GC)) are separated by whitespace from left to right. Overall analysis of allelic frequencies suggested that a strong break exists at Pacific Baja California separating Southern California (MD, CI, and EN) from Pacific Baja (PB), and the Gulf of California (GC).

subpopulations and to therefore infer population subdivision indirectly from these assignments, the methodology implemented in STRUCTURE has been demonstrated to have difficulties in assigning individuals when sample sizes are unequal (Kalinowski 2011) or when F_{ST} values are low (0.02-0.03 with 97% accuracy being attained at 0.05 or greater) (Latch et al. 2006). As sample sizes within the present study are skewed towards the Southern California Bight and pairwise estimates of divergence between the Gulf of California and the Mainland and Channel Islands are < 0.04 STRUCTURE may not have been capable of assigning Gulf of California individuals effectively or detecting the substructure that was identified by analyzing variances in allele frequencies (Tables 3 and 4). Based on this, the following discussion places greater weight on variance in allele frequencies than the results presented by STRUCTURE.

Hydrologic and zoogeographic data suggests that the Southern California Bight represents a faunal zone between Magdalena Bay, Baja California, to the south, and Point Conception to the

Table 2. F_{ST} values for *Atractoscion nobilis* from all four localities.

		F-Statistics		
Source of variation	d.f.	Sum of squares	Variance components	% variation
Among localities	3	20.877	0.076	4.33
Among individuals	155	250.953	−0.065	−3.68
Within individuals	159	278.000	1.748	99.35
Total	317	549.830	1.760	100
Fixation index (F_{ST})	0.04*			
***P* = 0.005**				

Significant *P* values after Bonferonni correction indicated by *.

Table 3. F_{ST} values for *Atractoscion nobilis* from three major regions (Southern California, Pacific Baja California, and Gulf of California).

F-Statistics				
Source of variation	d.f.	Sum of squares	Variance components	% variation
Among groups	2	20.385	0.161	8.76
Among populations within groups	1	0.492	−0.009	−0.49
Among individuals within populations	155	250.953	−0.065	−3.52
Within individuals	159	278	1.748	95.25
Total	317	549.83	1.835	
Fixation index (F_{ST})	0.09*			
P = 0.0001				

Significant P values after Bonferonni correction indicated by *.

north (Briggs 1974). The white seabass population affinities implied by microsatellite DNA analysis generally reflect the degree of intermingling expected from the prevailing hydrographic patterns along the California and Baja coastline. Oceanic patterns within the Southern California Bight from April to October (Lynn et al. 1982) as determined by dynamic heights, feature a general southerly flow at the surface (California Current). Originating in the subarctic Pacific, the California Current moves cold water towards the equator at maximum velocities of about 10 cm s^{-1}, leaving the mainland at Pt. Conception in the spring and flowing outside the Santa Rosa-Cortez Ridge. Thus the current diverges near the US/Mexico border, splitting into the Southern California Countercurrent (strengthened by the underlying Rodriguez current) that flows east and then north to border the mainland coastline and run the length of the Southern California Bight, and a southerly branch, that parallels the Baja coastline. By July to October, the California Countercurrent forms a large eddy (Southern California Eddy) virtually enclosing the Southern California Bight with the San Diego region at its southwestern border. Geostrophic flow in the eddy is less than 5 cm s^{-1}. Drift bottle studies (for example see Schwartlose and Reid 1972) reveal smaller eddies within the Southern California Eddy (that cannot be detected by geostrophic flow analysis): especially, a counterclockwise flow between Catalina Island and the mainland, and a clockwise flow between San Clemente Island and Catalina Island. These eddies increase the retention time and mixing of waters within the Southern California Bight. The divergence of the Southern California Countercurrent creates upwelling north of and including Bahia San Quintín. Water flows up from below the thermocline and away from the coast to create a nearshore lens of cold water south of the divergence. The water mass introduced into the SCB at this point is primarily cold water, and is devoid of larvae from many coastal fishes that occur as breeding adults in the waters about the nearby islands of the Southern California Bight (for example, see Moser et al. 1993). After leaving

Table 4. Pairwise F_{ST}, G''_{ST}, and Jost's D values for *Atractoscion nobilis* for the four localities. F_{ST}/G''_{ST} values are presented below the diagonal and Jost's D values above.

	Mainland	Channel Islands	Pacific Baja	Gulf of California
Mainland	—	−0.009	0.216*	0.122*
Channel Islands	0.003/−0.012	—	0.263*	0.105*
Pacific Baja	0.062*/0.294*	0.071*/0.350*	—	0.373*
Gulf of California	0.038*/0.170*	0.033*/0.148*	0.126*/0.501*	—

* indicates significant P values after Bonferroni correction ($P \leq 0.001$).

the Southern California Bight, the California current flows around the upwelling at Bahia San Quintin to encroach on Punta Eugenia. Because of the current flows, larval white seabass in this region most likely do not move into the waters of the Southern California Bight to mix with local stocks. Although currents may influence the distribution of species that utilize pelagic larval dispersal such as the white seabass, the region around San Quintin and Punta Eugenia has also been implicated as a barrier to gene flow for species lacking a pelagic larval stage, such as the black surfperch, *Embiotica jacksoni* (Bernardi 2000), and demonstrates the impact of the region on population connectivity among various lineages with differing dispersal strategies.

In addition to directional flow, the coastal upwelling and the subarctic origin of the California Current pose potential thermal barriers to larval fish. Upwelling around Bahia San Quintin in Mexico drops the water temperature in the area by as much as 8° C (11.0 vs. 19.0° C) in July (Alvarez-Borrego and Alvarez-Borrego 1982). The extent and annual duration of this temperature discontinuity is sufficient to significantly alter the ichthyofaunal assemblage of this region and has been indicated as a potential barrier to gene flow in the kelp bass, *Paralabrax clathratus* (Selkoe et al. 2007), the barred sand bass, *P. nebulifer* (Paterson et al. 2015), the spotted sand bass, *P. maculatofasciatus* (Chris L. Chabot pers. obs.), and the present study. While it seems that adult white seabass prefer cooler water temperature of 13-16° C (Aalbers and Sepulveda 2015), the temperatures that young-of-the-year (YOY) seabass encounter in areas of upwelling and in the California Current may restrict successful settlement. We found a positive correlation between YOY seabass occurrence, warm bottom temperature, and CPUE (Allen and Franklin 1988; Franklin 1991; Allen and Franklin 1992). Highest CPUE coincided with seasonally high temperature peaks for the three-year study and elevated bottom temperatures may be an important settlement cue for these fish as the number of larval seabass may be the most important factor that determines the success of settlement success. Although adult white seabass are capable of traveling great distances (up to 555 km) from the Southern California Bight north to central California (Aalbers and Sepulveda 2015), evidence that adults migrate between southern California and central Baja California is lacking at this time.

The divergence of the Gulf of California population of white seabass is consistent with the presence of a barrier to population connectivity originating somewhere in the vicinity of the Peninsula of Baja California. This warm-water region has been implicated in the divergence of several lineages with distributions on both sides of the Peninsula (Walker 1960; Stepien et al. 2000; Bernardi et al. 2003; Sandoval-Castillo et al. 2004; Bernardi 2014). As adult white seabass tend to prefer cooler waters, the warm tropical waters associated with the tip of the Peninsula are likely severing population connectivity between Pacific and Gulf populations resulting in the significant level of divergence observed in the present study.

Based on the results of the present study, three genetically distinct populations of white seabass have been observed within the northeastern Pacific. In support of this, recent ontogenetic comparisons of growth rates and otolith isotope analyses between Southern California Bight and southern Baja California white seabass populations have revealed significant differences between the two regions (Romo-Curiel et al. 2015; Romo-Curiel et al. 2016). As these populations demonstrate a lack of contemporary connectivity and are likely evolving independently, efforts to bilaterally manage US-Mexican white seabass fisheries should recognize the independent evolutionary trajectories of each population and manage them accordingly. Due to the isolated nature of these populations and their history of exploitation, any continued reduction in numbers will likely result in the loss of unique, possibly adaptive, genetic diversity and will place the species at risk in terms of future adaptive potential.

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Appendix 1. Microsatellite primers and repeat motifs for *Atractoscion nobilis*.

Locus	Repeat	Forward	Reverse
ATRNOB-D	CA_{30}	5′- ACT CAG CGT CTT TGT TTC TCA C -3′	5′- TGG TCC GTT TGT GTT CAG A -3′
ATRNOB-E	AAT_{19}	5′-CCA CGA AAA CAG AGC ATC AG -3′	5′- CCC AAA ACT ACA ACA AGC CA -3′
ATRNOB-F	TAA_{15}	5′-GAA TGG TGC CTG ATT TCT T -3′	5′- AGG GGA TTG TGA GGG AAT -3′
ATRNOB-K	GAG_9	5′- TCT TCC CTC CTG ACC TG -3′	5′-ATG CTT GAA TGT GAT TGA A -3′
ATRNOB-R	TTA_{11}	5′- CCT CAA ACA GTT CTC TCG TC -3′	5′- TCT TCA GAT AAA AGC AGG TAG -3′

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The Whitetail Damselfish (Family Pomacentridae), *Stegastes leucorus* (Gilbert, 1892), New to California Marine Waters with a Key to the California Species of Pomacentridae

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We report here on the first documented occurrences of the whitetail damselfish, *Stegastes leucorus* (Gilbert, 1892), in California and adjacent marine waters. Also, we provide a list of damselfishes (Pomacentridae) known from these waters and provide a key to the species.

On the weekend of 1–2 September 2012, Mr. Ken Kurtis observed a small, bright blue damselfish within the Casino Point Dive Park (33°20.9'N, 118°19.5'W) at Santa Catalina Island. Mr. Kurtis took a video of the fish, passed stills of these onto the second author, who tentatively identified it as a juvenile whitetail damselfish. This identification was made based on the characteristic bright blue color and the prominent black spot at the rear of the dorsal fin (Robertson and Allen 2015). On 7 September 2012, the second author located what was likely the same individual and, from September to early December 2012, filmed this fish on a number of occasions (Fig. 1). Still images taken from these videos were then sent to Mr. Daniel Gotshall and Dr. Giacomo Bernardi who confirmed the initial identification. Over this time, this individual remained in the same location—a depression just below the entry stairs in about 1–2 m of water.

After a series of storms in December 2012, the juvenile disappeared and was not seen again. On 2 August 2015, more than two years after the last sighting of the juvenile, the second author observed an adult *S. leucorus* (Fig. 2), identified by the brown body, light white band at the base of the caudal fin (that had faded over the last few months), and yellow margins on the pectoral fins (Thomson et al. 2000; Robertson and Allen 2015). This fish was observed for four months and is still present as of this writing. It lives in about 6 m of water, on an algae-covered rocky outcrop below, and adjacent to, the Casino breakwater. This is about 40 m from the juvenile's previous location. The fish appears to be territorial, always inhabiting an area of 4–5 m × 4–5 m that it defends from juvenile garibaldi, *Hypsypops rubicundus* (Girard, 1854). This individual likely shelters at night as, over these four months, the second author has never seen it in its daytime territory. We speculate that this fish may be the individual first observed in 2012 as it lives relatively close to where the juvenile was observed, although in an area that had rarely been surveyed by the second author during 2013 and 2014.

During 2015, there were several other sightings of *S. leucorus* in southern California. At Santa Catalina Island, Mr. Chris Evelyn photographed a juvenile off Howland Landing (33°27.6'N, 118°31.1'W) and there were also several (undocumented by us) reports of adult fish at Lover's Cove, located near the Dive Park. On 16 August 2015, Drs. Jack Engle and Dan Richards observed an adult near the southeast end of San Clemente Island at approximately 32°50.4'N, 118°22.2'W in a field of small boulders at a depth of about 10 m. In addition, on 25 October, a juvenile was observed and photographed by Mr. John Moore and Mr. Mark Pidcoe,

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Fig. 1. Juvenile whitetail damselfish, *Stegastes leucorus*, filmed during September 2012 at Santa Catalina Island. Photograph by William W. Bushing.

in about 15 m of water, off La Jolla Shores (about 32°51.5'N, 117°15.6'W). This fish was on the edge of La Jolla Submarine Canyon living within a patch of tunicates. Mr. Jovan Shepherd also photographed what was likely the same fish the next day in the same location.

In addition, Mr. Roger Uzun has provided us with video footage of large aggregations of young-of-the-year *S. leucorus* inhabiting shallow rocky areas around Islas Coronados (about 32°24'N, 117°14'W) just south of the US-Mexican border. He reports that there was a very heavy recruitment of this species to these islands during the summer of 2015. These juveniles are also territorial, again defending their territories against juvenile garibaldi.

Fig. 2. Adult whitetail damselfish, *Stegastes leucorus*, filmed during November 2015 at Santa Catalina Island. Photograph by William W. Bushing.

Table 1. Damselfishes (Family Pomacentridae) collected or observed in California marine waters. SIO = Scripps Institution of Oceanography Marine Vertebrate Collection.

Abudefduf troschelii (Gill, 1862). **Panamic Sergeant Major.** To 22.9 cm TL (Thomson et al. 2000). King Harbor, Redondo Beach, southern California (Pondella 1997) to Pucusana, Peru (Chirichigno and Vélez 1998), including Gulf of California (Fischer et al. 1995) and Islas Galápagos (Grove and Lavenberg 1997) and such offshore islands as Isla Socorro and Isla Clarión (Robertson and Allen 2015). Tide pools (Moser 1996) to 15 m (Robertson and Allen 2015).

Azurina hirundo Jordan & McGregor, 1898. **Swallow Damselfish.** To 17 cm TL (Robertson and Allen 2015). Anacapa, Santa Catalina, and San Clemente Islands, southern California (Richards and Engle 2001); Isla Guadalupe, Rocas Alijos, and Islas Revillagigedo (Allen and Robertson 1994). Shallow waters to perhaps 30 m (Robertson and Allen 2015).

Chromis alta Greenfield & Woods, 1980. **Silverstripe Chromis.** To 17.3 cm TL (J. Snow, pers. comm. to M. Love). Santa Catalina Island, southern California (Richards and Engle 2001), Islas San Benito, central Baja California (SIO 85-199), and (mainland) Arrecife Sacramento (29°40'N, 115°47'W; M. Love, unpubl. data), central Baja California to Pucusana, Peru (Chirichigno and Vélez 1998), including Gulf of California (Allen and Robertson 1994) and Islas Galápagos (Grove and Lavenberg 1997) and such offshore islands as Isla Socorro and Isla Clarión (Robertson and Allen 2015). At depths of 1–200 m (min.: Grove and Lavenberg 1997; max.: McCosker et al. 1997).

Chromis punctipinnis (Cooper, 1863). **Blacksmith.** To 30.5 cm TL (Miller and Lea 1972). Monterey Bay, central California to Punta San Pablo, southern Baja California (Miller and Lea 1972). At depths of 2–62 m (min.: Pondella et al. 2006; max.: M. Love unpubl. data).

Hypsypops rubicundus (Girard, 1854). **Garibaldi.** To 35.6 cm TL (Miller and Lea 1972). Monterey Bay, central California (Miller and Lea 1972) to southwest corner of Gulf of California, southern Baja California (Robertson and Allen 2015) and to Islas Revillagigedos and Islas Tres Marias (Robertson and Allen 2015). Intertidal to 39 m (min.: Mitchell 1953; max.: M. Love unpubl. data).

Stegastes leucorus (Gilbert, 1892). **Whitetail Damselfish.** To 17 cm TL (Allen and Robertson 1994). Santa Catalina Island, southern California (this paper) and Islas Coronados, northern Baja California (this paper) and Isla Guadalupe (Allen and Robertson 1994) and Islas San Benito (SIO 77-396), southwestern Baja California (Robertson and Allen 2015), Mazatlán, Mexico (Thomson et al. 2000), and such offshore islands as Isla Socorro and Isla Clarión (Robertson and Allen 2015). At depths of 0–18 m (min.: Robertson and Allen 2015; max.: SIO 77-396).

Miller and Lea (1972) listed two damselfishes (blacksmith, *Chromis punctipinnis* Cooper, 1863 and garibaldi) from California waters. With the occurrence of *S. leucorus*, six species are now known from California (Table 1). We provide a key to all California species.

Key to the Damselfishes of California

1a Body with 6 dark vertical bars; 1st and last stripe (on caudal peduncle) may fade in adults; blue or yellow in color: . . . . *Abudefduf troschelii*

1b Body with no bars 2

2a Body dark with white band at base of caudal fin and lacking spots; white, yellow, or light edge on pectoral fins; juveniles lighter, orange to yellow over purple to blue with a single dark ocellus at the rear of dorsal fin: . . . . *Stegastes leucorus*

2b Body orange, silvery, or with spots 3

3a Body orange; $\geq$15 soft dorsal rays; juveniles with blue spots on body: . . . . *Hypsypops rubicundus*

3b Body not orange and lacking blue spots; $<$15 dorsal soft rays 4

4a Body dark with black spots on posterior and caudal area: . . . . *Chromis punctipinnis*

4b Body without black spots 5

5a Body long, >3 body depths into standard length; body mainly silvery-blue in color; 12 dorsal spines; 27–31 lateral line pores: .... *Azurina hirundo*
5b Body shorter, about 2 body depths into standard length; body mainly one color (can be blue, black, or brown) with silver or white stripe along dorsal fin (can fade in large adults); 13 dorsal spines; 16–19 lateral line pores; juveniles without silver stripe but black body with iridescent blue stripes made up of spots: .... *Chromis alta*

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