



FREMONTIA

A JOURNAL OF THE CALIFORNIA NATIVE PLANT SOCIETY



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SPECIAL ISSUE: SEAWEEDS



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CALIFORNIA NATIVE PLANT SOCIETY

Dedicated to the Preservation of the California Native Flora

The California Native Plant Society (CNPS) is a statewide nonprofit organization dedicated to increasing the understanding and appreciation of California's native plants, and to preserving them and their natural habitats for future generations.

CNPS carries out its mission through science, conservation advocacy, education, and horticulture at the local, state, and federal levels. It monitors rare and endangered plants and habitats; acts to save endangered areas through publicity, persuasion, and on occasion, legal action; provides expert testimony to government bodies; supports the establishment of native plant preserves; sponsors workdays to remove invasive plants; and offers a range of educational activities including speaker programs, field trips, native plant sales, horticultural workshops, and demonstration gardens.

Since its founding in 1965, the traditional strength of CNPS has been its dedicated volunteers. CNPS activities are organized at the local chapter level where members' varied interests influence what is done. Volunteers from the 33 CNPS chapters annually contribute in excess of 87,000 hours (equivalent to 42 full-time employees).

CNPS membership is open to all. Members receive the quarterly journal, *Fremontia*, the quarterly statewide *Bulletin*, and newsletters from their local CNPS chapter.

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CNPS members and others are welcome to contribute materials for publication in *Fremontia*. See the inside back cover for manuscript submission instructions.

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For every seaweed there are stories, such as those for two Pacific coast kelps, the sea palm (Postelsia palmaeformis) and the ephemeral laminaria (Laminaria ephemera). Paul Silva relates the tales of their discovery and naming by Russian and Swedish explorers, keen-eyed Victorians, and resourceful Midwesterners.

CALIFORNIA'S NON-NATIVE SEAWEEDS
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It is well known that our terrestrial flora has numerous introduced species, some of which are especially noxious. Less well known are the weeds of the seashore flora. Several of these are discussed, in particular Caulerpa taxifolia, which can be extremely damaging to seaweed habitats.



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Many of us are familiar with the red alga "nori," which wraps around the rice in sushi. Few of us, however, realize that seaweed products are used extensively in numerous industries, including the preparation of foods and beverages, the manufacture of cosmetics, pharmaceuticals, and ink, and in textile sizing.

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Seaweeds are restricted vertically by the availability of light in deep water and by their ability to withstand desiccation in the intertidal zone. Each species has an optimal temperature range which determines its geographic distribution. The role of Point Conception in separating cold-temperate and warm-temperate floras is explained in detail.



INTERTIDAL MONITORING OF CALIFORNIA SEAWEEDS
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Marine biologists have documented the California intertidal for more than a century, but there remains much to decipher. Threats to the intertidal, both natural and man-made, have intensified efforts to monitor and further understand this fascinating ecosystem.

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THE COVER: Fronds and floats of *Macrocystis pyrifera*, the giant kelp, sometimes referred to as the "sequoia of the sea." An individual kelp plant can grow up to two feet per day. Kelp forests provide habitat and food for a wide range of life in central and southern California nearshore communities. Photograph courtesy of J. and J. Mondragon (www.mondragonfotos.com).

GUEST EDITORIAL

Our world is both challenging and inspiring, with moments of urgency juxtaposed with those of riveting beauty. The world of seaweeds is no exception. Last fall there was news of yet another old oil tanker off the coast of Spain that was in danger of breaking and spilling its cargo. To add insult to injury, this occurred along the same stretch of coast that had been inundated with oil just the year before. A request went out around the world via the Algae Listserv (www.seaweed.ie) for baseline data and for assistance with tackling the formidable task of remediation. Despite continuous wake-up calls, we still seem to be “asleep at the wheel” with respect to protecting the intertidal regions of the world and preventing these disasters from recurring.

Fortunately, the scientific community has been “waking up” for nearly half a century and is beginning to compile and synthesize long-term data sets that will document changes due to such events, and will thus provide ammunition in the fight for laws and policies that will protect our coasts and their native ecosystems, including the seaweed flora.

Worldwide this flora is impressive: there are some 8,000 species of marine algae—simple, salt-water dwelling organisms that, to quote Dr. Mike Guiry, professor of phycology, “fall into the rather outdated general category of ‘plants.’” The algae include three major groups which have evolved quite separately and are described by their accessory pigments: the reds (the most abundant), the browns (which include the kelps), and the greens (which may actually be part of the Plant Kingdom).

Along the coast of California we have a particularly rich flora of seaweeds, which includes some 700 species. This great diversity is due in part to the cold, upwelling ocean waters that bring nutrients and oxygen to our coastal intertidal regions. In addition, the geological forces that have formed our coast resulted in a gorgeous patchwork of uplifted rock, providing a multitudinous array of substrates for the seaweeds to anchor themselves with their holdfasts. Read about the diversity of California seaweeds in Paul Silva’s article on biogeography on page 18. And, as in the terrestrial flora, some seaweeds found in California are natives of other regions. Kathy Ann Miller writes about weedy seaweeds in her article on page ten.

Seaweeds themselves boast some amazing records. Consider the following: They have been found as deep as 268 meters in the waters of the Caribbean, as well as under the ice at Antarctica. The giant kelp, *Macrocystis pyrifera*, can grow up to two feet per day. Recently a whole new group of red coralline seaweeds have been discovered called rhodoliths, individuals of which are at least 150 years old, or which, if you take into account their capacity to reproduce vegetatively, may be thousands of years old.

Whether we are aware of it or not, our lives are impacted daily by marine algae, as they are used commercially in many familiar foods and products, such as the thickening agent of toothpaste and paint, and as the emulsifier in chocolate milk. They are the basis of a thriving industry off the southern California coast. Paul Silva writes of seaweeds and industry in his article on page 16.

Most native plant enthusiasts will celebrate with curiosity and appreciation California’s intertidal flora, but for those of you who might have less interest in these salt-water dwellers, you are at first teased in with two stories of seaweed discovery (page three) by Paul Silva. Professor Silva deserves special acknowledgement for his contribution to this issue, as he is one of the foremost authorities on California seaweeds.

—Kathleen Dickey
CNPS Santa Clara Valley Chapter
Member of the *Fremontia* Editorial Advisory Board

USEFUL WEBSITES AND CONTACT INFORMATION

Seaweed websites:

See “Seaweed Resources,” p. 30

California Native Plant Society (CNPS):

www.cnps.org, with links to conservation issues, chapters, publications, policy, etc.

To sign up for “NPCC News,” e-mail news on native plant science and conservation, send a request to npcc@cnps.org.

For updates on conservation issues:

Audubon Society www.audubon.org

Center for Biological Diversity
www.sw-center.org

Natural Resources Defense Council
www.nrdc.org

Sierra Club
www.sierrachub.org

Wilderness Society
www.wilderness.org

For voting information:

League of Women Voters
www.lwv.org, includes online voter guide with state-specific nonpartisan election and candidate information.

US Senate
www.senate.gov

US House of Representatives
www.house.gov

California State Senate
www.sen.ca.gov

California State Assembly
www.assembly.ca.gov

To write letters:

President George W. Bush
The White House
1600 Pennsylvania Ave. NW
Washington, DC 20500

Senator Barbara Boxer
or Senator Dianne Feinstein
US Senate
Washington, DC 20510

Your CA Representative
US House of Representatives
Washington, DC 20515

SEAWEEDS TELL THEIR STORIES

by Paul C. Silva

For every seaweed there is a story to tell, and getting to know these stories greatly enhances our appreciation of these diverse and beautiful plants. Here are two such stories.

SEA PALM

The western edge of the American continent was put on the map, literally and figuratively, when, on the 15th of July, 1741, the *St. Paul*, commanded by Alexei Chirikov, reached the shore of an island in what today we know as the Alexander Archipelago in southeastern Alaska. Vitus Bering, heading the Second Kamchatka Expedition and commanding the *St. Peter*, made landfall at Cape St. Elias at the tip of Kayak Island a few days later (on July 18th). The two ships had proceeded independently after having lost sight of one another in the fog.

The *St. Paul* returned to Kamchatka on October 8th, with most of the crew dead from scurvy. The *Saint Peter* was undergoing even greater hardships, being wrecked on the westernmost side of the Commander Islands close to Kamchatka. The crew overwintered on this island, which they named Bering Island in memory of their captain, who had died shortly after the shipwreck. In the spring, enough boards and nails were salvaged from the wreck to construct a small boat, which enabled only a handful of survivors to return to Kamchatka on August 25, 1742.

Tales of the great wealth of natural resources of “Bolshaya Zemlya” (“Big Land”), as the Russians initially called Alaska, quickly resulted in a flood of Russian adventurers, mostly trappers and fur traders. Their brutal treatment of the Aleut people and the near-extinction of the sea otter are well-known dark episodes of history. By



Postelsia palmaeformis, the sea palm, was named after the Estonian geologist and artist who painted seaweeds from nature during the 1826-1829 round-the-world voyage on the vessel *Seniavin*. Illustration from F.J. Ruprecht, 1852: *Neue oder unvollständig bekannte Pflanzen aus dem nördlichen Theile des stillen Oceans* [New or incompletely known plants from the northern parts of the Pacific Ocean], St. Petersburg.



Postelsia palmaeformis, the sea palm, growing with red algae and gooseneck barnacles. Photograph by G. Hansen.

1792 there was sufficient Russian presence in Alaska to warrant the establishment of a permanent settlement on Kodiak Island, followed in 1799 by the founding of the town of Novoarkhangelsk (New Arkhangel, now known as Sitka).

In order to supply food for the Russian colony, the government, in 1812, secured an area on the Sonoma County coast, which was planted with crops and protected by a fortification. It was named Rossiya (later called Fort Ross by Americans) while a nearby river was named Slavianka (later called Russian River by Americans). Trappers and fur traders were soon raiding the coast as far south as San Francisco. Russians competed with Americans for the eggs of sea birds, another lucrative item of trade. By 1840 nature's bounties were seriously depleted in northern California, and the Russian government, feeling the hot breath of the British to the north and Mexicans to the south, decided to abandon the project. The prestigious Academy of Sciences in St. Petersburg, upon hearing this decision, arranged for a young zoologist and naturalist, Ilya Vosnesensky, to go to Rossiya and survey the nearby animals and plants. The Sonoma coast has many spectacular kelps, and these were collected by Vosnesensky, who ignored the smaller seaweeds. His mission completed, the Russian government closed Rossiya in 1842,

selling the fort and its contents to John Sutter. Vosnesensky by this time was collecting in Baja California. His collections were sent to the Academy of Sciences, located in St. Petersburg.

The seaweeds collected by Vosnesensky were studied by Franz Josef Ruprecht, who was born in Austro-Hungary, studied medicine in Prague, and became the curator of botany at the Academy of Sciences at St. Petersburg in 1839. In 1852 Ruprecht published a paper in which he treated only five seaweeds and one seagrass from Sonoma County, but which is justly famous not only for the three new genera that he described, but also for the oversized and remarkably lifelike lithographs. The plate for *Egregia menziesii* is 1.46 meters long, has eight folds, and is spliced only once.

One of Ruprecht's new genera was the sea palm, which he named *Postelsia palmaeformis*. The generic name honors Alexander Philipou Postels, an Estonian-born geologist and artist who had painted seaweeds from nature while on board the *Seniavin* during the voyage around the world commanded by Friedrich Lütke (also transliterated as Litke) in the period from 1826 to 1829. In 1840, Postels and Ruprecht together had published a monumental "elephant" folio volume treating the collections of seaweeds made during that expedition. This very rare

book, *Illustrationes Algarum*, contains the original descriptions of many species that are common in California, although no collections were made south of southeastern Alaska. The specific epithet, *palmaeformis*, is self-explanatory, the resilient plants bending over in the surf reminiscent of palm trees during a hurricane or typhoon.

It may or may not be surprising that none of the several botanists who sampled the marine flora of Monterey during the late 18th century and early 19th century collected this quintessentially unique alga. Perhaps the reason for this lacuna is that the sea palm, hanging on for dear life on wave-swept rocks, signals would-be collectors to be on guard lest they find themselves in a similar life-threatening position.

Vosnesensky provided ample collection data. The three specimens illustrated in Ruprecht's plate were collected on an islet at the entrance to Bodega Bay, called by the natives "Omújüpai." They called the sea palm "Kakgunu-chale," whose meaning I do not know, but certainly it would have nothing to do with palm trees.

The sea palm belongs to the order Laminariales of the class Phaeophyceae (brown algae). It is one of several very distinctive kinds of kelp, as members of this order are called. It is essentially an annual, growing rapidly in spring,



In 1852 Ruprecht described one species of the surfgrass genus *Phyllospadix* (Zosteraceae Family). This plant is one of the few angiosperms that has adapted to life in the intertidal surf. Photograph of flowers and leaves by S. Sharnoff.

maturing in late summer, discharging spores, and remaining until the waves destroy it by relentless pounding or knock it off its perch. In the intense competition for space in the intertidal zone, *Postelsia* often finds itself perched on mussels or barnacles, which may be swept off the rocks all together. Overwintering is accommodated by the microscopic sexual plants that develop from the discharged spores. The fertilized egg begins development of the erect plant, but then waits until early spring, when rapid growth occurs. The spores often stick to the substrate close to the mother plant, so that in early spring a grove of very small "palm trees" may be seen surrounding the remains of the previ-

ous generation.

At the same time that Ruprecht described *Postelsia*, a Swedish around-the-world expedition on board the frigate *Eugenie* stopped in San Francisco Bay, where the naturalist, Nils Johan Andersson, collected a specimen of sea palm (probably from Point Lobos or Lands End on the Pacific side of San Francisco). This specimen was referred to a Swedish botanist, John Erhart Areschoug, who specialized in the study of kelps. Unaware of Ruprecht's work, Areschoug described the new species as *Virginia palma-maritima*. The generic name may bring to mind the State of Virginia or perhaps the Virgin Mary, but in fact it commemorates the leader of

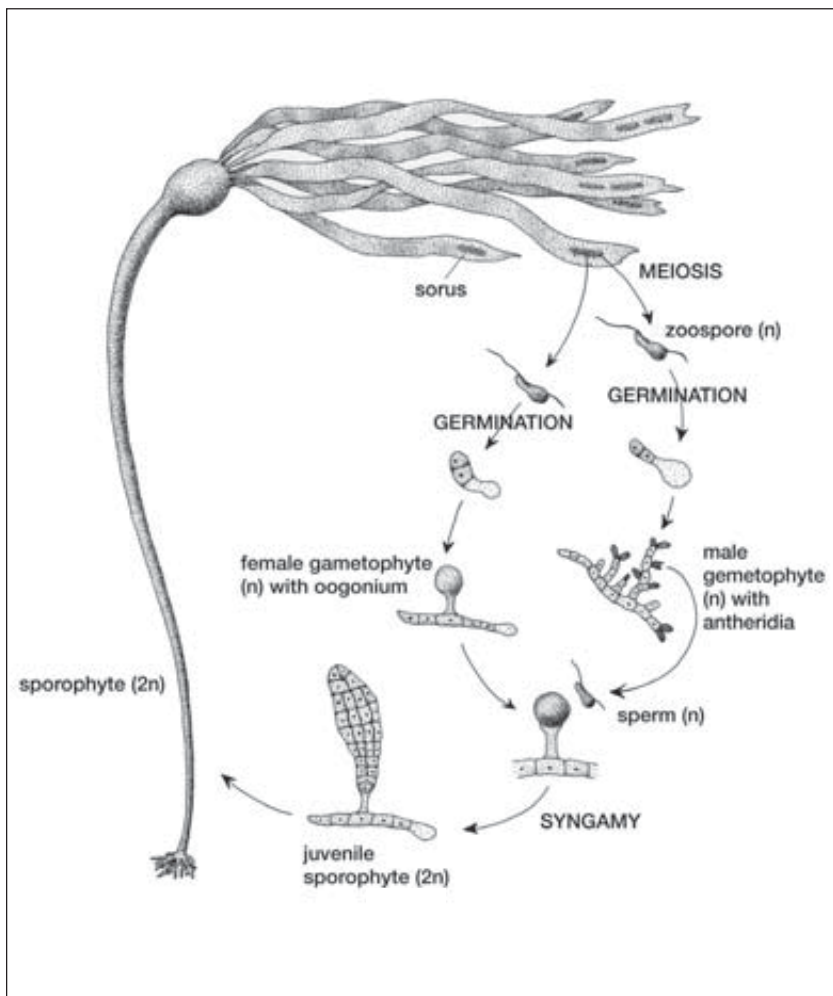
the expedition, C.A. Virgin. The epithet, *palmaeformis*, again is self-explanatory. Areschoug's paper was published in 1853, only a year after Ruprecht published *Postelsia*.

THE EPHEMERAL LAMINARIA

Our second story, involving another distinctive kelp, begins on the Monterey Peninsula, nearly a half-century later. *Laminaria ephemera*, as the specific epithet implies, is ephemeral, appearing in March and disappearing in August. It is attached to the substrate by means of a holdfast, from which there arises a stem ending in a simple blade. The blade produces an abundance of spores, which settle on a substrate and germinate to produce minute sexual plants. After an egg has been fertilized by a motile male gamete, the resulting zygote remains dormant or undergoes only the first stages of development into a macroscopic plant during winter. Growth of the new plants is very rapid in early spring, followed by maturation, spore discharge, and disintegration. *Laminaria ephemera* is one of only a few species of the genus that are annual. In most species the macroscopic plant is perennial, the stem continuing to increase in diameter while the blade is renewed at the beginning of each growing season after being torn away by the waves.

Laminaria ephemera is not only ephemeral, but also elusive, appearing in large numbers at only a few widely separated sites. It thus escaped the notice of naturalists on early expeditions.

It did not escape the sharp eyes of Mrs. J.M. Weeks, however, who first recognized its distinctness during one of her frequent forays to Carmel Bay. Mrs. Weeks was an enthusiastic and dedicated seaweed collector, as were several other ladies living in Pacific Grove during



The life cycle of the bull kelp (*Nereocystis*) is typical of all kelps, including *Postelsia palmaeformis* and *Laminaria ephemera*. Illustration by L. Scharf, from *Seaweeds of the Pacific Coast* by J. Mondragon & J. Mondragon (Sea Challengers 2003).

Pressed specimens of *Laminaria epebamera* collected by Mrs. J.M. Weeks, whose persistence and careful collecting habits succeeded in getting Professor W.A. Setchell's attention. Image use courtesy of the University Herbarium, UC Berkeley.



- These are *L. epebamera* Setchell
W.A. Setchell!



collected by Mrs. J. M. Weeks -

Mrs. J. M. Weeks Algae No. 129 Eco April 23-1897 - Carmel Bay, Monterey Co., Calif. - April 27, 1897
Laminaria Andersonii Fensholt, and *L. epebamera* Setchell.

the 1890s. Some were devoted to making spectacular mounts on deckle-edged cardboard to be sold in curio shops, perhaps to end up on someone's mantle in San Jose. Mrs. Weeks had a keen scientific interest and rejoiced when she learned that the University of California had added a phycologist to its faculty. That man was William A. Setchell, who was brought to Berkeley in 1895 to be the head of a newly organized botany department. Setchell brought with him extensive knowledge of the algae, having studied under the tutelage of two eminent cryptogamic botanists, Daniel C. Eaton of Yale University for his master's degree, and William G. Farlow of Harvard University for his doctoral degree. With this background, he satisfied both factions on the faculty—Yalees and Harvardmen.

Arriving in Berkeley two months after classes had begun, Setchell was impatient to sample the local flora. During Christmas break, he boarded a coastal steamer bound for San Pedro with a stop in both directions at Port Harford (now called Port San Luis). He collected seaweeds at the two sites. Shortly after the Christmas break, Setchell received an introductory letter from Mrs. Weeks (dated February), which he promptly answered, and thus began a lively correspondence that lasted through 1905.

The plant that was to be named *Laminaria ephemera* was first mentioned by Mrs. Weeks in a letter from Pacific Grove dated April 22, 1897, written upon her return from an excursion to Carmel Bay made in a phaeton pulled by "Old Lottie": "By this morn's Express sent a can containing a *Laminaria* of which I once found, some three or four years a single specimen / I had begun to think it a myth, as I could find no more of it / Yestermorning I came upon a great amount of it but my containing vessels & little cart were already full / I could not secure

enough for a set." (The "set" refers to the Phycotheca Boreali-Americana, a set of dried specimens sold to subscribers.) The remainder of the letter deals with possible arrangements whereby Setchell could either go to see the *Laminaria* or have it collected for him by a resident of Carmel. A year later, in a letter from "Carmel City" dated April 13, 1898, Mrs. Weeks wrote: "The *Laminaria* I sent you last spring is quite abundant. Do you care to see any more of it? . . . The plants are older than they were last year at this time. The stripes seem to be only an occasional feature / The sporangia cover a large portion of the frond. I noticed today on some I gathered to send away the disk was smooth & round about a fourth of an inch in diameter . . . I wish you might see them / They seem of the *Neriocystus* [i.e., *Nereocystis*] type . . ." A few days later (April 24), following Setchell's reply, Mrs. Weeks wrote: "In regard to the *Laminaria* I sent you: I need not say it is a painful disappointment to me not to be able to get at the plant. The portions of the beach that had enough of it accessible are bedded in with sand and all but the tips are buried. The sand shifts in a day. I can see it out in the deeper water but as the surf is bad there I don't feel strong enough to venture . . . I have been to a considerable expense in coming down here & am not very comfortable in the work . . . But I was so interested in that *Laminaria* that I came. Why do you call it *Andersonii* [*Laminaria andersonii*, a name misapplied to the species correctly called *Laminaria setchellii*]? It has no resemblance to that plant. Its holdfast is different from that, or indeed any other *Laminaria* I have known / Its stipe is tender / Its blade similar to the *Neriocystus* in substance and color."

Mrs. Weeks persisted, impatiently waiting for Setchell to study and describe this interesting seaweed. In a letter from Santa Cruz



Professor W.A. Setchell, photographed in his office, circa 1934. Photograph by W. Matthews, courtesy of the University Herbarium, UC Berkeley.

dated June 1, 1899, she wrote: "The *Laminaria* I sent is not in any particular like the one we have been in the habit of calling *L. Andersonia* / It is not the color, thickness, nor period of growth, or plan of forming sporangia of that plant . . . I thought when I commenced gathering it was young *Neriocystus* and wondered it grew so long without an air bladder & when I found a fully developed plant with several dark, even bands of different widths [sporangial patches] running down the length of it, it dawned upon me that I had found a stranger to my previous collection . . . I showed one of my mounts to Dr. Anderson [a physician in Santa Cruz who was keenly interested in seaweeds] & he asked if I had painted the stripes / He had never seen it. I was very much in hopes you would get down in time to see & study it where it grew, for I think it is short lived".

LEARNED AMATEUR CONTRIBUTES TO SEAWEED SCIENCE

Letter from Mrs. Weeks to Professor Setchell, demonstrating that although Mrs. Weeks was not a professional botanist, she was quite learned about seaweeds, not to mention classification and nomenclature.

msw
2-XII-98

Martinez, Nov. 18, 1898
Prof. W. A. Setchell

Dear Friend

I write

to enquire in what subdivision
Gloeosiphonia verticillaris &
Lomentaria ovalis are?

Have you assigned and named
the membranes provisionally
called *Kalymenia reticulata* &
" " " *corrugata*?

Is the *Halidrys osmundaceae*
Cystoseira " " " ?

The *Fucus* from Santa Cruz & the
flat thin bladed *Pelvetia* that I sent
from there, were they examined

and what are they? Did you find
more than one oospore in the flat
Pelvetia

There is a plant growing abundantly
in Carmel Bay that resembles the
Gelidium, Mr. Nott noticed it when
he was there the first time. I will
send a piece. I do not know what
it is. Dr. Anderson thought it
might be a *Gymnogongrus*. It is
not dichotomous

I found on looking over things
I had pressed free the rest of the
Nitophyllum I showed you I will
send a piece

Did I leave the *Fauschia* with
broad fronds? If I did please save it
for me. Your obliged Friend

J. M. Weeks.

msw
2-XII-98

Text of the letter reads as follows.

Martinez, Nov. 18, 1898

Prof. W. A. Setchell

Dear Friend,

I write to enquire in what subdivision *Gloeosiphonia verticillaris* and *Lomentaria ovalis* are? Have you assigned and named the membrane [sic] provisionally called *Kalymenia reticulata* & [ditto] *corrugata*? Is the *Halidrys osmundaceae* [ditto] *Cystoseira*? The *Fucus* from Santa Cruz & the flat thin bladed *Pelvetia* that I sent from there, were they examined and what are they? Did you find more than one oospore in the flat *Pelvetia*[?] There is a plant growing abundantly in Carmel Bay that resembles the *Gelidium*, Mr. Nott noticed it when he was there the first time. I will send a piece. I do not know what it is. Dr. Anderson thought it might be a *Gymnogongrus*. It is not dichotomous. I found on looking over things I had pressed free the rest of the *Nitophyllum* I showed you I will send a piece. Did I leave the *Fauschia* with broad frond? If I did please save it for me.

Your obliged Friend,

J. M. Weeks

Receipt of a reprint of the paper in which *Laminaria ephemera* was eventually published by Setchell was acknowledged by Mrs. Weeks on March 26, 1901, but it apparently wasn't until some months later (letter of November 25, 1901) that she discovered with chagrin that in the same paper Setchell had given the name *Weeksia* to a new genus of red algae. Previously, when Setchell had suggested describing a new species with an epithet commemorating its discoverer, Mrs. Weeks protested: "I am quite in earnest in not wishing my name attached to any plant" (letter of September 22, 1896). Mrs. Weeks summed up the feelings of all amateur collectors: "I shall rejoice when definition and classification are definitely & clearly settled" (letter of June 26, 1899). Incidentally, any shortcomings in Mrs. Weeks's writing should not be ascribed to lack of education: she graduated from Knox College in Galesburg, Illinois, in 1854, an unusual achievement for a woman of that period. Her own explanation strikes close to the heart of all marine phycologists: "You must excuse this if you can't read it readily as five days of rising about 3 A.M. & an ill turn make writing jerky business" (letter of June 20, 1897).

The story of *Laminaria ephemera* does not end here, but shifts to British Columbia, where Josephine E. Tilden, a professor in the botany department at the University of Minnesota, had established a biological station on the southwest coast of Vancouver Island with the financial help of one of her devoted students, Carolyn Crosby, whose family owned Crosby Mills (later General Mills). The station was near Port Renfrew, a port used for shipping logs from the adjacent forest. It was an idyllic site, with massive granite boulders covered with wave-beaten seaweed, including the sea palm (*Postelsia*). This seaweed was particularly striking, so that when Tilden arranged for the publica-

tion of a yearbook, she named it "Postelsia." One of her students, Robert F. Griggs, found an abundance of an annual species of *Laminaria* growing near the station, and unaware that it had already been described and named by Setchell, proceeded to describe it exhaustively in the 1906 edition of "Postelsia." He named it *Renfrewia parvula*. Griggs was impressed by the discoid holdfast vis-a-vis the stout branched holdfast of perennial species of *Laminaria* and thus established a new genus to accommodate the local species and a previously described Japanese species. The holdfast of *Laminaria ephemera*, however, is not strictly discoid, often having rudimentary branches (haptera). *Renfrewia* currently is not recognized as a genus separate from *Laminaria*.

Although *Laminaria ephemera* is delicate and shy, seeking sheltered pockets in the lowest intertidal and upper subtidal zones, while *Postelsia palmaeformis* is rugged and resilient, defying the strongest of waves, they share similar stories of duplicated "discovery." Even those seaweeds that are less distinctive have stories to tell. Victorians, who were intrigued, even obsessed by the seaside, its salubrious climate, and the inspiring array of creatures, were moved to write poems, of which the following, of uncertain origin but found in M.M. Howard, "Ocean flowers and their teachings" (1846), is most appropriate:

*Oh! call us not weeds, but flowers
of the sea.*

*For lovely, and gay, and bright-
tinted are we!*

*Our blush is as deep as the rose
of thy bowers—*

*Then call us not weeds, we are
Ocean's gay flowers.*



Professor Josephine E. Tilden returning from the third Pan Pacific Science Congress held in Tokyo, 1926. Use of photograph courtesy of S. Ducker.

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Caulerpa taxifolia, a beautiful, aggressive invasive tropical green alga, appeared in a harbor near San Diego in 2000. Image courtesy of the University Herbarium, UC Berkeley.

CALIFORNIA'S NON-NATIVE SEAWEEDS

by *Kathy Ann Miller*

The seaweed flora of California is a world-class treasure. The magnificent diversity and abundance of seaweed populations reflect the dramatic sweep of our state's rich coastal environments and habitats—from the Pacific Northwest to the subtropics, including rocky shores and reefs, sandy beaches, and offshore islands. Our scientific knowledge of California seaweeds is young, beginning with the 1791 *Malaspina* expedition of discovery, growing through the efforts of European and east coast botanists, and coming of age with the collected works of W.A. Setchell and N. L. Gardner at the University of California at Berkeley. And yet, to this day, the delineation of species within our most common genera poses daunting challenges to phylogenists, who continue to pursue field, culture, and molecular studies to unravel relationships at every taxonomic level.

The current comprehensive

flora, *Marine Algae of California* (Abbott and Hollenberg 1976) lists 669 species of red, brown, and green seaweeds. The actual number is certainly much greater with the addition of recently described species, species yet to be described, and species that are currently arriving. Of those more recent introductions, some come to California naturally, through range extensions due to El Niño events and long-term climate change, but some arrive via humans who unintentionally introduce non-indigenous species on hulls of ships or, for example, by improperly disposing of aquarium plants.

Non-native or exotic species, especially those that spread like weeds, are both familiar and newsworthy. (Weeds, strictly defined, are plants that live where they are not wanted and are ecologically or economically harmful.) Since the beginning of civilization, humans have moved plants and animals to serve them, either intentionally to pro-

vide food, shelter, or companionship, or inadvertently, as hitchhikers. For hundreds of years, our terrestrial California has been gilded—and altered forever—by the unintentional introduction of European grasses; the list of introduced Mediterranean, South African, and Asian weeds is enormously long. Pampas grass! Yellow star thistle! Scotch broom! Fennel!

In the last few decades, we have come to realize that our estuaries and coastal oceans are also vulnerable to introduced species, including invasive species that can cause economic and ecological nightmares. There are an estimated 175 non-native species of plants and animals in San Francisco Bay alone, and the number continues to grow. Rapacious invertebrates and fish lead the list and grab the news—the Asian clam, Chinese mitten crab, green crab, northern pike, striped bass (an intentional introduction) are a few. But have you ever heard

of the infamous “Killer Weed,” *Caulerpa taxifolia*? There are invasive seaweeds here, too.

Determining the presence of exotic seaweed species can be difficult if we have not witnessed the introduction. We consider creatures to be native when they occupy the area in which they evolved; usually there are natural barriers to the dispersal of a species. Sometimes these barriers shift through natural habitat or climate changes, allowing a species to expand its geographic range. Sometimes we are able to access new areas via new technologies, such as scuba diving or submersibles, and revise our records for the ranges of species. But to distinguish *introduced* species from those that are *native*, we must rely upon the history of collection data coupled with our understanding of species distributions and natural dispersal of populations.

When specimens from our coast were sent back to European specialists, vague collection notes (“in mare australe”) and mistakes as simple as mislabeling were frequent, and have left a legacy of confusion. For example, it was recently discovered and confirmed with molecular data that the type locality (original collection) of a very common red seaweed known as *Iridaea cordata* was the tip of South America, not Vancouver Island, Canada, the provenance written on the herbarium sheet. That species name is therefore not applicable to our west coast species (now known as *Mazzaella splendens*, based on a California type specimen described by Setchell and Gardner). Similarly, the southern California rockweed *Hesperophycus californicus* was once known as *H. harveyanus*, based on a plant supposedly collected in Monterey in the 1830s—but probably collected in France and not *Hesperophycus* at all.

Furthermore, many of our common seaweeds have extraordinarily broad “cosmopolitan” geographic

distributions and it is hard to discern their history. These species are known as “cryptogenic” because their original provenances are hidden from us. The ships that brought early explorers to our coasts were wooden reefs supporting creatures from every port visited over multiyear voyages, and were probably significant sources of introductions, long before scientists established a baseline for what is indigenous. For example, *Asparagopsis taxiformis* is a red alga, originally described from an Egyptian specimen, but considered a cosmopolitan member of subtropical and tropical communities worldwide. It occurs in southern California (San Diego, and the southern Channel Islands). Is it introduced? Has it extended its range from Baja California, Mexico? Or has it “always” been here? We must critically revisit nomenclatural history because the basis of our knowledge of seaweed distributions is cultural as well

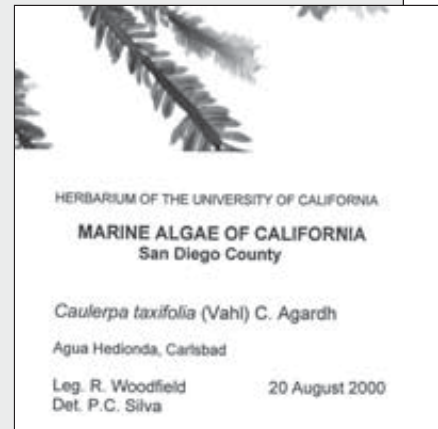
as biological.

Finally, as every amateur and professional phycologist knows, many species look extremely similar and are difficult to tell apart, constituting complexes of what may be cryptic (hidden) or sibling (closely related) species. Learning more about our seaweed flora—and detecting interlopers—is becoming increasingly important.

The Mediterranean Sea, with 85 introduced seaweeds, including nine that are considered invasive, is a hot spot for introductions. At the Thau Lagoon, an aquaculture site on the southern coast of France, 45 species of seaweeds (23% of the flora) are exotics, probably introduced with the Japanese oyster *Crassostrea gigas*. In contrast, we’ve recorded a modest 12 non-native seaweed species (or 2% of the seaweed flora) from our California coast. Most of these are diminutive and easily overlooked, and several have been reported only from our

SEAWEED SCIENTIFIC NAMES, COMMON NAMES, AND AUTHORS

For this article and those that follow, common names are only provided if available. Unlike terrestrial plants, most seaweeds do not have colloquial names. For purposes of precision, a scientific name may be followed by its author(s). If a species has been retained in its original genus, the author is the person who originally described the species, for example, *Postelsia palmaeformis* Ruprecht. If a species has been transferred to another genus, the name of the describer will appear in parentheses followed by the name of the person who made the transfer. Thus, the citation *Caulerpa taxifolia* (Vahl) C. Agardh indicates that this species was originally described by Vahl (in 1802 as *Fucus taxifolius*) and transferred to *Caulerpa* by C. Agardh (in 1817).



Label for only California collection of *Caulerpa taxifolia* at the University Herbarium, UC Berkeley. Herbarium labels rarely include the colloquial name of the plant collected, but always include the scientific name with its author.

own invasion hot spot, San Francisco Bay.

Good examples are *Aglaothamnion tenuissimum* (Bonnemaïson) Feldmann-Mazoyer and *Polysiphonia denudata* (Dillwyn) Greville ex Harvey, both small red filaments originating in England and detected in San Francisco Bay. More recently, another small red filamentous species, *Polysiphonia harveyi* J. Bailey, once thought to be a native of the east coast of North America, has been traced through molecular methods as originating in Japan and spreading, via several introductions, to the Atlantic, including the British Isles, New Zealand, and US, including California, where it has masqueraded as *Polysiphonia acuminata* Gardner and *P. simplex* Hollenberg. A great example of a sibling/cryptic species complex.

Another example of a sibling species complex that is yet to be teased apart is the green algal genus *Bryopsis*. In addition to *Bryopsis corticulans* Setchell, three bryopsidoid entities, with differ-

ent reproductive characteristics, are recorded from San Francisco Bay. One is entirely asexual, a good candidate for an introduced species (no need to find a mate). And by the way: *Bryopsis hypnoides* Lamouroux, reported from Humboldt Co. to San Pedro, was originally described from the Mediterranean. Like so many California cryptogenic species with far-flung distributions, we have to wonder: native or introduced?

The red alga *Caulacanthus ustulatus* (Mertens ex Turner) Kützing is a cosmopolitan, cryptogenic species, reported from Japan, Indonesia, South Africa, Spain, New Zealand—all places where plants have been designated as types for species now considered synonyms of *C. ustulatus*. This small, turfey species also occurs in Australia, Africa, India, and Hawaii, as well as British Columbia, Washington, and California. (As a student in 1979, I remember being shown a small population on Vancouver Island. Exotic! Exciting!) In southern California,

Caulacanthus has been observed at numerous sites during the last decade or so, but was not recorded during extensive Bureau of Land Management surveys 30 years ago. Just last year, I spotted a large red brown patch in the intertidal as I walked my sister's dog in a park on San Francisco Bay. This proved to be the first sighting of this species at the Bay. Where did it come from? How does it disperse? Are these new introductions, or is this species extending its range due to climate change?

Lomentaria bakodatensis Yendo is an inconspicuous red alga that has quietly spread from its native Japan to the Mediterranean, Philippines, Hawaiian Islands, Australia and the west coast from British Columbia, Washington, and Oregon to California and Mexico. We assume it is an exotic because it wasn't reported in early surveys (e.g., E. Yale Dawson's surveys of the Northern coast from Cape Mendocino to Crescent City). Because many of our California spe-



Bryopsis hypnoides, a green alga, was described originally from the Mediterranean. Line drawing from DeCew Guide, used with permission from P. Silva.

ILLUSTRATIONS FROM THE DECEW GUIDE

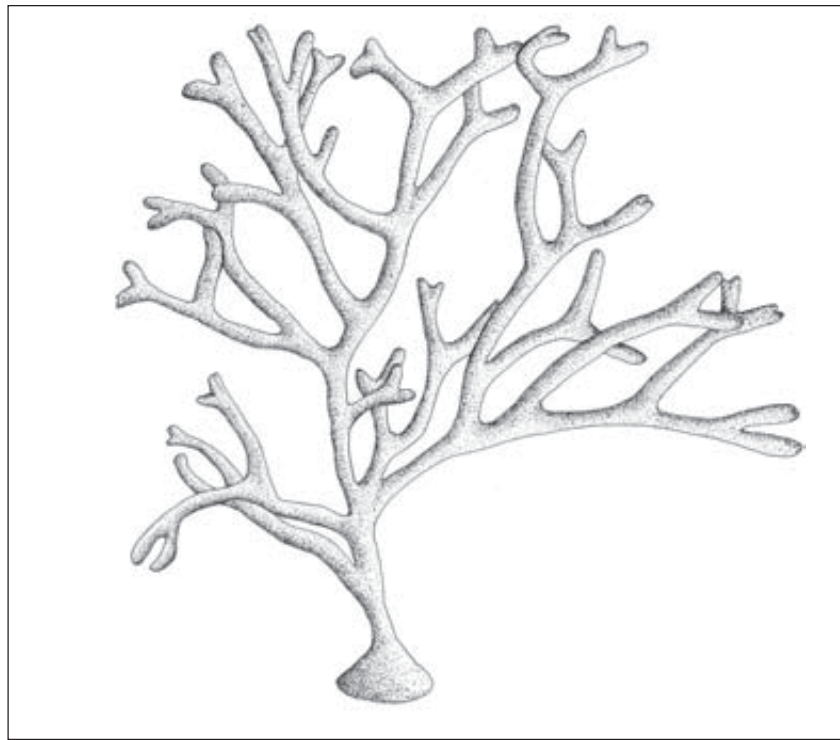
Throughout this article and within other articles in this *Fremontia* issue, illustrations appear from Tom DeCew's *Guide to the Seaweeds of British Columbia, Washington, Oregon, and Northern California*, a Web version of a book on northeast Pacific seaweeds conceived by the late Tom DeCew, and brought to its present state of completion with the collaboration of Paul Silva, Richard Moe, and Robert Rasmussen. DeCew planned the book as a detailed complement to *Marine Algae of California* by I.A. Abbott and G.J. Hollenberg (Stanford University Press, 1976).

For each of the species of macroalga (seaweed) that occurs relatively commonly in British Columbia, Washington, Oregon, or northern California, Decew assembled information from specimens in West Coast herbaria and from personal collections. Each page contains a graphic depiction of distribution and reproductive status, often along with a specially commissioned original line drawing. He also compiled all published references of scientific studies for each species. The Web version, which follows the layout of the book, including all of the data and most of the illustrations for the species of brown and green algae, can be found at <http://ucjeps.berkeley.edu/guide/>.

cies also occur in Japan, it is difficult to determine without good historical collections if a given species occurs naturally throughout the eastern and western north Pacific or if it is an introduction. *Gelidium vagum* Okamura is another small red alga, native to Japan, China, and Russia. It has a limited distribution in British Columbia and has now appeared in Tomales Bay, California. Since Tomales Bay is home to oyster mariculture, this species may have been introduced as a hitchhiker with oyster spat from Washington.

As in the Thau Lagoon, oysters have been the vector for many an introduced species, including *Sargassum muticum* (Yendo) Fensholt, a species that can be considered our first truly invasive species due to its rapid spread. Introduced to the west coast from Japan before World War II, it was detected in British Columbia in 1944, Oregon in 1947, Crescent City, California in 1963, Santa Catalina Island in southern California in 1970, and San Francisco Bay in 1973. While studies have not confirmed that *Sargassum muticum* is ecologically harmful, (e.g., displacing native species), it is certainly a conspicuous and abundant part of our intertidal and shallow subtidal communities. In 1973, when it arrived in the Solent region of southern England (possibly from a shipment of British Columbia oysters), efforts to eradicate it ended in failure, even after volunteers removed 475 tons over the course of three years. Such efforts here, if we chose to undertake them 30 years after the introduction, would surely fail as well.

Oyster mariculture may be implicated in the dispersal of the green alga *Codium fragile* subsp. *tomentosoides* (van Goor) P.C. Silva, another weed adept at asexual reproduction. *Codium fragile* comprises several well-behaved subspecies native to temperate Pacific coasts, but was lacking in the Atlan-



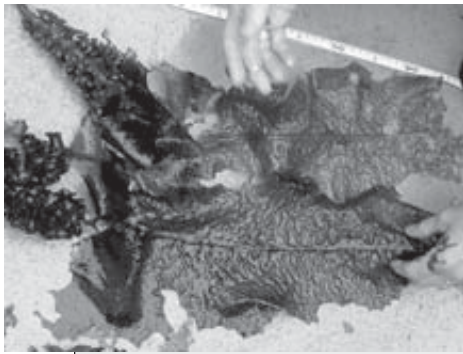
The distinctive “Dead man’s fingers,” *Codium fragile* subsp. *tomentosoides*, has the second, well-earned, name of “oyster thief.” Our native subspecies lives on the outer coast, while the invasive *C. fragile* subsp. *tomentosoides* has been found only in San Francisco and Tomales bays. Line drawing from DeCew Guide, used with permission from P. Silva.

tic until a weedy strain (subsp. *tomentosoides*) was introduced to the Netherlands from Japan (its presumed source) shortly before 1900. This weed has spread with increasing rapidity throughout the North Atlantic, including the Mediterranean and the North American coast from Nova Scotia to North Carolina. It is now at home in New Zealand, Australia, and California (San Francisco and Tomales bays). An herbivorous sea slug checks the growth of the weed in New Zealand. In England and Ireland, the weed has been reported to displace a native species, *Codium tomentosum*. In New England it overgrows and dislodges shellfish (thus earning the name “oyster thief”) and gangs up with an introduced bryozoan to displace native kelps. To date in California it is confined to two bays and is thus separated from our native subspecies, which is well represented on the outer coast from Alaska to Baja California, Mexico.

The next two non-native

seaweeds are infamous aggressors, though how they will play in California is yet to be seen. In 2000, both the green alga *Caulerpa taxifolia* (M. Vahl) C. Agardh, and the brown kelp *Undaria pinnatifida* (Harvey) Suringar showed up in southern California. News of the first has swamped interest in the second, because *Caulerpa* had proven itself to be a devastating plague in the Mediterranean. Distasteful to herbivores, it has covered acres of seafloor, out-competing native seagrasses and smothering native fauna.

The culprit is an escaped invasive aquarium strain, identified as originating in Australia and subsequently hybridizing with other strains, creating a strain tolerant of temperate waters. During eelgrass surveys, *Caulerpa* was discovered in a shallow lagoon, Agua Hedionda, near San Diego and in Huntington Harbor, California. Because the plant fragments and regenerates, it cannot be manually removed.



Undaria pinnatifida, native to Japan, Korea, and China, is known as wakame in Japanese cooking. Photograph by K.A. Miller.

PROTECT OUR COAST FROM AN INVASIVE KELP

Undaria pinnatifida originated in Asia and has spread around the world to Australia, New Zealand, South America, Europe—and now California. *Undaria* is unlike any other California kelp. Its blade is delicate (thin), elaborately lobed along the margin, and has a prominent midrib. It can be three to five feet long, and if you look closely, you'll see tiny dots scattered over the surface, formed by tufts of microscopic hairs. The reproductive structure (sporophyll) develops below the blade, just above the holdfast, and is unique in that it is deeply frilled, like old-fashioned ribbon candy. The blade persists from spring through summer, and then erodes back to the holdfast and sporophyll.

If you find this species, take a picture of it underwater. If this is not possible, collect a specimen for a photograph *but do not* throw it back into the water! Rather, dispose of it on land, and contact Dr. Kathy Ann Miller, Wrigley Marine Science Center, Santa Catalina Island, (310) 510-4012 (kam@usc.edu).

There are several websites with useful additional information about this seaweed (search the Web for *Undaria pinnatifida*). For example, the site at biology.usc.edu/people/potts/lonhart/undaria.html includes many images of this plant.



Holdfast of *Undaria pinnatifida*.



Blade of *Undaria pinnatifida*.

Caulerpa patches were covered with tarp and bleach was injected beneath. A couple of years of this treatment (and several million dollars) resulted in a tentative victory: *Caulerpa* has not been seen at these sites in more than a year, and has not been reported from new sites. Quarterly monitoring continues until complete

eradication can be declared.

Ten species and four subspecies of *Caulerpa* are sold in aquarium stores in southern California. Of these, 12 are capable of surviving in the temperate zone, and are potential escapees. Because of difficulties identifying the invasive strain, the chance of a new introduction is very

real until all species of *Caulerpa* are banned from the aquarium trade.

While news of *Caulerpa* reached the public in newspapers, television, and Internet reports, *Undaria pinnatifida*, a two meter long kelp native to Japan, Korea, and China silently skipped its way up the California coast from harbor to harbor, from Los Angeles to Santa Barbara. In 2001, it leaped to Monterey Harbor and a small cove on the leeward side of Santa Catalina Island. Over the past several decades, *Undaria* has invaded Europe, the Mediterranean, South America, and Australia and New Zealand, through deliberate introductions (it is a prized food) and probably by hitchhiking on the hulls of ships. Like many invaders, it has a broad tolerance for temperature and thrives in quiet water, especially in the presence of the nitrogen enrichment typical of harbors. In California harbors, it is a short-lived annual, recruiting in the early spring, and with a smaller pulse of new sporophytes in the fall at some sites, and then disappearing for the winter. Santa Catalina Island, one of the California Channel Islands, is the only site at which it co-occurs with native seaweeds in a relatively natural (non-harbor) setting. There it lives at record-setting depths (up to 24 m) in the clear offshore waters. In three years of observation at Catalina, *Undaria* has spread within the site, moving into shallower depths (including the understory of a giant kelp bed), but it has not extended its range to other sites around the island or other islands.

Because it is an annual, *Undaria* does not appear to compete with perennial native kelps, but it certainly warrants status as a potential pest, capable of usurping habitat for much of the summer. The California Department of Fish and Game is making efforts to eradicate it from Santa Barbara harbor, and volunteer groups are chipping away at the Catalina and Monterey populations. However, many predict that

any effort to remove *Undaria* at this point is too little and too late. The kelp life history promotes long-term survival of the species through highly variable conditions. Each kelp plant is capable of dispersing millions of spores and establishing populations of the microscopic, filamentous sexual phase. *Undaria* is probably here to stay, although we should make every effort to eradicate it. Whether it will continue its march up the coast remains to be seen.

A final species deserves mention, because there is evidence that it may be establishing itself in California after years of unsuccessful introductions. This is the brown alga *Ascophyllum nodosum* (Linnaeus) Le Jolis, the knotted wrack native to the Atlantic, used to steam clams and lobsters or pack bait. It has been sighted floating in the Bay on many occasions over the years, surely as discarded packing material, but only this year has a sample been collected

The brown alga *Ascophyllum nodosum*, native to the Atlantic, is used to pack bait. It may be establishing itself in California after many years of unsuccessful introductions. Image courtesy of University Herbarium, UC Berkeley.



that might indicate that it has settled in. This too was floating, like the ecad (ecological form) of *Ascophyllum* called *scorpioides*; attached plants have not yet been observed.

This example reminds us that the establishment of a non-native species is not a simple slam dunk. Those species blessed with a peculiar suite of attributes (broad physiological tolerances, copious reproductive abilities, and facile dispersal mechanisms) still require a large dose of luck to establish on foreign shores.

To date *Sargassum muticum*, *Caulerpa taxifolia*, *Undaria pinnatifida*, and perhaps *Caulacanthus ustulatus* can be considered invasive weeds as well as non-native components of the California flora. What will the future hold? Introductions seem to be increasing (*Caulerpa* and *Undaria* arrived simultaneously in the new millennium), and the consequences of this global homogenization of species are mixed. Some, or perhaps most, introductions are benign or neutral, but others are disastrous, setting the scene for “invasional meltdowns,” facilitating other invasions and sometimes increasing the impact of subsequent invaders. I’ve often thought that the urchin-dominated habitats that have replaced some of our kelp forests in southern California are fine settings for the invasion of seaweed species distasteful to urchins, who could really challenge our native kelps to a run for their money. But luck has been with us, so far. It’s clearly more important than ever to continue to study our shores and to train our students to recognize our native California seaweeds—and the new arrivals.

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CALIFORNIA SEAWEED INDUSTRY

by Paul C. Silva

Seaweed industry in California was born of necessity. Prior to the First World War, the mines of Stassfurt, Germany, were essentially the world's sole source of potash, which is used in making fertilizers, fireworks, and explosives. To replace this source in wartime, the Hercules Powder Company established a plant on the shore of San Diego Bay to obtain potash (and other chemicals) by incinerating giant kelp (*Macrocystis* sp.). At the peak of activity, there were 1,100 employees, but compe-

tion from other sources of potash caused the plant to close soon after the war ended.

The Second World War also produced a crisis by cutting off our supply of agar, normally imported from Japan. Agar is one of three commercially important water-soluble polysaccharides found in seaweed. Although it is principally known as the gelling agent of the substrate on which bacteria are grown, it also has many industrial uses. Prior to 1940, it was extracted mainly from various species of

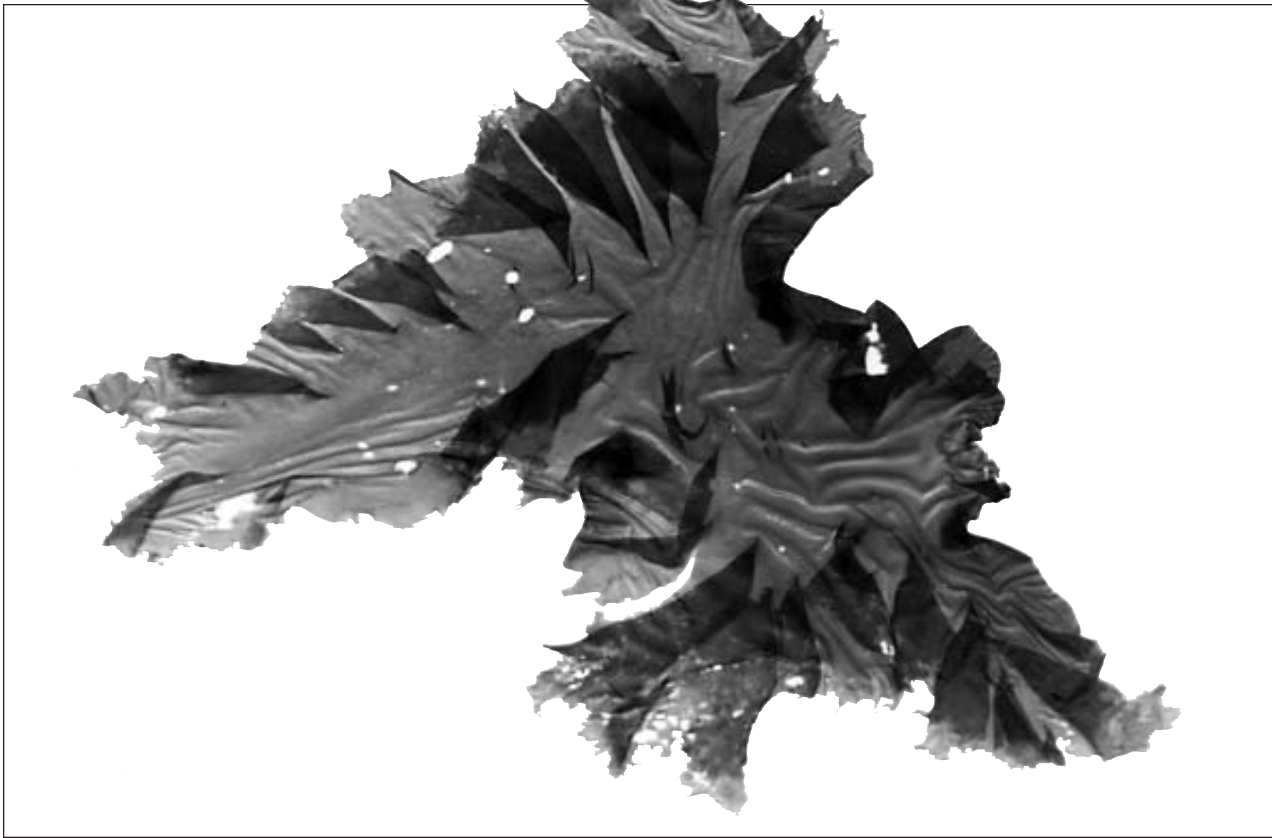
Gelidium, a red alga. The first agar factory in California was established in 1920 in Glendale, but operations were soon moved to San Diego. Initially, the chief function of the industry was to purify Japanese agar to bring it up to bacteriological standards, but with the supply cut off by the war, primary production was essential. The source was *Gelidium robustum*, which could be obtained in large quantities from fishermen in northern Baja California, where it grows abundantly in the lowest intertidal and shallow subtidal zones. Agar production in San Diego ceased about 1986 with the closing of the American Agar and Chemical Company, but the industry continues in Ensenada, Baja California.

The other two water-soluble polysaccharides ("phycocolloids") are alginate (the sodium salt of alginic acid), obtained from large brown seaweeds (kelps and rockweeds), and carrageenan, obtained from certain red seaweeds. All three phycocolloids are emulsifiers and are often used interchangeably, but they differ in certain physical properties so that each has its advantages. Both carrageenan and alginate, more than agar, are used in the making of dairy products, cosmetics, and pharmaceuticals, and in such industrial processes as textile sizing and ink manufacture. An alginate industry was started in San Diego in 1927 and thrives today under the name ISP (International Specialty Products) San Diego. The former Kelco Company figures prominently in the local history of this industry. The beds of *Macrocystis* that extend from San Diego to Monterey provide the raw material.

A small factory for processing carrageenan was operating in the San Francisco Bay area during the



This Kelco ship harvests and processes the tops of the giant kelp, *Macrocystis pyrifera*. The colloidal extract, sodium alginate, is used as a thickener in paints, dyes, beer, and canned foods. Use of photograph courtesy of J. Hansen.



Along with commercial, large scale harvesting, *Porphyra* sp., known as nori, is collected in northern California as part of a cottage industry.

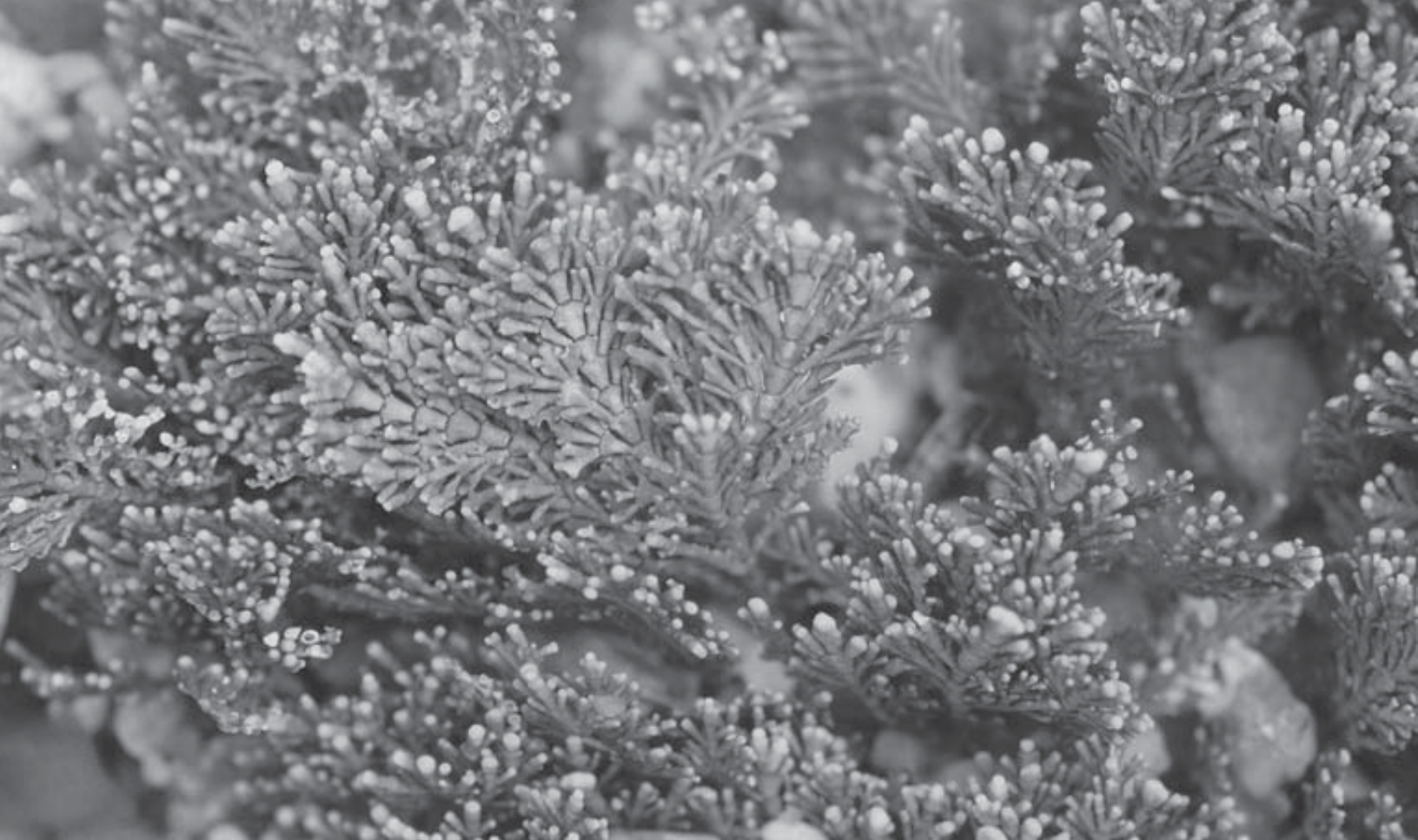
1930s, using *Mazzaella* spp. as a source, but the world market is now abundantly supplied, often saturated, by the output of seaweed farms in many tropical countries, especially the Philippines, where carrageenan-rich *Eucheuma* spp. is grown in ponds or on reefs close to shore. Historically, carrageenan was extracted from *Chondrus crispus* ("Irish Moss") by coastal peoples in the North Atlantic and used to thicken puddings.

In Japan, commercial production of foodstuffs from seaweed, especially amakusa nori from *Porphyra*, kombu from *Laminaria*, and wakame from *Undaria*, is big business, but no such industry has been established in California.

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A less utilitarian use of seaweed: toys made from bull kelp (*Nereocystis luetkeana*), with the air bladders forming perfect doll heads. Use of photograph courtesy of K. Hubbard.



Corallina vancouveriensis, a coralline alga, is a common inhabitant of the mid to low intertidal. Coralline algae are impregnated with calcium and may form a crust, be erect with jointed fronds, or both. Photograph by S. Sharnoff.

DISTRIBUTION OF CALIFORNIA SEaweEDS

by Paul C. Silva

Benthic marine algae, or “seaweeds” as those of us who know them on a first-name basis prefer to call them, are those algae that are attached to rocks, other algae, animals, or man-made structures such as wood pilings. They are big enough to see and feel, although it is necessary to use a hand lens or microscope to determine the essential structure of many small species. While their economic importance is insignificant compared to the role played by the microscopic phytoplankton at the base of the great ocean food web, their beauty and diversity have aroused the passion of naturalists for the past two centuries.

Seaweeds cling to the edge of

the continent, for the most part hidden from ordinary view. Few people have experienced the glorious sight of a rocky shore covered with a luxuriant growth of seaweeds exposed at extreme low tide. In California, such a sight is possible only very early on summer mornings or just before dark in winter. These times are dictated by the annual tidal cycle and are not likely to be chosen by the casual visitor to the shore. In addition, most people head for sandy beaches, where they encounter rotting masses of seaweed washed ashore, often giant kelp (*Macrocystis*) intertwined with feather boa kelp (*Egregia*), teeming with hungry critters, such as kelp flies and sand hoppers. Children like

to pop the floats of *Macrocystis* and use the *Egregia* as a jump rope. Thus the seaweed experience of most Californians would barely hint at the glorious diversity and beauty to be found in this fascinating group of plants.

VERTICAL DISTRIBUTION

Seaweeds do not venture upward beyond the splash zone because they must be washed by the sea at least once each day. Few species can tolerate the long periods of exposure imposed at high tide levels. As the tide level decreases, the number of species increases

markedly, the greatest diversity being found at the lowest tide level (about minus 0.6 meter on outer coasts of California) and in the adjacent subtidal fringe. Some species live only in the subtidal, at depths limited by the availability of light. When the water is exceptionally clear, a few species may grow at depths as great as 268 meters, as in the Bahamas (Littler et al. 1986). In California, the Channel Islands are noted for the clarity of the sea, being correlated with the absence of river runoff.

With increasing depth of water, the intensity of light decreases sharply while the quality of light changes dramatically. Red light is completely absorbed in the upper few meters so that a blue-green twilight prevails in deeper water. The various classes of seaweeds (red,

brown, and green), each of which has a characteristic complement of photosynthetic pigments that is effective in normal light, are adapted to living in deep water by the possession of accessory pigments with appropriate absorption spectra.

At very low tide, the exposed shore often appears to be divided into several horizontal zones, differing in color and texture depending on the species that find optimal growth conditions at those particular tide levels. Generally, one of the higher zones is comprised of members of the *Fucus* family, which are commonly called "rockweeds," while the lowermost zone is dominated by members of the order Laminariales, commonly called "kelps." The subtidal fringe is often bright pink from encrusting calcareous algae of the order Corallinales.

FLORISTIC ANALYSIS

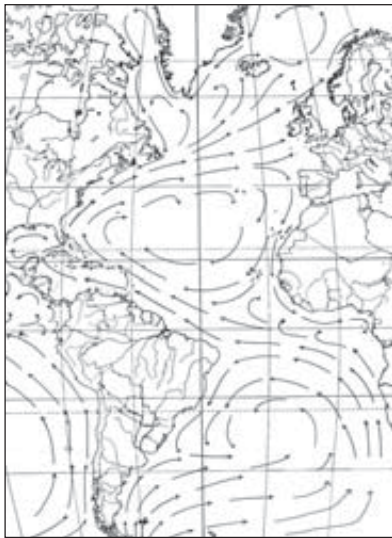
The coast of California is home to about 670 species of marine algae, a mere 12% of the number of higher plant species. Endemics (those species restricted to California) account for 14% compared to 24% for higher plants (Hickman 1993). By far the largest group of species (44%) are those that are essentially restricted to the Pacific Coast of North America, with ranges extending from some point north of California (some as far north as the Bering Sea) southward. This group includes mostly cold-temperate species, but also some that survive or even thrive in moderately warm waters. Another group (21%) are those that are essentially restricted to southern California and adjacent Baja California, constituting a warm-temperate flora. An equal number of species (21%) were originally described from areas other than the North American Pacific Coast and include so-called cosmopolitan species, introduced invasive species ("weeds" in the usual sense of the word), and many species with notably disjunct distributions that need to be confirmed by close taxonomic scrutiny. Many genera and even some species of the California marine flora are believed to occur also in Japan, but future molecular studies will probably reveal at least slight genetic differences between western and eastern Pacific populations.

TEMPERATURE: PRIMARY FACTOR IN DETERMINING DISTRIBUTION

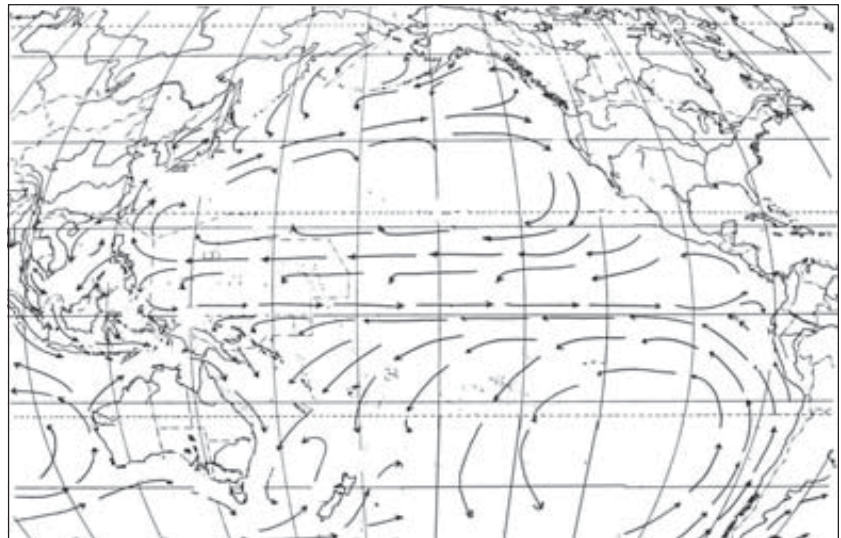
Temperature is the overriding factor in determining the geographic distribution of seaweeds, while oceanic currents impose and maintain the temperature regimes. The effect of the Gulf Stream on



Fucus gardneri, a rockweed, is a common inhabitant of the high intertidal zone. Line drawing from DeCew Guide, used with permission from P. Silva.



Oceanic currents in the Atlantic Ocean. Note particularly the Gulf Stream, which brings warm water from the equator to the eastern coast of North America and the Atlantic coast of Europe.



Oceanic currents in the Pacific Ocean. Note particularly the Kuroshio Current system, which brings warm water from the equator to the coast of Japan but ends as the relatively cold California Current.

climate is common knowledge. It originates as the North Equatorial Current and passes through the Straits of Florida with sufficient velocity to carry the warm water along the Atlantic coast of the United States as far as Cape Cod and across the ocean to the British Isles and Norway. Equally spectacular, but in reverse, is the Peruvian Current (formerly called the Humboldt Current), by which very cold water moving clockwise in the Southern Ocean is deflected by the tip of South America, sending it northward along the Pacific coast and imposing temperate conditions at tropical latitudes. Of greatest importance in the North Pacific is the Kuroshio Current system. Like the Gulf Stream, it originates as the North Equatorial Current and proceeds clockwise past the Philippines and Taiwan along the coast of southern Japan, where it is called the Kuroshio Current. North of Japan, it merges with the easterly drift of the North Pacific Ocean. On reaching North America, part of the current is deflected northward in a counterclockwise gyre in the Gulf of Alaska (Alaska Current) while part is deflected southward as the California Current.

The temperature of the currents is sharply reduced under conditions favorable to upwelling. In this process, prevailing westerly winds with cliffs to the left (in the northern hemisphere) push water, which has been warmed by the sun, along the coast. This forward movement is subjected to the Coriolis force (an effect of the rotation of the earth), which causes the warm water to be deflected to the right, away from the coast. Cold water then wells up from moderate depths. Low-lying coasts allow the winds to spread out and diminish in strength, while headlands confine the winds and thus intensify the effect of upwelling. In northern California and northern Baja California, intense upwelling begins in March and continues through July, with water temperatures in the spring lower than those of winter. When the prevailing north-northwest winds diminish and upwelling ceases in autumn, a relatively warm surface counter-current (the Davidson Current) flows northward along the coast, being especially noticeable from November through January. This counter-current is generated by the California Current and flows in all

seasons, but is pushed downward by upwelled water and moves upward when upwelling ceases.

In the southern hemisphere, the Coriolis force deflects the movement of water to the left, away from the coast as in the northern hemisphere since the cliffs that confine the winds are on the right. Upwelling along the coasts of Chile and Peru lowers the temperature of the Peruvian Current while upwelling in Namibia and Atlantic South Africa lowers the temperature of the Benguela Current. On the west coast of both South America and Africa, kelps, which are quintessentially cold-water plants, grow within the tropics.

Whether a current is warm or cold is relative. While the Alaska Current is sufficiently warm to ameliorate the climate of southern Alaska, the California current, enforced by upwelling, is cold in its northern reaches. Inshore water temperatures reach their maximum in late August and early September, but only in southern California do they reach 20°C or slightly higher. In northern California the usual annual range is 9-16°C.

Whereas the distribution of those species that grow in the in-

tertidal and shallow subtidal zones is controlled by the temperature of the surface water, those that live in deeper waters usually have a particular depth range correlated with temperature. For example, the kelp *Agarum fimbriatum* grows in the shallow subtidal zone in the Northwest, but it occurs in California only in deep water (to about 115 meters) in the Channel Islands, being inhibited by the warm surface water.

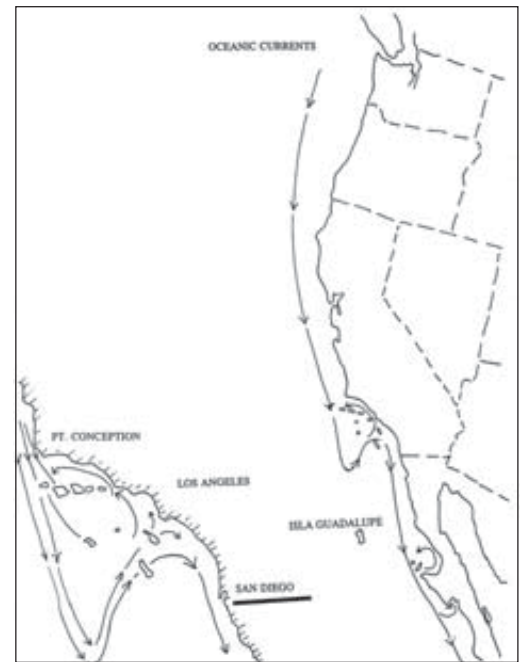
SECONDARY FACTORS IN DETERMINING DISTRIBUTION

When a species is within its acceptable temperature range, its distribution may be limited by lack of a suitable habitat. Factors influencing suitability include availability of a firm substrate, exposure to wave action, exposure to shifting sand and gravel, and salinity. Some species (called cumaphytes, or surf plants) are restricted to the most heavily exposed sites. Others prefer semi-protected reefs covered by sand. Most species have a particular niche, such as surf grass beds at zero tide-level, or the vertical sides of boulders. Most species can survive short periods of lowered salinity, but few can tolerate consistently brackish water. For example, many conspicuous species commonly found on the outer coast of central California are missing in San Francisco Bay, and those that are there penetrate to a distance from the Golden Gate in direct proportion to their tolerance of brackish water (Silva 1979). Whenever a creek discharges fresh water into the intertidal, the discharge will be accompanied by a brackish-tolerant flora composed of bright green strands (*Enteromorpha*) and blackish green carpets (blue-green prokaryotes, considered by some

biologists to be algae, and by other biologists to be bacteria).

GEOGRAPHIC DISTRIBUTION

The biogeography of the marine algae of California is a topic that has engaged me for more than 50 years. At the time that I began graduate work (1946), there was a widely held belief that Point Conception caused a major break in the marine biota, but there was no published evidence concerning seaweeds. The idea, which is largely zoological, is based on the lifelong work of William Healey Dall (1845-1927), a malacologist (Dall 1916). I doubt that during Dall's lifetime any significant collecting of molluscs or any other form of marine life was done in the vicinity of Point Conception. The coastline from Gaviota (just west of Santa Barbara) northward to Carmel Bay was nearly inaccessible prior to 1940. Highway 1 was built between Carmel Bay and San Luis Obispo County in the late 1930s, but was closed during the war. When I became immersed in the study of marine algae, I soon found that the only significant collections from along this stretch of coast were those made by (and for) Rhoda Ramona Reed, a master's student of Professor William Albert Setchell at Berkeley. Reed's family owned a ranch near Lion Rock on the northwest shoulder of Point Buchon in San Luis Obispo County. Collections from there and from "Oilport" were reported in a thesis that was submitted in May 1917 but was never published. Reed gave the location of her father's ranch as "Pecho," and indeed there is a Pecho Creek and Pecho Rock nearby. "Oilport" was a facility built in 1907 east of Port San Luis in San Luis Obispo Bay at a site now occupied by Shell Beach. Inexplicably, "Oilport" is



Oceanic currents along the west coast of North America. Note that the California Current flows southward past Pt. Conception into northern Mexico before reversing directions and sending a branch northward into the Southern California Bight.

neither in Goode's *California Place Names* nor in Jepson's index of geographical names. Reed extended the range of several species hitherto known only as far south as Monterey, and this information would have been useful to future workers had it been published. In the absence of published information on this stretch of coast, generalizations on the role of Point Conception in biogeography were in fact based on comparisons between the biota of Santa Barbara and that of the Monterey Peninsula.

During the period 1946-1952, at the suggestion of Gilbert Morgan Smith, my major professor at Stanford University, I collected intensively along the California coast, as well as on the Channel Islands of southern California and the mainland and coastal islands of northern Baja California. It turned out that Point Conception does indeed play an important role in the geographic distribution of Pacific coast marine algae (and assuredly marine animals as well), but

TABLE 1. SOUTHERN END-POINTS OF CONSPICUOUS COLD-TEMPERATE SEAWEEDS RESTRICTED TO THE MAINLAND OF CALIFORNIA (BUT INCLUDING THE FARALLON ISLANDS). COUNTIES ARRANGED FROM NORTH TO SOUTH.

Humboldt County

unspecified
Acrosiphonia spinescens (Kützting) Kjellman
Porphyra papenfussii Krishnamurthy
Porphyra pseudolanceolata Krishnamurthy
 Trinidad
Palmaria becatensis Hawkes
 Cape Mendocino
Sphacelaria racemosa Greville

Mendocino County

Point Cabrillo (near Caspar)
Coilodesme bulligera Strømfelt
Weeksia coccinea (Harvey) Lindstrom

Sonoma County

Shell Beach
Porphyra torta Krishnamurthy
 Bodega Head and Bay
Cumathamnion sympodiophyllum Wynne & Daniels
Odonthalia washingtoniensis Kylin
Porphyra sanjuanensis Krishnamurthy

Marin County

Tomales Bay
Chaetomorpha cannabina (Areschoug) Kjellman
Fucus spiralis Linnaeus
 Duxbury Reef
Laminaria groenlandica Rosenvinge
Odonthalia lyallii (Harvey) J. Agardh
Porphyra fucicola Krishnamurthy
Ulvaria obscura var. *blyttii* (Areschoug) Bliding

San Francisco County

San Francisco (City) and San Francisco Bay
Acrosiphonia saxatilis (Ruprecht) Vinogradova
Elachista fucicola (Vellely) Areschoug
Lola lubrica (Setchell & Gardner) A. Hamel & G. Hamel
Percursaria percursa (C. Agardh) Rosenvinge
Porphyra kanakaensis Mumford
Ralfsia fungiformia (Gunnerus) Setchell & Gardner
Urospora doliifera (Setchell & Gardner) Doty

Farallon Islands

Mazzaella parksii (Setchell & Gardner) Hughey et al.
Ulva conglobata Kjellman

Santa Cruz County

Greyhound Rock
Plocamium oregonum Doty

Monterey County

Monterey Peninsula
Arthrocardia silvae Johansen
Fauchea fryeana Setchell
Hollenbergia subulata (Harvey) Wollaston
Monostroma grevillei (Thuret) Wittrock
Porphyra abbottiae Krishnamurthy
Porphyra miniata (C. Agardh) C. Agardh
Porphyra schizophylla Hollenberg
Pylaiella tenella Setchell & Gardner
Rosenvingiella constricta (Setchell & Gardner) Silva
Serraticardia macmillanii (Yendo) Silva
Stictyosiphon tortilis (Ruprecht) Reinke
 Point Lobos
Chibaraea bodegensis Johansen
 Malpaso Creek
Porphyra smithii Hollenberg & Abbott
 Kasler Point
Lessoniopsis littoralis (Tilden) Reinke
Porphyra pulchra Hollenberg
 Jade Cove
Laminaria ephemera Setchell
 Little Sur River
Isabbottia ovalifolia (Kylin) Balakrishnan
 Point Sur
Pleurophycus gardneri Setchell & Saunders
 Big Sur River
Ulva stenophylla Setchell & Gardner

San Luis Obispo County

unspecified
Acrosiphonia coalita (Ruprecht) Scagel et al.
Porphyra lanceolata (Setchell & Hus) G.M. Smith
 San Simeon
Hedophyllum sessile Setchell

TABLE 1. (CONT.)

Cayucos

Porphyropsis coccinea (Areschoug) Rosenvinge

Atascadero State Beach

Bornetia californica Abbott

Montana de Oro State Park

Hymenena multiloba (J. Agardh) Kylin

Kornmannia leptoderma (Kjellman) Bliding

Macrocystis integrifolia Bory

Percursaria dawsonii Hollenberg & Abbott

Pylaiella gardneri Collins

Lion Rock

Pelvetiopsis limitata (Setchell) Gardner

Postelsia palmaeformis Ruprecht

Diablo Cove

Alaria marginata Postels & Ruprecht

Callophyllis crenulata Setchell

Clathromorphum parcum (Setchell & Foslie)

Adey

Nereocystis luetkeana (Mertens f.) Postels &

Ruprecht

Shell Beach

Hymenena fryeana Kylin

Pismo Beach

Farlowia conferta (Setchell) Abbott

Santa Barbara County

Point Sal

Dictyonium californicum Ruprecht

Erythrophyllum delesserioides J. Agardh

Point Conception

Abnfeltiopsis linearis (C. Agardh) Silva & DeCew

Analipus japonicus (Harvey) Wynne

Bossiella plumosa (Manza) Silva

Constantinea simplex Setchell

Dilsea californica (J. Agardh) Kuntze

Fucus gardneri Silva

Halosaccion glandiforme (S.G. Gmelin) Ruprecht

Hymenena flabelligera (J. Agardh) Kylin

Mastocarpus jardinii (J. Agardh) J. West

Odonthalia floccosa (Esper) Falkenberg

Phaeostrophion irregulare Setchell & Gardner

Gaviota

Gloiosiphonia verticillaris Farlow

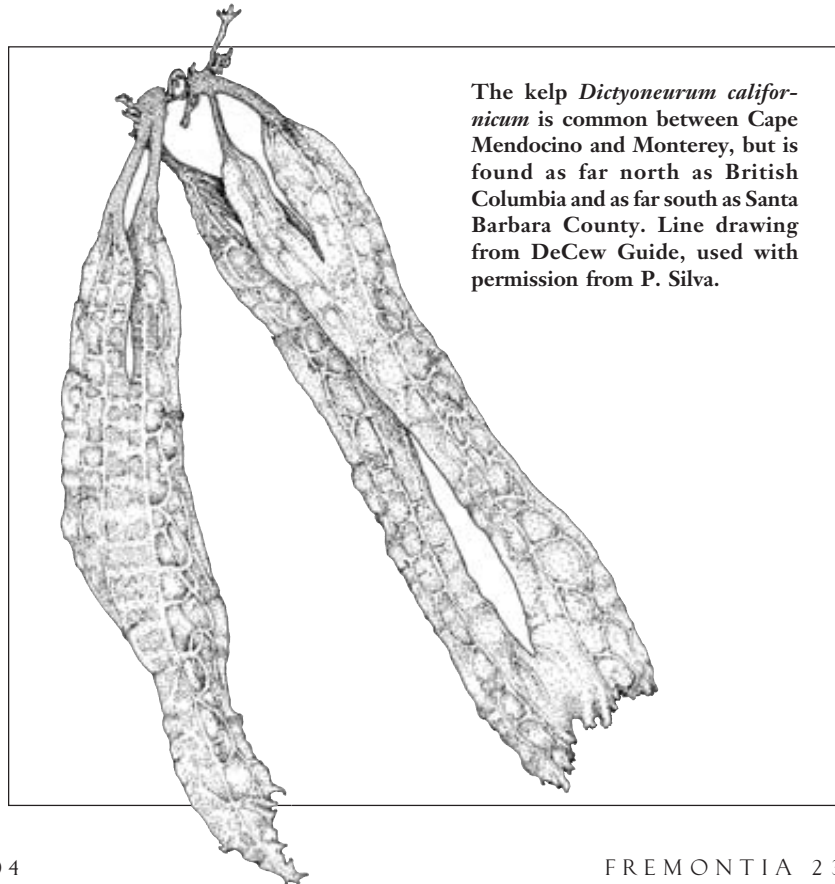
Goleta

Palmaria mollis (Setchell & Gardner) van der Meer & Bird

not in the simplistic way the story was usually told.

At Point Conception, the coast veers sharply eastward toward Santa Barbara. The relatively cold California Current continues its southward sweep, bathing the northern Channel Islands and then flowing into Mexican latitudes where it is warmed. Part of it then returns northward, bathing the southern Channel Islands with relatively warm water and continuing counter-clockwise in the Southern California Bight. The other part continues southward as a weak current. The relatively warm water in the Bight creates a sharp temperature gradient immediately east of Point Conception so that the Santa Barbara flora is indeed very different from that of the Monterey Peninsula.

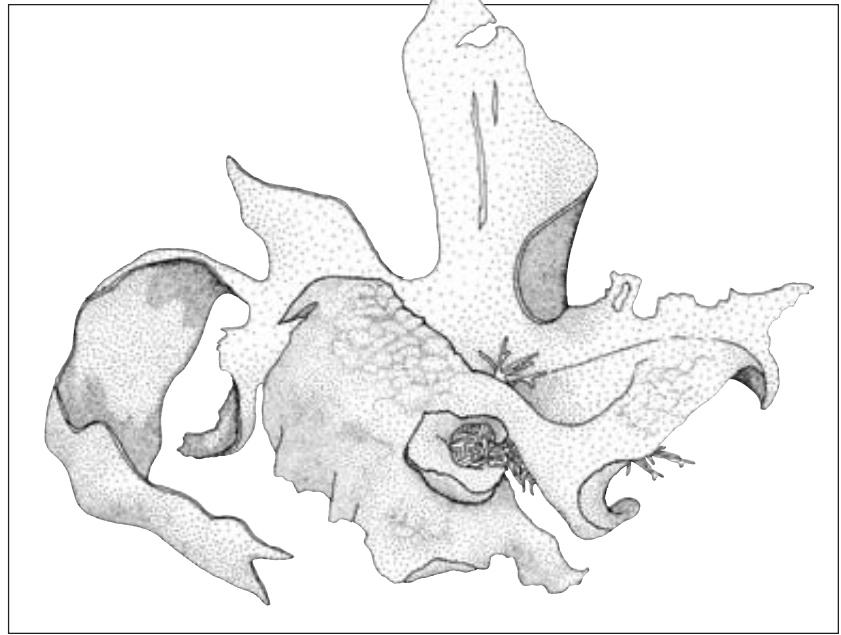
The ranges of cold-temperate



The kelp *Dictyonium californicum* is common between Cape Mendocino and Monterey, but is found as far north as British Columbia and as far south as Santa Barbara County. Line drawing from DeCew Guide, used with permission from P. Silva.

species are related to temperature rather than to latitude. Many cold-temperate species drop out at various points along the coast even before they reach Point Conception (see Table 1). *Postelsia palmaeformis*, for example, occurs only as far south as Lion Rock in San Luis Obispo County. Some species drop out at Point Conception or intrude a short distance into the Bight. Many species, however, continue their distribution on the northern Channel Islands (see Table 2). Some of these species skip the southern Channel Islands but appear again on the mainland of northern Baja California in pockets of upwelled cold water (see Table 3). *Laminaria setchellii*, for example, occurs on the California mainland as far south as Point Conception, then on the northern Channel Islands, with the southernmost locality being Punta Banda, just south of Ensenada, Mexico. Some species skip the Channel Islands as well as southern California, reappearing in upwelling areas of northern Baja California (see Table 4).

The warm-temperate flora of southern California does not offer a mirror image of the pattern shown by the cold-temperate flora in which species drop out progressively as the water temperature increases. Rather, it is largely confined to waters south of Point Conception, with only a few species venturing farther north. Those that do venture northward are restricted to pockets of relatively warm water, such as Stillwater Cove in Carmel and at Santa Cruz (see Table 5). At La Jolla and in the southern Channel Islands (San Clemente and Santa Catalina islands) there are several species that may be found in nearly all subtropical and tropical waters. As pointed out by Abbott and Hollenberg (1976), the marine flora of southern California comprises more species but less biomass than that of northern California, as is usually the case when a cold-water



Hedophyllum sessile, a distinctive kelp, is found from Alaska to Point Conception, but has yet to be found between Santa Cruz and Point Sur. Line drawing from DeCew Guide, used with permission from P. Silva.

flora is compared with a warm-water flora. Throughout the world, large fleshy brown and red algae are generally restricted to cold water.

An excellent overview of the seaweeds of southern California is given by Murray and Blair (1993), who provide floristic, geographic, and ecological analyses, including a detailed account of community structure and productivity. Nearly 60 species of California seaweeds,

including a remarkable number of members of the order Rhodophyta, are totally subtidal according to data given by Abbott and Hollenberg (1976). Their vertical ranges are variable. A few species occur in the subtidal fringe just below the lowest tide level and extend downward, but the majority are restricted to depths of at least ten meters. A few species occur as deep as 100 meters. Until the advent of

TABLE 2. CONSPICUOUS COLD-TEMPERATE SEaweEDS WITH MAINLAND END-POINTS BETWEEN THE MONTEREY PENINSULA AND GOLETA, SANTA BARBARA COUNTY, BUT ALSO FOUND ON THE CHANNEL ISLANDS.

- Antithamnionella spirographidis* (Schiffner) Wollaston
- Halymenia schizymenioides* Hollenberg & Abbott
- Mazzaella flaccida* (Setchell & Gardner) Fredericq
- Mazzaella splendens* (Setchell & Gardner) Fredericq
- Neoptilota hypnoides* (Harvey) Kylin
- Neorhodomela oregona* (Doty) Masuda
- Porphyra variegata* Setchell & Hus
- Prasiola meridionalis* Setchell & Gardner
- Urospora penicilliformis* (Roth) Areschoug

scuba diving, several species were known only from plants cast ashore after storms or pulled up in dredge hauls. A few species have been observed by divers, but are rarely if ever cast ashore, presumably disintegrating *in situ*. The geographic ranges of these subtidal species are erratic, in part depending on the availability of certain areas for sampling. Many ranges encompass one or more of several areas favorable to scuba diving and dredging. These areas include Bowie Seamount (about 75 miles west of the Queen Charlotte Islands, British Columbia), the Puget Sound (particularly Hein Bank in the San Juan Islands), Cordell Bank (Marin County), the Farallon Islands (San Francisco County), Monterey and Carmel submarine canyons and Schmieder Bank (Monterey County), Diablo Submarine Canyon (San Luis Obispo County), Scripps and La Jolla submarine canyons (San Diego County), and various diving and dredging sites in the Channel Islands and northern Baja California, including Tanner and Cortes banks. Kelp canopies, particularly those of *Macrocystis pyrifera*, provide a habitat for a specialized algal flora together with associated fishes and invertebrates.

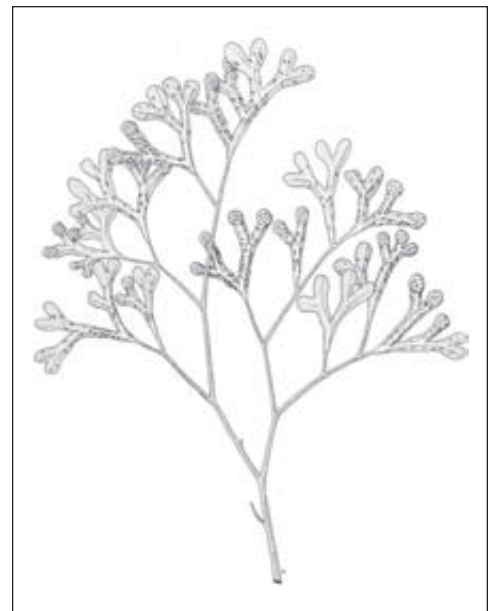
A very few species of the California flora are insular endemics, occurring in the southern Channel Islands as well as on various Mexican islands, especially Isla Guadalupe and Rocas Alijos. The high degree of endemism of the marine biota of Isla Guadalupe is easily explained by the ecological isolation of this island resulting from its position to the west of the cold upwelled waters at the same latitude on the Baja California peninsula. The contrast between the marine biota of Isla Guadalupe and the mainland, which is only about 160 nautical miles to the east, is striking. The absence of these insular endemics on the southern California mainland is more difficult to

TABLE 3. CONSPICUOUS COLD-TEMPERATE SEAWEEDS WITH MAINLAND END-POINTS IN CALIFORNIA BETWEEN THE MONTEREY PENINSULA AND GOLETA, SANTA BARBARA COUNTY, BUT ALSO FOUND ON THE CHANNEL ISLANDS AND IN NORTHERN BAJA CALIFORNIA.

Bossiella californica (Decaisne) Silva
Calliarthron tuberosum (Postels & Ruprecht) Dawson
Callocolax fungiformis Kylin
Callophyllis obtusifolia J. Agardh
Chondracanthus corymbiferus (Kützing) Guiry
Desmarestia latifrons Kützing
Farlowia compressa J. Agardh
Gloiopeltis furcata (Postels & Ruprecht) J. Agardh
Haplogloia andersonii (Farlow) Levring
Laminaria setchellii Silva
Mastocarpus papillatus (C. Agardh) J. West
Neorhodomela larix (Turner) Masuda
Peyssonneliopsis epiphytica Setchell & Lawson
Schimmelmannia plumosa (Setchell) Abbott
Scytosiphon dotyi Wynne
Sorantthera ulvoidea Postels & Ruprecht

explain. Part of the explanation may be the deterioration of mainland habitats. These endemics may have at one time been found on the mainland. The occurrence of several species of seaweeds that were found at San Pedro a hundred years ago, but not in recent times, is documented by specimens in the herbarium at the University of California, Berkeley. Alternatively, these endemics may be represented by small subtidal coastal populations waiting to be discovered. Three conspicuous species are currently considered strictly insular: *Cystoseira neglecta* Setchell & Gardner and *Sargassum palmeri* Grunow (both brown algae) and an undescribed species of *Codium* (a green alga).

The Monterey Peninsula is remarkably rich in seaweeds, both in number of species and in luxuriance of growth. Its richness in part



Hesperophycus californicus, a conspicuous brown warm-water rockweed, is only rarely found north of Santa Cruz. Line drawing from DeCew Guide, used with permission from P. Silva.

is due to the equally remarkable variety of habitats in the area, so that certain species find the lack of a suitable habitat rather than higher temperatures a barrier to extending their range southward (see Table 1).

In any given area, the general-

ized factors that affect the distribution of seaweeds are always modified, to a significant degree in certain places and at certain times, by local conditions such as inshore currents and countercurrents, localized upwelling, seasonal river and creek discharge, seasonal trans-

port of sand, and diversity of substrate. An exemplary account of the habitats and distribution of the seaweeds and seagrasses of a particular region is that by Stewart (1991), who shares in satisfying detail her extensive long-term observations of the marine flora of San Diego County.

TABLE 4. CONSPICUOUS COLD-TEMPERATE SEAWEEDS WITH MAINLAND END-POINTS IN CALIFORNIA BETWEEN THE MONTEREY PENINSULA AND GAVIOTA, SANTA BARBARA COUNTY, AND ALSO FOUND IN NORTHERN BAJA CALIFORNIA BUT NOT IN THE CHANNEL ISLANDS.

Abnfeltiopsis pacifica Silva & DeCew, ined.
Blidingia minima (Naegeli) Kylin
Delesseria decipiens J. Agardh
Desmarestia viridis (O.F. Mueller) Lamouroux
Porphyra gardneri (Smith & Hollenberg) Hawkes
Prionitis filiformis Kylin
Ptilota filicina J. Agardh

TABLE 5. NORTHERN END-POINTS OF CONSPICUOUS WARM-TEMPERATE SEAWEEDS.

Santa Cruz

Chondria decipiens Kylin
Chondria nidifica Harvey
Hesperophycus californicus Silva

Monterey Peninsula

Acrosorium venulosum (Zanardini) Kylin
Helminthora stricta Gardner
Laurencia pacifica Kylin
Laurencia subopposita (J. Agardh) Setchell

San Luis Obispo County

Cambria
Leptocladia binghamiae J. Agardh
 Shell Beach
Cystoseira setchellii Gardner

Los Angeles County

Redondo Beach
Laurencia snyderae Dawson

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INTERTIDAL MONITORING OF CALIFORNIA SEAWEEDS

by Kathleen Dickey

Members of the California Native Plant Society have long been passionate pioneers in documenting the identity, distribution, and abundance of terrestrial plants. Botanists worldwide estimate that more than half of all the plants in the world have now been identified. Marine plants and systems have also been well studied, and more than 8,000 species of marine macroalgae have been documented worldwide. In California alone, more than 650 species of marine algae are known, but there remains much to decipher concerning patterns and changes in community structure and species richness.

More research is especially

needed to correlate changes in the seaweed flora and vegetation structure with external forces, both physical and anthropogenic. One prime lesson gleaned from over half a century of intertidal monitoring is that the inherent patchiness in intertidal community organization makes extrapolation from observed changes to supposed causes challenging, and thus there is a great need for careful documentation.

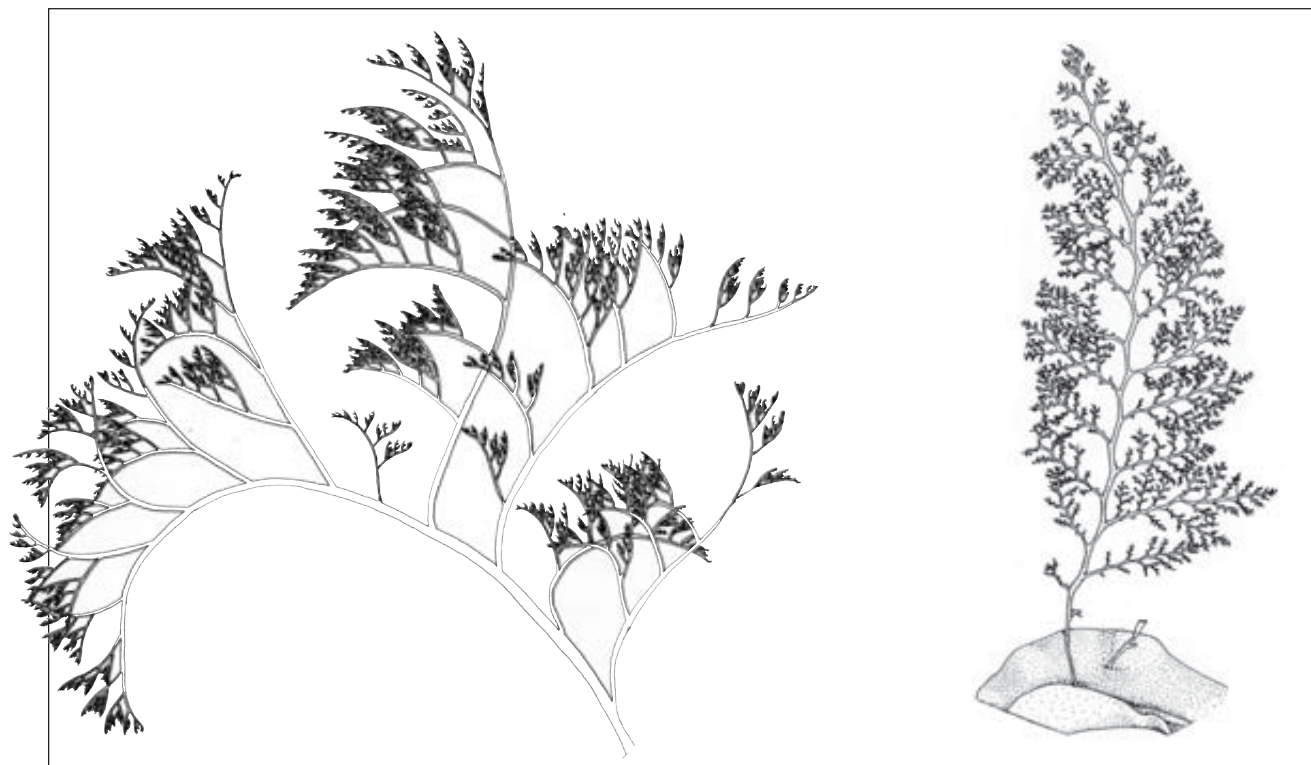
Intertidal monitoring studies fall into three general categories: 1) the descriptive or “snap-shot” studies; 2) longer term studies, including experiments testing questions that arose from the initial studies; and 3) long-term, collaborative monitoring projects dedicated to discerning

and describing patterns over time. These studies have been punctuated and inspired by external events such as oil spills, nuclear power plant development, sewage outfalls, and other impacts of human population growth.

It is challenging to census the marine environment consistently and over time, chiefly due to a lack of funding and personnel for such a long-term commitment. It is also often a physically demanding, or even hazardous job—there is occasionally the possibility of being bitten by an angry elephant seal in the course of a count! A benefit of the focus on documentation of intertidal habitats and species has been the renewed appreciation of and need



Teaching census techniques is an important part of the continuity of long-term monitoring projects. Here a group of students from the Branson School in Marin County are monitoring Duxbury Reef through the Sustainable Seas program, working with the Gulf of the Farallones National Marine Sanctuary. Photograph courtesy of J. Saltzman, Farallones Marine Sanctuary Association.



Recognizing the differences in branching patterns between two species of *Microcladia* as well as the differences in habit is critical to an accurate census. *Microcladia borealis* (left, x2) is saxicolous (grows on rocks) whereas *M. coulteri* (right, x 1/2) is epiphytic (grows on other plants). Line drawings from the DeCew Guide, used with permission from P. Silva.

for well-trained taxonomists, naturalists, and organismal biologists. After all, it's no use counting something that you can't identify.

A BRIEF HISTORY

The first surveys done in the intertidal zone were primarily descriptive. Beginning in the 1930s the early studies (notably those done by W.G. Hewatt, E. Yale Dawson, P.K. Dayton, M.S. Foster, M.M. Littler, and S. Murray—for a review of early work see Murray 2001) were carefully executed, using clear and readily repeated methodology. The locations of many of the early studies were determined by access to the tidepools and proximity to research stations.

E.F. Ricketts, author of the seminal *Between Pacific Tides* and proprietor of a biological supply house (not to mention the inspiration for the main character in John Steinbeck's novel *Cannery Row*),

intensively documented the rocky intertidal inhabitants and their respective zones on the Monterey Peninsula. One of the earliest formal intertidal censuses was conducted in a benchmark study in the same area by W.G. Hewatt when he set up a permanent transect to survey intertidal invertebrates at Hopkins Marine Station in 1931-33. Unfortunately for the seaweed community, he didn't include plants. Additional survey work was done by E. Yale Dawson, who monitored 42 transects in southern California in 1963.

In 1973, John Pearse and his students, funded by Sea Grant and local government agencies, conducted a survey of a mudstone reef using meter-square plots along permanent vertical transects (going from the high tide to low tide zone). They established one transect beneath a sewage outfall that was closed down in 1976. They have continued to monitor these sites.

WAKE-UP CALLS AND THEIR CONSEQUENCES

In 1969 an oil platform blew out in the Santa Barbara Channel. The ensuing disaster prompted a series of studies, sponsored by the Minerals Management Services, in order to obtain baseline data on the southern California coast. Suddenly the surveys that had occurred in the previous four decades had greatly increased value.

In contrast to the Santa Barbara oil spill, which stirred both local and statewide interest, the 1989 Exxon Valdez disaster grabbed attention around the world, when some eleven million gallons of oil spilled into Prince William Sound, Alaska, fouling 1,300 miles of a heretofore pristine intertidal region. When it came time for Exxon to fulfill their legal obligation to remediate these Alaskan habitats after the disaster, quantitative data were insufficient to establish what

had been lost. Unlike California, where there had been previous efforts along the southern and central coast to collect intertidal data, there simply wasn't enough known about the species and communities in areas affected by the Alaskan spill. As a consequence, Exxon is now appealing the settlement for punitive damages. This case provided an urgent wake-up call to those who monitor the marine environment. If the acquisition of basic scientific knowledge was not a strong enough incentive for establishing baseline data, then surely economics might provide a convincing argument.

WHAT HAVE WE LEARNED?

In some instances, scientists have documented considerable change. In other cases the results have been ambiguous. In follow-up surveys in the rocky intertidal of southern California localities, Steve Murray and his students have observed that the relative abundance of highly productive foliose algae has declined, to be replaced by turf-forming seaweeds, corallines, and crusts. The reasons for this may be anthropogenic, as there are simply many more people coming to the southern shores than before. In fact, it is estimated that over the past three decades the population of coastal counties in southern California has increased by more than 50%.

In 1995, 60 years after the Hewatt census of invertebrates at Hopkins Marine Station, Barry et al. repeated the same work, using the same transect and plots. They were surprised by what they found. First, in 32 of the 45 invertebrate species analyzed in detail, population abundances changed significantly. Second, animals that were considered "southern" species were now more common, with a concomitant diminution in "northern"

species. On the other hand, two northern snails increased in abundance, but seemingly by migrating to a lower spot in the intertidal. Mean sea surface temperatures increased about 3/4°C, during these 60 years, with an increase of approximately 3°C during July through August, the warmest months of the year.

In Santa Cruz, John Pearse and his students have continued to conduct yearly censuses, and after 30 years have only recently noticed a recovery in diversity at the site of the sewage outfall. Initially, at the outfall site, coralline algae were the overwhelmingly dominant species. In the late 1990s, signs of recovery at this site, as measured by increased diversity, included the return of surfgrass, soft-bodied invertebrates such as bryozoans, tunicates, and sponges, and some of the delicate foliose red algae. This is an excellent example of a long-term study that has captured important changes resulting from alleviating pollution stress.

One important consequence of the Exxon Valdez spill was new funding of large-scale, publicly and privately funded censuses. These include efforts by the National Marine Sanctuaries, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), the National Park Services (including an All-Taxa Biological Inventory at Tomales Bay in northern California), and the Multi Agency Rocky Intertidal Network (MARINE), a consortium of agencies and institutions in southern California.

In some cases, innovative inter-agency alliances have been forged between disparate groups, unified by the desire to document and preserve our marine heritage. Fishermen, students, volunteers, and local residents have been recruited to help university and government scientists with their census work. Traditional tools such as the plant press, transect, and quadrat are now augmented with GPS and GIS technology, and databases and images are often broadly

available on the Internet.

We are now in the era of synthesis and long-term, carefully designed experiments to try to tease out the mechanism of change in the intertidal zone. The need for an accurate inventory of California's intertidal flora is clear. With efforts of volunteers and professionals alike we will hopefully be able to have a more complete appreciation for the diversity of this state's seaweed flora, and for the beauty of the balance within and between intertidal ecosystems.

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SEAWEED RESOURCES

Compiled by Kathleen Dickey

If you are just beginning to learn about the wonders of seaweeds, the following list of reference books and websites will help you along your road of discovery.

BOOKS

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WEBSITES

Seaweed information and identification

www.seaweed.ie. The National University of Ireland, Galway. This comprehensive website includes database and images of seaweed from around the world.

www.mbari.org/~conn/botany/. Monterey Bay Aquarium Research Institute, Monterey, California. This site includes student work from the Hopkins Marine Laboratory Marine Botany class.

ucjeps.berkeley.edu/guide/. DeCew's Guide to the Seaweeds of British Columbia, Washington, Oregon, and Northern California. See page 12.



The red alga, *Phycodrys setchellii*. Line drawing, to be posted soon to the DeCew Website (see page 12), used with permission from P. Silva.

www.coml.org/coml.htm. Census of Marine Life. This is a global network of researchers from more than 50 countries engaged in a ten-year initiative (begun in 2000), with the goal of assessing and explaining the diversity, distribution, and abundance of marine life in the oceans—past, present, and future. This endeavor is funded by the Arthur P. Sloan Foundation. Two contributors to this site are the Oceanic Biogeographic Information System (OBIS) and the Natural Geography in Shore Areas (NaGISA).

Seaweed as food

www.seaweed.net. Mendocino Sea Vegetable Company, Mendocino County, California.

www.loveseaweed.com. Rising Tide Sea Vegetable Company, Mendocino County, California.

Intertidal monitoring efforts

www.marine.gov. Multi Agency Rocky Intertidal Network. This site

represents a consortium of institutions, state and federal agencies, and private endeavors in southern California conducting long-term intertidal monitoring projects. Agencies include California State University, Fullerton, Minerals Management Service, University of Southern California, University of California (Los Angeles, San Diego, Santa Barbara, and Santa Cruz campuses), Regional Water Quality Control Boards, PISCO (see website below), California Department of Fish and Game, the United States Navy, the National Marine Sanctuary, and the National Park Service.

www.biology.ucsd.edu/labs/roy/CBRISC/summary.html. Conservation and Biodiversity of the Rocky Intertidal of Southern California (with the acronym CBRISC, pronounced “SeaBrisk”). This site is aimed at assessing the health of Southern California’s coastal marine environment.

www.piscoweb.org. PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans). PISCO is a large-scale marine research program that examines near-shore marine systems. The program is based at four universities along the Pacific coast, and is funded by the Packard Foundation.

www.farallones.org/education_page/studentprojects.html#rocky. Farallon Marine Sanctuary Association (FMSA). Gulf of the Farallones National Marine Sanctuary, San Francisco, California Educators work with FMSA on two intertidal monitoring programs for students.

limpets.noaa.gov/. Long term monitoring program and experiential training for students (LIMPETS). Olympic Coast, Cordell Bank, Gulf of the Farallones, Monterey Bay, and Channel Islands.

www.mbnms-simon.org/. The Monterey Bay National Marine Sanctuary (MBNMS). One of 13 National marine sanctuaries around the country, MBNMS has just posted an interactive database at their website, called the Sanctuary Integrated Monitoring Network (SiMoN).

HARVESTING AND COLLECTING SEAWEEDS

California state Fish and Game regulations allows individuals to collect up to ten pounds of seaweed for noncommercial uses. The best time to collect is just after a storm or when the tide is going out, in order to ensure freshness. The best places to collect drift seaweed are open ocean beaches and rocky shores, away from creeks or rivers. Seaweeds from bays and inlets in California are best left alone. There are no poisonous seaweeds, although one genus, *Desmarestia*, contains hydrosulfuric acid and is quite acrid. Others, such as sea lettuce (*Ulva*), are just too tough to eat.

GENERAL RULES

1) Before you pick any seaweed, make sure that there are many more plants of the same species nearby. For example, in the case of the sea palm (*Postelsia*), one study shows that there need to be at least 120 plants in a stand for it to reproduce.

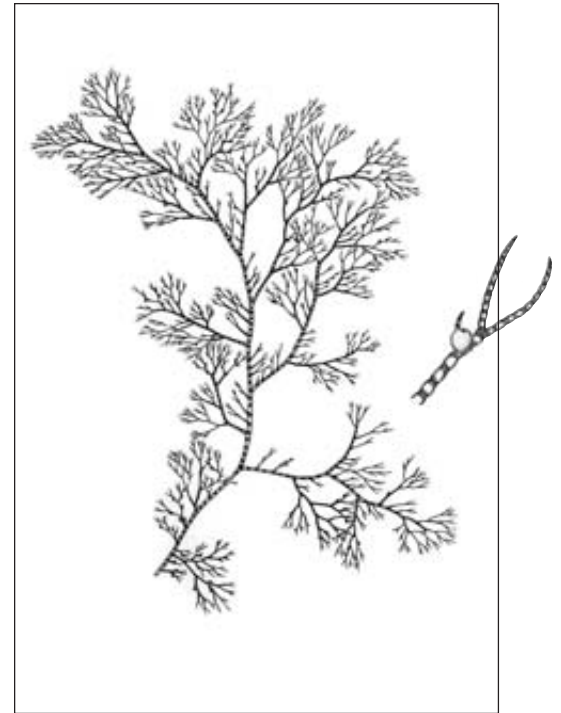
2) Some seaweeds are quite rare, so if you find an individual plant of any species, leave it alone.

3) Learn about the reproductive cycle of the seaweeds you are collecting, and what a fertile plant looks like. By not collecting fertile plants, the population will be able to replenish itself.

4) Do not assume that because a plant is growing in the ocean it will be toxin-free. Some seaweeds selectively uptake and concentrate minerals. Do not collect seaweed near a city or near a stream or river that might carry agricultural runoff into the ocean. As a general rule, bay waters (especially San Francisco Bay) should be off-limits.

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- Dawson, E.Y. and M. Foster. 1982. *Seashore Plants of California*. University of California Press. Berkeley, CA.
Druehl, L. 2001. *Pacific Seaweeds*. Harbour Publishing. Madeira Park, BC Canada.



The red alga, *Ceramium californicum*. Line drawing, to be posted soon to the DeCew Website (see page 12), used with permission from P. Silva.

NOTES AND COMMENTS

CNPS FELLOWS NOT UNDER-APPRECIATED

The January 2003 issue of *Fremontia* (Vol. 31(1):27) listed California Native Plant Society Fellows, but some of those honored with the title were inadvertently omitted from this list. Apologies are given to these Fellows, their friends, and families. Although a Fellow's name might have been overlooked, certainly their participation in the society is or has been greatly appreciated.

Fellows names are listed below with the date the title was received.

Mary Ann Matthews, 1993
Mary Rhyne, 1991
Florence Marsh, 1991

Beatrice Howitt, 1973
Jim Griffin, 1993
Jake Sigg, 1997
Joan Stewart, 1999
Randall Morgan, 2000

In addition, there may be others who should be included on this list. If you know if this is so and the date they became Fellows, please contact the Editor.

SUDDEN OAK DEATH UPDATES

In April of 2004, wood rose (*Rosa gymnocarpa*) was added to the list of nearly 30 confirmed *Phytophthora ramorum* host plants. Wood rose is

native to California, and is commonly found in a wide range of habitats. It is popular in the horticultural industry and is readily available from native plant nurseries in California, Oregon, Washington, and British Columbia.

As a host plant for the Sudden Oak Death pathogen, wood rose falls under *Phytophthora ramorum* regulations, requiring inspection before being certified for shipment from California nurseries. For those planting natives in your garden, be careful to obtain stock that is not infected with this pathogen.

For more information about Sudden Oak Death, go to the California Oak Mortality Task Force (COMTF) website at: www.suddenoakdeath.org.

LETTERS TO THE EDITOR

Weeds and Wildflowers (Volume 31, No. 2)

I wanted to say how much I enjoyed Jake Sigg's article on weeds, and also the article by Marjorie Schmidt! It would be great if *Fremontia* ran an article of historical quotes in every issue. Jake's article was so well-written and thought-provoking—I had not

considered the effect of pliantain and weeds like it before.

Kathy Kramer
East Bay Chapter

Weed Reference Correction (Volume 31, No. 4:34)

In the "Selected Articles on Weeds," the reference to "Control of the

Aleins" should be ascribed to Doris Ann Hoover, who sadly passed away recently. Doris was one of the original weed warriors in the LA Chapter, and these comments appeared first, if I remember correctly, in the local *Toyon*.

Michael O'Brien
Los Angeles/Santa Monica
Chapter

BOOK REVIEW

Pacific Seaweeds: A Guide to the Common Seaweeds of the West Coast, by Louis Druehl. 2000. Harbour Press, Madeira Park, British Columbia, Canada. Softcover, \$17.95.

Louis Druehl has been studying and teaching about seaweeds for more than 30 years, and recently started farming kelps in British Columbia. In this book he presents information and fascinating lore about seaweeds aimed at a general, interested audience. He in-

corporates taxonomy based on external morphology (for example, crusts, globular, small flat blades, cylinders) with a small "thumbnail" dichotomous key. The photographs and line drawings are very helpful in the field. As one must in any small book, Druehl focuses on some 100 of the more common seaweeds, perhaps with a disproportionate emphasis on his specialty, the "browns."

My favorite parts of this book are

the fascinating stories and asides that range from the intriguing to the preposterous. For example, he describes the sea palm, *Postelsia palmaeformis*, as being "severely attached to a rock." Additionally, he includes many simple recipes, some complete with verse. Altogether, this is a satisfying introductory book to accompany you in forays to the tidepools. It includes a helpful glossary and list of references.

RECIPE FOR MARINATED ALARIA

Thanks to Louis Druehl and Rae Hopkins,
Canadian Kelp Resources, Ltd.

Ingredients

1 cup dried *Alaria*, cut in strips (use scissors)
1/2 cup rice vinegar
3 Tbsp soy sauce
1 Tbsp sugar
1 tsp salt

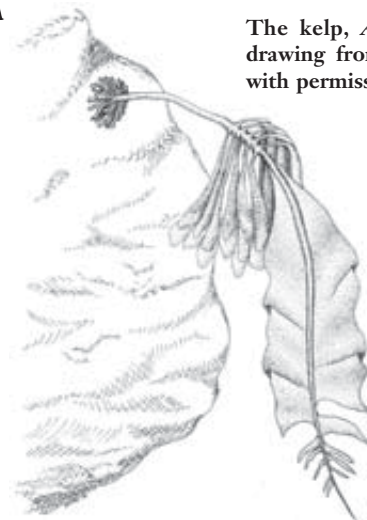
Optional and delicious additions

Thinly sliced cucumber
Finely grated carrots
Sliced green onions

Instructions

Place *Alaria* strips in bowl and cover with warm water for 1/2 hour to rehydrate. Drain. In a small bowl or jar, mix the rice vinegar, soy sauce, sugar and salt, and mix well. Pour over *Alaria*. Serve with wheat crackers as an appetizer.

To serve as a salad, add thinly-sliced cucumbers and serve on leaves of butter lettuce. Garnish with sliced green onions.



The kelp, *Alaria marginata*. Line drawing from DeCew Guide, used with permission from P. Silva.



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MATERIALS FOR PUBLICATION

Members and others are invited to submit material for publication in *Fremontia*. Instructions for contributors can be found on the CNPS website, www.cnps.org, or can be requested from *Fremontia* Editor, Linda Ann Vorobik, vorobik@rockisland.com, or c/o University and Jepson Herbaria, 1001 Valley Life Sciences Bldg. #2465, University of California, Berkeley, CA 94720-2465.

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FROM THE EDITOR

The seashore provides a contrasting experience to that which we find with walks to meadow or mountain. The smell of salt, view of ocean, and sound of wind and wave all combine to make a visit to the intertidal unique. This special issue of *Fremontia* leads us into the world of seaweeds, and provides preliminary information along with a few tools of understanding that may make your next visit there as joyful as any meadow stroll. And if you glory in diversity and detail, you will be delighted by this group of plants that differ so from our more familiar flowers of forest and field.

The Convening Editor, Kathleen Dickey, along with the contributors

Paul C. Silva and Kathy Ann Miller, have through their combined efforts offered several perspectives from which to consider algae. Silva relates stories of their discovery and how they are harvested for useful products. He also carefully describes how currents along our coast contribute to the great diversity of California seaweeds. Miller informs us of invasive seaweeds that we, as stewards to natural environments, should be on the lookout for. Dickey provides background information on seaweed research as well as how seaweeds are monitored, and why it is important to continue studying them. And if you are inspired to learn more, look to the back pages for a list of Web and other resources that

Dickey has provided, or try the recipe from the book review on page 32.

This issue begins my fourth year as Editor of *Fremontia*, and during that time my goal has been to provide a variety of articles that are backed by academic research and yet are interesting and available to a broad audience—with articles ranging from wildflower appreciation and horticulture, through ecology and taxonomy, to advocacy. I wish to make these issues the best they can be for our society, and welcome all letters that respond to individual articles or to the general scope of our California Native Plant Society journal, *Fremontia*.

Linda Ann Vorobik,
Editor

CONTRIBUTORS

Tom DeCew received his MS at Humboldt State University and his PhD at UC Berkeley. During his studies he canvassed West Coast herbaria to compile phenology and distribution data and searched the macroalgal literature for studies pertaining to West Coast seaweeds. The fruits of his labor resulted in "The Book," a bibliography to the biology of common north-east Pacific seaweeds with line drawings and tabular displays of latitudinal distribution and reproductive phenology. It was intended to complement *Marine Algae of California* by I.A. Abbott and G.J. Hollenberg. DeCew died prematurely in 1997, before his Magnum Opus could be published.

Kathleen Dickey is a research associate at the herbarium, UC Berkeley. She received her MS at UCSC. She has worked as a consultant for NOAA for the past four years, conducting intertidal censuses on Southeast Farallon Island, near San Francisco, California. Her particular area of interest is the pattern of distribution of intertidal algae. She is currently designing a set of "seaweed flashcards" to help identify seaweeds in the field.

Kathy Ann Miller is the resident scientist at the University of Southern California's Wrigley Marine Science Center on Santa Catalina Island. She earned her BA and PhD degrees in Botany at the University of California at Berkeley. She specializes in seaweeds of California and adjacent coastlines. Her current research includes studies of the systematics, ecology, and evolution of seaweed and eel grass populations around the California Channel Islands.

Paul C. Silva is a native son of California. He received his BA at the University of Southern California, his MA at Stanford University, and his PhD at the University of California, Berkeley. He has been on the staff of the University Herbarium since 1960 and is considered a world authority on seaweeds.



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