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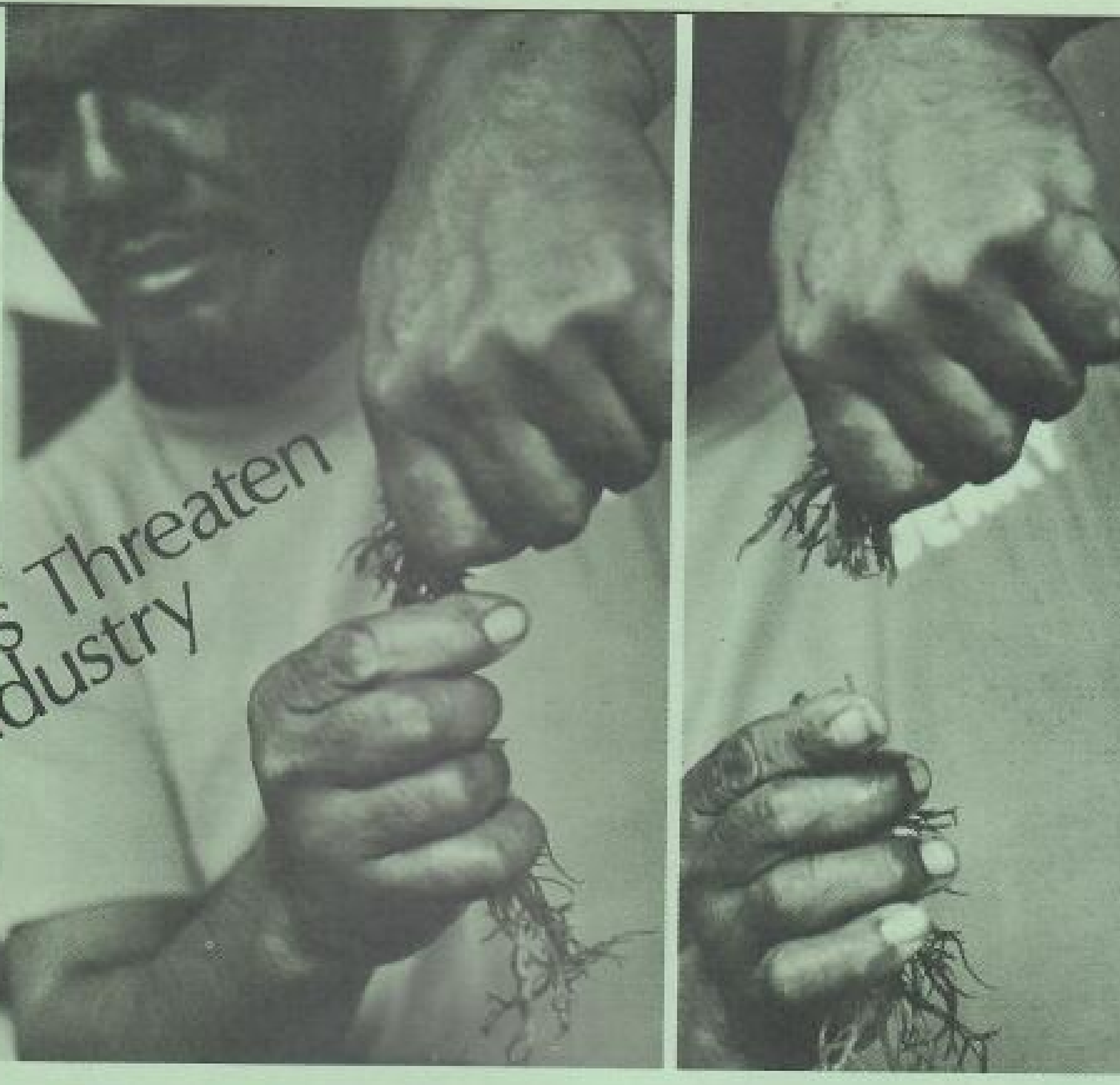
Harvest Practices Threaten Limu Industry



Jerry Kaluhiwa shows how to pick limu so that it will grow again. His bottom hand grips the limu holdfast attached to a rock. His top hand pinches or twists the limu off.

Government controls may be needed to preserve the limu (seaweed) industry in Hawaii, according to Jerry Kaluhiwa, director for the Limu Restoration Project near Heeia State Park in Windward Oahu.

Limu, especially ogo and manauea (species of *Gracilaria*), is becoming scarce and more expensive, Kaluhiwa said. Limu's scarceness, he contends, partly results from harmful practices of commercial harvesters and from shortsighted marketing.

"Five years ago limu was abundant. If we don't take care of this resource now, limu will soon be depleted," Kaluhiwa said.

Kaluhiwa believes governmental action may be needed to save existing limu beds and to protect new ones. Access to limu beds, he said, should be limited to prevent the beds from being destroyed by indiscriminate overharvesting. He cited the problems the project has had with limu pickers gathering limu from its sites in Kaneohe Bay that it uses to grow seedlings.

"Anybody can come in and pick the limu," Kaluhiwa said. "We can't stop them. All we can do is ask them to pick the limu in the right way so it can grow back."

Kaluhiwa also believes that commercial harvesters should be required to go through a licensing process in which they demonstrate the ability to properly harvest limu.

The methods for picking limu so that it may grow out again are simple:

- Pinch or snip the limu 1-1/2 inches or more above the holdfast, or the base of the stalk. Pinching or snipping the limu any closer to the holdfast may kill the plant.
- Reset the rock or object to which the limu is attached back into the water's bottom. If the rock is thrown back into the water, the limu may end up face down and die. Also, even if the limu ends right side up, wave action may flip it over.
- Pick underused species of limu. Many are edible and tasty, and harvesting may help to prevent them from overcrowding the more popular species.

Kaluhiwa suggested that local markets could help ease the pressure on popular limu like ogo and manauea by looking at the retail possibilities for underused species. To emphasize his point, Kaluhiwa said that he has seen chopped green onions used as a substitute in poke when popular limu is scarce. Poke is a raw fish product in which limu is an ingredient.

But Kaluhiwa feels that sellers may be slow to change their ways. For example, he told the story of the owner of a local market who refused to buy a large box of *Eucheuma spinosum* from him because it looked like "Godzilla." After much persuasion, the owner accepted the limu at no cost. Kaluhiwa said he had not walked 25 feet before a customer bought the whole box of limu for $35.

Kaluhiwa and Mark O'Donnell started the Limu Restoration Project about two years ago to teach people how to grow limu. The project also helps young people with family and other problems.

Currently, they are working with organizations on the islands of Hawaii and Molokai to start commercial growing operations. Kaluhiwa said that Oahu limu production alone cannot meet market demands for the seafood. ☐

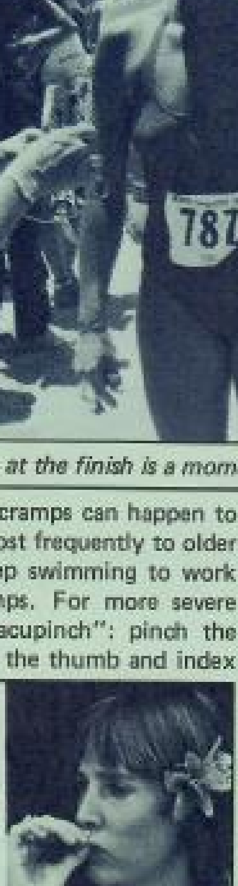
Roughing It (Continued from page 1)

one side and half on the other. For some, this may be a difficult skill to master.

9. Cut down on—better still, cut out—alcohol intake. Stop drinking alcohol three days before a race. Even moderate drinking can harmfully affect the body's temperature control mechanisms for three days.

Dangers to be wary of

1. Riptides, although dangerous, may carry you offshore a short distance but will not carry you out to sea. A riptide is generally narrow and you can swim out of one in a short time by swimming at a 45-degree angle to the pull.
2. Dangerous marine organisms can inflict painful injuries or introduce poisonous substances into the body. These substances may be especially harmful to people with allergenic reactions. Learn first aid treatments for such injuries.
3. Hand and leg cramps can happen to anyone, but most frequently to older swimmers. Keep swimming to work out mild cramps. For more severe cramps, try "acupinch": pinch the upper lip with the thumb and index finger and hold firmly until the cramp diminishes or stops (often a minute or more).



Coleman demonstrates how to do the "acupinch" to relieve hand and leg cramps.

4. Fatigue may develop more quickly from breathing difficulties or congestion resulting from recent illness or from pain from a wound, injury, sore, or sunburn.
5. Hypothermia (dangerous lowering of body temperature) is not a common problem for swimmers in Hawaiian waters. All swimmers, however, should know its symptoms and treatments.
6. Physical problems such as hypoglycemia (abnormally low blood sugar), migraine headaches, menstrual cramps, and even hangovers can become dangerous when coupled with swimming in cool or cold water.

What to do on race day

1. Eat a light carbohydrate meal (oatmeal is often suggested).
2. Study the course, current, and bottom conditions.

Checking in at the finish is a moment of pride and self-accomplishment.

3. Warm up by stretching or jogging for at least 15 minutes before the race.
4. Apply lubricating jelly where body chafing might occur (neck, crotch, underarms, chin).
5. When the race starts, run into the water as far as possible. Dive under surf and waves to keep from losing ground while going through the surf line.
6. To stay on course, try to (a) follow the faster swimmers, (b) select landmarks such as buildings and trees as directional aids, and (c) use sand ripple lines on the bottom, which normally run parallel to shore, as "lane markers."
7. Try to look up only once every 8 to 12 strokes to save energy and to maximize speed.
8. Breathe bilaterally to keep track of landmarks and to avoid water splash from other swimmers.
9. Save some of your energy for the finish, especially for getting back in through the surf line.
10. Body surf to the beach only if you know how and have sufficient breath.
11. Immediately report to race officials that you are safe if you drop out of the race for any reason. Spare your family, friends, and race officials needless worry and searching. □

UH Students Net National Awards In Marine Research

Three of eight national awards for graduate studies in applied marine research were given to University of Hawaii graduate students by the Sea Grant Association recently in Washington, D.C., announced Dr. Jack Davidson, director of the UH Sea Grant College Program.

The Sea Grant Association Student Awards went to doctoral degree candidate Eric De Carlo and to master's degree candidates David Shinn and Edward Siwak. The other awards went to graduate students from five other universities from across the nation.

"Having three of our graduate students receive a third of these national recognitions reflects favorably on our research program here at the University of Hawaii," Davidson said. "We are the only university to have more than one student receive an award."

Both De Carlo and Shinn were cited for research they conducted on manganese nodules. Siwak's award was based on his research of the effects of sunlight on certain bacteria used to measure the quality of sewage water.

The three were among 55 graduate students nationwide who submitted research abstracts for consideration. Each of the eight award recipients received a certificate and $125. The criteria upon which the awards are based include quality of research, the importance of the research on the oceans and freshwater, and clarity of presentation. □

The Marine Advisory Program Newsletter

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"Toward the Sea"

Volume 3, Number 10 University of Hawaii Sea Grant College Program October 1981

ROUGHING IT—THE SWIM WAY

Each year, more and more swimmers celebrate their practice and fitness training by competing in the 2.375-mile Annual Waikiki Roughwater Swim.

by Martha Coleman,
Aquatic Health and
Safety Specialist

Roughwater swimming may be the change of pace you are seeking if laps in a pool have become a chore. If you are jogging or are engaged in other physical fitness activities, you may find roughwater swimming a fun and challenging addition to your training program.

Unlike the predictable conditions of a swimming pool, open water conditions may vary widely from place to place and can change quickly. The tips below will help swimmers inexperienced in roughwater swimming to have safe and rewarding open water swims. Experienced roughwater swimmers may find the tips a useful check on their roughwater swimming practices.

Much of this advice has been summarized from the *Roughwater Summer Handbook for 1981*, published by *Swim Swim* magazine.

More and more swimmers who find roughwater swimming to their liking are joining the ranks of roughwater swimming competitors. Once you become hooked on roughwater swimming, you may want to train for and enter the 2.375-mile Annual Waikiki Roughwater Swim on Labor Day 1982.

Fitness and training

1. Have a complete physical examination once a year. If you are over 35, take an exercise stress test, too.
2. Attempt long roughwater swims only if you are in excellent health and a good swimmer. Train rigorously before any open water competition.
3. If entering a race (especially newcomers), swim the course distance several times the month before. Pool workouts are fine, but get some ocean practice to build confidence. Swim the race course if possible.
4. Only practice ocean swimming with a buddy who swims at your pace or accompanies you on a board.
5. Tell the lifeguard what you plan to do and ask about currents and bottom conditions.
6. Wear (a) an international orange or yellow cap for safety and to conserve body heat, (b) well-fitting goggles, and (c) a comfortable swimsuit.
7. Learn to breathe only on every 4th, 5th, or 6th arm stroke. This improves conditioning and prepares you for missed breaths if waves break over you.
8. Learn to breathe on both the right and left sides (called bilateral breathing). Breathe for half a workout on

(Continued on page 5)

Codium:

An Invading Seaweed

M. Dennis Hanisak,* Harbor Branch Foundation

Anyone who has walked along the shoreline of Rhode Island has probably encountered what at first glance resembles a heap of thick green spaghetti. Closer examination reveals that it is a green seaweed known as *Codium fragile* that has lost its mooring and been cast ashore. This species grows in shallow subtidal areas, with greatest abundance at depths of 1 to 2 meters, although occasional plants may be found at depths as great as 10 meters. Large areas of the coastal ponds of southern New England are clogged by its growth. What is particularly impressive about the abundance of Codium in Rhode Island is that this species was first observed there as late as 1962.

Codium is ecologically interesting because it is a species that is capable of rapidly expanding its geographical range. A native of Japan, this seaweed is now found on all the continents of the world. Along the northeastern coast of the United States, Codium was first reported in 1957 from Long Island Sound. This was shortly after the first successful space launch by the Soviet Union and fishermen who encountered this alien seaweed called it "Sputnik weed," a name suggesting a rather strange type of fallout from the Russians. Since then, *Codium* has been observed from Maine to North Carolina. Exactly how it was introduced is not known, but it was probably by way of shellfish or on ships from Europe or the west coast of the United States. Although of exotic origin, this species has become increasingly abundant and is now a dominant member of the subtidal community of the northeastern United States.

Codium has been considered deleterious to the shellfish industry and has been nicknamed the "oyster thief." It requires a firm substrate for attachment, like that provided by shellfish, and can cause shellfish mortality in several ways: (1) by removing oysters, for instance, from their moorings by increasing their buoyancy allowing them to be washed ashore or out to sea; (2) by increasing the frictional drag of mussels, for example, causing them to be torn from their substrate; and (3) by reducing shellfish mobility as in

*Received his doctorate in botany from URI in 1977.

instrument called WOTAN (Weather Observation Through Ambient Noise) which measures the level (loudness) of the ambient noise at the ocean bottom.

Two WOTANs were built at the Graduate School of Oceanography and have been deployed twice for comparison with data obtained from more conventional surface meteorological buoys. Figure 1 shows what WOTAN looks like. It consists of a hydrophone for receiving the sound, electronics which amplify and filter the signal to obtain the sound level at three frequencies, and a digital cassette tape recorder which can store over 100,000 measurements. The details of the physical mechanisms that produce the ambient noise are not known; but possible sources of the sound are breaking waves, oscillating bubbles in the upper layer of the ocean, and the movement of "catspaws" (wind puffs). It is hoped that measurements at three frequencies approximately an octave apart (4.3 kHz, and 14.5 kHz) will help us to discriminate among these possible causes.

We also know that the level of sound produced at different frequencies by rainfall is different from the level generated by wind. For each rainfall rate, the sound level is about the same at all frequencies while, for a given wind speed, noise decreases as the frequency increases. Thus, WOTAN may also be able to estimate rainfall at sea, a quantity which has been even more difficult to measure than wind.

The first trial of WOTAN was during the summer of 1978. The two instruments were deployed at the ocean bottom from early July to mid-September in 1800 meters of water between northwest Scotland and Iceland. One of the two functioned perfectly for the entire time, while the tape recorder in the other failed as soon as it was put in place. At the time of deployment, an international meteorological-oceanographic experiment involving 14 ships was conducted above the instruments. Woods Hole Oceanographic Institution moored a surface buoy with a high quality wind recorder about 5 km from the working WOTAN. Figure 2 shows a plot of wind speed derived from that instrument and from WOTAN. The agreement is remarkably good; at most times the differences were less than one knot. One meter per second is approximately equal to two knots. This is a good record considering that the design accuracy expected of satellites measuring winds is about 4 knots or ±10 percent, whichever is greater. The very spikey looking part of the WOTAN data is due to one of the ships being directly overhead. When the ship was off doing other work the record is clean. This does not pose a serious problem for future research, because the instruments are to be left unattended and away from ships. Since WOTAN "listens" to only a small area at the surface, distant shipping is not heard.

The second deployment of the WOTANs was from May to October of 1979 in the middle of the equatorial Pacific. Again, one instrument worked perfectly; the other worked well for four of the six months. They were separated in space by about 100 km, and surface buoy measurements were made for comparison. These data have not yet been processed in detail, but the results look as encouraging as the previous test. There is a clear indication of the same weather at both stations with an appropriate time delay caused by distance.

Some calibration problems remain to be resolved and the comparison with precipitation data has not yet been made due to lack of good surface measurements, but we expect to have a device in operation soon to acquire long-term oceanic wind data. The next experiment, and first "real science" may be a deployment of WOTANs off Cape Hatteras, where other measurements are being made by URI oceanographers. This location would allow us to study the intensification of weather systems as they move offshore and up the East Coast. Studies have shown that trying to predict the offshore wind from coastal stations is particularly inadequate.

The present WOTANs do not measure wind direction, which must be derived from surface weather charts and satellite cloud photographs. This shortcoming is being studied, and possibly the directional information can be obtained acoustically as well. We will, we hope, be able to deploy arrays of WOTANs in many regions of the ocean recording long-term wind data to help increase our understanding of the atmosphere, the ocean, and their mutual effect on climate.

the case of scallops, and increasing their susceptibility to predators. *Codium* can also be a nuisance to fishermen by clogging their nets and mechanical harvesters. Thus, *Codium* may be economically as well as ecologically important in New England coastal areas.

In order to understand the ecological success of this exotic species in Rhode Island, the author undertook a study of the physiological ecology of *Codium*. Laboratory and field studies provided observations under controlled conditions as well as in natural populations.

These observations indicate that temperature is the primary factor regulating the growth of *Codium*. Significant growth begins at about 10 to 12°C and increases with temperature up to 24°C, which is about the highest temperature observed in a natural population. Although warmer temperatures favor growth, *Codium* can tolerate extremely low winter temperatures. This wide tolerance for high and low temperatures permits this species, which belongs to a genus associated with the tropics, to survive throughout the year in temperate conditions. The effect of light on its growth is secondary to that of temperature. The low light saturation requirement of Codium compared to other seaweeds suggests that its ability to use radiant energy efficiently gives it a competitive advantage.

During the summer, when temperature and light conditions are most favorable, the availability of nitrogen limits the growth of *Codium* and probably that of most other seaweeds as well. *Codium* is quite competitive in obtaining nitrogen from the surrounding water. It can grow equally well on several different forms of nitrogen (nitrate, nitrite, ammonium, and urea). *Codium* may have a more efficient system than its competitors for obtaining nitrogen during times of low availability. It can take up different forms of inorganic nitrogen simultaneously and at relatively high rates. In addition, Codium continues to take up nitrogen during the winter even though it is not growing. This stored nitrogen is then used for new growth in the spring as soon as temperatures increase.

When interpreting the ecological success of an organism, one must take into account the effects of environmental factors on a species' method of reproduction as well as on its mature individuals. In Rhode Island, *Codium* appears to reproduce only by asexual zoospores. Reproduction of Codium reaches its peak during the late summer and early fall when conditions are most favorable for germination of zoospores and growth of sporelings. Since each mature plant can produce millions of zoospores, Codium can rapidly colonize a new substrate from nearby areas. The success of *Codium* is ultimately based on its genetic makeup; its reliance on asexual rather than on sexual reproduction allows it to retain its successful characteristics from one generation to another. Codium is a significant component of its ecosystem. Its annual primary production can exceed 400 grams of dry weight per square meter. Since no organisms graze to any significant extent on Codium, this plant material ends up as organic fragments in the detrital food chain. Most of this annual production is made available as one large pulse in the winter when older plants fragment in response to low water temperature. This fragmentation may indirectly benefit *Codium* because the resulting smaller individuals need less light and fewer nutrients and are more resistant to high levels of water motion.

In Rhode Island, it appears that Codium's detrimental effects on shellfish are probably minor and localized. *Codium* has probably had little effect on the decline of the local shellfish industry, a decline that began long before the appearance of Codium in the state.

Although Codium is still often considered an undesirable weed, there is little possibility of controlling it. Indeed, control probably should not be attempted on any large scale because *Codium* has become a valuable part of the coastal ecosystem. Its contribution in terms of productivity may be especially important, because most of it goes into the detrital food chain as one large pulse at a time when alternate food supplies are reduced. In addition, it provides a habitat for a large variety of algae and invertebrates throughout the year. *Codium fragile* may be exotic in origin, but it has become an integral part of the coastal and estuarine ecosystems of New England.

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THE LURE OF LIMU

"Sea vegetables" can be turned into either a feast or a work of art

By Pat Pitzer

Low tide on a weekend at Ewa Beach: Diamond Head's profile is etched in the distance against a bright blue sky as the sun beats down on an ages-old scene of *limu* pickers gathering their harvest.

While *limu* is the Hawaiian general name for all kinds of water plants, in common use it refers to the seaweeds that are edible or otherwise useful. Long considered a delicacy by the Hawaiians, *limu* is cosmopolitan in its appeal, and the gatherers at Ewa Beach are as diverse as the Islands' population: Hawaiians, Japanese, Chinese, Filipinos, Koreans, Samoans, haoles—perhaps a couple of hundred altogether, as far as the eye can see in either direction.

It is an aspect of Hawaii that many have never seen nor even realized exists, a contemporary version of a ritual of long ago, updated only by the use of plastic buckets and bags.

As the red, green and brown fingers of *limu* beckon from the waves, some gatherers go to meet it, hauling in their catch dripping and glistening from the sea. An ample Hawaiian woman wearing a colorful muumuu wades out into the surf and scoops up handfuls of *limu* from the water—a scene from another century.

Limu pickers have different styles. Some sort through the heaps of *limu* that have been washed up on the beach and marooned there by the receding tide. The beach is strewn with great mounds, much of it what the Hawaiians call *'opala*, "junk," no good for eating. Intermingled with it, however, are other, desirable *limu*, so the careful sorter reaps rewards.

Limu Manu of Hawaii

'Opala is a subjective term. One person's *'opala* is another person's caviar. Surprisingly, many of the *limu* pickers are disdaining the long, flat, bright green ribbons of the *limu* called *palahalaha* or sea lettuce, abundantly festooning the beach. This *limu*, one of the commonest in the Islands, can be a real delicacy with the proper preparation, but it is rarely collected because few people know what to do with it.

For many, *limu* gathering [is a] family outing with grandpa[rents,] parents and children all contrib[uting] to filling their buckets and bag[s with] treasures from the sea. One f[amily] stakes out a pile on the beach [and,] surrounding it, attacks from all [sides.]

Small children splash throu[gh the] surf with gusto for the game, fo[r] scoops with their hands and pr[ ] bringing back their share [of the] catch. Lithe teen-agers in [ ] gather their *limu* daintily, [ ] graduated from gusto to grac[e.]

There is a sense of camar[aderie] among the *limu* pickers. Whil[e they] are searching diligently and ch[oosing] knowledgeably, they approa[ch the] task as fun, not work, and tha[t is the] pervading spirit of the scene.

Perhaps there is still some [of the] old hunter-gatherer instinct [ ] Freed from the necessity of do[ing so,] we now can enjoy seeking o[ur] food from nature, finding it [at the] seashore instead of the superm[arket.]

The weekend *limu* gather[er, like] the weekend fisherman, [is en]gaging in a sort of sport with m[any of] the same elements present: a[n] outdoor environment share[d with] congenial people, rapport w[ith the] sea, and the reward of bounty [for the] table.

Limu gathering also takes p[lace on] Oahu's Windward shores [and] other beaches on the Neigh[bor Is]lands, for all have fertile *limu* [ ] You'll find different varie[ties]

Pat Pitzer is an associate e[ditor of] HONOLULU.

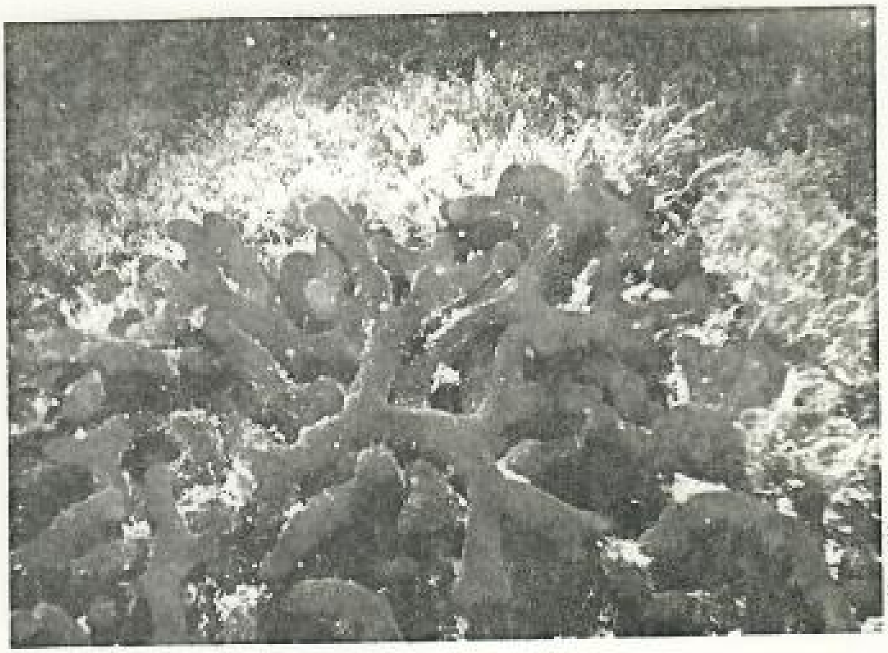
different locations, and in a single location the *limu* will vary according to the season. But, like Hawaii's flowers, there are some forms of *limu* present in each season year round.

Many of the gatherers at Ewa Beach are seeking the *limu* known by the Japanese name *ogo* and its native Hawaiian cousin, *limu manauea*. Members of the same genus (*Gracilaria*), they are by far the most popular *limu* for eating today in Hawaii and are harvested by commercial collectors who sell them to

Left: A beautiful Hawaiian seaweed as seen in its natural habitat is the limu kohu, *highly esteemed as a delicacy by the Hawaiians.*

Right: The limu wawae'iole *or "rat's foot" is one of the popular edible local seaweeds.*

Below: Limu pickers throng to Ewa Beach at low tide and to many other beaches in the Islands, reenacting a scene from the past.



"...Freed from the necessity of doing so, we can now enjoy seeking out our food from nature, finding it at the seashore instead of the supermarket..."

local markets. In colloquial parlance, both are often called *ogo*, with *limu manauea* known as "short *ogo*" or "red *ogo*," though it is actually a different species from the "long *ogo*." The latter is not native to Hawaii, but probably arrived here around the turn of the century, hitchhiking on the hull of a Japanese ship. Both have a similar mild flavor and crunchy texture and they resemble each other though, in general, *limu manauea* has a more reddish cast and is shorter and more branched than *ogo*.

Other *limu* collectors at the beach, particularly the Filipinos, are looking for the fleshy, spongy green *limu wawae'iole* or "rat's foot," which tastes better than it sounds, its name derived from the stubby, flattened ends of its cylindrical branches.

A young local woman with a fat green "rat's foot" *limu*, when asked how she fixes it, smilingly replies, "with chili pepper and shoyu." Ask a Filipino *limu* picker the same question and you get the answer, "with tomatoes and onions and *bagoong*." One traditional Hawaiian preparation for this *limu* was with sea urchin gonads, and you'll have to ask an old Hawaiian how to find *those*.

Occasionally someone comes up with a prize, a *limu lepe 'ula'ula*, the large, beautiful "cockscomb" *limu*, readily identifiable by its nickname, with its rich red, mottled color and toothed, fringed edges. It is also sometimes called "Pele's tongue."

Ignored by many but collected by a few knowledgeable in its preparation is *limu kala*, distinctive in appearance with its golden-brown holly-shaped leaves. This *limu*, which has a heritage of ritual and medicinal significance to the Hawaiians, is seasonal, dying out in late summer and returning in early spring.

A few are collecting *limu huna*, a tiny, delicate, lacy red variety with a mild flavor. It is not only good to eat, but is also exquisite when pressed.

This is the other side of the *limu* collector's coin—an appreciation of Hawaii's seaweeds not only as a delectable food but also for their variety and beauty in a pressed

composition. *Limu* can become eithe a feast or a work of art. You can pres some and eat the leftovers or vic versa. That's versatility.

As a prelude to experimentin with seaweed eating and press ing, I was introduced to *limu* gathe ing by Heather Fortner, author o *The Limu Eater, A Cookbook o Hawaiian Seaweed.* Fortner, wh has a degree in the natural history o Hawaii and who works for th

Left: Heather Fortner, author of The Lim Eater *cookbook, prefers the term "sea veg tables" to seaweed.*

Right: Eleanor Williamson and Isabel Abbott wrote an ethnobotanical study of th lore of limu.

LIMU EATING EXPLORED

If your only introduction to eating *limu* is *ogo* chopped in *poke* (Hawaiian style raw fish) or the dried seaweed called *nori* wrapped around *sushi*, you're missing a whole range of culinary possibilities. There are countless ways to enjoy these versatile sea vegetables and it's fun experimenting and discovering them. (You don't have to like slippery, slimy things, either.)

Here are some of my favorites, a combination of those gleaned from Heather Fortner's book, *The Limu Eater*, tips from Isabella Abbott and Eleanor Williamson, and recipes from Jeff Hunt, along with some of my own ideas thrown in.*

General observations: Each *limu* is distinctive in texture and flavor, but all have the tang of the sea, so I opted not to go the traditional Hawaiian route of salting the *limu* or letting it stand for hours or days in water to "ripen." I figured it was already salty enough and its flavor had sufficient authority.

Most types of *limu* blend well with a variety of other fairly strong flavors, such as garlic, curry, chili peppers, onion, sesame. *Limu* is extremely compatible with other sea creatures, fish and shellfish. It also goes well with chicken and beef.

To many, eating *limu* means eating it raw, mixed with raw fish or made into a relish or pickle. While it is good in these ways, that's only half the story. It is also delicious cooked and served hot as a vegetable or as an ingredient in a main dish. You can, in fact, prepare a seven-course *limu* dinner to serve to your more adventurous friends.

Just because a variety of *limu* is tough or unpalatable raw, don't overlook its possibilities cooked. If you try *limu 'aki'aki* raw, even chopped in a salad, its tough brown strands are like chewing vintage rubber bands, in my opinion. However, Abbott and Williamson noted that the Hawaiians of old baked this *limu* with chicken in an *imu*, offering a glimmer of hope for the tough little stuff. I chopped the *'aki'aki*, mixed it with melted butter, added a little mashed garlic and poultry seasoning, and packed it as a coating around pieces of chicken, then baked it in a slow oven in a pan covered with foil, removing the foil toward the end of the baking time to let the chicken brown. The Hawaiians knew what they were doing.

The holly-shaped leaves of the *limu kala* also tend to be tough when eaten raw, but they are marvelous as a stuffing for baked fish (another tip from the old Hawaiians). Taking off on Fortner's recipe for *limu*-stuffed baked fish, I took fish filets, placed a slice of bacon on each, sprinkled them with shoyu and chopped onion, then stuffed them with chopped *limu kala*, folded them over, wrapped the stuffed fish in *limu palahalaha* (sea lettuce and baked it in a moderate oven for a half hour. Fortner's recipe uses *ogo* o *limu manauea* as the stuffing, an this, too, is good, but I was particular ly partial to the *limu kala* as a stuffing

Limu kala is one of the best of man seaweeds that are delicious deep-frie in tempura batter. Heather Fortner' tempura recipe is a star for practicall any kind of *limu*. My favorites pre pared this way, in addition to *limu kala*, were the little red *limu huna limu kohu* (the prized red one sold i markets) and the nearly black hair like *limu huluhuluwaena*. (One of th traditional ways of eating the latter still practiced today, is chopped wit raw liver. My broad-ranging tastes d not extend so far as raw liver.)

* Excerpts from *The Limu Eater* by Heather Fortner are reprinted with permission of the University of Hawaii Sea Grant College Program.

LIMU TEMPURA

Many different kinds of *limu* can b cooked in this style, including *limu ma nauea* (ogo), *limu huna*, *limu huluhulu waena*, *'opihi limu*, *limu kala* and se lettuce.

1 lb. *limu*
1 cup flour
½ tsp. sugar
1 tsp. salt
1 Tblsp. shoyu
1 egg
¾ cup milk
Dash of MSG
Oil for deep frying

Clean the *limu* and drain well. Mix th other ingredients except the oil into a th batter. With a fork or salad tongs, pick suitable piece of *limu*, dip into the batt and coat thoroughly. Transfer to the h oil (approximately 375 degrees) and de fry until golden brown. Drain excess oil o paper towels. Serve hot as an appetizer

Hawaii Natural Energy Institute, has created an imaginative gourmet's guide to *limu*, covering more than two dozen varieties of edible Hawaiian seaweed.

Beyond her own experimentation, much of what she has learned about the art of *limu* eating she gathered word-of-mouth from anonymous *limu* pickers at the beach.

Limu gatherers share a kindred spirit. It is as if they are an initiated society with a secret—a knowledge of and aloha for *limu*. They are, however, friendly folk who gladly share their secret with the uninitiated. In fact, once they discover you're interested, they are eager to share information about the *limu* they're collecting and how they prepare it.

In addition to those we gather, Fortner gives me other *limu* treasures she has collected elsewhere. Among them is the *limu 'ele'ele* (the Hawaiian word for black) which actually is a dark green with filaments resembling long, soft, slippery, dark grass. Frequently found where freshwater streams meet the ocean, it is considered one of the most delicious by many *limu* eaters.

Another bears the descriptive Hawaiian name *limu huluhuluwaena*, meaning "pubic hair," for its almost black, hair-like strands. There is also some *limu 'aki'aki*, meaning "to nibble as a fish; bite, bite," which is what you have to do to eat the tough,

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side dish with shoyu and Chinese mustard.

Sea vegetables make excellent additions to soups and stews. Add them to your favorite stew or soup during the last few minutes of cooking time and they will serve as natural thickeners. *Ogo* and *limu 'ele'ele* are good this way, but best of all is the *limu lepe 'ula'ula*, the cockscomb, sometimes sold in markets as red sea lettuce. This soup from Fortner has a particularly splendid consistency and, if you like curry, it is superb with a little curry powder added.

LIMU LEPE 'ULA'ULA SOUP

1 cup wet *limu lepe 'ula'ula*, packed
1 onion, thinly sliced
1 Tblsp. oil
¼ cup rolled oats
5 cups water
3 Tblsp. shoyu
1 tsp. salt
1 tsp. black pepper

In a medium saucepan stir-fry the onion in oil until the strong smell goes away. Add the oats and cook until slightly browned. Cut or break the *limu* into bite-sized pieces, then add the water and *limu* to the soup pot. Bring to a boil, then lower heat and simmer for 20 minutes. The soup should not be too thick. Add shoyu and seasoning.

The English are *limu* eaters, too. As a cooked vegetable side dish for roast beef, they eat *Porphyra*, a seaweed they call laver. The variety of this broad-leafed seaweed found in Hawaii is called *limu pahe'e* or purple sea lettuce. I substituted the cockscomb *limu*, boiling it until tender and serving it with a sauce made of two parts beef gravy to one part lemon juice. An interesting and tasty accompaniment to roast beef.

Limu makes a zesty addition to omelets. Chop *limu kohu*, *limu 'ele'ele* or *ogo* and spread it over the omelet just before it sets, adding your choice of chopped onion, crisp crumbled bacon, grated cheese or all three. You may wish to blanch the *ogo* first to soften the crunchiness. Be prepared to be startled. The instant you plunge it into boiling water it turns bright green.

One of my most successful experiments was a takeoff on Fortner's *'opihi* in escargot sauce. Not having any *'opihi*, I substituted sliced cooked *tako* (octopus) in this garlic-butter-sea lettuce sauce, and it was, indeed, the *limu* eater's answer to escargots.

'OPIHI IN ESCARGOT SAUCE

Although *'opihi* are traditionally served raw, they are also excellent cooked in an escargot garlic-butter sauce. Chopped sea lettuce adds flavor and color.

'Opihi in the shell, preferably freshly picked
Butter to cover a pan to ¼ inch
Garlic, finely minced and mashed
Sea lettuce, finely chopped
Salt and pepper to taste

In a large saucepan melt the butter over low heat; add the garlic, sea lettuce and seasonings; mix well. Set the *'opihi*, foot down, in the hot butter and cook until *'opihi* loosen from shell—about 2 minutes. Remove from heat, serve immediately.

There are many superb salads using *limu*. The dark green *limu 'ele'ele* is particularly good chopped, combined with garbanzo beans and chopped onions and marinated a couple of hours in oil and vinegar, mixed in proportion to suit your taste (I like it half and half).

Limu makes an excellent pickle, relish or condiment, marinated in a variety of sauces. Here are two of Jeff Hunt's recipes featuring delicious marinades for *ogo* or *limu manauea*.

PICKLED LIMU

1 cup vinegar
1 clove garlic, mashed
1 stalk green onion, chopped
1 tomato, chopped
¼ cup shoyu
⅛ tsp. Aji-no-moto
1 green pepper, chopped
2 tsp. sugar
1 tsp. salt

Add rest of ingredients to vinegar. Boil *limu* in water 3 or 4 seconds, then drain it and place it in a jar. Cover the *limu* with vinegar mixture. Let stand for a day in the refrigerator to develop full flavor.

KOREAN STYLE LIMU

1 lb. *limu manauea* or *ogo*, chopped into 1- to 3-inch pieces
1 cup rice vinegar or to taste
⅓ cup shoyu
1 Tblsp. sesame oil or to taste
1-2 Tblsp. roasted sesame seeds
2 Tblsp. brown or white sugar
2 Tblsp. *mirin* (rice wine)
"Ko Choo Jung" hot sauce to taste (optional)
Chili pepper to taste
Chopped garlic to taste

Clean *limu* well; pour boiling water over *limu* until color just turns greenish. Drain. Mix ingredients together. Add *limu* to mixture. Refrigerate overnight. —P.P.

How many you can stack and press at one time depends on the quality of your press. Students in Jeff Hunt's class using a "proper" plant press, which can be ordered from the Mainland for $70, were able to stack and press a couple of dozen at a time. If you are really serious about getting into *limu* pressing, you may wish to consider this. But improvised do-it-yourself presses also work. Some of Hunt's students used pieces of plywood for the top and bottom of the press, with the pressure applied by adjustable buckle straps. Barbara Stephan has her students make presses by drilling holes in four corners of pieces of particle board. Screw clamps, fitting through the holes, apply the pressure.

Or you can make do with whatever you have on hand, stacking large books on top of the pressings, using rocks, bricks, concrete blocks or gallon bottles filled with water as your weights. With a makeshift press like this, however, you shouldn't try to stack more than 10 pressings at once.

You will need a moderately heavy weight to squeeze the water out of the *limu* and its mounting paper and to prevent warping. It is particularly important to distribute the weight evenly.

The other major thing to remember is to keep changing the newspapers as they absorb moisture, replacing them with fresh ones as the pressing is in progress. You should change the papers twice a day the first day and once a day after that until the piece is dry.

Limu usually will press in three or four days, though some of the larger, fleshier ones may take a week.

Most *limu* have enough mucilage in them to adhere to the mounting surface by themselves. You won't have to glue them since they have their own natural glue. The red varieties in particular stick the best, followed by the browns, then the greens. For those occasional ones that don't stick, use watered-down white glue and a fine brush to apply it very sparingly to the underside of the *limu*. Place the *limu* on the mounting paper, cover with waxed paper and press about an hour until the glue is dry.

With experience, you will learn which types press best, stick best, combine well together and, above all, you will learn the desirability of simplicity, to display the natural form and beauty of the *limu*. —P.P.

Far left: Barbara Stephen instructs students in trimming and arranging seaweed aesthetically before pressing it.

Above: Jeff Hunt gives his students at Windward Community College experience with pressing seaweed with two different kinds of presses.

Left: Ray Tabata demonstrates the exacting technique of lifting mounted limu *from a pan of water.*

rubbery, reddish-brown tubular fibers. Because of this characteristic, it is not a favorite collectors' item, though it can be redeemed with the right preparation.

Theoretically, all Hawaiian *limu* are edible in the sense that none are poisonous. But some are so calcareous that you could break a tooth on them, and others have such a bitter, unpleasant taste that you wouldn't choose to dine on them short of being marooned on a desert island. Edibility and palatability are two quite different things.

A caveat: Seaweeds, which are part of the large and diverse group of plants called algae, are classified according to color, and there are a few blue-green *limu* found in Hawaiian waters which may cause a rash and are not considered edible. Also, some seaweeds resemble corals in appearance because of their deposits of calcium carbonate. In fact, for many years these plants were mistaken for corals and were classified in the animal kingdom. While we think of Waikiki and the Islands' other fringing reefs as coral reefs, actually they are primarily composed of calcareous algae.

So, to be strictly accurate, one would have to say that all non-calcareous *limu* of the red, green and brown groups are edible. The color distinctions are sometimes misleading, for within each group there is a wide color variation and even a given species can take on different hues depending on the season, where it is growing and the amount of exposure to sunlight.

At any rate, among the edible and palatable seaweeds in Hawaii, there is an enormous variety in size, form, color, taste and texture.

"Sea vegetables" is Fortner's preferred term rather than seaweeds. It's a good point, since "weed" has a pejorative connotation, while "vegetable" indicates a nutritious edible.

The nutritional value of sea vegetables, like that of land vegetables, varies widely. However, all *limu* are rich in vitamins and minerals, have beneficial fiber content and are low in calories.

If you don't want to go to the ocean and gather your own, you can find some *limu* for sale in the markets, but your choice is limited. A recent check of the Farmers Market on Auahi revealed *ogo* for sale and *limu kohu*, a small, pink-to-red, pungent-flavored *limu* which they sell salted and rolled into little balls. Highly prized by the Hawaiians, *limu kohu* should be used sparingly because of its penetrating taste.

The venerable Tamashiro Market on King Street always has *limu* among its selections of delicacies and oddities from the sea. At Tamashiro's a steady stream of customers files past three big bins labeled "long *ogo*," "short *ogo*" and "cooked *ogo*." Taking plastic bags off rollers as one does in an ordinary grocery store for other vegetables, the customers scoop up handfuls of the sea vegetables and take them to the checkout counter to be weighed. This is vegetable-buying Island style.

Ogo at Tamashiro's sells for $2.65 to $2.95 a pound. The *limu* special that day was labeled "red sea lettuce" for $1.49 a pound. This, it turns out, is a popular term for the *limu lepe 'ula'ula*, the "cockscomb." Like the *limu wawae'iole* ("rat's foot"), this is an occasional item at the market, depending on the *limu* catch from the independent collectors who supply it. Almost every day you will find there the little red *limu kohu*, which at $2.98 for a 4-ounce container—on a per pound basis, close to $12—might be considered the caviar of *limu*.

Part of the reason for this variety's high price, in addition to the demand, may be the fact that it is difficult and sometimes dangerous to harvest, since it is found in rough water areas where there is heavy wave action. This is no place for the novice. Occasionally, as with *'opihi* pickers, *limu kohu* gatherers are overwhelmed by a wave and become casualties of the sea.

If you do go collecting other *limu*, it's best to go at low tide. Take along a bucket or a large plastic bag to put it in. You might find it convenient to take along several smaller plastic bags to keep the different kinds of *limu* separate in your larger container.

There are two cardinal rules of collecting. First, don't overharvest. Try not to collect more than you will use. The second rule applies to those

HARVESTING THE OCEAN

You use seaweed products every day but probably don't realize it. The next time you brush your teeth, shampoo your hair, drink a beer, or eat a salad or ice cream, think of seaweed.

Without seaweed, your toothpaste and shampoo wouldn't be smoothly blended, the ingredients in your salad dressing would separate, the ice cream would melt faster and have a less pleasing texture, and your beer would be murky and lacking a nice head of foam.

These are just a few uses of valuable extracts called colloids which are produced by certain brown and red seaweeds. Already a multimillion-dollar business, the market is expanding rapidly as new uses for these extracts are developing almost daily. Because of the clamor for colloids, there is an impetus for cultivating seaweed commercially that extends beyond its direct use as food.

Is there potential for cultivating seaweed in Hawaii, harvesting the ocean? Many people familiar with the field say yes, and believe that seaweed as a new commercial crop may have economic significance in Hawaii's future.

William Magruder and Jeffrey Hunt state in their book, *Seaweeds of Hawaii*, "Seaweeds have long been and still are commonly used as food in Hawaii. It is envisioned that their future use and value in industry and as food for animal aquaculture will far exceed that of human consumption . . . Hawaii's utilization of seaweeds has the potential of undergoing a transition from a 'wild harvest' food resource to one of planned seaweed farming."

Elsewhere, seaweeds are harvested specifically for their colloids, one dramatic example being the giant kelp off the coast of California. These sequoias of the sea have an extremely rapid growth rate and grow to be 100 feet tall.

Seaweed colloids are used extensively in a tremendous variety of products as stabilizing, emulsifying, thickening or jelling agents. Their application is widespread in food and dairy products, drugs and cosmetics, in the production of everything from wine to antibiotics to pet food, and in such diversified industrial processes as the manufacture of paint, paper, textiles, insecticides and rubber products. Research is being conducted in Hawaii and elsewhere on the use of seaweeds as an energy source to produce synthetic fuels.

Maxwell Doty, UH professor of botany, who has earned an international reputation for his work with seaweeds, speaks with enthusiasm for the ingenious applications of seaweed colloids. He points out that they are used to time-release fertilizer for crops and in timed release capsules for human medication—those capsules with all the little colored beads in them. It's the algae gels in the coatings that control the timed release, dissolving at different rates.

Versatile seaweed extracts are what keep the chocolate distributed throughout chocolate milk, instead of settling down to the bottom as it did in years past. Doty says it is a sign of the generation gap whether you automatically shake a bottle of chocolate milk or not.

Doty has developed commercial *limu* farming operations in the Philippines, Malaysia, Micronesia, Chile and on Christmas Island.

While there are experimental projects growing *limu* at several sites on Oahu and in ponds on Molokai, most of his projects are overseas because, he says ironically, "It's easier to get federal money for overseas projects."

Maxwell Doty, U.H. professor of botany who has pioneered seaweed-growing projects in other countries, believes it has significant potential as a future commercial crop for Hawaii.

who are picking *limu* live, rather than gathering from the beachwash. That is: Do not pull it up by the roots. (Actually, it doesn't have roots, but a point of connection to the bottom called a holdfast.) Take along a knife to cut off the top portion, always leaving the base part so the plant can continue growing and rejuvenate itself for future harvest.

Limu always should be cleaned thoroughly. It gets its initial washing in salt water at the beach. Many experienced collectors add some sea water to their container, and a few even take along a portable ice chest to keep the *limu* cool until it reaches the haven of the refrigerator.

Opinions of veteran pickers differ as to whether it's better to store the refrigerated *limu* in salt water or to shake the water from it and store it dry. You will probably want to keep it in a jar with a secure lid or, if in a plastic bag, be sure to twist the opening shut; even then, your kitchen may have something of the aura of the sea about it.

A *limu* enthusiast named Flora Lee Simpson, writing in a 1944 issue of *Paradise of the Pacific* on the joys of *limu* gathering and eating, tells of being advised by an old-timer that it keeps better in a jar without a lid. She tried it and related the results:

"The butter tasted of low tide, the milk tasted like a John Masefield poem, which poems, as everyone knows, were written to be read—not eaten, and when the door of the refrigerator was opened, Conrad's ghost stalked the room."

The durability or perishability of refrigerated *limu* of various types ranges widely, but most will keep at least a week or more and still be good for eating. There are exceptions, however, and a few fragile types are known by the insiders as "one-day *limu*"—best eaten within a day of the time they are gathered. The "cockscomb" *limu* is one of these, so the day it comes from the beach (or the store) let it find its way into a glorious soup or stew.

Whether for eating or for pressing, *limu* should not be given its final, thorough baptism in fresh water, removing any remaining bits of sand and debris, until you are ready to use it.

For the neophyte interested in learning more about *limu*, in addition to Fortner's *The Limu Eater*, two other books are recommended.

One is *Seaweeds of Hawaii*, an extensive photographic guide by William Magruder, a Ph.D. candidate at Stanford, and Jeffrey Hunt, an instructor at Windward Community College and a coordinator for the Marine Advisory Program. Their book contains color photographs and descriptions of 118 varieties of Hawaiian *limu*, edible and otherwise, as they appear in their native habitat. It graphically conveys the richness of variety in color, shape and form of this plant life nurtured by the sea.

The other valuable resource book is *Limu—An Ethnobotanical Study of Some Edible Hawaiian Seaweeds*

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"...Among the edible and palatable seaweeds in Hawaii, there is an enormous variety in size, form, color, taste and texture..."

The immediate objective of the experimental *limu* projects in Hawaii is to relieve the market demand for *ogo* as food. Although this market for fresh *ogo* is substantial, the greatest potential for farming *ogo* and *limu manauea* in Hawaii is in dried *limu* for export and as a source of commercially valuable colloids. Another colloid-producing species Doty thinks would work well in the Islands is *Eucheuma*, which is now being farmed successfully in the Philippines.

Doty envisions *limu* as a link in a diversified aquaculture program. Sea farms or marine plantations could grow seaweed as an add-on crop to provide food for the fish or shellfish being raised. Says Doty, "When you grow *limu* in a fishpond, you can double your yield of fish or shellfish. This is a big thing for fish farmers."

This technique is being used in the Philippines, where aquaculture is extensively practiced, often from a family farming approach.

The problems facing the would-be family *limu* farmer in Hawaii, says Doty, are: "site competition—the lack of available coastal sites and competing with recreation and development for their use, the lack of suitable legislation to permit reef farming on a small scale, and the overly concerned, ecologically inclined who don't know what they're talking about and are scared of possible consequences."

Still, he is hopeful. "Raising seaweed can be done here—and it's a crime that it has not been done. I think it's possible for Hawaii to have a commercial *limu* crop in the next few years." —P.P.

Limu
Continued from page 73

by Isabella Abbott and Eleanor Williamson. This small booklet offers a wealth of information on 12 common types of edible Hawaiian *limu* and their historical, traditional and contemporary uses. This book is now out of print, but it is available at the public library and the authors are planning a revised, expanded version including more varieties of *limu*.

Abbott, who holds a Ph.D. in botany, is a professor at Stanford and the University of Hawaii. Williamson is an assistant in anthropology at the Bishop Museum. Both are part-Hawaiian and have been friends since their years as classmates at the Kamehameha Schools.

Recognizing that *limu*—which the Hawaiians used as food, medicine and in ceremony—was an important part of the Island culture and that much of the lore of *limu* had been lost over time, the authors' purpose was to seek out and record remnants of this heritage.

They spent considerable time on all the Islands, speaking in Hawaiian with the senior members of the Hawaiian community, many of whom had been brought up by their grandparents, so their knowledge extended back a century or more.

Abbott and Williamson were delighted to discover that these older Hawaiians retained much information and folklore about *limu* and that many seaweeds were still used for food in rural areas.

The authors point out that, in early Hawaii, *limu* was an important part of the diet as the third major component of it, along with fish and poi. The *limu* contributed nutritional balance, interest and variety.

Limu played a role in the Island traditional food barter system. As they did with fish, the Hawaiians living near the shore would trade *limu* to the people in the uplands in exchange for taro and other foo plants grown there.

One Hawaiian seaweed significant in Hawaiian tradition is the *limu kala*. While this holly-like brown *limu*, commonly found on all the Islands, was used for food, it also played a major role in ritual and medicine. The word *kala* means "to loosen, untie, free, release", it also means "to forgive, pardon." The *limu kala*'s name is symbolic in both senses.

During the ritual of *ho'oponopono*, when the members of the family gathered to discuss and resolve grievances, *limu kala* was eaten to signify the asking and giving of forgiveness. Some of Abbott's and Williamson's sources remembered this use of the *limu* in family rituals from their childhood.

Guy Tamashiro, grandson of the founder of the family establishment locally famed as Tamashiro Market, offers customers a choice of "long ogo" or "short ogo."

Limu kala also contributed to a purification rite following the burial of a relative and to a ceremony for fishermen.

Another custom was that of making a *limu kala* lei for a sick person, who would then go into the sea wearing it and let the water carry away the lei, and with it the cause of the illness—the concept of *kala* meaning "to free."

Limu kala was chopped or chewed and applied as a poultice to coral cuts, a practice that continues today.

Other *limu* had medicinal uses for everything from backache to asthma. In addition, *limu* was eaten as a popular remedy for a general run-down feeling—an idea that is not at all far-fetched, since *limu* of many kinds are rich in vitamins and minerals.

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Early Collections of Hawaiian Marine Algae[1]

Isabella A. Abbott[2]

ABSTRACT: A group of specimens representing 40 taxa of Hawaiian marine algae has come to light and is among the earliest collections of Hawaiian algae. Though only 24 of the specimens can be tallied with a list of 112 marine plants published by J. E. Chamberlain in 1880 and 1881, they answer a great need for verification of published names. Sixteen of the previously named taxa are changed because of taxonomic opinion or nomenclature. Sixteen taxa are added from the collection that were not included in the Chamberlain list. The specimens are now housed in the B. P. Bishop Museum in Honolulu.

Though some marine algae were included among the early records of Hawaiian plants, for example, Gaudichaud's (1826–1830), Hawaiian algae were in general neglected until 1880 when a list (published also without change in 1881) by J. E. Chamberlain was reported. Encouraged by Asa Gray, Chamberlain sent the specimens he had collected to Harvard University and Yale University for identification by W. G. Farlow and D. C. Eaton, respectively. Portions of Chamberlain's collections, some of which I have seen, may be found at the Farlow Herbarium (FH) of Harvard University, Field Museum of Natural History (F), Chicago, and the University of California (UC), Berkeley, though complete collections that match his published list are not available at any of these herbaria. Chamberlain's list contains 112 species of marine plants (not all algae).

A few years ago, George F. Papenfuss, professor emeritus, University of California (Berkeley), sent to me a small collection of dried Hawaiian algae for identification. The package was marked in the handwriting of W. A. Setchell: "property of Bishop Museum, sent by C. N. Forbes, April, 1910. To be named and returned." I did not appreciate the historical importance of the 76 specimens until I started to work on them. This group of algae represents about 30 percent of the taxa named by A. B. Seymour (Harvard University) in an unpublished list that Harold St. John gave me in 1946. St. John thought that the algae were probably determined by Farlow. The list contains 112 species names and a note that 23 additional specimens were not identifiable at that time. These particular algae were collected by George P. Andrews of Honolulu, and pencilled-in numbers on the specimen cards correspond to numbers on the Seymour list. The specimens were sent to Cambridge on 20 April 1891, though they had been collected about 25 years previously. Apparently when identified they were returned to Honolulu and given to the Bishop Museum. In 1910 C. N. Forbes, then curator of the herbarium at the Museum, sent to Setchell a portion of the Andrews collection and included also some algae collected by the Rev. Edward Bailey of Wailuku, Maui. Some Andrews specimens bear 1876 as the date—Bailey's, 1874 and 1876.

This collection is particularly important to students of Hawaiian algae because of the large number of published names for which we have not been able to locate early specimens upon which the names were given. In such a situation, there are two options: (1) carry the lists without being able to evaluate them: (2) disregard them. The first option has been followed by some (Reed 1907, MacCaughey 1918) and the second by others (Abbott 1947). Eubank (1946) was able to clarify the status of certain of Chamberlain's names because some of his specimens were located at the Farlow Herbarium, Harvard

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Codium arabicum Kützing, 1856, p. 35. Silva in Egerod, 1952, p. 382.

Although this is a common species in Hawaii, it is not included in the Chamberlain list, but *Codium tomentosum* is listed. The latter name, as applied to Hawaiian specimens, is *Codium edule* Silva (Silva in Egerod, 1952, p. 394). Silva examined the *Codium tomentosum* of Chamberlain's list and assigned it to *C. edule*.

Collected by E. Bailey, Kahului, Maui, and by G. P. Andrews (#29) on Oahu, identified by Seymour as *C. adhaerens* C. Ag. but both thought by Reed to be "*Codium spongiosum*."

Enteromorpha clathrata var. *clathrata* (Roth) Greville, 1830, p. 181. Gilbert, 1965, p. 482.

Andrews's #10, identified by Seymour as *E. erecta* J. Agardh and by Reed as "*Enteromorpha plumosa*," was collected at Waikiki, Oahu.

Enteromorpha plumosa Kützing, 1843, p. 300. Gilbert 1965, p. 482.

Thought to be "*E. ramulosa*" by Reed, but in *E. ramulosa*, the ultimate branchlets are spinelike, whereas the specimen shows long branchlets, similar to those of *E. plumosa*.

Collected by G. P. Andrews (#11) at Waikiki, Oahu, identified by Seymour as *E. hopkirkii*, now accepted as a synonym of *E. plumosa*.

Microdictyon japonicum Setchell, 1925, p. 107. Egerod, 1952, p. 363.

Andrews's #14 shows annulate thickening, a characteristic of this species.

Collected by G. P. Andrews (#14) (#15 also cited by Seymour but not in this collection) as *Microdictyon agardhianum* Decáisne.

Siphonocladus tropicus (Crouan & Crouan) J. Agardh, 1887, p. 105. Egerod, 1952, p. 356.

Casually reported by Setchell and Gardner (1930) from Honolulu, and reported upon in detail by Egerod, this is surely the oldest known Hawaiian specimen.

Collected by G. P. Andrews (#34) on

Phaeophyta

Endarachne binghamiae J. Agardh, 1896, p. 26.

This may be the *Phyllitis fascia* (= *Petalonia fascia* [Müll.] Kuntze) that appears in Chamberlain's list, but until a specimen is found that more clearly shows a resemblance to *Petalonia* than to *Endarachne*, it seems best to recognize the densely intertwined medullary filaments of the specimens as belonging to *Endarachne binghamiae*. Miss Reed's note indicates that the center was hollow but I did not see this.

Collected by E. Bailey, perhaps on Oahu, 1876.

Rosenvingea orientalis (J. Ag.) Børgesen, 1914, p. 182.

Identified by Reed as "*Cutleria*?," this specimen was collected by E. Bailey, perhaps on Oahu, in 1876. Its irregular, slender branches and hollow axis characterize the species.

Rhodophyta

Gracilaria sp.

Reed annotated her #24 as "*Dumontia*?" (a red alga occurring in temperate and boreal seas), and under it, in Dr. Setchell's handwriting and initials, "*Eucheuma nudum*?" (a red alga common to the west and southwest of Hawaii, but not of natural occurrence in Hawaii). Cross sections show somewhat compressed medullary cells (therefore not *Dumontia* which is uniaxial, and not *Eucheuma* which has elongate filaments in the medulla). The specimen further lacks the verticillately placed laterals that constitute the cortex in *Dumontia* and the very much thickened cell walls of cells of the outer cortical layers of *Eucheuma*. *Eucheuma nudum* J. Agardh was recorded by MacCaughey (1918, p. 145) but whether his identification is based on Setchell's determination of the specimen cited here, or is from his own specimen which has not been located, is not known. It is highly unlikely that *Eucheuma* occurred in Hawaii in 1876.

Without reproductive structures, it is not
possible to give a species name to the

University. It is not known how many specimens were originally collected, nor precisely where they are housed. However, the collections upon which this paper is based appear to contain about one-fourth of the total number of the species in Chamberlain's list and may be used as supporting material for Chamberlain's voucher specimens that may never be found. Sixteen other taxa that are not listed by Chamberlain but were collected by Andrews and Bailey in the same period are added. A continual search for specimens named in the old lists must be maintained.

Most of the algae have notes in the handwriting of (and signed by) Minnie Reed; some of these notes indicate that the algae had been sent to A. B. Seymour for identification, and hence without doubt are the same specimens included in this paper. Five of the specimens are identified by Setchell in his handwriting. The Rev. Bailey apparently made good use of the weekly Wednesday afternoon excursions to the beach (near Kahului, Maui) of his charges at the Wailuku Female Seminary (Dibble 1909), and later he occasionally went to Paia, some miles distant, by way of the beaches (Laura C. Green, personal communication, ca. 1937) in connection with Maunaolu Seminary. No specimens from Paia are found in the present collection, but I have seen and cited some earlier (Abbott 1946).

Whether Reed annotated the collection at Setchell's request or intended to include them with her own larger collection is not known, but it is possible that some of these specimens represent her own published (1907) records. Thus when her collections (mostly at the University of California, Berkeley) are critically examined in the future, it will be necessary to study these Andrews and Bailey algae again. Some specimens are marked "duplicate," implying that there are others elsewhere.

RESULTS

Table 1 shows an inventory of the collection with the names published by Chamberlain (1880, 1881), gives unpublished identification by others since this may help future workers to understand the origin of some of the species names used in Hawaiian literature.[3] and finally shows the current classification of the species. All of these specimens will be housed in the Bernice Pauahi Bishop Museum in Honolulu.

The table is supplemented by an annotated list of 16 other taxa present in the collection but not referred to by either Chamberlain (1880) or Reed (1907). These constitute the earliest known Hawaiian specimens of some species that have been subsequently reported by others. Andrews's specimen numbers tally with the Seymour list and are so used; Bailey did not use numbers.

Reed's comments, where appropriate, are added. Since she rarely used author's names on binomials, I have no idea whether she obtained the name she used through an original reference or from a secondary source. I have therefore put her names in quotes. On the other hand, Seymour used authors with binomials and I use his determinations without quotes.

ANNOTATED LIST

Chlorophyta

Cladophora socialis var. *hawaiiana* Brand, 1905, p. 182. Gilbert 1965, p. 489.

Reed notes: "somewhat resembles the structure of *Cladophora nuda* especially its branching and long slender cells and much elongated slender upper ramuli." The specimen compares well with some of those collected by Gilbert in Hawaii, where he says the species is of wide distribution.

Collected by G. P. Andrews, Oahu, without number or date. There are 4 entries for *Cladophora* in the Seymour list.

[3]A particularly trying use of unpublished names of algae is to be found in some of the entries in the Hawaiian Dictionary (Pukui and Elbert 1971). Although it is laudable that the Hawaiian common name is linked to a scientific name, if the latter is unknown as occurring in Hawaii and there are no voucher specimens, the identification becomes difficult if not impossible.

Codium arabicum Kützing, 1856, p. 35. Silva in Egerod, 1952, p. 382.

Although this is a common species in Hawaii, it is not included in the Chamberlain list, but *Codium tomentosum* is listed. The latter name, as applied to Hawaiian specimens, is *Codium edule* Silva (Silva in Egerod, 1952, p. 394). Silva examined the *Codium tomentosum* of Chamberlain's list and assigned it to *C. edule*.

Collected by E. Bailey, Kahului, Maui, and by G. P. Andrews (#29) on Oahu, identified by Seymour as *C. adhaerens* C. Ag. but both thought by Reed to be "*Codium spongiosum*."

Enteromorpha clathrata var. *clathrata* (Roth) Greville, 1830, p. 181. Gilbert, 1965, p. 482.

Andrews's #10, identified by Seymour as *E. erecta* J. Agardh and by Reed as "*Enteromorpha plumosa*," was collected at Waikiki, Oahu.

Enteromorpha plumosa Kützing, 1843, p. 300. Gilbert 1965, p. 482.

Thought to be "*E. ramulosa*" by Reed, but in *E. ramulosa*, the ultimate branchlets are spinelike, whereas the specimen shows long branchlets, similar to those of *E. plumosa*.

Collected by G. P. Andrews (#11) at Waikiki, Oahu, identified by Seymour as *E. hopkirkii*, now accepted as a synonym of *E. plumosa*.

Microdictyon japonicum Setchell, 1925, p. 107. Egerod, 1952, p. 363.

Andrews's #14 shows annulate thickening, a characteristic of this species.

Collected by G. P. Andrews (#14) (#15 also cited by Seymour but not in this collection) as *Microdictyon agardhianum* Decaisne.

Siphonocladus tropicus (Crouan & Crouan) J. Agardh, 1887, p. 105. Egerod, 1952, p. 356.

Casually reported by Setchell and Gardner (1930) from Honolulu, and reported upon in detail by Egerod, this is surely the oldest known Hawaiian specimen.

Collected by G. P. Andrews (#34) on

Phaeophyta

Endarachne binghamiae J. Agardh, 1896, p. 26.

This may be the *Phyllitis fascia* (= *Petalonia fascia* [Müll.] Kuntze) that appears in Chamberlain's list, but until a specimen is found that more clearly shows a resemblance to *Petalonia* than to *Endarachne*, it seems best to recognize the densely intertwined medullary filaments of the specimens as belonging to *Endarachne binghamiae*. Miss Reed's note indicates that the center was hollow but I did not see this.

Collected by E. Bailey, perhaps on Oahu, 1876.

Rosenvingea orientalis (J. Ag.) Børgesen, 1914, p. 182.

Identified by Reed as "*Cutleria*?," this specimen was collected by E. Bailey, perhaps on Oahu, in 1876. Its irregular, slender branches and hollow axis characterize the species.

Rhodophyta

Gracilaria sp.

Reed annotated her #24 as "*Dumontia*?" (a red alga occurring in temperate and boreal seas), and under it, in Dr. Setchell's handwriting and initials, "*Eucheuma nudum*?" (a red alga common to the west and southwest of Hawaii, but not of natural occurrence in Hawaii). Cross sections show somewhat compressed medullary cells (therefore not *Dumontia* which is uniaxial, and not *Eucheuma* which has elongate filaments in the medulla). The specimen further lacks the verticillately placed laterals that constitute the cortex in *Dumontia* and the very much thickened cell walls of cells of the outer cortical layers of *Eucheuma*. *Eucheuma nudum* J. Agardh was recorded by MacCaughey (1918, p. 145) but whether his identification is based on Setchell's determination of the specimen cited here, or is from his own specimen which has not been located, is not known. It is highly unlikely that *Eucheuma* occurred in Hawaii in 1876.

Without reproductive structures, it is not
possible to give a species name to the

TABLE 1

INVENTORY OF HAWAIIAN ALGAE COLLECTED IN 1874 AND 1876

PUBLISHED NAMES (CHAMBERLAIN 1880)	LOCALITY	COLLECTOR (A. = ANDREWS; B. = BAILEY)	COLLECTION NUMBERS	UNPUBLISHED IDENTIFICATIONS (REED OR OTHERS)	CURRENT SCIENTIFIC NAME (AUTHOR'S IDENTIFICATIONS)
Amansia glomerata	Maui	B.	n	*Nitophyllum* sp.?	*Amansia glomerata* J. Ag.
Bryopsis plumosa	Lanai	B.	#28	*Bryopsis plumosa*	*Trichosolen oahuensis* (Egerod) Taylor*
Caulerpa clavifera	Oahu	B.	#11	*Caulerpa*	*Caulerpa racemosa* var. *macrophysa* (Kütz.) Tayl.
Centroceras clavulatum	Oahu	A.	n	(mixed with *Ceramium*)	*Centroceras clavulatum* (C. Ag.) Mont.
Ceramium (many var. undetermined)				13 specimens	(not identified to species)
Chondria baileyana	Oahu	B.	#6	*Chondria dasyphylla*	*Chondria baileyana* (Mont.) Harvey
Cladophora	Oahu	A.	#7, 8, n	*Cladophora fascicularis*	*Cladophora fascicularis* (Mert.) Kütz.
Cladhymenia[1]	Maui	B.	#2	*Calliblepharis*?	*Cladhymenia pacifica* Setch.
Desmia ambigua	Oahu	A.	#80(2)	*Desmia coccinea* of Seymour	*Chondrococcus hornemannii* (Mert.) Schmitz
	Maui	B.	(5)	*Chondrococcus harveyi* of Reed	*Chondrococcus hornemannii* (Mert.) Schmitz
Dictyota crenulata	Oahu	A.	#21	*Dictyota dichotoma* var. *intricata*	*Dictyota crenulata* J. Ag.
	Oahu	A.	#A	*Dictyota dichotoma*	*Dictyota crenulata* J. Ag.
Dictyota sandwicensis	Oahu	A.	#19	*Dictyota acutiloba* var. *distorta*	*Dictyota acutiloba* J. Ag.
	Oahu	A.	#26	*Dictyota furcellata*	*Dictyota acutiloba* J. Ag.
Galaxaura marginata	Maui	B.	#13(2)	*Galaxaura adriatica*	*Galaxaura fastigiata* Decaisne
Gracilaria coronopifolia	Oahu	A.	#36	*Gracilaria coronopifolia*	*Gracilaria coronopifolia* J. Ag.
	Oahu	A.	xy	*Sphaerococcus corallinus*	*Gracilaria coronopifolia* J. Ag.
Griffithsia	Oahu	A.	#86	*Corynospora australis*	*Corynospora pedicellata* (Smith) J. Ag.
Hypnea nidifica	Oahu	A.	#68	*H. nidifica* of Setchell, Reed	*Hypnea cervicornis* J. Ag.
H. pannosa	Oahu	A.	#77	*H. armata* of Reed; *H. cervicornis* of Setchell	*Hypnea cervicornis* J. Ag.
H. divaricata	Oahu	A.	#83	*H. armata* of Reed	*Hypnea cervicornis* J. Ag.
H. cornuta	Hawaii	A.	#25	*H. nidifica* of Reed	*Hypnea nidifica* J. Ag.
	Hawaii	A.	#28	*H. pannosa* of Setchell; *H. nidifica* of Reed	*Hypnea nidifica* J. Ag.
Hallyseris australis	Oahu	A.	#H	*Haliseris pardalis*	*Dictyopteris australis* (Sond.) Ask.
Halimeda tuna	Oahu	A.	#33		*Halimeda discoidea* Decaisne

Laurentia paniculata	Oahu	A.	#58	*Laurencia paniculata* of Seymour	*Laurencia nidifica* J. Ag.
L. nidifica	Oahu	A.	#60, 62	*Laurencia pinnatifida* of Reed	*Laurencia nidifica* J. Ag.
	Hawaii	A.	#21	*Laurencia ceylanica* J. Ag. of Setchell	*Laurencia parvipapillata* Tseng
Martensia flabelliformis	Maui	B.	n	*Martensia flabellulata* (6 specimens)	*Martensia fragilis* Harvey
Spiridia spinella	Oahu	B.	#22	*Spyridia spinella*	*Spyridia filamentosa* (Wulf.) Harv.
S. filamentosa	Oahu	A.	#85(2)	*Spyridia spinella*	*Spyridia filamentosa* (Wulf.) Harv.
	Oahu	A.	#38	*Spyridia spinella* of Reed	*Spyridia filamentosa* (Wulf.) Harv.
				S. filamentosa of Seymour	*Spyridia filamentosa* (Wulf.) Harv.
Taonia solieri	Maui	B.	n		*Spatoglossum solierii* (Mont.) J. Ag.
Vidalia obturiloba	Oahu	B.	#15	*Vidalia volubilis* of Reed	*Vidalia fimbriata* (Brown) J. Ag.
				Vidalia obtusiloba of Setchell	*Vidalia fimbriata* (Brown) J. Ag.
	Hawaii	A.	#111	*Vidalia obtusiloba*	*Vidalia fimbriata* (Brown) J. Ag.

NOTE: Published names given in original spelling. Collection numbers preceding Reed's name are hers except when collected by Andrews, then his; n signifies no number.

[a] Basionym: *Pseudobryopsis oahuensis* Egerod, U. C. Publ. Bot. Vol. 25, p. 372, 1952. *Trichosolen* Montagne 1860 has priority (Article 11, ICBN) over *Pseudobryopsis* Berthold in Oltmanns, 1904.

[b] *Chalbyrsonia pacifica* leg. J. E. Chamberlain #66, 1879 (without location); UC 940272; det. II. 1953 by M. S. Doty.

ment. Collected by E. Bailey in 1876, perhaps on Oahu.

Callithamnion byssoides Arnott in Hooker, 1833, p. 432.

The soft, globose thallus with pinnate branches and tetrasporangia about 30 μm diameter identify this species.

Collected by G. P. Andrews (#101) on Oahu, with no date, as *Callithamnion* sp.

Dasya bailouviana (Gmelin) Montagne, 1841, p. 161.

Tetrasporangial stichidia linear, with an acute apex, the stichidia about 118 μm wide and mature tetrasporangia 39–44 μm diameter. This collection under Reed (#19) and identified by her as "*Dasya ocellata*" is the biggest surprise of all the specimens in the early collections. The species has never been collected again in Hawaii. It is widely distributed in the North Atlantic and both American tropics.

Collected by E. Bailey, perhaps on Oahu, in 1876.

Dasya sp.

Reed's #18 is a common species of *Dasya* growing in Hawaii, particularly in bays on Oahu and as an epiphyte. Since the Hawaiian species have not been studied, there is no specific name as yet for this species.

Collected by E. Bailey, perhaps on Oahu, 1876.

Heterosiphonia sp.

Identified by its somewhat compressed thallus and alternately distichous branching, this species was epiphytic on *Hypnea*. As with the preceding species, members of this red algal family have not been studied in Hawaii.

Collected by G. P. Andrews on Oahu (#94) without date. The Seymour list identifies #94 as *Chondria tenuissima* var. *baileyana* Farl.

Laurencia spp.

Two different *Laurencia* specimens, one collected by G. P. Andrews (without number) on Oahu, and the other by E. Bailey at Kahului, Maui, are not identifiable at this time.

Drouetia sp. Dawson, 1949, p. 11.

A fairly common species belonging to the Rhodymeniales, with a short, solid stipe and circular to irregular blades, that is still without a specific name. All recent specimens that have been examined are either tetrasporangial or cystocarpic, but the specimen here shows both carpospore masses and cruciately divided tetrasporangia on the same plant. Reed did not note the cystocarps but did sketch the tetrasporangial sori and labelled the specimen *Halymenia*, a genus that does not have tetrasporangia in sori.

Collected by G. P. Andrews (#180) "not now to be determined," on Hawaii Island.

Porphyra sp.

Called "*Porphyra laciniata*" or "*P. leucosticta*" by Reed, this specimen was collected by E. Bailey at Kahului, Maui, without date. I am not able to give this specimen a specific name. A *Porphyra* species has been reported from the Hawaiian Islands a number of times, as the species is one of those eaten by Hawaiians (Abbott and Williamson 1974).

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MANGROVES

...swamps nobody likes

These dank and spongy jungles have been drained, cut and covered, but increasingly their pell-mell destruction is seen as a big mistake

Dan McCoy (Black Star)

An ecosystem vindicated: scientists now say mangroves, like this one in Florida, are linked to the well-being of many ocean fisheries.

MANGROVES

BY JOHN CAREY

A MANGROVE swamp can be a grim, forbidding place. Dense foliage blocks the sun. Mosquitoes whine and bite. Without warning, tree crabs drop onto the shoulders of human passersby. There is no solid footing in the mangrove mesh of trees and shrubs, just a spongy jumble of gooey mud and roots that sink down into dark water. "You stand on trees and look down at sharks and octopuses," says biologist Daniel Simberloff of Florida State University.

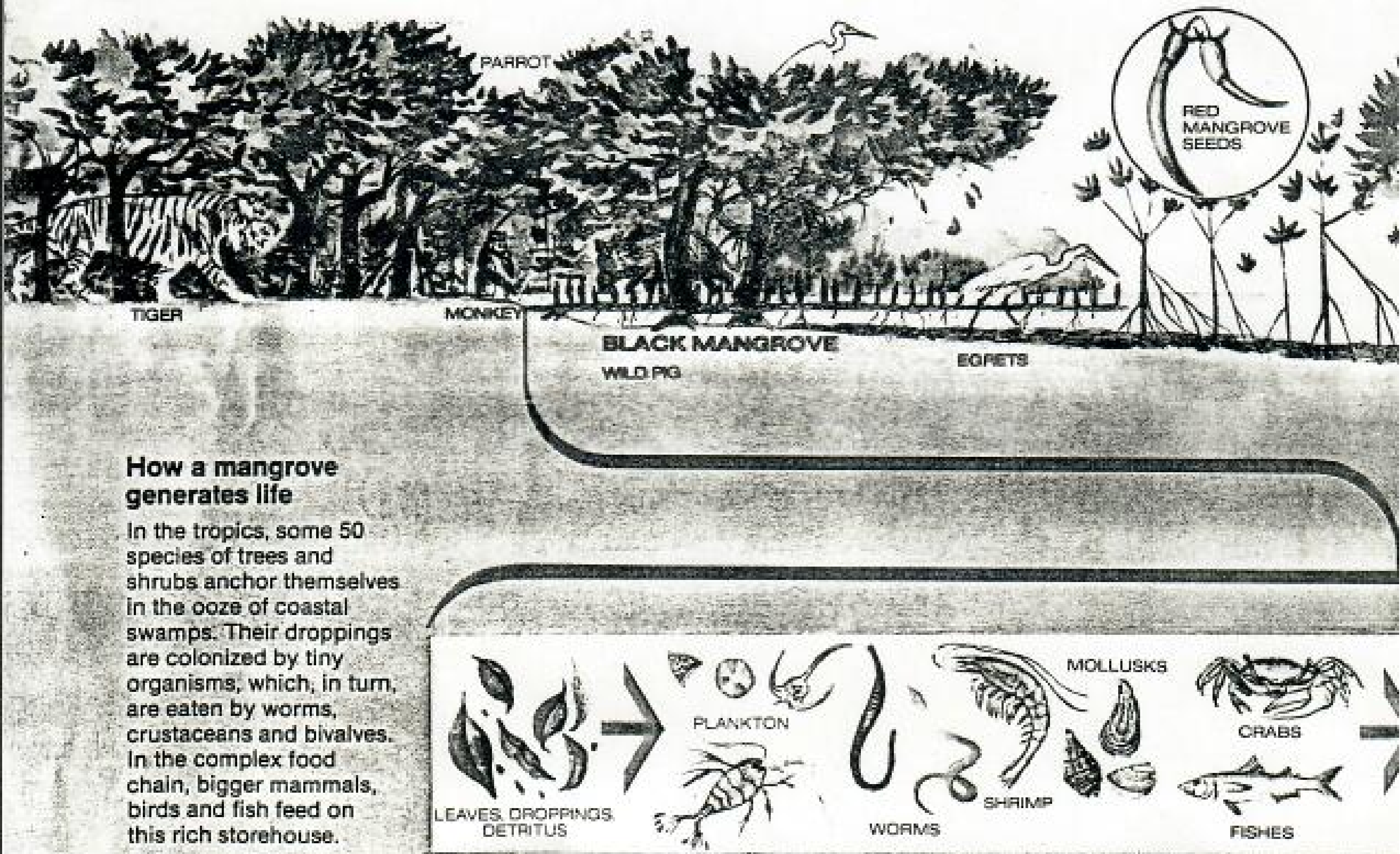
Indeed, some people find these seaside jungles the most horrible places in the world. Given that low popularity rating, it is not surprising that nations everywhere have hastened to drain, cut and cover them. In Indonesia alone, as much as 1,000 square miles of mangroves have been clear-cut to make wood chips. Worldwide, more than 60 percent of tropical coastlines were once fringed with mangroves. Now researchers estimate that figure has dropped below 40 percent, with losses currently running at the pell-mell pace of perhaps 4,000 square miles annually.

Increasingly, though, the policy of mangling the mangroves is seen as a big mistake. Researchers are coming to believe that these swamps nobody likes are actually critical nursing and feeding grounds for some of the world's great coastal fisheries. Though mangroves may appear inhospitable to people, governments from Bangladesh to the Philippines have begun to take a more kindly view of them.

The term mangrove refers to more than 50 species of tropical trees and shrubs in a dozen different families. What they share is the remarkable ability to live in a no-man's-land where tides swirl and fresh water mixes with salty oceans. "They grow where no other tree can," says Florida biologist Eric Heald — in tropical estuaries, and along salt marshes and muddy coasts. Some of the simplest mangrove ecosystems are in Florida, where only three species are found, each with its own niche. Nearest to the sea is the red mangrove, whose red wood and gray bark can tower as high as 80 feet. Closer in is the black mangrove. Often a shorter scrub tree, it has dark, scaly bark, but in places, it soars above the red mangroves. The small white mangrove grows where salty tides barely reach.

Red mangroves are lifted high above the ground by a system of branched, aerial roots that anchor the trees. In countries like Panama, where tides are large, this tangle of supports can lift a tree 14 feet aboveground. Known as "prop roots," they grow down from branches as well as out from trunks. Black mangroves also have gas-exchanging roots, which carry oxygen down beneath the mud. These projections to the prop roots, known technically as "pneumatophores," extend above the mud like a forest of tiny fingers.

Set forever in a brackish bath, mangroves battle for their lives against high levels of salt. The black mangrove actually has glands that excrete salt on its leaves. Other species, including the red mangrove, use a filtration system in their roots to keep salt from entering. Even so, mangrove sap is ten times



How a mangrove generates life

In the tropics, some 50 species of trees and shrubs anchor themselves in the ooze of coastal swamps. Their droppings are colonized by tiny organisms, which, in turn, are eaten by worms, crustaceans and bivalves. In the complex food chain, bigger mammals, birds and fish feed on this rich storehouse.

saltier than the sap of trees in temperate forests.

Lest they be swept out to sea without taking root, red mangrove seeds remain on the parent plant until they sprout. By the time they fall, these "propagules," which look like slender green cigars, are about eight inches long. Some plunge into the mud and put down roots immediately; others drift with tidal flows, finally tipping upward and bobbing along in an upright position. Floating propagules rapidly colonize sandbars, oyster bars and other accumulations of debris.

Within the sheltered mangrove swamps, life swirls in the rusty brown water which is colored by the tannin in mangrove bark and leaves. "Once you've seen a really productive, pristine mangrove ecosystem, you can't help appreciating what's happening there," says biologist William Odum of the University of Virginia. "It's like swimming over a coral reef." Each mangrove tree teems with life, from the crabs, snakes and beetles that creep among its leaves to the worms, killifish and lobsters that browse among its roots.

The story of how nutrients are used in the mangrove swamp has been unraveled only in the last 20 years. While doing graduate work at the University of Miami in the late 1960s, biologists Heald and Odum linked mangrove leaves with fisheries. Healthy mangrove communities drop almost 4½ tons of leaves per acre each year. Each fallen leaf is colonized by marine bacteria, fungi and protozoa. These tiny organisms turn indigestible cellulose into rich food. In six months, the biologists found, the protein in decaying red mangrove leaves increases fourfold. Black mangrove leaves, which decompose longer before being flushed out by tides, have a protein content "as high as steak," says Ariel Lugo, director for the Institute for Tropical Forestry in Rio Piedras, Puerto Rico.

This detritus is a big feast for small creatures. Tens of thousands of tiny crustaceans, bivalves and worms live in each square yard of muddy swamp bottom. They swarm over the decaying leaves, breaking them into little pieces. In turn, these animals are food for shrimp, wading birds like herons, roseate spoonbills and ibises — plus the young of many commercial and sport fishes, including tarpon, red drum and snook. Because they must cope with currents, turbidity, changing salinity and fluctuating oxygen concentrations, "organisms that make use of the mangrove estuaries pay a hell of a price," says Bernie Yokel, director of the Rookery Bay Marine Research Station near Naples, Florida. But they reap a handsome payoff, too.

Yokel has studied the pink shrimp, which are taken from Gulf waters near Key West, Florida, at an average rate of 20 million pounds per year. Spawned in the Tortugas, pink shrimp larvae migrate almost 100 miles to the shallow bays of southwestern Florida. By clinging to the bottom during ebb tides and letting go on incoming tides, the baby shrimp make a purposeful move into the mangroves, where they "eat anything they can find" as Yokel puts it. After two to six months of eating, they start the long journey back to their

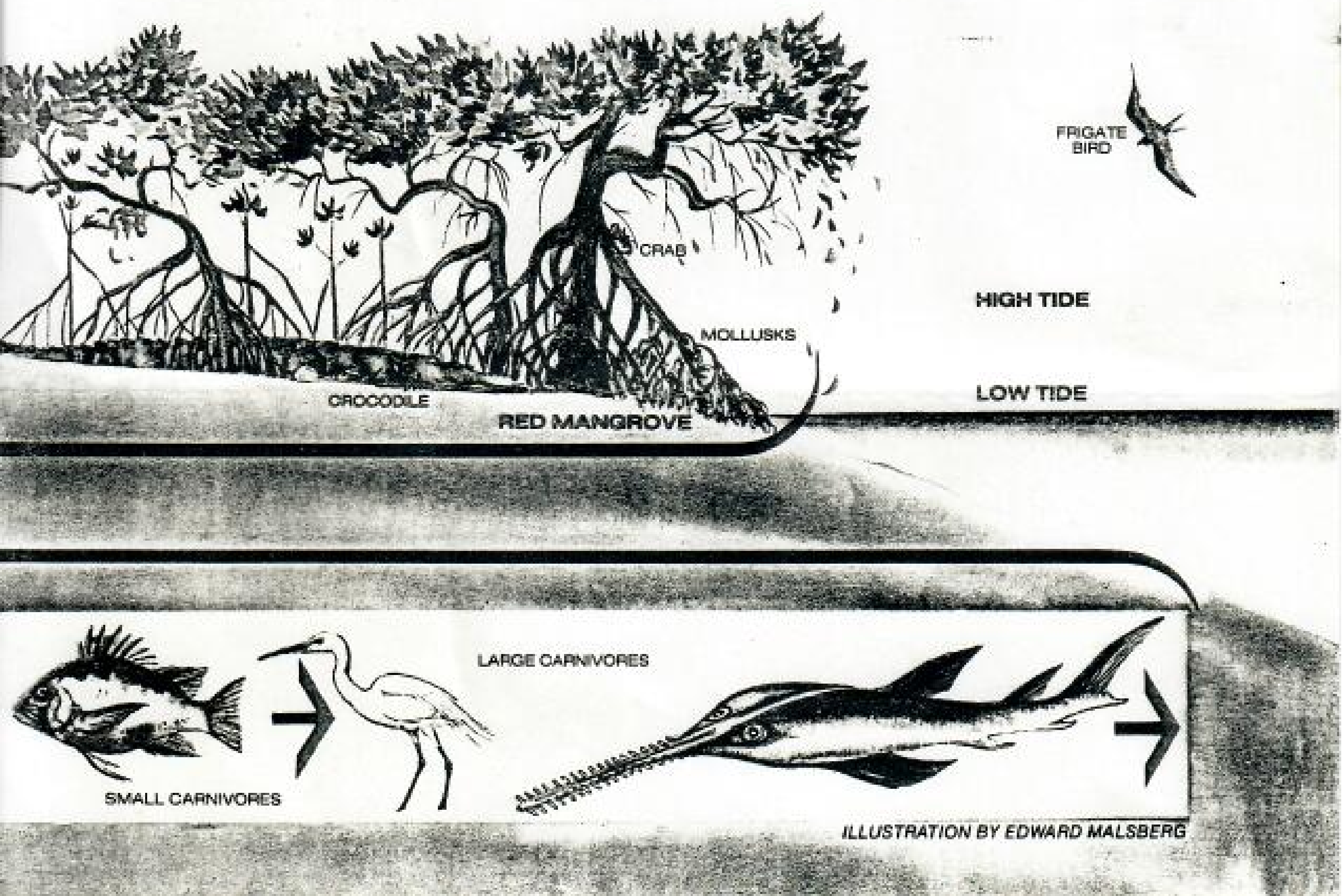


ILLUSTRATION BY EDWARD MALSBERG

breeding grounds to repeat the cycle.

The shrimp are fair game for mangrove fishes, which have learned to nose into shrimp hiding places in sea grass and mud. For example, the red drum swims with its head pointed down, while little filaments on its pectoral fins feel for the bottom. If the drum senses a shrimp move, it grabs for the food.

Another mangrove denizen is an isopod called *Sphaeroma terebrans*. This tiny crustacean is a notorious borer, killing the tips of new prop roots with the holes it makes. But when mangrove root ends die, two or three new roots shoot out above them. In this way, root systems of bored mangroves may become larger and more branched, better able to withstand hurricanes.

Much of the new interest in mangroves was spawned by Odum and Heald's research. "Until the link between fisheries and mangroves became clear, mangroves had no clientele," explains Lawrence Hamilton of the Environment and Policy Institute in Honolulu. That link has become ever clearer to governments, fishermen and biologists, who have found that fishery yields often decline where mangroves have been destroyed. For example, annual prawn production in India's mangrove-lined Pichavaram estuary equals about 88 pounds per acre, while a nearby estuary, free of mangroves, produces a mere 17 pounds per acre. In Florida's Tampa Bay, which by the 1970s had lost almost half of its mangroves to housing developments, commercial fishing fell off noticeably, according to area researchers and fishermen. But to the south, off the protected mangroves in Charlotte Harbor, the catch of drum and sea trout has remained constant.

Still, the link remains theoretical, circumstantial and controversial. And mangroves are not the only contributors to the food chain. Ariel Lugo estimates that dense mangrove islands sprawling across Florida's Rookery Bay supply only one-third of the bay's organic carbon. The rest comes from sea grasses and plankton that flourish in the bay's shallow waters. Indeed, bays and estuaries without mangroves support many fisheries, including anchovies off Peru.

Even so, there are other mangrove benefits. "Small diameter stems from mangroves are the two-by-fours of Malaysia," observes University of Miami biologist Samuel Snedaker. Mangrove wood provides pulp for paper in Bangladesh, tannins for curing sheep and antelope hides in Senegal, and charcoal for cooking fires throughout Southeast Asia. Indian cattle and Australian water buffaloes browse contentedly among prop roots and pneumatophores.

Except where people have modified the land, the tangled vegetation of mangrove swamps can also protect low-lying areas from devastating storm waves. But although mangroves can stabilize shorelines — in the early 1900s, they were planted as protection for the Florida Keys Railroad — they are not active land-builders and they can't stand up to prolonged pounding of surf. In Australia's Botany Bay, for example, changed wave patterns caused by new breakwaters have ravaged previously sheltered mangrove communities. In Bangladesh, on the other hand, there have been tremendous losses of life and property because the mangroves were destroyed.

Then, too, mangrove swamps harbor their share of animal rarities. A few American crocodiles still lurk along mangrove-lined creek banks on Key Largo. The elusive Key deer is limited to the mangroves and upland pines of Big Pine Key. Endangered Bengal tigers are found only in the Sundarbans mangroves of India and Bangladesh. As mangroves decline, animals which rely on them are living indicators of habitat loss. "The best barometer is the wading bird population," says marine researcher Yokel, adding: "We're down to an estimated 200,000 wading birds in Florida, one-tenth of what we had in the 1930s."

Causes of the habitat destruction are many. Scientists know that mangrove swamps depend on fresh water from rain and rivers to maintain their complex web of life, but in the mid-1970s, the Indian government didn't remember — or care — as it built a dam across the Ganges near the Bangladesh border. The loss of dry season fresh water siphoned off by the dam, and groundwater pumped for irrigation projects in India and Bangladesh is devastating the Sundarbans forest. One million acres of mangroves spread across the Ganges River delta in Bangladesh are affected. No one lives in the Sundarbans, partly because of its man-eating tigers, but its trees have provided a sustained yield of wood since British colonial times.

As the Sundarbans forest deteriorates, so do its feline inhabitants. A

Creatures of the land

In the swirling no-man's-land of mud, where tides mix salt water with fresh, numerous birds and mammals, including the yellow-crowned night heron (above), prowl for food. Fish called mudskippers (right) can live above water — or below.

Creatures of the sea

Underwater, the tangle of "prop roots" is home to an astonishing array of ocean life: a fiddler crab (below) from the Philippines; mussels and sponges (right) at Palau Island; and snappers and grunts (far right) at Grand Cayman.

German biologist recently discovered that Bengal tigers in the eastern part of the forest, where fresh water abounds, are sleek and healthy. But to the west, where salinity stunts the trees, the tigers are scrawny and mangy.

Ironically, vast mangrove forests have also fallen prey to good intentions and bright ideas of international development agencies. Complains Snedaker: "They look at mangroves and see 50 million acres of coastal soil for growing rice. If it were up to them, they would chop down every last mangrove." Rice-minded Indonesians have also permitted hundreds of thousands of acres of mangroves to be clear-cut in recent years. Trouble is, the mangrove soils contain salt and acid sulfates which make it tough indeed to produce respectable yields of rice. As Snedaker sees it, the Indonesian situation is "a horrible example of bad planning. The result has been crop failures, poor yields and the disruption of cultural patterns."

Similar problems have haunted attempts to clear mangroves for fish farming. In Costa Rica, shrimp ponds have to be flushed periodically with seawater to reduce acidity. The Philippines has made a number of successful milkfish ponds from the mangrove swamps. But productivity in some of the ponds drops off within a few years, and the ponds, enclosed by dikes, are simply abandoned. Observes Snedaker: "The

In a flash of pink, roseate spoonbills in Florida's Everglades stand out from their murky mangrove backdrop. Though mangroves may seem inhospitable to people, they are havens for wildlife.

travesty is that the ponds have been left intact. If they broke the dikes, the mangroves would come back."

Perhaps because of such unhappy stories, attempts are being made to stem the headlong decline of the mangroves. Bangladesh has negotiated a treaty with India that seeks more vital fresh water for the Sundarbans. In the Philippines, President Marcos has set aside 194,000 acres of mangroves, despite protests from fish pond owners. And Panama is planning to manage its mangroves for sustained yields of wood, a practice that some countries — notably Malaysia — have followed for almost a century. At the same time, international agencies are beginning to pay serious attention to the long-neglected mangrove forests. A recent 132-page report on the worldwide status of mangroves prepared by the International Union for Conservation of Nature and Natural Resources seeks to call high-level government attention to the role of these ecosystems.

Nowhere do black and red mangroves have better prospects than in Florida, where, as Bernie Yokel puts it, "mangroves have gone from being a wasteland plant to the sacred tree of south Florida." Below the mean high water mark, all mangroves are the property of the state and are protected by Florida law; farther upland, development is regulated by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. In a precedent-setting move in 1976, the corps stopped a major developer, Deltona Corporation, from adding 2,000 acres to a housing project on Marco Island,

Lynn M. Stone

where suburban ranch homes rub shoulders with prop roots. Much to the relief of a coalition of biologists and environmental groups which had been fighting Deltona for years, the corps' decision was upheld in the Federal District Court of Appeals in Washington last spring. Under the terms of a proposed settlement, Deltona will be allowed to develop homes on 300 acres of mangrove swamp, much of it marginal. But in return, Deltona will turn over 15,000 acres of wetlands to the state, ensuring an intact mangrove fringe from Rookery Bay clear around the tip of Florida.

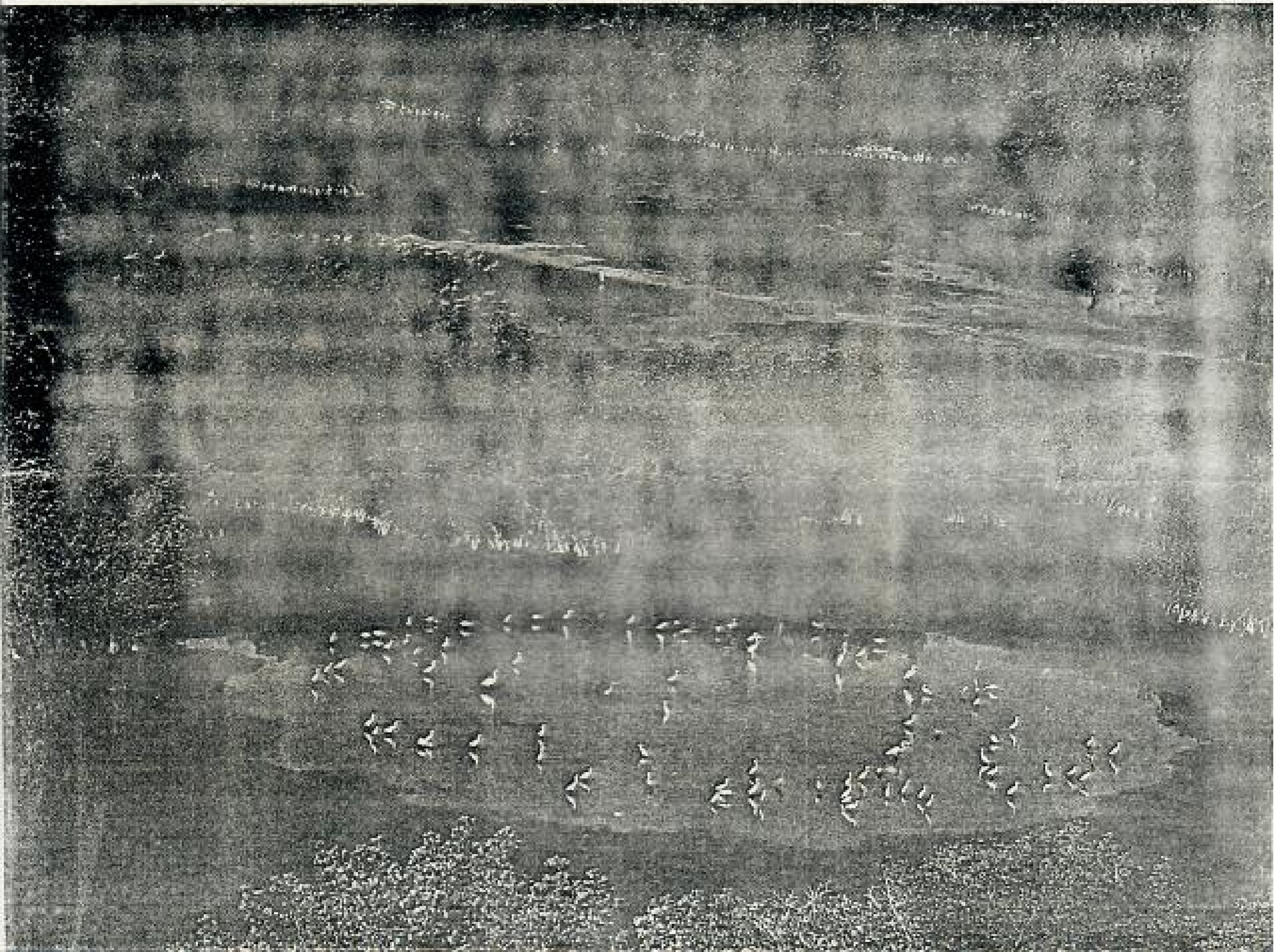
Another key court decision followed an oil spill in Puerto Rico. On March 18, 1973, the Greek tanker *Zoe Colocotroni* went aground on a sandbar off Cabo Rojo. Instead of waiting for the tide to refloat the vessel, the crew panicked and jettisoned 5,000 tons of oil, which drifted into the mangroves of Bahia Sucia (literally, "dirty bay"). About 40 acres were covered with oil; five acres of mangroves died. In response, the government sued for damages, and in 1978, the District Court in San Juan ruled that the value of 92,109,720 marine organisms killed by the oil plus the cost of replacing 20 acres of mangroves totaled $6 million. After an appeal, the damages were reduced to $1 million. "I don't care about the exact figure," says Ariel Lugo, adding. "The important thing is that the courts have ruled that mangroves have value."

Just as crucial to the mangroves' ultimate survival are battles being fought over small mangrove swamps. "If we looked at the sum of the small losses, we would be staggered by what we see," says Florida's Yokel. But increasingly, people are reacting. In 1972, Martin Marietta Alumina Corporation built a cooling pond for its aluminum plant on St. Croix in the Virgin Islands, destroying 30 acres of mangroves. The Corps of Engineers noticed the loss and asked the company to restore a nearby oil-damaged swamp in compensation. So Martin Marietta hired biologist Robin Lewis of Mangrove Systems, Incorporated, who planted more than 110,000 red and black mangroves on the site. Now, the seedlings are waist-high, each a ball of leaves perched atop a spindly grayish brown stem. Fragile and vulnerable though it is, growing in the shade of giant oil refineries and washed by the wakes of passing tankers, the miniature forest is alive with promise, a symbol of rejuvenation for the world's beleaguered mangroves. ■

John Carey covers science subjects for Newsweek *magazine. He is a graduate of Yale University's School of Forestry.*

Still vulnerable, mangroves like this one — with its wading egrets — are being destroyed at the rate of perhaps 4,000 square miles a year. But many countries are now moving to protect what remains.

M. P. Kahl



HAWAIIANS & THE SEA

Na Limu — The Seaweeds

by Keli'i Tau'a

Enteraining nightly — 9:30 p.m. to 12:30 a.m. — at the Princess Kaiulani

■ A favorite pastime of mine is to casually walk along the beach enjoying the serenity of the cool ocean breeze with the soft touch of the *limu* (seaweed) under my feet. Living my young life *mauka* (in the uplands) did not give me the opportunity to enjoy the beauty and fragrance of the ocean. Surrounded by the ocean, the Hawaiians felt an affinity to the sea, and in their poetry they explicitly expressed their love for the limu and its aroma. In the song "Royal Hawaiian Hotel" written in 1927, the writer says of the limu lipoa, *"O ka hone a ke kai i ka pu'u one la, me ke 'ala lipoa e moani nei, soft song of sea on sad dunes, wafting in fragrance of seaweed."*

In recent times, a song written and recorded by the late auntie Edith Kanakaole expresses the love I have for the ocean with its fragrant limu. Here is the song *"Ka Uluwehi O Ke Kai"* in its entirety with its beautiful translation.

He ho'oheno ke 'ike aku *ke kai moana nui la* *nui ke aloha e hi'ipoi nei* *me ke 'ala o ka lipoa*	Such a delight it is to see the great big ocean, so familiar and very cherished with its fragrance of the lipoa
He lipoa i pae i ke one *ke one hinuhinu la* *wela i ka la ke hehi a'e* *mai mana'o he pono keia*	It is lipoa which washes ashore onto the shiny white sand hot from the heating sun as you step on it don't think that this is fun!
Ho'okohukohu e ka limu kohu *ke kau i luna o na moku la* *'o ia moku 'ula la e ho* *'oni ana i 'o i 'ane'i*	How enticing is the display of limu kohu atop the rocks in the ocean, enticing one to pick them as they sway to and fro.
"Auwe, piha ka 'eke. Ho'i kakou!	"Oh, the bag is full. Let's go home!"
Ha'ina mai ka puana *ka lipoa me ka limu kohu* *hoapili 'oe me ka pahe'e* *'anoni me ka lipalu*	Let the story be told of the lipoa and the limu kohu, close companions of the pahe'e intermingled with the lipalu.

As time rapidly speeds by, I seem to appreciate whatever time I have to take my walks along the ocean because open beach space is certainly becoming scarce. As a matter of fact, even the limu is getting pretty thin due to over picking (down to the roots) and the rapid increase of polluted waters.

Hawai'i's creation chant, the "Kumulipo", presents the limu as the first plant in Hawai'i's birth story. The "Kumulipo" throughout makes a comparison between animals and plants on the land and animals and plants in the sea. Here are some excerpts from the famous story.

Parts of second verse

The Akaha's home was the sea, guarded by the Ekahakaha that grew in the forest.

All of third verse

Man by Waiolo-li, woman by Waiolola, the Akiaki was born and lived in the sea guarded by the Manienie Akiaki that grew in the forest. A night of flight by noises through a channel; water is life to trees; so the gods may enter, but not man.

The chant continues with thirteen verses which explain (in the same form as illustrated above) the creation of the seaweeds. The following chart defines the different seaweeds as they appear in the "Kumulipo" and gives the land plants with which they are compared.

"Kumulipo" Chart

VERSE	PLANT IN SEA	PLANT ON LAND
2	AKAHA, 'EKAHA — deep-sea seaweed; coralline	EKAHAKAHA — birdnest fern
3	'AKI'AKI — a coarse red seaweed	MANIENIE 'AKI'AKI — seashore rush grass
4	A'ALA'ULA — a branching velvety-green succulent seaweed	'ALA'ALAWAINUI — small native succulent forest herb, related to 'awa
5	MANAUEA — small red seaweed with stiff stems and branches	KALO MANAUEA — taro variety
6	KO'ELE'ELE — small, edible red seaweed with thick flattened stems and branches	KO PUNAPUNA KO'ELE'ELE — a sugar cane
7	PUA'IKI — red seaweed somewhat calcified; not edible	LAUAKI — small shrub
9	KELE — seaweed variety	EKELE — also called limukele; a moss growing on trees in rain forests
10	KALA — common, long, brown seaweed	'AKALA — raspberry
11	LIPU'UPU'U — also called kukae-a-kamapua'a green seaweed	LIPU'U — a small weedy, creeping grass moss
12	LOLOA — long seaweed	KALAMA LOLOA — tall ebony
13	NE — common seaweed	NENELEAU — sumach tree
14	HULUWAENA — also called pakelea-wa'a; irregularly branching dark red seaweed. Reserved for the queen.	HULUHULU 'IE'IE — an endemic woody, branching climber growing in altitudes of about 1,000 feet.

The Hawaiians enjoyed most of the products of the sea but especially the limu. In their diet it took the place of fruits as well as vegetables. Before the arrival of the missionaries, the only fruits available to the Hawaiians were bananas, coconu and mountain apples. The only vegetables available were taro, taro leaves ar sweet potatoes which had to be cooked before eating. Therefore, outside of p and *i'a* (fish and meat products), limu was an essential part of the Hawaiian diet. / times when the islands were in a state of famine, only fish and limu were eate

Up until 1819 when King Kamehameha died, the Hawaiian women we forbidden to eat bananas, coconuts, turtle, pork and some varieties of fish. Tl drastically limited the variety of foods the women could eat. When you consid these restrictions and the mere fact that the Hawaiian Islands did not afford mu variety to begin with, you'll realize that their diet was definitely monotonous. Tl many varieties of limu helped break the monotony.

When I say limu I am referring to all water plants that were edible or useful to tl native Hawaiians. Freshwater plants, lichens and mosses as well as seaweeds a classified as limu.

Most of the specific names given to limu describe the particular plant in son way. For example, *limu loloa* translated means long seaweed; *limu 'a'ala'ula* mea red fragrance and *pahe'e* means slippery.

Since gathering of limu was relatively easy and done on shore or in shallo waters, the women and children were usually responsible for bringing the lim home. However, the seaweed in deeper or rougher waters, or that which requir a boat to get to, was gathered by the men, who sometimes had wome accompanying them. Often it was easy to collect limu during the low tide becau the plants would break off at the roots and wash onto shore. However, at oth times, a sharp tool was needed to scrape and cut the limu from the coral ar rocks. If more than one variety of limu was gathered, each variety, after bei cleaned of sand, mud, and pebbles, was placed in separate containers. Since tl Hawaiians had to carry their water to and from their *hale* (house), they usual found it necessary and convenient to wash the limu at the ocean. It was als necessary to wash some of the varieties of limu in salt water because they wou lose their taste and freshness if washed in fresh water. After cleaning, the limu wa salted if necessary and then chopped, pounded, or broken into smaller pieces t be eaten raw as a relish with other foods. Raw fish was always eaten with som type of limu.

The Hawaiians in ancient times periodically cooked their limu with pig or dog i an *imu* (underground oven). This was usually done when there was war or famin in the land and taro and sweet potatoes were scarce. The limu *akiaki, hun manauea,* and *uaualoli*, which are a little hard in texture, were the varieties used i this way.

Limu that drifted to shore and were gathered by the Hawaiians included the lim *huaa, manauea, kala, lipe'epe'e* or *maneoneo, wawae' iole,* and others. Most c these grow in quiet waters near the shore in sand and mud, or on small stones. These limu can also be harvested by cutting them from their stalks. Other seaweeds that grew in this type of habitat and could be found drifting onto shore included the limu *'ele'ele, huluhulu-waena* or *pakaeleawa'a, huluilio, pahapaha, 'o'olu,* and *puaki.*

Other limus that grow near the tide line but do not usually drift to shore are the limu *akiaki, loloa, uaualoli,* and *luau.* In order to gather these limu in large

Far out on the coral reef is another variety of *uaualoli* along with the limu *kohu*, *'a'ala'ula*, *lipoa*, and *lipe'epe'e*. Gathering these limu requires strong swimmers with knives and chisels.

There are a few limu varieties that are gathered in small quantities in certain land districts because the people there seem to be the only ones who appreciate the taste. The limu *luau* is such a one. It appears in winter or spring, after storms, but only for a few days. At these times it can be found on large exposed rocks that are constantly hit by waves. It would certainly be unsafe for people to go and collect this seaweed if they are not familiar with the ocean.

Some of the limu were very important in the religious and healing aspects of Hawaiian culture. The limu *lipehu* or *lipa'akai* was good for rash as well as white blotches on the skin. The *'ele'elekai* also aided in white blotches on the skin. The *lipoa kuahiwi*, a nonedible mountain moss, helped with mouth sores, especially in children. The *manauea* (very popular for eating) and the *manaiea* were both used to treat miscarriages. The red limu *luau* was used to relieve chest ailments.

The limu *kala*, one of the seaweeds mentioned in the "Kumulipo" chant, is either cut or chewed and used as a poultice. The Hawaiians applied it to all types of cuts including open coral cuts. The Hawaiian word to forgive is *kala*, and the limu *kala* played an important part in the *'ohana* (family) ritual called "ho'oponopono," which was a method Hawaiians used to set things right. The *kala* was the physical symbol of this ceremony and was eaten after the praying was finished.

A Hawaiian scholar, David Malo, explained in his writings how limu was used in some of the rituals of ancient Hawai'i. In one ceremony that he describes, a *huikala* (purification) was performed. This was done by a temple priest who brought a bowl containing limu *kala* and turmeric in sea water. Standing before those who required cleansing, he purified them with oral prayer and the sprinkling of the water from his bowl.

An annual purification ceremony with the same ingredients was used during the month of Hinaia-'ele'ele (July) or 'opelu season. The fishermen would gather in the evening before the *Ku'ula* (fish god) with their nets to worship him. As they sat in the circle, the *kahuna* (priest) prayed for purification.

The limu *kala-kai*, a long brown seaweed, was also used for body weakness in children. The *lipu'upu'u*, or *kukae-o-kamapua'a,* was also used for that purpose. Other limu that were used medicinally included the limu *huna* for disorders of the alimentary canal and the limu *lipalawai* for congestion.

Besides all the limu mentioned there were also those that were *kapu* to the common people. The limu *kohu* was considered a prized possession, and at one point in the Hawaiian culture, only the *ali'i* (rulers) could eat it. They cultivated this seaweed on several islands. The limu *pahe'e* and *huluhuluwaena* were also *kapu* to the common people. The *huluhuluwaena* was given the name "queen's limu."

It has been estimated that 30 to 70 types of seaweed have been used for functional purposes in the Hawaiian community. We are only left with a small remnant of our great heritage. Look around and appreciate what you see, feel, touch, smell, hear, and love. *Aloha, a hui hou aku.* . . . **Keli'i**

Feb. 11, 1984

Dear Dr. Balazs:

Thank you for your letter ~~[illegible]~~ and reprint of your article. I have enclosed a couple reprints for you on my chemical investigations of the green algae.

I have found the sesquiterpenoid metabolite, caulerpenyne, in about 8 different species of *Caulerpa*. This is the most toxic metabolite present in *Caulerpa* spp, caulerpin is not as biologically active in a number of bioassays, and caulerpicin is generally found in *very* sm. amounts. Caulerpenyne concentrations vary, I have found that it occurs as 0-50% of the organic extract (0-2% of algal dry weight). Even within a species, caulerpenyne concentrations may be variable in different populations. Caulerpenyne has been isolated from C. racemosa in both the Pacific and Caribbean, I do not know about var. macrophysa.

I found your article to be very interesting. It appears that these turtles are only eating Caulerpa and other less preferred algae due to lack of availability of more preferred foods. Certainly their lower growth rates reflect their less than optimal diets.

I would be interested in hearing more about your turtle studies at Johnston Atoll.

Thank you.

Sincerely,

Valerie J Paul

9 September 81

Joe Whitney - Big IS.
told me that Honu, pronounced "ONU" is the Hawaiian name for Pterocladia, according to his mother.

January 29, 1985 F/SWC2:GHB

Dr. Bernabe Santelices
Pontificia Universidad Catolica
de Chile
Facultad de Ciencios Biologicas
Depto. de Biologia Ambiental y
Poblaciones, Casilla 114-D
Santiago, Chile

Dear Dr. Santelices:

Thank you very much for your recent letter asking about the extent of underwater _Pterocladia_ beds used by green sea turtles around the Hawaiian Islands. I have identified a number of coastal locations where _Pterocladia_ plays the major, if not sole, nutritional role in the diet of the Hawaiian green turtle. Some of these sites include Punaluu Bay, Kaalualu Bay, and Kiholo Bay on the Island of Hawaii; Kawailoa on Oahu's north shore; and Pakala on the northeast shore of Kauai. _Pterocladia_ is one of only nine kinds of benthic algae that account for nearly all forage used by green turtles in the Hawaiian Islands.

When you visit Hawaii again, I would appreciate having the opportunity to meet and talk with you more about the relationships of _Pterocladia_ and green turtles.

Sincerely,

George H. Balazs
Wildlife Biologist

GHB:vi

bc: Balazs
HL

Balazs

ALGAE FILE

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
FACULTAD DE CIENCIAS BIOLOGICAS
DEPTO. DE BIOLOGIA AMBIENTAL Y DE POBLACIONES
Casilla 114-D Santiago, Chile

Santiago, October 2nd, 1984

Mr. George H. Balazs
Wildlife Biologist
National Marine Fisheries Service
P.O. Box 3830
2570 Dole St.
Honolulu, Hawaii 96812
U.S.A.

Dear Mr. Balazs,

Thank you very much for your kind letter and your several publications sent to me recently.

I was most interested to know that P. capillacea is a very important food source for sea turtles and wonder if there are extensive underwater Pterocladia beds around the island. Unfortunately we have not worked on seaweed-sea turtle associations in Chile and therefore we have no papers on that matter. I will be glad to send to you any other reprint.

Sincerely,

Dr. BERNABE SANTELICES

BS/xag.

FORM 355 (08/81)

UH FEED AND FORAGE ANALYSES PROGRAM
AGRICULTURAL DIAGNOSTIC SERVICE CENTER
UNIVERSITY OF HAWAII AT MANOA
1800 EAST-WEST ROAD
HONOLULU, HAWAII 96822

University of Hawaii Cooperative Extension Service
U. S. D. A. Cooperating

MINERAL COMPOSITION*

DATE 10/15/85

REQUESTED BY GEORGE BALAZS

ADDRESS National Marine Fisheries Service
P. O. Box 3830; Honolulu 96812

COLLECTION SITE MAUI

COLLECTION DATE

UH No.	SAMPLE DESCRIPTION	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn
		(%)					(ppm)			
F85-195	Codium Edule - Channel	.09	4.45	1.68	1.98	> 8.75	44	385	10	9
196	Codium Edule - Outfall	.11	2.88	5.68	1.84	> 8.75	425	918	13	10
197	Acanthophora - Outfall	.29	1.44	4.38	.80	.95	1036	1838	198	67
198	Codium Reediae - Outfall	.14	1.13	1.15	1.60	> 8.75	244	251	34	21

* Dry matter basis.

P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Na = Sodium; Mn = Manganese; Fe = Iron; Cu = Copper; Zn = Zinc.

School of Natural & Mathematical Sciences

Seattle Pacific University
Seattle, Washington 98119
Phone: (206) 281-2140

George Balazs
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96722

1 November 1984

Dear George,

Thank you for the mailing labels, letter and copy of your History of Sea Turtles at Polihua Beach, Lanai report. The report is really interesting and I assume it will be published soon. I will use the information in my lectures on Maui in December. It looks as if my coming to Oahu will not work out for me as expected, it is just too close to Christmas and I cannot stay after Christmas. The samples you just sent look very interesting and I will be getting all the identifications to you before December.

Presently I am finished with the library research and am beginning to write two short chapters for a book concerning seagrasses. My job is to write about methods of sampling the epiphytes and macroalgae in seagrass beds.

I have just doubled my library literature collection on tropical algae. This will give me more material with which to back-up the identifications I make for you, as well as strengthen my own research needs. I was thrilled to receive volumes of rare reprints and books from Ron Phillips, as he clears his algae literature and concentrates more heavily in the area of seagrasses.

Your Hawksbill turtle find sounds exciting and I am sure you will be curious about the algae scrapings. Have a good Thanksgiving, George.

Aloha,

Dennis

Dennis J. Russell

[redacted]. from Maxwell S. Doty

Many authors have published Hawaiian names for seaweeds, or algae. This was a popular pastime early in the present century. Names published still earlier (e.g. Gaudichaud, 1826) are almost impossible to tie down to the species to which they probably referred. The following list is a compilation from the more extensive published common sources in which there was a consistent attempt made to associate the Hawaiian word with a scientific name. Of the scientific names in the list which follows there are a few that are still acceptable today for Hawaiian species.

The purpose of this list is twofold. First, it is a ready reference list for students of Hawaiian algae and anthropology. Second, it is to provide a record of the common disposition of many of the obsolete and garbled names published that are not expected to be found in finished treatises of either the Hawaiian language or the algae. A very few changes in spellings have been made in the case of scientific names; e.g. Gymnogongrus disciplinaris to G. disciplinolis.

The names in the following list are of two kinds - scientific or generic names and "limu names." The former are underscored, the latter are in capital letters. These are intermixed in one alphabetical series. In almost every case of a native name, Hawaiian usage would dictate its being preceded by the word "limu." As an example, the first word in this list would be spoken as "Limu aala-ula" and the second as "Limu aka-akoa." This interesting feature of syntax gives the Hawaiian language through this and other cases a form of nomenclature approaching that used by modern science in which a generic name is followed by a specific epithet as in the case of Ahnfeltia glomerata in the list below.

The pronunciation of the Hawaiian names follows very simple rules. Firstly, the stress with accent is on the next to the last syllable or alternating preceding syllables, unless a final vowel is marked with a macron

Dr...

as indicative of both stress and length. The letters themselves represent quite invariant sounds, other than for length of the sound. In northern Polynesia the consonants in general sound rather like those in English; though this is undoubtedly to some extent due to the long pronunciation of these words by otherwise English-speaking people. The glottal stop, shown by an apostrophe, represents a complete break, as between the oh's in English oh'oh, or, as in some pronunciations of <u>bottle</u>. The letter "w" presents a rather complex case for which there are no really simple rules. In general, after an "e" or an "i" this letter indicates the inclusion of a soft v-like sound about half-way between "vane" and "wane." "W" is never a strong letter, i.e. it is lax and never tense. After "u" and "o" it is slightly more like an English "w"; initially and after "a," both variants are heard. The vowels follow roughly the following pattern:

<u>a</u> as in <u>calm</u>.

<u>e</u> as in <u>get</u> with a hint of the long ā sound heard in <u>ate</u>.

<u>i</u> as the two "e's" in <u>peep</u> or <u>sleep</u>.

<u>o</u> as in <u>oat</u>.

<u>u</u> as in <u>you</u>.

'A'ALA-'ULA---(Hawaii). Codium muelleri (Reed); Codium tomentosum; Codium adhaerens (MacCaughey).

Ahnfeltia---AKIAKI; KOELEELE; EKAHAKAHA.

'AKA'AKO'A---Ectocarpus indicus.

'AKI'AKI---(Hawaii) Ahnfeltia concinna; KOELEELE; EKAHAKAHA (MacCaughey); Ahnfeltia polyides ([form of Ahnfeltia concinna?] fide Reed).

AKIULA---(Chamberlain).

'AKO'AKO'A---Coral or all jointed corals.

AKUILA---Chylocladia rigens.

ALAALAULA---Codium muelleri.

ALANI---LIMU MAKE? (Setchell); Dictyota spp.; Dictyota acutiloba distorta; Dictyota dichotoma (Reed).

'AL'AULA---ALAALAULA; Codium tomentosum (Neal, 1930); Codium muelleri (Setchell).

Amansia glomerata---PEPE-IAO; LI-PEPE-IAO.

Asparagopsis sanfordiana---KOKO; LIPAA-KAI.

AU-PUPU---Griffithsia ovalis.

'AWIKI-WIKI---Gymnogongrus (MacCaughey); Gymnogongrus vermicularis americana; Gymnogongrus disciplinalis (Reed).

Centroceras clavulatum---KIKALA.

Chaetomorpha antennina---NOHOMAHE.

Champia compressa---O-OLU.

Chnoospora pacifica---WA-WAHI-WA'A KAU-PAU.

Chylocladia rigens---AKUILA; KIHE.

Cladophora antennina---ILIO; MANU.

Cladophora nitida---HULU-ILIO.

Codium muelleri---(Hawaii) AALA-ULA; WAWAE-IOLE;WAWAE-MOA.

Codium spongiosum---HUWAI.

Codium tomentosum---'A'ALA'ULA.

Colpomenia sinuosa---PUHA.

Corallinaceae---AKO'AKO'A.

Dictyopteris---LIPOA.

Dictyota spp.---ALANI.

Dictyosphaeria favulosa---LIPUUPUU.

Ectocarpus indicus---AKA-AKOA; HULU-ILIO.

EEAU---(Chamberlain)

'EKAHA---Halimeda.

EKAHAKAHA---Gymnogongrus vermicularis americana; Gymnogongrus disciplinalis (Reed).

'EKAHAKAHA---(Maui); AKIAKI (Hawaii); KOELEELE (Hawaii; ex Chamberlain fide Setchell); Gelidium filicinum (Reed); Gelidium pusillum; ?Ahnfeltia concinna; Gelidium (Abbott); Gymnogongrus (MacCaughey).

'ELEAU---Ahnfeltia concinna (MacCaughey).

'ELE-'ELE---Enteromorpha compressa (Abbott); Enteromorpha intestinalis (Setchell).

Enteromorpha compressa---ELE-ELE.

Galaxaura lapidescens---PILILO'A.

Galaxaura rugosa---KAUNOA; OKALA.

Gelidium filicinum---MANAUEA.

Gelidium pusillum---LOLOA; EKAHALAHA; EKAHAKAHA.

Gracilaria coronopifolia---MANAUEA; KULAPEPEIAO.

Grateloupia filicina---PAKA-ELE-AWA'A (Kauai); HULU-HULU-WAENA (Hawaii); PAKELEAWAA.

Griffithsia ovalis---MOO-PUNA; KALIPOA: AU-PUPU.

Gymnogongrus---KOELEELE.

Gymnogongrus disciplinalis---UA-UA-LOLI.

Halimeda---EKAHA.

Haliseris plagiogramma---LIPOA.

Halymenia formosa---LEPE-AHINA.

HANA---Hypnea armata (MacCaughey).

HA'ULA---(very rare, Maui); Nitophyllum? (Reed)

HAWANE---Polysiphonia mollis (Abbott); Streblocladia? (Reed).

HINA'ULA---(Chamberlain).

HOLOMOKU---(Chamberlain).

HONA---Hypnea nidifica.

HO'ONUNU---(Puna, Hawaii) Laurencia obtusa var. racemosa (Setchell).

HU'AHU'AKAI---Sponge (ex Chamberlain fide Setchell).

HULU---Ceramium clavulatum (MacCaughey); Centroceras clavulatum (Reed).

HULUHULUWAENA---(all but Kauai) Grateloupia filicina.

HULU-'ILIO---Cladophora nitida or Chaetomorpha antennina; Jania rubens; Stigeoclonium amoenum; Centroceras clavulatum; Ectocarpus spp. (Reed); Ceramium clavulatum (MacCaughey); Ectocarpus indicus (Abbott).

HULUPUA'A---(S. Hawaii) Spyridia spinella (Reed).

HULUWAWAE-IOLE---(Reed); Centroceras clavulatum (MacCaughey).

HUNA---(Kona, Oahu, Kauai, Molokai) Hypnea armata; Hypnea nidifica (Bryan).

HUNE--Hypnea nidifica.

HUNEHUNE---(Chamberlain).

HUWAI---Codium spongiosum.

Hydroclathrus cancellatus---POHA.

Hypnea armata---HUNA.

Hypnea nidifica---HUNA; NANEA; HONA.

'ILIO---Chaetomorpha antennina; Cladophora (Bryan).

ILIOHA---Ulva. Probably = ILIOHAA.

'ILIOHA'A---(Chamberlain).

Jania rubens---HULUILIO.

KAHAKALA---(Chamberlain).

KALA---Sargassum spp.; Sargassum echinocarpum; Sargassum cymosum; Sargassum polyphyllum (Neal); Turbinaria.

KALA-LAU-LI'ILI'I---(Chamberlain fide Setchell).

KALALAUNUINUI---Sargassum echinocarpum; (ex Chamberlain fide Setchell). Probably = to KALA-LAU-NUI or

KALAWAI---Nais major (a flowering plant); (Reed).

KALIPOA---Griffithsia ovalis.

KAUNO'A---Galaxaura rugosa.

KAU-PAU---Chnoospora fastigata pacifica.

KEKUWELU---Gelidium spp? (Reed). Probably = KE KUWELU

KELE---(Chamberlain).

KIHE---Chylocladia rigens.

KIKALA---Centroceras clavulatum.

KIKI---(Chamberlain).

KIPA-AKAI---Asparagopsis sanfordiana (MacCaughey). Probably = LI PAAKAI.

KO'ELE---(Reed). (See KOELEELE).

KO'ELE'ELE---Gymnogrongrus; Gymnogrongrus vermicularis americana; Gymnogongrus disciplinalis; see KOELE (Reed); see AKIAKI.

KOHU---Asparagopsis sanfordiana.

KOIALE---(Chamberlain).

KOKO---Asparagopsis sanfordiana; Laurencia spp? (Setchell).

KOLOA---(Chamberlain).

KUKAEPUEO---ex Andrews Dictionary (Setchell).

KULAPEPIAO---Distorted Gracilaria coronopifolia (Setchell).

KUMULIMUKALA---(Chamberlain).

KUMULIPOA---(Chamberlain).

KUWELU---Gelidium spp? (Reed).

Laurencia---(sometimes confused with Asparagopsis).

Laurencia spp.---LIPUUPUU.

Laurencia obtusa var. racemosa---HOONUNU; MANEONEO.

LEPE-AHINA---Halymenia formosa. Probably = LEPE-O-HINA.

Liagora valida---PAPAAKEA.

Liagora decussata---PU-AKI.

LIMU- Algae in Samoan and Hawaiian. See note in introduction, above.

LIMULOLOA---(Chamberlain).

LIPA'AKAI---Asparagopsis sanfordiana.

LIPAHAPALA---Ulva lactuca (Reed).

LIPAHE'E---(Maui); = PAHEE (Hawaii); (Hawaii) Porphyra leucosticta (Reed).

LIPAKAI---ex Chamberlain (= LIPAAKAI?).

LIPA'AKAI---(Setchell).

LIPALAHALAHA---Ulva fasciata. (Maui); Ulva spp, Monostroma spp. (Setchell); Ulva lactuca; LIPALAHALOHA (MacCaughey).

LIPALA'Ō---(Chamberlain).

LI-PĀLĀ-WAI---Stigeoclonium falklandicum; Pithophora affinis. (Chamberlain).

LIPAUU---Laurencia (Setchell).

LIPE'E---Laurencia; ? contraction of LIPEEPEE (MacCaughey).

LIPE'E-PE'E---Laurencia (MacCaughey); Amansia glomerata (Puna?, Hawaii); Laurencia obtusa var. racemosa (Setchell).

LIPEHU---Asparagopsis sanfordiana (Chamberlain).

LI-PEPE-IAO---Amansia glomerata.

LIPEMALE---(Chamberlain).

LIPOA---"not strong kind" Dictyota divaricata (Setchell); Dictyota dichotoma; Haliseris pardalis (Reed); Haliseris plagiogramma; Dictyota acutiloba var. distorta (Neal).

LIPUPU---(Chamberlain).

LIPUULA---(Chamberlain).

LIPU'UPU'U---Dictyosphaeria favulosa (Setchell); Laurencia spp; Valonia utricularis.

LOLOA---(Maui, Kauai) *Gelidium* (Reed); *Pterocladia capillacea*; *Gelidium pusillum*; (Setchell) *Gelidium amansii* (Setchell).

LU'AU---(Maui) *Polypoes*? (Reed).

LU'AU---*Porphyra leucosticta* (Kauai).

LUPE---(Chamberlain).

MAKÁLOA---(Chamberlain).

MAKE---ALANI (fide Setchell), a *Dictyota*?.

MANAIEA---ex Andrews Dictionary; = MANAUEA (Setchell).

MANAUEA---*Gelidium filicinum*; *Gracilaria coronopifolia*.

MANEONEO---*Laurencia obtusa* var. *racemosa*.

MANU---*Chaetomorpha antennina*.

MAUAUWEA---(misprint of MANAUWEA?) ex Chamberlain (Setchell).

MENAUEA---(Kona, Oahu, Kauai, and Molokai) *Gracilaria* (Bryan).

Monostroma---LIPALAHALAHA.

MOOPUNA---KA-LIPOA; *Griffithsia ovalis*. Probably MO'OPUNA-A-KA-LIPOA.

MUALEA---rumored to be poisonous (Setchell).

NANEA---*Hypnea nidifica* (Setchell)

NANO'O---(Chamberlain).

NANUE---(Chamberlain).

NANUI---*Grateloupia filicina* (Setchell).

NEHE---*Spirogyra* spp. (Reed).

NEI---*Gymnogongrus vermicularis americana*; *Gymnogongrus disciplinalis* (Reed).

NOHOMAHE---*Chaetomorpha antennina*.

Nori---Japanese name for *Porphyra*, not Hawaiian.

OAOAKA---(Chamberlain).

Ogo---Japanese name for *Gracilaria lichenoides* var. *coronopifolia*, not Hawaiian.

'OHI'OHI'O---(Chamberlain).

'OKALA---*Galaxaura rugosa*.

OKUPE---(Chamberlain).

OLIPEEPEE---*Laurencia pinnatifida* (Reed).

OOCHIEA---(Chamberlain).

'O'OLU---*Champia compressa*; *Chondria tenuissima* var. *intermedia* (MacCaughey); *Laurencia obtusa* var. *racemosa* (Setchell).

OOPI---(Chamberlain) Probably = 'OPAE.

OURI---Sphaerococcus concinnus (Gaudichaud).

PA'AKAI---HALE (Chamberlain); LIPAAKAI? ex Chamberlain, (fide Setchell).

PAAKAIEA---(Chamberlain); PAKAIEA or Ulva? (Setchell).

PACAYA---(Gaudichaud) Ulva linza; Ulva compressa; Solenia compressa.

Padina pavonia---PEPEIAO; PILIPILIKO'A.

PAHAPAHA---(Tilden) Monostroma latissimum (Setchell); Ulva fasciata.

PAHAPAHA-O-POLI---Hale (ex Chamberlain fide Setchell). Probably = PAHAPA-O-POLIHALE and named for a place on Kauai where it occurs.

PAHE'E---(Hawaii) same as LIPAHEE (Setchell).

PAKA-EA---Ulva lactuca lacinata (Reed).

PAKAELEAWA (Maui)---HULUHULUWAENA; Grateloupia filicina (Setchell).

PAKA-ELE-AWA'A---Kauai, all but Hawaii (MacCaughey); Grateloupia filicina.

PAKAIEA---Ulva spp. and Monstroma in general (Setchell); Ulva fasciata.

PAKELEAWAA---(Maui) Grateloupia filicina (Setchell).

PAKELEAWEA---(ex Chamberlain) PAKELEAWAA? (Setchell).

PALAHALAHA---PAKAIEA? Monostroma? (Setchell); Ulva fasciata or Laurencia.

PALA-HALOHA---Ulva fasciata.

PALAPAHAKOU---Centroceras clavulatum (Setchell).

PALA-WAI---LI-PALA-WAI; stigeoclonium falklandicum; Spirogyra; Hydrodictyon reticulatum and other green fresh water species; (MacCaughey); Pithophora affinis.

PALEWAWAE---Laurencia spp. (Setchell).

PAPAAKEA---Liagora valida.

PE'EPE'E---(Maui) AALAULA (Hawaii); Codium muelleri (Setchell).

PEHU---(Chamberlain).

PEPE-AHINA---Halymenia formosa (MacCaughey).

PEPE-IAO---Amansia glomerata; Padina pavonia.

PEPEULU---(Chamberlain).

PILILO'A---Galaxaura lapidescens.

PILIPILIKO'A---Padina pavonia.

PĪPĪLANA---Entermorpha (Reed).

PIPILANI---(Chamberlain).

Pithophora affinis---PALA-WAI; LI-PA-LAWAI.

POĒĀ---Hydroclathrus cancellatus.

POLAO---Spirogyra spp. (Reed).

Polysiphonia mollis---HAWANE; PU-ALU.

Porphyra leucosticta---LUA'U.

PUAKĪ---Liagora decussata.

PUALU---Polysiphonia mollis.

PŪHĀ---Colpomenia sinuosa.

Pterocladia capillacea---LOLOA.

PUPUKANELIO---(Chamberlain).

RIMU---Tahitian, Tuamotu, and Maori name for algae and similar substances.

RIMOU---Les algues marines et fluviatiles (Gaudichaud).

RIMOU-KALA---Sargassum cune-folium et aquifolium (Gaudichaud).

Sargassum spp.---KALA.

Stigeoclonium amoenum---MULU-ILIO.

Stigeoclonium falklandicum---PALA-WAI, LI-PALA-WAI.

Turbinaria---KALA.

UAUALOLI---Gymnogongrus vermicularis americana (Reed); Gymnogongrus disciplinalis.

[illegible]---(Chamberlain).

Ulva---ILIOHA; PAKAIEA; PALAHALAHA.

Ulva fasciata---PAHAPAHA, PALAHALOHA; PAKAIEA.

Ulva lactuca---LIPA-LAHA-LAHA; PA-KA-EA.

Valonia utricularis---LIPUU-PUU.

WAWAEIOLE---Codium muelleri (Hawaii).

WAWAE-MOA---(Hawaii) Codium muelleri (Reed).

WA-WAHI-WA'A---Chnoospora fastigata pacifica.

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an earlier vessel would be much less likely a source of the introduction of *A. spicifera* than the "Yon 146."[11]

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Chapter 8

MUTAGENIC COMPOUNDS CONTAINED IN SEAWEEDS

Howard F. Mower

Seaweeds are not thought to be common constituents of the human diet, but they have been important human food material throughout history for the people of Oceania, those living in countries of Asia bordering the Pacific Ocean, and those in other seacoast areas. Examples of the use of seaweeds in traditional ethnic foods include sushi (cooked rice wrapped in seaweed) eaten in Japan, poki (raw seaweed mixed with uncooked fish, raw onions, peppers, and other vegetables) eaten in Hawaii, kim chee (fermented seaweed and cabbage mixed with chili peppers) eaten in Korea, and seaweed soup eaten in China. Seaweed-derived polysaccharides are also used in modern technology and are components of convenience foods and medicinal preparations of many types. Large numbers of humans could suffer significant exposure to hazardous substances if seaweeds contain significant amounts of mutagenic, genotoxic, or carcinogenic materials.

The red marine algae *(Rhodophyta)* have long been known to contain high concentrations of halogenated compounds.[1] They appear to be a unique source of brominated and iodinated compounds. Ten families representing five orders of red seaweeds (*Nemaliales, Cryptonemiales, Gigartinales, Rhodymeniales* and *Ceramiales)* have been shown to contain a diverse array of halogenated organic compounds.[2] In addition, some seaweeds of the *cyanophyta* and *chlorophyta* also accumulate halogen compounds.[3]

The simplest of the halogen compounds to appear in seaweeds is methyl iodide.[4] This compound is a mutagen, and some evidence exists that it is carcinogenic.[5] It has been detected in *Asparagopsis taxiformis* and similar species and found in elevated amounts in seawater near beds of the brown kelp *Laminaria digitata*.[6]

The essential oil of *Asparagopsis* is composed of 80% bromoform ($CHBr_3$), with carbon tetrabromide (CBr_4) as another major constituent.[7] While the genotoxicity of these brominated compounds is unknown, they, along with methyl iodide, may react with the chloride ion of sea water to produce the corresponding chlorinated compounds, chloroform ($CHCl_3$), carbon tetrachloride (CCl_4) and methyl chloride (CH_3Cl).[8] The first two substances have been reported to be constituents of *Asparagopsis*[7] and are known carcinogens and hepatotoxins.[8] Methyl chloride is the principal halocarbon of the atmosphere, and it has been proposed that marine algae may be a significant source of this material.[9]

The essential oil of *Asparagopsis* species can be as much as 5% of the dry weight of the seaweed.[10] Further investigation of this essential oil has shown that it contains a complex array of polyhalogenated hydrocarbons. Table 1 shows an aggregate of compounds found in *Asparagopsis*, as compiled from several studies.[2,11-13] Seaweed samples were collected from the Gulf of California, from the Caribbean, from Hawaii, and from the Spanish Mediterranean coast *(A. armata)*. Each sample contained most of these substances, but within one region there is some north-south variation in the biosynthesis of these halometabolites, which suggests that environmental influences can alter the halocarbon mixture found in any seaweed sample.

Very few of the substances listed in Table 1 have been tested for mutagenicity. Compounds of the series CCl_3–$COCCl_3$,[14] CCl_3–COOH,[15] and CCl_3–CHO are all mutagenic. However, the mutagenicity of the first two compounds results from reactive intermediates formed with dimethyl sulfoxide (DMSO), the solvent usually employed in mutagen testing. Thus their genotoxicity in the absence of this material may be minimal. Polyhaloacetones, bromo- and iodo-acetic acids are effective alkylating agents, combining with and inhibiting enzymes by reaction with sulfhydryl groups of cysteine, the hydroxy groups of serine and threonine,

[~~descriptions of solutions~~]

slides design

Ames Test 1 slide
Seaweed List
Work Bench
Colony Counter
Seperatory Funnel

Table 1 (continued)
CONSTITUENTS OF *ASPARAGOPSIS* SPECIES

Type of compound	No.	Structure	Estimated % in all hw
	107	$Br_2CH{=}CHCO_2H$	
	108	$BrIC{=}CHCO_2H$ $CHBr{=}CICO_2H$ or $CHI{=}CBrCO_2H$	
	109	$I_2C{=}CHCO_2H$ or $CHI{=}CICO_2H$	
Trihaloacrylic acids	110	$Br_2C{=}CBrCO_2H$	
	111	$BrIC{=}CBrCO_2H$ or $Br_2C{=}CICO_2H$	

Table 2
MUTAGENICITY OF SOME POLYHALOGENATED OCTADIENES OBTAINED FROM MARINE ALGAE

Compound	Maximum colonies/plate [TA100-(S9)]	Concentration μg/plate
$BrCH_2$–CCl(CH_3)–CH=CH–CHCl–CCl(CH_3)–CH=CHBr	270	50
$BrCH_2$–CCl(CH_3)–CH=CH–CHCl–CCl(CH_3)–CH=CHCl	253	50
$BrCH_2$–CCl(CH_2Cl)–CH=CH–CHCl–CCl(CH_3)–CH=CHCl	154	20
$BrCH_2$–CCl(CH_2Cl)–CH=CH–CHCl–CCl(CH_3)–CH=CHBr	135	10
$ClCH_2$–CHBr–CCl(CH_3)–CH=CCl–C(=O)–C(CH_3)=CH_2	370	20

and the amino groups of lysine and histidine.[16] Compounds with this type of chemical reactivity can be expected to combine with nucleophilic centers of DNA and cause mutations. It is not surprising that extracts of *Asparagopsis* are usually mutagenic, causing reversion of *Salmonella typhimurium* strain TA100 in the absence of rat liver microsomes.[17] Furthermore, considering the genotoxicity and carcinogenicity of vinyl chloride $CH_2{=}CHCl$, vinylidene chloride $CH_2{=}CCl_2$, chloroprene $CH_2{=}CH{-}CCl{=}CH_2$, dibromochloropropane $CH_2Br{-}CHBr{-}CH_2Cl$, ethylene dibromide $CHBr{=}CHBr$, acrolene $CH_2{=}CH{-}CHO$, and acetamide CH_3CONH_2, etc., it is quite easy to believe that many of the substances in Table 1 would be hazardous to human health.

In Hawaii, *Asparagopsis taxiformis* is called limu kohu, which means "the supreme seaweed". Japanese in Hawaii refer to it as ogo. It is highly prized for its aroma and flavor.[18] Beaches where the seaweed is abundant are often crowded with persons harvesting the algae. Whether consumption of this seaweed contributes to the cancer incidence in Hawaii is a question that will have to be further studied. It should be pointed out, however, that Hawaiians have one of the highest cancer incidences of any minority group living in the U.S., and the incidence of liver cancer in this group is higher than the U.S. average.

Another red marine algae, *Plocamium*, has been studied for the natural products it contains.[19] Five acyclic halogenated products were isolated and are shown in Table 2. These compounds were tested for mutagenicity, and all five induced revertants in *Salmonella typhimurium* strains TA100 and TA1535 in the absence of rat liver microsomes. The cross-conjugated ketone was the most mutagenic compound of the group and was approximately 200 times more active (revertants per nanomole) at 15 μg per plate as ethyl methanesulfonate, which was used as a positive control in this study.

Progress in this field has been greatly aided by the development of gas chromatography and the interface of GC columns to mass spectrometers. Table 1 is eloquent testimony to the power of this technique, especially when one considers that some of these compounds are present in trace amounts. To measure the mutagenicity of these substances requires several orders of magnitude more material than for their structure assignment by gas chromatography/mass spectrometry. The complete understanding of the genotoxicity of the components of the red algae must await the development of micromutation assay systems. However, many interesting mutagenic substances are certainly to be discovered in seaweeds.

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948
7232

CONSTITUENTS OF *ASPARAGOPSIS* SPECIES

Type of compound	No.	Structure	Estimated % in oil bw
Haloforms	1	$CHBr_3$	80
	2	$CHBr_2I$	5
	3	$CHBrI_2$	2
	4	CHI_3	
	5	$CHBr_2Cl$	
	6	$CHClI_2$	
	7	$CHCl_2I$	
	8	$CHCl_3$	
	9	$CHBrCl_2$	
	10	$CHBrClI$	
Dihalomethanes	11	CH_2Br_2	
	12	CH_2BrI	
	13	CH_2I_2	
Carbon tetrahalides	14	CBr_4	
	15	CCl_4	
Carbonyl dihalides	16	COI_2	
2-Haloethanols	17	ICH_2CH_2OH	1
1,2-Dihaloethanes	18	$BrCH_2CH_2I$	
Halogenated acetaldehydes	19	Br_2CHCHO	
Halogenated acetones	20	CH_3COCH_2Br	
	21	CH_3COCH_2I	
	22	$CH_3COCHBr_2$	2
	23	$BrCH_2COCH_2Br$	
	24	$BrCH_2COCH_2I$	
	25	CH_3COCBr_3	1
	26	CH_3COCBr_2Cl	
	27	$BrCH_2COCHBr_2$	
	28	$ICH_2COCHBr_2$	
	29	$Br_2CHCOCHBr_2$	
	30	$Cl_3CCOCCl_3$	
	31	$ClBrCHCOCH_2Br$	
	32	$ClBrCHCOCHBr_2$	
	33	$BrCH_2COCH_2Cl$	
	34	$ClCH_2COCH_2I$	
	35	$ClBrCHCOCHClBr$	
	36	$Cl_2CHCOCHBr_2$	
	37	$Cl_2CHCOCHClBr$	
	38	$ClBrCHCOCH_2Cl$	
	39	$Cl_2CHCOCH_2Br$	
	40	$Cl_2CHCOCHCl_2$	
	41	$ClCH_2COCH_2Cl$	
	42	$ClCH_2COCHCl_2$	
	43	$ClCH_2COCHBr_2$	
Halogenated 2-acetoxypropanes	44	$BrCH_2CH(OAc)CHBr_2$	
	45	$Br_2CHCH(OAc)CHBr_2$	
Dihaloisopropanols	46	$Br_2CHCH(OH)CH_3$	
	47	$BrCH_2CH(OH)CH_2Br$	
	48	$ClCH_2CH(OH)CH_2I$	
	49	$BrCH_2CH(OH)CH_2I$	0.01
	50	$ICH_2CH(OH)CH_2I$	0.009
Trihaloisopropanols	51	$BrClCHCH(OH)CH_2Cl$	
	52	$Cl_2CHCH(OH)CH_2Br$	
	53	$BrClCHCH(OH)CH_2Br$	0.01
	54	$Br_2CHCH(OH)CH_2Cl$	0.09
	55	$Br_2CHCH(OH)CH_2Br$	0.3
	56	$BrClCHCH(OH)CH_2I$	0.03
	57	$Br_2CHCH(OH)CH_2I$	0.03

CONSTITUENTS OF *ASPARAGOPSIS* SPECIES

Type of compound	No.	Structure	Estimated % in oil bw
Tetrahaloisopropanols	58	$Cl_2CHCH(OH)CHCl_2$	
	59	$BrClCHCH(OH)CHCl_2$	
	60	$Br_2CHCH(OH)CHCl_2$	
	61	$Br_2CHCH(OH)CHBrCl$	
	62	$Br_3CCH(OH)CH_2Cl$	
	63	$Br_2CHCH(OH)CHBr_2$	0.30
	64	$Br_2CHCH(OH)CHBrI$	0.03
	65	$Br_2CHCH(OH)CHI_2$	0.007
Halogenated 1,2-epoxypropanes	65	$BrCH_2CHCHBr_2$	
1,1,3,3-Tetrahalopropenes	66	$Br_2C=CHCHBr_2$	2
	67	$Br_2C=CHCHBrCl$	
	68	$Br_2C=CHCHCl_2$	
	69	$BrIC=CHCHBr_2$	
3,3-Dihaloacroleins	70	$Br_2C=CHCHO$	
Halogenated butenones	71	$Br_2C=CHCOCH_3$	
	72	$Br_2C=CHCOCH_2Br$	
	73	$Br_2C=CHCOCH_2I$	
	74	$Br_2C=CHCOCHBr_2$	2
	75	$Br_2C=CHCOCHBrCl$	
	76	$BrClC=CHCOCHBr_2$	
	77	$Cl_2C=CHCOCHBr_2$	
	78	$BrClC=CHCOCHBrCl$	
1,4,4-Trihalobut-3-en-2-ols[a]	79	$Br_2C=CHCH(OH)CH_2Cl$	0.01
	80	$Br_2C=CHCH(OH)CH_2Br$	0.03
1,1,4,4-Tetrahalobut-3-en-2-ols[a]	81	$Br_2C=CHCH(OH)CHCl_2$	
	82	$Cl_2C=CHCH(OH)CHBr_2$	
	83	$Br_2C=CHCH(OH)CHBrCl$	
	84	$BrClC=CHCH(OH)CHBr_2$[a]	0.03
	85	$Br_2C=CHCH(OH)CHBr_2$	0.6
1,1,1,4,4-Pentahalobut-3-en-2-ols[a]	86	$Br_2C=CHCH(OH)CBr_3$	0.04
Dihaloacetamides	87	$BrClCHCONH_2$	0.2
	88	$Br_2CHCONH_2$	0.7
	89	$ClICHCONH_2$	0.06
	90	$BrICHCONH_2$	0.5
	91	$I_2CHCONH_2$	0.3
Haloacetic acids	92	$ClCH_2CO_2H$	
	93	$BrCH_2CO_2H$	
	94	ICH_2CO_2H	
Dihaloacetic acids	95	Cl_2CHCO_2H	
	96	$BrClCHCO_2H$	
	97	$ClICHCO_2H$	
	98	Br_2CHCO_2H	
	99	$BrICHCO_2H$	
	100	I_2CHCO_2H	
Trihaloacetic acid	101	Br_3CCOOH	
Haloacrylic acids	102	$ClCH=CHCO_2H$ or $CH_2=CClCO_2H$	
	103	$BrCH=CHCO_2H$	
	104	$ICH=CHCO_2H$ or $CH_2=CICO_2H$	
Dihaloacrylic acids	105	$Cl_2C=CHCO_2H$ or $CHCl=CClCO_2H$	
	106	$BrCH=CHBrCO_2OH$	

SAFE SOLUTIONS
PROTECTING HEALTH AND ENVIRONMENT

September 10, 1991

George Balazs
National Marine Fisheries
2570 Dole St.
Honolulu HI 96822

Dear George,

Thank you for your interest and help in our turtle problem on Maui. I will be sending you a video of the turtles with tumors near Hononani condos [Honokawai, near Kaanapali Beach] where the algae is over grown in a shallow reef. The video is raw footage from Ursula and Pete Bennett from Canada, who you spoke with over the phone. We believe runoff from the Mahinahina channel project is feeding nutrients into the ocean, causing double blooms of the algae. Photos enclosed.

The samples of algae, and what it clings to are enclosed inside plastic bags. It would be interesting to see if there are any contributing factors of how the snails, if any that live in this plant life may be effecting the turtles. As we discussed it could be blood flukes, bacteria or viruses. Does moribilli virus [related to distemper] cause problems in turtles? I see where it is effecting dolphins in Rome, see article enclosed.

I look forward to working with you on this.

Eve Clute

Eve

669-5058

P.O. BOX 11634 LAHAINA, MAUI, HI 96761

Virus is killing dolphins off Italy and threatens endangered seals

By Alan Cowell
New York Times

ROME — For most of this past month, when people fled the cities and mass vacations stilled the fizz of urban life, Italy's silly season turned as usual to tales of animal woe — pet puppies abandoned by beach-bound owners, rats proliferating below the streets.

This year, though, there was a far more somber note.

Along the beaches of southern Italy, Italian and other European researchers report, at least 150 dolphins have been washed up since July, apparently victims of a virus that has spread from seals in the North Sea in 1989, to dolphins off the coast of Spain last year and now further eastward into the Mediterranean.

For Italy, the epidemic represents just one more twist in a sad story of pollution, algae blooms and ruthless fishing methods that threaten dolphins and other marine life, too. But the implications spread much further.

"We think it is heading toward the Ionian Sea and we are particularly concerned that it could spread to monk seals, which are already an endangered species," said Albert Osterhaus, a Dutch specialist, who has examined tissue and blood samples from the dead dolphins.

Concentrated off Greece, the Mediterranean's last colonies of monk seal are thought to number only around 200.

The morbilli virus, which causes measles in humans, weakens the dolphins and impairs their sonar navigation systems.

Domitilla Semmi, a spokeswoman for the environmentalist group Greenpeace, said one reason the dolphins fall prey to the disease seems to be that their immune systems are weakened by the high levels of toxins caused by the Mediterranean's pollution.

She said some 700 dolphins were washed ashore in Spain last year, representing only a small fraction of suspected deaths among an overall dolphin population that scientists have yet to quantify. Of the 150 known deaths in Italian waters this year, 100 have occurred in the last two weeks.

Some Italian researchers believe that for every 100 dolphins succumbing to the disease, only one is washed ashore, meaning that the total number of fatalities in Italian waters this year could be 15,000.

Despite concern among environmentalists, no one has come up with a cure. "It is impossible to stop the dolphins dying," said Leandro Stanziani, an Italian scientist at an Adriatic research institute.

Paolo Guglielmi, who represents the Italian Greenpeace organization, said, "Even if you are able to produce a vaccine, you can only use it on animals that have not been infected."

The epidemic among the dolphins has coincided with a further outburst of controversy over the use by Italian commercial fishermen of gigantic drift nets, 15 miles long and 40 feet deep, which environmentalists hold responsible for the widespread slaughter of whales, dolphins and turtles in the Pacific and in the Mediterranean.

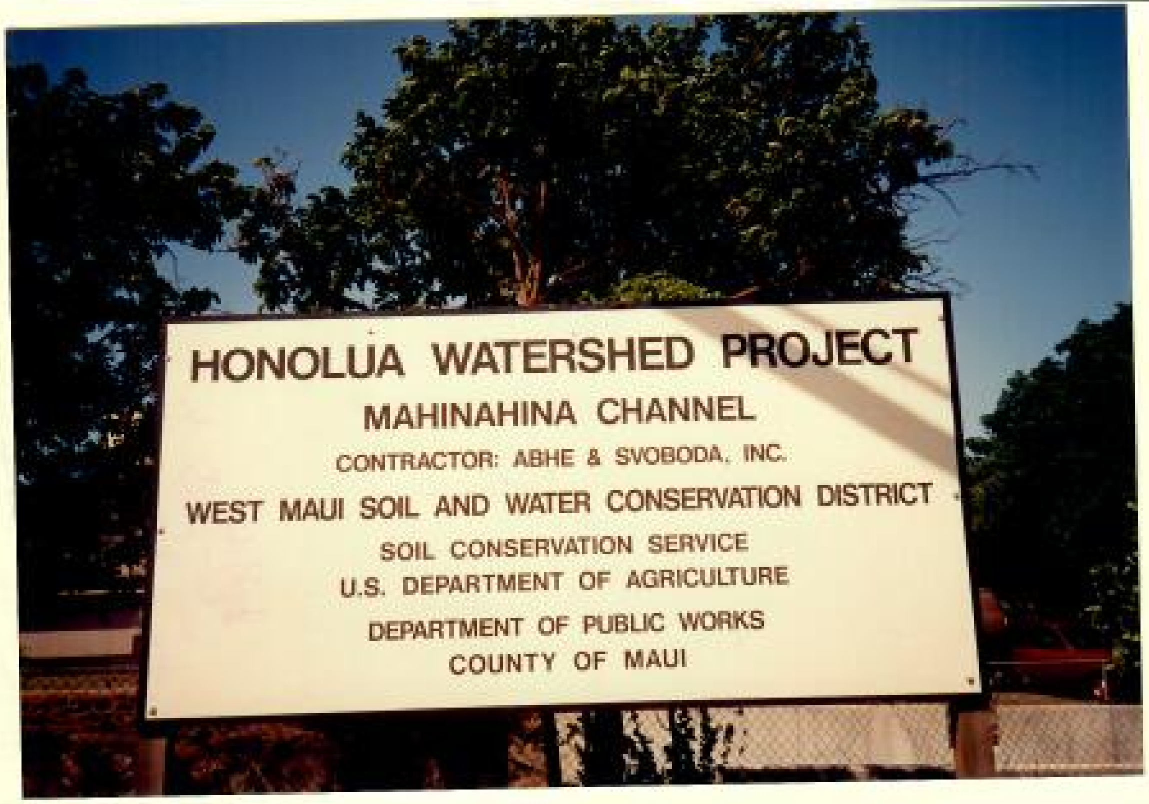
The controversy has burned here for two years and seemed to reach a peak this summer when the authorities outlawed the use of the nets.

In response, fisherman used their boats to blockade harbors on the Strait of Messina, curtailing ferry and other traffic between the Italian mainland and Sicily.

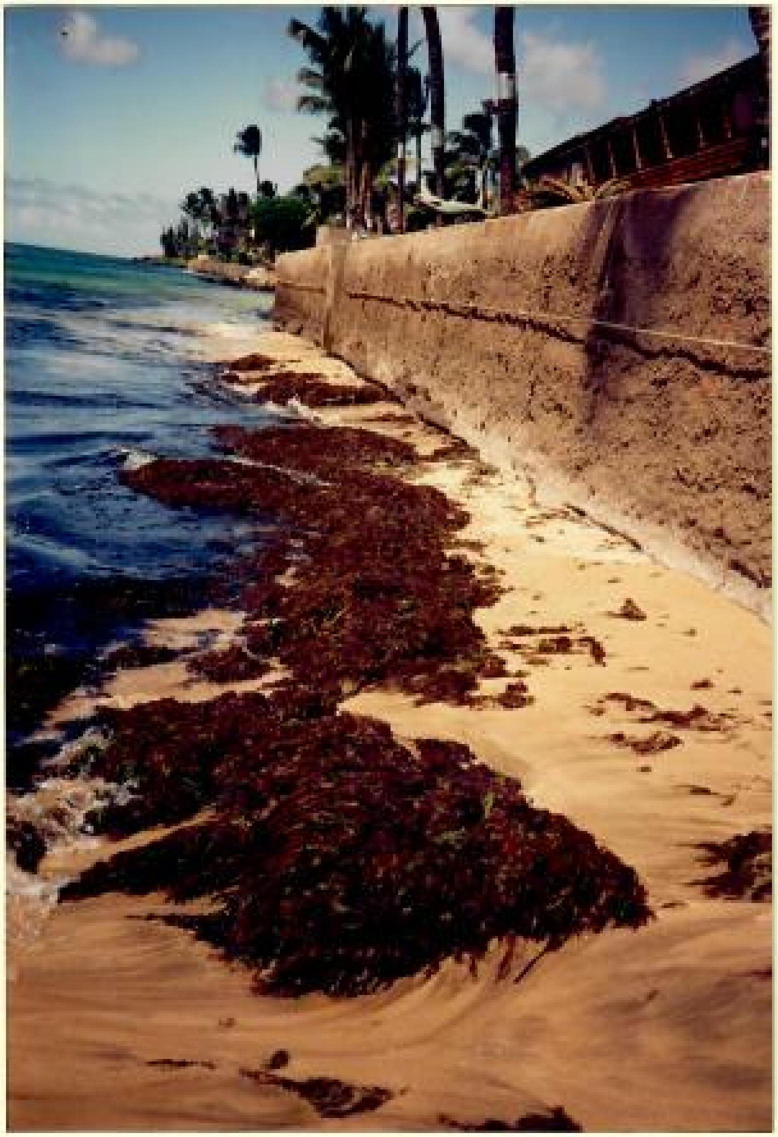
The authorities reversed their ban on the nets, spurring fresh challenges in the courts to their use.

"The prime issue is drift nets," Guglielmi said. "And we are trying to keep public interest high because of the problem."

The epidemic among dolphins has deepened the interest because "it's the first time it has happened in Italy," he said.



10 feet from Nohonani Condos
Honokowai, Lahaina, Maui



Beach in front of Kahonani Condo, where Pete + Ursula stayed and videoed algae + turtles with tumors

Vegetative Growth Rates of *Pterocladia capillacea* (Gelidiaceae, Rhodophyta)

J. G. Stewart

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(Accepted November 4, 1983)

Abstract

Although it has been shown earlier that thalli in some populations of *Pterocladia capillacea* grow slowly over periods of several years, an observation of possibly more rapid growth in an intertidal habitat suggested that under certain conditions this species might respond directly to seasonally variable environmental factors. Cultures were inoculated from thalli collected each month over a year and grown under 5 or 6 laboratory culture regimes. Initial growth and survival of apices was greater in cultures initiated between October and March. The maximum growth rates, however, were similar to growth rates measured by elongation of axes for *Gelidium robustum* and *G. nudifrons* determined in both field and laboratory studies. These uniformly slow growth rates, compared with growth of short-lived taxa, indicate that in these perennial algae slower growth is an inherent characteristic that is relatively independent of control by environment.

Introduction

Pterocladia capillacea (Gmel.) Born. et Thur., a gelidiaceous alga widely distributed on Pacific and Atlantic coasts, is considered to be a perennial plant. In Britain erect fronds grow for several years, elongating in yearly cycles (Dixon 1966). In southern California marked thalli persist for two or more years (Stewart 1968). Recently a field observation raised a query concerning whether the species is obligately restricted to the slow growth rate generally found as a corollary of being perennial. In mid-December 1978, below-freezing temperatures during early morning low tides killed most of the exposed thalli in an intertidal population near San Diego, California. Two weeks later only basal axes < 10 mm high remained pigmented; some thalli retained white (dead) distal fronds but most consisted of the lowermost portion of clumps that had been as high as 70–100 mm. By mid-March densely branched clumps of axes up to 30 mm high had developed and by mid-May the density and heights of individual thalli resembled pre-December growth. This observation raised the question whether, under specified conditions, these plants might be capable of attaining the more rapid relative growth rates characteristic of annual or shorter-lived plants, and thereby be profitably managed for agar production by utilizing short-term growth rates and vegetative propagation. *Gelidium heteroplatos* Børg. from Australia grows from spore to production of tetrasporangia in about 4 months, demonstrating the existence of a shorter life history in the *Gelidium-Pterocladia* groups of species (Ngan 1979).

The present study examines the potential vegetative growth rates from apices of thalli collected throughout the year establish to the range of inherent variability that can be expressed under different laboratory regimes.

Methods

On each of the eleven dates shown as T_0 in Table I thalli were collected from a patch approximately 2 m^2 within a bed of *Phyllospadix scouleri* W. Hooker in the low intertidal zone. At each T_0, visually clean, unbranched apices 4 mm long and portions of prostrate axes were cut from six adult (100–120 mm high) plants. These pieces were rinsed once in filtered sea water, then three times in sterile sea water. Thirty sterile petri dishes containing 30 ml of modified von Stosch medium (Murray *et al.* 1972) were inoculated with one tip from each plant. Five of these dishes, each with 6 apices and a portion of prostrate axis, were placed in culture chambers set for six different regimes of daylength and temperature. Beginning at T_1, 5–15 days after T_0, each piece was individually measured and transferred at two-week intervals as long as any remained pigmented. At each examination pieces with bleached tips were discarded; normally-pigmented tips were transferred. Later, older portions became bleached or disintegrated when infected with green endophytes and were measured and removed. The discarded-length data were carried forward and added to the final total growth measurement. GeO_2 (20 ppm) was added between T_{1-2} when necessary to remove diatom contaminants. Other algal contaminants were brushed or picked from tip surfaces. Growth from basal apices was evaluated at T_1 or T_2 then pieces of prostrate axes were discarded.

Experimental thalli were grown under cool-white 40 W fluorescent tubes to provide approximately 40–50 ft c (~ 8.64–10.76 $\mu E\ m^{-2}s^{-1}$) of light measured by a Weston 703–67 exposure meter. These, and light measurements from other studies that are discussed are given in the original units. Approximate conversions are shown in $\mu E\ m^{-2}s^{-1}$ for comparison. Light was low therefore compared with ambient field light during exposure on low tides when unshaded by the partial canopy of seagrass blades. Prior to the initiation of these experiments it had been determined that under these experimental conditions, higher light levels (> 70 ft c) (~ 15.12 $\mu E\ m^{-2}s^{-1}$) favored contaminants, were correlated with larger numbers of bleached thalli, and did not increase measurable growth.

The chamber at 20 °C 8–$\overline{16}$ h overheated and was not used for Sets V–XI. In September, near the end of the study, both 12 °C chambers lost refrigeration and thalli of Sets IX and X were killed.

Total measured increments for each Set in each culture condition (30 4-mm apices at T_0) were averaged to obtain the data shown in Figs. 1–4.

Results

Relative Growth; Seasonal Differences

The mean growth increments for each Set over the entire interval in which growth was sustained under each of six daylength-temperature combinations are shown on Figs. 1 a–f; Figs. 2 a–f show T_1 and T_2 data on a larger scale that allows the initial rates to be compared (Table I).

This latter comparison ranks Sets I and II (6/6 conditions), then Set VI (3/5 conditions) and Set V (3/6 conditions) as representing the tips with most rapid growth – more than 1 mm mean gain on Day 14. These Sets originated from collections made on 27 October, 21 November, 20 March, and 20 February respectively. Sets VII–XI consisted of slow or non-growing tips that exceeded 0.40 mm mean gain on Day 14 in only 4 of 25 possible conditions. Source thalli for these five Sets were collected between 1 May and 18 September, late spring to early autumn.

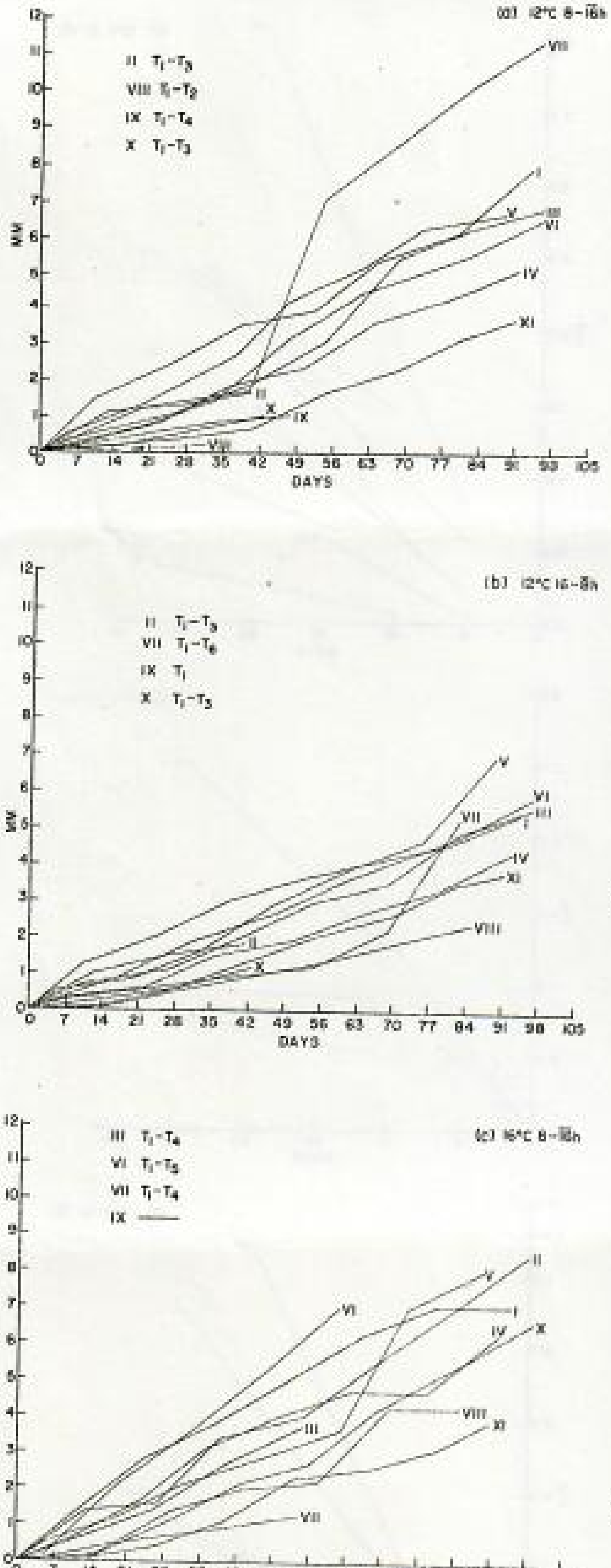
Maximum Growth Rates

Because the mean values shown in Figures 1–2 are calculated from a variable number (1–30) of apices including many that remained healthy in appearance without any increase in length, by themselves they

Table. I. Mean growth increments interpolated from Fig. 2 showing initial average growth rates in eleven Sets of cultures after 14 days of growth in laboratory.

T_0 = Set	27 Oct. I	21 Nov. II	19 Dec. III	20 Jan. IV	20 Feb. V	20 Mar. VI	1 May VII	9 June VIII	2 July IX	21 July X	18 Sept. XI
12 °C 8–$\overline{16}$ h	1.75	1.09	0.65	0.53	1.05	0.54	0.85	0.80	0.30	0.18	0.10
12 °C 16–$\overline{8}$ h	1.46	1.06	0.79	0.42	0.71	0.65	0.36	0.08	0.23	0.16	0.12
16 °C 8–$\overline{16}$ h	1.75	1.40	0.78	0.92	0.96	1.45	0.35	0.17	0	0.22	0.10
16 °C 16–$\overline{8}$ h	1.74	1.58	0.94	1.20	1.44	2.90	0.98	0.54	0	0.63	0.14
20 °C 8–$\overline{16}$ h	1.58	1.85*	0.92	0.58	1.49*	–	–	–	–	–	–
20 °C 16–$\overline{8}$ h	2.50	1.13	0.38	0.73	1.32	2.65	0.40	0.35	0	0.19	0.06

* All apices bleached and discarded before Day 14.



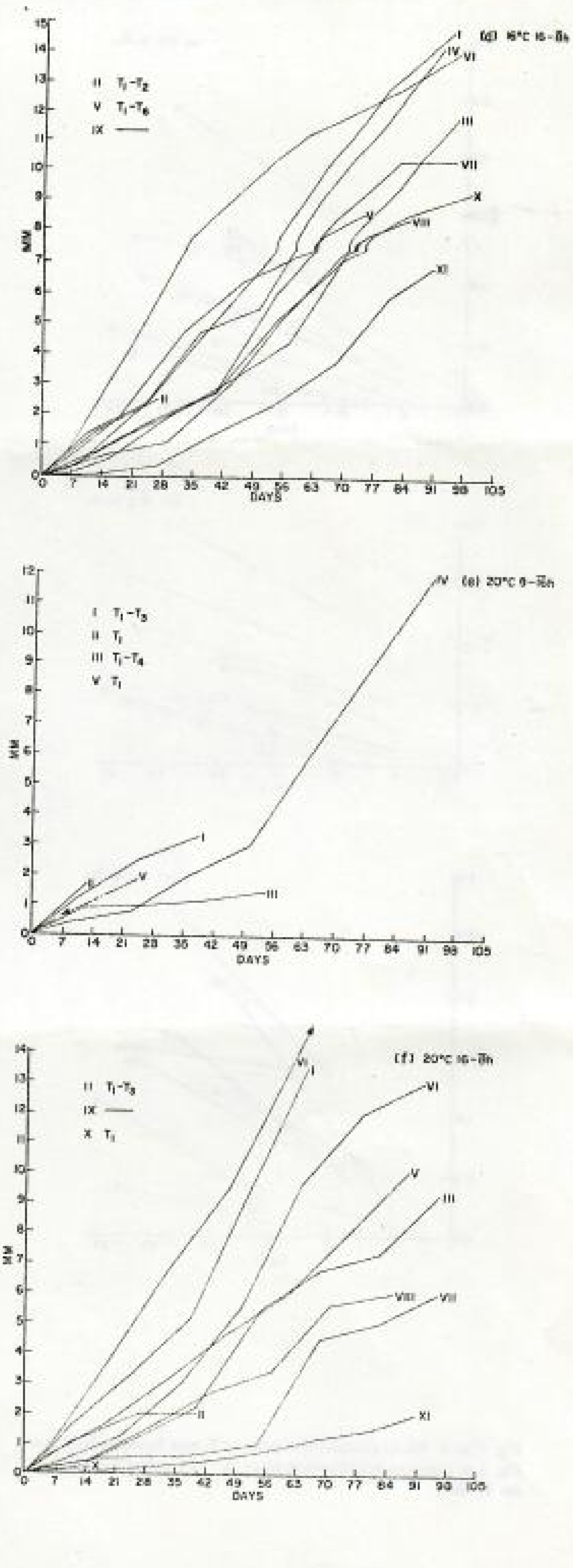
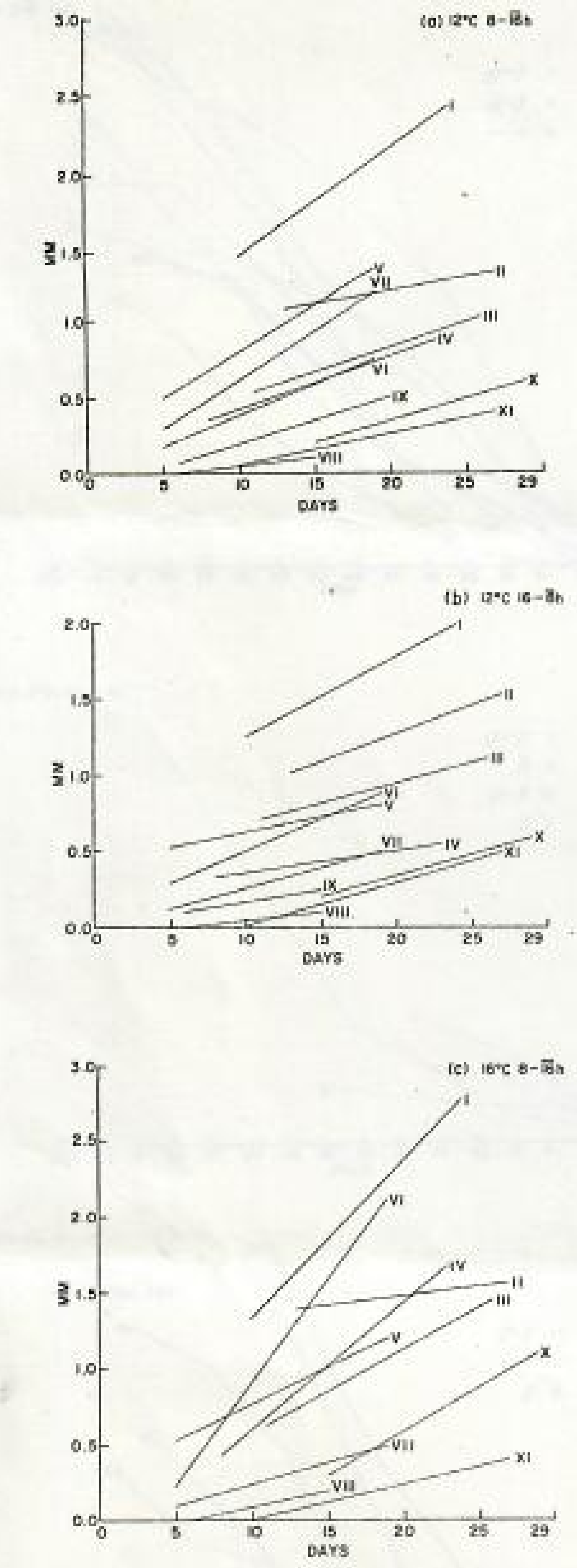


Fig. 1, a–f. Mean growth increments of apices (30/set at T_0) in eleven Sets with 6 temperature-daylength conditions, measured at T_1–T_7 or as noted. (f, VI = 18.6 at T_6 and T_7.)



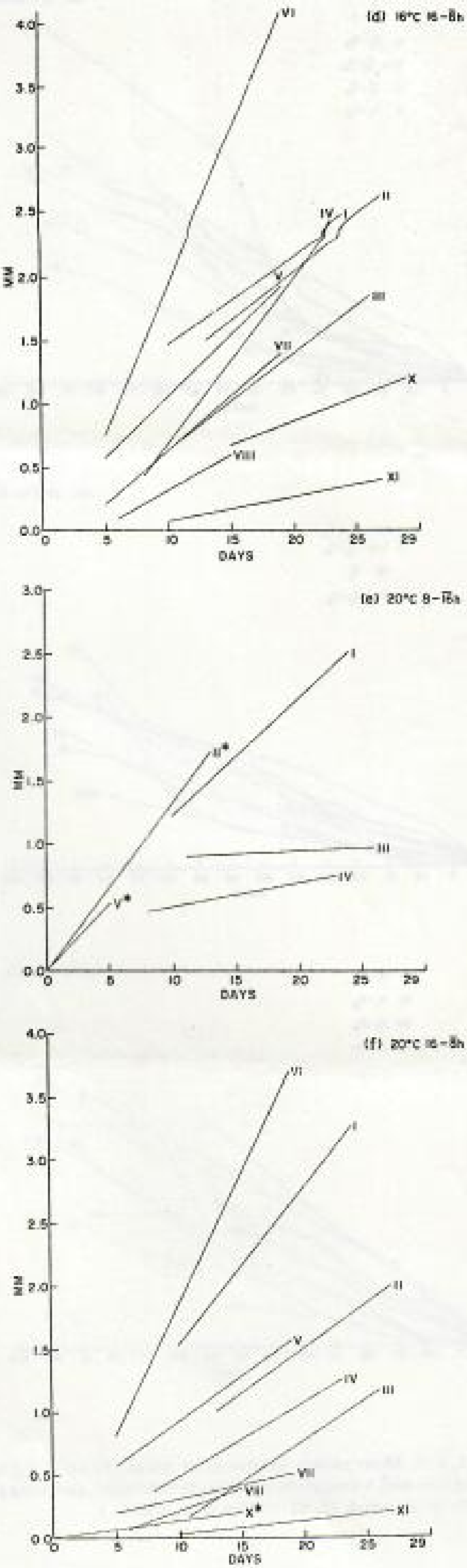


Fig. 2, a–f. Mean growth increments at T_1 and T_2 expanded from Fig. 1 to compare initial growth rates. (c–f IX = 0 at 6 days) *e, f no T_2 data.

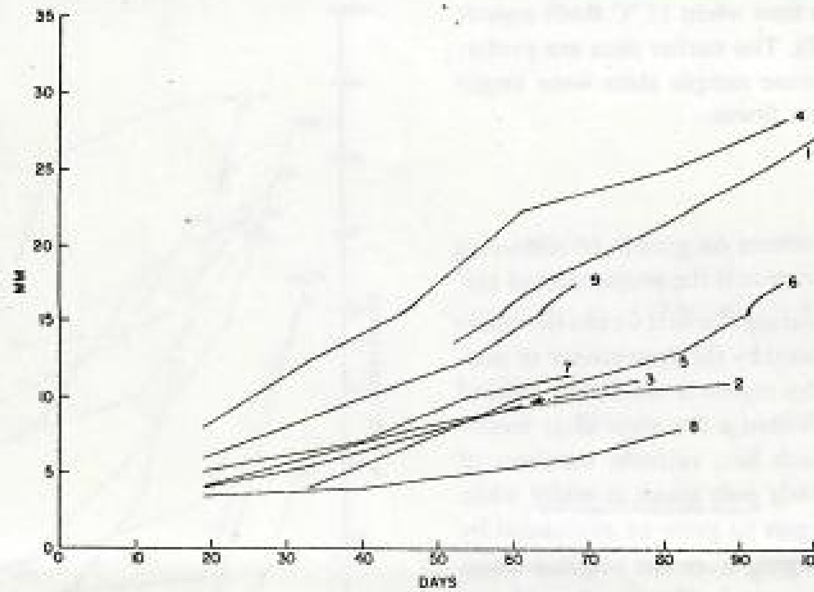


Fig. 3. Nine single-apex growth rates T_1-T_7. (1) = 34 mm at Day 123; slope remains similar. $8-\overline{16}$ h: 2, 3, 7. $16-\overline{8}$ h: 1, 4, 5, 6, 8, 9. 12 °C: 2, 3, 7, 8. 16 °C: 4, 9. 20 °C: 1, 5, 6.

are insufficient to indicate absolute growth rate potential. For this purpose nine series of measurements of single apices, extracted from the primary data records, serve as examples of growth rates attainable by individual thalli (Fig. 3). These rates, ~ 0.5–3.0 mm wk^{-1}, are similar to rates shown by the less precise data of Figure 4 when corresponding daylength-temperature conditions are contrasted. The two highest mean rates (Fig. 4) were measured at 16 °C and 20 °C with 16 h of light. (Data for 20 °C $8-\overline{16}$ h cannot be used in this comparison because they lack sets VI–XI which were the slower or no-growth Sets.) At T_7 (85–99 days) these two high $16-\overline{8}$ h rates give a mean calculated increment of somewhat less than 1 mm wk^{-1}. Single apices also at 16 °C or 20 °C at $16-\overline{8}$ h give individual measured rates of ~ 1.4–2.0 mm wk^{-1}. The 12 °C apices of Figure 3 (2, 3, 7, 8) and in Figure 4 show slower growth: 10–12 week mean rates of ~ 0.5 mm wk^{-1} and individual rates ~ 0.7–1.0 mm wk^{-1}. Rates calculated from the heterogeneous data therefore are consistently lower than individual measured rates based on those few apices that, for whatever reasons, ended up as "winners."

Temperature Differences

Figure 4 indicates that 1) 16 h of light is more favourable to growth at both 16 °C and 20 °C and 2) growth at 12 °C is slower than at 16 °C or 20 °C. There is a discrepancy between relative growth of 12 °C and 16 °C cultures at $8-\overline{16}$ h before T_4 (43–

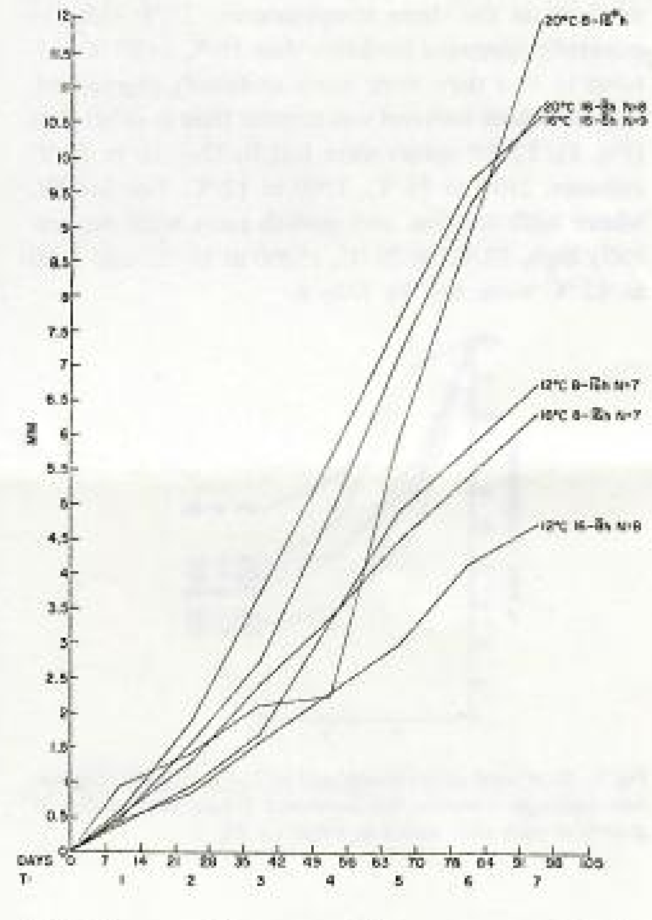


Fig. 4. Mean growth increments with 6 temperature-daylength conditions. Sets combined. Total number of days of growth at each Time interval varies because T_0 to T_1 = 5–15 for different Sets. N = number of Sets measured at final time interval; N = 11 at T_0. * 20 °C $8-\overline{16}$ h lacks Sets VI–XI and final N = 1.

56 days) and after this time when 12 °C thalli appear to overtake 16 °C thalli. The earlier data are probably more reliable because sample sizes were larger and contaminants were fewer.

Tip Loss

An additional test of effects on growth of collecting at different times of the year is the proportion of viable apices in each Set during the first weeks of experimental growth, evaluated by the appearance of normal pigmentation in the region immediately behind the apical meristem. Within a few days after inoculating the dishes in each Set, variable numbers of apices became completely pale green or white while others had already begun to grow as evidenced by clean narrow tips emerging from the original 4 mm piece. Thus the differences in the number of tips transferred at T_1 probably directly reflect differences in the collected plants at different times of the year. Figures 5 and 6 show the percentage of tips remaining at intervals throughout the study in each daylength-temperature regime and for each Set. Data in Figure 5 reinforce my qualitative overall evaluation of thalli at the three temperatures; 12 °C cultures generally appeared healthier than 16 °C or 20 °C cultures in that they were more uniformly pigmented. In Set I where survival was greater than in other Sets (Fig. 6), 11/60 apices were lost by Day 10 in 20 °C cultures, 2/60 in 16 °C, 7/60 in 12 °C. For Set IV, where both survival and growth rates were moderately high, 22/60 at 20 °C, 15/60 at 16 °C, and 3/60 at 12 °C were lost by Day 8.

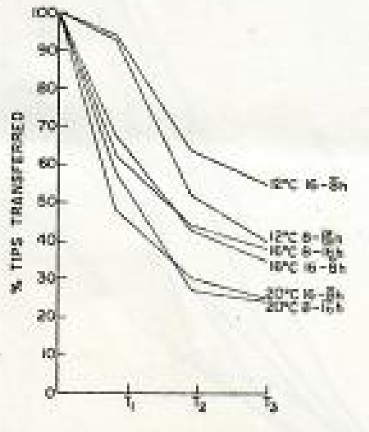


Fig. 5. % of total apices transferred at T_1-T_3 in each temperature-daylength condition, Sets combined. Total number of days of growth at each time varies as noted for Fig. 4.

In Set I most thalli in both 20 °C chambers were discarded after 35 days. The single thriving apex at 16–8 h continued to grow until discarded at T_3 (Fig. 3). In Set II, all 20 °C cultures were dead after 27 days.

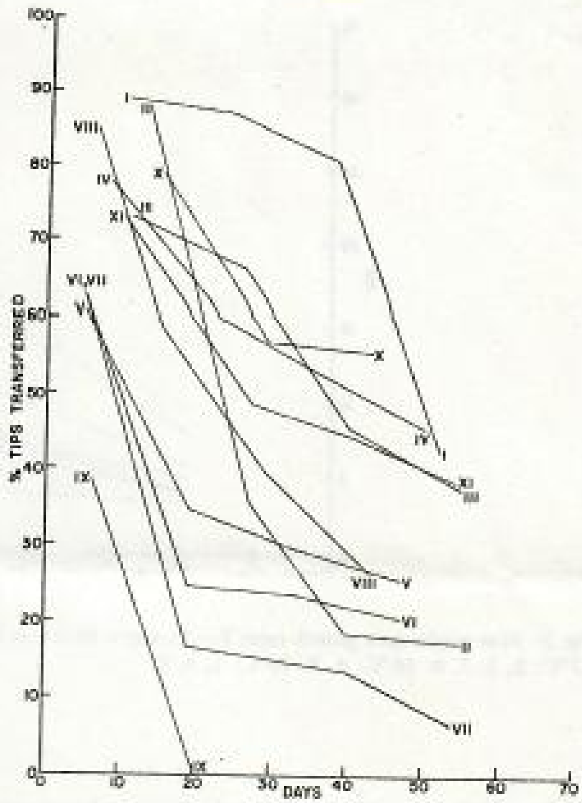


Fig. 6. % of total apices transferred at T_1-T_4 (Sets I–VIII and XI), T_1-T_2 (Set IX) or T_1-T_3 (Set X). Conditions combined. T_0 (0 days) = 100%, 30 apices.

A possible explanation may be related to the observation that chaetophoralean endophytes developed early and throughout cultures in Set II and this contaminant was always associated with dying tissue. Although it spread only slowly into newer tissue, if present in inocula the meristematic cells could be affected before new growth left the originally infected area behind.

Ranking of Sets by Tip Survival and Growth

When differences among the Sets in tip loss (Fig. 6) are ranked, Sets I, III, IV, and X are consistently high and VI, VII, IX are low. This assessment of vigour points to somewhat different conclusions than those based on the Day 14 mean growth data of Table I. Sets I and II both grew and survived well initially. After Day 10 Set II began to die and measurements of growth after Day 13 (t_1) rely on a total of 12 apices for 16 °C + 20 °C, 26 and 27 apices in each of the 12 °C conditions. Sets V and VI, with rapid early growth, also lost larger numbers of tips during this time, while Set X with poor intial growth, retained more apices throughout. I suggest that part of the apparent ambiguity in these two aspects of successful growth in culture – early retention of inocula vs mean elongation of axes – is a consequence of the same artifact referred to above: elimination of less successful thalli raises average values for the remainder. Nevertheless, the consistently rapid growth maintained throughout 123 days, combined with low tip loss in Set I, supports the presumption that there are optimal times to initiate cultures from natural populations.

Competing Algae

Few if any of the dishes remained unialgal for periods of more than several weeks. Brown filaments of several types (ectocarpoid) were most frequently seen but were not associated with any obvious deterioration of the *Pterocladia* axes. A representative count of 37 dishes, T_6 for Set V, T_4 for Set VI, showed one of two distinctive brown filaments in 29 of the dishes, chaetophoralean endophytes in 26 dishes, and *Enteromorpha* germlings and acrochaetoid filaments each in one dish. At other times a red blue-green, resembling a *Phormidium* species, *Ulva* and *Leucothrix* (filamentous bacteria) were found. At longer day lengths the brown filaments tended to be equally or more prevalent at 12 °C than at 16 °C or 20 °C and did not appear to be competitively favoured by warmer temperatures. These filaments and the green endophytes were largely mutually exclusive on/in individual thallus pieces. The brown filaments grew only on pigmented undamaged *Pterocladia* axes and their presence was not related to growth rate at the apex. All green endophytic cells appeared to be similar. When samples were subcultured, the morphology was characteristic of chaetophoralean algae. These contaminants always grew in pale or dead tissue that eventually disintegrated and was discarded. Presence or absence of either or both of these most common contaminating algae was not correlated with either slower or faster growing axes, suggesting that nutrient depletion by epiphytes was probably not a significant cause of slower growth for the *Pterocladia* thalli. Of the methods tried, none provided or maintained unialgal cultures throughout the period of study.

Prostrate Axes

The initial growth responses of basal axes, or "rhizoids," were largely recorded as plus or minus at T_1, or T_2 if no growth but healthy tips were noted at T_1. Greater or lesser proportions of tips that quickly showed new apical growth and the amounts of growth generally accorded with differences in the concurrent growth from apices of erect axes. In Set IX, for example, pieces of basal thallus were all dead 6 days after inoculation while in Set IV all pieces showed new growth after 8 days. Most dishes in other Sets contained few to several prostrate tips with new growth, establishing that this part of the thallus can be grown at least initially in the same manner as the erect parts.

Branching

The unbranched inocula most often remained unbranched or developed only short branch initials that did not grow beyond 1–2 mm. Dishes with more extensive branching occurred at both 12 °C and 16 °C at both day lengths; data are insufficient to relate branching to any single condition.. A dish from Set IV (16 °C 16–$\overline{8}$ h) contained the greatest branch growth, shown in Figure 7. This degree of branching was not approached in other cultures, but demonstrates that some thalli will branch under the conditions tested.

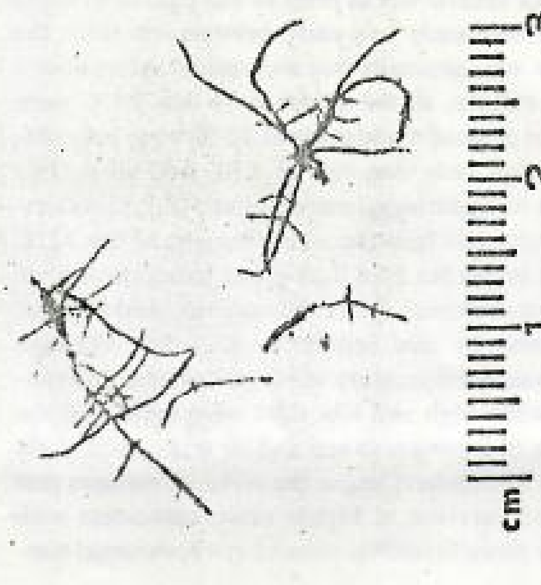


Fig. 7. Maximum branching (Set IV), 16 °C 16–$\overline{8}$ h, after 79 days of growth.

Tetraspore Germination

Tetrasporangia were observed on collected thalli throughout the year but were abundant in apices of percurrent primary axes only in collections made in summer-fall months. Dishes were inoculated with apical sori, containing spores in tetrads, in Sets I–IV and VIII but no germlings were found under any conditions.

Discussion

Natural environmental conditions that vary with season include factors that can be correlated with higher and lower relative initial growth, and these are discussed below. The results of this study clearly support the hypothesis that potential for subsequent vegetative growth is influenced by prior environmental factors although intrinsic seasonal variation in growth rate potential is not discounted. The data of Table I contrast the differences in growth rates that characterize the cultured thalli collected at different times of the year. Long-term average (Fig. 1) trends are similar to the early, perhaps more reliable rates (Fig. 2) and together the data support the conclusion that thalli collected late October to March provide more satisfactory inocula for culture growth for this species. Two related explanations seem plausible: prior environmental stress has direct detrimental effects, and reproduction adversely influences vegetative growth. Both depend on seasonal factors that are correlated with the observed variability in these data.

Set IX was conspicuously unsuccessful (July 2 collection). For several weeks prior to this date and during the late June-early July early morning low tides, the weather was unusually hot and sunny. After only 6 days in culture, all the apices at 16 and 20 °C were bleached or dead while those at 12 °C were pale. After 20 days only one tip, of 150, was alive. July weather brought foggy mornings and Set X, collected 21 July, was healthier. Termination of the 12 °C cultures in this Set after T_3 was due to overheating in these two chambers rather than unprovoked death of the plants. By mid-September (Set XI) although ocean water temperature continued warm, differences between high and low tides were small and the duration of exposure to sun and air was considerably less. Set I (October) began the series of cultures that grew and survived at higher rates, coincident with possibly more favorable natural environmental conditions.

The second factor that might affect vigour in inocula is the reproductive status of the plants prior to collecting. In early June (Set VIII) nearly every collected plant bore tetrasporangial sori in distal apices, suggesting that the poor survival and growth observed in Set VII apices might have been related to early unobserved stages of reproductive development. Thalli through the summer months bore tetrasporangial sori; apices snipped for culturing were selected from thalli lacking, or with few, but it is likely that these too represented thalli where reproductive processes had been initiated but were not yet recognisable. Since tetrasporangia were most abundant during the same period that cultures grew slowly, an inverse relation between reproductive and vegetative growth at this time could account for some portion of the differences in cultured growth rates over the 12-month study cycle.

Edelstein (1977) compared growth of *Gracilaria* sp. (*G. tikvahiae*; McLachlan 1979) in culture asking, as in this study, if the source and type of thalli selected as inocula influenced the success of cultivation. The time of year the thalli were collected was determined to be one of several important controlling factors – late summer plants were judged unsuitable. She believed this is best explained as a result of the plants "having undergone extensive growth in the field, . . . (hence) probably deficient in nutrients," an explanation equally applicable to *Pterocladia* data, and possibly related additionally to the abundance of tetrasporangia coincident with slow vegetative growth.

The maximum initial average rate calculated, 2.9 mm in 14 days (Set VI, 16 °C 16–$\overline{8}$ h), is approximately half of an estimated average field growth rate of 3 mm wk^{-1} between January 1 and March 10 (Stewart unpubl. data). High single-apex rates are approximately 1 mm wk^{-1} (Fig. 3). these comparisons suggest that even at maximum rates growth over a year in static or quiet water would not equal or exceed growth under natural conditions.

Regenerative growth in culture, distinct from growth potential of intact apical meristems of this study, has been demonstrated for segments of *Pterocladia capillacea* in the Mediterranean (Felicini and Arrigoni 1967, Felicinini 1970). In their cultures cut surfaces developed new axes that under low light [100 lux, less than the 40–70 ft c (~ 8.64–15.12 μE m^{-2} s^{-1}) used in the present study] resembled creeping prostrate portions of natural thalli. Typical erect branches formed with >750 lux and a 12 h day length (Felicini 1970). Cut surfaces, 4 mm from the apical meristems in San Diego plants also produced narrow cylindrical "buds" such as are figured in the two studies of Italian plants, indicating that regenerative potential throughout the range of the species is probably similar.

As has been shown with other algae from various habitats, growth rates are rather uniformly enhanced at higher temperatures within reasonable ranges (Stewart unpubl. data). In colder water (monthly $\bar{x}$ ~ 8–16 °C) on the southern and western shores of the British Isles (Dixon 1977) *Pterocladia capillacea* plants are as large as typical thalli from either the Gulf of California or southern California intertidal sites, and the largest thalli known are subtidal specimens from colder water habitats below or near the thermocline boundary off California. Water temperatures in these localities can be compared by means of data in Roden (1964), SIO (1981), and U.S. Navy (1974). Santelice's (1978) study of Hawaiian Gelidiaceae showed that the effect of temperature on growth rates was relatively unimportant compared with the effects of light intensity and water movement. Growth increased between 50–200 ft c (~ 10.76–43.04 $\mu E\ m^{-2}s^{-1}$) with a 12 h day length, while temperatures above 20 ° C increased bleaching (equivalent to tip loss of this study) at all light levels tested. These tropical *P. capillacea* thalli grew well up to 400 ft c (~ 86.08 $\mu E\ m^{-2}s^{-1}$) with water movement simulated by a rotary shaker; with nitrate-enriched sea water changed every 6 days, shaking, 400 ft c light (~ 86.08 $\mu E\ m^{-2}s^{-1}$) intensity and 24 or 28 °C, a maximum growth rate "close to 4 percent daily" was attained, based on increase in wet weight. A very simple approximation using a 1 mm increment in a week from a 4 mm fragment gives a 3.5% daily increase for the thalli in the present study. If such a comparison is valid, it appears that populations in these two parts of the world do not differ greatly in this characteristic.

The failure to germinate tetraspores was not unexpected, as earlier attempts to produce germlings from this species have been equally unsuccessful. Germination and early development from tetraspores and carpospores of *Gelidium amansii* Lamour. from Tokyo Bay (Ohno 1969) utilized light up to 10,000 lux at 25 °C. Suto's study (1950) of spore shedding in the same species and in *Pterocladia capillacea* (as *P. tenuis*) reports field observations and implies that efforts to induce discharge in the laboratory had not yet succeeded.

Ngan's (1979) unpublished thesis contains extensive information about germination and early growth of red algal spores. Both carpospores and tetraspores of *Gelidium heteroplatos* from northeastern Australia germinated in laboratory experiments but with different optimal temperatures and light levels. It is important to note that in many experiments (Ngan 1979, table 8.5) only very small percentages of hundreds of spores germinated emphasizing that the numbers of sori observed in other studies including the one described here may have been wholly inadequate to have obtained any significant results.

Despite an occasional field observation of short recovery periods of apparently more rapid growth, *Pterocladia capillacea* regularly behaves as a characteristically slow-growing perennial plant in natural populations (Dixon 1966, Stewart 1968) and in laboratory cultures. Rates similar to those reported here for axis elongation in *P. capillacea* have been found for four related species. *Gelidium robustum* grew at an average rate of approximately 1.8 mm wk^{-1} in a year-long field study (Barilotti and Silverthorne 1972). *G. nudifrons* grew 0.57–0.92 mm wk^{-1} in laboratory tests (Stewart unpubl. data). Luxton (1977) reported elongation rates of 100 mm yr^{-1} (1.9 mm wk^{-1}) for New Zealand *Pterocladia lucida* (R. Br.) J. Ag. grown in outdoor running sea water tanks. Growth rates for *G. pusillum* (Stackh.) Le Jol. from India (Mairh and Sreenivasa Rao 1978) although determined in cultures somewhat similar to those used in the present *Pterocladia* study, were primarily expressed by the percentage increase in fresh weight and cannot be easily compared with elongation rates. One experiment, however, measured maximum elongation of individual apical fragments for 60 days and found increases ≤ 10 mm, an average weekly rate close to data summarized here for other gelidiaceous algae.

These rates contrast with growth of 3–6 mm wk^{-1} for axes of several small non-perennial, short-lived taxa of red algae (Stewart unpubl. data). These data, thus contrasted, substantiate the conclusion that the relatively slow growth that appears to be characteristic of species of *Gelidium* and *Pterocladia* is an intrinsic feature of the taxa rather than one that can be manipulated by external physical factors. Large scale experiments to enhance growth for possible harvest as a source of agar are presently in progress. These are emphasizing nutrient enrichment and may provide information about the extent to which growth can be realistically expected to be increased by management techniques (Harger and Neushul 1982).

Acknowledgements

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91 09 15

Dear George,

GREETINGS AND ALOHA!

Thanks for the package of turtle info. I read it all.

I have completed the turtle video and it runs 58 minutes. I have more turtle stuff if you are interested but digest that for now.

I am also sending you newspaper articles of my activity while on Maui this summer. It starts with a LETTER TO THE EDITOR about how disgusting the ocean at Honokowai was, to articles about the testimony given to the Public Works Committee (a misnomer if there ever was one), to this weekend's effort of a 6 page letter to the MAUI NEWS (dunno if it will get published but you have record of it) and a 2 pager to our best known environmentalist, Dr. David Suzuki.

My problem is, I am torn between the algae and the turtles. By the way, I think the two are related. Funny how in the area that turns out to be the worst algae area in West Maui (see video) we also have several turtles with major infections.

both are related to water quality we believe..

I can't tell you everything I want to about our turtles as I still need to work on completing the "algae video" this weekend.

I will tell you this. I love turtles. I volunteer to help you in any way I can. But in return, I ask your help in the algae issue. Can you get your FEDS to light a fire under some butts on Maui Council? Can you send some of my stuff to some eyeballs who should be seeing this?

Also, I want you to think of a way, a diver can mark turtles UNDERWATER. THERE *HAS* TO BE A WAY. Next summer, I intend to video our turtles as much as possible and therefore need SOME way to identify them.

I also intend to dive with the OLOWALU population for comparative purposes. I am prepared to bet there are fewer instances of tumours at Olowalu because pollution and upland run off there is virtually non-existent.

I would like you to come to Maui next summer. Dive with our turtles but more important TEACH us so we can assist you with these creatures. You have two divers here committed and willing to dive twice/three times a day with the same population over 6-8 weeks WITH video. We also have an SLR in an IKELITE housing and will shoot stills for you if you provide the film.

This algae thing has already cost us about $600 in materials, phone calls, faxes, videos etc.

That's why we can't afford to shoot slides too

Any new developments re. turtles will be appreciated too.

Ursula Keuper-Bennett

91 09 18

Tomorrow I send the tape! I have attached the "Algae Video" right after the turtle stuff. When you see it, I think you'll understand why it took us so long to produce! I did not want to send the turtle stuff without the rest of the video.

Anyway...

Take care & aloha

Keuper-Bennett

LETTER TO THE EDITOR (MAUI NEWS)

Greetings and ALOHA!

Today is Saturday, September 14th. EXACTLY one month ago to the day the MAUI NEWS headline read "COUNCIL SEES HOW ALGAE IS PROBLEM". The article summarized testimony given regarding the explosive algae bloom in West Maui. I am one of the divers whose testimony and video finally convinced the committee and the experts that this was NOT a natural phenomenom but a man-made problem resulting from upland run-off. Your article quoted Committee Chairman Pat Kawano as saying the council will approach the mayor to "request for funding to pay for studies of the algal bloom. If the mayor doesn't come up with funding within two weeks, Kawano said, the council will tackle the problem and try to find a source of funds." MAUI NEWS Aug 14th 1991 P.1

Although I have been back in Canada for three weeks now, I have been monitoring the activity, or more accurately NON-activity of your Maui Public Works Department.

I spent five weeks of my six week vacation video-taping the algae growth, finally following the growth to its source at the Honolua Watershed Project by the Hale Ono Loa condominium in Honokowai. I can't even estimate the hours that went into preparing for the Public Works meeting August 13th. The hours that went into researching, the hours into editing my 10 hours of underwater video into a 15 minute VHS version to show council. The money for xeroxing, faxing and now the calls from Canada to the mayor person-to-person (I was unsuccessful) to Wayne Nishiki's office, to Eve Clute, to Dr. Steve Dollar (finally tracked him down to Washington) I figure this three week phone bill will hit just under $100.00.

Just last week I bought a used 8mm tape player because editing off my video camera was so tedious.

No exaggeration that so far, this algae has cost me close to $600.

I hope this gives you some idea of the time and money I have put into this issue. Now if this same level of commitment would come from people in government, not only would the algae problem be solved but I submit it never would have started in the first place.

I have been pulling ALL my underwater video of the Honokowai area from 1988 to 1991.

The thing I find remarkable as well as sobering is this. Had I reviewed the 1989 tapes and pulled off the algae shots instead of the pretty "tourist shots", I could have saved Maui considerable expense and grief. It was so obvious Honokowai was worse than either Kaanapali or Kapalua and yet we did not report this. Maui county responded to the 1989 algae bloom by funding a study off Kaanapali just about a mile and a half shy of where the problem really was.

By scanning my videotapes from 1989 and fresh from the 1991 Honokowai algae experience, one thing stands out. 1989 ain't got NOTHIN' on 1991!

By good fortune, there are shots of the same reef system, or same section of reef, or same coral head from 1989 and 1991. The comparison is dramatic and chilling. Entire reefs laced with algae in 1989 now have 90 to 100% coverage.

Nothing is more shocking however than fastforwarding through mid July 89 video and seeing a huge elkhorn coral head white and alive, supporting an entire colony of Domino damsels and then pulling the 91 tape of the same elkhorn coral green; dead and choked with algae. Of all the video of the devastation that says it all.

This summer, I was also requested to go to Kihei and snorkle around the Maui Sunset. What has Honokowai to do with Kihei? I believe the people in Honokowai are looking into the future should they wish to drive to Kihei.

I have video around the shore of the Maui Sunset. (notice I did not call it a beach). Seaweed was piled two feet deep in places, was pilau with stench and moved with the black of small flies. (Of interest was in all that seaweed, I found no evidence of the Cladphora algae infesting West Maui!)

But why take my word for it. Go there. Have a look. Better yet, if you can stand it. Go into the water like we did. Go in barefoot, I insist. You know that wonderful feel of firm sand you get on Hawaiian beaches? Don't expect it there.

Imagine stepping barefoot into a week-old cow pad. That is the best analogy. There is about two inches of goop there, so you kind of sink down in it and the stuff oozes between your toes. Now if that doesn't gross you out, bend down and scoop out a hand full. Come on, do it for your own curiosity. You know how Hawaiian beach sand is this golden colour? Well the black stuff you have is just a couple years' worth of rotted seaweed. By the way you won't have to put that stuff to your nose, you can already smell it. Eau de Kihei 91....

Snorkle out and you will give up because the water is turbid and only the hardy kamaainas go there to gather limu.

I spoke to one Hawaiian who said this area always had plenty of seaweed but nothing like this. On our drive to Kihei we counted no fewer than three drainage ditches mauka side. Of course there are people who will tell you the seaweed there is "natural".

And I agree. It is the natural consequence of a very shallow section of ocean and run-off.

What alarmed me about the Maui Sunset section of Kihei is how incredibly shallow it is. We went quite a distance before we got to our waists and never did get in over our heads. This makes this area a prime candidate for where NOT to allow run-off to run off.

What has this to do with Honokowai?

Honokowai is shallow too. Honokowai is tucked halfway between Kaanapali (Where Sewage Meets Sea) and Kapalua (Number One Beach in America) By the way, anyone interested in my video of Number One Beach in America and the algae there?)

I fear for Honokowai.

Remember the storm of August 7th? Well, I watched the red-brown water crashing down through that watershed project.

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Was there anyone testing what was in that run-off? And we are talking MILLIONS of gallons. I saw the great Kaanapali sewage gush and it pales by comparison. And while the water people announced 'NO SEWAGE GOT INTO THE OCEAN', I *CAN* assure you, ALL the upland run-off from the Honolua Watershed project reached the shallow waters off Honokowai.

This summer, I counted no fewer than three sewage spills in Kaanapali. The first big one that leaked an estimated 8 million gallons and then two from the same site near the car rental areas. Having read the Maui News, this was not the first time, Kaanapali had sewage leaks.

Of course, none of this stuff gets to the ocean.....(and if you believe that, I have some tundra in Northern Ontario I would like to sell you)

During his testimony on August 13th, Dr. Steve Dollar was asked why other islands did not have the algae problem Maui does. He replied that no other island has the degree of "channelization" Maui does. He went on to say in his several visits here, he has repeatedly wondered whether this channelization would eventually lead to problems.

I fear for Honokowai.

There is a little known project in the planning stages for North Kaanapali Beach. Honokowai starts where North Kaanapli Beach ends.

Now with ALL the literature and studies citing run-off as a major source of problems in water quality, there are plans underway for concrete culverts and concrete channels to run into two grassed trapezoidal channels to drain into the ocean there. And within a mile of that is the already offending Honolua Watershed project presently feeding algae growth in Honokowai!

On the flight home, I read the Lahaina News and found there are plans for the Napili Trade Center (Napili is upcurrent from Honokowai). This entire area has seen major frantic-frenzy development of hotels and condos. Bulldozers destroy the natural ground cover and expose the rich red Maui soils to the first heavy rain. I can just see what construction of a major Napili development will do.

Apparently, Council Member Patrick Kawano said he would vote for the project if he was "convinced the developer would remedy any potential drainage problems at the project."

I ask this question of Mr. Kawano already knowing the answer.

Has Maui Council funded an INDEPENDENT environmental study of the potential problems such a development might have on the ocean surrounding Napili?

I know the answer already... how could you expect such a study in a place where there is only ONE guy responsible for monitoring the ocean for the entire island? How can you expect such a study to ANTICIPATE potential problems in a place where the government not only merely REACTS to problems but needs a 40 year old plus Canadian visiting sport diver to make noises in the first place?

I am hoping to get this published in the Maui News to reach

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residents of Napili, Kahana, Honokowai and Kihei. Already Kihei is getting a poor reputation for its fouled pilau beach. The Honokowai, Kahana, Napili region won't be far behind if Maui Council takes its island-time to address this problem.

Last thing I read on the plane home was the Lahaina News article that said Mayor Lingle "said she is concerned about the rapid growth of seaweed in waters off of West Maui but also is concerned about not trying to be "all things to all people." (LAHAINA NEWS Vol 13 #8 p.1)

That made me realize the mayor does not consider water quality to be all that important. Rather myopic for a place that entices millions each year for the ocean and the sun, don't you think? Ask yourself why tourists come here in the first place? Why do they get on planes and endure long flights across the Pacific. For me it is ten hours direct.

Perhaps the mayor knows something I don't. Maybe Maui's economy doesn't need tourists like I thought it did. Maybe her people have done a survey to discover most tourists come here for the golf or the hotels or the T-shirts in Lahaina and few care about algae pads in the sand or algae brushing their legs while swimming. Maybe tourists limit themselves to the pools. Maybe I am a rare tourist who wants clean water and a clean beach.

I will say this to ANYONE who will listen.

The ALGAE problem is NOT a separate issue. It sits ugly cheek to jowl with unbridled development. I see your entire island as a company town. The developers are getting rich at your expense. Many are like absentee landlords, prepared to suck your island dry, zero concern for kamaaianas and their island way of life. Plans and construction are always underway for more hotels, for a bigger runway all to lure more tourists to your island.

This summer in The Maui News, statistics revealed that Maui and Kauai attract the tourists with the highest annual income, referred to as FIT (Free and Independent traveller. Typically they stay longer, make their own flight arrangements, rent cars, travel all over the island and spend far more than the average tourist. Oahu, no surprise, attracts the low end package deal traveller who targets Waikiki, stays about 7-10 days or does the 3 day 4 island hop.

I also read this summer that Maui is becoming concerned about fewer tourists visiting. For now you can blame this on the recession. But I ask you. Of the first-time tourists, who endured the traffic backups from Kahana to Kaanapali, who saw and smelled the sewage gushing by the road, who were grossed out by the algae in the water and on the beach, I ask you, how many of those Malihinis will be back?

You are going to lose your Free Independent travellers. They will go elsewhere. You will go the way of Oahu left with mainly the package deals. You will have to lure perhaps twice as many tourists to Maui just to maintain your present revenues. Can you see it? Maui will be a house taken over by its guests... with an infrastructure already straining with the present load.

And your mad dash to lure tourist bucks here is only equalled by the "island-time" you take in improving your infrastructure... or the "island-time" you are taking to solve the algae problem.

I remember coming to Maui in 1977 for the first time. I was struck by the quiet beauty and repeatedly people would say "Yes, we have rules here about development. No hotels or condos higher than the palm trees. Maui council is adamant about that! We are NOT going to make the same mistake Oahu did."

How ironic in retrospect.

Because not only are you repeating Oahu's mistakes. In the case of channelization and algae, you are even inventing your own!

All kind of pitiful actually. Here I went to the University of Hawaii where I was taught how Hawaii is a leader in ocean research and how you see yourselves as the "guardians" of ocean and land... how proud you are of your islands and how you stand ready to protect their beauty.

UA MAU KE EA O KA AINA I KAPONO

The Life of the Land is perpetuated in its Righteousness.

Yeah? Well the Life of the Land is spewing into your oceans through concrete channels every time there is a heavy rain!

You got ONE guy who takes ONE sample a month from highly developed areas like Kaanapali and Mahinahina. ONE guy, once a month! Then results are sent to Honolulu and the one guy on Maui doesn't get the results! ("Results from the chemical samples from this site and others along the coast go to a computer on Oahu, and Shiigi doesn't get a report back. MAUI NEWS date unknown 1991).

This is just short of not monitoring at all.

What is happening right now is strictly Third World, no kidding.

There are still Hawaiians who believe in Pele. I am a Canadian who believes in Moana. (Hawaiian goddess of the Ocean) Every time I enter the water, I feel her presence. She has granted me safe passage for 15 summers now. The secrets she has shared with me! She has sent me her creatures knowing they will be treasured as friends. In return, I pick up all the bottles, cans, potato chip bags, plastic knives and forks from her floors. And when necessary, I, like the Polynesians, can be fierce of heart defending her waters.

The indiscriminate con/des/truction around West Maui has taken its toll on the surrounding ocean. There are limits to Moana's ability to heal herself. The algae is her phlegm, which she coughs and spits onto the beaches of West Maui.

(6) 8/6

As for me. I am a Canadian Sport Diver who knows all TOO clearly the inertia of government (if you think algae is slimy you should check out OUR Prime Minister!) and your concept of "island-time". I urge home owners in West Maui and Kihei to verify what I have said and then clamour for action on the part of the Maui Public Works Committee.

This letter will not conclude my role in all this. There are other newspapers to write, and TV stations to send tapes to.

ALOHA and MAHALO for reading this far.

U Keuper-Bennett

416-826-6564 (VOICE)
416-826-2287 (MODEM)
416-457 (FAX)

Ursula Keuper-Bennett
Mississauga, Ontario,
CANADA

I know this letter is too long for the usual LETTER TO THE EDITOR. I hope you will find this important enough for consideration in COMMENTARY as you did the last one I sent you.

Why am I doing this? Why am I spending so much money on this?

BECAUSE I **KNOW** I AM RIGHT ABOUT THIS STUFF and only a worthless shit would do nothing.

I have gotten a Friday subscription to the MAUI NEWS. My first issue arrived yesterday. I wish I had the money for a Monday to Friday plus Sunday thing, but...

I guess you know I will be back next summer. Mainly because I am curious as hell but also because I want to continue the longitudinal monitoring of our dive site at Honokowai.

And could you let Jill Engledow know I said hi? She has been instrumental in covering this algae story and I am indebted to her.

COPIES TO

Eve Clute (and anyone she wishes to send copies to)

Dr. David Suzuki (TORONTO STAR Environmentalist
Host of TV program THE NATURE OF THINGS)

TORONTO STAR TRAVEL Section

GLOBE AND MAIL TRAVEL Section

Lydia Dotto (SCIENCE writer)

State of Florida

Department of Natural Resources **Memorandum**

1/10/92

Hi George -

Hope you had nice holidays. I'm afraid I'm of no help with your *Hypnea* question - I have not started looking at my Cm gut contents yet. I'm sure the Wershoven's will have some info for you.

I promise to trace Cm juvenile flippers for you from Florida Bay. Going sampling week of 20 Jan. Will send some after that.

Look forward to seeing you in February? Hope you're coming.

Best,
Barbara

Glad the hatchling feet worked out from Jeanette. :)

I'm trying to get the punch from Elliott.

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DIMETHYL TEREPHTHALATE POLLUTION IN RED ALGAE

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(*Received in revised form 27 February 1990*)

Key Word Index—*Phyllophora nervosa*; *Acanthophora delilei*; *Hypnea musciformis*; red algae; pollution; dimethyl terephthalate.

Abstract—Pollution of seawater and marine animal tissue by phthalate esters in the *ortho* form is recorded in the literature but this is the first study showing the pollution of marine algae by a phthalic acid ester in the *para* form.

INTRODUCTION

Derivatives of phthalic acid isomers have been widely used in various industries. When the *ortho* esters of phthalic acid were detected in seawater and rivers [1–4], and also in tissue of marine animals [5, 6], they were generally accepted as pollutants produced by industry which found their way into the seas in an uncontrolled manner.

The other isomer of phthalic acid dimethyl ester in the *para* form, terephthalic acid dimethyl ester, is a monomer of a polyester compound used largely as a synthetic textile material. This paper describes the isolation and identification of dimethyl terephthalate as pollutants of three red algae.

RESULTS AND DISCUSSION

The compound isolated from algae was obtained as needles, mp 140°; yield per kg of algae: 0.075 g for *Phyllophora nervosa*, 0.055 g for *Acanthophora delilei*, 0.1 g for *Hypnea musciformis*. Its spectral data is as follows.

IR ν_{max}^{KBr} cm^{-1}: 1718 (C=O), 1539, 1503 (Ar), 1679, 1616 (C=O), 1434, 1392 (CH_3), 1275 (C–O); ^{1}H NMR, ($CDCl_3$) δ 4.0 (6H, *s*, 2 × OMe) and 8.17 ppm; ^{13}C NMR, ($CDCl_3$) δ 52.37 (OMe), 129.53 (C-2, C-3, C-5 and C-6), 133.93 (C-1 and C-4) and 166.27 (CO) ppm.

Comparison of the data related to the compound which had been obtained from the tested algae with those of an authentic sample showed that the compound was dimethyl terephthalate. This substance was first isolated from *P. nervosa* collected from Şile on the Black Sea in March 1985. The results on the algae tested for dimethyl terephthalate according to the years of collection are shown in Table 1.

The fact that this compound could not be detected in the same kind of algae in one year but having been isolated in other years suggested the contamination of algae and consequently of Black Sea and Aegean Sea by industrial pollutants.

Table 1. Occurrence of dimethyl terephthalate in red algae

Algae	Year 1985	1986	1987	1988	1989
P. nervosa	+	+	+	+	—
A. delilei	+	—	+	+	nt
H. musciformis	+	—	+	+	nt

+, Detected; —, not detected; nt, not tested.

EXPERIMENTAL

Material. Phyllophora nervosa D. C. (Grev.) from Sile, Black Sea, Mar 1985, Jan, Dec 1986, Feb 1987, Jan 1988 and Dec 1989. *Acanthophora delilei* (Lamour.) from Narlidere, İzmir, Sept 1985, Oct 1986, 1987 and 1988. *Hypnea musciformis* (Wulf) Lamour. from Zeytinalani, İzmir, Sept 1985, Oct 1986, 1987 and 1988.

Extraction and separation. Dried and powdered alga was extracted with $CHCl_3$ or MeOH or EtOAc under reflux by stirring continuously at 80°C for 2 hr. The extract was filtered and the solvent removed in a rotary evaporator. The residue was shaken with 0.1 M HCl, the acidic part filtered and then extracted with EtOAc. The EtOAc layer was evapd and the residue applied onto a silica gel 40 (Merck) column (0.063–0.2 mm). Elution was carried out with petrol (40–60°) – EtOAc (1:3). Eluates were collected and then evapd. The residue obtained was crystallized twice from Et_2O or Et_2O–petrol (1:4).

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of pyridine (0.5 ml) and Ac_2O (0.5 ml) was allowed to stand at room temp. for 3 hr, then MeOH (4 ml) was added to the soln which was evapd to give a residue. This was purified by CC on silica gel to give **5** (13 mg). $C_{26}H_{36}O_8$. ν_{max}^{KBr} 3620, 1735, 1650, 1235, 1120, 1100, 1070, 1036, 980, 950 cm^{-1}; MS *m/z*: 476 $[M]^+$, 458, 448, 430, 416, 398, 380, 370, 356, 338, 328, 310, 295, 283, 265, 250, 149, 109, 43 (base peak). δ: 6.21 and 5.52 (each 1H, *br s*, 17-H_2), 5.40 (*br d*, 5 Hz, 11α-H), 4.36 (*dd*, 4, 12 Hz, 7β-H), 4.27 and 3.97 (each 1H, *d*, 11 Hz, 19-H_2), 2.14, 2.02 and 1.93 (each 3H, *s*, 3 × OAc), 1.48 (*br s*, 9β-H), 1.09 (3H, *s*, 18-Me), 0.96 (3H, *s*, 20-Me).

Diacetate of rosthornin B (**6**). A soln of **2** (20 mg) in Ac_2O–pyridine was stirred at 70° for 72 hr, then treated in the same way as for **5** to give **6** (11 mg). $C_{24}H_{34}O_6$. ν_{max}^{KBr} 1735, 1645, 1235, 1090, 1035, 975, 946, 930 cm^{-1}; MS *m/z*: 434 $[M-2 \times ketene]^+$, 416, 398, 374, 356, 328, 314, 296, 283, 253, 109, 43 (base peak). δ: 6.22 and 5.76 (each 1H, *br s*, 17-H_2), 5.47 (*dd*, 4, 12 Hz, 7β-H), 5.40 (*br d*, 5 Hz, 11α-H), 4.25 and 3.93 (each 1H, *d*,

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DIKETOSTEROID FROM MARINE RED ALGA *HYPNEA MUSCIFORMIS*

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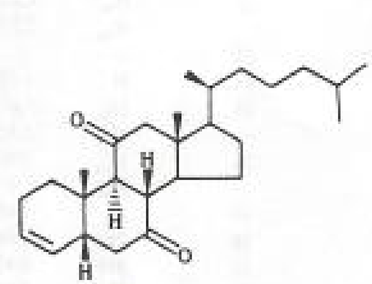
Key Word Index—*Hypnea musciformis*; Rhodophyta; red alga; diketo steroid; 5β-cholest-3-ene-7,11-dione.

Abstract—The isolation of a diketo steroid is reported from the hexane extract of the marine red alga *Hypnea musciformis*. The compound has been characterized as 5β-cholest-3-ene-7,11-dione based on 2D-NMR analysis.

INTRODUCTION

The major sterols of the red algae are C_{27} compounds. Cholesterol predominates, but in several species desmosterol has been detected [1–10]. However, 22-dehydrocholesterol is reported to be present in relatively large amounts only in *Hypnea japonica* [11] and *Hypnea musciformis* [8]. Red algae also contain traces of C_{26}, C_{28} and C_{29} sterols [6, 7, 12]. Isolation of a 3-keto steroid [13, 14] and a 3, 6-diketo steriod [15] in some species is also documented. We now report, for the first time, the isolation of 7,11-diketo steroid from *Hypnea musciformis*.



1

RESULTS AND DISCUSSION

The hexane extract of air-dried seaweed was chromatographed over silica gel by gradient elution (ethyl acetate–hexane). A crystalline compound (1) was obtained by elution with 10% ethyl acetate in hexane.

The ^{1}H NMR spectrum and mass spectral fragmentation of compound 1 revealed that it was a steroid with a C_8H_{17} side chain. It gave a pink colour with the Komarowsky reagent [16], indicating it to be a keto-steroid. The ^{1}H NMR spectrum displayed signals at δ0.68 (3H, H_3-18) and δ0.93 (3H, H_3-19) for the two tertiary methyls, a signal at 0.98 (3H, *d*, $J = 6.5$ Hz, H_3-21) and a signal for six protons at 0.84 which was assigned to the isopropyl group situated in the side chain. These signals are comparable to those in the spectrum of cholesterol (δ0.68, 3H, H_3-18, 1.00, 3H, H_3-19, 0.91, 3H, *d*, $J = 6.3$ H_3-21 and 0.85, isopropyl).

The ^{1}H NMR spectrum of 1 also showed two multiplets at δ5.20 (*dd*), 5.31 (*dt*) and the ^{13}C NMR spectrum gave two signals at δ137.58 (*d*) and 126.56 (*d*) indicating a disubstituted double bond. The multiplicity of the olefinic proton signals showed the presence of the $-CH_2-CH=CH-CH<$ system which indicated the presence of a double bond between C-3, C-4 in ring A.

A sharp intense peak at 1705 cm^{-1} in the IR spectrum and ^{13}C NMR signals at δ211.09 and 208.95 indicated the presence of two six-membered cyclic keto groups. The $\lambda_{max}^{CHCl_3}$ at 213 nm showed that both keto groups and the double bond are not in conjugation. Thus it could not be a 2-keto compound. If compound 1 was to be 1-keto, 12-keto, the ^{13}C NMR signals should have appeared

Table 1. NMR spectral data of compound 1

Position		^{1}H	COSY	DEPT	^{13}C	HeteroCOSY
1.	H_{eq}	2.37	(2.01, 1H_{ax}), (2.00, 2H_{ax}) (1.86, 2H_{eq})	CH_2	46.52	(2.37, 1H_{eq}) (2.01, 1H_{ax})
	H_{ax}	2.01	(2.37, 1H_{eq}), (2.00, 2H_{ax}) (1.86, 2H_{eq})			
2	H_{eq}	1.86	(2.00, 2H_{ax}), (2.37, 1H_{eq}) (2.01, 1H_{ax}), (5.20, 3H)	CH_2	30.02	(1.86, 2H_{eq}) (2.00, 2H_{ax})
	H_{ax}	2.00	(1.86, 2H_{eq}), (2.37, 1H_{eq}) (2.01, 1H_{ax})			
3	H	5.20	(5.31, 4H), (1.86, 2H_{eq})	CH	126.56	(5.20, 3H)
4	H	5.31	(5.20, 3H), (2.08, 5H)	CH	137.58	(5.31, 4H)
5	H	2.08	(5.31, 3H), (2.31, 6H_{ax}) (2.40, 6H_{eq})	CH	30.02	(2.08, 5H)
6	H_{ax}	2.31	(2.40, 6H_{eq}), (2.08, 5H)	CH_2	37.30	(2.31, 6H_{ax}) (2.40, 6H_{eq})
	H_{eq}	2.40	(2.31, 6H_{ax}), (2.08, 5H)			
7	—	—	—	—	211.10	—
8	H	1.27	(1.15, 14H)	CH	56.67	(1.27, 8H)
9	H	2.60	—	CH	57.44	(2.60, 9H)
10	—	—	—	—	41.18	—
11	—	—	—	—	208.96	—
12	H_{ax}	2.29	(2.57, 12H_{eq})	CH_2	36.93	(2.29, 12H_{ax}) (2.57, 12H_{eq})
	H_{eq}	2.57	(2.29, 12H_{ax})			
13	—	—	—	—	42.84	—
14	H	1.15	(1.27, 8H)	CH	55.80	(1.15, 14H)
15	H_{ax}	1.09	(1.52, 15H_{eq})	CH_2	23.44	(1.09, 15H_{ax}) (1.52, 15H_{eq})
	H_{eq}	1.52	(1.09, 15H_{ax})			
16	H_{eq}	1.45	(1.67, 16H_{ax})	CH_2	21.61	(1.45, 16H_{ax}) (1.67, 16H_{ax})
	H_{ax}	1.67	(1.45, 16H_{eq})			
17	H	1.45	(1.67, 16H_{ax}), (2.04, 20 H)	CH	53.43	(1.45, 17H)
18	3H	0.68	—	CH_3	12.15	(0.68, 18Me)
19	3H	0.93	—	CH_3	12.44	(0.93, 19Me)
20	H	2.04	(0.83, 21Me), (1.45, 17H) (2.05, 22H_a), (1.18 22H_b)	CH	39.97	(2.04, 20 H)
21	3H	0.98	(2.04, 20 H)	CH_3	20.74	(0.98, 21Me)
22	H_a	2.05	(1.18, 22H_b), (2.04, 20 H)	CH_2	39.22	(2.05, 22H_a) (1.18, 22H_b)
	H_b	1.18	(2.05, 22H_a), (2.04, 20 H)			
23	H_a	1.26	(1.87, 23H_b), (1.18, 22H_b)	CH_2	28.38	(1.26, 23H_a) (1.87, 23H_b)
	H_b	1.87	(1.26, 23H_a)			
24	H_a	1.57	(1.56, 25H), (1.84, 24H_b)	CH_2	30.02	(1.57, 24H_a) (1.84, 24H_b)
	H_b	1.84	(1.57, 24H_a)			
25	H	1.56	(0.84, 26, 27Me)	CH	28.38	(1.56, 25H)
26						
27	6H	0.84	(1.56, 25H)	2Me	22.24	(0.84, 26, 27Me)

above δ212. In the ^{1}H–^{1}H COSY spectrum the proton on C-5 showed cross peaks with that of C-6 indicating the absence of a 6-keto compound. Thus the two keto groups of 1 are located at the C-7 and C-11 positions.

The high resolution mass spectrum exhibited a molecular ion peak at *m/z* 398.3215 $[M]^+$ (61.8%) and other fragment ions at *m/z* 313 $[M-C_6H_{13}]^+$ (68.9%), 285 $[M-C_8H_{17}]^+$ (36%), 299 $[383-C_6H_{12}]^+$ (33.8%).

The ^{13}C NMR assignments of 1 (Table 1) were determined with the help of ^{13}C NMR coupled, decoupled, DEPT (Distortionless Enhancement of Polarisation Transfer) spectra and also with HeteroCOSY (^{13}C–^{1}H) experiments. The DEPT experiment with a flip angle of 135° revealed the presence of seven CH peaks (resonating at δ57.4, 56.6, 55.8, 53.4, 39.9, 30.0 and 28.38) and three Me peaks (resonating at δ22.2 and 12.2 for two Me each and δ20.7 for one Me) which gave signals in the positive direction. The eight peaks [resonating at δ46.5, 39.2, 37.3, 36.9, 30.02, 28.4, 23.4, 21.61, (30.02 corresponded for two CH_2 groups)] in the negative direction indicated the presence of nine CH_2 groups.

Proton connectivities were further deduced from the ^{1}H–^{1}H COSY spectrum (Table 1). H-3 and H-4 appeared as multiplets at δ5.31 and 5.20, respectively, and were coupled. H-3 (δ5.31) further showed cross peaks with H-2 (δ1.86) which again showed cross peaks with H-1 (δ2.01, 2.37). H-4 (δ5.20) gave connectivities with H-5 (δ2.08) which further showed cross peaks with H-6 (δ2.40, δ2.31).

The NOSEY spectrum further showed the through space connectivity between H-5 (δ2.08) and H_3-18 (δ0.68) which confirms the stereochemistry at H-5. The Hetero-COSY spectrum showed all the ^{13}C–^{1}H cross peaks (Table 1).

EXPERIMENTAL

The alga *Hypnea musciformis* was collected from the west coast of India (Lat. 22°28'N, Long. 69°05'E) during low tides in November 1986. The washed, air-dried, and pulverised alga (5 g) was extracted with hexane (3 × 5 l) at room temp. with the help of a mechanical stirrer. The solvent was removed in a rotavapour connected to aspirator, to yield a dark green extract (12 g). The concentrated hexane extract was chromatographed over silica gel and compound 1 was eluted with hexane–EtOAc (9:1) Compound 1 $[\alpha]_D^{20} = -20.5°$ ($CHCl_3$, *c* 5.03), UV $\lambda_{max}^{CHCl_3}$ nm: 213 IR λ_{max}^{KBr} cm^{-1}: 2950, 2910, 1705, 1460, 1425, 1385, 1375, 1360, 1345, 1325, 1300, 1280, 1265, 1255, 1240, 1165, 1135, 1085, 1070, 1045, 1015, 990, 970.

Chemical shifts are reported relative to TMS. ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) were measured in $CDCl_3$, EIMS were obtained at 70 eV.

The DEPT experiments were performed using polarization transfer pulses of 45 and 135°, respectively, to obtain in the first case all $-CH$, $-CH_2$, $-Me$ groups and in the other case positive signals for -CH, and -Me and negative ones for $-CH_2$ groups. All 2-D NMR experiments (COSY, NOESY & Hetero-COSY) were performed on a Bruker 500 MHz FT-NMR spectrometer. The mixing time for the NOESY experiment was 800 msec.

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AN HYDROXY DIKETOSTEROID FROM THE MARINE RED ALGA *HYPNEA MUSCIFORMIS*

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(*Received* 12 *September* 1989)

Key Word Index—*Hypnea musciformis*; Rhodophyta; red alga; marine organism; hydroxy diketosteroid; 5β-cholest-1-ene-20-hydroxy-7,11-dione.

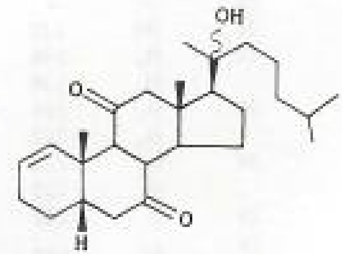
Abstract—The isolation of a new hydroxy diketosteroid is reported from the marine red alga *Hypnea musciformis*. This compound has been characterized as 5β-cholest-1-ene-20-hydroxy-7,11-dione.

INTRODUCTION

There has been continuing interest in the sterols and steroids of marine organisms ever since the earliest studies of Henze [1] and Doree [2] showing the potential for new sterols other than cholesterol. The discovery of many new marine sterols confirms the predictions made long ago by Bergmann [3] regarding their diversity. In the sterol composition of the red algae, C_{27} compounds are found to be major constituents in which cholesterol predominates; trace amounts of C_{26}, C_{27} and C_{29} compounds [4–6] have also been found. The isolation of demosterol [7], a 3-keto steroid [8, 9] and a 3,6-diketo steroid [10] is documented in some species. 22-Dehydro cholesterol is reported to be present in relatively large amounts only in *Hypnea japonica* [11] and *H. musciformis* [12]. We now report for the first time the isolation of 5β-cholest-1-ene-20-hydroxy-7,11-dione (1) apart from the earlier reported 5β-cholest-3-ene-7,11-dione [13] from *H. musciformis*.

RESULTS AND DISCUSSION

The steroidal nature of the new compound (1) was revealed by the ^{1}H NMR spectrum and the mass spectral fragmentation pattern. The former displayed signals at δ0.84 (3H, *s*, H_3-18) and 0.96 (3H, *s*, H_3-19) for the two



1

tertiary methyls, a signal at δ1.33 (3H, *s*, H_3-21) and a signal at δ0.87 (6H, *d*, *J* = 6.8 Hz) which was assigned to the isopropyl group situated in the side chain. The IR peaks at 1365, 1375 and 1165 cm^{-1} further confirmed the presence of an isopropyl group. The signals were comparable with that of 5β-cholest-3-ene-7,11-dione [13] (δ0.68, 3H, *s*, H_3-18; 0.93, 3H, *s*, H_3-19; 0.98, 3H, *d*, *J* = 6.5 Hz, H_3-21 and 0.84, 6H, *d*, *J* = 6.6 Hz, isopropyl). Thus a downfield shift of the C-18 methyl signal by 0.18 ppm and of the C-21 methyl signal by 0.35 ppm was observed.

The IR spectrum exhibited a broad signal at 3450 cm^{-1}. The downfield shift of the C-21 methyl singlet at δ1.33 and the ^{13}C NMR signal at δ75.09 for C-20 revealed the presence of a hydroxyl group at C-20. The mass spectrum exhibited a molecular ion peak at *m/z* 414 $[M]^+$ corresponding to the molecular formula $C_{27}H_{42}O_3$. The other major fragment ions, 396 $[M-H_2O]^+$, 329 $[M-C_6H_{13}]^+$ and 268 $[M-C_8H_{18}O]^+$, further confirmed the presence of a hydroxyl group in the side chain.

The ^1H NMR spectrum of compound 1 also showed multiplets between δ5.5 and 5.6 integrating for two protons. The 2D-J resolved spectrum gave signals at δ5.58 (1H, *d*, *J* = 8 Hz) and 5.54 (1H, *dd*, *J* = 8 and 2.5 Hz) indicating the presence of two olefinic protons which were further confirmed by the ^{13}C NMR signals at δ138.60 and 125.34. The multiplicity of these signals showed the presence of a $-C-CH{=}CH-CH_2-$ system. Thus the double bond is situated between C-1 and C-2 of ring A.

A sharp intense peak at 1705 cm^{-1} in the IR spectrum and ^{13}C NMR signals at δ211.33 and 209.08 indicated the presence of two six-membered cyclic keto groups. The $\lambda_{max}^{CHCl_3}$ at 216 nm showed that both keto groups and double bond were not in conjugation. Thus 1 could not be a 3-keto compound. If 1 had a keto group at C-12 the ^{13}C NMR signal should have appeared above δ212. In the $^1H-^1H$ COSY spectrum the proton on C-3 showed a cross peak with that of C-4 indicating the absence of 4-keto group. The 2D-*J* resolved spectrum showed the C-8 proton (1H, *dd*, *J* = 10 and 1.8 Hz) indicating the absence

Table 1. NMR spectral data of compound 1

H or C	^1H		COSY		^{13}C	7,11-Diketo-steroid [13]
1	H	5.58	(δ5.54, 2H)		138.86	46.52
2	H	5.54	(δ5.58, 1H)	(δ1.82, $3H_{eq}$)	125.34	38.02
3	H_{eq}	1.82	(δ5.58, 2H)	(δ1.30, $4H_{ax}$)	46.42	126.56
			(δ1.24, $3H_{ax}$)			
	H_{ax}	1.24	(δ1.82, $3H_{eq}$)			
4	H_{eq}	1.55	(δ1.30, $4H_{ax}$)	(δ2.08, 5H)	36.96	137.58
	H_{ax}	1.30	(δ1.55, $4H_{eq}$)	(δ1.82, $3H_{eq}$)		
5	H	2.08	(δ1.55, $4H_{eq}$)	(δ2.40, $6H_{eq}$)	41.65	41.83
6	H_{ax}	2.31	(δ2.40, $6H_{eq}$)		31.33	37.30
	H_{eq}	2.40	(δ2.31, $6H_{ax}$)	(δ2.08, 5H)		
7	—	—	—	—	211.25	211.10
8	H	2.27	(δ2.60, 9H)	(δ1.60, 14H)	57.50	56.67
9	H	2.60	(δ2.27, 8H)		59.47	57.44
10	—	—	—	—	55.88	41.18
11	—	—	—	—	208.99	208.96
12	H_{ax}	2.32	(δ2.57, $12H_{eq}$)		39.75	36.93
	H_{eq}	2.57	(δ2.32, $12H_{ax}$)			
13	—	—	—	—	43.40	42.84
14	H	1.60	(δ2.27, 8H)	(δ1.85, $15H_{eq}$)	56.61	55.80
			(δ1.22, $15H_{ax}$)			
15	H_{eq}	1.85	(δ1.60, 14H)		23.44	23.94
	H_{ax}	1.22	(δ1.60, 14H)			
16	H_{ax}	1.30	(δ1.22, $15H_{ax}$)	(δ2.16, 17H)	21.61	21.61
	H_{eq}	1.31	(δ1.30, $16H_{ax}$)			
17	H	2.16	(δ1.30, $16H_{ax}$)		53.43	53.43
18	3H	0.84	—	—	12.53	12.15
19	3H	0.96	—	—	13.87	12.44
20	—	—	—	—	75.09	39.97
21	3H	1.33	—	—	23.13	20.74
22	H_a	1.48	(δ2.02, $23H_b$)	—	41.19	39.22
	H_b	1.48	(δ2.02, $23H_a$)			
23	H_a	1.69	(δ1.48, $22H_a$)	(δ1.22, $24H_b$)	29.32	28.38
	H_b	2.02	(δ1.69, $23H_a$)	(δ1.48, $22H_b$)		
24	H_a	1.12	(δ1.22, $24H_b$)	(δ1.62, 25H)	38.05	38.02
	H_b	1.22	(δ1.69, $23H_a$)	(δ1.12, $24H_a$)		
25	H	1.62	(δ1.12, $24H_a$)	(δ0.87, 26 & 27 Me)	28.44	28.38
26						
27	6H	0.87	(δ1.62, 25H)		22.32	22.24

of a $-CH_2-$ group at position 7. Thus the two keto groups could only be present at positions 7 and 11.

The ^{13}C NMR assignments for 1 are given in Table 1, and are comparable with those of 5β-cholest-3-ene-7,11-dione [13]. The proton connectivities were deduced from the ^1H–^1H COSY spectrum (Table 1). The H-1 (δ5.58) and H-2 (δ5.54) protons were coupled. H-2 (δ5.54) showed a cross peak with H-3 (δ1.82) which in turn showed a cross peak with H-4 (δ1.30). Because 1 has nearly identical spectral features with its 5β-cholest-3-ene-7,11-dione congener, the former is characterized as 5β-cholest-1-ene-20-hydroxy-7,11-dione.

EXPERIMENTAL

The alga *Hypnea musciformis* was collected from the west coast of India (lat. 22°28'N, long. 69°05'E) during low tides in December 1988. The alga (5 kg) was washed with fresh water and soaked in MeOH. It was extracted with hexane and the solvent was removed on a rotavapour connected to an aspirator, to yield a dark green extract (2 g). The extract was chromatographed over silica gel and compound 1 was eluted in hexane–EtOAc (4:1), which was further purified by repeated CC. Compound 1: UV $\lambda_{max}^{CHCl_3}$: 213 nm; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3450, 3000, 2940, 2850, 1705, 1455, 1445, 1420, 1410, 1375, 1365, 1355, 1340, 1320, 1300, 1265, 1250, 1235, 1155, 1075, 1035, 1005, 965 and 910. Chemical shifts were reported relative to TMS. The ^1H NMR (500 MHz) and ^{13}C NMR (125 MHz) were measured in $CDCl_3$. EIMS were obtained at 70 eV. The 2D NMR experiments were performed in a Bruker 500 MHz FT NMR spectrometer.

Acknowledgements—Financial assistance from the Department of Ocean Development, Government of India, New Delhi, in the form of a sponsored project is gratefully acknowledged. We are grateful for the 500 MHz FT NMR national facility provided at the Tata Institute of Fundamental Research, Bombay-400 076.

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12/12/91
Dennis - Good stuff! Please note, photocopy and return to me. Geo.

BOB + JEANNE WERSHOVEN

12/7/91

WERSHOVEN
10126 BOYNTON PLACE CIRCLE
BOYNTON BEACH FL 33437

GEORGE,

I DID RECEIVE A CALL FROM DAVID SHREKTI ABOUT A WEEK AGO - WE'ILL PROBABLY GET TOGETHER AS SOON AS THE WEATHER IMPROVES AND DAVID GETS HIS GEAR DOWN HERE. SOUNDS LIKE HE'S A GREAT PHOTOGRAPHER.

HYPNEA MUSCIFORMIS. YEP. WE GET IT IN SOME OF THE GI TRACTS OF OUR TURTLES. RECENTLY WE HAD TWO ADULTS STRAND WITH SMALL QUANTITIES OF THIS ALGAE AND HYDROIDS IN THE GUT. WE HAVE ALSO HAD 2 STRANDINGS OF SMALL (40+CM.) GREEN TURTLES WITH THIS ALGAE IN THE GUT (COMPRISING 90% + OF THE SAMPLE). THESE STRANDINGS OCCURRED IN 1987 AT JOHN U. LLOYD STATE PARK. THIS ALGAE IS COMMON OFF THE PARK AS WELL AS IN POMPANO AND OTHER AREAS. THE TURTLES DO APPEAR TO PREFER GELIDIUM CRINALE WHEN PRESENT. AN ADDITIONAL OBSERVATION - FURTHER UP OUR COAST WHERE LEW EHRHARTS OCEAN SIDE TURTLES FEED WE HAVE NOTICED LOTS OF THIS ALGAE ON THE BOTTOM. I'M NOT SURE LEW OR HIS STUDENTS HAVE IDENTIFIED THE STOMACH CONTENTS OF THEIR STRANDED TURTLES.

IF YOU NEED MORE INFO OR HELP ETC. LET US KNOW. GOOD TALKING W/YOU.

BOB + JEANNE W.

Dennis - I'm writing to Lew Ehrhart right now to ask; most greens in Florida are thought to eat the seagrasses common there, Geo.

Pacific Science (1983), vol. 37, no. 2

Ecology of the Imported Red Seaweed *Eucheuma striatum* Schmitz on Coconut Island, Oahu, Hawaii[1]

DENNIS J. RUSSELL[2]

ABSTRACT: The introduced alga *Eucheuma striatum* Schmitz was studied regarding its spread, control, and ecology in Kaneohe Bay, Oahu, Hawaii. Its distribution in Kaneohe Bay during May 1976 was nearly the same as when it was originally planted 2 yr earlier. It lacked the ability to disperse over shallow depressions both in the reef and in deep water, and it did not colonize neighboring reefs without the help of man. Depth was the single most important physical factor limiting its dispersal. A total fresh weight standing crop of from 21 to 24 metric tons of *E. striatum* was recorded on a 500-m-long section of reef edge from December 1976 to June 1977. When protected from grazing its growth rate was about 5.0 percent/day. Data support the conclusion that the population on the reef edge was maintained only by a steady influx of thallus fragments that escaped from enclosed experimental plantings on the reef flat. When the experimental plantings were removed the population could not maintain itself and soon disappeared. *Eucheuma striatum* did not compete with native algal macrophytes and appeared to be the basis of a community richer in animal species than adjacent reefs. It provided 10–20 tons/mo of food for grazing fish, shelter, and a substratum for numerous invertebrates. *Eucheuma striatum* did not attach to corals, but it did cause their death by shading.

THE INTRODUCTION OF ALIEN SEAWEEDS to Hawaii probably occurs regularly. Some have been introduced accidentally by ship (Doty 1961), others for commercial and experimental purposes (Doty 1978). In all, at least 17 species of alien marine algae have come to Hawaii since World War II (Russell 1981). One particular kind of *Eucheuma striatum* Schmitz was imported on 9 September 1974 for scientific experiments in the field (Doty 1977). This large, smooth, erect alga (Figure 1) was discovered by a Filipino seaweed farmer on a reef near Sitang Kai, Sulu Province, Philippines, and is sometimes referred to as *tambalang* (Fortner 1978, Glenn and Doty 1981), apparently after the name of the farmer who found it. In this article it will be called simply *Eucheuma*.

Once in Hawaii *Eucheuma* was planted in several locations, particularly on nets and in wire holding pens on the northwestern reef bordering Coconut Island in Kaneohe Bay, Oahu (Figure 2). It grew rapidly and was exceedingly prolific, even without cultivation. Indeed, the population of *Eucheuma* grew so rapidly it began to alarm the public and came to the notice of scientists at the Hawaii Institute of Marine Biology (HIMB) located on Coconut Island (McGlinn 1976*a*). On 23 October 1976 a group of 50 volunteers removed about 4 tons of the estimated 50 tons of seaweed on Coconut Island (McGlinn 1976*b*). The concern was that it might continue to grow and spread, disrupt the balance in the food web, and trigger unpredictable changes in the fragile environment of the Hawaiian reefs (Griffin 1977).

Nevertheless, while some people were trying to prevent the spread of *Eucheuma*, others were transplanting the alga to new locations on Oahu and filing for permits to raise it in ponds and on reefs (Tune 1976, Hunter 1978).

The introduction of *Eucheuma* to Hawaii is

[1] This work is part of the author's Ph.D. thesis, completed in May 1981 for the Department of Botany, University of Hawaii at Manoa, Honolulu. It was supported in part by National Science Foundation grant OCE 76-24414. Manuscript accepted 3 January 1983.

[2] Seattle Pacific University, Biology Department, Seattle, Washington 98119.

FIGURE 1. *Eucheuma striatum* Schmitz from Coconut Island reef-edge population.

a unique occurrence but similar in some respects to the introduction of *Sargassum muticum* (Yendo) Fensholt to the Pacific coast of the United States and Canada (Scagel 1956) and to Great Britain (Farnham, Fletcher, and Irvine 1973); and to the introduction of *Codium fragile* subsp. *tomentosoides* (Van Goor) Silva to the Atlantic coast of the United States (Bouck and Morgan 1957) and Europe (Farnham 1980, Silva 1957). Each was introduced in conjunction with a marine aquaculture project, and each spread into the surrounding environment. The introduction of *Eucheuma* differs, however, because it was introduced for its own cultivation (Doty 1978), while *Sargassum* and *Codium* were incidental introductions associated with the transplanting of oysters from Japan and other locations. In each case man appears to be the most important influence in the dispersal of these alien algae. Man may also be the most important dispersing agent for *Eucheuma* in Hawaii.

When the present research was started little was known about the ecology of the form of *Eucheuma striatum* which had been introduced. It did have an important biological limitation, however. Apparently, *Eucheuma* could reproduce only by vegetative fragmentation. The following hypothesis therefore was proposed: Any physical or biological factor that limits the dispersal of viable vegetative fragments will also prevent the invasion of new territory by *Eucheuma*. Two additional aspects of *Eucheuma* were also studied: its effect on the reef animals and its competitive effects on algae already established on the reef.

MATERIALS AND METHODS

Surveys on Coconut Island and adjacent reefs in Kaneohe Bay were initiated in May 1976 (Figure 2). While being towed beside a motor boat in water 2–3 m deep, I surveyed the extent of the population, and then with SCUBA I determined the distribution of the thalli in deeper water. These surveys were

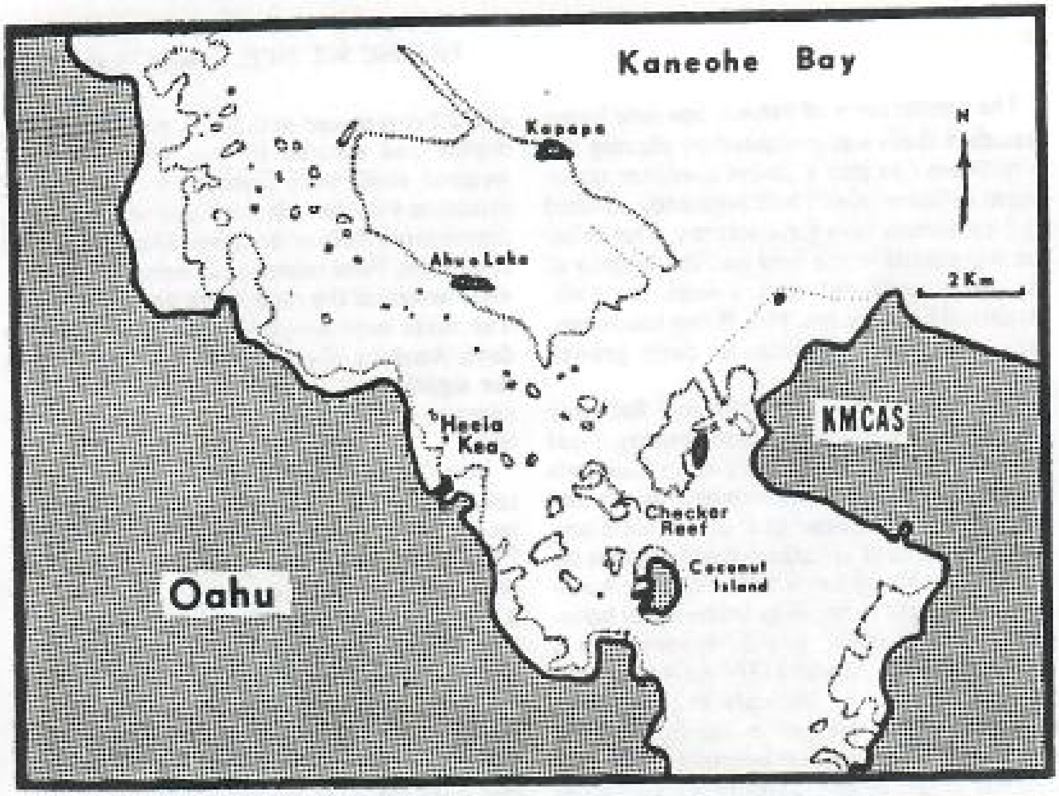

FIGURE 2. Coconut Island, situated in Kaneohe Bay on the Island of Oahu, Hawaii.

repeated intermittently from March 1976 to July 1978.

Quantitative samples were taken using a 46-cm-diameter ring inside of which all the *Eucheuma* was harvested and weighed while still fresh. One sample was taken at each depth—1, 2, and 4 m—at five locations, at approximately 3 mo intervals from December 1976 to March 1978.

An estimate of how much *Eucheuma* was leaving the experimental area located on the reef flat was obtained by removing and weighing the fragments that were caught in a 250-m-long Griff Net, Type NG, 2-cm-mesh size (Griffolyn Co., Inc., Houston, Texas). This net was installed on 1 October 1976, 18 mo after *Eucheuma* was planted on the reef. It was placed in a semicircle downstream from the two largest experimental plantings. These plantings were part of a research project directed by M. S. Doty and were separate experiments indirectly related to the present study.

The sizes of fragments left behind after workers handled *Eucheuma* in the experimental areas were determined by duplicating their efforts, not on the reef but in a flat-bottomed boat. The boat was loaded with thalli and the thalli transferred into rice bags. The pieces that had broken off, and which the workers would normally allow to be washed away, were gathered from the bottom of the boat and each piece weighed individually on an Ohaus triple-beamed balance.

The sinking rates of *Eucheuma* fragments were determined by timing the descent of various branched and unbranched pieces in calm seawater. The sinking rates were compared statistically by converting the weights to $\log_{10}$ and calculating the linear regression of branched and unbranched fragments separately.

The regeneration of branch tips into larger branched thalli was evaluated by placing 100 2-by-5-mm tips into a 20-cm diameter translucent cylinder, which had both ends covered by 1-mm-mesh fiberglass screens. The cylinder was placed in the field and the lengths of the pieces measured once a week for 8 wk. Statistical Package No. 194, Wang Industries, Inc., was used to determine daily growth rates.

Current patterns across the reef flat were determined by following nine drifting 1-gal plastic bottles nearly full of seawater. Currents in deeper water were determined by tracing the path of a methylene blue dye cloud along a meter stick held at various depths. Light intensity was measured with a Seconic Auto-Lumi L-86 light meter in an underwater housing. The light meter was calibrated with a General Electric Model 8DW58Y4 exposure meter. Temperature fluctuations were measured by Taylor maximum–minimum thermometers. Water motion was measured with calcium sulfate blocks (Doty 1971). Dissolved oxygen was determined by the Winkler method (Strickland and Parsons 1972). Standard t tests were used to analyze the data.

The growth and survival of *Eucheuma* thalli along the reef edge and at various depths were investigated in several ways. A polypropylene lead-weighted line (50 m long, 1 cm diameter) was anchored on Coconut Island and extended across the channel bottom to the reef located directly to the west. The line was attached to concrete blocks at 3-m intervals, and two thalli of *Eucheuma* were attached to each block until the greatest depth (ca 17 m) was reached, about two-thirds the distance across the channel. The thalli were weighed before being attached to the line and were weighed again 37 and 44 days later.

In another experiment, the same line was moved 2 m north (to avoid the shade of a rock), and four more thalli were tied to the line and weighed once a week for 4 wk. Growth rates for the two experiments were compared.

The significance of both depth and grazing on the survival of *Eucheuma* was tested by placing thalli inside and outside of four polyvinylchloride covered wire-mesh cages (mesh size 2.5 cm) placed at 0.5, 2.0, 6.0, and 12.0 m depths and secured to the reef. Four preweighed thalli were fastened to a length of insulated wire and placed diagonally through the center of each of the cages 30 cm above the cage floor. Four more thalli were placed on a wire outside of the cage 30 cm above the floor. The thalli were weighed every 5 days for 30 days. Analysis of covariance was used to test the significance of the data, and the differences in growth rates were compared by a t test.

Four unbranched thallus fragments were taken from the reef edge and placed in a protective pen at the north end of Coconut Island. They were allowed to grow there for 1 mo, photographed, placed on the reef edge for 3.5 hr, and retrieved and photographed again.

A 10-m length of the reef was cleared of all *Eucheuma* fragments to a depth of 12 m. A fence of Griffolyn netting was erected around the cleared area to prevent more fragments from entering and to prevent the fragments that were placed in the clearing from leaving. A 4-mm-diameter polypropylene line was attached to concrete blocks at the corners of the clearing and down the slope. Repeated inspection with SCUBA assured against fragments' intrusion into or loss from the experimental area.

Thalli were gathered from a protected area and placed in the shallow northern corner of the clearing. Thirty kilograms of thalli were allowed to drift into the clearing and remain there for 3 days. Their final positions were mapped before the pieces were gathered and weighed. The same procedure was repeated using 180 kg of thalli, but they were allowed to remain in the clearing for 74 days.

The effects of fish grazing were further studied by capturing the fish that were swimming in the *Eucheuma* and examining the contents of their guts. Algae in the gut were identified, counted, and measured.

Interactions between *Eucheuma* and local algae and invertebrates were noted during the surveys. Some of the interactions were photographed with Ektachrome 135, ASA 160, and Panatomic X, ASA 32, film and a Yashica Electro 35 camera. Quantitative data for determining species diversity were obtained

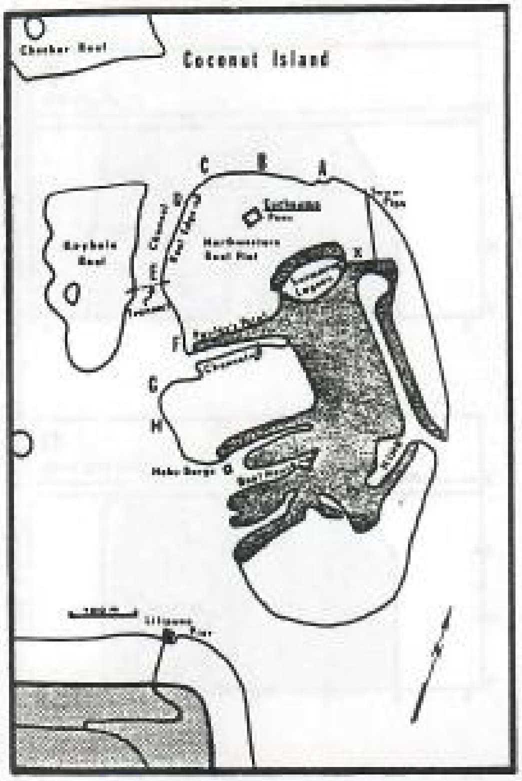

FIGURE 3. Locations of the sampling positions, experimental areas, and transects on Coconut Island. A protected area (X) was used for regeneration experiments.

by sampling with the ring method. A 46-cm-diameter metal ring was placed over the *Eucheuma* or substratum, and the algae and animals within it gathered by hand. Five ring samples were taken on each of two sections of the reef (Figure 3): at D among *Eucheuma* and at H where there were no *Euchema* thalli. All of the macroscopic algae and invertebrates, except corals, were gathered and counted.

RESULTS AND DISCUSSION

Distribution of Eucheuma on Coconut Island, 1976 to 1978

In March 1976 *Eucheuma* was located across the entire reef flat and along the reef edge at the northern end of the island (Figure

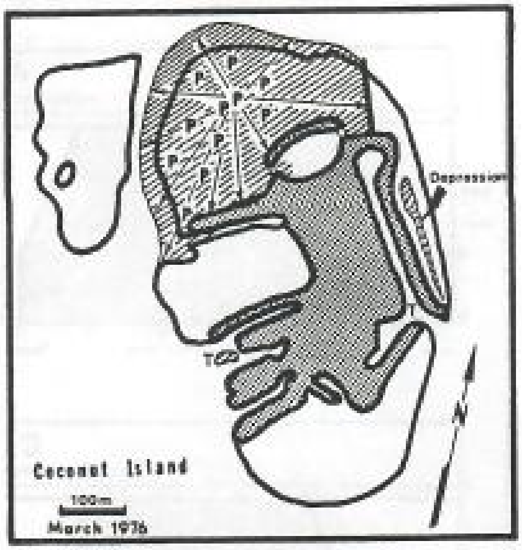

FIGURE 4. The maximum distribution of *Eucheuma* on Coconut Island. The letters P indicate where *Eucheuma* was originally planted, and the hatching indicates the maximum distribution. A T indicates a transplant location.

3) and was distributed 120° southwest around part of the island (Figure 4). Several tons of *Eucheuma* thalli were also located in depressions. *Eucheuma* fragments also were found inside a manmade seawater swimming lagoon near the lagoon's southwestern entrance (Figure 4).

Thallus pieces were found distributed along the reef edge and down slope to a depth of 5–17 m (Figure 5*A*). Loose fragments were located two-thirds of the way across a channel, but only to where the channel reached its maximum depth. Unattached fragments of *Eucheuma* were also found in shallow water (Figure 5*A*), but only in a limited area along the reef edge. The thalli found farthest away from the plantings were also the deepest.

The distribution of fragments in the channel was in the shape of a trapezoid (Figure 5*A*). This pattern would be expected if the fragments were being dispersed simply at random from the top of the underwater slope at the reef edge to the channel bottom. It appeared that the alga spread into deep water and stopped. Thalli were not present beyond the deepest portion of the channel, and no

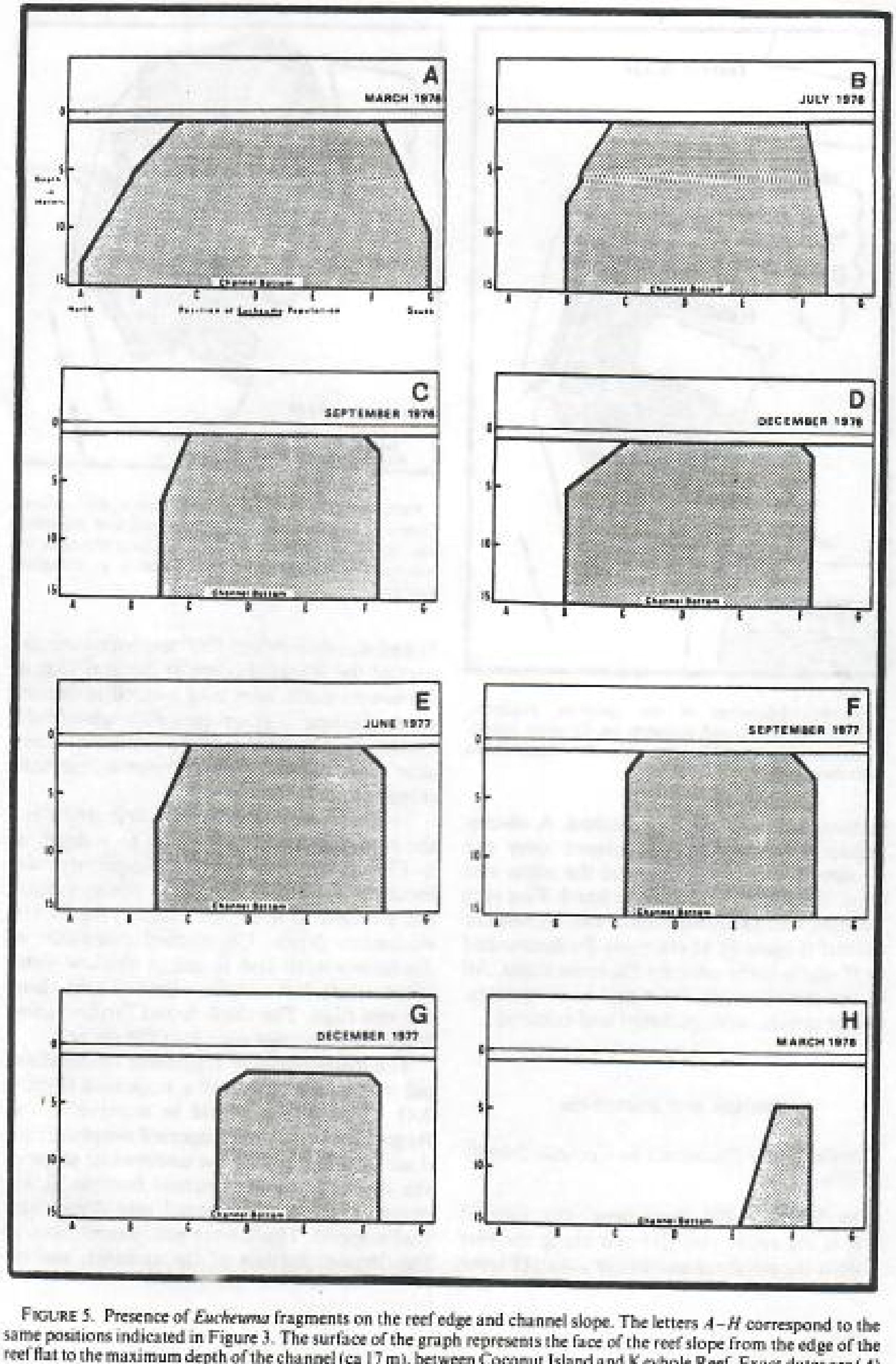

FIGURE 5. Presence of *Eucheuma* fragments on the reef edge and channel slope. The letters *A–H* correspond to the same positions indicated in Figure 3. The surface of the graph represents the face of the reef slope from the edge of the reef flat to the maximum depth of the channel (ca 17 m), between Coconut Island and Keyhole Reef. Exact dates are (*A*) 20 March 1976, (*B*) 13 July 1976, (*C*) 14 September 1976, (*D*) 10 December 1976, (*E*) 3 June 1977, (*F*) 10 September 1977, (*G*) 14 December 1976, (*H*) 20 March 1978.

TABLE 1

AMOUNTS OF *Eucheuma* ON THE REEF EDGE OF COCONUT ISLAND (KG)

	DECEMBER 1976 DEPTH (m)			JUNE 1977 DEPTH (m)			SEPTEMBER 1977 DEPTH (m)			DECEMBER 1977 DEPTH (m)		
POSITION	1	2	4	1	2	4	1	2	4	1	2	4
A	0	26	0	0	0	0	0	0	0	0	0	0
B	0	31	26	0	20	3	0	0	21	0	10	0
C	0	34	0	0	46	6	0	17	10	0	0	0
D	4	34	0	0	63	34	0	69	16	0	21	4
E	28	20	9	0	40	33	0	20	1	0	31	9
Total	32	145	35	0	169	76	0	106	48	0	62	13
Sample averages	6	29	7	0			0	21	10	0	12	3
Grand total	212			245			154			75		
Average	14 ± 7.3			16 ± 10.8			10 ± 9			5 ± 5		
× 1,500 m²	21,000 ± 10,950			24,000 ± 16,200			15,000 ± 13,500			7,500 ± 7,500		

thalli or germlings of *Eucheuma* were found on Keyhole Reef (see Figure 4).

In July 1976 a decline in the area of occurrence of thallus fragments was noted (Figure 5*B*). In September 1976 a further decline in distribution had occurred (Figure 5*C*). In October 1976 a Griff Net was installed on the reef to try to stop the flow of fragments from the experimental pens to the reef edge. By December 1976, however, a survey showed the distribution of fragments had increased rather than declined as expected (Figure 5*D*). The results of ring samples indicated there were 22 metric tons, wet weight, of *Eucheuma* on the reef edge and slope (Table 1, Figure 6). In June 1977 the distribution was the same as it had been nearly 1 yr earlier (Figure 5*E*), and the estimated amount of *Eucheuma* had increased to about 24 tons (Table 1).

The experimental pens, which appeared to be the source of the fragments in spite of the Griff Net, and the large *Eucheuma* thalli that were on the reef flat west of position A, were removed later in June 1977. Three months later, in September, the area of occurrence had narrowed (Figure 5*F*), and the biomass had declined to 17 tons (Table 1). By December 1977, 6 mo after the pens had been removed, the entire distribution had narrowed still further and the thalli, which had been in shallow water, had settled 1 m deeper than early in June 1977 (Figure 5*G*). In March 1978 the population of fragments had declined to a fraction of its size 2 yr earlier (Figure 5H), the fragments were not observed in water shallower than 2 m, and the estimated biomass for *Eucheuma* along the reef edge and slope was only 10 kg.

The most extensive distribution of *Eucheuma* appeared in March 1976, 16 mo after the original thalli were placed on the reef (Figures 4, 5). The source of the thalli was the experimental plantings from which fragments drifted with the currents (Figure 7), across the reef to the edge, and into the currents in deeper water (Figure 8).

A map of *Euchuema* distribution showed that the outer boundaries ended abruptly wherever there were shallow depressions or deep water, such as the 2-m-deep shallow channel near Pauley's Point and the 17-m-deep channel between Coconut Island and Keyhole Reef (Figure 4). *Eucheuma* did not cross either channel but accumulated in the hollows and depressions on the reef, especially in the dredged portions near shore.

These data do not imply that *Eucheuma* had completely disappeared from Coconut Island. It was still present on the reef flat after the reef-edge population disappeared, but in much smaller amounts and in sandy areas not occupied by many other forms of marine life.

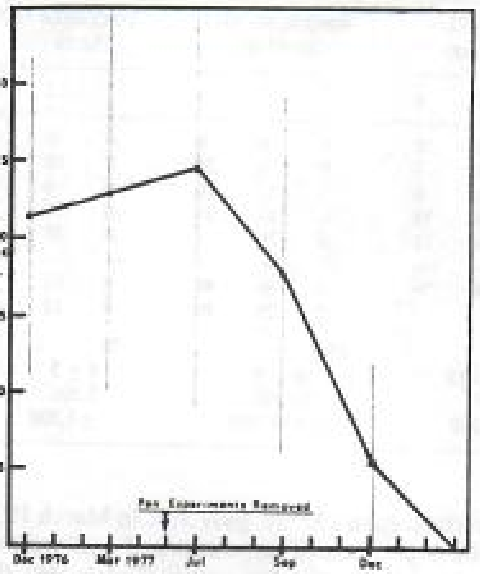

FIGURE 6. The total estimated fresh weight amount of *Eucheuma* present on the northwestern reef edge of Coconut Island as a function of time. Vertical lines represent 95 percent confidence intervals.

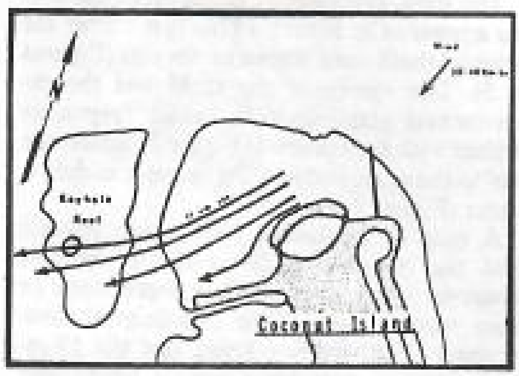

FIGURE 7. The paths taken by drifting bottles across the northwestern reef flat of Coconut Island during a normal trade-wind day.

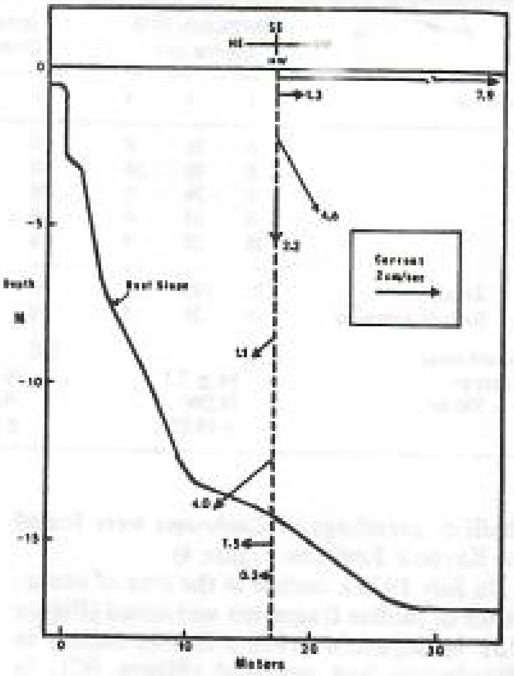

FIGURE 8. Strength and direction of current as a function of depth at position *E* on Coconut Island.

In March 1978, after *Eucheuma* had disappeared from the reef edge, there still were several accumulations of actively growing thalli in depressions on the reef flat. The largest amount that remained was in a depression on the more eastern reef flat (Figure 4). This dredged depression contained an estimated 0.1 tons of *Eucheuma* on 14 December 1976, 3.0 tons on 3 July 1977, 13.0 tons on 12 December 1977, and 13.0 tons again in March 1978. An estimated 0.5 tons also occupied a depression near an unused sewer pipe in March 1978 (Figure 3). Near the northeastern entrance to the swimming lagoon were located 2 tons, and 0.03 ton was located 10 m west of the southwestern entrance to the swimming lagoon.

Dispersal of Eucheuma by Man

When *Eucheuma* was planted on the northwest reef flat of Coconut Island, it grew so rapidly that it attracted the attention of several people not associated with the planned experiments. Some of these people soon became interested in growing the alga for themselves, and transplanted thalli to other areas in Kaneohe Bay (Figure 4). *Eucheuma* grew in each of these places although most of the thallus pieces were eventually removed by hand during the various control efforts.

Eucheuma thalli were planted by fishermen near Heeia Kea in Kaneohe Bay (Figure 2), and a worker on Coconut Island sent some *Eucheuma* to friends in Hilo, Hawaii. About 12 kg was sent to residents at Ewa Beach, Oahu, but the fate of these thalli is not known. Several transplants were made from Kaneohe Bay to an enclosed seawater pond at Kahuku Farms, Oahu.

Eucheuma was sent from Kaneohe Bay to Fiji, Christmas Island, Fanning Island, and other locations in the Pacific. The desirability of *Eucheuma* as a commercial crop inspired marine agronomists to transplant it to five or more countries in the Pacific Ocean within 3 yr of its introduction to Hawaii (Doty 1979, Russell 1983).

Physical Limits to the Spread of Eucheuma

Because this particular kind of *Eucheuma* was not found to produce viable spores in Hawaii, other means of reproduction were investigated. At the tip of each branch this alga has a cluster of apical cells potentially high in regenerative capabilities; they may be able to regenerate new thalli after breaking off from larger thalli. Small size would allow dissemination to greater distances on weaker currents than is true for the bulk of *Eucheuma* found on the reef. Results support the conclusion, however, that this means of dispersal is unlikely.

The slowest sinking rate (1 cm/sec) was with 2-mg apical tips (Figure 9). These fragments did sink slower and would be carried farther by currents than the larger pieces. However, it was found that if these tips were carried by currents and washed over the reef edge they would be moving across the bottom of the reef flat at a depth of 50 cm and already would be in slow-moving currents that would direct them away from neighboring reefs (Figure 8). If they were dropped into a 10-cm/sec surface current, they would be carried only 5 m from the reef edge before sinking 50 cm into slower currents and eventually to the bottom of the channel. It is possible that an extreme current or turbulence could buoy small fragments and carry them farther, but how far and in what direction would be impossible to predict.

The importance of very small fragments would be even more significant to reproduction if they were produced in abundance by the alga. However, small thallus branch tips or pieces, such as those described, were in areas of a harvest. Most of the thalli growing on the reef edge had no small acute tips characteristic of the thalli growing in the experimental pens or in the depressions near land. The reef-edge thalli were gnarled and lacked branches of small diameter, except at their bases.

One hundred apical tips (2 × 5 mm) were cultured to see if they would grow into full-sized thalli. Only 50 percent survived the first 2 wk (Table 2), and after 10 wk 28 percent were still living and had increased substantially in size. Growth in length of the tips

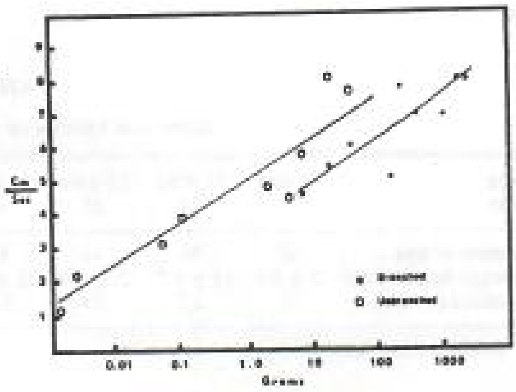

FIGURE 9. Regression of the sinking rates for branched and unbranched *Eucheuma* thalli as a function of size.

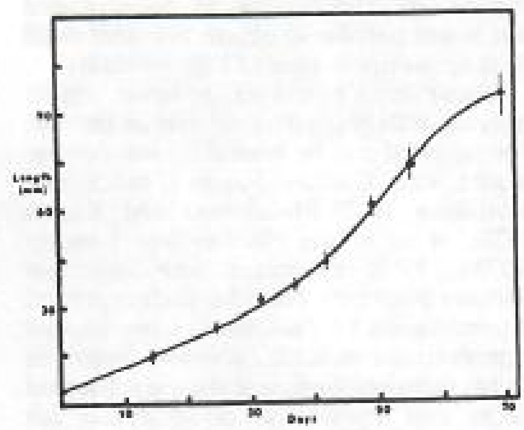

FIGURE 10. Growth curve for the increase in length of 2-by-5-mm *Eucheuma* branch tips.

TABLE 2

GROWTH IN LENGTH OF *Eucheuma* APICAL TIPS

DATE DAYS	31 MAY 0	13 JUNE 13	23 JUNE 23	30 JUNE 30	5 JULY 35	11 JULY 41	18 JULY 48	25 JULY 55	8 AUG 64
Number of tips	100	50	44	42	41	38	32	31	30
Average length (mm)	5 ± 0.0	15 ± 0.7*	23 ± 1.6	31 ± 1.6	36 ± 2.1	44 ± 2.8	61 ± 4.3	75 ± 8.1	95 ± 9.6
Standard deviation	0	2.3	5.4	5.4	6.7	8.7	12.3	23.0	26.7

* Confidence interval of 95 percent.

followed an S-shaped curve with the rate of length increase slowing as girth expanded (Figure 10). The experiment demonstrated that it was possible to obtain full-sized thalli from apical tips in spite of high mortality.

Regeneration in culture, however, apparently has little bearing on survival on the reef. The potential may be present, as was demonstrated with *Codium fragile* (Fralick and Mathieson 1972, Malinowski and Ramus 1973), or as in the Fletcher and Fletcher (1975*a*, 1975*b*) experiments with *Sargassum muticum* fragments, but other factors prevent the realization by *Eucheuma* of this asexual reproduction potential. *Eucheuma* fragments do not form holdfasts, and the most buoyant pieces with regenerative capability are not found on the reef except after a harvest. Thus, there is no evidence that such small pieces are important in the dispersal of this alga. It appears that *Eucheuma* does not have any effective mechanism for dispersal over deep water or out of depressions, hollows, or channels and is unable to colonize neighboring reefs without human help.

The greatest accumulation of *Eucheuma* (23 tons) occurred on the reef edge, but this was not a permanent or established population. It was only a temporary accumulation of fragments that was moving slowly into deeper water unsuitable for its growth. This conclusion is supported by the following evidence.

Approximately 1400 kg/mo was being lost from the thalli in the experimental pens and plantings (Table 3). These thalli moved across the reef flat at 10 m/hr during a normal trade-wind day. They washed over the reef edge and were added to the mass of *Eucheuma* accumulating there. The growth rate of *Eucheuma* thalli in shallow water is 4–5 percent/day (Doty 1977). These data would indicate that 23 tons along the reef edge should increase to about 60 tons in 1 mo. No substantial increase was seen, however (Table 1). The thalli appeared to be healthy, yet 37 tons/mo were not being realized or were disappearing from the reef edge.

TABLE 3

AMOUNT OF *Eucheuma* CAUGHT IN A GRIFF NET LOCATED DOWNSTREAM FROM THE EXPERIMENTAL PENS

Date (42 days)	AMOUNTS GATHERED (kg)	RATE (kg/day)
1 Oct 76	14	
5 Oct 76	18	5
8 Oct 76	182	61
10 Oct 76	109	55
19 Oct 76	23	3
22 Oct 76	27	9
29 Oct 76	109	16
30 Oct 76	182	182
5 Nov 76	209	35
7 Nov 76	134	67
12 Nov 76	151	30
Total	1158	463
Average	105 ± 43.6*	46 ± 32.9†
Standard deviation	73.7	53.1

* Confidence interval of 95 percent.
† 1380 kg/mo.

An experiment was designed to follow the path of fragments that drifted over the reef edge. Thalli (180 kg) were allowed to drift into a cleared portion on the reef edge where they were left undisturbed for 74 days (Figure 11). When they were recovered the total weight (131 kg) was 27 percent less than the original amount released. Of the remaining thalli, 82

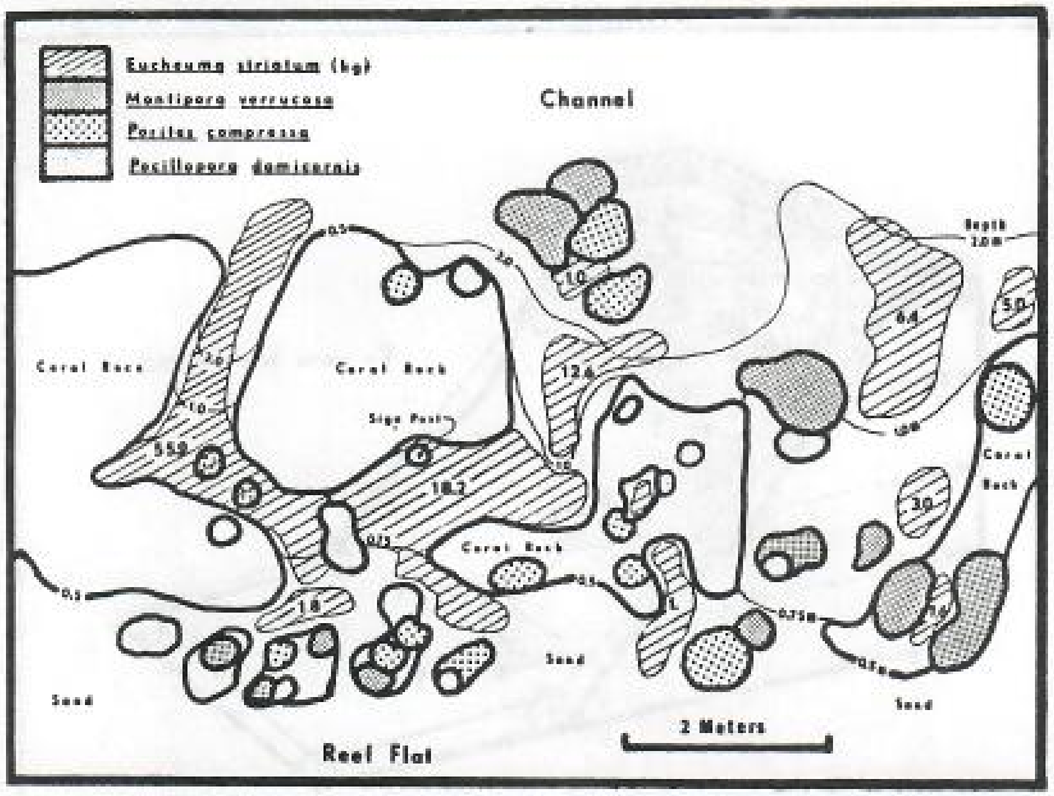

FIGURE 11. Top view of the area at position *E* showing the quantities of *Eucheuma* thalli that remained in the cleared area 74 days after they were released and their relation to rock and coral.

percent were retained between coral heads and rock (Figure 11) and 18 percent had slid down the slope into water deeper than 2 m (Figure 12). None of the surviving pieces had small branches on them, and no small branch fragments were found in the vicinity. The loss of algal material was so great that no net increase in this mass of released *Eucheuma* fragments could be demonstrated.

The *Eucheuma* thalli that drifted into the deep, stagnant channel water did not survive. Thalli were monitored along a transect line to a depth of 16 m (Figure 13): thalli on the channel floor either lost two-thirds their original weight in 37 days or were reduced to decaying masses; thalli 6 to 9 m deep lost weight during the final 17 days; and those at 1 m depth were the only pieces that gained weight during the 54 day experiment (Table 4).

A second similar experiment was more definitive. The transect line was moved 2 m north to avoid the problems of shading by a rock in shallow water. Four thalli on the reef flat averaged 4.3 percent growth per day (Table 5). There was a significant drop in weight for most of the thalli that were between 1.0 and 3.5 m, and thalli below 6 m lost weight (Table 5, Figure 14).

Even though a few healthy looking thalli were found to a depth of 17 m during the surveys, experimental evidence suggests that thalli below 6 m eventually die. The few healthy looking thalli seen on the channel bottom during the surveys may have been recent immigrants that had not yet begun to decay. There was, however, an anomalous decrease in weight between 1 and 3 m depths (Figure 14) which could not be explained on the basis of physical properties that change with depth. The losses were far greater than expected con-

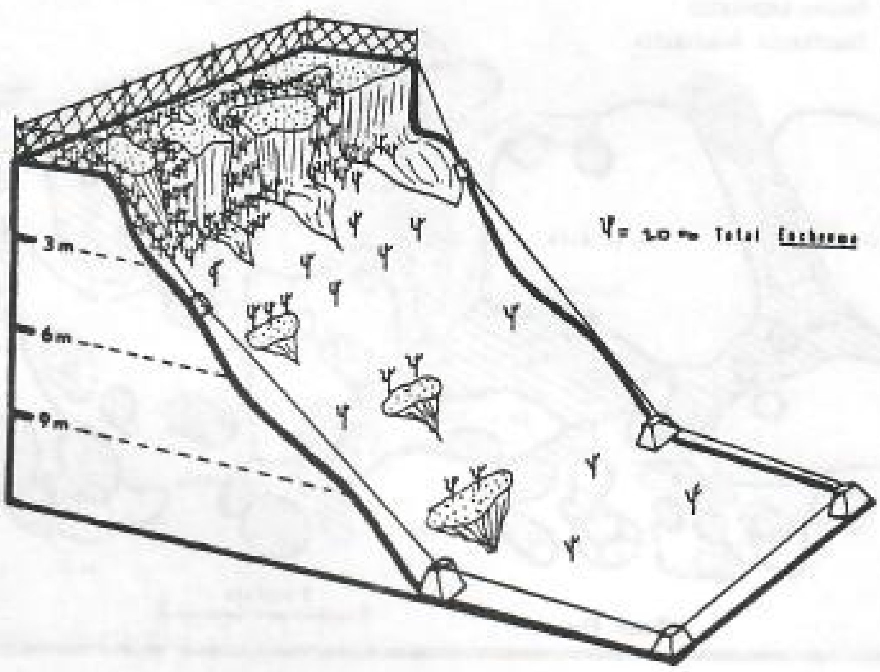

FIGURE 12. Sectional view showing the horizontal and vertical positions of *Eucheuma* thallus locations on the reef edge and channel slope. Each diagrammatic thallus represents 1 percent of the total weight recovered.

sidering the thalli just below them gained slightly in weight. It appeared that fish might be feeding on the thalli. Another experiment was designed that eliminated the fish by placing *Eucheuma* inside protective wire-mesh cages. Then, growth rates of *Eucheuma* at different depths were compared.

The results of these tests showed a significant decrease in the growth rates of thalli between 0.5 and 2.0 m depths (Figure 15). This decrease corresponded to a significant decrease in light intensity and water motion (Table 6). The effect of fish grazing is discussed in the following section.

The maximum depth at which *Eucheuma* grew differed slightly from experiment to experiment. This problem may have been a result of changing conditions in Kaneohe Bay rather than experimental error. These data, nevertheless, support the conclusion that the uneven edge of the reef flat, with its coral heads and ledges of rock dissected by deep grooves, was not holding the fragments securely in place, but was acting as a sieve. It was simply delaying the progress of the fragments as they drifted into deeper water where they could not live.

The final evidence for this conclusion came after the June 1977 survey, when the reef flat experiments were removed (Figure 6). This abruptly ended the flow of fragments across the reef. By September 1977 the thalli had receded from the northern end of the reef slope (Figure 5*F*) and the total amount of *Eucheuma* had declined (Figure 6). By December 1977 no fragments were in water less than 2 m deep

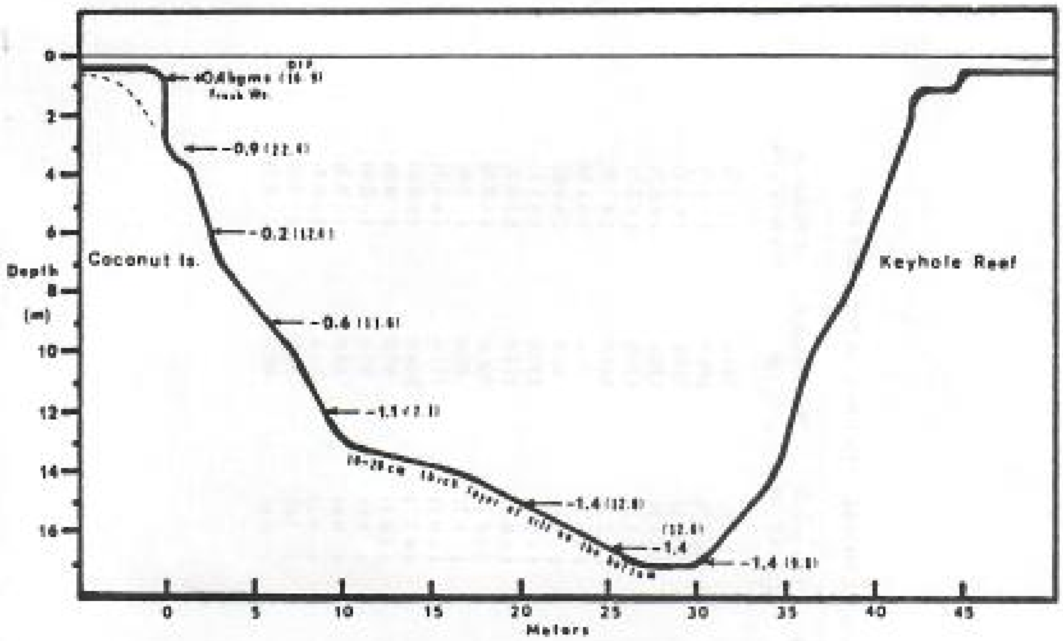

FIGURE 13. The fresh weight gained or lost by *Eucheuma* thallus fragments after remaining tied to concrete blocks for 44 days at various depths across the channel at position *E*. Diffusion Index Factor (DIF) values are in parentheses: the lower the value the slower the water motion.

TABLE 4

Growth and Survival of *Eucheuma* as a Function of Depth, 13 July–4 September 1976

DEPTH (m)	DATE			CHANGE IN WEIGHT (kg)	FINAL AVERAGE WEIGHT (kg)	AVERAGE IN WEIGHT (kg)
	12 July	18 August	4 September			
1.0	2.3	8.3	4.6	+2.3		
	2.3	3.8	2.7	+0.4	2.7	+0.4
3.0	1.4	4.5	—	−1.4		
	1.4	2.0	1.0	−0.4	0.5	−0.9
6.0	1.4	1.3	1.8	+0.5		
	1.4	0.7	0.5	−0.9	1.2	−0.2
9.0	1.4	0.9	0.5	−0.9		
	1.4	0.9	1.0	−0.4	0.8	−0.6
12.0	1.4	0.5	0.5	−0.9		
	1.4	0.0	0.0	−1.4	0.3	−1.1
15.0	1.4	0.0	0.0	−1.4		
	1.4	0.1	0.0	−1.4	0.0	−1.4
16.0	1.4	0.5	0.0	−1.4		
	1.4	0.2	0.0	−1.4	0.0	−1.4
	1.4	0.0	0.0	−1.4		
	1.4	0.0	0.0	−1.4	0.0	−1.4

TABLE 5

Changes in Fresh Weight of *Eucheuma* Thalli Growing on the Reef Flat at Various Depths to 9.5 Meters, 29 October–26 November 1976

DEPTH (m)	29 OCTOBER (g)	5 NOVEMBER (g)	CHANGE IN WEIGHT (%/day)	12 NOVEMBER (g)	CHANGE IN WEIGHT (%/day)	19 NOVEMBER (g)	CHANGE IN WEIGHT (%/day)	26 NOVEMBER (g)	CHANGE IN WEIGHT (%/day)
0.5	117.0	154.0	(+4.0)	230.0	(+5.9)	312.0	(+4.5)	398.0	(+3.5)
0.5	62.0	80.0	(+3.7)	118.0	(+5.7)	157.0	(+4.2)	198.0	(+3.4)
0.5	71.0	99.0	(+4.9)	140.0	(+5.1)	185.0	(+4.1)	238.0	(+3.7)
0.5	42.0	54.0	(+3.7)	76.0	(+5.0)	99.0	(+3.9)	123.0	(+3.2)
1.0	65.0	68.0	(+0.7)	185.0*	(—)	108.0	(−7.4)	125.0	(+2.1)
1.5	75.0	86.0	(+2.0)	105.0	(+2.9)	122.0	(+2.2)	140.0	(+2.0)
2.0	98.0	104.0	(+0.9)	66.0	(−6.3)	67.0	(+0.2)	76.0	(+1.8)
2.5	102.0	107.0	(+0.7)	121.0	(+1.8)	84.0	(−5.1)	88.0	(+1.0)
3.0	95.0	96.0	(+0.2)	113.0	(+2.4)	129.0	(+1.9)	139.0	(+1.1)
3.5	94.0	103.0	(+1.3)	107.0	(+0.6)	111.0	(+0.5)	114.0	(+0.4)
4.0	76.0	88.0	(+2.1)	97.0	(+1.4)	102.0	(+0.7)	100.0	(−0.3)
4.5	87.0	91.0	(+0.6)	96.0	(+0.8)	88.0	(−1.2)	88.0	(0.0)
5.0	99.0	104.0	(+0.7)	107.0	(+0.4)	111.0	(+0.5)	113.0	(+0.3)
6.0	100.0	104.0	(+0.6)	112.0	(+1.1)	140.0	(+3.2)	148.0	(+0.8)
6.5	109.0	99.0	(−1.4)	95.0	(−0.6)	97.0	(+0.3)	97.0	(0.0)
7.0	104.0	96.0	(−1.1)	97.0	(−0.2)	97.0	(0.0)	92.0	(−0.8)
7.5	87.0	94.0	(+1.1)	94.0	(0.0)	90.0	(−0.6)	89.0	(−0.2)
8.0	127.0	120.0	(−0.8)	63.0	(−8.8)	62.0	(−0.2)	64.0	(+0.5)
8.5	77.0	75.0	(−0.4)	72.0	(−0.6)	58.0	(−3.0)	58.0	(0.0)
9.5	104.0	100.0	(−0.6)	99.0	(−0.1)	99.0	(0.0)	98.0	(−0.2)

* The original thallus was lost and replaced at this point.

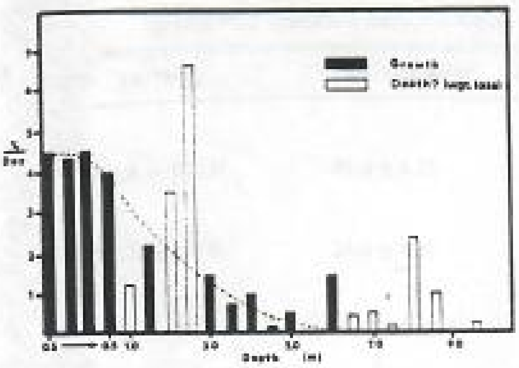

Figure 14. Percent growth per day of *Eucheuma* thalli tied at 1-m intervals along a line from 0.5 to 9.0 m depth at position *E*. Each histogram represents a single thallus, and the dashed line represents the expected growth rates.

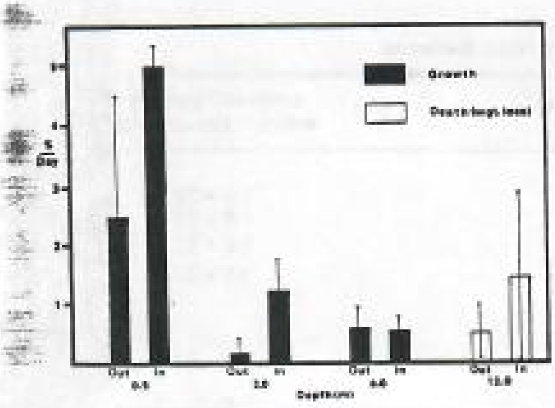

Figure 15. The average percent growth per day of four *Eucheuma* thalli tied to the outside and four thalli tied to the inside of protective cages at four depths at position *E*.

(Figure 5*G*), and by March 1978 only a few fragments were on the reef edge (Figure 5*H*). The reef "sieve" was emptied of its contents in 8 mo.

Biological Factors Limiting Eucheuma Growth

The following evidence supports the conclusion that fishes grazing along the reef edge contributed to a significant loss of algal biomass and a lowered growth rate.

Different species of fishes were seen swimming between and beneath the loose clumps of *Eucheuma* thalli. Most were juvenile scarids (parrotfish) and acanthurids (surgeonfish), although several carnivorous fishes were also present. The gut contents of both herbivores and carnivores were examined for *Eucheuma* (Table 7). As expected, none of the carnivorous fish species had any algae in their digestive tracts, but four out of five captured individuals of *manini* (*Acanthurus triostegus sandvicensis* Randall and Gaimard) and the yellow tang (*Zebrasoma flavescens* Randall) contained from 6 to 166 pieces of *Eucheuma* branch tips and cross sections in their guts (Table 7). These pieces ranged from 1 to 2 mm wide and from 1 to 3 mm long. A few pieces (less than 1 percent) of *Acanthophora spicifera* (Vahl) Boerg. and *Gracilaria bursapastoris* (Gmel.) Silva were also present, but *Eucheuma* was the primary food item. Grazing was intense and partially responsible for the lack of growth by the reef-edge population of *Eucheuma*.

When *Eucheuma* cuttings were taken from the reef edge and placed in a protective pen they produced an abundance of branches. These newly branched pieces were again placed on the reef edge; all of the new branches disappeared within 3.5 hr. All of the branches had been severed to their bases, and only the 2.0-cm-thick portions of the thalli were left. The herbivorous fishes appeared to selectively graze on the smaller branches of *Eucheuma*. This explains the gnarled, branchless appearance of thalli on the reef edge. During the final stages of the disappearance of *Eucheuma*, the fishes began eating the thicker portions of the thalli that were still available.

The best estimate of how much was being eaten by fishes was obtained by combining the results of several experiments. A 515-g branched *Eucheuma* thallus was lowered into a holding pen with 40 *palani* (*Acanthurus dussumieri* Randall). The fish ate 51 g from the thallus in 3.5 hr. Another thallus weighing 500 g was placed into a pen with four *kala* (*Naso unicornis*), twelve *A. dussumieri*, one *A. triostegus sandvicensis*, and two Ambon tobys (*Canthigaster amboinensis*), and after 2 hr the thallus had lost 35 g to the fishes. The individuals of *A. dussumieri* were the most aggressive fish in this group and the only ones actually seen eating the thallus. They placed their

TABLE 6

PHYSICAL CHARACTERISTICS MEASURED DURING THE CAGED AND NONCAGED *Eucheuma* EXPERIMENT

DEPTH (m)	OXYGEN (μg-at O_2/L)*	WATER MOTION (DIF)	TEMPERATURE (°C)	LIGHT LUX
0.5				
Inside cage		33.9 ± 6.3		
Outside cage	0.495 ± 0.013	36.9 ± 5.1	27.4 ± 0.59	38,000 ± 8,500
2.0				
Inside cage		12.8 ± 1.9		
Outside cage		11.4 ± 1.0	26.5 ± 0.42	20,000 ± 11,000
6.0				
Inside cage		13.5 ± 2.5		
Outside cage	0.422 ± 0.0	14.6 ± 3.0	26.3 ± 0.45	12,000 ± 5,000
12.0				
Inside cage		9.7 ± 2.7		
Outside cage	0.389 ± 0.0	14.4 ± 3.1	26.0 ± 0.30	2,000 ± 1,400

* Microgram-atoms of oxygen per liter.

TABLE 7

GUT ANALYSES OF FISHES CAPTURED NEAR *Eucheuma*

FISH SPECIES	NUMBER OF *Eucheuma* PIECES IN GUT	AVERAGE FRAGMENT WIDTH × LENGTH (mm)
Acanthurus triostegus		
#1	166	1.0 × 2.0
#2	6	1.5 × 2.0
#3	18	1.0 × 2.0
Zebrasoma flavescens	37	1.5 × 2.0
Chaetodon miliaris		
#1	0	
#2	0	
Chaetodon trifasciatus	0	

mouths over the seaweed branch tips and swam onto them while biting repeatedly. The *palani* stopped feeding after 30 min when all the small branches had been eaten. Under these conditions fishes ate 7.1 percent of the thalli within 3.5 hr.

In one experiment, 32 percent of the thallus weight was eaten from fragments allowed to drift over the reef edge, and 27 percent was lost when the experiment was repeated. When growth rates of caged and uncaged thalli were compared (Figure 15, Table 8) they showed that the fishes reduced the growth rate at 0.5 m depth by 50 percent and at 2.0 m depth by 80 percent, an average reduction of 65 percent. If these figures are extrapolated the fishes could graze from 10 to 20 tons/mo from the reef edge.

Effects of Eucheuma on Reef Animals

Eucheuma thalli provided shelter for reef fishes, especially the bluespotted goby (*Asterropteryx semipunctatus* Ruppell) and the conger eel (*Conger marginatus* Valenciennes). Nearly every time *Eucheuma* thalli were harvested, individuals of *A. semipunctatus* were inadvertently taken with the thalli into the boat. The eel, *C. marginatus*, which was nearly the same color as *Eucheuma*, was often found swimming among the loose thalli, as were moray eels (*Gymnothorax* spp.).

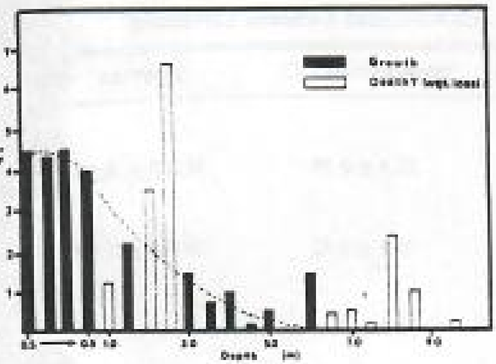

FIGURE 14. Percent growth per day of *Eucheuma* thalli tied at 1-m intervals along a line from 0.5 to 9.0 m depth at position *E*. Each histogram represents a single thallus, and the dashed line represents the expected growth rates.

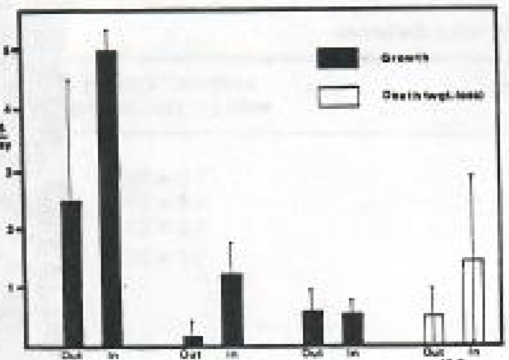

FIGURE 15. The average percent growth per day of four *Eucheuma* thalli tied to the outside and four thalli tied to the inside of protective cages at four depths at position *E*.

(Figure 5*G*), and by March 1978 only a few fragments were on the reef edge (Figure 5*H*). The reef "sieve" was emptied of its contents in 8 mo.

Biological Factors Limiting Eucheuma Growth

The following evidence supports the conclusion that fishes grazing along the reef edge contributed to a significant loss of algal biomass and a lowered growth rate.

Different species of fishes were seen swimming between and beneath the loose clumps of *Eucheuma* thalli. Most were juvenile scarids (parrotfish) and acanthurids (surgeonfish), although several carnivorous fishes were also present. The gut contents of both herbivores and carnivores were examined for *Eucheuma* (Table 7). As expected, none of the carnivorous fish species had any algae in their digestive tracts, but four out of five captured individuals of *manini* (*Acanthurus triostegus sandvicensis* Randall and Gaimard) and the yellow tang (*Zebrasoma flavescens* Randall) contained from 6 to 166 pieces of *Eucheuma* branch tips and cross sections in their guts (Table 7). These pieces ranged from 1 to 2 mm wide and from 1 to 3 mm long. A few pieces (less than 1 percent) of *Acanthophora spicifera* (Vahl) Boerg. and *Gracilaria bursapastoris* (Gmel.) Silva were also present, but *Eucheuma* was the primary food item. Grazing was intense and partially responsible for the lack of growth by the reef-edge population of *Eucheuma*.

When *Eucheuma* cuttings were taken from the reef edge and placed in a protective pen they produced an abundance of branches. These newly branched pieces were again placed on the reef edge; all of the new branches disappeared within 3.5 hr. All of the branches had been severed to their bases, and only the 2.0-cm-thick portions of the thalli were left. The herbivorous fishes appeared to selectively graze on the smaller branches of *Eucheuma*. This explains the gnarled, branchless appearance of thalli on the reef edge. During the final stages of the disappearance of *Eucheuma*, the fishes began eating the thicker portions of the thalli that were still available.

The best estimate of how much was being eaten by fishes was obtained by combining the results of several experiments. A 515-g branched *Eucheuma* thallus was lowered into a holding pen with 40 *palani* (*Acanthurus dussumieri* Randall). The fish ate 51 g from the thallus in 3.5 hr. Another thallus weighing 500 g was placed into a pen with four *kala* (*Naso unicornis*), twelve *A. dussumieri*, one *A. triostegus sandvicensis*, and two Ambon tobys (*Canthigaster amboinensis*), and after 2 hr the thallus had lost 35 g to the fishes. The individuals of *A. dussumieri* were the most aggressive fish in this group and the only ones actually seen eating the thallus. They placed their

TABLE 8

GROWTH RATES OF *Eucheuma* THALLI GROWN OUTSIDE AND INSIDE PROTECTIVE CAGES AT FOUR DEPTHS, 8 JUNE–18 JULY 1977

DEPTH (m)	DATES: 28 June (%/day)	3 July (%/day)	8 July (%/day)	13 July (%/day)	18 July (%/day)	TOTAL	AVERAGE	STANDARD DEVIATION
0.5								
Outside the cage	0.9	3.5	4.4	4.5	−0.9	12.4	2.5	3.09
Inside the cage	4.6	5.2	4.6	5.5	4.9	24.8	5.0	0.39
2.0								
Outside the cage	−0.5	0.5	0.2	0.2	0.2	0.6	0.1	0.29
Inside the cage	1.7	2.1	0.4	0.6	1.0	5.8	1.2	0.72
6.0								
Outside the cage	0.2	1.2	0.1	0.8	0.9	3.2	0.6	0.47
Inside the cage	0.5	0.8	0.8	0.3	−0.1	2.3	0.5	0.56
12.0								
Outside the cage	0.3	−0.8	−0.4	−0.3	−0.9	−2.2	−0.4	0.58
Inside the cage	−0.2	0.2	−0.2	−3.7	−0.9	−6.6	−1.3	2.46

Eucheuma thalli also provided a substratum for numerous invertebrates. Among the invertebrates recorded were sessile solitary and colonial ascidians, sponges and peristome ciliates (which covered the bases of the thalli like a white fur), and several mobile holothurians.

The numbers of invertebrates living among the *Eucheuma* thalli were compared to a similar area on an adjacent reef where *Eucheuma* thalli had never been present (Figure 3*H*). In the *Eucheuma* area, 97 individual macroscopic invertebrates, not counting corals, were found on *Eucheuma* thalli, for an average of 5 ± 2 species per sample (Table 9). At the control site, 25 invertebrates were recorded with an average of 1.8 ± 1 species per sample ($P = 0.05$). The reef with *Eucheuma* on it had a significantly higher index of diversity than did the reef without the alien (Table 9).

Effects of Eucheuma *on Corals*

When fragments of *Eucheuma* were allowed to sink or drift onto the reef edge, thalli weighing 55.9 kg covered two small living *Porites compressa* coral heads (Figure 11). After 74 days the corals were dead. Larger coral heads nearby, not covered by *Eucheuma* thalli, were not damaged. Coral death was probably a result of shading (Table 10).

It was more common to find damaged *Eucheuma* than damaged coral when the two were found in contact. Usually no attachment was formed by either the animal or the alga; instead, *Eucheuma* became abraded by the coral. Several branches of *Eucheuma* thalli were found next to *Porites compressa*, which attached to the alga (Figure 16). Yet, the alga did not form a connection with the coral, but rather a callus formed on the alga where the two were in contact.

An erect sponge, *Toxadocia violacea*, was also found attached to *Eucheuma*, which reacted by forming a wartlike callus on itself where the animal was attached. This interaction was found only once, although *T. violacea* occurred regularly among the *Eucheuma* thalli.

Effects of Eucheuma *on Other Algae*

Only two nonalien algal macrophytes grew with *Eucheuma* on the reef edge. These algae, *Dictyosphaeria cavernosa* (Forsk.) Boerg. and *Caulerpa racemosa* var. *peltata* Lam., were present in small quantities beneath *Eucheuma*

TABLE 9

INDEX OF SPECIES DIVERSITY AT POSITION E COMPARED TO POSITION H

SPECIES	SAMPLE REPLICATES 1	2	3	4	5	TOTAL
POSITION E						
Solitary Ascidians						
#1	11	6	1	4	4	26
#2	7	7	0	1	0	15
#3	11	0	0	0	5	16
#4	2	1	0	0	0	3
Colonial Ascidians						
#5	2	2	0	0	0	4
#6 (This species was found on the base of every *Eucheuma* examined.)						
Echinoderms						
#7	3	4	6	2	9	24
#8	1	2	2	0	0	5
#9	0	0	0	0	2	2
#10	0	0	0	0	0	0
Sponges						
#11	0	0	0	1	0	1
#12	0	0	0	0	0	0
#13	0	0	0	1	0	1
Total	37	22	9	9	20	97
Average 5 ± 2						
Total species 11; a = 3*						
POSITION H						
Solitary Ascidians						
#1	7	5	2	1	4	19
#2	0	0	0	0	0	0
#3	0	0	0	0	0	0
#4	0	0	0	0	0	0
Colonial Ascidians						
#5	0	0	0	0	0	0
#6	0	0	0	0	0	0
Echinoderms						
#7	0	0	0	1	0	1
#8	0	0	0	0	0	0
#9	0	0	0	0	0	0
#10	0	0	0	1	0	1
Sponges						
#11	0	0	0	0	0	0
#12	1	0	0	0	3	4
#13	0	0	0	0	0	0
Total	8	5	2	3	7	25
Average 1.8 ± 1						
Total species 4; a = 1						

NOTE: The formula used to estimate the Index of Diversity was $S = \alpha \mathrm{Log}_e \left[1 + \frac{N}{\alpha}\right]$, where α is the Index of Diversity, S is the total number of species, and N is the total number of individuals (Lewis and Taylor 1967).

* Significant at the 5 percent level.

TABLE 10

THE EFFECT OF *Eucheuma* ON CERTAIN PHYSICAL FACTORS

	POSITION OF MEASUREMENT	
PHYSICAL FACTORS	Beside the thalli	Under the thalli
Light (lux)	40,000 (100%) ± 25,000	1,000* (2.5%) ± 563
Oxygen (μg-at O_2/L)†	0.482 ± 0.003	0.454 ± 0.019
Water motion (DIF)‡	8.1 ± 0.47	9.4 ± 2.34

* Significant at the 1 percent level.
† Microgram-atoms of oxygen per liter.
‡ Diffusion index factor.

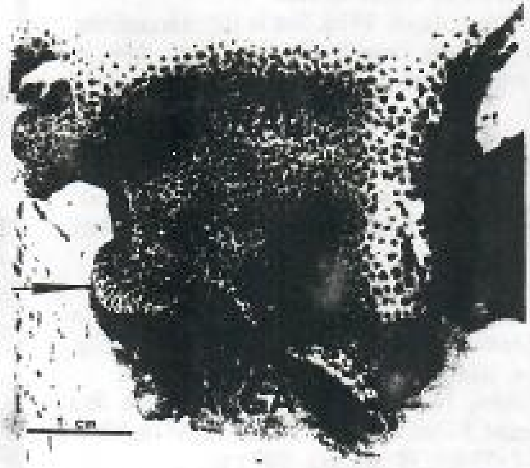

FIGURE 16. *Porites compressa* attached to *Eucheuma* (indicated by arrows).

thalli. No other large algae inhabited the grooves in the reef edge in the area or the grooves on adjacent reefs, although several species, which appeared to be unaffected by *Eucheuma*, grew on the coral substrate between the grooves.

In Kaneohe Bay, *Eucheuma* inhabited the barren sand-covered grooves on the reef edge which were not inhabited by native algae and thus appeared to be noncompetitive. A similar situation occurred in Puget Sound, Washington, where *Sargassum muticum* entered a niche empty of other large native algae (Scagel 1956). In Europe Farnham et al. (1981) reported that *S. muticum* invaded and increased in biomass at Bembridge, Isle of Wight, but did so without harm to the local population. *Codium fragile*, which was introduced to France, did not compete with native algae (Feldmann, 1956) because it occupied substrata not utilized by native species.

SUMMARY

1. *Eucheuma striatum* Schmitz was imported on 9 September 1974 from the Philippines and placed on a Coconut Island reef flat in Kaneohe Bay, Oahu, for scientific experimentation. Fragments from these thalli drifted across the reef flat and established an unstable population (ca 24 metric tons) along the reef edge.

2. People not associated directly with the Coconut Island experiments transplanted *Eucheuma* to other locations in Hawaii (Heeia Kea, Ewa Beach, Kahuku, and Hilo). It was also sent to Fiji, Christmas Island, Fanning Island, and other locations in the Pacific.

3. This particular kind of *Eucheuma* did not produce spores; reproduction was by fragmentation. Small fragments of branch tips were capable of disseminating over short distances and would regenerate into full-sized thalli. Tips were not an effective mechanism for dispersal over deep water; they did not form holdfasts and were not found on the reef except after a harvest.

4. *Eucheuma* did not have the ability to cross channels and accumulated in depressions on the reef. The greatest accumulation

was on the reef edge, but this was only a temporary population that was moving into deeper water unsuitable for its growth.

5. After the experimental holding pens on the reef flat were removed, the reef-edge population disappeared in 8 mo. This population was actually moving slowly into deeper water.

6. Fish were grazing an estimated 10–20 tons of *Eucheuma* per month, which resulted in a significant loss of algal biomass and a lowered apparent growth rate.

7. *Eucheuma* provided a substratum for numerous invertebrates. The reef with *Eucheuma* had a higher index of invertebrate species diversity than a control reef.

8. *Eucheuma* inhabited barren sand-covered grooves on the reef edge which were not inhabited by native algae. *Eucheuma* thus appeared to be noncompetitive.

ACKNOWLEDGMENTS

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To my friend George
Dennis

ICES mar. Sci. Symp., 194: 110–125. 1992

The ecological invasion of Hawaiian reefs by two marine red algae, *Acanthophora spicifera* (Vahl) Boerg. and *Hypnea musciformis* (Wulfen) J. Ag., and their association with two native species, *Laurencia nidifica* J. Ag. and *Hypnea cervicornis* J. Ag.

Dennis J. Russell

Russell, D. J. 1992. The ecological invasion of Hawaiian reefs by two marine red algae, *Acanthophora spicifera* (Vahl) Boerg. and *Hypnea musciformis* (Wulfen) J. Ag., and their association with two native species, *Laurencia nidifica* J. Ag. and *Hypnea cervicornis* J. Ag. – ICES mar. Sci. Symp., 194: 110–125.

Acanthophora spicifera, a red seaweed, which was introduced to Hawaii in the 1950s, is well established on all the Hawaiian islands except Hawaii. It has a heterogeneous distribution limited primarily by water motion between DIF 10–80 and temperature (25–27°C). Salinity has been less limiting (19–36‰). Competition between *Acanthophora* and two native algal species (*Laurencia* spp. and *Hypnea cervicornis*) is discussed. Another introduction, *Hypnea musciformis* entered the *Laurencia* niche in 1977 and has partially displaced *H. cervicornis*. Changes within the *Laurencia* niche due to the introduction of two alien marine algal species are discussed.

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Introduction

Eighteen species of marine macro-algae have been introduced to Oahu, Hawaii, since 1950. Two are highly successful "weedy" species, nine are marginally successful and seven have failed to become established (Table 1). Recently, most of these introductions have been in conjunction with aquaculture projects where the algae have been transported by air from as far away as Florida and the Philippines to Hawaiian reefs in locations where they would most likely be successful. Currently, only the ecological effects of *Kappaphycus alvarezii* (=*Eucheuma striatum*) (Doty, 1988) have been researched (Russell, 1983). The effects introduced species have on the native species ecology are unique to each one that enters the Hawaiian Islands, and an understanding of how they may change the ecosystem is critical for the conservation and management of the reefs, just as it is for the terrestrial ecology (Lewin, 1987). The research presented here deals specifically with the ecology of *Acanthophora spicifera* (Vahl) Boerg. and *Hypnea musciformis* (Wulfen) C. Ag. (two highly successful introduced species) and their competition with *Laurencia nidifica* J. Ag. and *Hypnea cervicornis* J. Ag. (two native species).

Acanthophora spicifera is the most widespread and successful alien alga in Hawaii. It appeared for the first time in Hawaii in the early 1950s (Doty, 1961), perhaps entering on a barge from Guam, or possibly along with fish imported to the Waikiki Aquarium (Russell, 1987). It has a relatively continuous distribution in nearly all of the tropical and subtropical seas of the world: Panama (Earle, 1973), Cuba (Taylor, 1967), the Mediterranean (Feldmann, 1937) (where it was introduced via the Suez Canal), Bangladesh (Nurul-Islam, 1976), Viet Nam (Dawson, 1954), Indonesia (Atmadja, 1977), Philippines (Levring *et al.*, 1969), and locations in between. However, before 1950 there was a gap in its distribution across the Central Pacific until it arrived in Hawaii (Trono, 1968), a location for which it was well suited.

The physical parameters for *A. spicifera* habitation in other locations are broad and varied. It is found in sheltered bays (Taylor and Bernatowicz, 1969), on shores exposed to the open ocean (Kim, 1964; Taylor, 1967), and in moderate to strong wave action (Womersley and Bailey, 1970). *Acanthophora* occurs 1–3 m deep, near shore in the eulittoral, upper sublittoral or lower intertidal zone (Doty, 1970; Earle, 1973; Tabb and Manning, 1961; Taylor, 1967), cannot withstand prolonged exposure to air (Kilar and Lou, 1986), and is

Table 1. Marine macro-algae introduced to Oahu, Hawaii, since 1950.

Species	Introduced to new location	Time of introduction	Place of origin	Degree of success	Commercial value	Competition with native species
Acanthophora spicifera (Vahl) Boerg. (S,A)	Pearl Harbor and/or Waikiki	After 1950 26 Apr 1952	Guam	Highly successful	None	*Laurencia nidifica*
Eucheuma denticulatum (Burm.) Col. & Herv. (T)	Honolulu Harbor Kaneohe Bay, etc.	October 1970 to late 1976	Philippines	Successful	Kappa-Carrageenan	Unknown
*Eucheuma isiforme** (C. Ag.) J. Ag. (T)	Kaneohe Bay	Jan 1974	Florida	Not successful	Iota-Carrageenan	None
Gracilaria epihippisora Hoyle (T)	Waikiki Kaneohe Bay	Apr 1971 Sept 1978	Hawaii Is.	Marginal	Agar	Unknown
Gracilaria eucheumoides Harvey (T)	Kaneohe Bay	mid 1970s	Philippines	Unknown	Carrageenan	Unknown
Gracilaria salicornia (C. Ag.) Dawson (T)	Waikiki Kaneohe Bay	Apr 1971 Sep 1978	Hawaii Is.	Highly successful	Agar	Unknown
Gracilaria sp. (IT)	Honolulu Harbor	1971	Philippines	Unknown	Carrageenan	Unknown
Gracilaria tikvahiae McLachlan (T)	Kaneohe Bay Kahuku	mid 1970s	Florida	Successful	Carrageenan Fresh produce	Unknown
Hypnea musciformis (Wulfen) J. Ag. (T)	Kaneohe Bay	Jan 1974	Florida	Highly successful	Kappa-Carrageenan	*Hypnea cervicornis* *Acanthophora spicifera*
*Kappaphycus alvarezii*** (Doty) Doty (T)	Honolulu Harbor Kaneohe Bay, etc.	9 Sep 1974 to late 1976	Philippines	Successful	Kappa-Carrageenan	None known
*Kappaphycus striatum*** (Schmitz) Doty (T)	Honolulu Harbor Kaneohe Bay, etc.	5 Aug 1970 to late 1976	Pohnpei and Philippines	Successful	Kappa-Carrageenan	Unknown
Lola lubrica (S. & G.) Ham. & Ham. (CO)	Makapuu and Kahuku	1976	California	Not successful	None	None
Macrocystis pyrifera (L.) C. Ag. (T)	Makapuu Keahole Point	1972 1980s	California	Not successful	Alginates	None
Nemacystus decipiens (Suhr.) Kuck. (UK)	Waikiki	1950s?	Unknown	Successful	None	Unknown
Pilinella californica Hollenberg (CO)	Makapuu Kahuku	1976	California	Not successful	None	None
Porphyra sp. (T)	Oahu	(?)	Japan	Unknown	Nori	Unknown
Wrangelia bicuspidata Boerg. (UK)	Kaneohe Bay	1974(?)	Unknown	Successful	None	Unknown

Introduced by (S) = ship, (A) = aquarium activities, (T) = transplanted, (CO) = with clams and oysters, (UK) = unknown
*Two distinct forms of *E. isiforme* were introduced, both failed to survive (see Cheney, 1988).
***K. alvarezii* = *Eucheuma striatum* var. *tambalang*; *K. striatum* = *E. striatum* var. *elkhorn* (see Doty, 1988 and Glenn and Doty, 1990).

normally found below the mean low tide level (Rao and Sreeramalu, 1974). The substratum to which it attaches is also varied: sand and rock (Taylor and Bernatowicz, 1969), shells (Dawson, 1954), concrete (Varma, 1959), rubber bands (Mshigeni, 1978), logs (Dawes *et al.*, 1978), and buoys (Anand, 1940).

Trono (1968) suggested that *A. spicifera* may be limited to high islands, which may contain certain vital micronutrients (Doty, 1954). However, Tsuda (1964) found *A. spicifera* on Tarawa, Kiribati, a low calcareous atoll. Temperature has been suggested as a more important factor governing its distribution, since *Acanthophora* tends to disappear in mid-winter in Bermuda (Taylor and Bernatowicz, 1969) and Trono (1968) suggested that it may be limited to waters that remain above 23.5°C.

Tabb and Manning (1961) also found an increase in the amount of *Acanthophora* when salinity decreased, but found it could tolerate high salinity. Soegiarto (1972) also reported a correlation between the local distribution of *A. spicifera* in Kaneohe Bay, Hawaii, and low salinity, low water motion, sandy substrata, and municipal pollution. From these observations the distribution of *A. spicifera* in Hawaii was expected to be limited to areas with lower than normal salinity, moderate wave action or water motion, at a depth of 1–3 m or less, below low tide and within an average temperature of 23.5°C.

The algal species with which *A. spicifera* has been reported are also numerous, but only a few occur with it regularly in other geographical locations. *Laurencia* spp. are associated with *A. spicifera* in the Philippines (Doty, 1970), in Panama (Earle, 1973), Indonesia (Atmadja, 1977), and Florida (Kilar and Lou, 1986), while *Hypnea* spp. are associated with *A. spicifera* in the Gulf of Mexico (Kim, 1964), Viet Nam (Dawson, 1954), and the Philippines (Doty, 1970). In Hawaii, *Acanthophora* has colonized the reefs in zones occupied by *Valonia ventricosa* J. Ag., *Colpomenia sinuosa* (Roth) Derbes and Solier and *Bornetella sphaerica* (Zanard.) Solms-Laubach (Santelices, 1977), and *Hypnea cervicornis* J. Ag. (Mshigeni, 1974). This paper tests the hypothesis that *A. spicifera* forms associations with *Laurencia* and *Hypnea* species in Hawaii and competes, displaces, or replaces them on the reef.

After the majority of this study was completed, another alien alga was introduced to Hawaii, *Hypnea musciformis* (Table 1). This fast-growing, weedy species was introduced from Florida to Kaneohe Bay, Hawaii, early in 1974 (Abbott, 1987), along with *Eucheuma isiforme* (C. Ag.) J. Ag., for marine agronomy experiments. By 1977 it had entered the same niche with *Acanthophora*, *Laurencia*, and *Hypnea cervicornis* and significantly altered the ecology. The direction and extent of change due to this fourth member of the association is also discussed.

Materials and methods

A systematic survey of all accessible shores and a specific sampling method was used on six of the Hawaiian Islands. Seventy locations were sampled, including most of Hawaii's harbors and a wide selection of the shoreline types.

When *Acanthophora* was found, a 46-cm diameter ring was placed over the heaviest growth of the alga, all of the thalli present within the ring were removed by hand, sorted to species, and weighed wet and dry. The occurrence of *A. spicifera* along the shores was tested using 95% confidence intervals for a binomial distribution.

Salinity was measured at each location with an American Optical Corp. refractometer No. 10419, temperature with calibrated mercury-filled thermometers, depth with a meter stick, and water motion with calcium sulfate blocks (Doty, 1971). Water motion is represented as a Diffusion Increase Factor (DIF), a value based on the enhanced dissolution rate of calcium sulfate blocks in moving water compared to their dissolution rate in still water. Water motion was measured once at each location and analysis of variance was used to test the significance of differences between the data.

Data was also collected from three transects on the windward side of Oahu over a consecutive 31-month period. These transects are subjected to the same general weather conditions and represent high, medium, and low water motion habitats (Fig. 1). All of the algae inside a 46-cm diameter ring were sampled at regular intervals along each transect and weighed wet and dry.

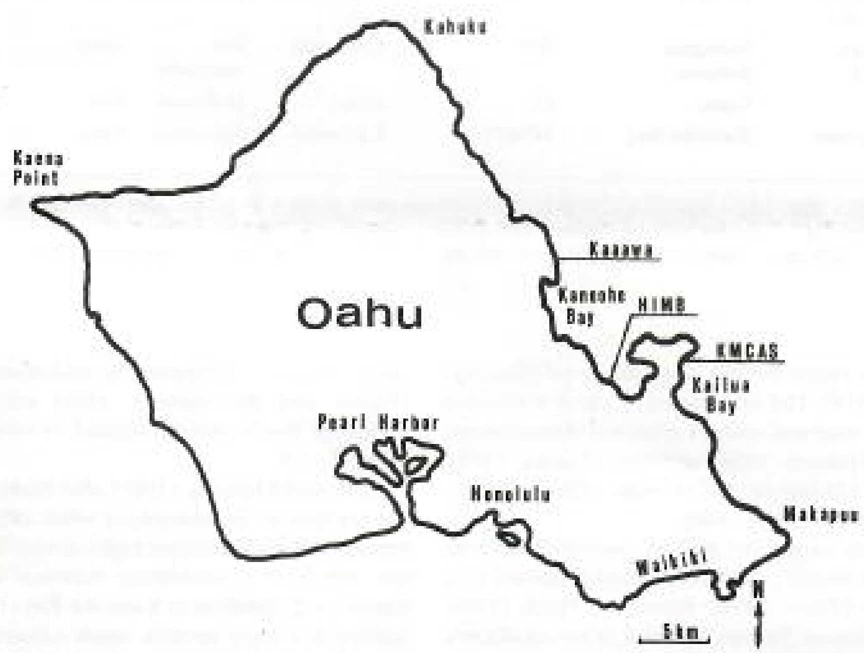

Figure 1. Map of Oahu, Hawaii, showing locations of the three transect sites (KMCAS, Kaaawa, HIMB) and important place names.

These same methods were used to determine the standing crop of species in other studies going on simultaneously (1973–1976) in Hawaii by other investigators (Santelices, 1977; Glenn *et al.*, 1990).

The Kaneohe Marine Corps Air Station (KMCAS) transect crosses a solution bench reef of solid amalgamated coral limestone, exposed to strong wave action and high water motion, on the Kailua Bay side of Ulupau Head on Mokapu Peninsula (Fig. 1). A line marked at 5-m intervals for 40 m (the width of the reef) was placed on the reef once a month, at the same location, and ring-samples made at each 5-m interval.

The transect at Kaaawa was located near a sugar mill ruins on State Highway No. 83 (Fig. 1). The 80-m long transect extended east from the shore perpendicular to the highway. The reef flat is in an area of moderate wave action and consists of sand, amalgamated coral limestone, and boulders. Samples were taken at 5-m intervals for the first 13 months, 10-m intervals for the next 7 months, and at 20-m intervals for the final 11 months.

The transect in Kaneohe Bay was on a sandy reef-flat 80 m east of Lilipuna Pier, used by the Hawaii Institute of Marine Biology (HIMB), 4 km inside the Kaneohe Bay barrier reef (Fig. 1). It is in an area of light wave action and low water motion and extended 110 m north from a retaining wall and terminated at the reef edge. Depth, water motion, temperature, and salinity were measured along each transect for the duration of the study.

Competitive interactions between *A. spicifera* and other algae were investigated by comparing the total and seasonal standing crop fluctuations of *A. spicifera* along the transects with the other algal species present. The Index of Diversity (Lewis and Taylor, 1967) was solved numerically on an HP28S calculator.

Competitive interactions between *A. spicifera* and *Laurencia nidifica* were tested both in the laboratory and in the field. The apparatus used was a 15 × 25 × 40 mm block of plastic sponge (Magla Products, No. 2033-738) glued with contact cement to the top of an 8-mm diameter, 70-mm long tapered hardwood dowel which was wedged into a 6-mm diameter hole drilled into a 25 × 25 × 100 mm, painted, mild steel bar (Fig. 2). Thirty of these units were placed into a 20 × 68 × 144 cm tank filled with Kaneohe Bay sea water, which flowed over the experiment at $10\,l\,min^{-1}$. Three liters per day of nutrient solution (10 g KNO_3 and 10 g $NH_4\,NO_3\,l^{-1}$) was mixed at the rate of 250 ml h^{-1} with the incoming water once a day.

Both *A. spicifera* and *L. nidifica* were gathered from a reef in Kaneohe Bay. Each piece had a holdfast and was trimmed to weigh 1.0 g. Two slits were cut into each sponge and two thalli placed onto each slit at random, either as pairs of the same species (controls) or one of each species. Each pair was placed together so they were touching and secured to the sponge with a soft thread. These units were placed at random in the water tank, exposed to natural light (35 000–100 000 lux at noon), 13 h light and 11 h darkness, 24–28°C, a water flow that gave a DIF of 8 ± 2.

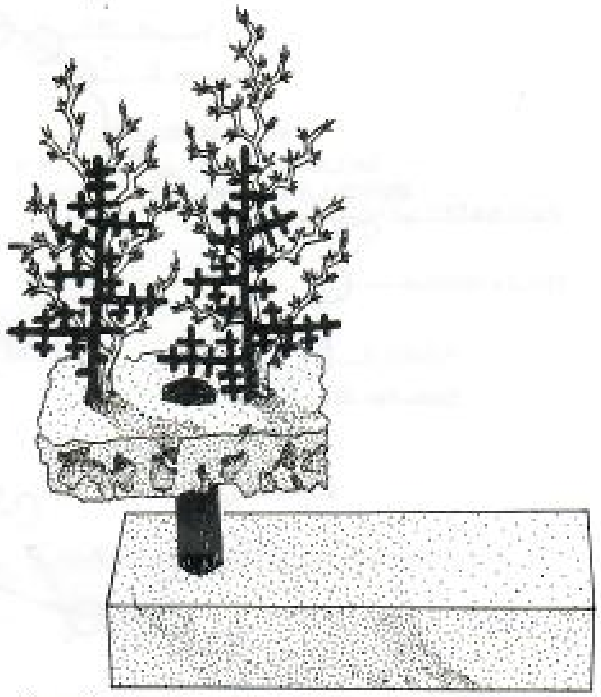

Figure 2. Apparatus used in the competition experiments between *Acanthophora* (light thallus) and *Laurencia* (dark thallus).

A duplicate experiment was conducted in the field on a Kaneohe Bay reef. Replicates were positioned on a cleared area normally inhabited by both *A. spicifera* and *L. nidifica*. The area was protected from grazing fish, rolling stones, and large drifting algae by a one-inch square mesh size plastic covered wire fence. The thalli were cleaned of epiphytes daily by hand. Growth rates of *Hypnea musciformis* thalli were studied at this same place. Temperature was 24–27°C and DIF was 58 ± 2. The experiments lasted nine days each and the results were tested using analysis of variance.

Results and discussion

Distribution of *Acanthophora* in the Hawaiian Islands

Acanthophora is well established on Oahu Island, but does not have a homogeneous distribution. Twenty-two of 33 sampling locations on Oahu had more than a trace of *A. spicifera* (Fig. 3). The largest quantities were on wide reef-flats at Wailupe and Ala Moana along the southern shore and Hauula and Punaluu along the northeastern shore (Table 2), but there was only a trace in samples from the southeastern shore and no thalli were present along the western shore, except in Pokai Bay.

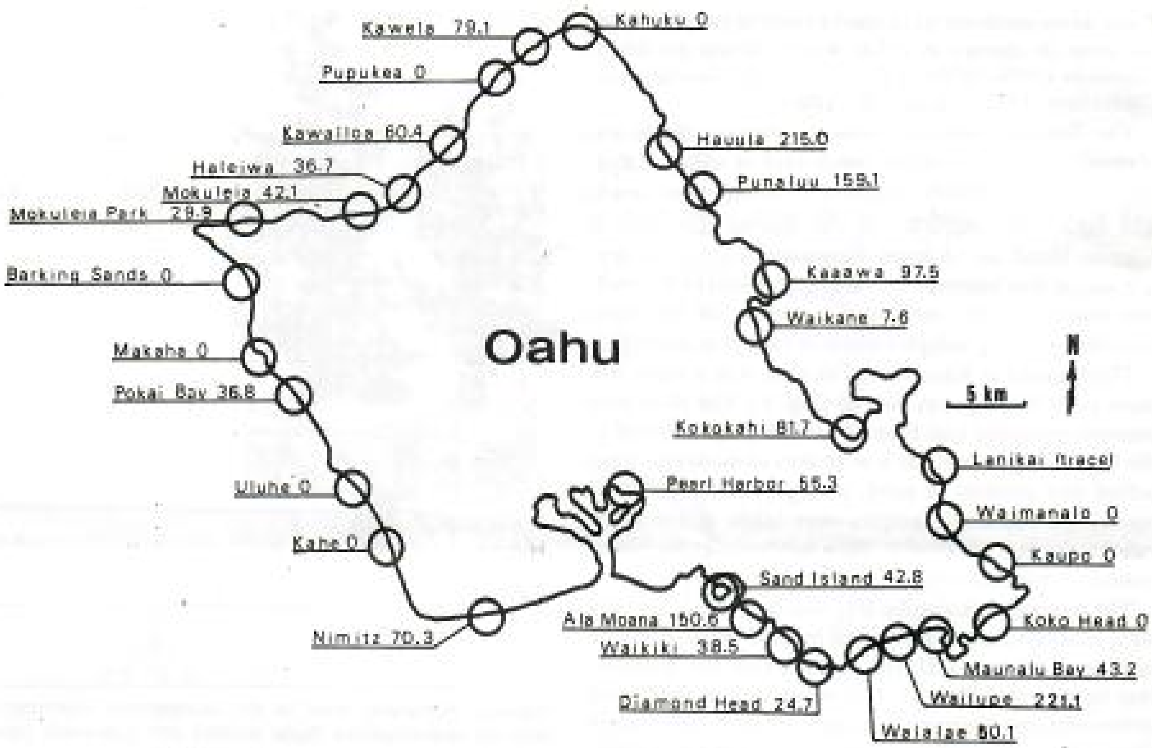

Figure 3. The distribution and quantities (g/m^2) of *Acanthophora* on Oahu, Hawaii.

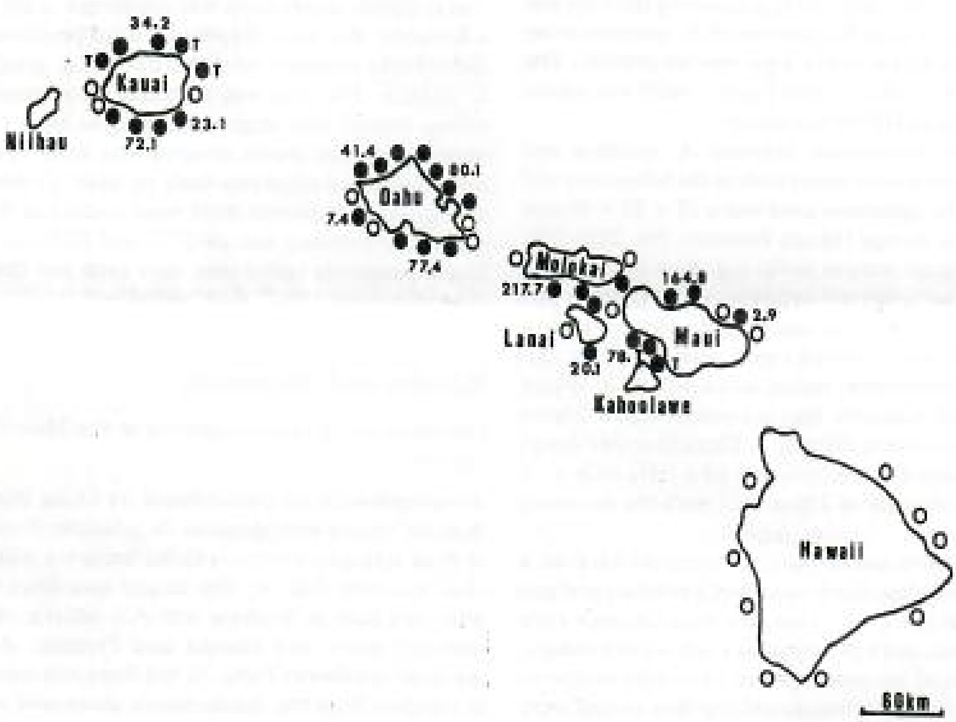

Figure 4. A summary of the distribution of *Acanthophora* on the major Hawaiian Islands. Solid circles indicate it was present, open circles indicate it was absent. The numbers are average quantities (g/m^2) of *Acanthophora* on the shores indicated.

Table 2. Amounts of *Acanthophora spicifera* and the physical features of locations surveyed in the island of Oahu.

Location	Dry wt. g/m²	DIF	°C	Salinity
Kaupo	0	66.5 ± 5.9	25	35.0
Waimanalo	0	74.2 ± 1.0	24	35.0
Lanikai	Trace	58.8 ± 2.6	28	35.0
Kailua	Trace	62.5 ± 15.4	28	35.0
Kokokahi	81.7	36.8 ± 0.3	28	35.5
Lilipuna Pier	122.7	45.0 ± 1.2	28	35.0
Waiahole	7.6	56.6 ± 3.1	28	19.5
Kaaawa	97.5	65.6 ± 3.5	27	35.5
Punaluu	159.1	50.3 ± 2.3	25	35.0
Hauula	215.0	48.9 ± 2.3	25	35.6
Kahuku	0	96.7 ± 6.3	25	35.6
Kawela	79.1	55.2 ± 4.5	23	23.9
Pupukea	0	Destroyed	25	34.2
Kaiwailoa	60.4	57.6 ± 4.7	25	33.1
Haleiwa	36.7	51.0 ± 1.8	26	35.0
Mokuleia	42.1	43.7 ± 1.6	25	34.3
Mokuleia Park	29.9	52.8 ± 2.7	25	35.0
Barking Sands	0	Destroyed	25	35.5
Makaha	0	88.1 ± 8.0	25	35.5
Pokai Bay	36.8	46.5 ± 1.8	26	35.0
Uluhi	0	91.4 ± 9.0	26	35.5
Kahe Point	0	61.3 ± 7.3	32*	35.5
Nimitz	70.3	Lost	28	35.0
Pearl Harbor	55.3	Lost	28	35.0
Sand Island	42.8	49.0 ± 2.5	28	35.0
Ala Moana	150.6	Lost	28	35.0
Waikiki	38.5	66.4 ± 2.6	28	35.0
Diamond Head	24.7	80.6 ± 1.9	28	35.5
Waialae	50.1	52.7 ± 2.1	28	35.0
Wailupe	221.1	40.6 ± 4.5	28	35.2
Maunalua Bay	43.2	43.8 ± 1.6	28	36.0
Koko Head	0	84.4 ± 4.5	25	35.0

*This reef was artificially heated by water from an electricity generating plant.

Acanthophora is also well established on the outer islands, except on the island of Hawaii. It is distributed along the shores of Kauai, Molokai, Lanai, and Maui in patterns similar to those on Oahu (Fig. 4). The largest quantities (234.0–294.3 g/m²) were present on wide reef-flats, near shore, never in the breaker zone, but rather in areas protected from strong wave action (Table 3). Lesser amounts were found on bench reefs and little or no thalli were on shores exposed to the trade winds and high energy water motion. The only island *Acanthophora* was not found on was Hawaii (B. Magruder, Bishop Museum, has just recently found trace amounts at Kawaihae) (Fig. 4), which characteristically has unprotected shores of igneous rock exposed directly to wave action and no coral reef-flats. This heterogeneous distribution, however, could also be due to other factors, such as substratum type or availability, temperature, or salinity.

Table 3. Amounts of *Acanthophora spicifera* and the physical features of locations surveyed in the Hawaiian Islands.

Location	Dry wt. g/m²	Temp. °C	Salinity
Kauai Island			
Haena	Trace	25.5	34.0
Hanalei	46.4	21.0	28.0
Anini	90.4	22.0	35.0
Moloaa Bay	Trace	22.0	34.0
Waipouli	0	22.0	34.0
Hauula	Trace	21.5	34.0
Ahukini	115.6	22.0	34.0
Kalapaki	Trace	22.0	34.0
Nawiliwili	0	22.0	34.0
Poipu	137.2	25.5	35.0
Port Allen	85.6	23.0	35.0
Kikiloa	65.6	23.0	34.0
Kekaha	0	23.0	34.0
Molokai Island			
Halawa	0	22.0	35.0
Pohakuloa	269.2	22.0	35.0
Kamalo	150.8	23.0	34.0
Kaunakakai	234.0	24.0	34.0
Kepuhi	0	22.0	35.0
Lanai Island			
Federation Camp	40.9	28.0	35.0
Manele Bay	20.1	27.0	34.0
Kamalapau	0	22.0	35.5
Maui Island			
Kahului	35.2	26.0	32.0
Hookipa	294.3	25.0	35.0
Waianapanapa	0	25.0	32.0
Hana	5.7	25.0	32.0
Maalaea	Trace	26.0	35.0
Polo Beach	Trace	26.0	35.0
Launiupoko	234.0	28.0	35.0
Lahaina	Trace	28.0	35.0
Hawaii Island			
Laupahoehoe	0	25.0	35.0
Hilo Harbor	0	23.0	30.0
Leleiwi	0	23.0	33.0
Honaunau	0	26.0	35.5
Kailua-Kona	0	26.0	35.0
Kawaihae	0	25.0	35.0
Kalapana	0	24.0	34.0

Distribution in relation to substrata and wave action

The habitats in which *A. spicifera* was found ranged from moderately exposed shores (Hauula and Haena, Kauai; Polo Beach, Maui) to protected bays (Kokokahi in Kaneohe Bay, Oahu). The five basic types of habitats which *Acanthophora* thalli occupy have been based on exposure to wave action and DIF values (Fig. 5). These are, (1) moderately exposed basaltic shores or seaward sides of jetties (Fig. 5a), (2) narrow bench reefs of eroded amalgamated coral limestone (Fig. 5b), (3) extensive coral reef-flats (Fig. 5c), (4) protected natural bays with a sand or silt covered bottom (Fig. 5d), and

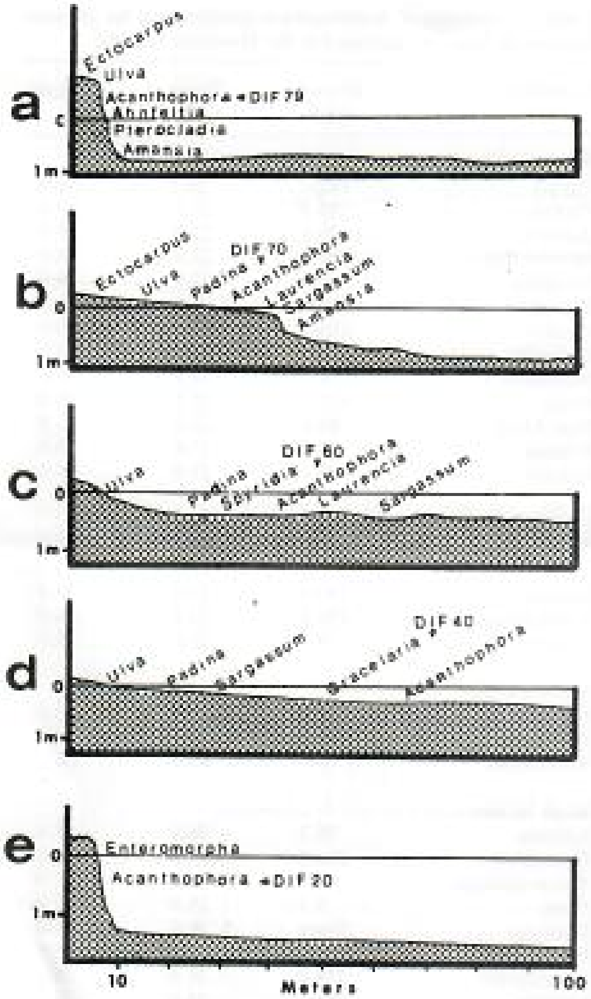

Figure 5. A summary of the habitats where *Acanthophora* is found and its position relative to other algae and water motion (DIF); (a) exposed open shores or jetties, (b) narrow bench reefs, (c) extensive coral reef-flats, (d) protected natural bays, (e) harbors.

(5) harbors (Fig. 5e). *Acanthophora* was usually the most abundant alga in estuaries or bays on all the islands except Hawaii. Generally, *Acanthophora* thalli were short (4–10 cm), compact, and very dense on the substratum in high water motion areas (Fig. 5a, b), in contrast to thalli, which were tall (10–15 cm), more openly branched, and occurred in scattered clumps in moderate or low water motion areas (Fig. 5c, d, e). Its plastic morphology has allowed it to adapt to different conditions and invade a diversity of habitats.

Distribution in Hawaiian harbors

Acanthophora was present in 17 of 21 harbors surveyed (Tables 2 and 3), which means it is able to grow in areas where boats are available as substrata and disseminating agents. It was not present, however, at Nawiliwili Harbor, Kauai; Kaumalapau, Lanai; Kawaihae Boat Harbor; or Hilo Harbor, Hawaii. In addition, its thalli were found growing on a variety of substrata: basaltic jetty rock (Kahului, Maui), concrete abutments (Ahukini Landing, Kauai), on a concrete boat ramp (Hana, Maui), a seawall (Manele Bay, Lanai), on a wooden floating pier, hemp ropes, painted steel buoys, and the hulls of boats (Port Allen, Kauai; Kaunakakai, Molokai; Manele Bay, Lanai), and on mooring lines in Lahaina Harbor, Lahaina Harbor, Maui.

Acanthophora was attached to the hull of a tug boat (*Lihue III*) at the waterline in Port Allen, which made regular runs to Oahu and would drydock in Honolulu Harbor every two years. In addition, 28.4 g wet weight of *Acanthophora* was removed from a 15-m long sailing yacht, *Oriana*, from Honolulu, while it was moored at Kaunakakai, Molokai. Another sailing boat from Oahu, in Manele Bay, Lanai, also had *Acanthophora* growing on its hull. *Acanthophora* has the ability to colonize boat hulls and was probably carried to all the ports in Hawaii shortly after its introduction. Its present pattern of distribution on the island shores reflect its ability to survive the physical or biological conditions it encountered after being introduced and disseminated.

Distribution in relation to water motion, temperature, salinity, depth, and season

There was a highly significant difference between the average values of water motion in areas with and without *A. spicifera* on Oahu (Table 2). The average water motion was higher (DIF 78.9 ± 2.7) in locations without *A. spicifera* than in areas with it (DIF 52.8 ± 0.4). Water motion was also a prominent feature distinguishing the three transects from each other (Fig. 6). The average water motion values along the KMCAS transect were significantly higher at the 5% level and more variable than at either the Kaaawa or HIMB transects (Fig. 6). There was also an abrupt and significant increase in DIF values at KMCAS at 30 m from shore, which coincided with an abrupt decrease in the biomass of *Acanthophora* (Fig. 7). At 25 m the DIF value was 66.6 ± 4.1 and at 30 m it was 84.8 ± 5.3, and at 25 m the biomass of *Acanthophora* was high (82.7 g/m^2), while at 30 m it was only 46.4 g/m^2. The fore-reef, with stronger water motion, did not support the growth of *Acanthophora*, even though the depth, temperature, salinity, and substratum were

Table 4. Average depth, water motion, temperature, and salinity at the three transects.

Parameter	KMCAS	Kaaawa	HIMB
Transect length (m)	40	80	110
Depth (cm)	3.6 ± 1.9	23.4 ± 7.7	43.1 ± 11.5
Water motion (DIF)	63.3 ± 20.3	45.1 ± 3.2	21.6 ± 4.6
Temperature (°C)	27.6 ± 1.7	25.1 ± 0.3	24.9 ± 0.2
Salinity	34.4 ± 0.6	33.0 ± 1.6	33.3 ± 0.9

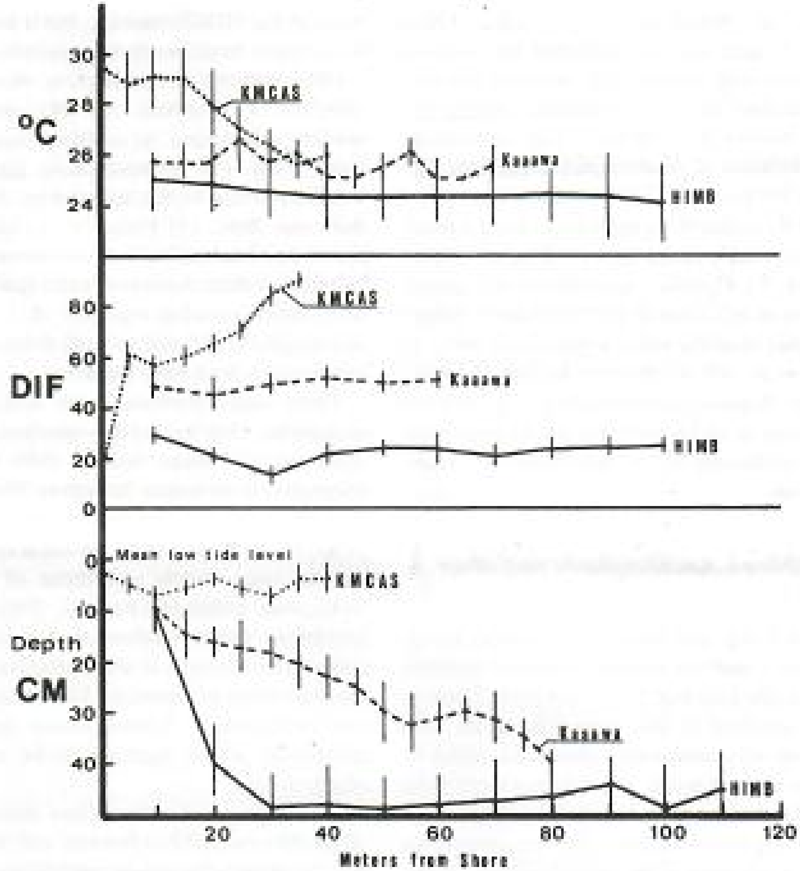

Figure 6. Average temperatures, water motion (DIF) and depths at mean low tide along the transects at KMCAS, Kaaawa, and HIMB.

nearly the same. Water motion, with an upper value of ca. DIF 80, appears to prevent the growth of *Acanthophora* in certain high wave action areas on the reef and exposed shores of Hawaii.

The lowest recorded water motion value where *Acanthophora* was growing (DIF 13.0 ± 3.0) was 30 m from shore at the HIMB transect (Fig. 6). The average at this transect was DIF 21.6 ± 2.9, the lowest of the three transects. Difficulties in culturing *Acanthophora* were also related to water motion. Thalli would not grow without added fertilizer in the competition experiment at DIF 7.8 ± 1.0. Together, these data indicate *Acanthophora* requires water motion of at least DIF 10 before growth will occur. This means *Acanthophora* is limited to habitats in Hawaii within the limits of a DIF 10–80 range.

The monthly *Acanthophora* standing crop fluctuated in relation to temperature changes, although to a lesser extent than for water motion. The months with a maximum standing crop of *A. spicifera* correspond with the warmer months (Fig. 8). The greatest growth occurred when the temperatures were 26.7 ± 1.2°C at Kaaawa and 24.9 ± 1.2°C at HIMB. An indication of the upper limits of its growth was seen at the KMCAS transect, where the average water temperature was significantly higher. Here the standing crop of *A. spicifera* increased when the water temperature decreased from 28.0°C to 26.7°C (Fig. 8). *Acanthophora* was also absent from the artificially heated reef (32°C) at Kahe Point (Table 2). *Acanthophora* grows best in a temperature range of ca. 25–27°C. This is higher than the 23.5°C suggested by Trono (1968) and also higher than the optimum temperature for growth of *Acanthophora* and *Gracilaria* in Florida (Dawes *et al.*, 1978). However, it is closer to the range in which *Acanthophora* grows in Indonesia, 26.5–33.0°C (Atamadja, 1977). Attempts to verify these field results in the laboratory failed because the high water motion values, also required for good growth by *Acanthophora*, could not be duplicated in the growth chambers available.

Although the average salinity between shores without *Acanthophora* was significantly higher (35.1 ± 0.3‰) than the salinity of shores with it (33.8 ± 0.9‰) (Table 3), there was no correlation between the standing crop of *A. spicifera* and salinity at the three transects during the seasonality study. It was found in locations with low salinity (19.5‰) at Waiahole and Kawela, Oahu (23.9‰) (Table 2) and was not affected by seasonal rains, which temporarily significantly lowered the salinity to 23.4 at Kaaawa and 28.8 at HIMB, during one unusually rainy season in February. The correlation between the occurrence of *Acanthophora* and low salinity suggested by Soegiarto (1972) was not substantiated by this study and *Acanthophora* appears to have a much broader salinity tolerance range (ca. 19–36‰) than previously suspected. In Florida, *Acanthophora*'s photosynthetic peak was at 20‰ and its photosynthetic output was ten times higher than the other algae over a range of 20–30‰ (Dawes *et al.*, 1978). Salinity did not correlate with differences in *Acanthophora* standing crop between locations or the seasons and is probably not an important limiting factor contributing to the distribution of *Acanthophora* in Hawaii.

The relation between *Acanthophora* and other algae on the reef

Laurencia nidifica J. Ag. and *Hypnea cervicornis* J. Ag. were the two most common species observed growing next to and physically attached to *A. spicifera*. *Laurencia nidifica* was attached to the same substatum with *Acanthophora* and was commonly physically fused to *Acanthophora* by natural grafts to such an extent both thalli had to be broken or torn to separate them completely during sorting and weighing. *Hypnea cervicornis* was also closely associated with *Acanthophora*, especially at the HIMB transect, but it was usually entangled in its upper branches as an epiphyte.

Five patterns of distribution were seen between *A. spicifera*, *L. nidifica*, and *H. cervicornis*. (1) Each species was found as solitary thalli attached to the substratum. (2) *Acanthophora* and *L. nidifica* were found attached to the substratum and to each other at the same time. (3) Either *L. nidifica* or (4) *Acanthophora* were found with *H. cervicornis* entangled as an epiphyte in their branches, and (5) often all three species were found growing together, *A. spicifera* and *L. nidifica* tangled and fused to each other with *H. cervicornis* epiphytic in both their branches.

These same patterns were reflected in herbarium specimens. One herbarium specimen of *Laurencia* spp. collected in Hawaii before 1950 had *H. cervicornis* entangled in its upper branches. Five out of 50 herbarium specimens of *A. spicifera* from Hawaii and other places in the Pacific had *Laurencia* spp. mixed with them on the same sheets and three of them also had *H. cervicornis* attached (Russell, 1981). This implies the specimens were together on the reef when they were collected, especially if one considers how difficult it is to separate them completely. The *Laurencia nidifica*, *Hypnea cervicornis*, *Acanthophora spicifera* association mentioned above appears to be supported by these observations.

Other species that were less directly associated with *A. spicifera* were *Ulva fasciata* and *Ahnfeltia concinna* J. Ag., in areas with nearly vertical basaltic substrata and

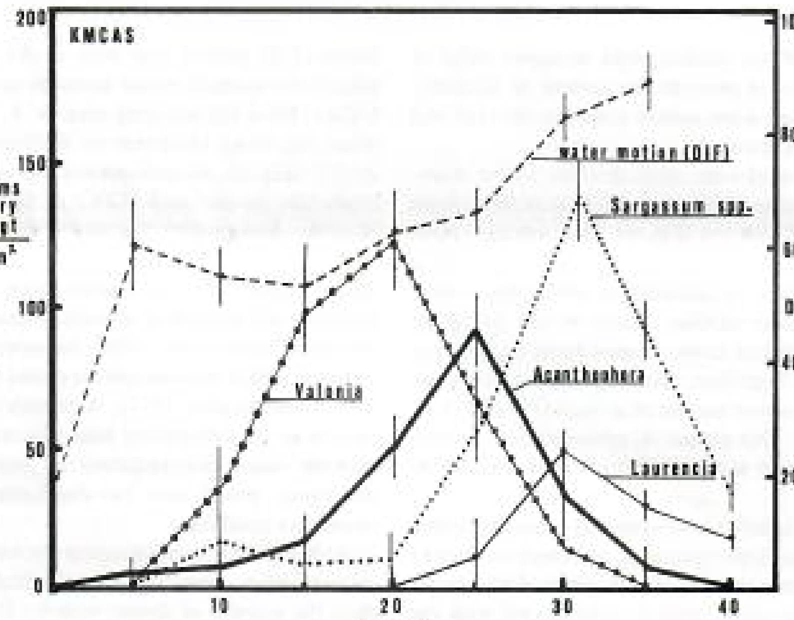

Figure 7. Distribution of *Valonia aegagropila*, *Acanthophora spicifera*, *Laurencia* spp., and *Sargassum* spp. across the reef at the KMCAS transect (n = 16) compared to water motion (DIF).

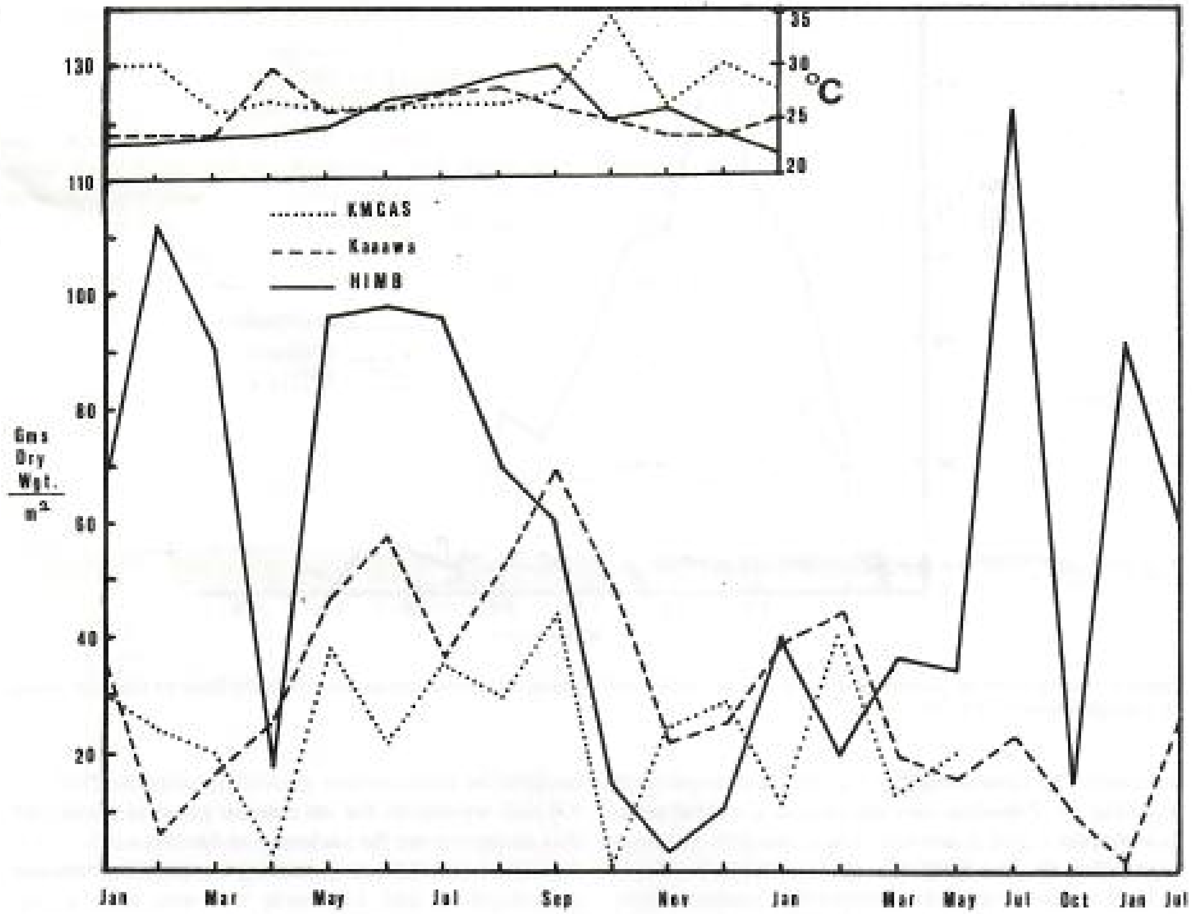

Figure 8. Seasonal comparison of *Acanthophora* standing crops at the KMCAS, Kaaawa, and HIMB transects in relation to temperature.

high water motion (Fig. 5a). *Padina japonica* Yamada and *L. nidifica* on solid eroded coral substrata (Fig. 5b, c), and *Gracilaria coronopifolia* and *Enteromorpha* spp. in sandy or silted locations (Fig. 5d, e). These were common members of the community, but were not in direct competition with the greater mass of *Acanthophora* on the reefs.

The distribution of different species across the nearly flat shallow reef at the KMCAS transect occurred in distinctly visible zones. Of the 26 species of algae present, only *Sargassum polyphyllum* J. Ag. and *Valonia aegagropila* C. Ag. were present during each month of the study, were in the same number of samples, but were distributed on different portions of the reef. The average maximum biomass for *V. aegagropila* was located 20 m from shore, for *A. spicifera* it was 25 m from shore, and for *Sargassum* spp. (*S. polyphyllum*, *S. obtusifolium* J. Ag. and *S. echinocarpum* J. Ag.) it was 30 m from shore (Fig. 7). *Laurencia nidifica* and *L. obtusa* var. *rigidula* Grun. were also present, directly seaward from *A. spicifera* (Fig. 7), where they formed a turf or densely arranged dwarf plants characteristic of fore-reefs subjected to strong wave action (Kilar and McLachlan, 1986). The distribution of *Laurencia* between *Acanthophora* and *Sargassum* puts it in direct competition for space, especially with *Acanthophora*, with which it also forms a turf. This turf is nearly all *Acanthophora* thalli at 25 m, but blends with *Laurencia* at 30 m. Before *Acanthopora* entered Hawaii, *Laurencia* probably formed a turf between *Valonia* and *Sargassum*, but after the introduction of *Acanthophora*, *Laurencia* was forced seaward by competition as *Acanthophora* colonized the surfaces most suitable for its growth.

These zones have also been reported from Panama by Kilar and McLachlan (1986), where the fore-reef is referred to as the *Laurencia* Zone and the back-reef as the *Acanthophora* Zone. The authors also attribute this zonation to differences in water motion and *Acanthophora*'s mode of reproduction by vegetative fragmentation, which allows it to rapidly colonize available space. The reef studied by Santelices (1977) at Hauula, Oahu, only had a back-reef *Valonia* Zone and the *Acanthophora* Zone, but no *Laurencia* Zone, because that reef did not have a DIF over 60 during the course of

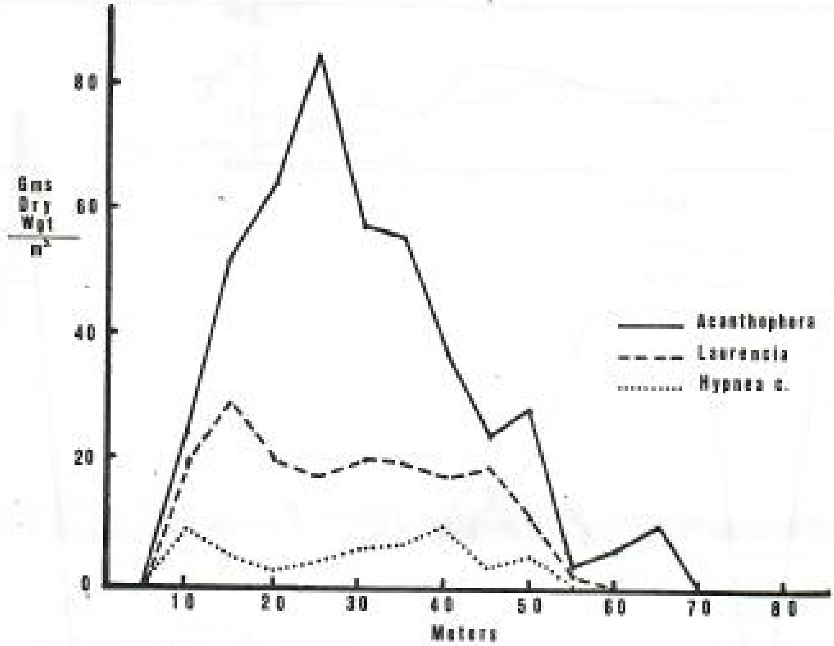

Figure 9. Distribution of *Acanthophora*, *Laurencia nidifica* and *Hypnea cervicornis* across the reef at the Kaaawa transect: based on average amounts (n = 20).

the study. The optimum DIF value for *Acanthophora* is 66.6 (Fig. 7). Zonation only appears on a reef between *Acanthophora* and *Laurencia* when the DIF gradient approaches 80. The KMCAS reef (a solution bench) is an ideal location for further competition studies in light of what Olson and Lubchenco (1990) have suggested, because the water motion gradient is extensive (DIF 20-90) and represents the only major physical parameter that changes from the back-reef to the fore-reef.

Additional evidence indicating competition between *Acanthophora* and *Laurencia* was also seen at the Kaaawa transect. *Laurencia nidifica* was one of three

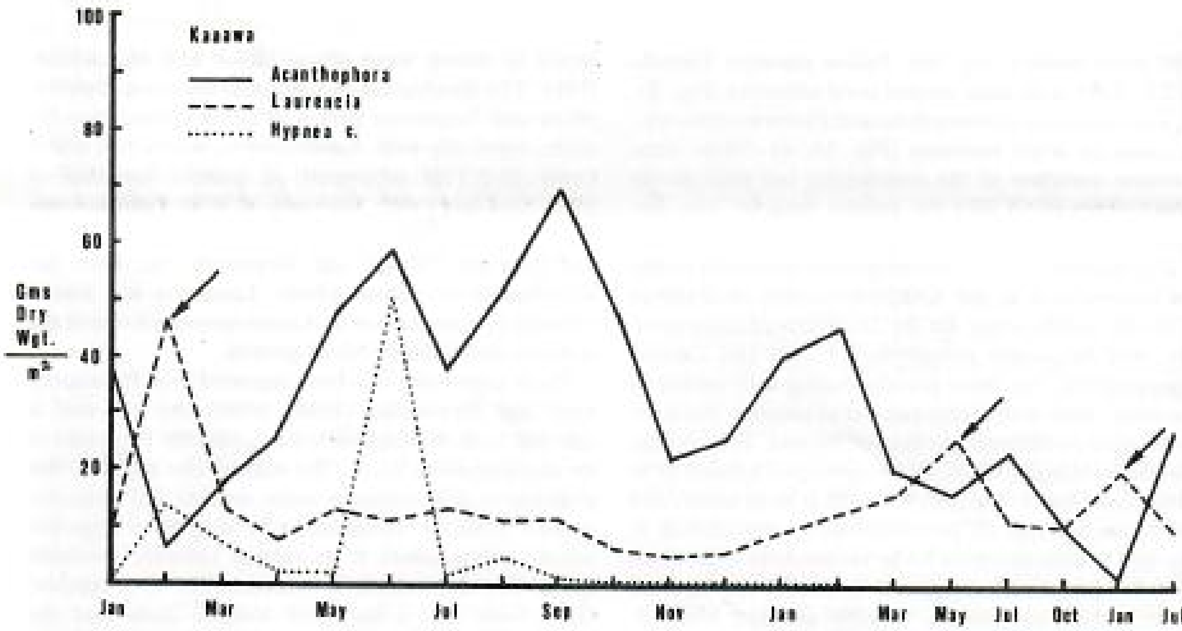

Figure 10. Seasonal comparison of *Acanthophora*, *Laurencia nidifica*, and *Hypnea cervicornis* standing crops at the Kaaawa transect; based on average amounts (n = 20).

Table 5. The number of samples in which various species were present at the three transects. Most frequent species listed first.

Species	KMCAS	Kaaawa	HIMB
Acanthophora spicifera	68	107	160
Laurencia nidifica	30	107	3
Hypnea cervicornis	4	53	41
Ulva spp.	0	21	74
Lyngbya majuscula	5	85	5
Padina japonica	46	28	0
Gracilaria bursapastoris	0	6	59
Sargassum echinocarpum	30	18	14
Valonia aegagropila	60	1	0
Hypnea pannosa	0	0	58
Gelidiella acerosa	50	0	0
Sargassum polyphyllum	39	0	0
Ceramium fastigiatum	0	8	30
Cladophora socialis	35	0	0
Spyridia filamentosa	24	7	0
Bornetella sphaerica	23	6	0
Dictyosphaeria versluysii	18	9	0
Dictyota acuteloba	0	26	0
Sargassum obtusifolium	19	0	0
Halimeda discoidea	4	11	0
Cladophora fasciculata	0	13	0
Microdictyon japonicum	13	0	0
Bryopsis pennata	0	0	11
Pterocladia capillacea	10	0	0
Enteromorpha intestinalis	1	3	4
Grateloupia filicina	0	1	5
Sphacelaria tribuloides	5	0	0
Galaxaura spp.	1	3	0
Centroceros clavulatum	0	0	3
Dictyosphaeria cavernosa	1	2	0
Gracilaria coronopifolia	0	3	0
Hypnea spinella	2	0	1
Neomeris annulus	1	2	0
Rosenvingea orientalis	0	0	3
Dictyota crenulata	0	2	0
Griffithsia sp.	0	0	2
Jania capillacea	2	0	0
Symploca hydnoides	0	2	0
Wrangelia penicillata	0	2	0
Chnoospora miniata	1	0	0
Cladophora luxuriens	0	1	0
Codium edule	0	1	0
Ectocarpus indicus	1	0	0
Lobophora variegata	0	1	0
Tolypiocladia calodictyon	0	0	1
Total samples	493	527	474
Total species	26	29	17
Index of species diversity*	6 ± 1.0	7 ± 1.2	3 ± 0.9

*S = aLog (1 + N/a), a is the Index of Diversity, S is the total number of species, N is the total number of occurrences (Lewis and Taylor, 1967).

species present during all the months studied at Kaaawa. The other two were *Hypnea cervicornis* and *Lyngbya majuscula* Gomont; however, only *Laurencia* occurred in each of the 107 samples containing *Acanthophora* (Table 5) and only *Laurencia* and *Hypnea* had the same distribution as *Acanthophora* across the reef (Fig. 9). None of the other 23 species had this high correlation. *Laurencia* was also the only species that increased in biomass as *Acanthophora* biomass decreased (Fig. 10). Kilar and Lou (1986) found that *Acanthophora* was dominant over *Laurencia* on the reef, but in periods of stress, when *Acanthophora* is damaged, *Laurencia* becomes dominant, because it better withstands exposure to air. These observations support the hypothesis that *Acanthophora* is probably suppressing the growth of *Laurencia*.

Table 6. Standing crop of *Hypnea musciformis*, in relation to other algal species on Checker Reef in Kaneohe Bay, Oahu.

		Wet wt.		Dry wt.	
Species*	Month	(g/m²)**	%	(g/m²)	%
Hypnea musciformis	Apr	1212.3	60.2	136.9	50.1
	May	356.6	21.8	36.6	16.5
	Jun	173.0	13.0	18.9	12.8
Acanthophora spicifera	Apr	19.5	0.9	4.4	1.6
	May	978.0	59.8	115.1	51.9
	Jun	571.3	43.1	69.0	46.8
Laurencia nidifica	Apr	167.7	8.3	39.6	14.5
	May	112.6	6.9	15.9	7.2
	Jun	227.9	17.2	21.6	14.7
Sargassum echinocarpum	Apr	84.4	4.2	24.8	9.0
	May	48.3	3.0	9.8	4.4
	Jun	114.7	8.6	23.6	16.0
Dictyosphaeria cavernosa	Apr	518.7	25.8	63.3	23.2
	May	93.9	5.7	14.2	6.4
	Jun	172.0	13.0	23.4	15.9
Halimeda discoidea	Apr	12.1	0.6	4.1	1.5
	May	46.9	2.9	30.0	13.5
	Jun	67.5	5.1	14.3	9.7

*Species not included if found in only one sample.
**Averages based on four ring samples.

In contrast to KMCAS and Kaaawa, *Laurencia* was rarely found on the HIMB transect, while *Hypnea cervicornis* was more abundant here than at the other two transects. *Hypnea* was the most common species in direct physical contact with *Acanthophora* at HIMB, usually as an epiphyte (Table 5). The other species common on this reef (*Ulva fasciata* and *U. reticulata*) were mainly distributed on portions of the reef away from *Acanthophora*. However, competition between *Acanthophora* and *Hypnea* did not appear to be happening, since the seasonal standing crop peaks of *Hypnea* generally corresponded with the peaks of *Acanthophora* (Fig. 11).

At HIMB, *Acanthophora* utilizes worm tubes, that rise from the sand, as a substratum, a resource not used by other algae (Brostoff, 1985). The *Acanthophora* thalli, in turn, provide a substratum to *Hypnea cervicornis* (which does not attach directly to worm tubes). In addition, as *Acanthophora* grows it provides more sur-

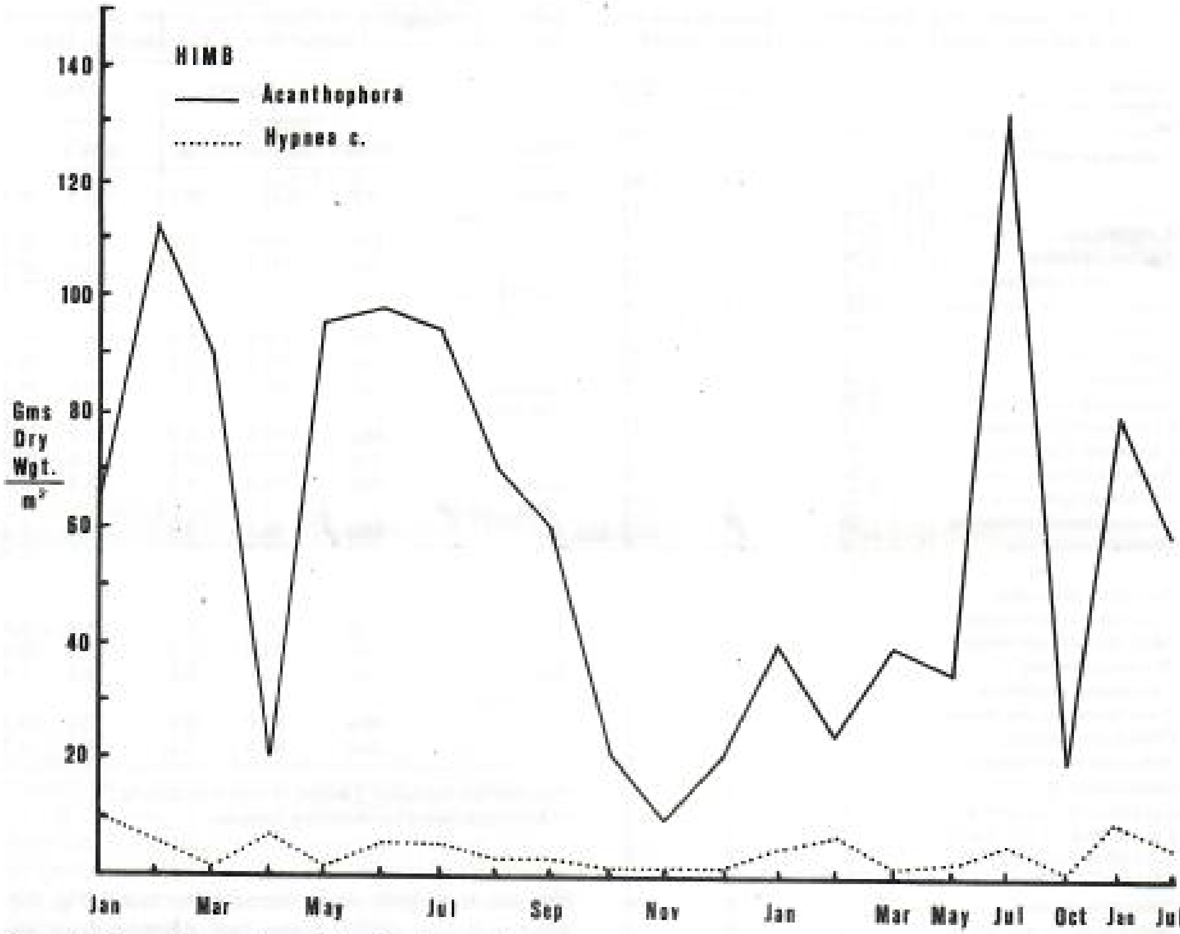

Figure 11. Seasonal comparison of *Acanthophora* and *Hypnea cervicornis* standing crops at the HIMB transect; based on average amounts (n = 20).

face for *Hypnea* and carries it higher into the water column, where its growth is enhanced. Another epizoic utilization by *Acanthophora* and *Laurencia* occurs on decorator crab carapaces (Kilar and Lou, 1986). In addition, the crab prefers to eat *Laurencia* rather than *Acanthophora*, a competitive advantage for the latter.

Competition between *Acanthophora* and *Laurencia*

Similar results were observed in each experiment designed to test competition between *Acanthophora* and *Laurencia*. When *Acanthophora* and *Laurencia* were grown together there was a depression of growth (Fig. 12). Although the results were not statistically significant at the 5% level, each experiment in a controlled environment and in the field gave the same subtle suppression of growth. Since all thallus sizes were the same and shading was not a factor, the competitive mechanism used here is most likely chemical.

Although *Acanthophora* has a much wider range of habitats than *Laurencia*, the evidence supports the hypothesis that *Acanthophora* invaded the niche in the reef community occupied primarily by *Laurencia nidifica*. Competition between these species is probably occurring since: (1) both are in close physical contact with each other (frequent fusions occur), (2) they both occurred in every sample at Kaaawa, (3) they are present together in a variety of herbarium samples, (4) they have the same or overlapping distribution on the reefs at Kaaawa and KMCAS, (5) the growth of *Laurencia* increased only when *Acanthophora* biomass on the reef declined, and (6) there is a suppression of growth when the two species are grown together that is not present when each is grown separately. *Acanthopora* and *Laurencia* appear to be competing for that space on the reef which is in the position of optimum water motion for each.

Introduction of *Hypnea musciformis* to the *Laurencia* niche

After much of the work on *Acanthopora* was finished, *Hypnea musciformis* was introduced to Oahu and began its spread throughout the islands. Although it was intro-

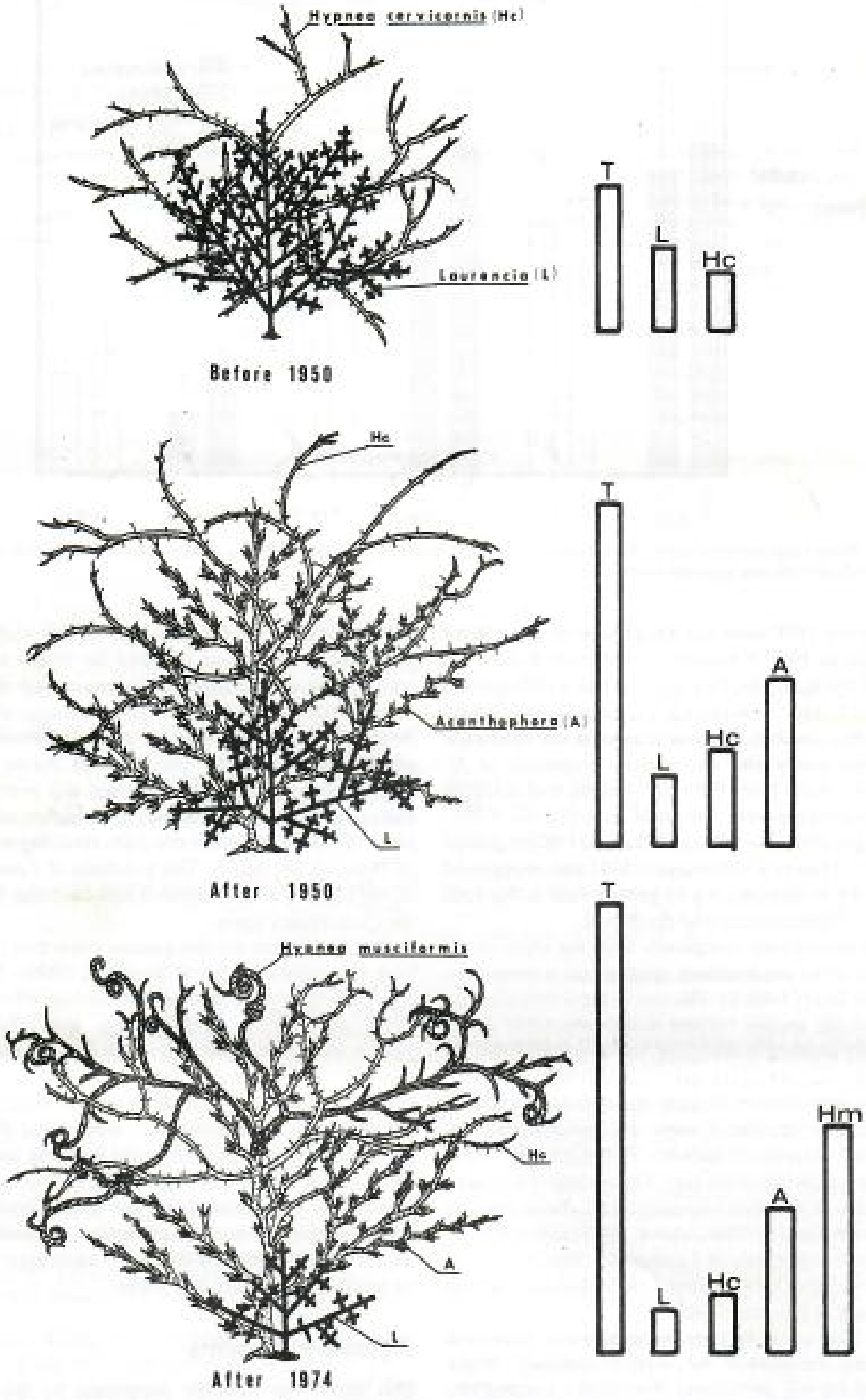

Figure 13. The relative positions and quantities (histograms) of the two native species, *Laurencia nidifica* and *Hypnea cervicornis*, before alien algae were introduced to Hawaii, after *Acanthophora spicifera* was introduced, and after *Hypnea musciformis* was introduced.

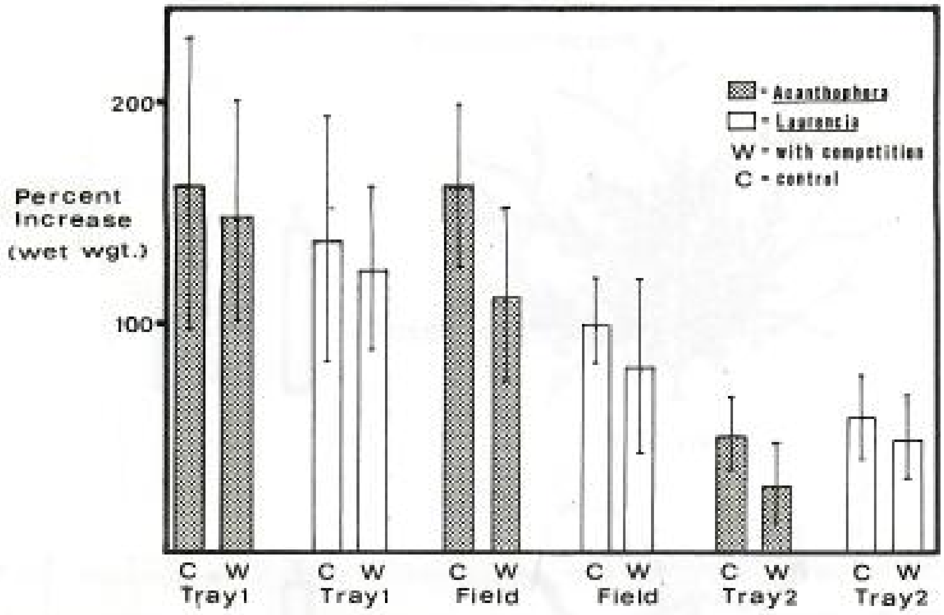

Figure 12. Percentage increase in weight of *Acanthophora spicifera* and *Laurencia nidifica* grown alone and with each other for ten days under three different growing conditions.

duced in early 1974 there was a lag phase of about three years; then in 1977 it became a dominant feature on several of the Kaneohe Bay reefs. It has a high growth rate (10–12% day^{-1} was recorded for it in Kaneohe Bay) although this was difficult to determine in the field since it fragments easily and also gathers fragments of *H. musciformis* thalli from the drift. Humm and Kreuzer (1975) reported a growth rate for *H. musciformis* of 50% day^{-1} (at 28–29°C, 34–35‰) and Dawes (1987) reported 20% day^{-1}. Humm and Kreuzer (1975) also recognized the difficulty in determining its growth rate in the field because of fragmentation and predation.

Hypnea musciformis completely took the place of *H. cervicornis* as the predominant epiphyte on *Acanthopora* on Checker Reef (Table 6). The task of accurately separating and sorting species became nearly impossible as *H. musciformis* attached to dozens of *Acanthophora* branches by tenacious hooks. Additionally, its morphology, except for the hamate branches, is nearly the same as *H. cervicornis*. These two introduced algae (*A. spicifera* and *H. musciformis*) represented between 56.1 and 81.6% of the bulk of algae growing on the reef. The success of *Acanthophora* in Hawaii was soon surpassed by *H. musciformis*, as it spread to Waikiki in 1980 (Abbott, 1987) and was being washed up in windrows at Launuipoko Beach park on Maui in December 1984. In June 1986 it was also collected from the reef at Kauhau, Lanai.

Before 1950 a simple association between *Laurencia* and *Hypnea cervicornis* was well established. When *Acanthophora* was introduced after 1950 it entered this same niche, competed with *Laurencia* (depressing its growth slightly), but enhanced the productivity of *H. cervicornis* and the reef as a whole (Fig. 13). When *H. musciformis* invaded it also entered this niche, by epiphytizing *Acanthopora*, and had the ability to compete well against *H. cervicornis*. *Hypnea musciformis* is also an epiphyte on *A. spicifera* and *L. scoparia* J. Ag. in Brazil (Schenkman, 1990). It again increased the total productivity of certain reefs in Hawaii. As the four algae grow together the system becomes top heavy and the increased drag causes the upper branches of *Acanthophora* to break and enter the drift, resulting in windrows of algae on the beach. The holdfasts of *Laurencia* and *Acanthophora* remain behind and continue to grow as the cycle begins again.

These two alien species possess traits that favor them over the native species (Carpenter, 1990). They have high growth rates, high spore production, effective vegetative propagation, self-thinning, are effective epiphytes, have high surface to volume ratios, morphological plasticity, one has a persistent holdfast, and they resist herbivory. *Acanthophora* and *H. musciformis* are competitively dominant over *L. nidifica* and *H. cervicornis* in Hawaii and provide good working material for competition studies in the field. The complexity of effects that alien seaweeds have on the ecology of an area after they are introduced needs to be understood to help predict the impacts that other alien algae may have on native marine flora and fauna.

Acknowledgments

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Pacific Science Volume I Oct. 1947

Brackish-Water Algae from the Hawaiian Islands[1]

ISABELLA A. ABBOTT[2]

MARINE ALGAE FROM the Hawaiian Islands (in older literature, the Sandwich Islands) have been collected or studied by a few phycologists. Brackish-water species, however, although essentially marine in relationship, have not been systematically studied for this area.

The present study of the brackish-water species was begun late in 1943, in connection with a survey co-operatively conducted by the University of Hawaii and the Territorial Board of Agriculture and Forestry, on fishponds bordering the ocean. At first, two ponds on the island of Oahu were selected for study. In the following year, however, more data and investigation of other ponds seemed desirable. Three additional ponds on Oahu and eight on the island of Molokai were selected and included in the survey. The study of algae, as well as that of animal life, was thus extended to include all these fishponds.

It soon became apparent that the variety of algal forms present in the chosen ponds constituted so large a problem that it would be best to enlist the aid of certain specialists. Myxophyceae were sent to Francis Drouet of the Chicago Natural History Museum and diatoms were sent to Paul S. Conger of the U. S. National Museum, where earlier collections of Hawaiian diatoms are deposited. In the present report are included the bulk of the Chlorophyceae, and all Phaeophyceae and Rhodophyceae.

In the course of this study, a preliminary account of some of these algae by J. T. Conover, made under the direction of G. F. Papenfuss at the University of California, was received. Since the majority of the species in the notes of Conover had already been determined, there was little in his account that requires special mention here.

The present writer reports 9 genera of green algae, 1 of brown, and 11 of red. The algae studied are in the writer's herbarium; duplicate sets will be deposited in the herbarium of the Bishop Museum, and elsewhere if quantity permits.

Species listed seem to include those previously known only from the marine, or only from fresh-water, habitats, with the exception of one species of *Polysiphonia*. This genus, to the writer's knowledge, is known only from strictly saline or brackish-water habitats; it was found in a fresh-water pond, and was accompanied by such a well-known fresh-water genus as *Spirogyra*.

The writer is indebted to Charles Engard, who collected nearly all the specimens of algae. Members of the University fisheries staff, especially Yoshinori Tanada, were extremely helpful with habitat data. Thanks are extended to Kazue Watanabe, who executed most of the drawings.

[1] Research Paper 7, Cooperative Fisheries Staff of the Territorial Board of Agriculture and Forestry and the University of Hawaii. Manuscript received February 28, 1947.

[2] The author completed most of the work on this paper while on the Department of Botany staff, University of Hawaii, and finished the manuscript at the University of California, Berkeley, with the aid of the excellent algal herbarium (cited as U. C. Herb.) and library at the latter institution.

HABITAT

The fishponds already mentioned are discussed by Hiatt (ined.) from the standpoint of construction and as a habitat for fish and invertebrates. These ponds are usually enclosures along the seacoast but may at times be exposed directly to the sea. They are enclosed by a stone or mud wall oceanward. Into some ponds fresh-water streams enter on the land side. The ponds were handed down among the natives for generations, and were used mainly for the purpose of raising fish for the kings and chieftains of the various islands until 50 years ago, when they became somewhat commercialized. Several of the ponds under study, however, are still held within the original families who were given the ponds by chieftains.

The continued utilization of these fishponds no doubt has been encouraged by the desire of various racial groups in the Hawaiian Islands for certain kinds of table fish which live in brackish water, at least during part of their life history. It was found by the zoologists in the 1946 biological survey that the two most desirable fish, mullet (*Mugil cephalos*) and milkfish or awa (*Chanos chanos*), fed largely on microbenthos, and the milkfish fed also on larger algae if they were available (Hiatt, *loc. cit.*). Identification of the dominant algae was made in order to help "farm" the fishponds intelligently, as it was found that the food chain ultimately rested with some of these forms.

These ponds furnish a type of habitat the study of which may give additional ecological information. They are not usually more than 6 feet in depth, and thus would allow the penetration of light sufficient for the growth of algae. However, the water is usually turbid and stirred by the wind. The bottom, consisting of mud, or more rarely mud and sand, is frequently moved by the ebb and flow of the tide through the gates from the adjoining ocean. In most ponds, therefore, the algae must of necessity be attached to the walls or on halophytic phanerogams [*Batis maritima, Halophila ovalis* (R. Br.) Hooker; see Fig. 1].

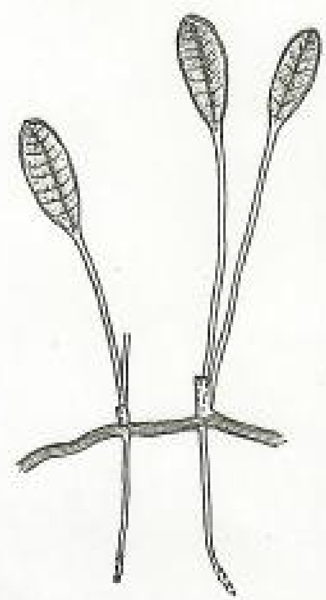

FIG. 1. *Halophila ovalis* (R. Br.) Hooker. Habit of a portion of a plant from Molii Pond. Natural size.

Most of the algae show an affinity for the more marine (sea wall) portions of the ponds. They are found abundantly in such localities, and but sparingly in other regions of the ponds. The fresh-water species are restricted to the mouths of streams where there is little contact with the ocean, or to fresh-water ponds which are apparently fed by artesian wells. Diatoms are abundant epiphytically, and in some ponds form a thick mat on the floor of the pond, mixed with other small algae and the larvae of certain animals.

No seasonal variation in the appearance and disappearance of various forms was noted.

OCCURRENCE OF ALGAE

The ubiquitous *Enteromorpha* appeared in all stations of the ponds, in water ranging in salinity from that of the open ocean to almost fresh. Two distinct species, showing much variability, were recognized. The two species of *Ulva* present, on the other hand, showed distinct preference for the more saline portions. *Cladophora,* that troublesome entity, was present in all situations; such distribution would lead one to believe that variations of marine and fresh-water forms are to be found mixed in the ponds. Other green algae did not occur in great quantity, as did the three just mentioned.

True fresh-water algae (*Spirogyra,* desmids) were recorded from the fresh-water ponds.

The only brown alga found was *Ectocarpus indicus,* which occurred as a common epiphyte on other algae as well as on other plants. The variation shown by this species led to a critical examination of all species which might be growing in this area. The results, which are included with the species description, require placing in synonymy two species, one of which was so placed quite independently of Boergesen (1941).

The red alga collected most frequently (from all but two ponds) was a species of *Polysiphonia,* described here as new to science. Another species of *Polysiphonia* found abundantly in fresh water could not be identified with the foregoing species, nor with any other, as it lacked reproductive organs. This seems to be a new record for the occurrence of this genus in fresh water (chlorinity values were 2.48 to 2.54 parts per thousand). This species was found in a fresh-water pond, strangely called Salt Lake, which is apparently fed by subterranean wells. An old connection with the sea has apparently been sealed off. Other red algae found in some quantity are *Erythrotrichia carnea, Centroceras clavulatum,* and species of *Ceramium.* The red algal species were nearly in contact with the ocean and thus may be thought to be marine, with the exception of the fresh-water *Polysiphonia.*

KEY TO THE ALGAE

A simple key is presented to aid the interested reader with some botanical training to identify as far as genera the algae found in the fishponds. Technical terms have therefore been reduced to a minimum.

PART I. CHLOROPHYCEAE. The grass-green algae.

1. Plants with uninucleate cells..............2
1. Plants multinucleate or with multinucleate cells 4
   2. Parenchymatous 3
   2. Filamentous, unbranched, free-floating, with spiral chloroplasts ....*Spirogyra,* p. 196
3. Tubular plants, one layer thick in section ....*Enteromorpha,* p. 196
3. Foliose plants, membranous, with simple to cleft margins, two layers thick in section..................*Ulva,* p. 197
   4. Filaments unbranched 5
   4. Filaments profusely branched........7
5. Entangled 6
5. Attached, rhizoids only from the basal cell, cells often bulbous........ ....*Chaetomorpha,* p. 197
   6. Floating, or if attached with short rhizoidal branches along the entire attaching length, with few to several nuclei..*Rhizoclonium,* p. 197
   6. Matted, completely multinucleate, non-septate except at the location of reproductive organs................ .... *Vaucheria,* p. 198
7. Plants in bushy soft tufts, the branches lateral, opposite, alternate, or fascicled, cut off from the main axis ....*Cladophora,* p. 198
7. Branches not cut off from the main axis 8

8. Branches radial, the plant erect, without trabeculae..*Bryopsis*, p. 198
8. Branches opposite mainly (in some marine species whorled), the plants with rhizomatous base and erect leaf-like portions, with trabeculae ....*Caulerpa*, p. 199

PART II. PHAEOPHYCEAE. The brown algae. Plants epiphytic, branches secund, with sporangia pedicellate or sessile, lateral or terminal........*Ectocarpus*, p. 199

PART III. RHODOPHYCEAE. The red algae.

1. Plants epiphytic, filamentous, mostly microscopic, with little differentiation of reproductive parts, asexual reproduction mainly by monospores..2
1. Plants erect, filamentous to compressed, wiry to firm and cartilaginous, asexual reproduction by tetraspores 3
2. Thalli erect or creeping, uniseriate; in well-developed specimens 3 to 4 cells thick at base, chromatophore stellate........................ ....*Erythrotrichia*, p. 200
2. Thalli erect, arising from a pseudoparenchymatous base, or from a single cell, branches chiefly lateral, chromatophores parietal...... ....*Acrochaetium*, p. 203
3. Axis flattened 4
3. Axis terete 5
4. Branching pinnate, tetrasporangia cruciate, in sori in swollen lateral branches..............*Gelidium*, p. 203
4. Branching dichotomous or lateral, tetrasporangia cruciate, scattered in the thallus..................... ....*Grateloupia*, p. 205
5. Plants wiry, sparingly branched, in matted tufts......*Wurdemannia*, p. 204
5. Plants flaccid, bushy, with many branches 6
6. Tetrasporangia zonate, branches frequently terminating in a ho ....*Hypnea*, p.
6. Tetrasporangia cruciate, branch free ....
7. Plants large, the thallus cylindri and parenchymatous..*Gracilaria*, p.
7. Plants mainly epiphytic, essentia filamentous ....
8. With cortications, the superfic cells shorter than the central c
8. Without cortications, the supe ficial cells as long as the centr cell ....
9. Plants corticated at the nodes, or b little beyond............*Ceramium*, p.
9. Cortication throughout of small rectangular cells in a longitudin series....................*Centroceras*, p.
10. Colorless hairs lateral, spiralling male and female reproducti structures borne in connectio with the hairs..*Polysiphonia*, p.
10. Hairs in threes, terminal, tetr sporangia borne on the dete minate branches..*Taenioma*, p.

DESCRIPTIONS OF SPECIES

CHLOROPHYCEAE

Spirogyra Link, 1820: 5

Two species are distinguished in th genus on the basis of number of chloropla One species is from Salt Lake, and the oth from a fresh-water pond adjacent to Ua pue. Neither species can be identified b cause of the absence of fertile material.

Enteromorpha Link, 1820: 5

Enteromorpha flexuosa (Wulfen) J. Agard Till Alg. Syst. (3): 126, 1883.

Plants tufted, to 14 cm. in height, usual less, crenelated or simple, with little or ge erally no branching. Cells usually arrang longitudinally in a straight series (Setch and Gardner 1920: 256). Specimens co pare favorably with those in U. C. Herb., and one in herbarium of Bishop Museum. Hawaiian specimens examined: *Tilden 558* (Bishop); *Reed 171, 198, 312, 452, 487, 515* (U.C.).

Found in Kuapa Pond at various stations, Kihalaeo Pond, Kupeke, Keawanui, Niaupala, Ilae, and Molii.

Reported from the Hawaiian group by Lemmermann (1905), Reed (1907), Rock (1913), and MacCaughey (1918).

Enteromorpha intestinalis (Linn.) Link, Epistola, p. 5, 1820.

Plants to 20 cm. in height, much branched, the branches whorled, alternate, or opposite. Cells angular in surface view. Some of the specimens from the ponds are in agreement with Setchell Hawaiian Algae *16*, determined by Collins (U.C.).

In all the major ponds.

Reported from the Hawaiian Islands by Reed, Setchell (1905), Rock, and MacCaughey.

Ulva Linnaeus, 1753:1163

Ulva Lactuca Linn., Sp. Plantarum 2: 1163, 1753.

Plants to 15 cm. in height, expanded, with scalloped margins, attached to rocks, twigs, wood, and other algae. Plants are usually light green in color. Base with many rhizoids.

In all the major ponds.

Reported from the Hawaiian Islands by Lemmermann, Reed, Rock, and MacCaughey. Abundant in marine habitats.

Ulva fasciata Delile, Flore d'Egypte, p. 153, 1813 (see Fig. 2).

Dark green plants to 20 cm. in height, cleft and digitate, attached to rocks, forming large patches. Plants not as membranous as *U. Lactuca*. Rhizoids are few.

Collected in Kihaloko, Keawanui, Ualapue, Niaupala, all on Molokai Island.

Reported by Setchell, Reed, Tilden (1901*a*), Reinbold (1907), Rock, and Neal (1930).

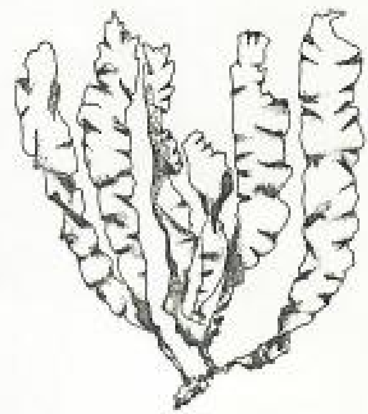

FIG. 2. *Ulva fasciata* Delile. Habit of a plant from Keawanui Pond. ¼ natural size.

Chaetomorpha Kützing, 1845: 203

Chaetomorpha aerea (Dillwyn) Kützing, Sp. Alg., 379, 1849.

Tufts of unbranched filaments to 4 mm. in height. Cells inflated, to 120 μ in width, the walls thickened and stratified.

Molii on *Batis maritima*, Kupeke on a bivalve, Keawanui on pond wall.

Chaetomorpha antennina has been reported by Reed, and I have examined her collections of this species. None are of the *Ch. aerea* type. Others reporting other species of *Chaetomorpha* from Hawaii are Chamberlain (1860), Reinbold, Lemmermann, and MacCaughey. Setchell, MacCaughey, and Rock also report *Ch. antennina*.

Rhizoclonium Kützing, 1843: 261

Rhizoclonium sp.

Only one undeveloped specimen, whose determination to species is not possible.

Ualapue Pond, entangled on *Polysiphonia*. Newly reported here for the islands.

Vaucheria De Candolle, 1801: 17

Plants matted, floating, or on the bottom of shallow parts of the ponds. Filaments entangled, coenocytic, with spherical oogonia or antheridia. These structures are stalked or (in ours) sessile.

Three types of plants are found in the ponds, one with no reproductive organs. Determination is thus incomplete for this specimen. The genus is newly reported from the Hawaiian Islands.

Vaucheria dichotoma (Linn.) C. Agardh, Synop. Alg. Scand., 47, 1817.

Large, free-floating masses, in the summer with oogonia and antheridia. Oogonia sessile, globular; antheridia with a terminal opening, sessile, shaped much like oogonia but slightly more elongate.

Kuapa Pond. In abundance.

Vaucheria Thuretii Woronin, *in* Bot. Zeit., 157, 1869.

Filaments 60–80 μ in diameter, in dense patches. Plants monoecious, with sessile spherical oogonia; antheridia curving to a lateral pore.

Keawanui Pond. Rare.

Vaucheria sp.

A sterile specimen, with measurements smaller than the two species just mentioned, was found in Molii Pond attached to a mollusk.

Cladophora Kützing, 1843: 262

Plants bushy, to 15 cm. in height, with prominent lateral branches cut off from the main axes. Each cell multinucleate with many chloroplasts.

A most variable genus, with representatives by far the most commonly found in brackish water. Identification cannot be made with certainty without a large amount of comparative material. Lacking this, determination must be left at the genus.

In all the ponds, but in abundance especially in the more saline ones.

Compared with the published illustrations of Brand (1905), these specimens show much variation, and relationships cannot be established without examining the specimens used by him.

Bryopsis Lamouroux, 1809*a*: 133

Bryopsis pennata Lamouroux var. *secunda* (Harvey) Collins and Hervey, Amer. Acad. Arts and Sci., Proc. 53: 62, 1917.

Only one plant, 2 cm. in height, was collected, in the more saline portions of Keawanui Pond. The main branches arise from a rhizoidal base, and branch in a pinnate manner, the pinnules opposite each other. A few branches show the secund type of orientation. The plant is dark green.

Distribution: Florida, Bermuda, Bahamas, and islands of the West Indies to Aruba Island, Netherlands West Indies (for the species).

A rather exhaustive comparison has been made of this specimen with other *Bryopsis* specimens from this area, and also from other parts of the world, with emphasis on tropical forms. The comparisons have been made in the University of California Herbarium.

With certain specimens from Hawaii (*Reed 1173, 1150, 1068*) our specimen is in good agreement. Close comparison is also possible with plants from Samoa and Tahiti (*Setchell 1…* Tutuila, and *Setchell and Parks 5185*, Tahiti, both as *B. Harveyana*), from Formosa (legit … Yamada), and to some extent specimens from Dwarka (*Boergesen 5534* as *B. plumosa*), the Gulf of California (Turner's Island, *Dawson 688* as *B. plumosa* var. *pennata*), and from New Guinea (*Kärnbach 29*, det. Grunow, as *B. Harveyana*). Specimens on sheets 341389, 341498, and 341… which have been determined as *B. Harveyana* by Setchell show little agreement with our specimen. These plants are from the Malay Peninsula. Likewise little similarity can be detected between the Hawaiian specimens and those of the Atlantic determined as *B. plumosa* (exemplified by *Setchell 150* from Woods Hole), or of the Caribbean forms of this species.

The North American specimens seem to be Boergesen's variety *typica* of *B. plumosa*. Boergesen's varieties *pennata, Harveyana,* and *Leprieurii* of *B. plumosa* (1911: 147; 1913: 115) show more similarity to variety *typica* than do our specimens to any of these. Boergesen (1946: 341) has raised *B. Harveyana* to specific rank. Setchell's *B. Harveyana* of Samoa (1924) and Tahiti (1926) should not be included in synonymy with *B. plumosa* var. *Harveyana,* as those specimens are quite different from Boergesen's specimens.

It is obvious from the literature that there is great confusion as to species limits in this genus. Lacking critical specimens, I am following the interpretation of Taylor (1928) and of Collins and Hervey (1917). At best, this practice is not too satisfactory, as the Pacific plants by and large are somewhat different from the Atlantic and Caribbean forms. A large suite of specimens and comparison with type material are desirable.

Bryopsis plumosa has been reported from the Hawaiian Islands by Chamberlain, Tilden, and MacCaughey. I have examined the Tilden specimen (453) in American Algae Century V (1901*b*), and find it to be identical with ours. In all probability, the records are in agreement with the material mentioned here.

Caulerpa Lamouroux, 1809*b*: 136

Caulerpa Sertularioides (Gmelin) Howe *in* Torrey Bot. Club Bul. 32: 576, 1905.

Plants to 4 cm. in height, creeping parts clinging tightly to sand and rock particles, the upper portions flattened laterally, with opposite or nearly opposite "leaflets."

At one station, adjacent to the main regions of Kuapa Pond, near the connections to the sea.

The genus is common in marine habitats in the Hawaiian Islands; this species and one related closely to it are among the more prominent members of the genus in Hawaii. Reported from the Hawaiian group by Eubank (1946).

PHAEOPHYCEAE

Ectocarpus Lyngbye, 1819: 130

Plants tufted, filamentous, arising from a single basal cell, or from a group of cells, with or without rhizoids at the base, attached to twigs, wood, or other algae. Plants in this series to 6 cm. in height, but more usually 1–2 cm. Reproduction by plurilocular or unilocular sporangia.

In the sense of Hamel (1939: 66–67) the species which is described below would more properly fit in the segregated genus *Feldmannia,* which differs in a few characters—mainly in that it has discoid chromatophores, whereas the limits of *Ectocarpus* are such as include only those members of this complex which have ribbon-like chromatophores.

One of the characters used to separate *Feldmannia* further is the strong ramifications of filaments near the base, a character not shown by our plants. Sporangia are typically pedicellate in *Feldmannia,* a condition only infrequently occurring in our specimens.

Giffordia, in the sense of Hamel, is characterized by discoid chromatophores also, but sporangia are always sessile, and the plant has intercalary growth. These are not constant characters in our plants.

It would thus seem best to retain the species below in the genus *Ectocarpus, sensu latiore,* until European workers who have authentic material can establish further characters for the separations so badly needed in this complex.

In making a survey of literature pertinent to Hawaiian material, some confusion was encountered with *Ectocarpus Duchassaingianus* Grunow (1870), recorded for the Pacific from Samoa (Setchell, 1924). From the literature, this species seemed identical with *Ectocarpus indicus* Sonder, recorded earlier by Weber-van Bosse (1913: 129) from Malaya. The writer has examined material used by Setchell in his study, and has concluded that his plants are synonymous with *E. indicus* Sonder.

When these studies were completed, reprints of Boergesen's instructive Mauritius papers were received, and it was interesting to find that he had come to the same conclusions regarding *E. Duchassaingianus,* which he based on specimens from the Danish West Indies (Virgin Islands).

Examination of a large number of specimens collected in the fishponds and in marine habitats, as well as those deposited in the herbarium of the Bishop Museum, Honolulu, and the herbarium of the University of California, Berkeley, has led the writer to believe that there is much variation in specimens as well as in interpretation of *Ectocarpus indicus*. These notes, and those that directly follow, are a result of the examination of a large series. Such studies have led the writer to consider *Ectocarpus Mitchellae* in the sense of Saunders (1901, in Tilden 1901*b*) and *E. Sargassi* Saunders as identical with the material in the present investigation. These specimens are from Hawaii and are distributed by Tilden (American Algae Century V, nos. 439, 440a, and 440b). I have examined both Bishop Museum and University of California specimens of the exsiccatae and find them identical with *E. indicus*.

Ectocarpus indicus Sonder, *in* Zollinger, H. Verzeichn. . . . indischen Archipel. . . . 1842–48, p. 3 (not as usually cited: *in* A. Moritzi, Syst. Verzeichn, 1857) (see Fig. 3*a–d*).

Ectocarpus Duchassaingianus Grunow, Alg. Novara, 1870, p. 45.

Ectocarpus Sargassi Saunders, *in* Tilden American Algae Century V, nos. 440a and 440b, 1901*b*.

Plants tufted, branching primarily dichotomous with many lateral branches, the main branches about 10 μ wide. Sporangia attached, sessile or stalked, on the inner surface of the branches, oval to oval-clavate, distributed throughout the plant. Plants rising from a creeping base.

Abundant in Kuapa Pond, usually on *Batis maritima;* Wailupe, Molii Ponds, on Oahu Island. Also found in Keawanui, Kupeke, Ualapue, Niaupala Ponds, Molokai Island.

In the marine habitat, commonly oc ring on species of *Sargassum*.

Specimens examined (in U. C. Herb.) *Ectocarpus indicus, Potts 1173a,* deter by Setchell, from Samoa; *Lindauer 28,* Lindauer, from New Zealand; *Nas* from Egypt (Red Sea); *Li 124* ex Tseng, det. Setchell, from China; *K. Iyengar 83,* det. Gardner, from Bomba *E. Duchassaingianus: Tilden 32,* det. Til from Tahiti; *Boergesen 1093, 1250,* Boergesen, from the Virgin Islands[a]; *Ha 45,* det. Hamel, from the French Anti *Taylor 39308, 39602,* det. Taylor, from Netherlands West Indies.

Tilden 440a, 440b, as *Ectocarpus Sarg* Saunders, det. Saunders, in Tilden Ameri Algae Century V; *439* as *E. Mitchellae,* Saunders. These specimens are from Hawaiian Islands. (Exsiccatae from Bish Museum and University of California He baria examined.)

Distribution: Throughout warmer seas.

Previously reported by Reed, MacCaugh Lemmermann, and Neal.

RHODOPHYCEAE

Erythrotrichia Areschoug, 1847: 209

Erythrotrichia carnea (Dillwyn) J. Agardh, Till Alg. Syst. (6): 15, 1883.

Plants attached singly, or in small loo tufts, to 4 cm. in height, the uniseriate fil ments attached to other algae by a singl disk-shaped basal cell which may becom lobed. The lower, older parts of the plan may be two or three cells in width. Chro matophore stellate, with a prominent pyr noid. Reproductive structures not seen.

Found in all major fishponds, epiphytic on *Enteromorpha* spp., *Grateloupia, Poly siphonia,* and *Gelidium. Erythrotrichia car nea* is here reported from the Hawaiian

[a] These specimens as well as others collected by Boergesen in the Virgin Islands and identified as *E. Duchassaingianus* (1913: 159) were transferred by him to *E. indicus* (1941: 16).

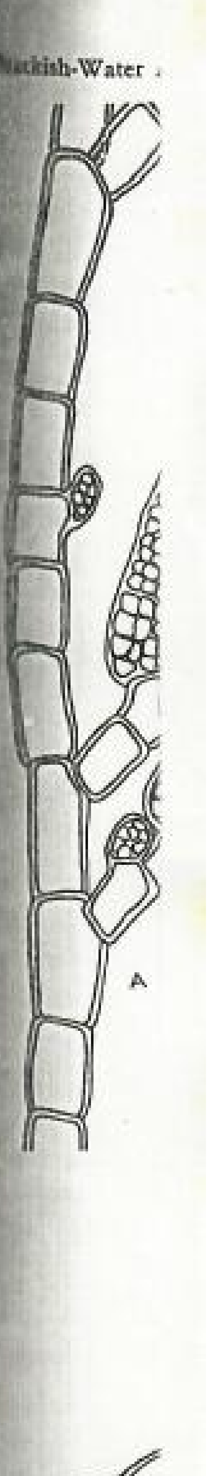

FIG. 3. E sions 30 m Basal porti gium. Scal

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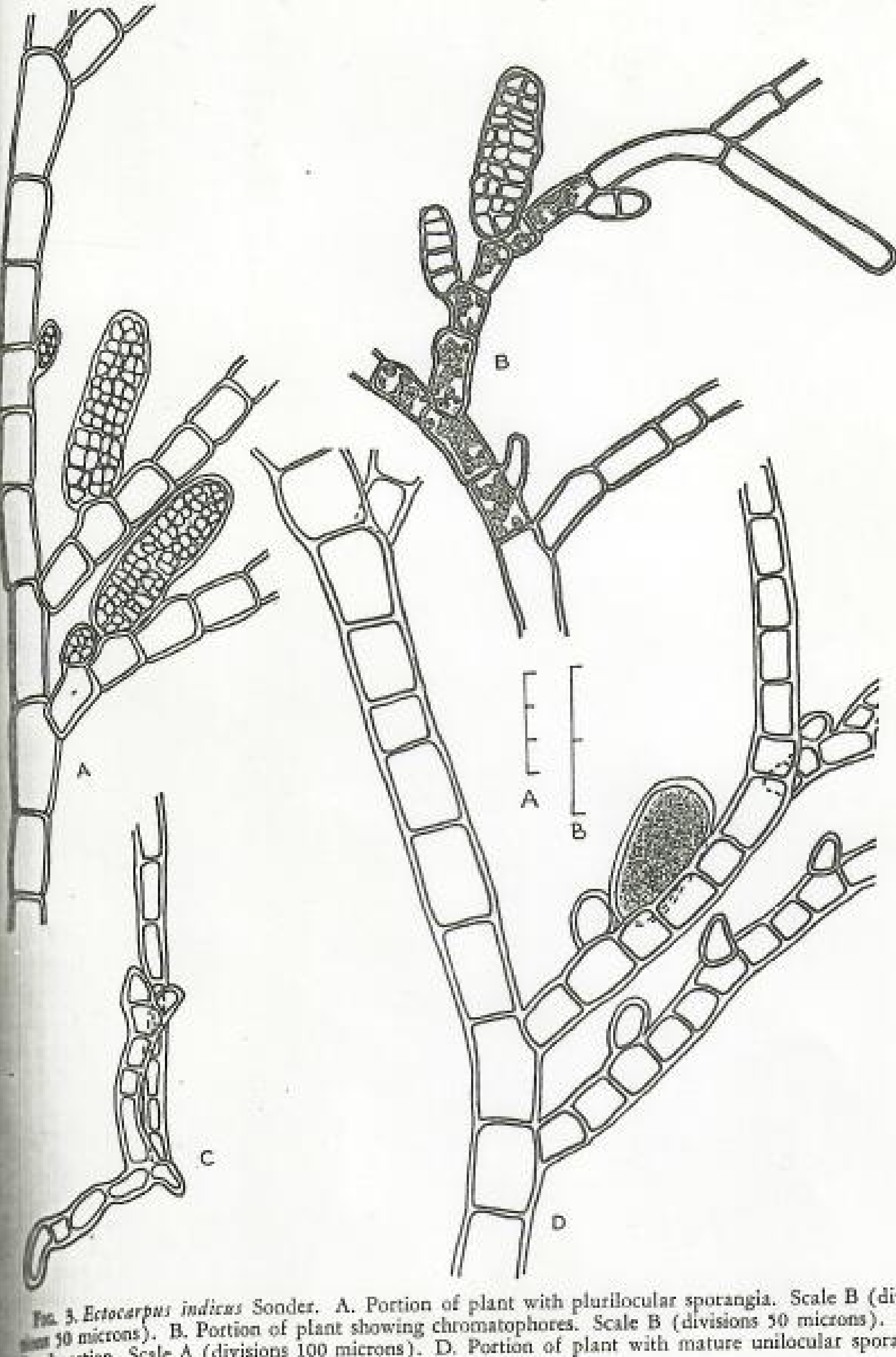

FIG. 3. *Ectocarpus indicus* Sonder. A. Portion of plant with plurilocular sporangia. Scale B (divisions 50 microns). B. Portion of plant showing chromatophores. Scale B (divisions 50 microns). C. Basal portion. Scale A (divisions 100 microns). D. Portion of plant with mature unilocular sporangium. Scale B (divisions 50 microns).

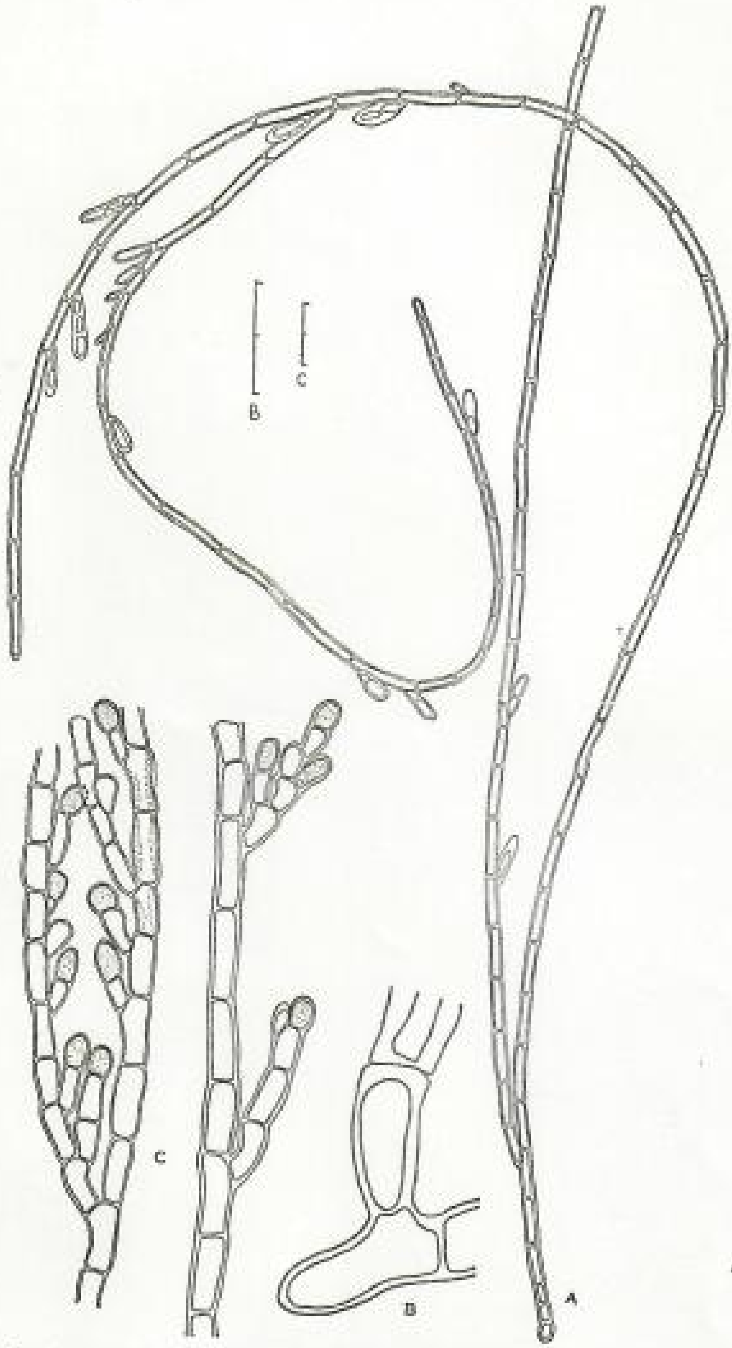

FIG. 4. *Acrochaetium robustum* Boergesen. A. Habit of plant with monosporangia. Note single basal cell. Scale B (divisions 50 microns). B. Portion of plant with part of multicellular base. Scale C (divisions 10 microns). *Acrochaetium seriatum* Boergesen: C. Portions of plants showing monosporangia. Scale C (divisions 10 microns).

Islands for the first time. It occurs commonly on many marine algae in this area.

Distribution: Occurring commonly in the tropics, epiphytic on littoral and sublittoral algae; extending into temperate waters as far north as England (type locality).

Acrochaetium Nägeli, 1861: 402

The treatment of this genus is based on the work of Papenfuss (1945), who has seen our specimens.

Acrochaetium robustum Boergesen, Mar. Alg. D. W. I., 2 (1): 40–43, 1915 (see Fig. 4*a–b*).

Plants tufted, to 1 cm. in height, epiphytic, with a simple or branched basal cell partly to wholly endophytic. Branching predominantly lateral, sometimes alternate, but at the base dichotomous. Cells with a parietal chromatophore and a single pyrenoid, and with pit connections readily seen. Cells to 4 μ in width, and twice as long. Monosporangia prominent, sessile or pedicellate, appearing laterally near the tips of the fronds, singly or in pairs. Terminal sporangia are often seen. Sexual organs not seen.

Found in Kuapa Pond, epiphytic on *Batis maritima*, and a piece of coniferous wood. Not the same species as other marine specimens from this area. The genus is newly reported from the Hawaiian Islands.

Distribution: Danish West Indies, Japan.

Acrochaetium seriatum Boergesen, Mar. Alg. D. W. I., 2 (1): 32–35, 1915 (see Fig. 4*c*).

Plants to 5 mm. in height, tufted, soft, epiphytic on *Ulva fasciata*. Branching chiefly lateral, occasionally alternate. Erect portions arising from a multicellular creeping base. Monosporangia borne singly or in clusters, sessile or pedicellate. In Keawanui Pond, Molokai Island, on *Ulva fasciata*.

Distribution: Danish West Indies, Macassar.

Both these species of *Acrochaetium* were collected in the more saline portions of Kuapa and Keawanui. In all probability they are not true brackish-water species. Species of *Acrochaetium* occur frequently on larger algae in the marine environment in this area.

Gelidium Lamouroux, 1813: 40

Gelidium pusillum (Stackhouse) Le Jolis *in* Soc. Sci. Nat. Cherbourg, Mem. 10: 139, 1863 (see Fig. 5).

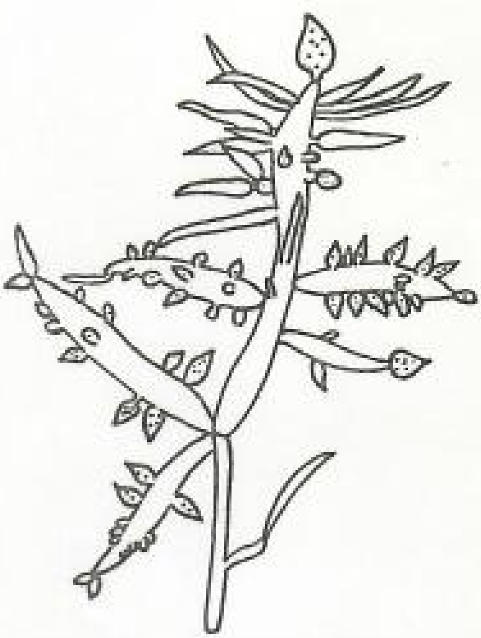

FIG. 5. *Gelidium pusillum* (Stackh.) Le Jolis. Habit of portion of a plant. × 4.

Plants small, associated loosely in clusters, with a creeping base bearing erect parts to 3 cm. in height. Branching irregularly pinnate or alternate, with both branches and axis markedly flattened. Rhizines occupy a large central area of the branches with small cortical cells in three rows on the outside.

Tetrasporangia in small bulbous lateral branchlets, sunken below the surface. Tetraspores in cruciate groups when mature, the young tetrasporangia frequently showing only one division. Sexual plants not seen.

Found in Molii Pond, Oahu; Ilae, Keawanui, Kupeke, and Ualapue Ponds, Molokai, infrequently occurring, and with many epiphytic diatoms and *Erythrotrichia carnea.*

Distribution: In the tropics, northward to England (type locality).

This species is a variable one, and perhaps these plants represent a distinct entity, but for the present it seems best to identify them with the species. All species of *Gelidium* are named "limu loloa" or "limu ekahakaha" by the Hawaiians. The species here noted has been questioned by Reed. MacCaughey lists the species. It does not seem to be either of the *Gelidium* spp. listed by Neal.

Gelidium pusillum var. *conchicola* Piccone and Grunow *in* Piccone, Contribuzione all'algologia Eritrea, Nuovo Giornale Bot. Ital., 16: 316, 1884.

Plants smaller than the species, to 5 mm. forming tufts, but inconspicuous. Blades flattened especially at the tips. Rhizomes with small colorless rhizoids. The plant is sterile.

Fragment of plants from Molii Pond, associated with *Cladophora* sp. and *Polysiphonia.* Newly reported from the Hawaiian Islands.

Distribution: Bermuda, Florida, Colombia.

These plants agree favorably with description and figures of Taylor (1928).

Wurdemannia Harvey, 1853: 245

Genus incertae sedis. Taylor, 1928, 1941, 1943, 1945, lists the genus with the Gelidiales, but in 1940 lists it in the Cryptonemiales (Rhodophyllidaceae). Feldmann and Hamel, 1934, list it in the Gelidiales. Harvey (1853) and Boergesen (1919–20) list it as uncertain.

Wurdemannia miniata (Draparnaud) Feldmann et Hamel *in* Revue Générale de Botanique 46: 545, 1934 (see Fig. 6; Fig. 7*b*).

Wurdemannia setacea Harvey, Nereis Bor. Am. (2): 245, 1853.

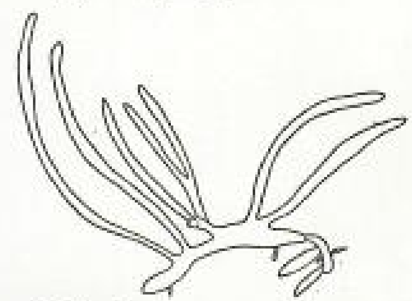

FIG. 6. *Wurdemannia miniata* (Drap.) Feldmann et Hamel. Habit of plant. × 1½.

Plants in thickly matted dark red tufts to 4 cm. in height, attached to the substratum by numerous disk-shaped holdfasts from which run several cylindrical rhizomes. Main axis erect, sparingly branched, terete, and of firm consistency. The young branches show large medullary cells which become smaller toward the outside. Superficial cells are somewhat square and contain many chromatophores. In surface view, these cells are small and irregularly shaped.

Tetrasporangia are found in sori near the tips of the branches with few modified sterile filaments. The sporangia are zonately divided. Sexual plants are not known.

Found in Molii, Oahu Island; Ilae and Keawanui, Molokai Island.

Distribution: Mediterranean (Montpellier, type locality). Harvey's plant was collected at Key West. It is also known in the Atlantic from the Brazilian coast northward to Bermuda.

Reported here for the first time from the Hawaiian Islands, and for the Pacific.

When sexual plants are known, this species will probably be segregated from the Gelidiales because of its zonate tetrasporangia.

Grateloupia

Grateloupia filicin
Syst. Alg., 241,
Grateloupia filicin
Nuova Not., 26

Plants purplish
in height, erect,
groups by a singl
a percurrent main

FIG. 7. A. *Gr*
crons). B. *Wur*
(divisions 10 mi
microns). D. *H*
sporangia. Scale

Grateloupia C. Agardh, 1820: 221

Grateloupia filicina (Wulfen) C. Agardh, Syst. Alg., 241, 1824.

Grateloupia filicina forma *hawaiiana* Mazza, Nuova Not., 26: 75, 1915.

Plants purplish-red, cartilaginous, 14 cm. in height, erect, the fronds attached in groups by a single holdfast; branching with a percurrent main axis, the whole plant assuming a pyramidal shape. Branches to 3 mm. in diameter, linear, acuminate. Medulla composed of spherical cells of moderate size in transverse section, occasionally showing stored dextrin particles, surrounded on the outer surface by two layers of compact small cells. Plants collected are sterile.

Found in Keawanui, near pond gate in quiet water, with much epiphytic *Erythrotrichia carnea.*

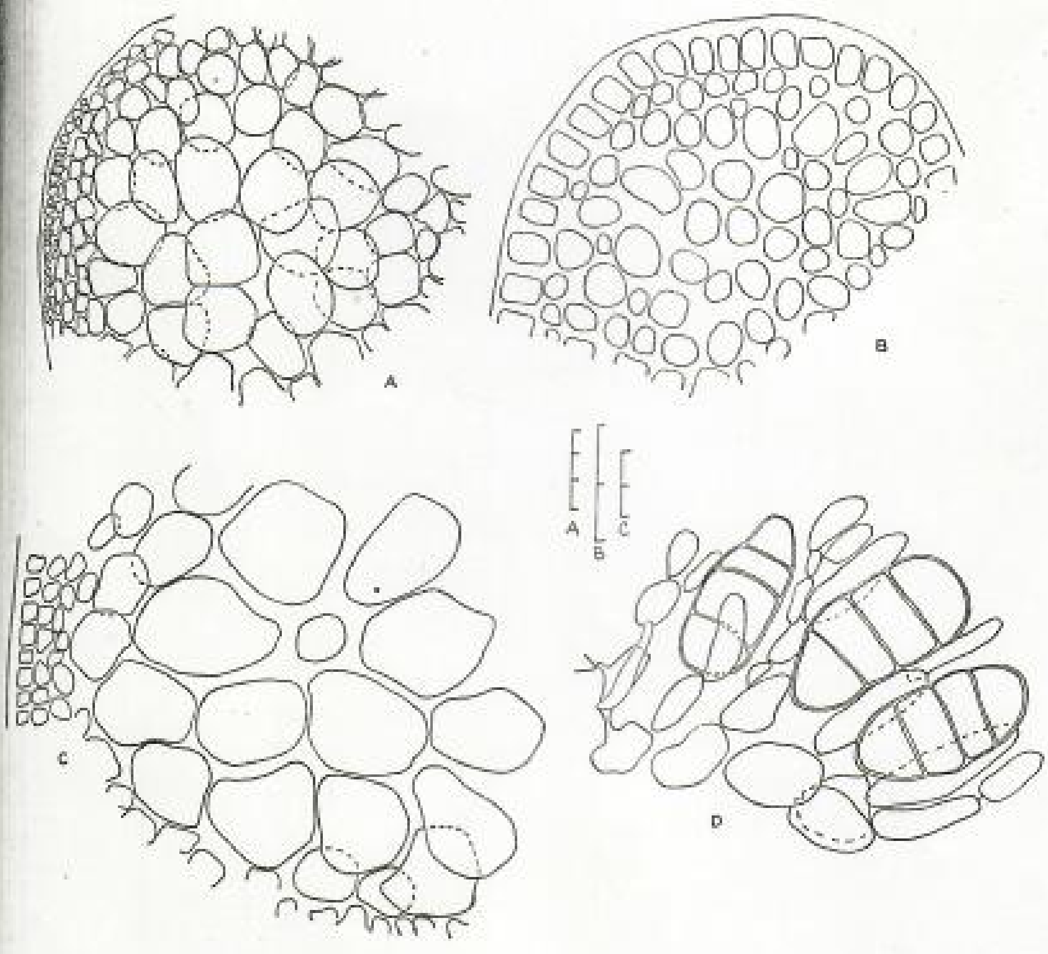

FIG. 7. A. *Gracilaria coronopifolia* J. Agardh. Cross section of thallus. Scale A (divisions 100 microns). B. *Wurdemannia miniata* (Drap.) Feldmann et Hamel. Cross section of thallus. Scale C (divisions 10 microns). C. *Hypnea nidulans* Setchell. Cross section of thallus. Scale B (divisions 50 microns). D. *Hypnea nidulans* Setchell. Cross section of portion of fertile branch showing tetrasporangia. Scale C (divisions 10 microns).

Distribution: Widely occurring in warm waters, into colder regions.

This is an alga of choice eating qualities, much desired by Hawaiians. It grows well in various localities on the islands of Hawaii and Maui especially, and is occasionally seen in certain localities on the island of Oahu, where it is said to have been planted for the late Queen Liliuokalani. The alga is known on Hawaii as "limu huluhuluwaena," and on Maui as "limu pakeleawaa." If it were not so well known, it would be difficult to place the plants collected, because they are sterile.

Grateloupia filicina has been reported from the Hawaiian area by Reed, Rock, MacCaughey, and Setchell. *G. dichotoma,* reported by Chamberlain, has not been substantiated.

Specimens examined (in Herbarium Bishop Museum): *Drew 641,* Waikiki; Rock, Apr., May, 1908, Waikiki; Bailey in 1876, Lanai Island. *Tilden 507,* Kapaa (Kauai Island), does not seem to be this genus.

Gracilaria Greville, 1830: 121

Gracilaria coronopifolia J. Agardh, Sp. Alg. 2 (2): 592–593, 1852 (see Fig. 7*a;* Fig. 9).

Gracilaria No. 1, No. 2, Neal, Hawaiian Marine Algae, 68, Fig. 18*b,* 1930.

Plants erect, to 15 cm. in height, pink at tips, white below, with one or more fronds attached to a single holdfast. Branching frequent, dichotomous, arcuate at tips, with a corymbose aspect. Branches cylindrical in transverse section with a large medullary region of colorless rounded cells slightly thickened, surrounded by a narrow cortical layer and a layer of smaller superficial cells. Female plants with prominent pink to red cystocarps in the upper branches. Cystocarps with thick outer covering and a small ostiole. Male and tetrasporangial plants not seen.

Found in Keawanui and Ilae ponds, Molokai.

Distribution: "ad Wahoo [Oahu] Insularum Sandwicensium." Apparently endemic to the Hawaiian Islands, and found quite commonly in the marine habitat. Reported by Reinbold.

The "limu manauea" of the Hawaiians (the "ogo" of the Japanese) is characteristic of sandy, sheltered areas about the islands. Two other species of *Gracilaria* are listed in the literature from Hawaii: *G. confervoides* by Chamberlain and MacCaughey, and *G. euchemoides* by Chamberlain. Neither of these species has been collected by the writer. *G. coronopifolia* has been mentioned by Chamberlain, Lemmermann, Reed, Rock, MacCaughey, and Setchell, and questioned by Neal. Neal's two species (No. 1 and 2) are this species. Other forms from the islands have been studied but it is difficult to place them with certainty.

Hypnea Lamouroux, 1813: 131

Hypnea nidifica J. Agardh, Sp. Alg. 2 (2): 451, 1852 (see Fig. 8).

FIG. 8. *Hypnea nidifica* J. Agardh. Habit of a portion of a plant. × 2.

Plants erect to 20 cm. in height, or more usually matted and attached epiphytically to other algae, with slender branches alternate or whorled and closely beset with very short branchlets, the ultimate tips simple and straight. Plants red to reddish-green when fresh. In section, the main axis shows a large medullary layer surrounded by cortical cells in radial rows of smaller cells, and a somewhat firm superficial layer of angular cells. Tetrasporangia circling the base of the short branchlets, the cortical cells forming distinct radial filaments in these areas. Sporangia zonately divided. Male and female plants not seen.

Found in Ilae Pond, growing with *Ceramium* spp., and *Polysiphonia*. In the Hawaiian area, common in sandy shallow waters.

Distribution: "ad insulis Sandwich." Reported by Reinbold from the Hawaiian Islands, and from Malaya by Weber-van Bosse (1928: 453).

Hypnea nidifica seems more closely related to *H. cornuta* in habit than to *H. cervicornis*, a comparison made by J. Agardh. The anatomy of the frond is closer to the next species than to the two species just mentioned. Tetrasporangia are like those of most other species.

The species has been listed by Chamberlain, Lemmermann, Reed, Setchell, Rock, MacCaughey, and Neal. *Hypnea armata* has been listed by Reed, Rock, and MacCaughey. *Hypnea cornuta*, *H. pannosa*, and *H. divaricata* mentioned by Chamberlain have not been verified.

Hypnea nidulans Setchell, Veg. Tutuila Island, Carnegie Inst. Wash. 20: 161–162, 1924 (see Fig. 7*c–d*).

Plants smaller than *H. nidifica*, much twisted and branched, growing in small tufts among other algae. It is chiefly differentiated from *H. nidifica* in having tetrasporangia in nemathecia near the tips of the fertile branchlets. In cross section, the cortical cells are smaller, with small uniform superficial cells. Only tetrasporangial plants were collected.

Found in Molii Pond. Newly reported from the Hawaiian Islands.

Distribution: S a m o a (type locality), *Setchell 1084*, type, in U.C. Herb., *Setchell and Parks 5158* in Herb. Bishop Museum. Also reported by Boergesen (1943: 62) from Mauritius and by Weber-van Bosse (1928: 454) from Malaya.

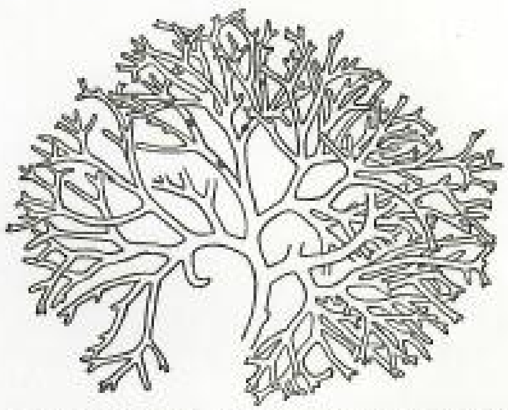

FIG. 9. *Gracilaria coronopifolia* J. Agardh. Habit of a portion of a cystocarpic plant. Natural size.

Centroceras Kützing, 1841: 731

Centroceras clavulatum (C. Agardh) Montagne, Flore d'Algerie, 140, 1840–1850.

Plants filamentous, usually in matted tufts, stiff and brittle, or floating and entangled with other algae; dark purplish-red in color, or pinkish where exposed. Fishpond specimens are 6–8 cm. in height with irregular branching and short internodes at the tops of the branches, the tips sometimes forcipate. Spines at the nodes most prominent in the upper parts of the filaments, 4 to 6; in the older parts usually 2 or deciduous. Spines are of two or more cells. Cortical cells in section, 28 to 40 in the nodal portions. Tetrasporangia sub-external, formed in a horizontal row of 4 to 8 at the nodes, tetrahedrally divided.

Found abundantly in portions of several fishponds open to the sea: Molii on Oahu Island; Ilae, Keawanui, Kupeke on Molokai Island.

Widely distributed throughout tropical waters. It is one of the most frequently encountered of shallow-water algae in the Hawaiian area. *Tilden 401* (American Algae, Century V) in Herbarium University of California as *Ceramium diaphanum* is *Centroceras clavulatum*. This specimen is from the Hawaiian Islands.

The structure of plants of this species is very variable, but the species is readily separated from the next (*Ceramium*) in being more brittle and usually larger, and in possessing continuous corticating cells.

It is listed from the Hawaiian Islands by J. Agardh, Chamberlain, Setchell, Reed and Rock, and, as *Ceramium clavulatum* C. Agardh, by Lemmermann and MacCaughey.

Ceramium (Roth) Lyngbye, 1819: 117

Ceramium is a large and complex genus. The limits of many of the species, especially the tropical ones, are as yet ill defined. Consequently, it seems best not to assign specific names to either of the following species, especially since not all necessary plants were found.

Ceramium sp. (1) (see Fig. 10*a–b*).

Plants 4–8 cm. in height, dark pink to red, lying in soft tangled mats among other algae. Base of plants sometimes with rhizoids, the upper ends usually free. Branching irregularly dichotomous, with prominent forcipate

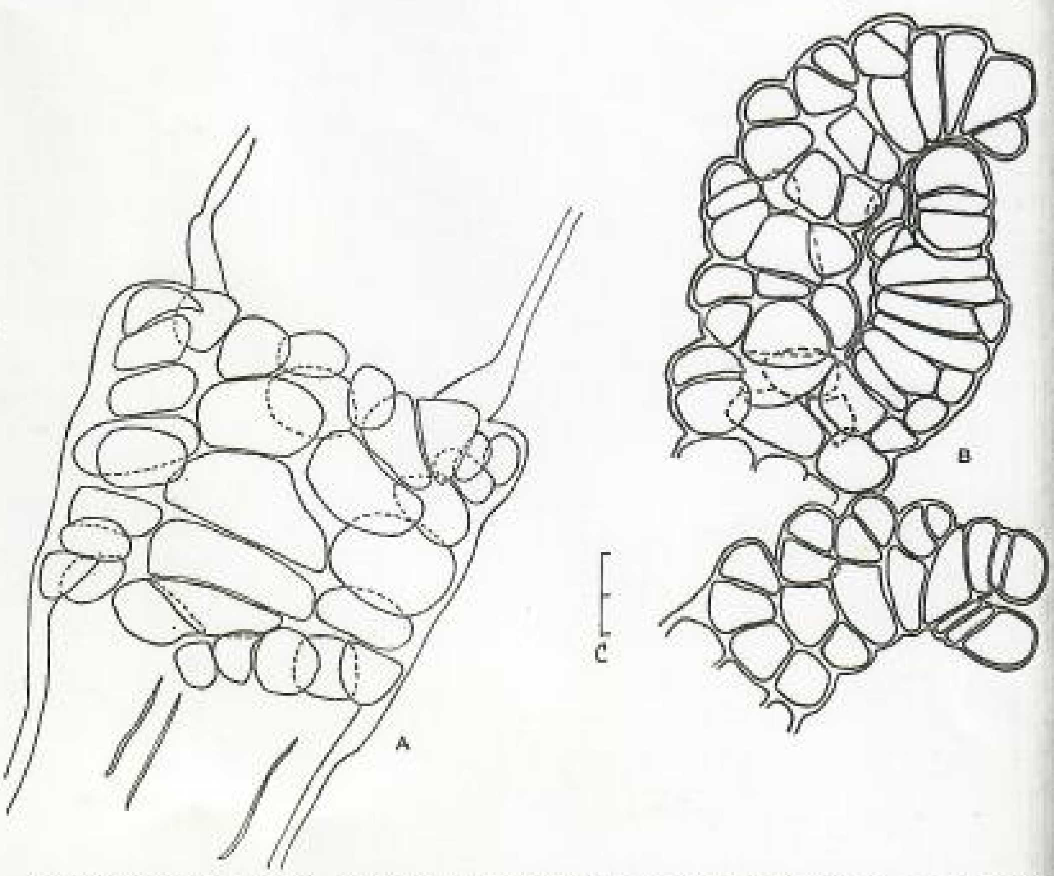

FIG. 10. *Ceramium* sp. (1). A. Nodal region showing cortication. Scale C (divisions 10 microns). B. Tips of two plants, in the above figure showing forcipate nature. Scale C (divisions 10 microns).

FIG. 11. *Ceramiu*
(divisions 10 micro
microns). C. Tips

ı, Setchell, Reed,
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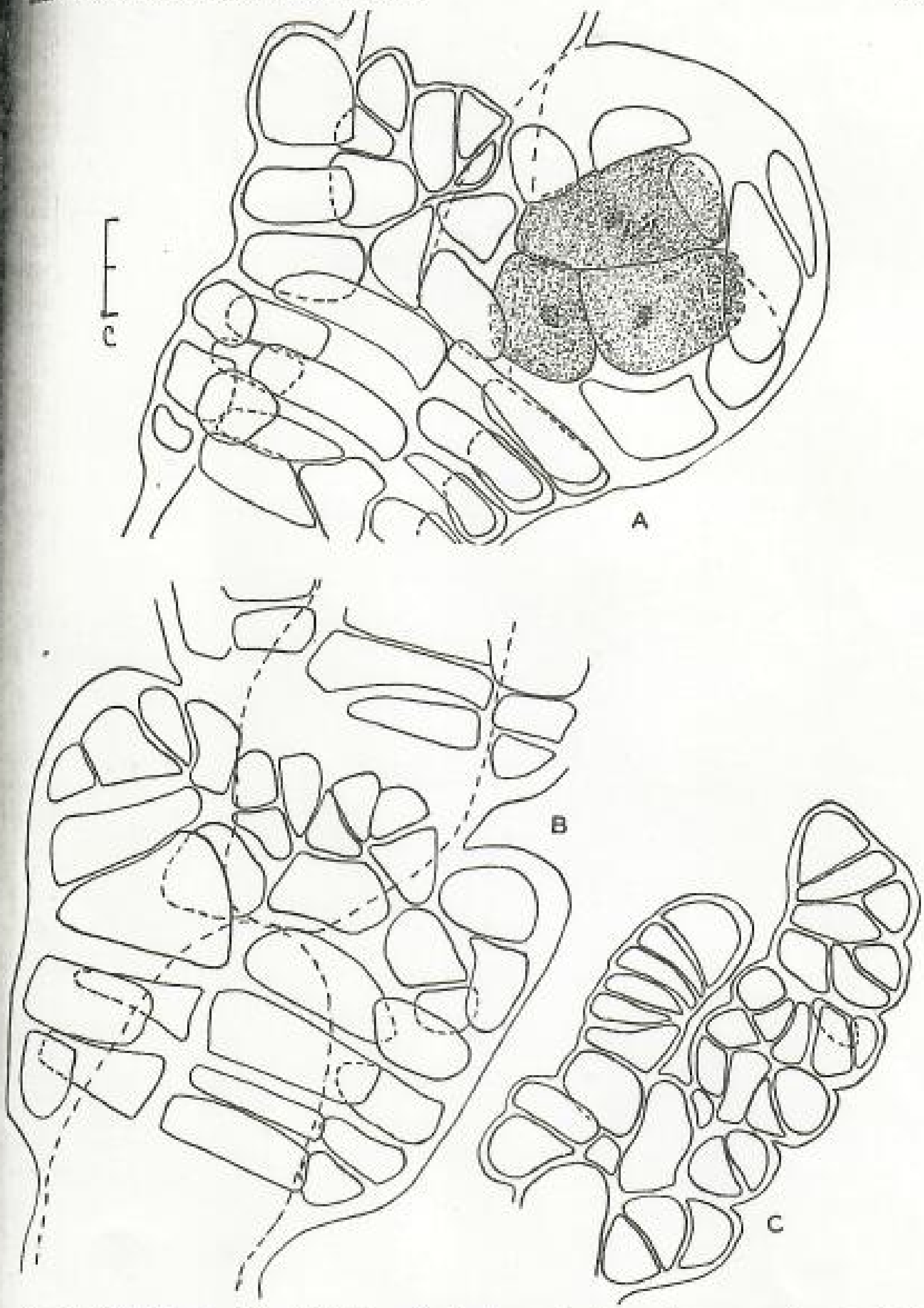

FIG. 11. *Ceramium* sp. (2). A. Nodal region showing cortication and tetrasporangium. Scale C (divisions 10 microns). B. Detail of node, showing underlying central cells. Scale C (divisions 10 microns). C. Tips of plant. Scale C (divisions 10 microns).

tips in some plants, and only a suggestion in others.

Specimens collected are sterile.

Found in Ilae Pond, Molokai Island.

Ceramium sp. (2) (see Fig. 11*a–b*).

Plants 2–3 cm. in height, dark pink, tufted, erect, branching with a percurrent main axis, the tips dichotomous and occasionally forcipate. Outer edges of the branches markedly dentate. Nodal bands close in the younger parts, in the older parts quite separated. Mature nodes marked by three rows of flattened cells below the septum, and smaller, angular cells above. Tetrasporangia 70 μ in diameter, sub-exposed, with an upgrowth of smaller cortical cells over them. Sporangia usually single at the node, rarely two. Spermatangial and carpogonial plants not seen.

Found in Ilae Pond, Molokai Island, and Molii Pond, Oahu Island, in the more saline portions adjacent to the sea.

Neither of these species of *Ceramium* seems to be one of those reported previously from the islands: *C. Kuetzingianum* by MacCaughey and *Ceramium* sp. by Neal. *Ceramium diaphanum* by Tilden is *Centroceras clavulatum*.

Taenioma J. Agardh, 1863: 1256

A detailed account of this genus, and particularly the following species, may be found in Papenfuss (1944) and Tseng (1944).

Taenioma perpusillum (J. Agardh) J. Agardh, Sp. Alg. 2 (3): 1257, 1863.

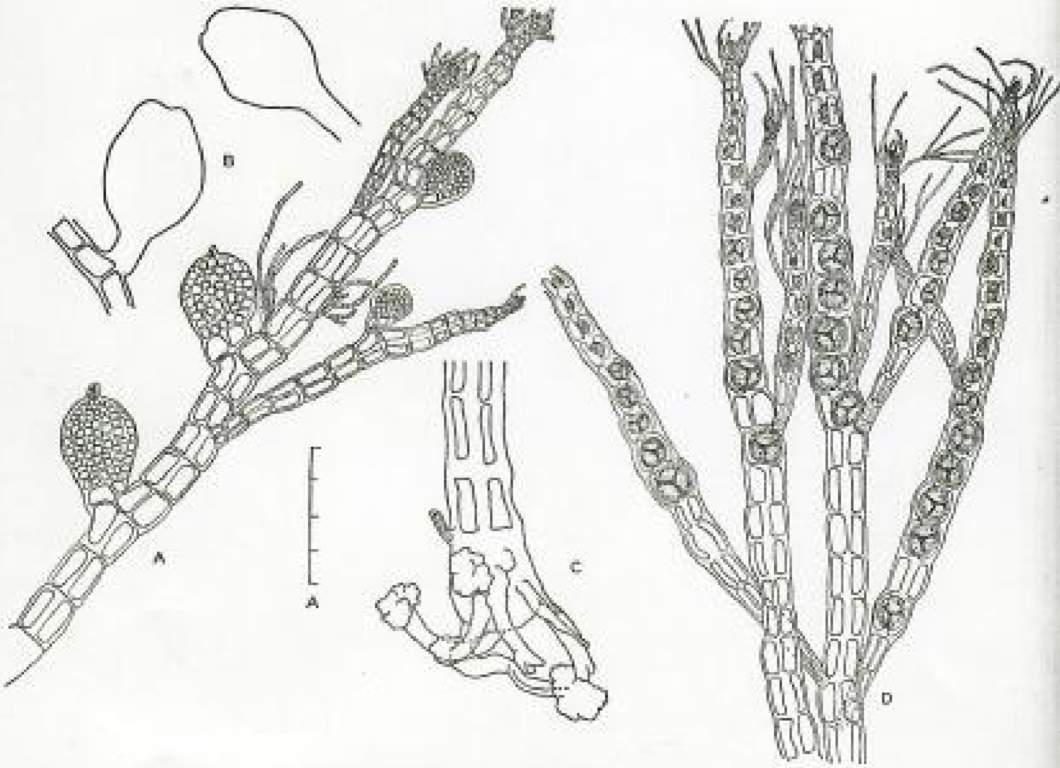

FIG. 12. *Polysiphonia aquamara* Abbott. Type specimens. Scale A (divisions 100 microns). A. Habit of cystocarpic plant showing young and mature cystocarps. B. Shape of cystocarps from another branch. C. Basal portion of tetrasporangial plant. D. Habit of plant showing tetrasporangia (cover cells have been omitted).

FIG. 13. *Polysi*
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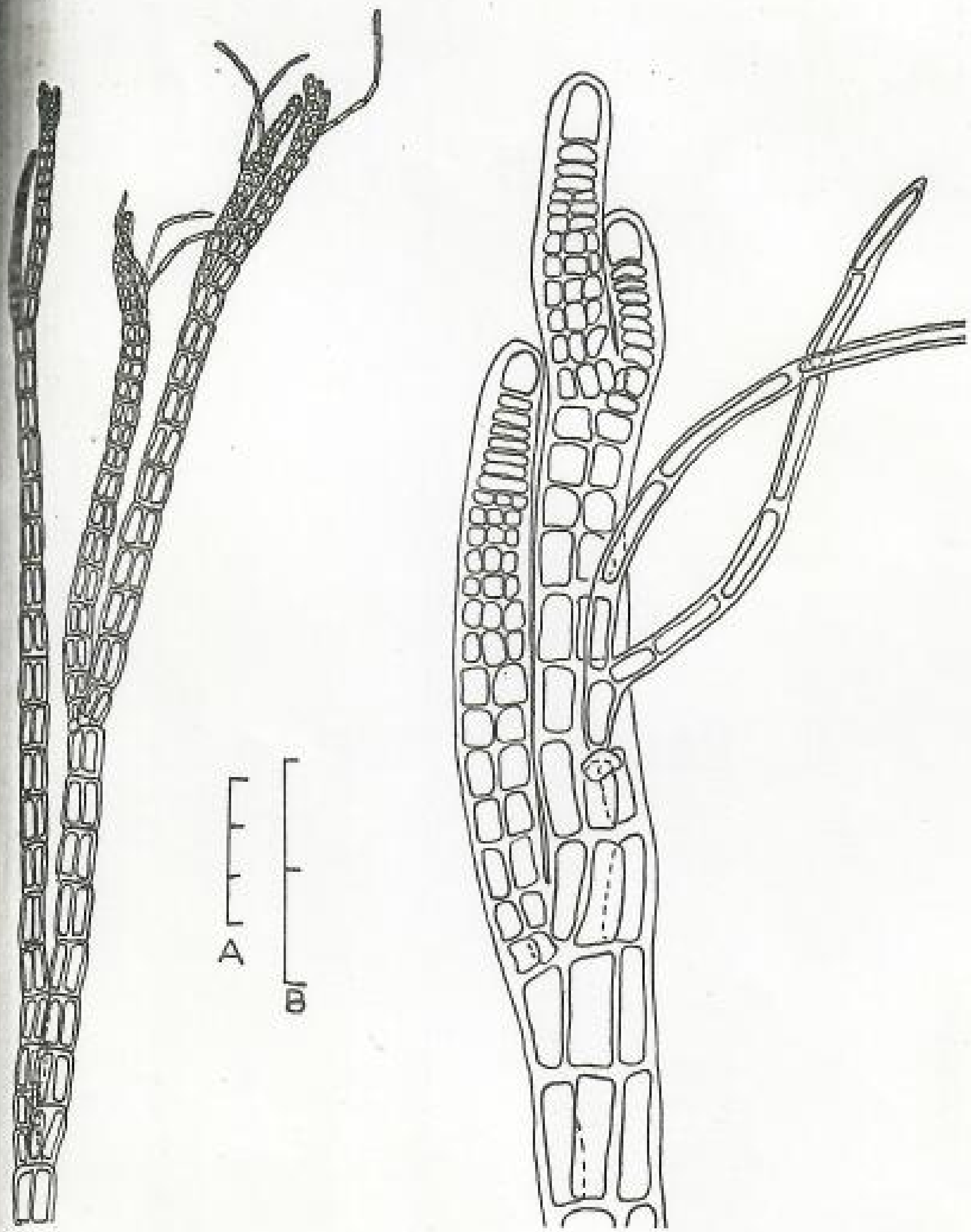

FIG. 15. *Polysiphonia* sp. Habit of sterile plants from fresh-water pond (Salt Lake). Illustration on left, Scale A (divisions 100 microns); on right, Scale B (divisions 50 microns).

Plants in small tufts, epiphytic on other algae, or on small sessile animals, filamentous and soft. The determinate branches of this species end in three hairs as opposed to two terminal hairs in *T. macrourum*.

Specimens collected were sterile.

Keawanui Pond, Molokai Island, with *Polysiphonia*.

This species is uncommon in this area. Reported from the Hawaiian Islands by Chamberlain and Papenfuss.

Polysiphonia Greville, 1824: 90

Section *Oligosiphonia*

Polysiphonia aquamara sp. nov. (see Fig. 12*a–d*).

Plantae penicillatim fasciculatae, ad 8 cm. longitudine sed plerumque minores, roseo-purpureae, molles, erectae, basi rhizoideis permultis praedito nec repente, ramis adscendentibus, alternis, origine spiralibus. Trichoblasti in articulos omnes insertae; cellulae pericentrales 4, haud corticatae; tetrasporangia e ramulis secondariis ultimis, plantae apicem versus locatis, orta, in serie recta vel tortuosa. Plantae cystocarpicae validiores, cystocarpis alternis, late urceolatis.

In *Batidem maritimam* vel plantas alteras phanerogamicas, raro in lapides vel conchas obsoletas, crescentes.

Plants tufted, without a prostrate creeping portion, to 8 cm. in height, usually smaller, reddish-purple, soft. Base composed of many rhizoids. Erect filaments arise from the base with branches ascending, alternate and spiraling in a counterclockwise directon, slightly divergent to ¼, with branching chiefly at the tips. Trichoblasts frequently appearing whorled, inserted in the young parts on every segment alternately, in the older parts leaving scar cells. The branches of the trichoblasts are 2 to 3 ranked, 50–200 μ in length, in the male plants covering ⅓ the length of the tips of the axis. Pericentral cells 4, non-corticated.

Tetrasporangia borne in ultimate branches near the tip of the plant, in a straight series or tortulose, or when in the main branches occasionally alternate. Spores dark brown to blackish, sporangia 4-partite, 20 μ (usually less) in diameter.

Antheridial clusters borne on the basal unbranched portion of a trichoblast, alternate, subcylindrical, with antheridia blunt to round. Cystocarpic plants stouter than others, the cystocarps alternate, broad urn-shaped, with pyriform carpospores.

TYPE: *Abbott 1535*, legit C. J. Engard, from Station 7, Kuapa Pond, Oahu Island, epiphytic on *Batis maritima*. This number includes tetrasporangial, cystocarpic, and spermatangial plants, of which I designate the tetrasporangial as the type specimen. These plants were collected April 7, 1944.

This new species of *Polysiphonia* is very abundant in the major fishponds, occurring on *Batis maritima*, rocks, and dead shells. It resembles *P. subtillisima*, which has also been found outside the strictly marine environment, but is distinguished from it in that it has no prostrate creeping portion.

Polysiphonia sp. (see Fig. 13).

A species of *Polysiphonia* found in fresh water (Salt Lake Pond, Oahu); grows abundantly on the pond walls, attached to phanerogams, or to rocks. It has four pericentral cells. Infrequent trichoblasts are found near the tips of the plants. Although repeated collections were made, no fertile material was found. The salinity in this pond was found to be nearly that of fresh water (2.9).

To the best of my knowledge, this is the first report of the genus in fresh water.

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Limu—choice depends upon personal preference, heritage

At the far edge of Ewa Beach where the chain-link fence divides the park from the military area, small groups of people work patiently sorting and resorting seaweed.

They are the limu gatherers. (Limu is the Hawaiian word for seaweed.) Many have looked for limu since they were children and will

from the sea
mike markrich

spend hours choosing the three or four kinds they want from the approximately 100 species that wash ashore here.

The choice depends on both personal preference and cultural heritage.

The Pick of the Limu and Seafood

The Waianae coast has a special relationship with the ocean, says Candyce Fujii of the Waianae Community Action Program. And for that reason, it seemed appropriate to have a seafood and *limu* cooking contest in conjunction with the Statewide Ocean Conference that was held on the coast last week.

"A lot of the residents use the ocean as a source of food," said Fujii, who coordinated the cooking contest held Saturday at Makaha Resort. "They cook with seafood and they do use limu that they have gathered for food. Basically, we held the contest to allow Waianae coast residents to show off their talents."

Limu essentially is seaweed. Actually, the Hawaiian word means any water plant. But *limu* has become the word commonly used for edible seaweed.

IRENE M. SELLERS, of Waianae, was the big winner in the *limu* cooking contest with *Limu Lipepe'e* Salad, a combination of *limu lipepe'e*, tomatoes, onion, shoyu and dried shrimp. *Lipepe'e* (which means hidden) is a type of limu that grows in shady places or in holes where you might also find sea urchins.

Mix the *oio*, egg, cornstarch, sugar, salt and soup stock. Cut the vegetables into thin strips and then chop fine. (Boil the *gobo* and carrots first.) Mix all the vegetables with the fish mixture. Form into cakes. Deep fry in oil until golden brown. Cool. Serve with salad.

Salad

1 head lettuce, cubed and soaked in ice water
5 ripe tomatoes, cut into bite-sized pieces
1½ tablespoons pepper or to taste
½ cup mayonnaise

Drain the lettuce. Mix with tomatoes and pepper. Refrigerate until serving. Just before serving mix the salad with the mayonnaise.

ONO CLAM-LIMU

(Second place limu contest, by Hanako Ohelo)

½ pound fresh ogo limu
1 large tomato
1 to 2 tops of green onions
¼ cup shelled whole clams
¼ Maui onion, optional
3 tablespoons rice vinegar
2 tablespoons sugar
½ teaspoon salt
Dash of pepper

An internationally known seaweed expert, Prof. Isabella Abbott, explains: "You may like turnips; I may hate them. All of them are edible, but some you like better than others."

According to Abbott, there are 18 species commonly used in Hawaii. The limu varies so much in taste and texture that it is collected by people with specific uses for it in mind.

"I know a lot of people who eat it Japanese style, pour hot water on it and mix it with miso. But when it comes to seaweed, I'm Hawaiian; I like it just plain with salt," Abbott said.

Filipinos tend to look for types of seaweed that are similar to those found in the Philippines. Types of limu that can be eaten fresh with salad and mixed in a fish sauce known as "bagoong" are the most popular. Rosa Sencia of Kalihi comes often to Ewa Beach with her granddaughter to look for limu. Says Sencia, "It's good, maybe tasting like in P.I., thin and long."

Abbott noted that limu is also an important ingredient in a Hawaiian fish sauce known as palu.

Because of the difference in tastes, the limu gatherers often do not compete for the same limu. Filipinos may prize a type of seaweed known to Hawaiians as huna in their fish sauce while Hawaiians would not collect it because they find it bitter.

Japanese people look for the popular ogo that is used for poki and many other dishes, while people of Hawaiian ancestry look for a wide variety of limu that can be used in different Hawaiian dishes.

Evelyn and Frank Giron of Honouliuli search for four kinds of limu at Ewa Beach. They look for waiwaiole (a green spongy limu known locally as "rats' feet"), red lettuce, ogo and huluhuluwaena — a red limu they use for fish sauce.

Evelyn Giron says, she collects limu for food and for health reasons. "This has iodine; it's good for you. Also it's important for roughage." She says she hopes her children will learn to collect limu, "so they can know how to survive, so in hard times they can go catch fish, get opihi and eat limu."

Ewa Beach is a popular place to gather limu because it has one of the largest varieties of seaweed of any easily accessible beach on Oahu.

The limu grows at a depth of six to 10 feet and the constantly rough waters at Ewa Beach are believed to pull the limu loose. This and the closeness of Pearl Harbor, which has brackish water seaweeds that drift over to Ewa Beach, account for the wide variety of seaweed that is found there.

The techniques of getting limu are as varied as the people who come for it. Some wade in the water to gather armfuls of the brown limu and then look through it carefully with sharp eyes and quick, skillful hands.

Others dive for it and pluck it out by its roots. Botanists discourage this method, because when it is pulled out it doesn't grow back. (The early Hawaiians are said to have always cut the limu with a knife, leaving enough so it would grow again.)

Those who have searched for limu for a long time just walk through the limu and feel for the ones they want with their feet.

There is a commercial market for limu and skilled gatherers such as a man who goes by the name Moresi Jr. He now lives in Kalihi but came there from Samoa and can gather with his family as much as 70 pounds in six hours.

Says Moresi Jr., "It's a kind of game. We gather them and we sell it for $1.50 per pound. The stores sell it for $2.50."

The most highly prized limu, limu kohu, is not commonly found at Ewa Beach. It sells for $8 per pound wet weight even though 90 percent of it is water.

Although there is some complaint that there are more people gathering limu and that there is more opala (slimy or junk limu) than ever before, the limu gatherers continue to come to Ewa Beach.

Abbott spends a large amount of time at Ewa Beach doing research. She has always found the people are happy and absorbed in their work of gathering limu. "They don't find it tedious at all. They are interested in what they find. They are with their family and friends and it's a lovely day in the sun. It (Ewa Beach) is one of the most joyous places on the whole island."

Isabella Abbott's Ogo Kim Chee Recipe

2 pounds ogo chopped into 2- to 3-inch pieces
Handful of coarse Hawaiian salt
2 cloves of garlic (chopped) per quart of wilted seaweed
1 or 2 chopped round onions or 1/2 cup chopped green onions
chopped chili pepper to taste or 1/2 teaspoon cayenne pepper)
½ teaspoon paprika

Wash and clean the limu. Salt and wilt by letting stand over night. The next day, drain off any liquid, add garlic, onions and paprika. Pack tightly in jars, seal and let stand. It should be ready in two or three days.

Hanako Obelo, also of Waianae, took second and third places in the *limu* contest with Ono Clam-*Limu* and *Limu*-n-Aku, respectively. Both dishes call for *ogo*, which is also called *limu manauea*. *Ogo*, a Japanese word, is the most widely available *limu* in markets in Hawaii.

Theola Silva, of Waianae, was the first-place winner in the seafood contest with fishcake made from *olo* and a salad to serve with the fishcake.

Musu' Maneafaiga, of Waianae, captured second and third places with Coconut Fish and Makai Fish, both of which call for any type of local fish.

THE CATCH TO both the *limu* and seafood cooking contests was that entries had to include *limu* and seafood from Hawaii waters, Fujii said. Contestants also had to use the Hawaiian name for the *limu* and seafood in the recipe.

A panel of seven judged the dishes for nutritional value, taste, ease of preparation, innovation and presentation.

Sellers and Silva each won round-trips for two to the Big Island and $20 gift certificates for groceries. Both will appear on "Let's Go Fishing" on KHON-TV and prepare their prize recipes.

Here are the first-, second- and third-place recipes from both the *limu* and seafood contests:

LIMU LIPEPE'E SALAD

(First place limu contest, by Irene M. Sellers)

¼ pound limu lipepe'e
1 large tomato, sliced
1 medium onion, sliced thin
¼ cup shoyu
¼ pound dried shrimp

Pick *limu lipepe'e* from the reef near the shore. Clean it with salt water and drain. Return *limu* to clean salt water and store in refrigerator until ready to use. When ready to prepare salad, drain *limu*. In a large bowl, combine *limu* and all other ingredients. Toss and serve. Delicious with poi or rice.

FISHCAKE

(First place seafood contest, by Theola Silva)

1 pound olo fillets, scraped into a paste using the edge of a spoon
1 egg
½ cup cornstarch
1 tablespoon sugar
1 teaspoon salt
1 teaspoon soup stock
String beans
Carrots
Gobo
Green onions

Place the *limu* in hot boiling water for 15 seconds or until *limu* turns light green. Remove from water quickly so as not to overcook. Place *limu* in colander to drain. Dice tomato into ¼-inch pieces and slice Maui onion thin. Chop the green onion tops. Cut clams in half. Chop the *limu* into 1-inch pieces. Place the *limu*, tomato, onion, onion tops and clams in a medium bowl. In a small dish, combine the rice vinegar, sugar and salt and pepper. Stir until the sugar and salt are dissolved. Pour the mixture over the *limu* mixture and toss lightly. Serve.

LIMU-N-AKU

(Third place in limu contest, by Hanako Obelo)

1 pound fresh aku, raw
1 cup ogo limu, parboiled
3 tablespoons oyster sauce
1 teaspoon ground kukui nut
¼ teaspoon chili pepper or 1 teaspoon chili pepper water
1 teaspoon water

Cut *aku* and *limu* into ½-inch pieces. Combine in bowl with all other ingredients. Mix and serve.

COCONUT FISH

(Second place seafood contest, by Musu Maneafaiga)

1 medium onion, chopped
1 teaspoon onion salt
1 teaspoon curry powder
1 can coconut milk
3 pounds any local fresh fish

In a mixing bowl, combine the onion, salt, curry powder and coconut milk. Mix well and set aside. Clean and scale the fish, if necessary. Place the fish in a pot and cover with water. Boil until the fish is cooked (fish is cooked when it begins to flake). Drain the fish. Put fish back into pot. Add coconut milk and simmer 4 minutes. Garnish with shrimp, breadfruit and taro and serve.

MAKAI FISH

(Third place seafood contest, by Musu Maneafaiga)

2 tablespoons whole wheat flour
½ cup water
1 egg
¼ teaspoon pepper
¼ teaspoon curry powder
1 medium onion, chopped
2 tablespoons oil
½ cup green onion
3 to 4 pounds fresh local fish

Scale and clean the fish, if necessary. In a bowl, mix the flour and water. Add the egg, chopped onion, pepper and curry powder. Spoon this mixture over the fish on both sides. Remove fish to a greased skillet and saute 30 minutes—15 minutes on each side. Garnish the the cooked fish with green onion.

Star-Bulletin

Food

Section F

Honolulu

Wednesday, August 12, 1981

Irene Sellers, left, won the limu cooking contest with her salad of limu lipep'e, and Theola Silva took top honors in the seafood category with her fishcake made from oio.

March 10, 76 S-B

Slick of Seaweed Is Breaking Up

A seaweed algae slick deposit on ocean waters off Lanikai and Waimanalo beaches apparently is breaking up after causing problems for weekend boaters.

The U.S. Coast Guard reported the slick had extended from offshore Sea Life Park to offshore Bellows Beach. However, Sea Life Park officials reported today that ocean waters in their vicinity were clear today.

The seaweed algae apparently originated in the Kawainui Swamp area near Kailua. It is not considered a pollutant.

The algae normally is not noticeable because wind and surf break up the material. However, weather conditions during the weekend apparently caused the slick to stay in a mass formation.

5-B MAY 20, 76

Seagrass Study Is Project of 8 Institutes

By Helen Altonn
Star-Bulletin Writer

A University of Hawaii scientist who specializes in seagrass ecology and computer programming has combined the two for an international research network to keep tabs on seagrass beds.

Botany professor Kent Bridges designed computer programs for the seagrass ecosystem study, involving eight cooperating institutes.

The project is funded by the International Decade of Ocean Exploration, a National Science Foundation program.

BRIDGES EXPLAINS THAT seagrass is an important link in nature's life chain of vegetables, animals and mankind. The whole chain is affected if one or the other is disturbed, unbalanced or destroyed.

He points out that if seagrasses weren't available to feed milkfish in the Indo-West Pacific areas the people would be deprived of a vital supply of protein.

If there were no seagrass beds in Alaska, waterfowl would lose their food source and the fishing industry would be disrupted.

Coral reef ecosystems in most of the tropics are bound to seagrass beds through fish and invertebrate herbivore food chains.

SEAGRASS BEDS also are believed to provide protection for shorelines in case of erosion, hurricanes or other disasters, Bridges said.

He said a seagrass called eelgrass disappeared from the ocean floors during the 1930s but no one knows why.

"If we had had our research group set up at that time, we might know the answer. Who knows, we might even have mediated the problems," he said.

"As it is today, if a factory or some industrial plant is dumping waste material, or hot or cold water, into an ocean area and we feel some of the seagrasses are threatened, we would suggest certain changes to the factory."

Bridges said, "Just getting together for meetings and writing papers isn't enough," to organize studies of seagrasses so researchers got together through computer programs.

THEY'RE USING A computer terminal (typewriter-like devices connected to the computer) and computer centers in Illinois and California to share information.

Bridges said, "We can leave messages and ideas about the gathered data in the computer bank, too. This allows anyone on the team access to these materials and messages. We can each use the data according to our own experiences."

The researchers have a corps of volunteers — field samplers — who remove plants from the ocean for the scientists to study. Divers even go into icy waters, such as Puget Sound, to recover plant samples.

THE MATERIAL IS analyzed in one of the institute laboratories and the information channeled into the computer data bank.

"Then I look at this material by retrieving it from the computer to see if anything unusual is happening," Bridges said.

"Let's say we found the waters unexpectedly warm. I'd send a message to a fellow researcher in Texas whose specialty is temperature tolerances and he could follow through on the analysis.

"In this way, even though we are geographically separate, we can work as though we shared one laboratory."

Aug 19, 76 5-B

Farming of Seaweed Under Study Here

By Jerry Tune
Star-Bulletin Writer

In two 50-foot-square plantings at Coconut Island in Kaneohe Bay, a high-yield variety of red seaweed is growing under the watchful eyes of scientists.

The mass of seaweed increases by 2 to 5 per cent a day. At a 3 per cent growth rate, the mass will double every 21 days.

The University of Hawaii Marine Biology research team monitors the growth every week. Some day in the future the data collected from Kaneohe Bay may be used for a commercial seaweed farming operation on Oahu.

"THIS IS BASIC data that has never been gathered," said Maxwell Doty, the University of Hawaii botanist who has been following seaweed for years.

The results will allow scientists and businessmen to appraise actual farming sites without detailed testing of each site.

Commercial seaweed farming is being done in Asia, including one location in the Philippines which involved pioneering efforts by Doty. However, it took about 10 years and between $250,000 and $500,000 before that operation began to pay off.

DOTY BECAME acquainted with the eucheuma variety of seaweed in 1957. When political unrest in the 1960s reduced the supply imported from Southeast Asia, the prime American user of the algae provided Doty with the support needed to begin a research and development project in the Sulu Sea in the Philippines.

For the past year, Doty has been growing a cold-water, fast-growing strain of eucheuma striatum as well as the high-demand species spinosum in Kaneohe Bay to determine how well these economically desirable species grow in Hawaii.

Funding for the project has been through the Sea Grant program and the State marine affairs coordinator.

THE ECONOMICS is still a bit fuzzy for Hawaii, but Doty says the good-quality seaweed can go for up to $600 a ton and the lower-grade seaweed for about $350 a ton.

The buyers are a relatively small group of companies, including about seven major concerns in Europe, Japan and the United States.

The algal gels have been used in pharmaceuticals, foods, and industrial products to trigger timed release capsules for headache and cold remedies, keep instant puddings fluffy, hold the frothy head on beer, and remove the burnt taste from concentrated milk.

These same gels can be used as a binder for such products as ice cream, lipstick and other cosmetics, automobile tires, and pellets for aquaculture feed.

IN HAWAII, the economics is more difficult to assess because of the question of leases for submerged lands or reef flats, the price of labor if seaweed is hand-harvested, and the institutional red tape that confronts any new business.

Lowell Funk, a Hawaii businessman who has begun a farming operation in Samoa, estimates a minimum of $200,000 to $250,000 is necessary to cover costs for a two-year period during which no income will be generated.

However, Doty says that cash can come back quickly if the sales are made by letters of credit. Payment then is made by banks when the seaweed is put on a ship.

IN THE NEXT few years, local companies may be going into commercial seaweed farming if some of the problems can be ironed out.

Doty says three local companies are looking at seaweed farming.

Taylor "Tap" Pryor is using seaweed to help purge the water of nitrates and phosphates at his aquafarm in Kahuku. Pryor is growing plankton in seawater pumped in from the ocean. After the plankton is drained out, the nutrient-rich water is passed through production

Turn to Page G-3, Col. 3

Seaweed Farming Here Still Far From Feasible

Continued from Page G-1

trenches where clams and oysters are grown.

THE ECONOMICS of seaweed farming is intriguing, since it could involve relationships between big companies and family-unit farmers who do the actual harvesting.

In the past, Doty has talked about using the gracilaria variety of seaweed known here by its Japanese name, ogo.

The "long ogo" is green, red or black in color, while the "short ogo" appears red in local markets. The wholesale price is about 50 cents a pound.

(The Hawaiians, who call it limu, and the Japanese have been eating seaweed for years. Hawaiians in older times knew of at least 70 species of limu which could be used for food and medicine.)

DOTY THINKS as much as 250,000 to 500,000 pounds of seaweed a year could be marketed locally.

A second marketing possibility involves volume deals with outside buyers for shipment to processing plants.

While a commercial buyer probably would want a minimum of 10 tons per order, Doty says it might be possible to start off with one or two tons at first.

Storage costs would add to overhead expenses, but Doty points out that seaweed can be stored in a relatively small space.

"THE STORAGE doesn't have to be anything special — just something to keep the rain off of the seaweed," Doty said. "The rats and mice won't eat it . . . It's too salty for them."

The farming of seaweed for the big commercial users may depend on the development of a mechanical harvester. And because most seaweeds require free flowing circulation, reef flats ere considered the best place to grow and cultivate them.

Application for the lease of submerged lands must be submitted to a variety of government organizations. The lease arrangements would be made through the State Department of Land and Natural Resources.

There hasn't been a big interest so far in the reef flats, according to the department. About a year ago one person did talk briefly to the State, but there's no policy for the reef flat leases.

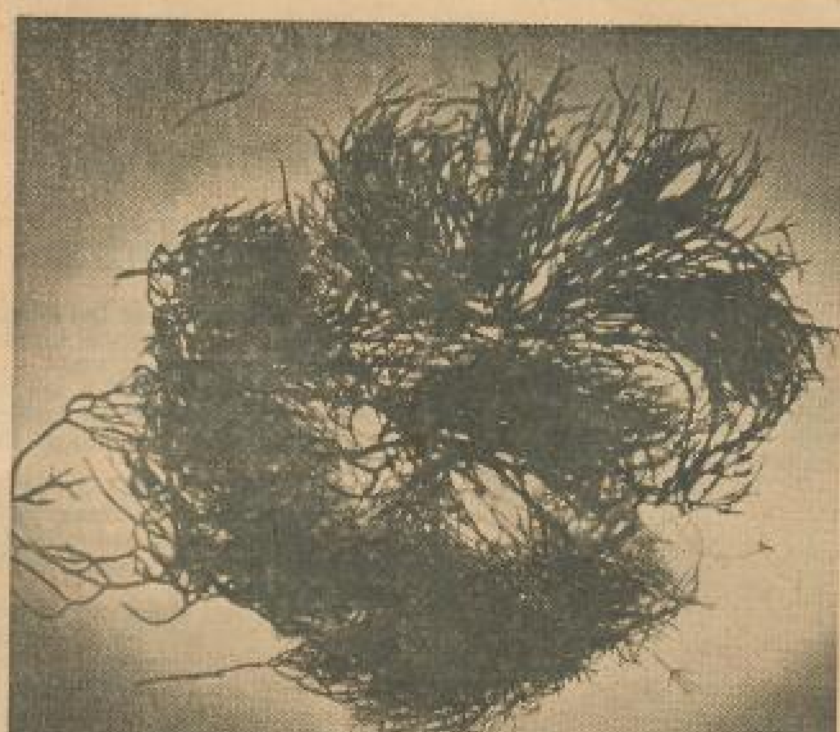
IF SEAWEED farming is done in the waters around the shoreline, Doty says it won't hurt the fishing.

"The fishing should improve," he said, "because water going through the seaweed gains about 10 per cent more oxygen. The fish also can feed on the seaweed and get protection from their enemies."

Doty said there were plans to put some test seaweed farms in fishponds on Oahu, and the pond owners had agreed, but funding cuts canceled the plans.

Commercial farming in Hawaii is still a while off in the future. Doty has about one more year of watching and testing the seaweed at Coconut Island.

Aug 19, 76 5-B



LOCAL DELICACY—Many families enjoy eating iodine-rich limu (ogo).

Signs Taken Down

Seaweed Problem Seems to Be Over

By Alan T. Matsuoka
Star-Bulletin Writer

State Health department signs warning people against swimming at Kalama Beach will be removed today since an unusually high concentration of a rash-causing seaweed appears to have subsided, a spokesman said yesterday.

John Gooch, a public health official with the department's epidemiology branch, said signs posted two weeks ago will be taken down because no new cases of the rash were reported over the Labor Day weekend or during this week, even though the beaches were being used.

"The currents apparently have carried the seaweed into the deep water from whence it came," Gooch said. Warning signs posted at Kailua Beach were removed several days ago, he said.

THE SEAWEED, called Lyngbya majuscula Gomonte, caused an itching and burning rash within hours after fragments were caught between bathing suits and skin, and in some cases developed into blisters. If left untreated, symptoms lasted about three days.

The first case was reported to the Health department Aug. 16 and within two days lifeguards and hospital emergency rooms reported 41 cases of people affected by the rash.

Since then, though, the number of cases has tailed-off as the currents and weather conditions which brought the seaweed apparently started carrying it away.

The final tally of cases was 86 as of yesterday, said Gooch, who described the figure as "minimal" and suspected that there were several more incidences which were not reported.

"There were some very serious cases having to do with the personal parts of men and women, you can imagine," he said. Although the irritation vanished in a few days, "it was probably miserable for a few days," he added.

GOOCH SAID the seaweed generally was confined to the two beaches where the signs were posted. A few cases were reported from the Waimanalo area, but not enough to cause concern or prompt warnings, he said.

Scientists are unsure of the reasons for the seaweed's periodic emergence and decline, but theories revolve around such factors as rainfall, wind and tidal movements. Gooch said it appears that the seaweed emerges close to shore every four or five years, and that there had been two other occurrences which followed that pattern before the most recent one.

The seaweed's normal environment is on the ocean floor at a depth of about 100 feet, he said. It washes up to the shore when the seaweed, for unknown reasons, is loosened.

One peculiar aspect of the seaweed found by scientists is that it apparently varies in toxicity, he said.

"At times it's perfectly harmless, and at other times there are these violent reactions," Gooch explained. "No one knows why."

Sunday

The Sunday Star-Bulletin & Advertiser

Advertiser photo

Jerry Kaluhiwa with junk harvested from seaweed beds. Fish nibble at manuea like rabbits eat lettuce, but the worst predator is man, he says.

Garde

His c

Nineteen-year-old Pat Aweau is a gardener who works under water. His unusual crop is seaweed, a vegetable so much in demand that it costs $2.50 per pound in the grocery store.

So many people are picking seaweed that they have wiped out large beds in shallow water between the reef and the shore, leaving the ocean floor bare.

That's why Aweau has gone into gardening.

He's a volunteer in a unique project which for the past year has been planting seaweed, like you would corn or beans, in an effort to bring back the native resource.

The seaweed is called manuea by Hawaiians who use it in poki. Japanese call the seaweed ogo and use it for making namasu.

Jerry Kaluhiwa, leader of the project, said they've found that manuea, if picked correctly, will grow back in about 2½ months and can then be harvested again.

One problem is that many seaweed pickers pull it up by the roots so that it doesn't grow back at all.

Kaluhiwa said he and his staff of about a dozen teen-agers also have discovered that you can plant seaweed and grow it much as you would lettuce in the garden.

Just as rabbits nibble at a lettuce patch, fish nibble on seaweed, retarding its growth, Kaluhiwa said.

"But the worst predator is man," he said. "We plant seaweed in wire cages to protect it from the fish. Then people come along and take the seaweed, cages and all."

He said one of his first "gardens" of planted seaweed near Coconut Island was wiped out by seaweed pickers while his crew was working in another area.

Hawaii Report

Prepared by the staff of The Honolulu Advertiser November 2, 1980 A-3

ner deals in seaweed

rop's growing — swimmingly

Pat Aweau, wading Kaneohe Bay shallows, brings in seaweed grown in cage.

bob krauss

Advertiser columnist

The project is now headquartered at Heeia offshore Heeia State Park and the Heeia fishpond. They've also planted seaweed gardens off Heeia-kea and Kahaluu. Potentially, most of the shoreline of Oahu can be planted, Kaluhiea said.

Seaweed grows anchored to bits of rock. Aweau said he collects small seaweeds attached to rocks and "plants" them in underwater patches by pushing the rocks into the sand.

Kaluhiwa said they've also figured out how to plant unattached seaweeds. These loose streamers of manuea are gathered and placed under a nylon netting over a rocky ocean bottom. Within a few weeks, the manuea attaches itself to the rocks and begins to grow into a luxurious underwater garden.

Bob Nakata, executive director of the Kualoa-Heeia Ecumenical (KEY) Project, said Kaluhiwa came to him with the idea about a year and a half ago.

He said the supply of seaweed had been reduced when the reef runway of Honolulu International Airport wiped out large patches. In addition, increased population pressure from users of seaweed, including immigrant Filipinos and Vietnamese, was stripping whole offshore areas bare.

The Heeia-kea Community Association put together a limu proposal for which Nakata got a year of funding through the city's Office of Human Resources from the federal Youth Conservation and Community Improvement Program.

The limu project spent about $50,000 in 12 months. This paid for two supervisors and 11 teen-agers who surveyed what seaweed was still available, gathered it, planted it, tended the gardens every day and carried out trash they found on the ocean floor.

The year of funding has ended, but Kaluhiwa, Aweau and Randy Kalahiki are keeping the program alive on a volunteer basis in hopes they'll get some money by January.

Kalahiki said there is no longer any doubt that seaweed can be planted and grown.

"If communities would get behind the project, it could be viable for many community associations," he said. "The associations could grow their own seaweed and then expand to fish and crabs. That helps with the grocery bill."

Kaluhiwa said he would like to see seaweed protected by licensing the pickers much as inshore fishermen are licensed now.

Beaches in Kailua Hit by Stinging Seaweed

Thursday, June 9, 1983 Honolulu Star-Bulletin A-19

Swimmers at Kailua Beach may be exposing themselves to seaweed dermatitis, according to the state Department of Health.

Ten persons have been reported suffering from the problem — which may result in reddening, itching or peeling of the skin, and blisters.

The health department recorded the reports of contacts with the offending seaweed, lyngbya majuscula, in waters at the northern and southern ends of Kailua Beach. Lifeguards at Kailua received a few similar reports.

The itching and other symptoms have been reported by swimmers at Windward Oahu beaches in summer months for several years, according to the health department.

The seaweed consists of fine threads the width of horse hairs and is olive drab in color. Strands may mat together into a felt-like mass.

This type of seaweed grows in offshore waters in many Island sites, but is only toxic in certain places at certain times of some years.

Persons who develop symptoms after contact with the seaweed should consult their family physician.

Persons who swim off Kailua Beach may minimize the effect of the seaweed by avoiding obvious patches of it in the water and by showering themselves thoroughly and washing their swimsuits immediately after leaving the water.

It is expected that in a matter of days or weeks the wind, tide and ocean currents will move the toxic growth away from the beach. Health officials are monitoring the beach in the meantime.

Mystery Glob May Be Algae, Shrim

6/2/84 HSB

The odorous, grainy substance found floating on the surface of Kaneohe Bay Thursday is definitely not sewage but it could be algae or the remains of brine shrimp, according to state and city officials.

Oahu Civil Defense Agency administrator Malcolm Sussel advised people to stay out of the water near the area and not to eat any fish or other seafood taken from Kaneohe Bay until more information is obtained.

Don Horio, spokesman for the state Department of Health, said there were no reports of anyone suffering ill effects from exposure to the substance which was described as white and as yellowish-brown by people who spotted it near the Waikane pier and off Waiahole Beach Park.

The state sent samples to the Institute of Marine Biology for analysis.

"We are now looking at the possibility that it is algae or the remains of brine shrimp," Horio said.

The Coast Guard has also sent samples for analysis to AECOS Labs Inc., a private laboratory. Coast Guard officials said the material was found from Kahaluu Pond to Kualoa Point.

RICK GUINTHER, a marine biologist involved in the testing, said the organism could be phytoplankton or algae, forms of floating plant life.

"When the wind dies and there is a poor mixing of the water the algae collects and lies close to the surface," he said. These two conditions combined can create a gas and cause the strong odor.

Under the microscope the substance looks like little spheres of clear material hooked together with a yellowish cast to it, Guinther said. The material also has an oil content — not petroleum — which is characteristic of most algae, he said.

Although he handled the substance with his bare hands, Guinther suffered no ill effects he advised against swimmi the area or eating shellfish that area for a couple of we

Debra Westerberg, spoke an for the Coast Guard in lulu, said the material is cha its physical shape and that down wind will be affect the smell.

"You will probably smell fore you would even see it said.

Botanist Notes Marine Algae Similarity

By Harry Whitten
Star-Bulletin Writer

A prize-winning Chilean botanist, now in Honolulu, is fascinated by the similarity between marine algae and plants on Easter Island and those in Hawaii.

Bernabe Santelices, who received his Ph.D. in 1975 from the University of Hawaii, was recently awarded the Manuel Noriega Morales Prize by the Organization of American States (OAS).

Sanford M. Siegel, chairman of he UH botany department, said the award is "a world-class prize."

Besides the citation, the award includes a $12,000 grant which Santelices plans to use on research concerning seaweeds along the Chilean coast. He plans to write a book on the taxonomy, ecology, economics and importance of seaweed for fishermen.

CHILE EXPORTS $25 million worth of seaweeds a year to Japan, the United States, Canada and Europe, he said. The seaweed is used in the additive food industry.

Chile has 500 species of seaweed, about 20 percent of which is also found along the North American coast, Santelices said.

He has been on the faculty of Catholic University of Chile for about 18 years, with time out for graduate study at the University of Hawaii under Maxwell S. Doty, professor of botany and an authority on seaweeds.

Research for his thesis was done on Hawaiian seaweeds along the Windward Coast.

His return trip has been to work again with Doty and other university scientists to study literature on seaweeds at the university and to prepare for a symposium next January in Chile on the use of seaweed. Doty will attend the symposium.

Santelices will be here another week before going to Washington, D.C., to receive the award,

given him largely because of concern by the OAS for coastal ecosystems, he said.

WHILE HERE, he is conferring with Isabella A. Abbott, Wilder professor of botany, who is collaborating with him in the study of marine algae of Easter Island.

Abbott is the author of a recently published booklet, "Limu, an Ethnobotanical Study of Some Hawaiian Seaweeds."

Easter Island, 2,400 miles west of Chile, is governed by that nation. It is famed for the gigantic stone busts in human form, carved from hard volcanic rock.

Santelices was there in 1981 making collections. He said the island's land flora has been much disturbed but comparisons with Hawaii's algae and plants can be made from data collected on early expeditions.

The island's population, numbering only about 2,000, is of Polynesian origin. Santelices said fish and invertebrates have a strong relation with those of Polynesia.

Thomas S. Barthel, in his book, "The Eighth Land," said that Polynesians brought yams, sweet potatoes, banana shoots, taro, ti, sugar cane, sandalwood and the paper mulberry tree to Easter. These are plants also familiar in Hawaii.

Bernabe Santelices
Awarded major prize

Pterocladia = Hawaiian name?

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Hawaiian Uses of Limu

Tales of Old Hawai'i

By Russ Apple

ANCIENT HAWAIIANS knew, and had names for, up to perhaps 70 kinds of limu. Seven or more of these can still be found, seasonally, in Island fishmarkets.

When a Hawaiian says limu, he sometimes uses it as a general name for any plants which grow under water — fresh or salt — as well as for liverworts and lichens which grow in damp places. Even the moss which grows on rocks in fresh water streams is limu.

But, both today and in ancient Hawai'i, the word limu meant mostly edible algae gathered from either fresh or salt water.

Thus, limu means tasty seaweed.

Hawaiians relish seaweed. In the old days it was fish, poi and limu. Fish and poi supplied the protein, carbohydrates and minerals necessary for adequate nutrition.

LIMU SUPPLIED not only variety, but added some elements such as iodine and multi-vitamins.

Women, helped by the children, gathered most of the limu

or served as a side dish.

Limu was the tasty relish which put variety into the ancient Hawaiian diet.

Hawaiians had other uses for seaweed. One variety was chopped or chewed and used for a

Limu was the tasty relish that put variety into the ancient Hawai-

dling the body of a dead member.

Limu kala was eaten as part of a regular family ritual, the ho'oponopono, to lessen family tension and set its members "right" with each other.

Each summer, a priest used limu kala, with tumeric and sea water, to ritually cleanse fishermen before the season on mackerel opened.

When a lingering illness was almost over, a lei of limu kala, worn open at the bottom, was placed on the patient. The sufferer moved into the surf — away from land at all times — until the waves washed off the lei.

Any guilt or evil which caused the sickness washed off with the lei.

Another variety, limu kalawai, made love potions. What special phrases a lovelorn maiden spoke while preparing the potion have been lost. Once prepared, the girl ate some and gave some to the man she wanted.

WHILE TODAY the symbolism

As she examines manuwai seaweed, Isabella Abbott says: "You can follow the collectors from Hanauma Bay to Waianae over a period of months and you can tell where they have been every step of the way . . . There's bare rock where I knew there used to be plants. From Nanakuli to Waianae, it's clean as a whistle."

Advertiser photo by Carl Viti

pick the ogo," said Ernie Choy, who works with his family at the Deli at the end of Heeia Kea pier on Kaneohe Bay.

Choy said that from his window he can look out over the bay and watch entire families move from ogo patch to ogo patch taking everything in their path.

Kaneohe fisherman Malcolm Varde said he thinks part of the problem is that the people picking the ogo are immigrants unfamiliar with the way things are done in Hawaii.

"The local people kind of know. They have a set of rules that means that they pick some for themselves and leave behind some for somebody else. These guys pick for subsistence purposes to sell . . . They come in 10 or six at a crack in inner-tubes and you know they're not picking 20 pounds for tonight's poke."

But University of Hawaii Sea Grant Extension agent Mark Suiso said it is wrong to blame immigrants for the problem. He said that gathering ogo to sell in the market is the only way many of them can feed their families. Besides, he says, "local people are just as greedy as anybody else.

"The whole attitude is that, 'If I don't take this limu, somebody else will, so I better get all.' . . . The problem is that the state says that everybody has open and equal access to everything in the ocean."

Director Henry Sakuda said his state Division of Aquatic Resources has received a number of calls about the ogo problem. He said a new regulation concerning the taking of ogo is being drafted and that public hearings are planned to discuss it. But he said the real need is to educate the public about the proper method of picking or cutting the plant.

Abbott said people need to learn to conserve ogo by picking or cutting the leaves but leaving the stem and root.

I asked her if she would take me to some of her favorite ogo picking areas.

"It would be a waste of your time and mine," she said sadly.

A-18 Honolulu, October 6, 1985 The Sunday Star-Bulletin & Advertiser C

Seaweed harvesters leaving once-fertile areas almost barren

from the sea

mike markrich

Isabella Abbott is a world recognized authority on the popular local seaweed known as ogo. But even she doesn't know where to find it on Oahu anymore.

Commercial harvesters have taken so much of this once-plentiful seaweed for use in poke (a raw fish and seaweed entree) that many of the places where she once went to look for this limu are now barren.

"It's the same old story," Abbott said. "You can follow the collectors from Hanauma Bay to Waianae over a period of months and you can tell where they have been every step of the way . . . There's bare rock where I knew there used to be plants. From Nanakuli to Waianae, it's clean as a whistle."

She said the problem is the way in which people are harvesting for what she estimates is a $300,000 a year ogo market. She said that rather than cutting off the top of the plant with a knife so that it grows back, many commercial gatherers pull out the entire plant by the roots. As a result, the plant is not able to grow again in the same place.

"It's like pruning a fruit tree," said Abbott, who has studied seaweeds for more than 40 years. "If you trim the branches carefully, the tree will grow back even fuller than before. But if you cut it in half and pull up the roots, that's it."

Abbott said ogo only grows in certain areas along the shoreline where rocks sit upon a sandy bottom to a depth of approximately 4 feet.

She said that because the plant is so selective in its choice of habitat, it does not grow back again in the same place when pulled out.

In Chile, Abbott said, so much ogo has been pulled off the rocks in recent years to satisfy the seaweed export market that it has become an endangered species.

Although the problem has not yet reached that stage on Oahu, there is concern among people living on Kaneohe Bay that ogo-growing areas there are disappearing.

"I think maybe that the people doing it don't know how to

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LOVES ALGAE—George Herzer is enthusiastic about Hawaiian waters and red seaweed. —Star-Bulletin Photo by Terry Luke.

Entrepreneur Plans to Market Seaweed at $10-20 a Tea Bag

By Helen Altonn
Star-Bulletin Writer

One of the best remedies for sunburn is found under water on Penguin Bank off Molokai, says a man who dives in the area.

It's a seaweed known by its Japanese name, ogo, says George Herzer. Its official name is Gracilaria bursapastoris, a member of the Rhodophyta (red seaweed) family.

Local scientists say, however, that they are not aware of abundant amounts of seaweed growing on Penguin Bank.

"I love it — I love algae," Herzer said, pulling containers of the dried stuff from drawers and cupboards on his yacht, Queen Victoria, at the Ala Wai Yacht Harbor.

He poured a little ground algae (not the red kind) into a glass of water and offered it as a "soap" for washing hands. It worked just fine.

He also mixed some dried red seaweed with water to show how it feels on the skin. Mrs. Herzer is as enthusiastic as her husband about the algae. She said it's a good moisturizer and "so soft for shaving."

University of Hawaii botanist Maxwell Doty and Bishop Museum botanist William Magruder — both algae specialists — said seaweed gels do have wide use for cosmetics, shampoos and other things.

But they question Herzer's source of red seaweed at Penguin Bank. They said there isn't any abundance of seaweed there, especially gracilaria.

"It would be nice to know what seaweed it was and where it came from exactly," Magruder said. "It can't come from Penguin Bank."

"I'd like to see a piece of seaweed he's using," Doty said. "He may be getting a seaweed and extracting a gel from it and using it for cosmetic preparation, and they're quite good by the way. But I don't think he's getting it from gracilaria or ogo at 14 fathoms on Penguin Bank."

Herzer, an Argentine, says he operated an algae laboratory in Patagonia for 14 years. Before that, he was president of a laboratory in Buenos Aires that produced insulin.

Herzer arrived here in 1981 during a three-year trip around the world on his yacht with his wife and five children.

Herzer returned three years ago with his family to stay and see for himself what he had been reading about the past 10 years in books on Hawaiian seaweeds. He said he has consulted with University of Hawaii and Bishop Museum scientists and studied the museum's algae collection.

HE SAID ONE of his sons, 24, has red hair and fair skin that burns easily. "I studied the effects and reaction of algae and I found this one will do it. . . ." The red algae contains the same kind of nutrients found in the aloe plant "but it is 10 times more powerful," he said.

Seaweed doesn't prevent sunburn but soothes the skin with a "cool effect," Herzer said. If his son burns and blisters, the algae makes the blisters disappear, he said.

He has started to package the algae into "sunburn pads" to begin marketing the product. He calls it Limu-Kai "to explain very clearly that it's an ocean algae. It is pure protein."

He said it will be "very expensive." Each little bag, similar to a tea bag, will cost $10 to $20, he said. "But on the body, it's fantastic."

Ocean-lovers scurry to find cause of 'green slime' algae's big bloom

The Maui News / MATTHEW THAYER photo

Dive Instructor Pete Priedhorsky holds some of the algae bloom that once again has started littering Kaanapali beaches. Priedhorsky found the small clump of seaweed tucked in his dive suit when he emerged from the water last week. He says there is plenty more where it came from. "At 80 feet down it's growing all over," he said.

By JILL ENGLEDOW
Staff Writer

KAANAPALI — The "green slime" is coming back to west side waters, and people concerned about the quality of the ocean there are trying to figure out what to do about it.

The slime is algae, a natural inhabitant of the ocean that has gotten out of hand in the past and shows signs of doing so again this year. Divers and environmental activists worry that 1991 could be a bad year for ocean users, as 1989 was.

That year, a heavy bloom of algae all along the west coast off Kaanapali and north of there created what one diver called "disgusting" conditions in the water. Swimmers reportedly came ashore draped in green algae, and the stuff covered rocks visible at low tide. Waters were murky and smelled of rotten seaweed, several witnesses recalled.

Rep. Roz Baker said private property owners dredged and hauled away tons of the stuff from the shoreline near their land.

Bobby Iaconetti, a diver who works at the Hyatt Regency Maui, said he has lived here all his life and had never seen anything like the algae bloom of 1989. He's worried it could be worse this year because the algae has appeared earlier in the spring.

By August 1989, the waters were

See OCEAN-LOVERS
on Page A5

Ocean-lovers scurry to find

Continued from Page A1

thick, and this year "it's already at an advanced stage," Iaconetti said.

Divers started seeing an unusual abundance of algae in water 40 to 80 feet deep as early as February.

Though the algae reportedly begins its growth cycle in deep water, it washes in and is trapped in the circle of Kapalua Bay, diver Kevin McAfee said. It has cut visibility there on a good day from more than 80 feet to about 25 feet, and "sticks to the reef like Velcro," he said.

"It's going to kill off a lot of coral, I'm afraid."

Some people who live near and work in the waters off the shores of West Maui think the problem of overabundant algae blooms is getting worse because of increased nutrients from runoff from fertilizers, sewage or both.

Scientists who have looked into the problem say that while runoff could contribute, there are too many variables in the ocean environment to say whether these blooms are caused by the human presence on shore.

A marine biologist who used state money last year to study the water off Kaanapali said he found no unusual sign of nutrients, and while there was no algae either, he expects that sort of problem would be there from year to year.

Dr. Steve Dollar of the University of Hawaii Institute of Marine Biology said he isn't sure why the algae blooms happen, but the fact that it is starting this year in deep water indicates that shoreline pollution has little to do with the bloom.

Such blooms are not uncommon, occurring off the shores of Kihei and Paia, for example, as well as elsewhere in the islands. The blooms could be simply a natural cyclical occurrence, other scientists said, and only a serious study of the situation will come up with real answers.

That's something the concerned citizens agree with, and they want to encourage funding for the kind of study that will decide whether something on land is causing the bloom and what can be done about it.

West Maui environmental activist Eve Clute said the Kaanapali Ocean Recreation Management Association met Saturday to discuss the situation, and the County Council will talk about it Friday at its regular meeting.

One bit of possibly good news is that the particular species of algae blooming now is not the same species that caused problems two years ago.

Skippy Hau of the Department of Land and Natural Resources Division of Aquatic Resources sent samples of this bloom to Dr. Isabella Abbott, a botanist at U.H.

Abbott said this time the same genus, Cladophora, is appearing, but it's a different species, one that is found in deep water. The species that appeared in 1989 occurs in all depths of water, she said, and also seemed to have a double-time life history, living out its life cycle in two weeks rather than between one full moon and the next.

Abbott said she doesn't know for sure that the current bloom won't cause trouble close to shore, but it is a species that so far has been collected only in deep water.

Abbott suspects the bloom is natural and seasonal, and there's no evidence runoff is encouraging it. She said there is a study going on in Big Island waters, trying to learn whether the addition of nutrients like nitrogen and phosphate will change seaweed growth, but it's hard to do this kind of research in the field because of all the variables in the ocean.

Maui marine biologist Dr. Frederic Martini agrees it's hard to point the finger at any one source for algae growth when there are "27 variables" to take into account.

Martini said the algae that caused the 1989 problem is one that flour-

cause of algae's big bloom

ishes in disturbed waters, with siltation and freshwater input. He said the last bloom appeared in a time of high surf, which could have moved nutrients from shore to deeper waters.

"Just about any nutrient source is enough" to encourage growth, he said.

Hau said while nutrient runoff could contribute to the problem, algae blooms are a natural phenomenon in the spring.

But the abundance of the 1989 bloom and of the present one makes some west side residents think something besides increased light and warmth is encouraging growth.

They say the algae blooms more after heavy rain, indicating that something washing into the water feeds it.

Some think sewage entering the ocean may have something to do with the problem. They say it could be sewage injected into the ground years ago, now finding its way into the ocean through underground channels or lava tubes.

Dollar's study showed no sign of that, and county Wastewater Management Chief Eassie Miller said the county's system has no outfall that could be feeding the bloom. Sewage is pumped straight to the treatment plant at Honokowai, and the effluent disposed of through injection wells is low in nitrogen, he said.

The Kaanapali system, previously a private system, now is tied into the county system, and its pumping station hasn't overflowed onto the golf course for about three years, Miller said.

Iaconnetti said the algae growth is "like a forest" in an area around a discharge pipe that protrudes into the ocean near the Royal Lahaina Hotel. Miller said that is not part of the county system, but could be part of a land drainage system. In that case, it might indeed be funneling fertilizer runoff from golf courses, sugar land and landscaped areas into the ocean, as some have speculated.

State environmental officer Blake Shiigi, who is responsible for monitoring water quality around the island, said he checks the water off Kaanapali for both bacteria and for the kinds of nutrients found in fertilizers. Shiigi said the bacteria counts have been normal, indicating no sewage contamination.

Results from the chemical samples from this site and others along the coast go to a computer on Oahu, and Shiigi doesn't get a report back. The sampling is part of a program to develop baseline data on what's in the ocean.

Shiigi said the state is starting a new testing program in deep water this week, and he'll have help from Oahu to test deep waters for heavy metals and toxics. He doesn't know if this will include nutrient testing as well.

"Until we do a study, there's no way for us to reach a reasonable conclusion" about runoff, Shiigi said. And with only one man doing all the environmental testing for the entire county, "we just don't have the resources to do a study right now."

Eugene Akazawa, supervisor for the state's ocean water testing section, agreed the Health Department has no resources to address the algae probem, and suggested the university or a private consultant needs to be hired to do a "more specialized survey."

Akazawa said it's "a reasonable assumption that there's some sort of nutrient source that's encouraging growth." He said it's possible there's a source somewhere in deep water of runoff from an underground channel, perhaps accumulated sewage effluent from injection wells used years ago.

Akazawa said the department will work with DLNR and whomever it can to at least document the occurrence, recording what happens so someone eventually can figure out why such blooms happen.

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Maui seaweed excess problem to be studied

By Edwin Tanji
Advertiser Maui County Bureau

WAILUKU, Maui — Bishop Museum scientist William Magruder, one of the state's top researchers on Hawaii seaweeds, is leading a task force to study the problems caused by algae "blooms" that have been plaguing some Maui waters for the past several years.

In a presentation to the Maui Council Public Works Committee last week, Magruder said he also will prepare a proposal for a county-funded study of the problem. The county has allotted $15,000 for the study.

The committee approved a resolution asking the state Department of Health to conduct a study, saying it may help the work already started by Magruder.

Although problems of excess limu, or seaweed, have occurred periodically around the state, a green limu — identified for now only as a species of *Cladophora* — has been causing increasing concern off West Maui.

The *Cladophora* was first reported in mid-1989 off Kaanapali and now is found from Lahaina to Kapalua. Based on observations and reports from divers, Magruder said the *Cladophora* is found in waters from 40 to 60 feet deep. During the summer months, however, it accumulates nearer shore, posing a nuisance to swimmers and snorkelers.

What's causing the seaweed to spread? Magruder offered no firm answers.

He said he is approaching the research with an open mind, making no assumptions about the causes of the blooms despite numerous claims and theories focusing on use of fertilizers on golf courses and large fields.

"It's not obvious why it's happening," he said.

He cited theories that include overfishing of the fish that eat the limu, excess nutrients from sewage leaks into the ocean, and siltation from runoff during heavy rains.

He said use of fertilizers and pesticides by homeowners may be a factor.

Large mats of drying seaweed along the shorelines are a smelly nuisance, hampering beachgoers and attracting flies and other insects. Two other seaweeds are causing problems of seasonal blooms that result in large amounts of seaweed washing ashore on Maui as well as elsewhere in the state.

One is an introduced red seaweed, *Hypnea musciformis*, that reportedly first appeared in Oahu's Kaneohe Bay in the late 1970s and rapidly spread to most of the islands. It is a thick, bushy seaweed growing in nearshore waters.

The other is a common Hawaiian limu, *Ulva fasciata*, commonly known as sea lettuce or palahalaha. It is a flat, green limu found usually attached to rocks along the shoreline.

Magruder said the palahalaha is the culprit in a summer bloom in Kahului Harbor that leaves piles of rotting limu along the shoreline. The cause of the bloom is apparent, he said. The harbor is an enclosed area, with little flushing from the open ocean and with high nutrient levels.

Determining the source of the nutrients in the harbor waters is another matter. Potential sources include injection wells from the Kahului sewage treatment plant or the Maui Pineapple Co. cannery, runoff in the two drainage channels leading into the harbor, leaks from old sewer lines and even old cesspools that were covered long ago.

On the *Cladophora* found off West Maui, Magruder said he only has preliminary observations based on reports by other divers and his own diving expeditions. But the green seaweed apparently is limited to West Maui for now.

He said he did not know if it is an introduced species, like the *Hypnea musciformis*, or is a species that originated in Hawaiian waters and suddenly bloomed off Maui.

EPA expert leads Maui battle for cleaner sea

Approach is watershed management

By Edwin Tanji
Advertiser Maui County Bureau

WAILUKU, Maui — A marine ecologist on loan from the federal Environmental Protection Agency is heading an effort to develop a West Maui watershed management plan to deal with pollution in the waters off West Maui.

The project could be a model for other areas of Hawaii where pollution of the ocean is an issue, according to Bruce Anderson, deputy state health director for environmental affairs.

NEIGHBOR ISLAND NEWS

Wendy Wiltse, the EPA scientist, last week organized an advisory committee that will help develop information and make recommendations for managing the area.

She said she also welcomes comments from residents of West Maui, including long-term residents who can discuss conditions in years past and those who have proposals for solutions to problems.

The advisory committee includes representatives of major landowners such as Pioneer Mill and Maui Land & Pine, scientists, Lahaina residents and various county officials.

EPA scientist Wendy Wiltse can be reached at the Lahaina Comprehensive Health Center, phone 661-0464.

Developing an agenda for themselves, the members yesterday said their primary concern is developing information on what is in the sediments carried in runoff during rainstorms.

They also want information in areas such as the impact of sedimentation on the ocean environment, how much runoff would occur naturally, the cost of dealing with storm runoff and determining what is contributed by residents using chemicals in their homes.

There is $850,000 in federal funding available for Wiltse's two-year position as well as for various studies looking for causes of high nutrient levels in the waters off West Maui. The state has provided another $100,000 for research.

The area has suffered from a periodic algae bloom of a type of green seaweed that is rarely seen in other areas of the state. Preliminary studies determined there is a high level of nitrates in the seawater.

Wiltse and Anderson said the project is unique in Hawaii in taking an all-encompassing watershed approach to a problem in the ocean.

It involves studying all activities in an area in trying to determine the cause of a problem in the ocean.

"It's a more holistic, integrated approach to management of land and water resources," Wiltse said.

Anderson said there are two similar but less comprehensive programs on Oahu aimed at managing activities on land to prevent pollution of the ocean. A project in Waimanalo seeks to develop a watershed management plan, while a program in Kailua will involve volunteers monitoring runoff.

Maui News ; Mon Jun 28, 93

Seaweed problem fouling shoreline around Kuau Bay

PAIA — Tons of *hypnea musciformis* (hooked seaweed) is rotting on the shore of Kuau Bay and other once-pristine beaches of Maui's north shore. This summer's accumulation of the obnoxious seaweed is the heaviest seen since this column first reported on the problem in 1986.

A recent survey found a solid wall of the rotting stuff stretched more then 120 feet along the beach in Kuau. The pile was three feet deep and about 12 feet wide, and under the intense summer sun it gradually decomposed into a soggy, putrid mass. The portion of this wall of seaweed that is not kept wet by the waves gradually dries up, but the front part of the mass is kept alive and is constantly supplemented by additional deposits.

Hypnea musciformis was brought to Hawaii in the 1970s as a possible source of a chemical similar to agar, which is used as a culture medium or a gelling agent in foods. Unfortunately, it proved difficult and expensive to process, and the project was ended. But the seaweed remained in Kaneohe Bay, where the ill-fated experimentation took place.

PAIA
William D. Tavares

Isabella Abbott, professor of botany at the University of Hawaii, recently informed me that the pest has spread to all the major Hawaiian Islands except the Big Island and is most-widely established on Maui. According to Abbott, *hypnea musciformis* is acting like other introduced weeds, running wild in its proliferation, much as lantana did when it first was introduced.

Several years ago, Abbott sent me some recipes for preparing this seaweed into food. The plant contains high-quality calcium and iron, more of vitamins A and C than most fruits and vegetables, and lots of iodine. Anyone interested in eating the stuff can phone me for the recipes at 579-9224. As Abbott told me, if you can't beat it, eat it.

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Christmas House, the annual fundraiser for Hui No'eau Visual Arts Center, will be held Dec. 3, 4 and 5 at 2841 Baldwin Ave. in Makawao. The event will showcase the handmade works of hui members and include distinctive jewelry, toys, holiday ornaments, quilts and other items. Screenings for items to be sold are scheduled for each Thursday in July. Hours are from 9 a.m. to 1 p.m. this Thursday and July 15 and 29, and 1 to 5 p.m. July 8 and 22.

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The Tau'a, Bissen, Wilhelm, Soares, Kim, Kaholokula and Lyons families will hold their first Luaehu ohana reunion July 2-5 at Punaluu, Oahu. The seven families originated in the district of Huelo, Maui.

The reunion committee urges all those interested in attending to contact Holly Kim on Oahu at 456-0688.

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Funds OK'd to research algae bloom

The Senate Appropriations Committee has agreed to a request from U.S. Sen. Daniel Inouye to earmark $400,000 in EPA money to study and combat a mysterious green algae bloom off west Maui, Inouye announced yesterday.

Experts are still trying to determine what caused the algae to bloom at increased rates since 1988. The bloom has been blamed for destroying coral, and has interfered with recreational uses of the West Maui beaches.

The cause of the algae has not been determined, but one possibility is that excessive nutrients are washing into the water from Maui County sewage effluent or fertilization of fields and golf courses.

Earlier this year the U.S. Senate approved another $500,000 in National Oceanic and Atmospheric Administration funding to study the problem.

Hanauma Bay Educational Programs recognized for environmental work

by Jill Ladwig Katter

Hanauma Bay Educational Programs, a non-profit, environmental organization, recently won a Chevron Conservation Award for its efforts to restore the reef at Hanauma Bay. Hanauma Bay Educational Programs (HBEP) was the first Hawaii organization to receive the honor in the 39-year history of the award.

The program was born after several groups realized the need for an educational effort to reverse the effect that overuse has had on the fragile reef ecosystem. The Hawaii Sea Grant Extension Service, the City and County Department of Parks and Recreation, and the State Department of Land and Natural Resources banned together to form HBEP in 1989.

The unique, volunteer-driven program combines a beach side information desk, cleanup patrols, a fish food exchange program called the "pea patrol", an outreach program for schools, and natural history tours of the bay. The combined efforts have proven surprisingly successful.

"Our biggest accomplishment has been the reduction of visitors feeding the fish inappropriate foods," says Lisa King, educational coordinator for HBEP. "The word has gotten out that bread, peas, and corn are not acceptable food for the fish."

The HBEP outreach program is also successful. The program went on the road in March and spent a week at Maui public schools to educate students about the reefs of Hawaii.

"Our main objective with all of our education efforts is to increase public knowledge about the fragility of reefs and to encourage stewardship of the marine ecosystem in general," King adds.

A total of 25 individuals and environmental organizations from around the country were recognized at the award ceremony, which took place in Washington, D.C. King and Park Manager Alan Hong attended the ceremony, and brought home a bronze plaque and a check for $1,000. The money will be used to continue the program's efforts.

The state legislature recently allocated more than $100,000 to keep the program going for another year. That indicates the wisdom and foresight of the state, according to Dr. Jack Davidson, director of the UH Sea Grant College Program.

"We are extremely proud of HBEP and of Lisa's accomplishments," says Davidson. "Sea Grant is in the business of planting seeds to solve problems, nurturing the creative effort, and then letting a project or program stand on its own, and HBEP clearly accomplished that."

Lisa King and Alan Hong receiving the Chevron Conservation Award from Jim Sullivan, Vice President of Chevron Companies.

—photo courtesy of Chevron

Watch out for this marine organism: *Palythoa toxica* (Limu-make-o-Hana)

Description: *Palythoa toxica*, a zoanthid, is an anemone-like animal that lives attached to other *P. toxica* in a colonial mass which resembles soft coral. The heavily-encrusted individuals average 5 mm in diameter and may grow to 14 mm in height, but colonies may be extensive. The oral disk is brown, often with random patterns of white spots around the mouth. It is sometimes found in surge pools at Lanai Lookout and Blowhole on Oahu, and the Hana district on Maui. Non-toxic zoanthids exist, including the common *Palythoa tuberculosa* or cushion zoanthid.

Symptoms/injuries: The strong toxin present in the mucus of this species can be deadly if ingested. If any mucus is accidently ingested or if the animal comes in contact with an open lesion, get emergency help immediately. *Palythoa toxica* was reportedly applied to speartips in old Hawaii to make them lethal.

Treatment: Rinse promptly and thoroughly with water to remove toxin. Consult a physician immediately.

Protective measures: Do not touch these animals and stay away from areas where they are found.

Sea Grant Investigates...

Sponges ofer clues to medical remedies

by Angela S. Miller

Hawaii Sea Grant researcher Dr. Paul J. Scheuer has devoted the bulk of his 40-year career looking for sponges — sponges that hold more than water.

Dr. Paul J. Scheuer in his lab at the University of Hawaii, where he isolates molecular structures of marine invertebrates. —*Sea Grant photo*

Scheuer believes formulas for new medicines may be locked up in the molecular structures of these marine invertebrates.

The medical world is in constant need of treatments for new diseases, such as AIDS, and old diseases, such as cancer, because human systems have become immune to some current drugs, Scheuer said.

Researchers are turning to the oceans as the world's "single largest untapped source of new, organic chemicals, many without terrestrial counterparts," he said.

Scheuer, a professor of chemistry at the University of Hawaii since 1950, began his lifetime research into the biomedical benefits of marine metabolites when he "discovered sea urchins" while snorkeling.

"I saw some beautifully-colored sea urchins at Hanauma Bay, and I was wondering whether anyone knew what the chemical nature of their color was,'' Scheuer said.

When his initial investigation revealed that little was known about the chemical composition of marine invertebrates, Scheuer embarked on a line of research that would make him a leading authority on the subject. In 1973, he authored *Chemistry of Marine Natural Products*, the first book of its kind on the subject. Since then, he has edited several more books of compiled essays from marine scientists around the world.

Scheuer applied his knowledge of marine invertebrates to the biomedical field when he joined a group of biologists who were studying the ecology, chemistry, and pharmacology of ciguatera poisoning, an ailment caused by eating contaminated fish.

Scheuer explains why sessile, soft-bodied invertebrates are ideal specimens for biomedical research: "By conventional wisdom, animals that can swim fast or that have spines or hard shells are not apt to need much chemistry to protect themselves, while a sponge that sits in one place has to develop some other defense (in order to avoid getting eaten up) ."

The chemical defenses of many of these animals contain molecular structures never before identified by man. These newly discovered structures serve as a model for chemists to follow in synthesizing new compounds.

Scheuer and his team of researchers collect various sponges and other marine invertebrates in waters around Hawaii and South Pacific islands. They evaluate the animals for potentially useful biological properties at UH and mainland laboratories.

"We have two fairly good leads at the moment to anti-HIV activity but no pure compound yet ," Scheuer said. "Lots of things can happen between now and then, but the early anti-HIV results are very promising,'' he said.

The compounds, which are still undergoing the purification process, were found in a tunicate from Pohnpei and a green alga from Malaekahana Beach Park on the North Shore of Oahu.

Since the organisms are used for research purposes only, the discovery of a new drug from their molecular structure will not mean a mass harvesting of the oceans, Scheuer said. Scientists will eventually culture the organisms or synthesize them in the laboratory as a source for a newly discovered drug.

In 1980, a scientist from a Japanese pharmaceutical company asked Scheuer to take over research of a sponge that his company was not willing to spend the time or money to investigate. One of Scheuer's graduate students determined the molecular structure of a compound called okadaic acid and published his results. Further research revealed that the compound serves as an effective tumor promoter, which helps cancer researchers in their study of cellular regulation — a major area being employed in the search for a cure for cancer. Today, okadaic acid is commercially available and a widely used experimental chemical for the basic study of cellular regulation.

"The ironic thing is that the original company did not think it was of any use," Scheuer said.

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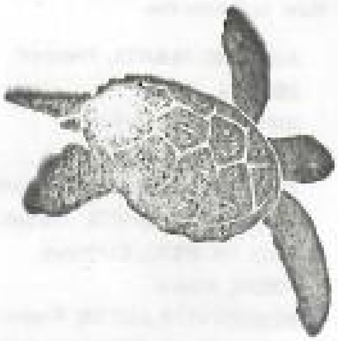

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John F. Bamrick and Edward T. Cawley
Consulting Editors

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how to know the seaweeds

Second Edition

Isabella A. Abbott
Hopkins Marine Station
of Stanford University

E. Yale Dawson

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Preface

The oceans have long been considered to be limitless as a dumping grounds for our wastes and our burgeoning technology. In recent years, though, clean ocean water (as with the air around us) has become a goal that we Americans, at least, are trying to reach. A marine flora with large numbers of species abounds in clean water. Fewer species are found in polluted water, although some species such as *Entromorpha* (a green alga) is frequently present where fresh water intrudes, and others, such as *Ulva* (also a green alga), where nitrogenous levels are high. Since algae are at the base of the food web, it is clear that various animals higher in the web may not do so well in areas that have had algae removed by one means or another.

Whether we shall be eating algae in the near future, or animals that feed or are housed upon them, attention has been focused upon the algae as never before. This Field Guide is intended to help identify various species of algae along our coasts, with emphasis on the common or very conspicuous ones. Of the 175 genera included here, 79 of them are common to the east and west coasts of the United States, 15 occur only on the east coast, 55 on the Pacific coast, and 26 occur in Florida and the Caribbean. Many of the latter also may be found in Hawaii. Although there appears to be a heavier emphasis on the Pacific coast algae, it must be remembered that there are far more distinct genera of brown and red algae occurring on the Pacific coast than elsewhere on the North American continent. Additionally, the first author of this Guide, Dr. Dawson, as well as the present author are primarily students of Pacific algae.

Assuming that one becomes familiar with only the genera common to both coasts, one would know about half of the common marine algae of the United States—a very good beginning indeed. In the use of the illustrated keys, it is hoped that once having found what appears to be a good match for the specimen in hand, reference will then be made to the excellent local floras (see Bibliography) that are available. In this way, the collector progresses beyond obvious recognition and becomes a student of these most interesting plants.

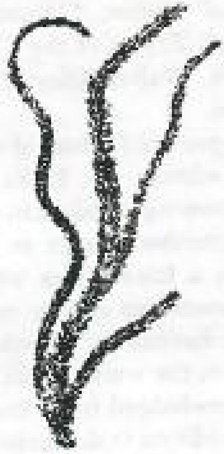
Among the unusual and conspicuous algae that a stroller may encounter on the Northern California beaches, for example, is *Nereocystis*, a kelp conspicuous for its single large pneumatocyst. The stipe below the pneumatocyst, when cut off, may be used as a musical horn, sounding much like a trumpet. Though frequently encountered as drift on these northern beaches, its geographic range is limited. Similarly, the whitish segments of *Halimeda*, a green alga found in southern Florida and the Caribbean, are frequently brought in as a "funny coral", although the distribution of this genus in the United States, being warm-temperature dependent, is even more restricted than the cold-temperature dependent *Nereocystis*.

The original text and organization of this book by Dr. Dawson have been followed. This edition brings the geographic distribution and the nomenclature of various species up to date, adds some new information, substitutes some illustrations for others, and adds some new illustrations in order to make comparisons easier. A new bibliography has also been prepared.

For general advice, I thank Professor William Randolph Taylor of the University of Michigan and Dr. Walter Adey of the Smithsonian Institution.

Finally, a personal word about the author of the first edition, Dr. E. Yale Dawson, who died in a drowning accident in 1966, at the peak of a distinguished career in phycology. Dr. Dawson was a friend, one who was admired for his tremendous energy and achievements. His contributions to knowledge of algae, particularly in the warm Pacific, are large and will be acknowledged for a long time. To his memory, this edition is dedicated.

Isabella Abbott



The Vegetation of the Sea

Four-fifths of the surface of our globe is covered by salt water, and since all of the multitudes of animal inhabitants of this vast aquatic environment are ultimately dependent upon the photosynthetic plants, we may say that in one sense the marine plants are the most important of all the groups of organisms on earth.

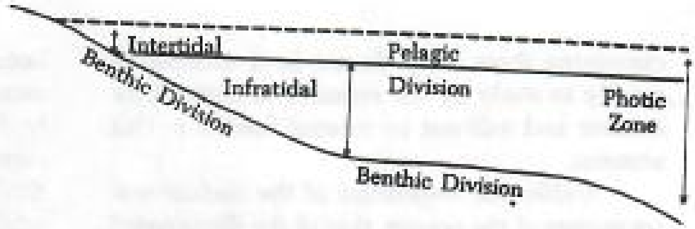
In the sea, extremes of climate are modulated by the water medium, and the vastly predominant environment is one of monotonous darkness and cold. Accordingly, the diversity of living things on the whole is less than on the land, and while some groups are poorly represented, others are entirely lacking. Thus, whereas the highly developed mammals are sparsely represented in the sea and the insects not at all, in the marine vegetation the seed plants and fungi are few and the ferns and mosses absent. On the other hand, some of the phyla of organisms present in the sea are absent on land, or much less richly developed there. This is true of the several groups of plants known as algae of which the great bulk of the marine vegetation is composed.

With the exception of the bacteria and of a few parasitic and saprophytic fungi, virtually all of the marine plants are autophytic, that is to say, independent and capable of providing their own food by means of photosynthesis. To do this they need two primary raw materials, namely, water, which is seldom in short supply, and CO_2. Energy for the process of photosynthesis must be supplied by sunlight which, however, is largely absent in the sea. Most of the marine environment is totally lacking in sunlight which penetrates, even in the most exceptionally clear water, only to as much as three or four hundred feet. Accordingly, these autophytic plants are restricted in the immensity of the oceans to a relatively thin layer of illuminated surface water and to the narrow intertidal and infratidal fringe within this photic zone. In these places, however, they may be remarkably abundant.

The general habitats of the plants of this illuminated portion of the sea may be diagrammed as in Figure 1. The vegetable inhabitants of the pelagic division, that is, of the water mass itself, are the phytoplankton, while those of the benthic division, or the sea floor, are what we may call the seaweeds, or attached algae.

The phytoplankton consists of free floating, unattached plants which move about only as their water medium moves. With few exceptions they are unicellular forms of microscopic size requiring quite high magnification to render them visible (Fig. 2). Despite their

Figure 1 Diagram of the general habitats of the plants of the sea.



small size, their habitat in the surface waters of all of the oceans is so vast and their numbers so great that they actually account for more than 95% of the vegetation of the sea.

Several different kinds of organisms make up the phytoplankton (Fig. 2) of which may be mentioned the diatoms, the pigmented dinoflagellates, the silicoflagellates, the coccolithophores and a few blue-green algae. Most abundant of these constituents are the diatoms, of which several million may sometimes occur in a single quart of sea water. These are unicellular members of the division Chrysophyta whose protoplasm secretes a beautifully sculptured, bivalved, silicious shell (Fig. 3). The shell is basically like a pill-box in structure, but often is marvelously modified for flotation where perpetuation of a species depends upon the ability to remain in the photic zone.

Because of the tremendous numbers of these tiny plants in the sea, and of the perpetual rain of their insoluble silicious shells on the bottom, great deposits accumulate which may be hundreds of feet deep. Some of these deposits have been raised above sea level and form the beds of diatomaceous earth such as occur at Lompoc, California, and are exploited commercially for the making of fine scouring compounds.

On account of the very small size of the phytoplankton organisms, the high magnifications needed for viewing them, and the special methods required in collecting, preserving and

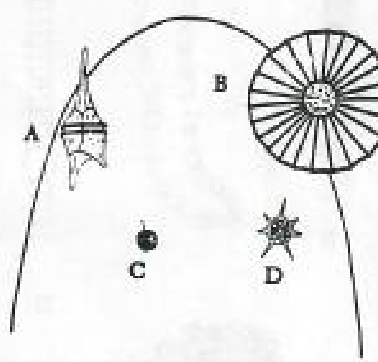


Figure 2 Some representatives of the phytoplankton. A. A dinoflagellate, *Ceratium*. B. A diatom, *Planktoniella*. C. A coccolithophore, *Pontosphaera*. D. A silicoflagellate, *Distephanus*. All are drawn to the same scale (X 225) and are shown against a heavy outline which represents the point of a dissecting needle.

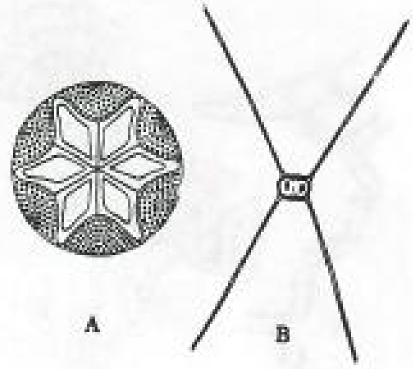


Figure 3 Examples of two different forms of planktonic diatoms. A. *Asterolampra*, a broad, flat, disc-like form. B. *Chaetoceros*, a very small-bodied form with long hairlike modifications of the silicious frustule to aid in flotation. Both × 200.

examining them, they do not lend themselves readily to study by the amateur or elementary student and will not be treated further in this account.

Unlike the vegetation of the surface water masses of the oceans, that of the illuminated sea floor and of the shore consists mostly of readily visible plants of which some reach large size. Among these, to be sure, there are many microscopic forms, including littoral diatoms (Fig. 4) and minute blue-green algae (Fig. 5) which sometimes form more or less conspicuous macroscopic colonies. These must be neglected here, however, in favor of the three main groups of seaweeds with which we need be concerned, namely, the Green Algae (Chlorophyta), the Brown Algae (Phaeophyta) and the Red Algae (Rhodophyta). The seed plants, although of very few kinds, are exceedingly abundant in many coastal habitats and will be accounted for and illustrated at the end of this book.

These three groups of algae which make up the vast majority of the seaweeds are named because of the predominant colors which their members commonly assume, and are technically distinguished by the chemistry of their pigments. Thus, the Green Algae are characteristically pigmented only by green chlorophyll, while the Brown and Red Algae have their chlorophyll masked by other pigments. On this account the Green Algae almost always appear green in color, while the others may be neither brown nor red, depending upon the relative dominance of the chlorophyll or of the masking pigments. When the color is such as to leave one in doubt as to the group to which a plant may belong, other characters must be taken into account in identification. Because of the difficulty experienced by most students in recognizing according to color the main group to which a seaweed belongs, the present key treats all of the Green, Brown and Red Algae together, separating them from each other without particular regard to color.

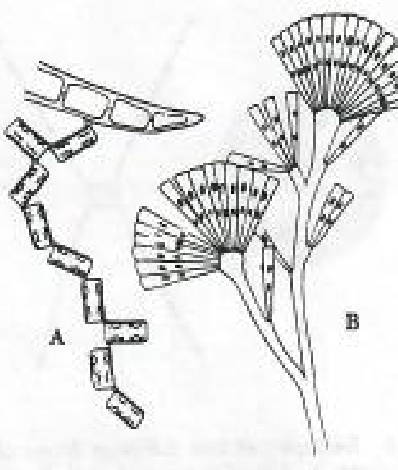


Figure 4 Two examples of different forms of littoral diatoms. A. An epiphytic, chain form, *Grammatophora*. B. A stalked form, *Licmophora*.

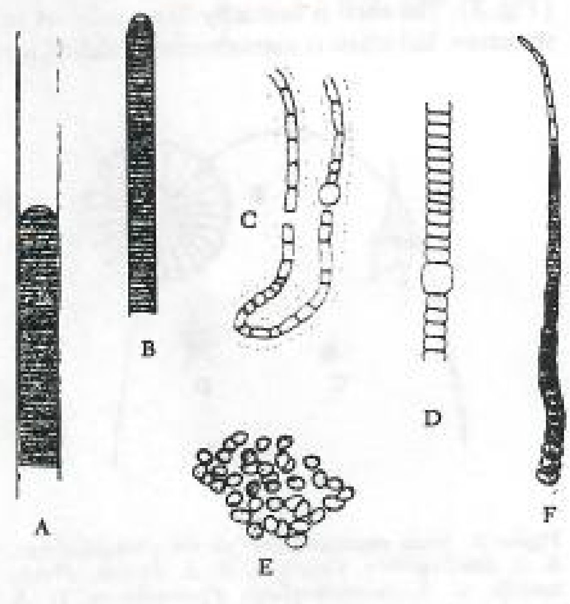


Figure 5 Some examples of Blue-Green Algae. A. *Lyngbya* sp., × 200. B. *Oscillatoria* sp., × 200. C. *Brachytrichia* sp., × 275. D. *Hormothamnion* sp., × 330. E. *Entophysalis* sp., × 500. F. *Calothrix* sp., × 275.

How to Collect Seaweeds

Seaweeds rarely grow in the free floating state, but instead are fixed firmly at their bases and remain stationary throughout life. Only in the Sargasso Sea northeast of the Caribbean and in the Gulf of Thailand are there sizable quantities of the brown alga *Sargassum* (see Fig. 141) living in the free floating state. Elsewhere the seaweeds grow attached to the bottom or to each other. Since an unstable bottom such as one of sand or mud is unfavorable to the attachment of seaweeds, they are usually absent from such substrates except in quiet bays and lagoons where agitation is slight. On surfy shores the algae are essentially confined to rocky places where their firm attachments give them resistance to wave shock. This is especially true along the rugged, wave-swept Pacific Coast where the collector rarely encounters the richly vegetated quiet bays or estuaries such as occur so frequently along the Atlantic Coast.

The coasts of the United States offer a diversity of marine habitats scarcely equalled by those of any other nation. This diversity is so great that no single set of directions can be made suitable for a collector among the Florida keys, another on Cape Cod and another on Puget Sound. One can only make a few general remarks and suggestions, leaving the rest to the adjustability and ingenuity of the American individual wherever he may be.

At the outset it is clear that one must get to the seashore to collect seaweeds, but this is not always as simple as it may seem. Many of our rocky shores abounding in algae are subject to surf of varying intensity whereby collecting is made difficult or impossible except at times of lowest water. Accordingly, it is necessary to select a suitable time for the collecting trip, depending upon the state of the tide. Tide tables issued by the U. S. Coast and Geodetic Survey or by various sporting goods houses for the use of fishermen should be consulted for the times of suitable low water. The so called "minus tides" are the best, but even with only moderately low water much can be done if the surf is not too severe. The collector should plan to begin work at the shore at least two hours before the time of low tide in order to work the clearer water of the falling tide and to select his material successively from higher to lower levels while the plants are freshly exposed and still wet and unshriveled from desiccation.

Collecting equipment on a rocky shore should consist of a pail or two for carrying the specimens, a quantity of plastic bags for separating the larger species, and a number of small, screw-cap vials provided with 3% formalin into which small but important specimens may be preserved from loss or mixing.

For removing small plants from rock surfaces a heavy knife or other scaping tool is used, while encrusting forms which adhere too firmly may be obtained by using a geologist's hammer for cracking off pieces of the supporting rock.

Collecting Tools

At the upper levels one will find a number of minute species on the exposed rock surfaces, including various crustose forms which the initiate may overlook unless they are pointed out to him. Lower down, depending upon the amount of exposure to desiccation, one will encounter larger and smaller fleshy, clumping forms grading into the densely matted turfs, or heavy, continuous beds of algae at the lowest tide levels. It will not be enough to look superficially over the array of seaweeds to obtain a good collection, for many species will be hidden under others or will occur only in particular pools, in certain shaded crannies, along the edges of surging tideways, or on the exposed faces of outermost rocks subject to the heaviest surf. Many species will be found growing only as epiphytes or as parasites on other, larger species and should be obtained by selection of suitable portions of the host plants. Algal turfs consisting of many species may be brought back as a mass to be examined for their individual constituents in the laboratory. At lowest water level the collector will profit by wading out (in hip boots in cold areas) to look under overhanging rocks, in crannies and pools for the various species which can endure only momentary exposure to the atmosphere.

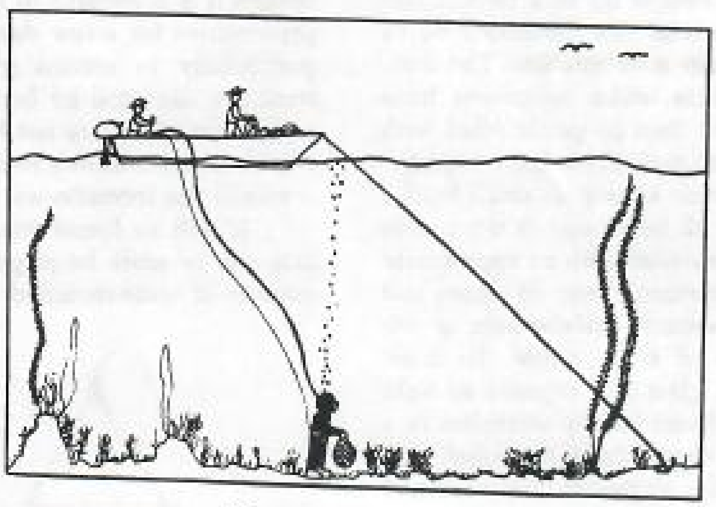
When the tide has begun to flow one must hasten to finish the work at low levels before retracing steps inward. With the incoming tide time may be taken to seek special pools and rocky habitats at higher levels which have been passed over before, and there to find additional species. Shaded cliffs subject to spray, the walls of sea caves, the under edges of rocks in tide pools, high, warm pools polluted by guano, and other such diverse habitats will all yield different species. Even pieces of dead shell or coral may exhibit a greenish cast indicating the presence of boring green algae.

After the selection of the attached algae from the intertidal rocks has been completed there is yet another source of specimens which should not be passed by. Especially at times of unfavorable tides one may profit much from examining the beach drift which often accumulates in quantity in coves or along sand beaches adjoining rocky areas. It is among these cast specimens that many of the species of the deeper, infratidal waters may be found and selected with much greater ease than through the use of a boat and dredge. If driftweed is examined after a storm while the material is still fresh and has not been exposed long to the bleaching and drying action of the sun and air, many specimens in good condition may be selected.

Apart from rocky shore habitats the algologist finds many other situations in which seaweeds may be found. Many areas in which surf is light or absent, such as the sandy or muddy shores of bays, lagoons and estuaries, will yield specimens. Such quiet habitats are especially well populated in tropical regions, and within the range of the mangrove the algal flora of its roots is an interesting one which should not be overlooked. The piling of wharves and the rock or concrete of artificial breakwaters will yield many species. Indeed, along the vast sandy stretches of the Gulf of Mexico, these will be the principal algal habitats. Even mobile objects may have their seaweed floras. Thus, boat hulls will yield several species as may also the backs of sea turtles and several kinds of crabs. Particular species have even been found attached to the intersegmental grooves of isopods parasitic on certain fishes.

Beyond the level of low tide, and apart from those cast ashore in drift, the algae of infratidal waters must be obtained by means of diving or by some manner of dredging. In very quiet, surfless waters a collector may wade about observing the bottom by means of a glass-bottom bucket and reaching specimens with ease. In depths of more than three feet, observation is best afforded by a face plate and collections made by placing specimens in a skiff as they are obtained by the diver. In depths of more than ten feet the diver must be provided with breathing apparatus in order to spend the time below the surface necessary for the selection of specimens. The "aqualung" has recently become popular with skin-divers and its use may readily be learned in most any area of warm, quiet water where these sportsmen thrive. In colder waters the diver must be provided with SCUBA or the heavy diving suit and helmet. It is this heavy suit which is normally used by the commercial seaweed collectors who harvest *Gelidium* and other *agar*-yielding seaweeds from the infratidal beds along the Pacific Coast.

Apart from those areas where skin-diving may be done comfortably, the collecting of infratidal algae is best accomplished by the use of a dredge handled by a powered winch on shipboard. The use of various devices of this sort is described by Sverdrup, Johnson & Fleming, The Oceans, Prentice-Hall, Inc., 1942, and may be observed on ships operated by the several oceanographic institutions of the country.



Harvesting *Gelidium*

Preservation of Seaweed Collections

When the day's collecting has been completed the specimens should be preserved as quickly as possible to prevent unnecessary deterioration. This is best accomplished at the shore by means of one or more five-gallon tin cans. Sea water should be brought up in a bucket and mixed with commercial 40% formaldehyde to obtain approximately a 3% solution. The various plastic bags into which specimens have been separated may then be partly filled with the preservative and tied. These bags, together with bulkier materials as well as small bottles of specimens may all be placed in the can in preservative and provided with an appropriate label. The tin of specimens may be closed and kept for months without deterioration of the specimens or loss of color, while the same specimens kept in glass jars exposed to light would be bleached and largely worthless in a few days. The tin may, indeed, be sealed with solder and boxed for shipment with ease and without fear of damage to the contents.

Of utmost importance in the preparation of any collection is the provision of adequate field data in the field collection notebook, and the careful preparation of labels. For this purpose all pertinent observations on the character of the habitat, size and aspect of the various dominant species, the major associations, water temperature, substrate type, exposure, etc., should be recorded before leaving the field. These data should be incorporated in the permanent book of field notes, in which a consecutive series of collection numbers is tabulated.

Upon return to the laboratory the preparation of specimens may begin at once, although it is preferable to leave the material in preservative for a few days time. This applies particularly to certain species which when fresh are damaged by being immersed in tap water, but which are not harmed by the same treatment after having remained a few days or weeks in the formalin-sea water solution.

It will be found most convenient to obtain one or more large porcelain trays and a number of wide-mouthed jars of various sizes

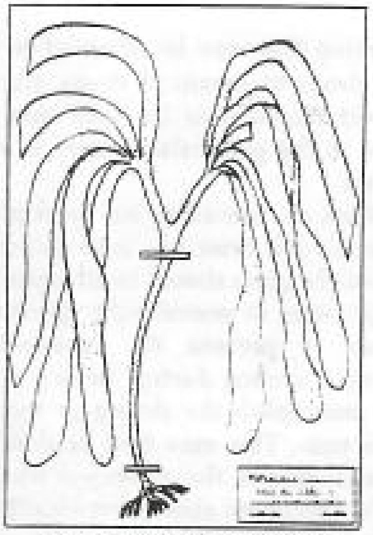
A Dredge

into which to sort the specimens. After quickly washing with tap water the various species should be separated into the jars, each species receiving a number which is listed in the field notebook beneath the field data previously recorded. Of each of the species, especially the smaller or more delicate forms, appropriate portions should be placed in small vials (4 dram shell vials) for future use in making preparations for microscopic examination. These, of course, also receive in each case the same field number assigned to the remaining material of a given species.

After the segregation of all of the species into separate containers the drying may begin. Two methods may be employed depending upon the nature of the specimens. Crustose specimens which have been brought from the shore along with pieces of their substrate may be dried directly in the air and preserved in the dry state in small boxes of suitable size. Articulated, calcareous algae which are so fragile and (or) so three dimensional as to suffer badly from pressing, should be treated in the same way, or preferably, soaked for several days or weeks in a solution of about 40% glycerine in 3% formalin before being dried and placed in the small boxes. Most of the remainder of the algae may be dried in a standard plant press.

Inasmuch as the algal specimens should ultimately be mounted on standard 11½ by 16½ herbarium paper,[1] whole sheets or suitably sized pieces of this paper may be used for the next step which is the backing of the specimen as it is floated out for drying.

Mounting may best be done in a broad, shallow tray large enough to accommodate a full size herbarium sheet. The sheet of paper to be used in each instance should be immersed in water in the bottom of the tray. The water should be of the least depth suitable for floating out the particular specimen at hand and spreading it on the paper. After the plant has been spread out in a natural appearing manner on its suitably sized sheet in the water



A Finished Herbarum Sheet

tray, the sheet should be lifted carefully from one side to allow the water to drain off gradually and to leave the specimen spread out and undisturbed on the sheet. A device for affecting this drainage may be made from a piece of galvanized sheet metal by bending down the corners to form short legs. These will permit the middle to be depressed slightly for spreading a specimen and released to allow the water to drain off evenly.

The sheet or card bearing the spread specimen may be placed directly on a dry felt in the press and covered either with a piece of cloth or a piece of waxed paper. Cloth will serve best for drying coarse, succulent specimens, while the waxed paper will prove more satisfactory for smaller forms and especially very lubricous or mucilaginous ones. Very coarse specimens need not be spread on paper at all, but arranged between cloths in the press.

1. This and other herbarium supplies, press materials, paste, packets, etc., may be obtained from herbarium supply houses such as Carpenter/Offutt Papers, Inc., 2150 Army Street, San Francisco, California 94119; Turtox Biological Supplies, 8200 South Hoyne Ave., Chicago, Ill. 60620, or Ward's Natural Science Establishment, P.O. Box 1712, Rochester, N. Y. 14603.

After drying they may be mounted on the herbarium sheets by means of straps. Each specimen sheet should bear the collection number assigned to the particular species in the field note book.

When the spreading has been completed and the last felt drier has been placed over a specimen, the press should be strapped up with the application of considerable pressure. It is necessary to prevent the specimens from shrinking or curling during the drying process and to accomplish the drying in the shortest possible time. This may best be done by frequent changing of the driers,—at least once a day. The specimens should not be subjected to heat, as by placing the press in an oven, but, rather, dehydrated by frequent replacement of the wet driers with warm, dry ones. In changing the driers the first wet one on top should be removed and a dry one placed over the specimen, then, by insertion of one hand beneath the next lower wet felt while the other is placed on top, the whole layer may be lifted and turned upside down without disturbing the specimens or the cloth or waxed paper covering them. If this process is repeated quickly for each sheet and the pressure promptly reapplied in the press, good specimens will result in which a large proportion will adhere to the paper satisfactorily by means of their own mucilage. Drying will usually take from two days for delicate specimens to a week for coarse ones. It will usually be more quickly and satisfactorily accomplished after killing the specimens in formalin than otherwise. Care must be taken to be sure the drying is complete before removal of specimens from the press, for otherwise shrinkage of the specimen and consequent wrinkling and curling of the paper backing will result.

In the preparation of the marine algae herbarium it will be found necessary to provide for the storage of several different kinds of preservations. The fleshy species which lend themselves to pressing and mounting on herbarium sheets may be handled in the same way as are terrestrial plants. Those which have adhered well to backing sheets during the drying process may be mounted by pasting to standard herbarium sheets. Tin paste or standard herbarium paste should be used. Rubber cement, plastic cement, staples, etc., are not satisfactory. Coarser specimens which are dried free of backing may be fixed to herbarium sheets by means of paste or by strips of gummed cloth. When the herbarium label, (Fig. 6) properly inscribed, has been pasted to the lower right hand corner of the sheet the plant is ready for filing. If portions of the specimen have been retained in liquid preservative, this should be indicated somewhere on the sheet for future reference.

MARINE ALGAE OF CALIFORNIA

Locality: La Jolla, California

June 1, 1946

Habitat: In deep shade at base of cliffs on southwest side of bay, among boulders subjected to heavy surf. Essentially sublittoral growth conditions. Temp. 18.8° C. at 5 a.m.

Collected by E. Yale Dawson **No.**

det. by

Figure 6 A Sample Algal Specimen Label

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Liquid preserved specimens usually may be kept in dilute formalin for months or a few years without difficulty, but for long periods of time 65 to 70% ethyl alcohol seems to be more satisfactory. A convenient procedure is to keep the small bits of preserved material in 4 dram shell vials in the one-gross boxes in which they are sold. They may be cross-referenced (indexed) on the herbarium sheets by means of reference to consecutive numbers written on the corks. More permanent filing of these is accomplished by placing them within air tight, glass capped, pint mason jars.

Bulky specimens, especially calcareous forms and crustose species adhering to rocks, shells, and so forth, may best be kept in small boxes fitting into standardized cardboard trays. The trays may be numbered and the labelled specimens referred to by means of cross-reference sheets in the herbarium file.

Specimens that are too small for convenient mounting on herbarium sheets may be placed in small packets affixed to the sheet, or, if very small and delicate, mounted whole on slides or mica (the latter preferred since breakage is minimal, but mica is difficult to purchase) and then cross-indexed. Inasmuch as the preparation of slides for study and reference is of great importance in phycology, it seems well to explain here an easy method suitable for the majority of specimens.

Permanent slides may readily be made of most species and for most general morphological purposes by using the ordinary crystal clear variety of "Karo" corn syrup (Corn Products, Co., New York). Clear honey, with experimentation on dilution necessary, will also work but is less reliable than corn syrup. Material to be used should be adequately preserved first in formalin or alcohol, dipped briefly in water and placed on a microscope slide. The specimen is first stained in a water-soluble dye such as 1% aqueous aniline blue, or in 1% aqueous fast green or acid fuchsin to which a drop of acid (usually 1% hydrochloric acid) is added, then rinsed off with a drop or two of distilled water. For delicate material, each of these liquids may be removed by blotting the edges with a piece of paper towel, being careful not to take up the delicate specimen at the same time. The specimen should now be arranged in one plane or flattened as much as possible, then a drop of corn syrup, diluted to 35% with distilled water, is added. The slide may be left uncovered in a dust-free place for 8 to 12 hours when the syrup will have dried down so that excessive plasmolysis (shrinking) of the cells of the specimen has been avoided. Another drop of more concentrated syrup (about 80%) is added, and a cover slip applied to complete the preparation which is self-sealing. Instead of leaving the slide uncovered, a cover slip may be applied carefully after the first application of syrup, and on drying, more syrup (at greater concentration) may be added around the edges of the cover slip. The slides so prepared should be kept flat for a week or more, adding 80% syrup along the edges as necessary. When completely dry in a week or so, they may be stored in ordinary slide boxes. In the case of sections of algae that have been made, because of the usually dense structure, 50 to 80% solution of corn syrup may be used directly.

Dropping bottles of syrup in various dilutions should have a few crystals of phenol, or thymol added to them in order to discourage fungi from growing in the sugar syrup. Label the bottles as *poison!*

For making sections of many specimens, a freezing microtome will prove to be the greatest help not only for the number that can be made in the shortest time, but a controlled thickness can be achieved. Adapters are available for using razor blades on these instruments, hence obviating the greatest complaint against their use—the need to sharpen a microtome knife. In addition to the ice that is made and which holds the specimen in place, using

10% solution of agar or gum arabic is helpful in giving the specimen "body".

The average phycologist, however, aims to make excellent hand sections, using a single-edge razor blade, since what he or she wishes to examine does not require a large number of sections. Practice on fleshy algae, using *Gracilaria* as an example, or blade-like algae, such as *Dictyota*. A dissecting microscope through which you can see what you are cutting and also the thickness of the section is of great help. Fresh, or preserved, or dried specimens may be used. A drop of water, or dilute corn syrup should be used when working with dried specimens in order to expand the section, which will usually return to very nearly their normal size and shape. If they do not expand, a little heat may be applied. Stubborn cases usually respond to the addition of potassium or sodium hydroxide and gentle heat. The use of liquid detergent (about 10% solution, diluted with water) is helpful in softening all brown algae and coarse green algae. The most convenient cutting method is that whereby the specimen fragment is held with a finger or a glass slide held at an angle on a microscope slide, or on a white card, and sliced with the blade against this support and guide.

Calcareous algae present special problems in sectioning. They must be decalcified first. For coralline algae, the fixative usually contains strong acids which will accomplish decalcification. The specimens are usually embedded in paraffin or celloidin. Sectioning and staining procedures may be found in accounts of botanical microtechnique such as Johansen's Plant Microtechnique, McGraw Hill & Co., 1940.

What to Look For

In beginning a study of the seaweeds the student usually expresses surprise that the members of a single family or genus appear to be entirely different from each other, while, on the other hand, members of completely unrelated groups may look alike. This is so because his superficial examination of the plants has not permitted him to see the features by which the plants may be related or distinguished. It must be emphasized that for the beginner, who has as yet no acquaintanceship with the various forms, microscopic examination of the vegetative structure and also of the reproductive organs of the plants is essential to an understanding of them and to his success in the use of the key which follows.

VEGETATIVE STRUCTURES

Among these macroscopic marine algae with which we are dealing, the seaweeds, the protoplasm is always surrounded by a cell wall which may assume a multitude of different forms and which may range from thin to thick, and from rigid to gelatinous. In a great many of the smaller algae, or even larger forms whose thalli are finely dissected, much of the cellular structure may be observed simply by making a whole mount of a piece of the thallus on a slide. The larger and coarser forms, however, have such a dense structure that it is impossible to make out details of cellular structure unless thin, transparent sections are cut to show the organization of the cells in the plane desired.

Many of the delicate forms will show under the microscope that they are made up of a single row of cells constituting a uniseriate filament. Some such filaments are always unbranched, while others are branched in various ways. The diagrams in Fig. 7 show several different manners of branching which may be encountered.

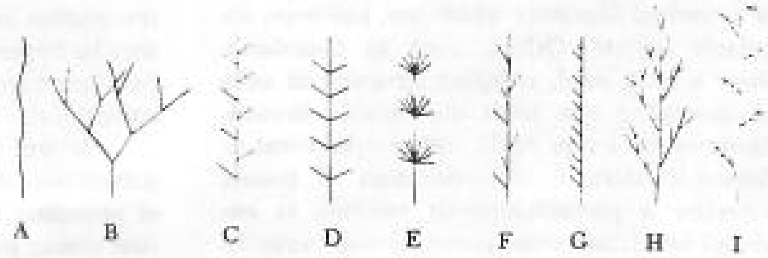


Figure 7 Some examples of different kinds of branching in the marine algae. A. Unbranched (simple); B. Dichotomous; C. Pinnate alternate; D. Pinnate opposite (distichous); E. Verticillate (whorled); F. Multifarious (irregular); G. Pectinate or secund; H. Monopodial; I. Sympodial.

Among uniseriate filaments, some will be encountered which have short cells, about as long as wide, while others will have elongated cells (See Figs. 96 and 97). Still others will exhibit only occasional cross walls, often only at the points of branching. These will be coenocytic (syncytial) forms of marine green algae in which the cells are multinucleate. Among these coenocytic green algae are a number of forms in which cross walls are rare or entirely lacking in the filaments, so that the entire plant consists of a variously ramified hollow tube. The famous *Valonia ventricosa* (See Fig. 13) consists essentially of a single large, multinucleate cell which may become as large as a hen's egg.

Other filamentous thalli will be found to be multiseriate, or made up of several rows, tiers or layers of cells. Sometimes it will be possible to interpret the structure satisfactorily by focusing through the more or less transparent external cells to observe the inner ones, but if there are more than two or three layers of cells involved it usually will require a cross section or longitudinal section to determine the cell forms and relationships. Such sections will often result in the discovery that the filament which appeared to be solid is actually a hollow tube, or that the central region contains a distinctive kind of cell structure which was invisible from the outside.

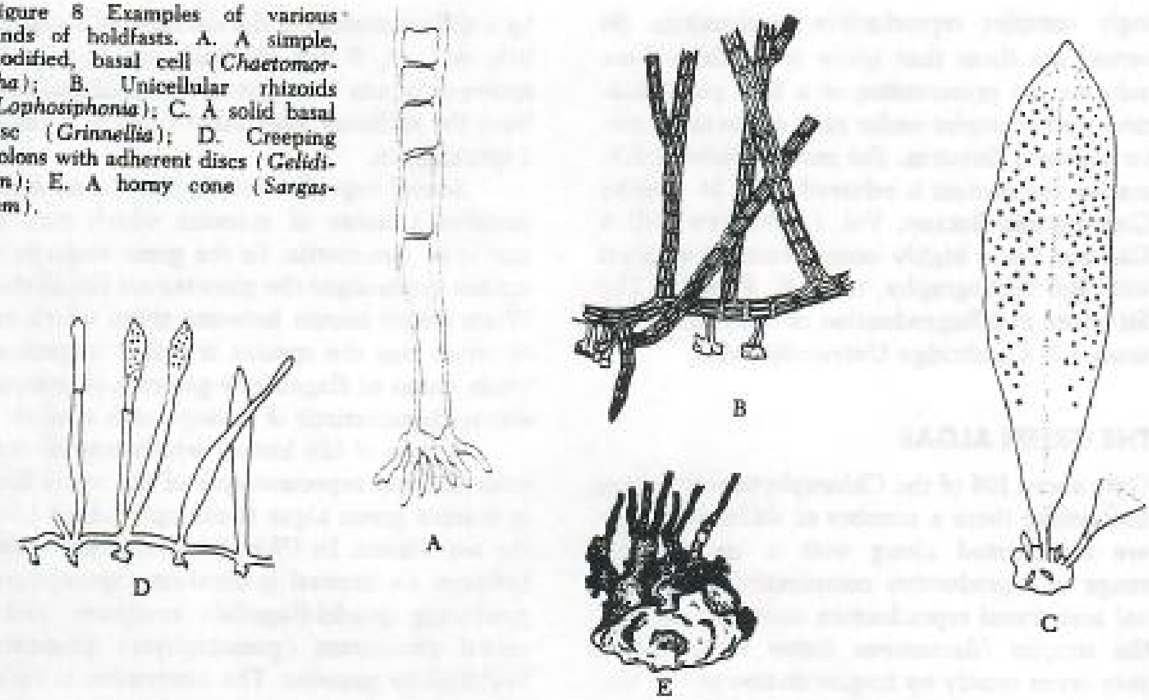
Coarser thalli will be found to be made up in a variety of different ways. Some quite large plants such as *Codium fragile* may consist entirely of branched, unseptate, coenocytic filaments, while slippery or gelatinous plants such as *Nemalion* often are similarly composed of branched filaments which are, however, regularly septate. Others, such as *Gracilaria*, show a firm, solid, compact structure of cells of increasing size from the outside inward. Many of the larger thalli, either cylindrical or flattened, show a differentiation of tissues whereby a parenchymatous medulla is enclosed by a filamentous cortex, or vice versa. In some of the giant kelps, such as *Nereocystis*, such specialized structures as sieve tubes comparable to those of higher plants occur.

It is often necessary to examine the apex of thallus branches to determine the manner of growth. The apex, also, is often so relatively delicate that it permits observation of cellular structure which is obscured in the denser, older parts of the thallus (See Fig. 18). Growth may occur in a variety of ways. In some uniseriate filaments, growth may proceed by intercalary division of cells in any part, or in a special region of the filament (See Fig. 106). In trichothallic growth, such intercalary divisions occur in multiseriate thalli at the base of one or more hairs (See Fig. 19 and Glossary for explanation of these terms). Apical growth may occur in other ways, namely, by means of a single apical cell which cuts off new cells on its inner face, or by a small or large number of cells forming a group of apical cells, producing several parallel axial filaments simultaneously. Still another manner of growth is observed in many flattened thalli in which the actively meristematic cells lie along the margin so that growth proceeds by expansion of the margins. Some algae have apical growth from a single apical cell when young, but this is replaced later by a marginal meristem.

It will be worth while for the student to take particular notice of the apices of branches in the Red Algae, for in that group especially the characteristics of the apex will provide important clues for identification. He will find, for example, that the presence of a single apical cell is usually associated with the presence of a central axial filament and that the recognition of these and of other such features may be important in understanding the vegetative structure for the purpose of interpreting correctly the steps in the key.

It will become evident as experience is gained in making cross sections for the purpose of revealing the features of internal structure that young portions of a plant are much more

Figure 8 Examples of various kinds of holdfasts. A. A simple, modified, basal cell (*Chaetomorpha*); B. Unicellular rhizoids (*Lophosiphonia*); C. A solid basal disc (*Grinnellia*); D. Creeping stolons with adherent discs (*Gelidium*); E. A horny cone (*Sargassum*).



satisfactory for sectioning than very old ones. The additional complications contributed by secondary growth of certain tissues often obscure the important basic features of structure. Accordingly, one should exercise some care in the selection of a suitable fragment for sectioning, or should repeat the operation on several different parts if difficulties are encountered in the first interpretation.

The manner of attachment to the substrate differs widely in the marine algae from a holdfast consisting of a single modified basal cell, to various kinds of penetrating or entangling rhizoids, multicellular, adherent discs, creeping stolons, and massive clasping hapteres (Fig. 8). In many instances the kind of attachment constitutes an important generic or specific character, and identification may be impossible without a knowledge of it. Accordingly, it is important for the collector to obtain complete plants including the holdfast wherever possible, even if this may require breaking the rock upon which a specimen is growing.

REPRODUCTIVE STRUCTURES

Unlike the several seed-bearing marine flowering plants which are treated at the end of this book, the algae reproduce, with few exceptions, by means of microscopic spores. Although these spores themselves are very small, the reproductive structures which produce them are often large enough to be visible to the unaided eye and are useful in providing distinctive characters for classification purposes. For this reason the student should acquaint himself with some of the more general aspects of algal reproduction before endeavoring to identify his specimens.

The widespread misconception that the algae are "just simple, primitive plants" is quickly dispelled when one studies their marvelously varied life histories and often exceedingly complex reproductive mechanisms. So varied are these that space is available here only for the presentation of a few generalizations and examples under each of the three major seaweed divisions. For more detailed information the student is referred to G. M. Smith's Cryptogamic Botany, Vol. 1, McGraw Hill & Co., and for a highly comprehensive account with full bibliography, to F. E. Fritsch's The Structure and Reproduction of the Algae, Volumes 1-2, Cambridge University Press.

THE GREEN ALGAE

Only about 10% of the Chlorophyta are marine, but among these a number of different orders are represented along with a considerable range in reproductive complexity. Both asexual and sexual reproduction occur. In some of the simpler filamentous forms reproduction may occur mostly by fragmentation of the filament, but more commonly some kind of spore is produced which may germinate to produce a new plant. Two common kinds are the motile, flagella-bearing zoospore, and the non-motile aplanospore. These may be produced simply by a differentiation of the contents of a vegetative cell. or, if the structure producing the spores is in any way specialized and different from the ordinary vegetative cells, it is called a sporangium.

Sexual reproduction in the Green Algae involves a union of gametes which may be motile or non-motile. In the great majority of marine green algae the gametes are flagellated. When fusion occurs between those which are of equal size the species is called isogamous, while union of flagellated gametes of unequal size is characteristic of anisogamous species.

A type of life history which may be considered fairly representative of the many larger marine green algae is exemplified by *Ulva*, the sea lettuce. In *Ulva*, an alternation occurs between on asexual generation (sporophyte) producing quadri-flagellate zoospores, and a sexual generation (gametophyte) producing bi-flagellate gametes. The alternation is called isomorphic because the sporophyte plant (diploid generation) is essentially identical in external appearance with the gametophyte plant (haploid generation). The life cycle is diagrammed in Fig. 9.

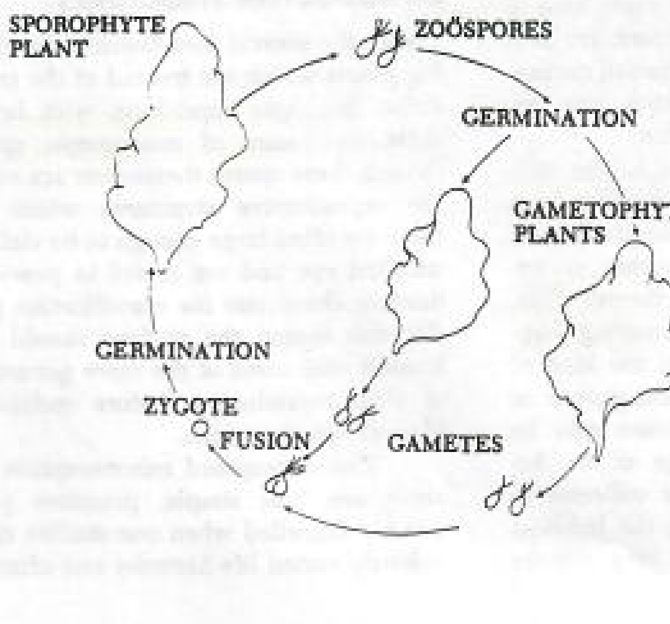


Figure 9 Diagram of the life cycle of *Ulva*.

Unlike *Ulva,* some genera of marine green algae bear special structures (sporangia and gametangia) for the production of their reproductive cells, but students will find that most genera of green algae can be recognized so readily from their vegetative form that reproductive organs usually need not be present for identification to that point. Specific identifications, on the other hand, may often require careful study of the reproductive organs and of the life history, sometimes even to the point of culturing the plants to obtain living spores and gametes for examination.

THE BROWN ALGAE

As a broad generalization it may be said that all the brown algae, with the exception of the Fucales, have an alternation of sporophyte and gametophyte generations, but among the greatly diversified forms of this large marine assemblage a number of variations and complications in the life histories are superimposed upon this fact. On the other hand, the beginning student will be relieved to know that the majority of the large brown, seaweeds have only one general kind of life cycle with which he needs first to become familiar. In this great majority of instances the large, macroscopic plant which is collectable in the field is the sporophyte generation which alternates with a microscopic gametophyte generation. The microscopic sexual plants are rarely detectable in nature and have been learned about through laboratory culture studies. Thus, among the brown algae treated in this account, with the exception of the orders Ectocarpales and Dictyotales, the plants encountered in the field will be of only one generation, namely, the sporophyte.

The life cycle of *Eisenia* is presented as an example of this prevalent heteromorphic type of alternation in which the two generations are dissimilar. Fig. 10.

Although in the order Fucales, which contains many of our commonest rock weeds

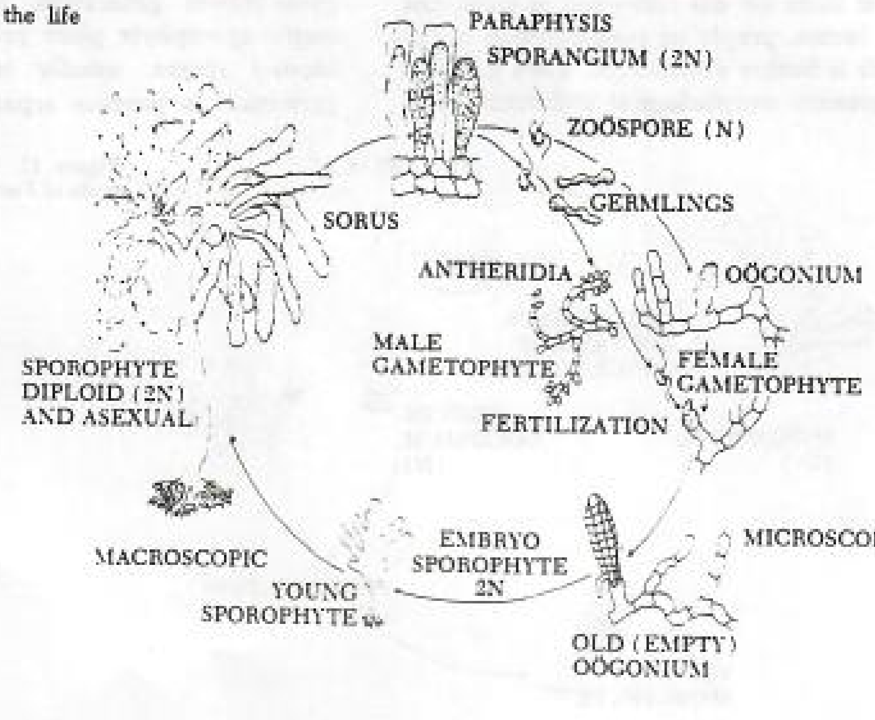


Figure 10 Diagram of the life cycle of *Eisenia.*

such as *Fucus*, *Pelvetia*, *Ascophyllum*, etc., the macroscopic plant of the field is the sporophyte generation, the life cycle differs markedly from that of *Eisenia* in the elimination of the gametophyte generation. The life cycle of *Fucus* is diagrammed in Fig. 11. Note that the number of functional eggs in the macrosporangium is a key character which is used in step 166 of the key.

Nothing has been said about the orders Ectocarpales and Dictyotales in which the gametophyte plants are present and are usually essentially like the sporophyte plants. At this point the student need only be aware that he will encounter both asexual and sexual plants of these groups in his collecting and that in most cases either will serve equally well with regard to the use of this illustrated key.

THE RED ALGAE

The elementary student of phycology has long been perplexed by the problem of recognition of various kinds of red algae in the field, for many of them are not really red in color, but green, brown, purple or even blackish in nature. He is further discouraged when told that their primary morphological distinction from other algae is found in the presence of non-motile male gametes which fuse with a special female sex organ, the carpogonium. It is because of such situations which often make it practically impossible for a beginning student to place his specimens in the right algal division that the present artificial key is designed to key out all groups together without regard to natural relationships.

Nevertheless, in the use of the key one will find frequent cause to be acquainted with some of the fundamental aspects of reproduction in the Red Algae, for in this group especially, the reproductive structures are often conspicuous and serve conveniently in the recognition of a number of genera.

Again as a broad generalization it may be said that a large majority of the Red Algae have an alternation of not two, but three generations, namely a sporophyte and a gametophyte generation which are isomorphic, and a carposporophyte generation which remains attached to and, in a sense, parasitic on the gametophyte generation. Briefly, a macroscopic sporophyte plant produces non-motile asexual spores, usually tetraspores, which germinate to produce separate male and fe-

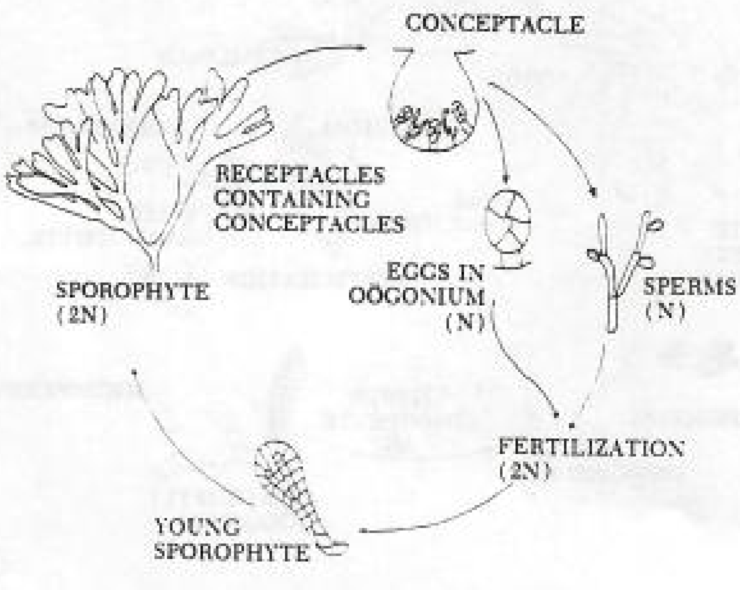


Figure 11 Diagram of the life cycle of *Fucus*.

male gametophyte plants. The male plants produce non-motile sexual cells (spermatia) which are freed and lodge against and fuse with the female sex organ (carpogonium) on the female plant. As a result of gametic union which may occur in a variety of ways, a new generation begins development in or on the female gametophyte. This generation consists of a tissue called a gonimoblast which produces carpospores in a number of ways, often within a special enveloping structure called the pericarp (see Figs. 38, 39). The liberation of the carpospores and their germination begins the development of the sporophyte generation again, whereby the cycle is repeated.

The genus *Gracilaria* may be used as an example of the kind of life cycle (Fig. 12A) that is characteristic of most of the red algae except for many in the orders Bangiales and Nemaliales. In the latter order, many species show a life history containing large gametophytes with microscopic sporophytes. *Bonnemaisonia* (Fig. 12B) is an example of this life history.

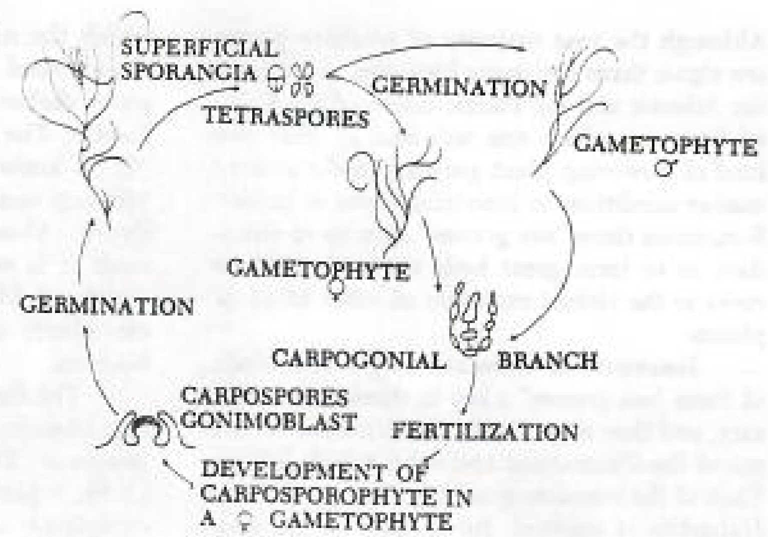


Figure 12A Diagram of the life cycle of *Gracilaria*.

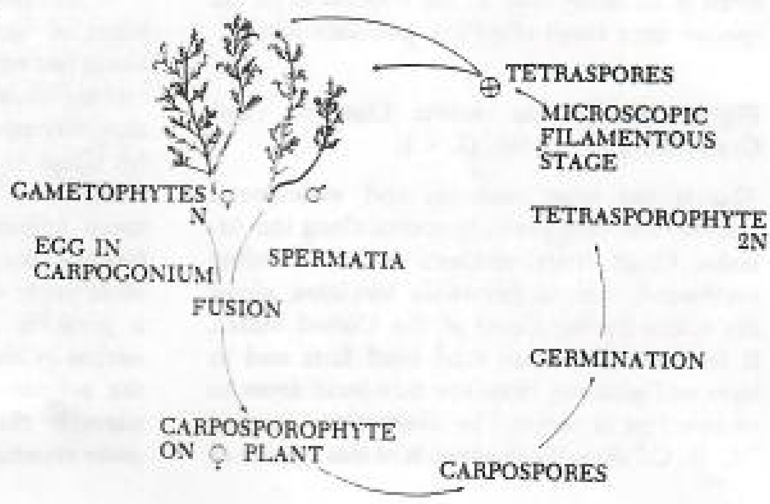


Figure 12B Diagram of the life cycle of *Bonnemaisonia*.

The Marine Flowering Plants

Although the vast majority of seashore plants are algae, there are many localities along both the Atlantic and the Pacific coasts of the United States at which one will find at least one kind of flowering plant growing under strictly marine conditions in intertidal water or below. Sometimes these "sea grasses" may be so abundant as to form great beds on sand, mud or rocks to the virtual exclusion of other kinds of plants.

Inasmuch as there are only a few kinds of these "sea grasses" a key to them is unnecessary, and they may readily be identified by the use of the illustrations and notes which follow. Each of the common genera is illustrated. Only *Halophila* is omitted, for it may be encountered in quantity only in the Florida keys. Its species have small elliptical, petiolate leaves.

Figure 240 *Zostera marina* Linnaeus (Eel Grass) A., B., C., × 0.5; D. × 1.

This is our most common and widespread marine flowering plant. It occurs along the Atlantic Coast from southern North Carolina northward, and, in favorable localities, along the entire Pacific Coast of the United States. It commonly lives on tidal mud flats and in bays and estuaries from low tide level down to twenty feet or more. The illustrations marked "A., B., C." show three variants of this species of which the narrow-leaf forms "A., B." are like those found along the Atlantic Coast and in some sheltered bays and estuaries along the Pacific. The large broad-leaf form shown in "C." is known as *Zostera marina* var. *latifolia* Morong, and is the commoner form of Pacific shores. Along the open southern California coast it is often found on sandy bottoms in depths of fifteen feet or more. Fragments of the plants are commonly cast up on sandy beaches.

The flowers and fruits of eelgrass are rather obscure. Part of a fertile stem (spadix) is shown at "D.," and two developing seeds are visible where the enveloping spathe does not completely cover them.

Because eelgrass is an important food plant of birds and of many marine animals along our coasts, it received a great deal of attention about twenty years ago following its almost complete disappearance from the Atlantic Coast in 1931-32. The importance of this destructive "wasting disease" of *Zostera* led to much scientific research in an attempt to determine its cause, and although not proved, the most likely cause is now thought to have been a parasitic mycetozoan, *Labyrinthula*, living within its leaves. It took about fifteen years for the eelgrass to return to normal growth, apparently through the development of strains more resistant to the parasite.

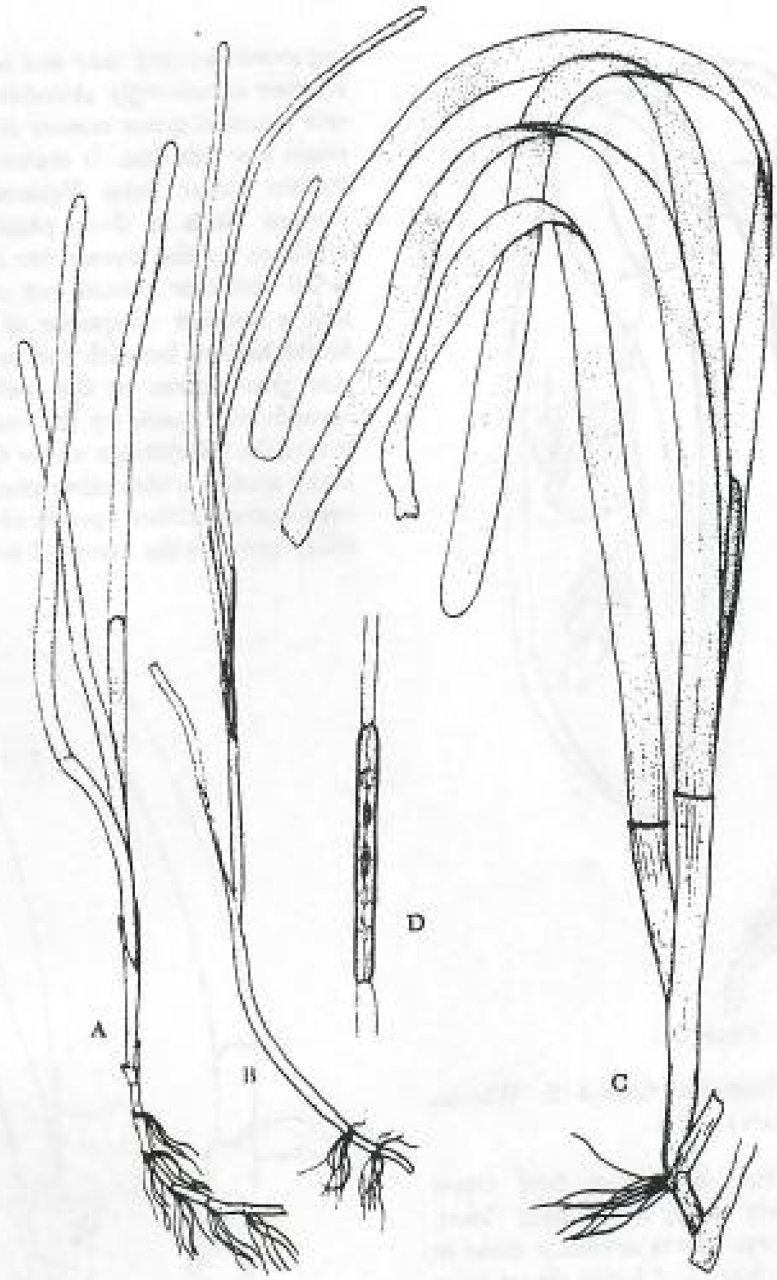


Figure 240

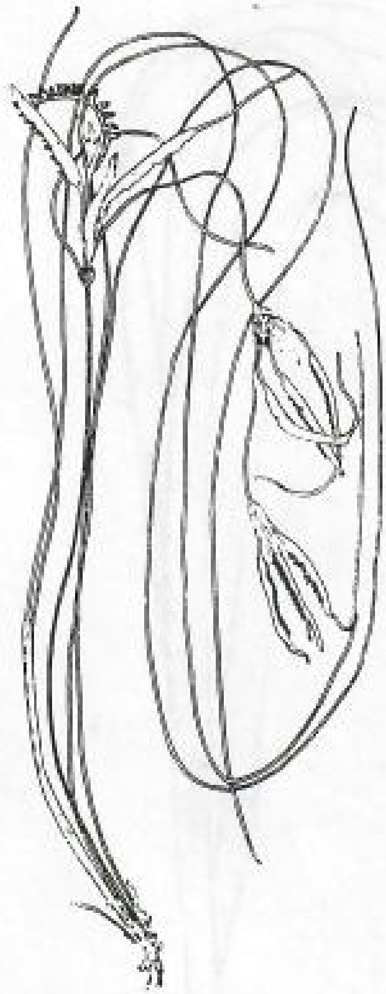


Figure 241

Figure 241 *Phyllospadix torreyi* S. Watson (Torrey's Surf Grass) × 0.4.

This is one of two species of Surf Grass which occur widely along our Pacific Coast. Unlike *Zostera*, these plants normally grow in rocky places from intertidal levels down to as much as 50 feet along surfy shores. *P. torreyi* has narrow, compressed, somewhat wiry leaves and long flowering stems bearing several spadices as shown in the figure. It occurs from northern California southward. *Phyllospadix scouleri* Hooker, our only other species, has thinner, shorter leaves and short, basal flowering stems bearing only one or two spadices. It is often exceedingly abundant, forming extensive emerald green masses on rocky reefs near mean low tide line. It occurs along the entire Pacific Coast from Vancouver Island into Mexico. Both of these plants are commonly mistaken by the layman for eelgrass. The seaweed collector should not overlook the fact that a number of species of algae are to be found hidden beneath the protecting layer of surf grass leaves on the reefs. If one simply spreads and opens up the mantle of leaves to reveal the inhabitants under them, he will find many species which otherwise might be passed over unseen. Other species of algae characteristically grow on the leaves of surf grass.

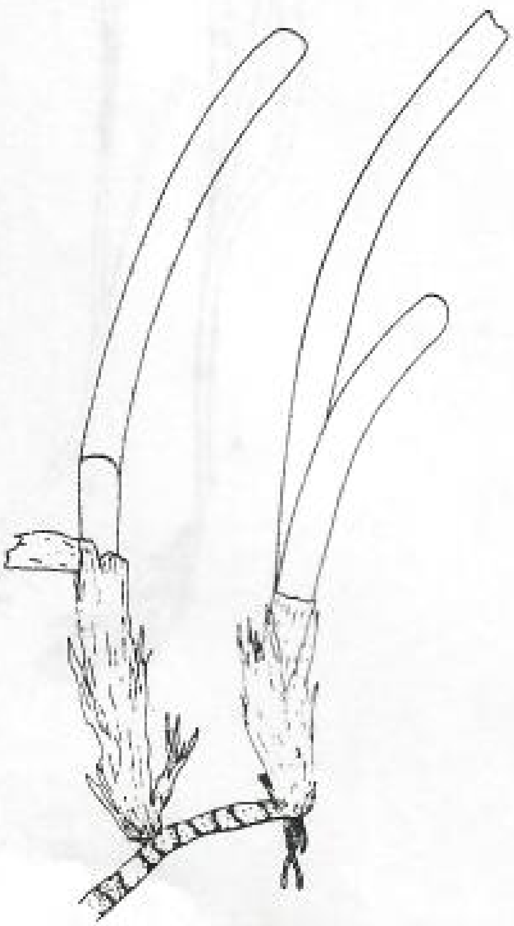


Figure 242

Figure 242 *Thalassia testudinum* Koenig & Sims (Turtle Grass), × 0.6.

This plant occurs in vast submarine fields around the Florida coasts, into the Caribbean, from near low tide level to as much as 35 feet. So abundant is it that in many places the leaves are washed ashore in sufficient quantities to be gathered for fertilizer. The rich vegetation of these marine meadows provides abundant food for marine animals, and in former times supported enormous numbers of sea turtles. The broad, strap-like leaves distinguish it from the other marine seed plants of the Florida area. It occurs outside the range of *Zostera*, so need not be confused with that plant. Some of the most attractive, and most distinctive of the large tropical green algae (*Udotea, Penicillus* and *Caulerpa*) may be found in turtle grass beds as may the important sediment-producer, *Halimeda.* Many species of algae grow epiphytically on the leaves.

Fig. 243 *Syringodium filiforme* Kützing, × 0.56.

This is the Manatee Grass, better known in botanical literature, but incorrectly so, as *Cymodocea manatorum* Ascherson. The plant was first described by Kützing in 1863 from a specimen collected in the Virgin Islands and apparently mistaken for an alga. It occurs widely along the Florida coasts and westward to Louisiana. It often grows on infratidal sandy bottoms associated with *Thalassia* and *Halodule*, from which genera it is readily distinguished by its terete or semi-terete leaves.

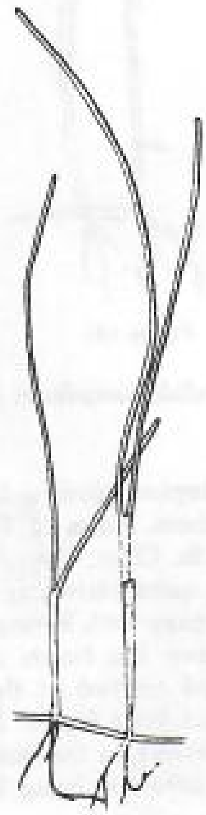


Figure 243

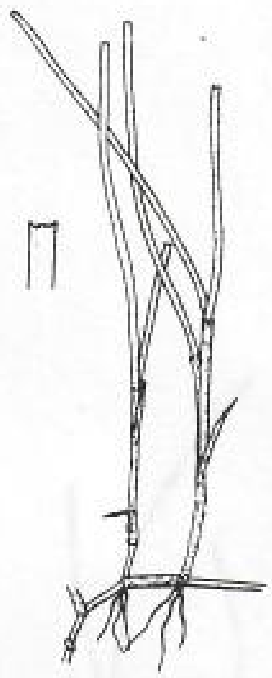


Figure 244

Figure 244 *Halodule beaudettei* den Hartog × 0.8.

This is another tropical species, largely confined to the southern coasts of Florida, but also occurring at St. Croix, Virgin Islands. It occurs in shallow, quiet, often stagnant water, frequently in company with *Syringodium* and *Thalassia.* Its narrow flat leaves are distinctively truncate and toothed at the apex, as shown in the small inset figure. *H. wrightii* Ascherson is commoner in the islands of the West Indies, and differs in being bicuspidate at the leaf apex.

Although easily confused with *Syringodium*, a handful of *Halodule* leaves would contain more leaves than a handful of *Syringorium*, and would weigh less as well. The flat leaves are distinctive.

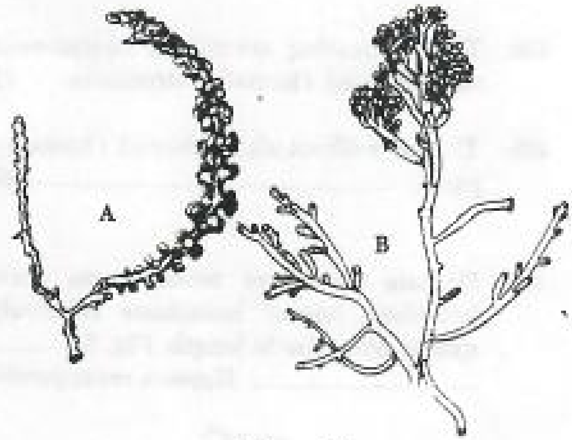


Figure 64

Figure 64 *Laurencia* spp. (habit)

A. *Laurencia papillosa* (Forsskal) Greville. Habit of a portion of a clumping plant, × 1.5. B. *Laurencia obtusa* (Hudson) Lamouroux. Habit of a portion of a clumping plant, × 1.5. Both of these species are common along the coasts of Florida, in the Caribbean, and the Gulf of Mexico. Several other cylindrical species occur more or less commonly in Florida and also along the California coast where *L. pacifica* Kylin is common in certain localities from Southern to Central California. Flattened species of *Laurencia* key out under step 181a (see Fig. 226).

38a Thallus gelatinous and slippery; cortex of short, free filaments with large terminal cells. Fig. 65. .... *Sphaerotrichia divaricata*

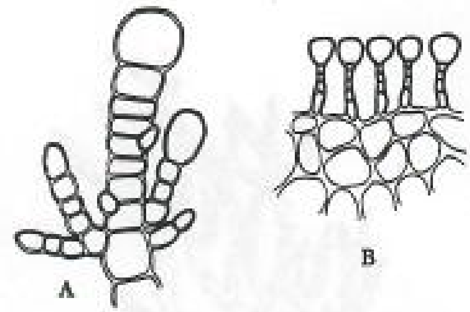


Figure 65

Figure 65 *Sphaerotrichia divaricata* (C. Agardh) Kylin

A. The apex of a plant highly magnified to show the enlarged apical cell, × 560. B. A small portion of a transection of a thallus to show the free cortical filaments with their large terminal cells, × 200. The structural features of this plant and other such gelatinous forms are usually best observed by crushing out terminal portions of branches on a slide. Commonly epiphytic on larger algae during the summer from New Jersey northward. Some forms tend to be hollow.

38b Thallus not particularly gelatinous or slippery; cortex not as above. 39

39a Medulla of filaments radiating from the large, central axial filament. Figs. 58, 66. .... *Endocladia muricata*

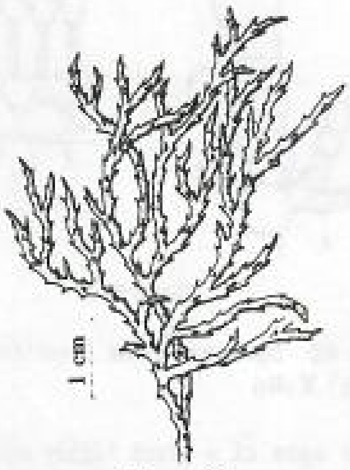


Figure 66

Figure 66 *Endocladia muricata* (Postels & Ruprecht) J. Agardh

A small portion of a clump to show the spiny character of the branches. A common, low, densely tufted or matted plant on rocks at rather high intertidal levels along the entire Pacific Coast.

39b Medulla more or less parenchymatous. Fig. 67. 40

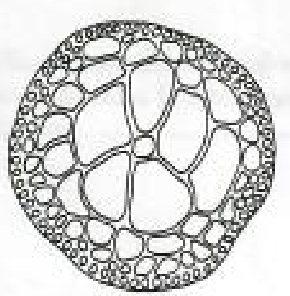


Figure 67

Figure 67 *Hypnea* sp.

A transection of a thallus to show the parenchymatous type of structure, × 30. Habit drawings of various *Hypnea* species are shown in figures 68 and 71.

40a Thallus bearing occasional conspicuous sickle-shaped (hamate) structures. 41

40b Thallus without sickle-shaped (hamate) parts. 42

41a Hamate structures terminal on main branches; lateral branchlets relatively sparse, irregular in length. Fig. 68. .... *Hypnea musciformis*

Figure 68

Figure 68 *Hypnea musciformis* (Wulfen) Lamouroux

A small upper part of a plant, × 1.5, showing the hamate branch tips and the irregular, unequal lateral branchlets. This tropical plant ranges northward to Massachusetts in warm, protected places. Other species of the genus lack hamate tips and key out at step 43b.

41b Hamate structures lateral on main branches; lateral branchlets relatively uniform in length. Fig. 69. .... *Bonnemaisonia*

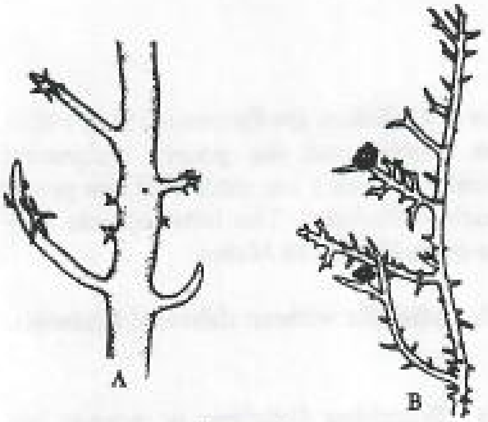


Figure 71

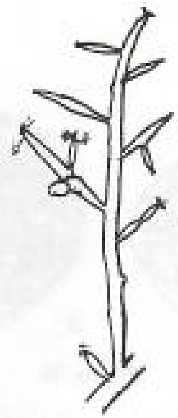


Figure 72

Figure 71 *Hypnea* spp.

A. *Hypnea cornuta* (Lamouroux) J. Agardh. A small part of an axis magnified × 6.4 to show the stellate branchlets. B. *Hypnea cervicornis* J. Agardh. Habit of a small part of a matted plant showing shell fragments attached by small discs and simple, spine-like branchlets, × 2.4. Both of these are tropical plants of Florida and the Gulf Coast. Two or three other species may be encountered in this region as well as the distinctive *H. musciformis* which appears in the key at step 41a. Two other species are frequent in southern California during the summer.

44a Young growing points with short or long deciduous hairs around the apical cell. Fig. 72. .... *Chondria* (in part)

Figure 72 *Chondria tenuissima* (Goodenough & Woodward) C. Agardh.

A small portion of a plant to show the branched, deciduous hairs aggregated around the growing apices and the spindle-shaped branches, × 5. This is the coarser of the two common species of *Chondria* with emergent apices along the Atlantic coast as far north as New England. Two other species occur north of New Jersey, several to the south of North Carolina, and two species are abundant in southern California. They vary from quite delicate plants with main axes less than ½ mm. thick to quite large, coarse plants 25 cm. tall with axes 2 mm. thick.

44b Young growing points without deciduous hairs especially aggregated around the apical cell. Fig. 18B. 45

45a Medulla, especially the outer medulla, with slender, rhizoidal filaments packed between the larger medullary cells. Figs. 73, 74. .... *Gelidium* (in part)

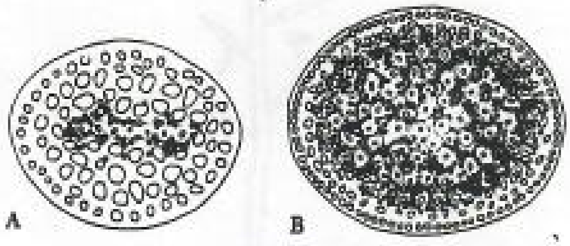


Figure 73

Figure 73 Transections of *Gelidium* spp.

Transections of parts of two different species to show A. the aggregation of rhizoidal filaments in the central region of the medulla, and B. the aggregation in the outer region of the medulla. The latter is the more common situation encountered in species of *Gelidium*, but species of *Pterocladia* also show this structure.

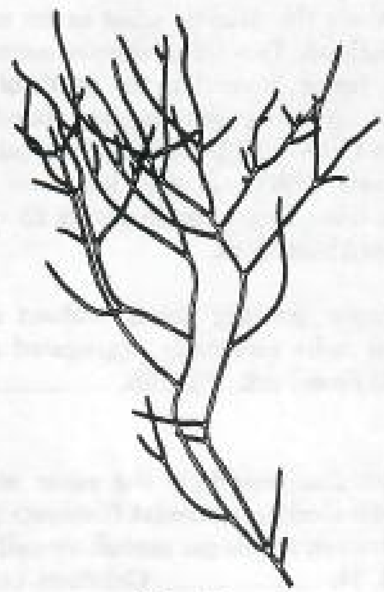


Figure 74

Figure 74 *Gelidium nudifrons* Gardner

A small portion of a plant about 18 cm high to show the slender, subcylindrical form and the rather remote branches, × 0.8. Most of the species of *Gelidium* are flattened (Step 185b) but this species and the poorly understood *G. crinale* (Turner) are somewhat compressed to nearly cylindrical. The latter species may occur from Florida to Maine.

45b Medulla without rhizoidal filaments. 46

46a Branching distichous or more or less unilateral. Fig. 75. .... *Microcladia*

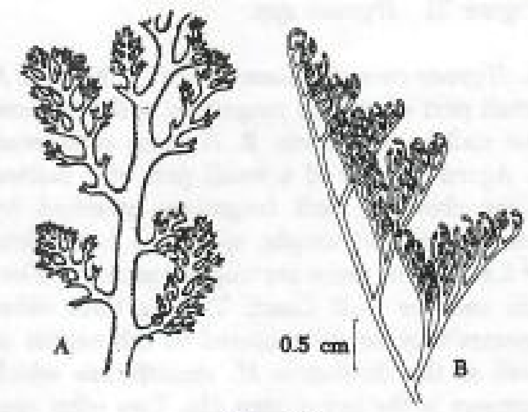


Figure 75

Figure 75 *Microcladia* species.

A. *Microcladia coulteri* Harvey. A small upper portion of a plant showing the distichous branching of the slightly compressed axes, × 3.2. Common along the entire Pacific Coast, often together with similar *M. californica* Farlow. B. *M. borealis* Ruprecht, common from central California north through Alaska, is unusual for its unilateral branching.

46b Branching multifarious. 47

47a Parenchymatous medulla with a central core of relatively slender, longitudinal filaments. Fig. 76. .... *Cystoclonium purpureum*

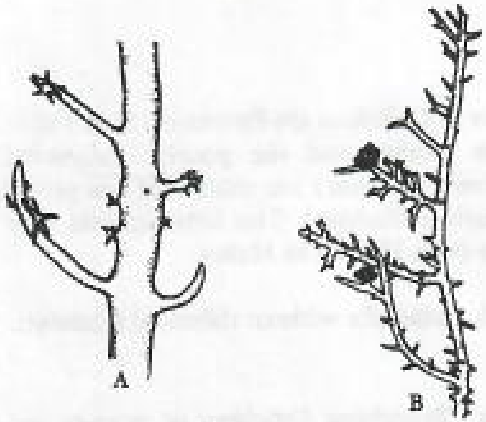


Figure 71

Figure 71 *Hypnea* spp.

A. *Hypnea cornuta* (Lamouroux) J. Agardh. A small part of an axis magnified × 6.4 to show the stellate branchlets. B. *Hypnea cervicornis* J. Agardh. Habit of a small part of a matted plant showing shell fragments attached by small discs and simple, spine-like branchlets, × 2.4. Both of these are tropical plants of Florida and the Gulf Coast. Two or three other species may be encountered in this region as well as the distinctive *H. musciformis* which appears in the key at step 41a. Two other species are frequent in southern California during the summer.

44a Young growing points with short or long deciduous hairs around the apical cell. Fig. 72. .... *Chondria* (in part)

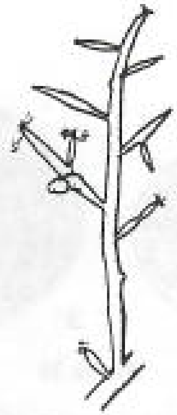


Figure 72

Figure 72 *Chondria tenuissima* (Goodenough & Woodward) C. Agardh.

A small portion of a plant to show the branched, deciduous hairs aggregated around the growing apices and the spindle-shaped branches, × 5. This is the coarser of the two common species of *Chondria* with emergent apices along the Atlantic coast as far north as New England. Two other species occur north of New Jersey, several to the south of North Carolina, and two species are abundant in southern California. They vary from quite delicate plants with main axes less than ½ mm. thick to quite large, coarse plants 25 cm. tall with axes 2 mm. thick.

44b Young growing points without deciduous hairs especially aggregated around the apical cell. Fig. 18B. 45

45a Medulla, especially the outer medulla, with slender, rhizoidal filaments packed between the larger medullary cells. Figs. 73, 74. .... *Gelidium* (in part)

ticillata. J. Agardh. A small part of a plant, × 5. Both of these species and about eleven others are to be found in the warm waters of the Florida coasts. Some of them are flattened and either subsimple or pinnately branched. These will be encountered farther on in the key at steps 148 and 160.

58b Thallus regularly or irregularly septate. 60

59a Thallus traversed internally by a network of trabeculae. Figs. 89, 90, 91. .... *Caulerpa* (in part)

Figure 91

Figure 91 *Caulerpa* sp.

Transection of an axis to show the internal network of trabeculae, × 9.

59b Thallus not traversed internally by a network of trabeculae. Fig. 92. ...... *Bryopsis*

Figure 92

Figure 92 *Bryopsis* species to show habitat and form.

A. Habit of *Bryopsis plumosa* (Hudson) C. Agardh, a common species in temperate waters.
B. *Bryopsis pennata* Lamouroux × 22. A portion of *B. pennata* Lamouroux, common in warmer tropical regions, here shown with bilateral branching, but both rows of branches occasionally unilateral. Life history studies of various species have shown different life forms and different genetic compositions.

60a Branching radially symmetrical; branchlets whorled. 61

60b Branched or unbranched; if branches present, these not whorled. 62

61a Gametangia between (enclosed by) cells of secondary whorls. Fig. 93. .... *Dasycladus vermicularis*