Hawaiian Turtles PART 2 of 2

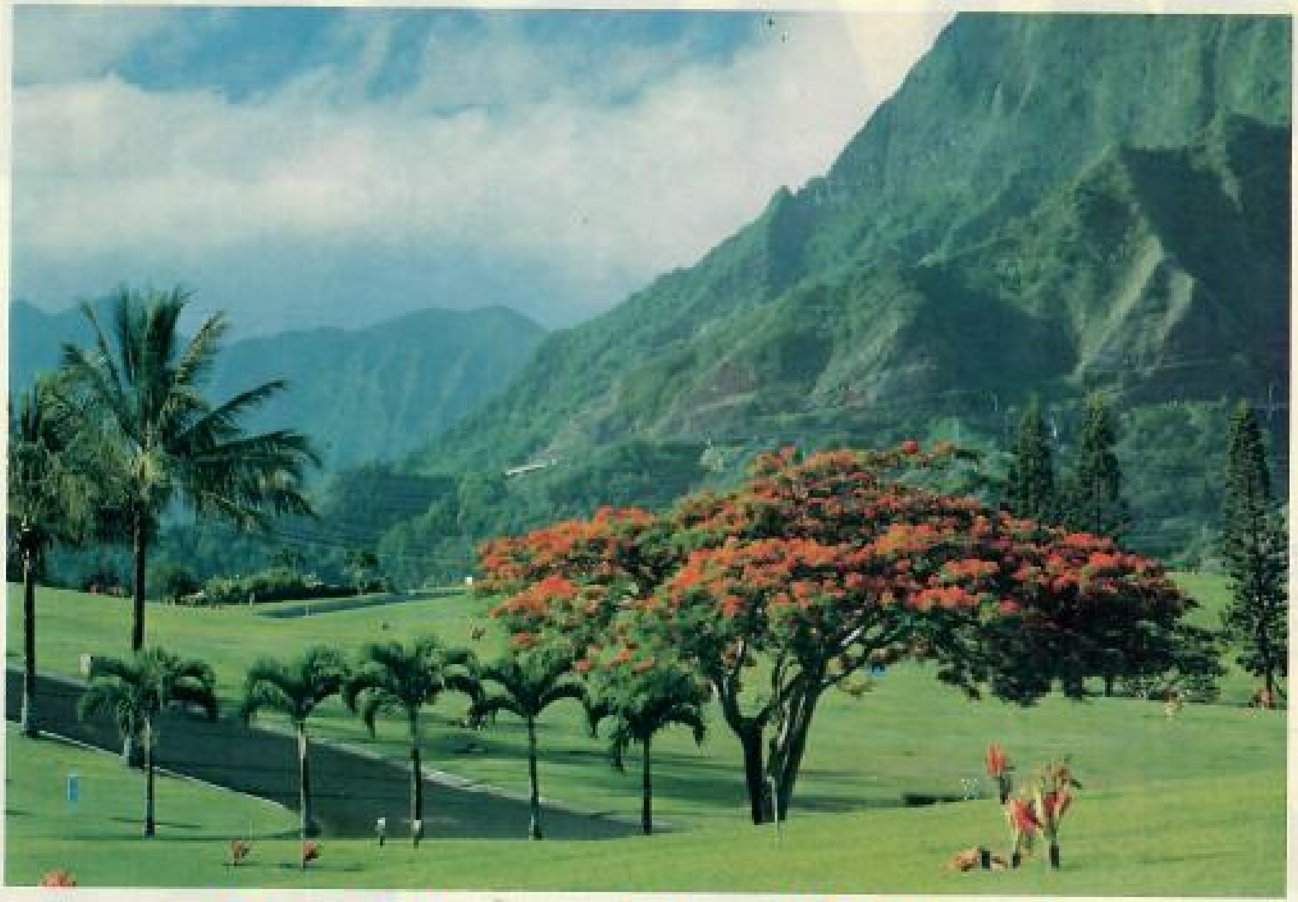
HAWAÏI AND HAWAÏIANS 1960s-1990s
G.H. BALAZS FOLDER

# NIIHAU The Mysterious Island

By Tom Horton

One hundred and thirty-six miles southwest of the glitter and grime of Waikiki, an old man wearing a lopsided cowboy hat is leading a saddled, sway-backed horse along a golden beach that is deserted except for him, his horse, and, farther down the beach, a young girl with long, black hair who is sitting picking seashells from the sand, her horse standing motionless beside her.

In splendid isolation the long beach bakes in the sun, while a mile out at sea, deep blue water rises in six-foot swells which rush toward the land like curling curtains of enormous force, until a coral reef knocks the thunder out of their charge, and the beach remains undisturbed by the surf's gentle arrival.



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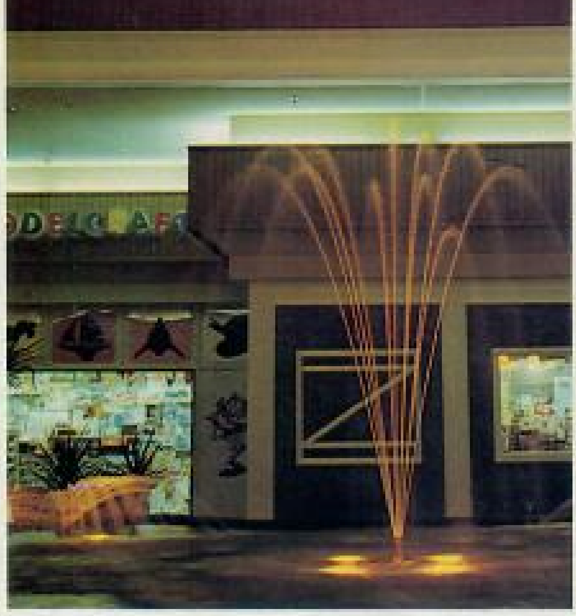

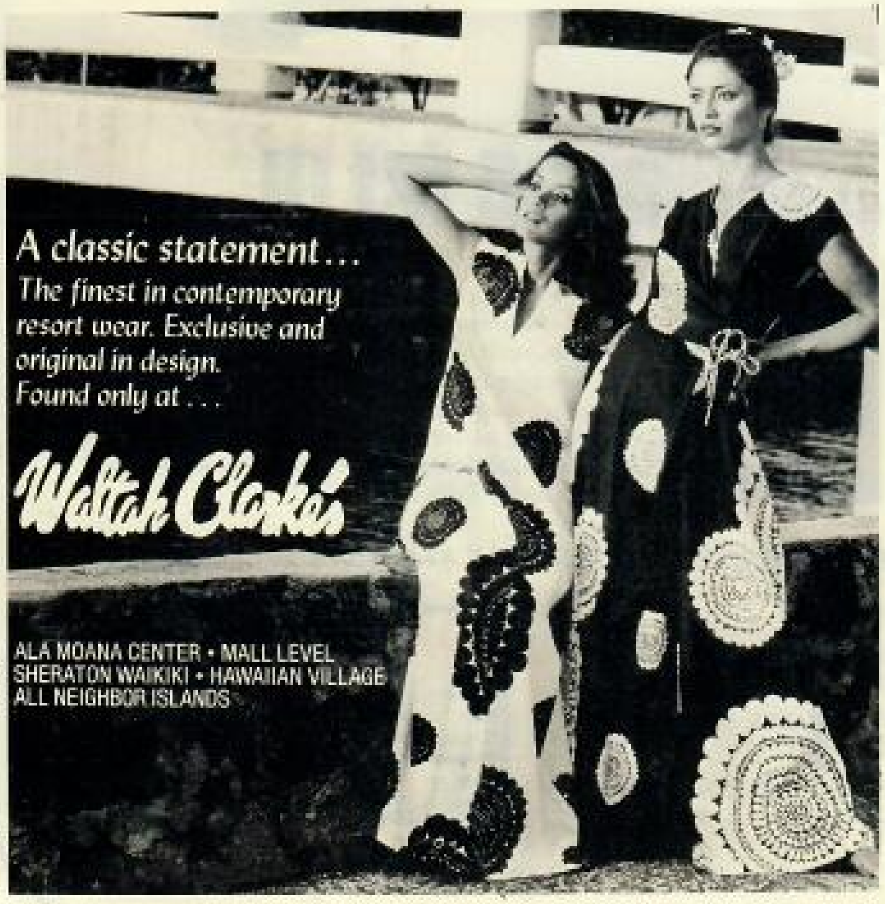

## Niihau

*Continued from page 53*

$10,000. She would convert it into her own private Island estate. But like a retired couple who buy land in Florida that looked good on television, Mrs. Sinclair must have had poor knowledge of what Niihau was really like. She found it too isolated, too hot and dry, too barren, and a stark contrast to the lush regions of the Hawaiian Islands. So she scrapped her plans for an estate on Niihau and bought land in rich, fertile Makaweli on nearby Kauai. That became her feudal homestead and there she lived a vigorous life until dying at the age of 92.

Mrs. Sinclair kept Niihau in the family holdings. Eventually, controlling interest passed to a grandson, Aubrey Robinson, son of a Sinclair daughter. It was the beginning of a remarkable family dynasty which remains unbroken to this day.

There were 650 Hawaiians living on Niihau when Kamehameha IV sold it out from under them. And that population was a dramatic drop from a missionary census count of 1,047 in 1831. The Sinclair purchase further depleted the Niihau population, reportedly because the natives determined there was no way they could ever own any of the land on which they lived.

If Niihau had a sufficient water supply, it might have become a sugar plantation. Or, if it had a more favorable altitude, it might have been suitable for growing pineapple. Instead, it was judged to be good only as ranch land. That is what it became and what it remains: a sheep and cattle ranch owned and supervised by the Robinson family and operated by the Hawaiian tenants who are paid a salary and provided housing and various other benefits. (The Robinsons still live on Kauai.)

> ***"Mrs. Sinclair found Niihau too isolated, too hot and dry, too barren and a stark contrast to the lush regions of the Islands"***

Mrs. Sinclair's grandson, Aubrey Robinson, had five children. Two of them, Alymer and Lester, are credited with preserving Niihau well into the 20th Century and setting the "hands-

## Tutu's Kitchen

**Margaret Stone**

# Cooking with Island Fish

The Islands offer a wide variety of fresh fish for preparation, and almost as many kinds of preparations as kinds of fish.

Unlike other cities, fresh fish is more often found whole in Honolulu markets than in filets. Shopping for fresh fish presents three difficulties: finding a market, knowing the English equivalent for Hawaiian names that are generally used for identification and checking for freshness.

Here in Honolulu there are a few wholesale fish markets that also sell retail. One of the most interesting and well-known is Tamashiro Market on North King St. Although the aroma is reminiscent of a fishing village and one must roll up the cuffs of long pants so as not to get wet, the fresh fish selection is excellent. The sales people will not only help you in fish selection, but also tell you how to prepare the fish, if you ask. Tamashiro is also famous for other seafood specialties.

TOM MYRICK

Another popular market is the Farmer's Market on Auahi St. Under one roof, this market offers several different vendors from whom to choose your fish.

In addition, I am impressed with the fish department at Star Market at Kahala Mall. It is bright, clean and stocked with a good variety of fish.

To help translate those Hawaiian names you will find in all of these markets, here are the English equivalents of popular fish:

Ahi—yellow fin tuna
A'u—marlin
Uhu—parrot fish
Onaga—red snapper
Opakapaka—pink snapper
Aku—skipjack tuna
Moi—thread fish
Kumu—goat fish
Ono—wahoo
Opelo—mackerel like fish
Ulua – Jack Crevalle fish
Mahimahi—dolphin family fish

Many people avoid buying a whole, fresh fish because they do not know how to select one. Checking for freshness is simple; look at both eyes and gills. The whites of the eyes should be clear and firm, not filmy or sunken. The gills should be red, for as the fish becomes older, the gills lose color, turning a faint pink.

Once you have purchased the fish you must decide how to cook it. Here is a brief list of fish especially good for certain preparations:

**Baking** – kumu, mahimahi, mullet, uhu, opakapaka and ulua.

**Broiling** – akule, kumu filets, moi, sea bass, mahimahi, moi or ulua slices.

**Frying** – ahi, sea bass, baby ulua (papio), or any other small fish.

**Steaming** – kumu, mullet, moi, onaga and opakapaka.

Here are some specific preparations:

### STEAMED RED SNAPPER

–As prepared by Executive Chef William Salvadore of the Naniloa Surf Hotel and presented on "Let's Go Fishing" (KHON).

| | |
|---|---|
| 2 | lbs. Red Snapper (Opakapaka/Ehu) |
| 1-2 | large Ti leaves |
| 4 | whole peeled canned tomatoes – chopped |
| 1 | c. liquid from tomatoes |
| 1-1/2 | lemons (use one lemon to make lemon crowns) |
| 1-2 | tbs. rock salt |
| 2 | cloves garlic – minced |
| 1/2 | round onion – chopped |
| 1 | large fresh mushroom – chopped |
| 1/2 | c. water chestnuts – chopped |
| 3 | oz. peanut oil |
| 3 | tbs. Oyster sauce |
| 3/4 | c. White Wine |
| 1/2 | c. fish stock |
| 2 | butter pats |
| 2 | tbs. vegetable oil |
| 1 | tbs. Cornstarch – mixed with a little white wine to make a thin liquid |
| 1/4 | c. chinese parsley – coarsely chopped |
| 2 | drops Tobasco sauce |

Make 2 slits in each side of the fish, rub half a lemon over the whole fish, rub rock salt over outsides and sprinkle inside of fish. Place on large Ti leaf and put in steamer for approximately 20-30 minutes, or until eyes pop out.

For sauce, saute in sauce pan: Vegetable oil, one pat butter, onions and mushrooms, until onions are clear. Add garlic and water chestnuts, let simmer for about 2 minutes. Add white wine and reduce liquid by one-half. Add salt and pepper to taste, tomatoes, tomato liquid and oyster sauce. Let simmer for 15-20 minutes, then add two drops of tobasco, cornstarch mixture to thicken, swirl in one butter pat.

While sauce is simmering, heat peanut oil until it just begins to smoke. Ladle over done fish to add a crispy texture. Place fish on platter. Ladle sauce over fish, garnish with Chinese parsley and lemon crowns, vanda orchid and parsley. Serves: 4-5 people.

### MAHIMAHI STEAKS with OYSTER STUFFING

| | |
|---|---|
| 6 | medium sized oysters |
| 1/2 | c. cracker crumbs |
| 1/4 | tsp. salt |
| 1/8 | tsp. pepper |
| 1 | tsp. chopped parsley |
| 2 | tbs. melted butter or margarine |
| 6 | fish steaks (sliced in two) |
| 1 | tbs. lemon juice |
| | butter or margarine for basting |

Drain oysters and cut in pieces. Add crumbs, salt, pepper, parsley and melted butter. Mix well. Place half the fish slices on a greased baking dish, drizzle with lemon juice and sprinkle with a little salt and pepper. Spread with oyster stuffing and place remaining fish slices on top. Brush with melted butter. Bake in 350 degree oven for about 40 minutes, basting a time or two with more melted butter.

Serve with maitre d'hotel butter. Melt 1/2 cup butter or margarine. Stir in a tsp. of chopped parsley, 1/2 tsp. salt and the juice of a half a lemon. Serves 6.

### SAMOAN COCONUT CREAM

| | |
|---|---|
| 1 | c. frozen coconut cream (thawed) |
| 1/4 | c. chopped green onions |
| 1/4 | c. lime juice |

Mix thoroughly. Chill. To be used as a dip for cooked fish.

*"If the people go to church every Sunday and pray, that's the only way to hold the Island . . ."*

the best luaus in all Hawaii but they aren't for sale. Here people sing and dance with a genuine Hawaiian beauty which will never be witnessed on a nightclub stage. There is fabulous fishing and wild game, but no charter boats and no guns. There is also no electricity, no liquor, no unemployment, no crime. (And, judging from the 1974 gubernatorial election, only one Democrat. Randy Crossley received 64 votes; George Ariyoshi one.)

Niihau is Hawaii's only mysterious Island. Inside the Seven-Islands-in-One-Day planes flying over it, Niihau is pointed out to tourists as the *Forbidden Island.* That's as close as anyone can come to commercializing this last, solitary holdout against American missionary and economic zeal to save native Hawaiians from themselves. Two-thirds of Niihau's population of approximately 240 are believed to be pure Hawaiians. Most of the rest are at least part Hawaiian. English is taught in the Niihau school (which goes to the eighth grade), but Hawaiian remains the first language of the Island. And the old Hawaiian way remains the basic lifestyle.

Living much as their ancestors lived before Hawaii was *civilized* by missionaries and merchants, the people of Niihau subsist mainly on fish from the sea and game from the treacherous interior of the arid island that is only 18 miles long and three to six miles wide. This one remaining preserve of nearly pure Hawaiiana is possible not because of the persistence of the Hawaiians, but because of the strong beliefs of one family of Scottish heritage who has owned, maintained and protected Niihau through five generations, or since it was purchased from King Kamehameha IV in 1864 for what it costs today to join a Honolulu country club – $10,000. For more than a century the family known today as The Robinsons, a family as mysterious in some ways as their Island, have repelled all invaders, foreign or domestic, individuals or governments, in their fierce determination to keep Niihau what other Islands can only be in part: Hawaiian.

Tiny, isolated Niihau's first outside visitor was Captain Cook, who stopped there in 1778 while searching for a water passage through North America from the Pacific to the Atlantic. Bad weather forced Cook's ship to remain anchored at Niihau for several days. He left with a supply of yams, three goats, two swine and the seeds of Niihau melon, pumpkin and onion.

Nearly a century later, the ship *Corsair* stopped in Honolulu on its way to British Columbia. Leading the expedition was a beautiful, bountiful and always-bonneted *grande dame* with a restless spirit and a name fit for a historical novel – Eliza Mc-

Aerial Photos by Baron Wolman

The scene is so ripe for a South Seas romance, you expect the girl picking seashells to be Mitzi Gaynor and the man leading his horse toward her to be Rosanno Brazzi, who any minute will break into *"Some Enchanted Evening."* At the least, a tour bus will suddenly pop out of the keawe bush and disgorge a platoon of tourists eager to encircle and photograph *the real Hawaii.*

It can't happen. It hasn't happened for several generations, and if one inflexible, ruling family continues to have its way – a way that is almost feudal in nature – it will never happen.

This is Niihau and the richest tourist in the world can't rent a room on this island or walk this beach. Here are off" attitude. Both are remembered as lean and lanky, silent Gary Cooper types, and silence is a Robinson family trait which remains in force today.

Aylmer was the most colorful of all the Robinsons. Harvard-educated, he spoke Hawaiian and, like his father, took an avid interest in the Protestant church and missionary work. He was known on Niihau as *Ka Haku Makua* – the old boss. Many regard Aylmer Robinson as the most important individual in determining the history of Niihau.

Aylmer died in 1967, leaving a 75 per cent interest in Niihau to his brother, Lester, and his brother's wife, Helen. Lester, less colorful than Aylmer but equally dedicated to preserving and protecting Niihau from the outside world (Lester was also Harvard-educated and spoke Hawaiian), died in 1969 at the age of 68.

At the time of Lester's death, the *Honolulu Advertiser* said in an editorial, "With Lester Robinson's death came the fear that the last preserve of Old Hawaii also may pass away." But the *Star-Bulletin* responded, "Those interested in the past will be encouraged to know that Robinson passed on to his sons, Keith and Bruce, his feelings for the Island and its status as something removed from time."

There was good reason to worry about Niihau's future. Periodic criticism of the Robinsons' handling of Niihau, described as domineering, provincial and even backward, would spring from various sources. In 1946 a territorial legislative investigating committee headed by Sen. Francis H. Brown made headlines by visiting Niihau and deriding it as "50 years behind the times." That it was more accurately 100 years behind the times, and the Robinsons wanted to keep it that way, seemed to escape the legislative thinking.

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Education of Niihau children has often been questioned. They attend the first eight grades on Niihau and can then continue in high school on Kauai or at Kamehameha High School in Honolulu; a few in recent years have gone on to the University of Hawaii. In 1970 a Department of Education official reported that although the students of Niihau School ranked tops in the state in discipline, they probably ranked at the very bottom in learning. He blamed the Robinsons' "keep off" attitude. (D.O.E. does, however, make periodic visits to Niihau, as do other state agencies.)

Also in 1970, Gov. John A. Burns sent a controversial bill to the Legislature proposing that Niihau be purchased by the State. For some reason, Burns seemed to believe the island could be bought for less than $2 million. He proposed that it be "saved" by letting the Hawaiian Homes Commission operate it for Hawaiian homesteading and cattle ranching. Burns' proposal met heavy opposition from Hawaiian groups and the bill was killed by the State Senate. Burns tried again in 1972, again without any measure of success.

The Robinson family responded to Burns' 1970 proposal by declaring that they were not willing to sell, but that they would give the State "first refusal" if the family should ever consider selling Niihau at any time in the

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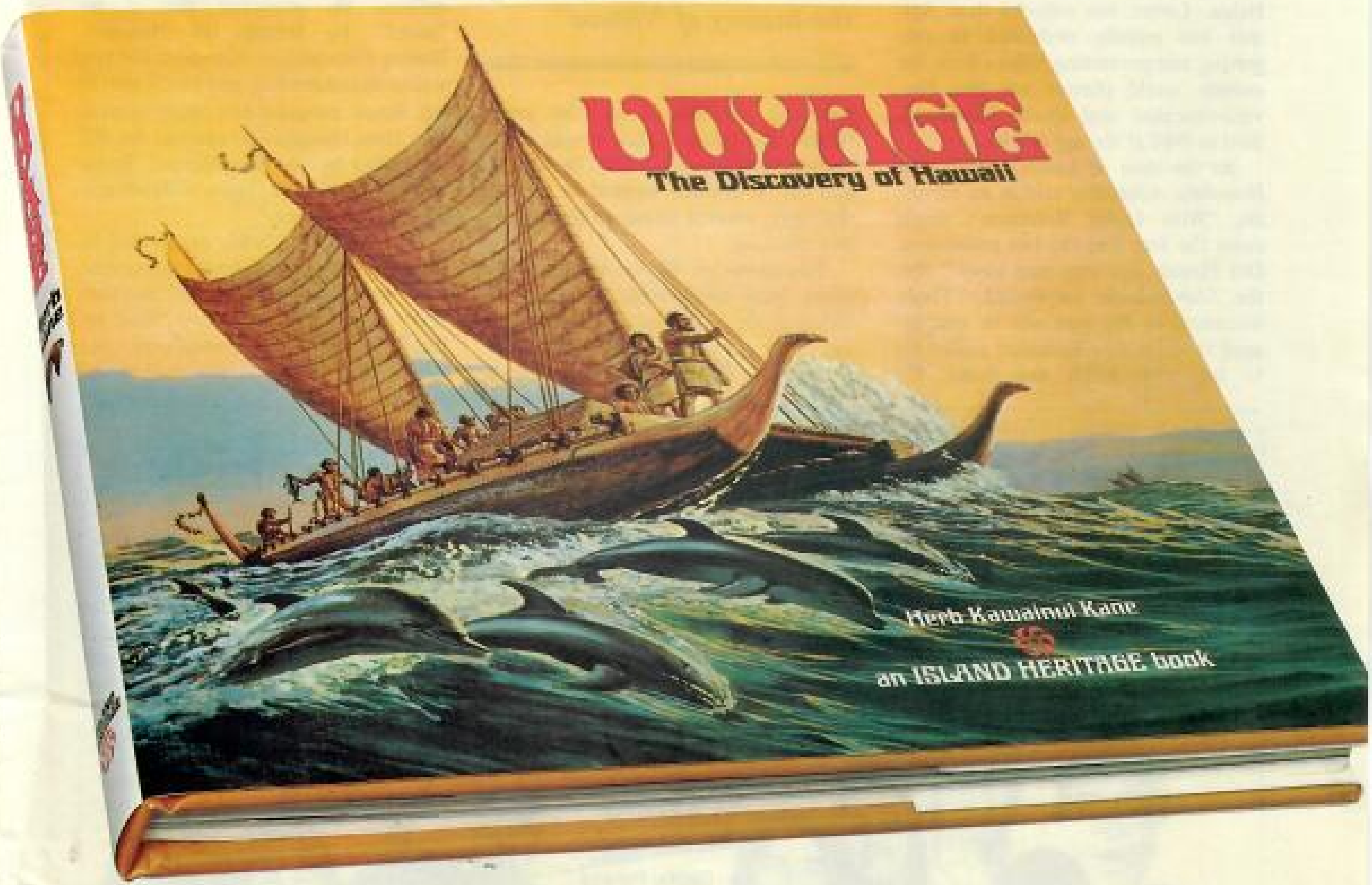

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Niihau is still there and still Hawaiian. The Robinsons are still saying no. Visitors are restricted to friends, relatives and former Niihau residents. Formal requests from anyone else, especially reporters, to visit Niihau are always turned down, politely but firmly. The Robinsons do not even grant interviews and do not like to be quoted about Niihau. Bruce Robinson, however, did tell a reporter in a short telephone interview that he does not feel there have been any major changes on Niihau since his father, Lester, and uncle, Aylmer, died. He said he could not let "one reporter" on Niihau because "there would be a whole line to follow." He described the family as "very protective," and added, "People who live on Niihau want it that way." Said Robinson, "We're a private, operating ranch. We're not set up for tourism and all the trappings that it would bring."

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Robinson's guard against publicity is understandable if you consider that in 1961 *Newsweek* wrote about Niihau as the last repository of pure Hawaiian blood and described the residents as "devout Christians, but as combative as pagan warriors."

One criticism of the Robinsons that isn't heard is that they are keeping Niihau for profiteering reasons. It has always been a struggle to make the ranching operations even break even, and sources close to the Robinson family have estimated that in recent years the Robinsons have spent as much as $50,000 a year to maintain Niihau's privacy.

How much longer can Niihau remain a recluse from time? No one knows. But as some commented when the State was trying to buy the island, "Everyone wants to save Niihau. But from what?" HONOLULU

water. They have a reservoir now but it's still hard. When there's no rain, they go into the church all in a body and they pray. And sure enough the rain comes. They are very religious. Everyone goes to church regularly.

"The Robinsons are wonderful. They love the Hawaiians. They care. Of course, they are strict. Not every Tom, Dick and Harry can go there. That's why you hear a lot of stories, but don't believe them, because these people (the Robinsons) want to conserve their island. They want to keep the Hawaiians happy, and not let them become commercialized like the Hawaiians in Honolulu. The people are very respectful and appreciative of their bosses. They just really love the Robinsons. If they want to have a holiday they ask the Robinsons if it is okay, then everybody has a holiday.

"Their way of showing love and respect is by putting a shell lei on you, like we do with flower leis. This is why I have my collection. It is worth $250,000. But I would not sell one. When they know I'm going home, they come down along the side of the road with leis in their hands. They stop the truck and kiss me and present me with the leis. It's their way of saying they love me. Making shell leis is very important on Niihau. Women get up very early, at 6 a.m. They make breakfast and cook and fix lunches for the men. The men leave the house around seven. Then when the women are through with their housework, they make leis.

"Niihau never changes much. I noticed little change during the first 20 years I visited there. Always the same happy, wonderful people. The families there are so kind. If they're having dinner, they call out when you're walking along the street, whether they know you or not. You enter the house without any questions being asked. They're so open-hearted. If I were to walk the roads of Niihau and fall asleep on one of those roads, nobody would harm me. I would feel safe. That was the oath of Kamehameha and his *mamala hoa* law – "the broken paddle." In other words, he said, the elder people, the children and the women are safe to walk the Islands and lie down and go to sleep, and his word was that no one would molest or harm them in any way for fear of death. But of course today in Honolulu...

"On Niihau, the people feel safe. They are protected. They have love and happiness." Pau

# "Moe" Keale

*"Toloa ame ka pu'uwai hamama o kanaka o Niihau."*

**"The men of Niihau grow very tall, and their hearts are very big."**

*One of the largest is Wilfred Nalani "Moe" Keale. Although born in Honolulu, his father came from Niihau and Moe spent every summer of his youth on Niihau. He once told his friend Carl Lindquist, "I'll never forget that first year on Niihau. What really threw me was how happy everybody was, and how they went out of their way to help each other. Right then I figured that heaven must be something like Niihau." At the end of each summer, Moe was reluctant to leave: "A couple of times I thought about running away, but everybody knows everybody else, and I knew my father would give me a good licking." A member for years of the Sons of Hawaii, he now has his own musical group, Moe Keale and Anuenue.*

"Our family lived outside the village. We rode horseback and we also used Army trucks to run cattle. In our spare time we would play music, fish, hunt. Good hunting and fishing! We cooked outside over an open fire. They're getting classy now with kerosene stoves from Sears.

"We have luaus you wouldn't believe! Some last two or three weeks. When my oldest brother got married I had to dig *six* imus. The men go hunting and the women go fishing and looking for opihi for the luau. The whole island works on the luau. We worked very slowly getting ready. Never rush on Niihau. When we run out of food, we go hunt and fish and the luau continues. Until finally someone says, 'Okay – enough.'

"Sunday, we go to church, pray, go home and eat. Stay in the house all day. After sundown everyone goes bananas again. Everything stays the same on Niihau. A guy fishes, he gets a lot of fish, more than he can handle. He splits them among the village. Lot of surf and spear fishing. Lobster, too. Big lobsters!

"We chase the pigs on horseback. When the pig gets tired, he turns and charges. Then you kick 'em with your feet and tie 'em up. Kill 'em at home. I remember one time I was chasing this buggah – weighed 300 pounds! – and he finally got tired and stopped and charged. I got off my horse and kicked it – and I missed and fell down. My father kicked me in the butt! All the men on the island go hunting. They tie up pigs and leave them on the trail. On the way back they pick 'em up. Never run short of pigs. They have everything they need to eat there. Except candy! I send candies and cookies and Chinese moon cakes for the kids over there. You know what they eat for candy? Keawe beans.

"There's no crime. The law says if you are caught stealing, you be kicked off the island. No one does that over there. You can hunt turkeys at Thanksgiving but that's all. The law says you must leave the chickens and turkeys alone. I don't know why but Robinsons say don't touch. There's a tree in the front yard and the chickens and turkeys sit in it screaming all the time – the buggahs know you can't touch 'em!

"There's no place to go for dates. No theater. No dating. Maybe sneak over to one girl's house and pick her up. Not much to do unless she like to

*Please turn to page 173*

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410pp.

# OPEN SEA MARICULTURE

## PERSPECTIVES, PROBLEMS, AND PROSPECTS

*Edited by Joe A. Hanson*
Oceanic Foundation, Hawaii

Dowden, Hutchinson & Ross, Inc.
Stroudsburg, Pennsylvania

and fresh water the system is capable of producing can be adequate to serve a modest nonindustrial community [10]. This agriculture system is in operation in Mexico. Thus far, the total atoll production concept has not been acted upon.

Bearing these ideas in mind, we are led to contemplate the possibility, for the Pacific island atolls, of combining the University of Arizona's agriculture concepts with mariculture, water desalination, power production, and even reasonable support of tourism. Could such a concept be developed along an avenue that would avoid dangerous addiction to external economic support?

## Atoll Environment

The general features of Pacific atolls were delineated in Chapter 12 and the characteristics of their sea environment described in Chapters 4 and 5. Here we offer no more than a brief recapitulation.

Atolls and high and low islands in the Pacific are the tips of volcanic mountains rising steeply from the deep-sea bed. Where one of these mountains has subsided beneath the surface, coral growth activity maintains a ring of islets surrounding one or more lagoons. Where the tip of a mountain remains above the surface, high or low islands surrounded by coral reefs exist. In all cases, deep water is nearby.

Since coral grows only in warmer waters, relatively high water temperatures characterize the atoll marine environment. Surface waters typically are low in nutrients, although the underlying rock frequently is rich in phosphorus. Highly constant tropical trade winds, narrow tidal ranges, clean air, and abundant sunshine are the other usual environmental features.

## Atoll Mariculture Prospects

At the outset it must be recognized that atoll mariculture will differ in at least one respect from mariculture based on man-made platforms: whereas the latter demands, for the most part, high-volume production systems only, the former admits consideration of low-volume cultures as well. The products of low-volume cultures on islands and atolls could provide a valuable component of the local diet for any indigenous population, as well as an attraction to visitors.

Nutrition. In Chapter 7 we discussed the question of stimulating plankton production with inorganic nutrients. In an atoll system there appear to be at least three prospective sources from which inorganic nutrients might be derived: commercial fertilizers, phosphorus-rich water from deep wells, and artificial upwelling. Of the three, the latter seems the most attractive, since the St. Croix experiments mentioned in Chapter 7 indicate its feasibility. Were the nutrient-rich deeper water to be pumped into the lagoon it would not require heating to remain on the surface; consequently, only low hydraulic pumping power would be required. However, the rate of influx of cold water into the lagoon could not be overly high without depressing biological activity. Should a required nutrient-input rate exceed the tolerable rate of cold-water input, it might be necessary to supplement the deep water with artificial fertilizers or to warm it before injecting it into the lagoon. During most days, warming might be accomplished by routing the water through wide, thin, solar-heated tanks before discharging it into the lagoon. But if reliance is placed on the direct utilization of solar radiation, a backup system for cloudy days will be necessary. This presumably could take the form either of an artificial fertilizer supply or of storable energy that could be used to heat the water. If some backup system were not provided, any intensive-production ecosystem that became dependent upon a high rate of nutrient input would be risking starvation during cloudy weather.

If a suitable, and presumably adjustable, nutrient-input rate is established, a high rate of plankton production should occur in the lagoon. With this the culturing of secondary producers for direct human consumption becomes possible. Oysters, mussels, clams, shrimp, and the herbivorous finfish are all possible candidates. Whether a lagoon would be devoted entirely to a monoculture of one form, or whether a more complex polyculture or series of monoculture subsystems would be appropriate, would depend on a variety of factors, including the character of the lagoon, the species intended for culture and their interactions, and the needs of the human population of the atoll. Where an atoll would be a mariculture station only, it would probably tend toward monoculture; if an atoll or island supported a significant population, plus perhaps other industry, series monoculture or polyculture would probably be more appropriate.

Species Selection. Opinions vary concerning which species are appropriate for atoll-based mariculture. In the recent Pacific Island Mariculture Conference [11] no less than 32 kinds of organisms were examined with varying degrees of enthusiasm. These are

- Green sea turtle, *Chelonia* sp.
- Hawksbill turtle, *Eretmochelys imbricata*
- Cardinal fishes, family Apogonidae
- Eels, *Anguilla* sp.
- Goatfishes, family Mullidae
- Groupers, family Serranidae
- Jacks, family Carangidae
- Mahimahi (dolphinfish), *Coryphaena hippurus*
- Milkfish, *Chanos chanos*
- Mollies, *Poecilia sphenops* (for baitfish)
- Mullets, family Mugilidae
- Siganids, family Siganidae
- Tilapia, *Tilapia* sp.

- Brine shrimp, *Artemia salina*
- Coconut crab, *Birgus latro*
- Malaysian prawn, *Macrobrachium rosenbergii* (fresh water)
- Mangrove crab, *Scylla serrata*
- Shrimp, *Penaeus* sp.
- Northern lobsters, *Homarus* sp.
- Spiny lobsters, *Panulirus* sp.
- Various clams, families Lucinidae, Arcidae, Veneridae, and Cardiidae Psammobiidae
- Giant clams, *Tridacna* sp. and *Hippopus* sp.
- Mussels, *Mytilus smaragdinus* and *Perna canaliculatus*
- Octopus, *Octopus* sp.
- Giant oyster, *Crassostrea echinata*
- Japanese oyster, *Crassostrea gigas*
- Pearl oyster, *Pinctada* sp.
- Pink oyster, *Crassostrea mordax*
- Rock oyster, *Crassostrea glomerata*
- Winged pearl oyster, *Pteria* sp.
- Tritons, *Charonia* sp.
- Trochus, *Trochus niloticus*

Accepting all these forms as possibilities, the best crop composition for any given atoll system would result from creative design attuned to atoll characteristics. When a mariculture operation expands beyond the subsistence scale to become a significant component of an atoll economy, world market demand rather than local tastes alone will influence crop selection. One product to be considered for export might be *Artemia*. Brine shrimp are ideal food for the larvae and young of a number of carnivorous forms. Moreover, if they could be cultured and harvested in volume they could form a valuable component of prepared feeds. To the extent that mariculture in any form becomes important, the world market for *Artemia* will certainly increase.

Feed for carnivorous crops might be derived from imported pelletized feeds or from herbivores produced locally. The latter approach could involve either direct feeding by carnivores on the young herbivores (polyculture) or the harvesting of young herbivores for controlled feeding to a carnivorous culture (series monoculture).

If young herbivore production reached sufficient volume, their controlled release into the waters beyond the lagoons could result in a significant concentration of pelagic finfish, such as mahimahi and jacks, and of demersal predators such as groupers. Concentrations might be stimulated further by the addition of fish attractants, such as those with which Klima has experimented. The populations thus attracted might be harvested directly as an ancillary crop, and they might also comprise a valuable sport fishery for those islands catering to tourism.

The two sea turtles listed should be considered as a potential source of additional income for island populations. The females return to their hatching site to lay after reaching maturity and could be harvested selectively after laying their eggs. The natural laying sites could be protected until hatching occurred, or the eggs could be artificially incubated, and the young turtles, which apparently grow rapidly, could be raised in the lagoon until they were large enough to be reasonably predation-resistant, and then released. Alternatively, prepared feeds for these animals are being developed [11], so it may soon be feasible to culture them to maturity in the larger lagoons as one component of a polyculture system.

Another possibility, of course, is lobsters and crabs. If lagoons offered (or could be provided with) adequate shelter, and if population densities were low enough to reduce cannibalism to an acceptable level, these crustaceans might form valuable, detritus-removing components of a polyculture system. Going a step farther, if high-density rearing devices are developed, the deeper lagoons might prove an excellent place to locate them. There might even be a possibility that well-enclosed and nutrified lagoons could serve as synthetic "pelagic" regions for the larval stage of *Panulirus*.

**Energy.** Much more often than not, atolls are attractive sites for the development of conservative-energy systems. Even though tidal fluctuations are comparatively low, tidal flows through lagoon passages may measure several knots during more than half the daily cycle. Abundant sunshine makes the idea of solar stills for fresh water seem attractive and raises the distant vision of the Helios–Poseidon concept described in Chapter 13. The characteristic proximity of deep cold water might enable a modest ocean thermal gradient machine to serve the power needs of an atoll society, its tourism industry, and its mariculture industry. In addition, most atolls lie in the trade-wind belts, allowing the probable feasibility of wind machines to meet power needs. Combine these energy sources, either singly or in some integrated combination, with hydrogen production, and it seems that the dependency of atoll communities on waning fossil-fuel reserves is not necessarily mandatory.

## THE NEXT STEPS

We should not be surprised to find major air and sea transportation terminals and noxious industry following power production into the oceans. The pressures either to remove them from the terrestrial living environment or to impose ever more restrictive controls on their interactions with that environment show every sign of continuing and increasing. As they do, offshore siting must begin to appear less and less economically prohibitive, as is the case with power production. Since these activities will require power, and since economies of scale as well as synergistic benefits can be effected through associations, one might expect the gradual evolution of offshore industrial complexes. This, of course, seems likely to lead toward larger and larger resident populations within these offshore complexes. And so the concept of floating cities, being pursued in Hawaii and Japan recently, might be more realistic than it appears at first glance.

Indeed, should transportation facilities and industry other than power plants begin to move seaward, we shall necessarily become ever more familiar with the marine environment. Then we may expect to see the eventual development of open ocean mariculture systems far more sophisticated than any of the concepts we have offered for consideration in this study. The basic engineering technology is available; it requires only purposeful development and refinement. If there are roadblocks other than inertial thinking and economic conservatism, they are our limited biological knowledge and sluggish legal system.

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# 15

# A NATIONAL MARICULTURE PROGRAM

*J. A. Hanson*

Considering the prospects and possibilities of the preceding chapter, is it worthwhile to consider launching a national-scale, mariculture research and development program? The answer unequivocally is yes.

What, in truth, might be the benefits of such a program? First, of course, there is the obvious potential of generating needed—and wanted—animal protein at competitive prices for domestic and foreign markets. It does not appear to be only a question of (national) self-sufficiency. If one or a few nations develop clear mariculture superiority, they will almost certainly enjoy a continuing world-market advantage as less alert nations continue to deplete natural fisheries. It would seem that any industrialized nation, watching the accelerating depletion of its natural resources and the concurrent increase in difficulties in maintaining a desirable world trade balance, could scarcely remain insensitive to this potential, which may well increase in importance as a direct function of the failure to control human populations and a concomitant rise in the cost of adequate nutrition.

Second, mariculture and marine environmental protection are both facets of the entire global environment question. Virtually all the knowledge developed by mariculture research will be valuable also in learning how to protect the marine environment from irreversible degradation, both locally and globally.

Third, and tied closely to the previous two considerations, those nations which are first into open sea mariculture operations will without doubt be the setters of precedent with respect to those changes in international maritime law which must necessarily accompany such developments. Technological, economic, and political advantages (and disadvantages) are inseparable in today's and tomorrow's world scene.

Fourth, U.S. foreign policy is based to a considerable extent upon its image as a wealthy and munificent world power, ready with technological and material wealth to assist less fortunate neighbors. To continue this foreign policy is to continue this image, and the image demands both attractive technology and material wealth.

Fifth, the rate of migration of industrial functions offshore, discussed in

PACIFIC SCIENCE April 1968
Vol. 22 No. 2

# An Account of the Species of the Red Alga *Polysiphonia* of the Central and Western Tropical Pacific Ocean

## II. *Polysiphonia*[1]

GEORGE J. HOLLENBERG[2]

ABSTRACT: Seven polysiphonous species are described. Three species are new: *Polysiphonia dotyi*, *P. pentamera*, and *P. tsudana*. *P. howei* proves to be a very widely distributed species. *P. exilis* and *P. tepida* were previously known from the tropical Atlantic Ocean. *P. homoia* was previously known from the Pacific coast of Mexico. Of the polysiphonous species of *Polysiphonia* represented by the present study, none are corticated.

KEY TO THE SPECIES (continued from Part I)

26. Epizoic; erect branches 45–50μ in diameter .............................. *P. tsud*
26. Not epizoic; erect branches 100μ or more in diameter ..............................
27. With 5 pericentral cells ..............................
27. With 7 or more pericentral cells ..............................
28. Chiefly erect from a basal tuft of rhizoids; trichoblasts at intervals of 2–3 segments; se ments of main branches mostly 1.5 diameters long or longer ................ *P. hom*
28. Chiefly prostrate or decumbent; trichoblasts at intervals of 5 or more segments; segments main branches 1 diameter long or shorter .......................... *P. pentam*
29. Trichoblasts and scar-cells at infrequent intervals; plants of estuaries and harbors ...... .............................................................. *P. tep*
29. Trichoblasts and scar-cells commonly one per segment ..............................
30. Pericentral cells in longitudinal rows; wall-scars relatively prominent where trichoblasts .............................................................. *P. ex*
30. Pericentral cells in offset positions in successive mature segments ..............................
31. Rhizoids cut off as separate cells from the distal end of the pericentral cells; pericentral not tumid .............................................................. *P. how*
31. Rhizoids remaining in open connection with the pericentral cells; pericentral cells m tumid .............................................................. *P. do*

***Polysiphonia dotyi*** sp. nov.
Fig. 1*A*, 1*B*, 4, 5

Chiefly prostrate or sometimes clambering algae; prostrate and erect branches mostly 140–160μ in diameter; rhizoids unicellular wi broad open connection with the pericentral c and with mostly discoid or occasionally m cellular apices; erect branches frequent, 1.0–(10) mm high, with segments m shorter than broad and tumid, especially ab lateral branches few, arising in association w trichoblasts; pericentral cells mostly 8– ecorticate, arranged in offset positions in su cessive segments; trichoblasts one per segm with a right hand spiral turn of one pericen cell between successive trichoblasts, mostly ru mentary but occasionally to 1.2 mm long.

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[1] Acknowledgments and designations used for collectors are given in Part I of this series (Pacific Science 22(1):56–98). The material collected by C. R. Long, and reported in Parts I and II of this account, was collected under the auspices of the Pacific Ocean Biological Survey Program conducted by the Division of Birds, Smithsonian Institution.

[2] University of Redlands, Redlands, California. Manuscript received January 17, 1967.

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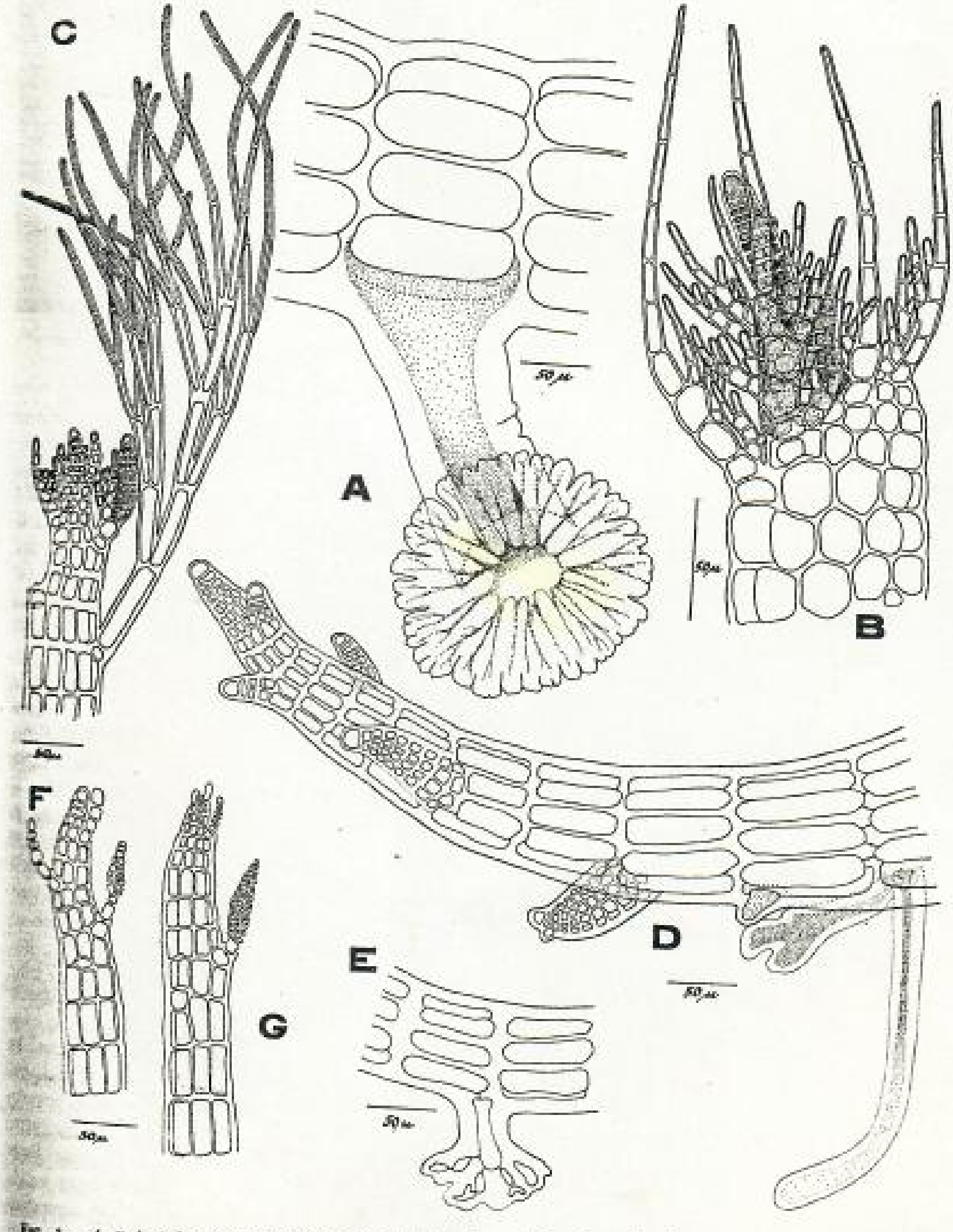


FIG. 1. *A, Polysiphonia dotyi,* portion of a prostrate branch showing rhizoid in open connection with the pericentral cell and ornately digitate tip. *B, Polysiphonia dotyi,* apex of branch, showing trichoblasts and origin of young lateral in connection with a trichoblast (the shoot apex and the young lateral branch are stippled). *C, Polysiphonia exilis,* apex of branch. *D, Polysiphonia howei,* apex of prostrate branch with exogenous laterals and rhizoids at distal end of pericental cells. *E, Polysiphonia howei,* showing multicellular tip of mature rhizoid. *F* and *G, Polysiphonia tsudana,* with young and older spermatangial stichidia.

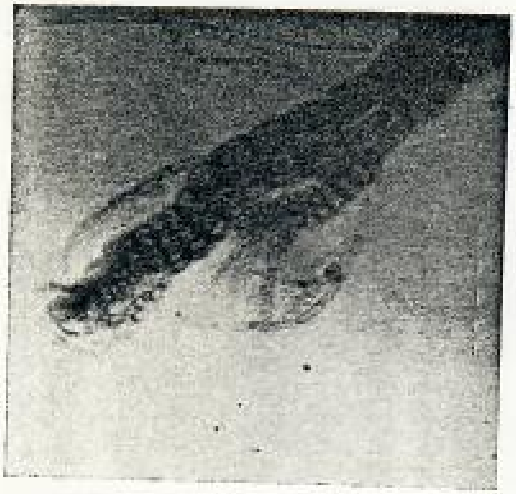


FIG. 4. *Polysiphonia dotyi*, photomicrograph of a vegetative branch apex.

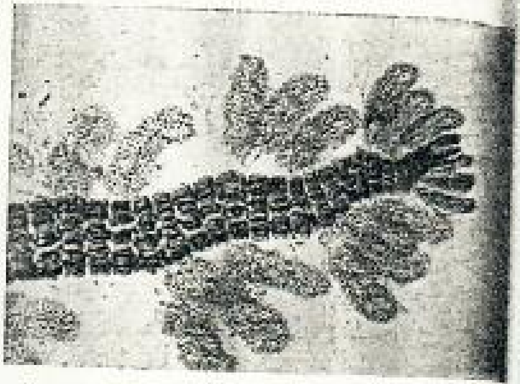


FIG. 5. *Polysiphonia dotyi*, photomicrograph of a branch apex bearing spermatangial stichidia.

4–6 unequal dichotomies, soon deciduous leaving small scar-cells in both prostrate and erect branches; tetrasporangia to 100μ in diameter, in spiral sequence near branch apices, considerably distending the segments at maturity; spermatangial branches 140–200 × 60–75μ, oblong with broadly rounded tips, arising as a primary branch of a trichoblast.

[*] Plantae praecipue prostratae aut interdum scandentes; rami prostrati erectique plerumque 140–160μ diam.; rhizoidea unicellularia, plerumque discoidea, interdum multicellularia; connectionem latam apertamque cum cellulis pericentralibus habentia; rami erecti non numerosi, 0.5–1.0–(10) mm alt., segmentis plerumque brevioribus quam lata, necnon tumidis, praecipue supra; rami laterales pauci, in associatione cum trichoblastis enascentes; cellulae pericentrales plerumque 8–10, ecorticatae, in segmentis successive ex ordine sitae; trichoblastae una in unoquoque segmento, per unam cellulam pericentralem inter trichoblastas successivas spiraliter versae; maxima ex parte elementariae, interdum, autem, ad 1.2 mm long., et 4–5 dichotomias inaequales habentes, mox deciduae, cellulas-cicatrices parvas in ramis et prostratis et erectis relinquentes; tetrasporangia ad 100μ diam., in spira prope apices ramorum, dum maturuent segmenta aliquantum distendentes; rami spermatangiales 140–200 × 60–75μ, oblongi, in cacuminibus late rotundati, ut ramus primarius trichoblastae enascentes.

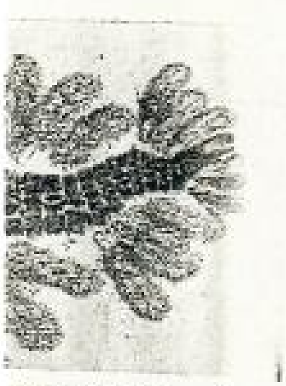
TYPE: H. 48–1213.16, tetrasporic, Amen I., Bikini Atoll, July 7, 1948.

ADDITIONAL COLLECTIONS: PHOENIX ISLANDS—L. 2433.2, spermatangial, on *Halimeda* sp., McKean I., Oct. 19, 1964; MARSHALL ISLANDS—D. 9693A, on reef drop-off, lagoon side near Ine Village, Arno Atoll, legit Leonard Horwitz, Aug. 22, 1951; H. 48–0914.25, outer reef, Uk I., Bikini Atoll, July 9, 1948; H. 48–1091.15, on *Pocockiella*, outer reef Arji I., Bikini Atoll, July 12, 1948; H. 48–2894.6, tetrasporic, on *Udotea* sp., Nama I., Bikini Atoll, July 15, 1948; CAROLINE ISLANDS—D. 23688.2, on dead coral on reef at Quoi I., Truk Group, legit E. Meñez, Aug. 2, 1960.

An unusual feature of this species is the broad open connection of the rhizoids with the pericentral cells. The writer is not aware of this feature occurring in any other species with more than 4 pericentral cells. A feature which it shares with only a few species, including *P. bowei*, is the offset position of the pericentral cells.

*Polysiphonia exilis* Harvey, 1853:47
Figs. 1*C*, 3*C*

Plants epiphytic or on dead coral, chiefly prostrate, attached by unicellular rhizoids, commonly with digitate or bulbous tips, cut off by a cross-wall from the center or proximal end of the pericentral cells, mostly short but occasionally as much as 2 mm long; pericentral cells mostly 9–11, around a relatively large central cell, ecorticate, in straight rows longitudinally; walls to 20μ thick, often stratified; erect branches 3–6 mm high and 160–170μ in diameter, with segments mostly 0.5–0.75 diameters long, arising almost exclusively cicatrigenously from the prostrate branches and having few or no lateral ramuli; trichoblasts on erect



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branches commonly well developed, as much as 2 mm long and 28–40μ in diameter at the base, with mostly 3–5 dichotomies, the final branches tapering to delicate tips; trichoblasts arising one per segment on erect branches, with 2 pericentral cells and approximately ¼ spiral turn between successive trichoblasts, mostly soon deciduous but often relatively persistent, leaving small scar-cells and prominent wall-scars at the point of abscission; scar-cells on prostrate branches often 2 or more segments apart; tetrasporangia 50–65μ in diameter, in spiral sequence in the tips of erect branches, not much distending the segments; sexual plants unknown.

TYPE LOCALITY: Key West, Florida.

COLLECTIONS EXAMINED: HAWAIIAN ISLANDS —D. 18713, Midway I., legit C.H. Lamoureux, Oct. 6, 1962; D. 19127U, dredged 10–14 fa, Pokai Bay, Oahu, July 30, 1959; MARSHALL ISLANDS—D. 9691.1 tetrasporic, D. 9692A, tetrasporic, D. 9696A, lagoon reef drop-off, Ine Village, Arno Atoll, legit Leonard Horwitz, Aug. 22, 1951; H. 48–0290.2, inner reef, Eric I., Bikini Atoll, July 13, 1948; H. 48–0914.18, on *Pocockiella* sp., outer reef, Uku I., Bikini Atoll, July 9, 1948; H. 48–Y58.2, on dead coral, Biijiri I., Eniwetok Atoll, July 26, 1948; H. 48-Y72, on other algae, Runit I., Eniwetok Atoll, July 27, 1948; CAROLINE ISLANDS—all legit E. Meñez, Aug. 1960: D. 15413.1, D. 15416.1, on *Hypnea* sp., eastern part of Helen Reef, Aug. 28, 1960; D. 15897.8, tetrasporic, on dead coral, reef at Quoi I., Truk I., Aug. 1, 1960; D. 23187.2, D. 23751.2, D. 23756.2, on coral and on other algae, Quoi I., Truk I., Aug. 2, 1960; D. 23565, tetrasporic, on other algae, reef of Iwayama Bay, Palau I. (7°20′N, 134°31′E).

Examination of a fragment of the type, W.H.H.24, kindly sent from the Harvey Herbarium at Trinity College, Dublin, by Hilda Parks, reveals features which in detail correspond closely with those of the Pacific specimens, leaving little room for doubt concerning the identity of the latter, even though they are considerably smaller and with fewer lateral branches than the type. Another minor difference may be mentioned. The central cell is relatively small in the type material but is usually nearly twice as broad as the pericentral cells in the Pacific specimens.

A specimen which seems to be a variant of *P. exilis* is represented by D. 18713, collected by Charles H. Lamoureux, Midway I., Dec. 16, 1962, cast ashore following a heavy storm. The erect branches are unbranched and slightly smaller than those of other Pacific specimens of *P. exilis*. There are 14 pericentral cells. Trichoblasts tend to occur at intervals of 2–4 segments rather than on every segment, as is typical for the species. The plants were sterile.

*Polysiphonia homoia* Setchell and Gardner
1930:162; Hollenberg 1961:356
Fig. 2*B*

Plants flaccid, epiphytic, to 3 cm high, attached by a basal tuft of unicellular rhizoids, mostly with digitate tips and cut off by crosswalls from an original basal cell (spore?) and from adjacent pericentral cells; 5 pericentral cells, ecorticate, with walls thin and hyaline except near the base, and with segments in main axes to 2.5 diameters long and with clear dissepiments; main axis 100–420μ in diameter, of segments 1.5–2.5 diameters long; branches arising in connection with trichoblasts, at intervals of mostly 6–12 segments, slightly narrowed at the base; branching mostly pseudodichotomous; trichoblasts at irregular intervals, mostly 2–3 segments apart in ⅕ spiral sequence, up to 400–550μ long with 4–6 dichotomies and slender tapering tips, with basal cell very short and with the cell next to the basal cell about 15μ in diameter and up to 6 diameters long; tetrasporangia to 55μ in diameter, in short slightly spiral series, not much distending the segments; cystocarps slightly ovate to nearly globular and 200–240μ in diameter, with ostiolar cells prominently enlarged at maturity in comparison with cells immediately below them; spermatangial branches measuring 200–275 × 40–45μ, arising as a primary fork of a trichoblast, without sterile tip.

TYPE LOCALITY: Guadalupe I., Lower California, Mexico.

Central Pacific collections are from the Hawaiian Islands only: D. 19144C1, on *Galaxaura* sp. dredged 6–13 fa, Port Allen, Kauai, Nov. 12, 1959; D. 19104E1, and D. 19104F1,

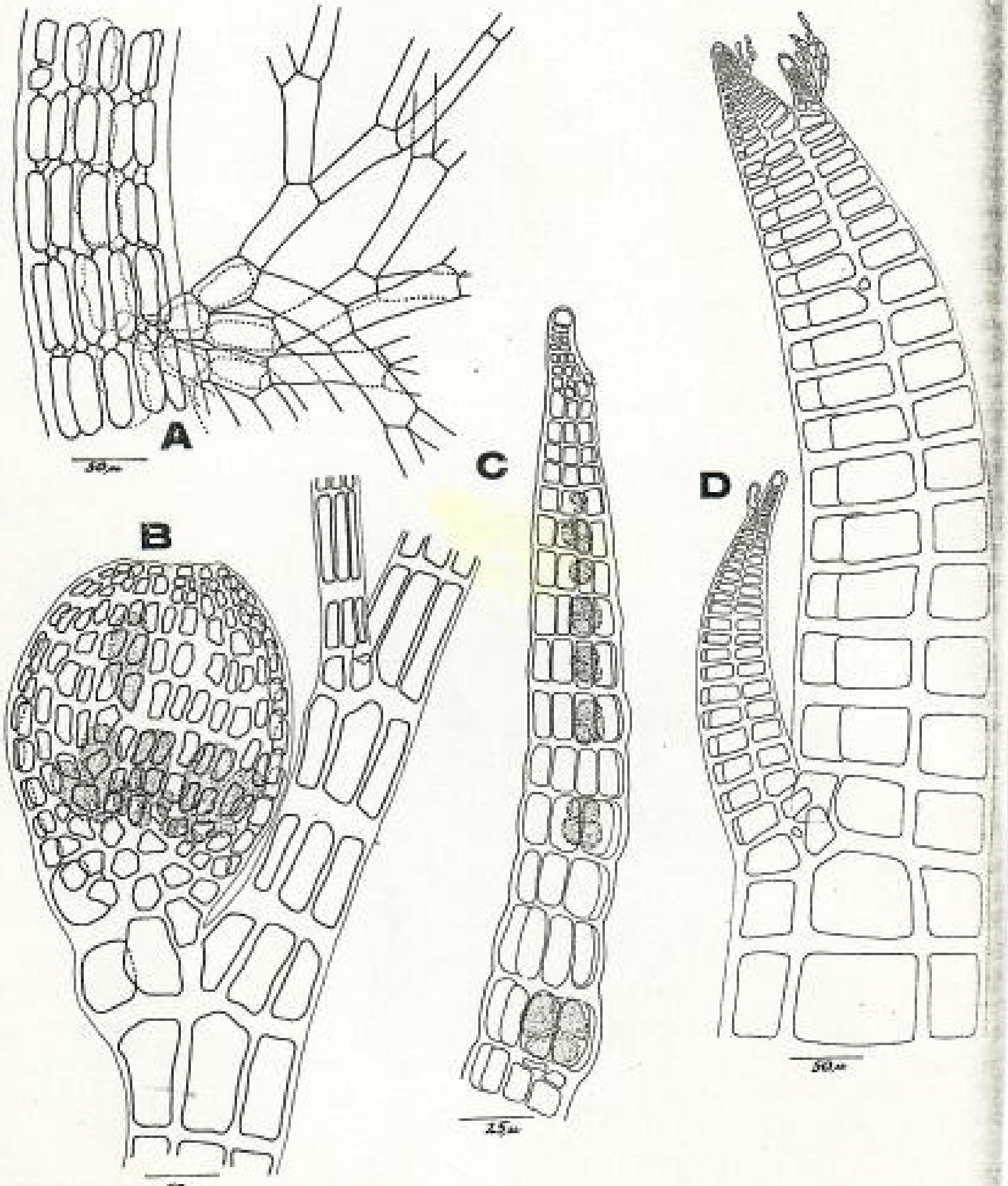
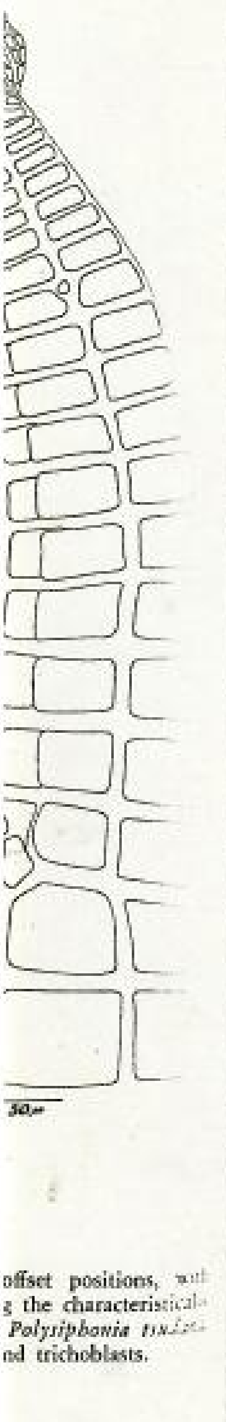


FIG. 2. *A, Polysiphonia howei,* portion of a branch showing pericentral cells in offset positions, with two secondary pit connections with pericentral cells of adjacent segments; also showing the characteristically short basal cell of a trichoblast. *B, Polysiphonia homoia,* cystocarp (immature). *C, Polysiphonia tsudana,* tetrasporangial branch. *D, Polysiphonia pentamera,* apex of a branch, showing laterals and trichoblasts.



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cystocarpic, on *Gracilaria*, 20–55 fa, Explosive Ammunition Area, Oahu, July 24, 1959; D. 19118A1, on *Cnoospora* sp. 16–25 fa, Pokai Bay, Oahu, Aug. 1, 1959; D. 19134D1, on other algae, 25 fa, outside channel buoy, Kaneohe Bay, Oahu, July 25, 1959; D. 19135Z1, spermatangial, on *Hypnea* sp., 26 fa, Waialua, Oahu, Aug. 2, 1959; D. 19136F3, cystocarpic, 15 fa, Waialua, Oahu, Aug. 2, 1959; D. 19143T1, cystocarpic, on *Liagora* sp., 15 fa, Ilio Point, Molokai, Sept. 7, 1959.

This alga seems to be a plant of deeper water. It compares favorably in most respects with the description of the type and previously the only known collection of this plant. It differs in two respects: (1) the tetrasporangia are reported as occurring in straight series in the type material, and (2) the type is described as having a short sterile tip on the spermatangial branches.

*Polysiphonia howei* Hollenberg, in Taylor 1945:302; Hollenberg 1958:64.

*P. rhizoidea* Meñez 1964:217, *P. yonakuniensis* Meñez 1964:219, *P. yonakuniensis* Segi 1951:257, *Lophosiphonia obscura* Weber v. Bosse (1923) not of Falkenberg 1901:500

Figs. 1*D*, 1*E*, 2*A*

Plants forming low dense mats on rocks, up to 1.5 cm high and to 7 cm or more in diameter; prostrate branches 100–170µ in diameter attached by unicellular rhizoids, with digitate to multicellular tips, often several per segment, each cut off by a cross-wall from the distal end of the pericentral cell; erect branches 100–150µ in diameter, arising exogenously at the tips of prostrate branches, or sometimes cicatrigenously, at intervals of 6–8 or more segments, at first strongly curved toward the apex of the prostrate branch, and bearing frequent, mostly curved, lateral branches; prostrate branches giving rise ventro-laterally to prostrate lateral branches in alternating positions on either side mostly 2 segments distal from each erect branch; 8–10 pericentral cells around a relatively large central cell, the pericentral cells, beginning 8 or more segments from the branch tip, shifting to offset positions, so that each pericentral cell is in contact at either end with 2 pericentral cells of the adjacent segment, with each of which it soon develops 1, or sometimes 2, secondary pit connections; segments in prostrate and erect branches mostly less than 1 diameter long; trichoblasts relatively coarse, to 600µ long and 28µ in diameter at the base, with short basal cells, even at maturity, and with about 4 dichotomies, not diminishing greatly toward the rounded tips, arising at no regular intervals but frequently, one per segment in ¼ spiral sequence, at least in upper parts; tetrasporangia 45–55µ in diameter, in spiral series in the ultimate branches, not distending the segments; cystocarps ovoid, 175–200–(360)µ in diameter; spermatangial branches near branch tips 120–170µ long and 35–50µ in diameter on a sturdy 1-celled stalk, without a sterile tip, arising from the entire trichoblast primordium or frequently one from each primary branch of the trichoblast.

TYPE LOCALITY: Berry I., Bahamas.

MATERIAL EXAMINED includes the following: HAWAIIAN ISLANDS—D. 8461, 8462, tetrasporic, Kaneohe Bay, Oahu, Nov. 24, 1950; D. 10816, Kapoho Point, Kailua, Oahu, Oct. 10, 1953; Josephine E. Tilden 602, tetrasporic, Laie Point, Oahu, June, 1900 (as *P. calothrix* Harvey); D. 13448, 13458B, tetrasporic, on basalt ledge, west lip of Pohoiki Bay, Island of Hawaii, legit M. S. Doty and A. J. Bernatowicz, Nov. 10, 1956; D. 13076, Anaehoomalu, Island of Hawaii, legit Amy Sollenwell, Nov. 15, 1952; D. 17220A, Punaluu Bay, Island of Hawaii, Jan. 29, 1953; D. 17304, low mats on lava, Laupahoehoe Point, Island of Hawaii, Jan. 28, 1953; D. 19256, tetrasporic, spermatangial on prehistoric lava flow dike, east of 1955 flow, 6–8 inches above high tide level, Keekee, Island of Hawaii, Dec. 23, 1959; D. 19354, in shaded crevices of 1955 lava flow, Keekee, Island of Hawaii, Sept. 8, 1960; D. 19359, King's Landing, Panaewa, Island of Hawaii, Sept. 13, 1960; AMERICAN SAMOA—T. 701–704, on intertidal basalt, mouth of Fagasa Bay, Tutuila I., Aug. 21, 1964; T. 682, on a log above high tide level, Afono, Tutuila I., Aug. 22, 1964; PHILIPPINE ISLANDS—D. 16198, above low tide, western shore of Cuenco I., Hundred Islands, Pangasinan Prov., legit M.S. Doty and E. Meñez, Feb. 15, 1958; D. 18077B, tetrasporic, cystocarpic, south of Sasa wharf, Davao, legit E.

Meñez, July 26, 1958; EAST INDIES (Siboga Expedition collections loaned from Rijksherbarium, Leiden, and identified by Mme. Weber v. Bosse as *Lophosiphonia obscura*)—Sta. 14, Kangean I., east of Java, Mar. 14, 1899; Sta. 165, Fausses Pisangs I., west of New Guinea, Aug. 20–22, 1899; Sta. 277, Dammer I., east of Timor, Jan. 9–11, 1900; Sta. 296, coast of Timor, Jan. 24–26, 1900; SINGAPORE—D. 16425A, on mangrove stems and roots at sea edge of mangrove swamp near Caltex refinery, Paudan Nature Reserve, Nov. 31, 1957; CEYLON—W. Ferguson, Ceylon Algae 239 (as *Lophosiphonia obscura*), Rijksherbarium.

The wide distribution of *P. howei* in the Atlantic and Pacific Oceans was previously reported by Hollenberg (1958:64). The present study extends the distribution westward to the Indian Ocean and shows that this species is common throughout the tropical Pacific. Furthermore, a collection by J. Feldmann at Roscoff, France, Aug. 25, 1946, is probably to be identified with this species. Erect branches arise in the characteristic exogenous manner from prostrate branches, and the specimens exhibit most of the detailed features of the species, although the rhizoids arise from the middle of the pericentral cells instead of from the distal end. Hence it seems probable that *P. howei* occurs also in southern Europe.

***Polysiphonia pentamera*** sp. nov.

*P. fragilis* Tsuda 1964:11, not of Suringar 1870:37. *P. mollis?* Weber v. Bosse (1923:356) (in part), not of Hooker and Harvey.

Fig. 2*D*

Plants epiphytic with prostrate branches 2–3 cm long and (115)–175–200µ in diameter, and with segments mostly shorter than their diameter, attached by unicellular rhizoids which are cut off from the pericentral cells by a cross-wall; assurgent erect branches to 3.5 cm high of a similar diameter and with segments about 1 diameter long in older parts and very short in younger terminal parts; branching mostly exogenous, sometimes cicatrigenous, pseudodichotomous and occasionally somewhat distichous, at relatively wide angles and at intervals of (6)–12–25 segments, the branches not constricted at the base, arising in connection with trichoblasts; pericentral cells 5, ecorticate; walls hyaline, firm, and of moderate thickness, mostly but little constricted at the clear dissepiments; trichoblasts mostly at intervals of 12–14 or more segments, with 3–4 dichotomies, quickly deciduous, leaving small scar-cells; tetrasporangia about 55µ in diameter in very long, slightly spiralling series up to 60 or 70 in the upper branches; sexual reproduction unknown.

Plantae epiphyticae, ramos prostratos 2–3 cm long et (115)–175–200µ diam., segmentis plerumque brevioribus quam lata habentes; per rhizoidea unicellularia quae a cellulis pericentralibus per dissepimentum separantur affixae; rami erecti assurgentes ad 3.5 cm alti ramis prostratis diametro similes, segmenta in partibus vetustioribus aeque longa ac lata et in partibus iuvenibus terminalibus brevissima habentes; rami plerumque exogeni interdum cicatrigene, pseudodichotomi et interdum satis distichi, angulis relative latis, intervallis (6)–12–25 segmentorum, ramis ad basim non constrictis, in associatione cum trichoblastis enascentibus; cellulae pericentrales 5, ecorticatae; parietes hyalini firmi satis crassi, ad dissepimenta manifesta saepissime vix constricti; trichoblastae plerumque intervallis 12–14 vel plurim segmentorum dispositae, 3–4 dichotomias habentes, cito deciduae cellulas-cicatrices parvas relinquentes; tetrasporangia ca. 55µ diam. 60–70 in serie longissima subspirali in ramis superioribus; reproductio sexualis ignota.

TYPE: G. 524.2, tetrasporic, from a depth of 28 m, in the lagoon, Eniwetok Atoll, Aug. 31, 1955.

ADDITIONAL COLLECTIONS: HAWAIIAN ISLANDS—D. 19135W2, on other algae, dredged 26 fa, Waialua, Oahu, Aug. 2, 1959; GILBERT ISLANDS—D. 18937A, from a coral reef, Marakei I., legit M. J. Cooper, July, 1962, and identified by Tsuda (1964:11) as *P. fragilis* Suringar; CAROLINE ISLANDS—D. 21223.1, tetrasporic, creeping on a *Padina* sp., on a reef flat near the bridge between Kolonia and Jokii I., Ponape Group (6°58'N, 158°11'E), legit E. Meñez, June 25, 1960; EAST INDIES—two collections made on the Siboga Expedition and identified by Weber v. Bosse (1923) as *P. mollis?* Hooker and Harvey; Sta. 77, on other algae dredged 40–60 m, Borneo Bank, southeast of Borneo, June 12, 1899; Sta. 133, Lirung, Salibabu I., "flottant le long du bateau," July 25–27, 1899; VIETNAM—Da. 11277, tetrasporic, as *P. fragilis* Suringar, Ile de Tre; Da. 11278A, tetrasporic, as (*P. coacta* Tseng) from Nhatrong, Feb. 16, 1952.

This species resembles *P. fragilis* Suringar as interpreted and figured by Okamura (1929, Vol. VI: Pl. 255, figs. 1–15). However, Okamura describes trichoblasts as arising one per segment. Segi (1951:251, as *P. forcipata* Harvey) describes and figures a similar plant with trichoblasts on every segment. *P. pentamera* also resembles *P. polyphysa* Kützing, collected by Vieillard in New Caledonia, and figured in Kützing (1863, Vol. 13:20). *P. polyphysa* is described as having 5 pericentral cells and very short segments, but the branch apices are described as forcipate, and the pericentral cells as "valde inflatis."

*Polysiphonia tepdia* Hollenberg 1958:65
*P. flabellulata of* Meñez 1964:219, (non *P. flabellulata* Harvey 1860:330); ?*P. denudata* Taylor (1960) as concerns non-corticated forms
Fig. 3*D*, 3*E*

Plants 1–8 cm high, very soft and flaccid, assurgent from a brief prostrate base attached by numerous unicellular rhizoids, which are cut off by a cross-wall mostly from the proximal end of the pericentral cells, which may have digitate tips and may be as much as 1.3 mm long; pericentral cells mostly 7, sometimes 6 in upper branches, or 8 at the base, ecorticate, with segments in median parts of main erect branches mostly 1–1.5 diameters long and 140–250μ in diameter; walls thin and hyaline or thick and stratified in lower parts; main axes not prominent, branching pseudodichotomously at wide angles up to 45 degrees below, at very narrow angles and somewhat distichous in upper parts, with 4–10 or more, but mostly 8, segments between successive branches; branches arising in connection with trichoblasts; trichoblasts commonly 1–2 between successive branches, often poorly developed, but sometimes well developed, 200–500μ long and with 2–3 forks and delicate tips, mostly soon deciduous, leaving small scar-cells; tetrasporangia 50–70–(95)μ in diameter, in short or longer straight series in the ultimate and subultimate ramuli; cystocarps subglobose and about 160μ in diameter, according to Meñez (1964:219). I observed only immature cystocarps; spermatangial branches not observed in the material examined, but described by Meñez as arising as a primary branch of a trichoblast.

TYPE LOCALITY: Beaufort, North Carolina, United States mainland.

COLLECTIONS EXAMINED (all from the Hawaiian Islands): D. 9765A, tetrasporic, near the Army Gate, Sand I., Oahu, Jan. 27, 1952; D. 18020, tetrasporic, cystocarpic, Kaneohe Bay, Oahu, Oct. 10, 1953; D. 19756, tetrasporic, scraped from the hull of a boat in Ala Wai Yacht Harbor, Honolulu, Oahu, Nov. 14, 1951; H. 62–12, from an aquarium of sea water in which fish were being reared and fed the *Polysiphonia* for food, Sans Souci Beach Laboratory, Waikiki, Oahu, Dec. 3, 1962; an unnumbered collection, by I. A. Abbott, from Keawanui Pond, Molokai, Aug. 24, 1944.

A plant described and figured by Boergesen (1918:269, figs. 263, 264) may be *P. tepida,* although Boergesen's fig. 264 shows rhizoids in open connection with the pericentral cells.

***Polysiphonia tsudana*** sp. nov.
*Polysiphonia* sp. of Tsuda 1965:21
Figs. 1*F*, 1*G*, 2*C*

Prostrate branches 40–62μ in diameter, composed of segments about 1 diameter long, attached by unicellular rhizoids, which are cut off by a cross-wall from the center or distal end of the pericentral cells; erect branches arising mostly cicatrigenously at close but irregular intervals, to 4 mm high and 45–50μ in diameter, mostly unbranched, with segments 1 diameter long or less; pericentral cells 4 in the prostrate branches, 6–9 in erect branches, about the same size as the central cell, ecorticate, commonly of unequal length in a given segment and not strictly in longitudinal rows; trichoblasts infrequent and very rudimentary, but primordia (or scar-cells) commonly one per segment and in mostly ¼ spiral sequence, except in tetrasporangial branches where they are unilateral; tetrasporangia about 36μ in diameter, one per segment in short, non-spiralling series, somewhat distending the segments; spermatangial branches (immature) lanceolate, to 65μ long, apparently without a sterile tip, on a very short, 1-celled pedicel, arising from the entire trichoblast primordium; cystocarps unknown.

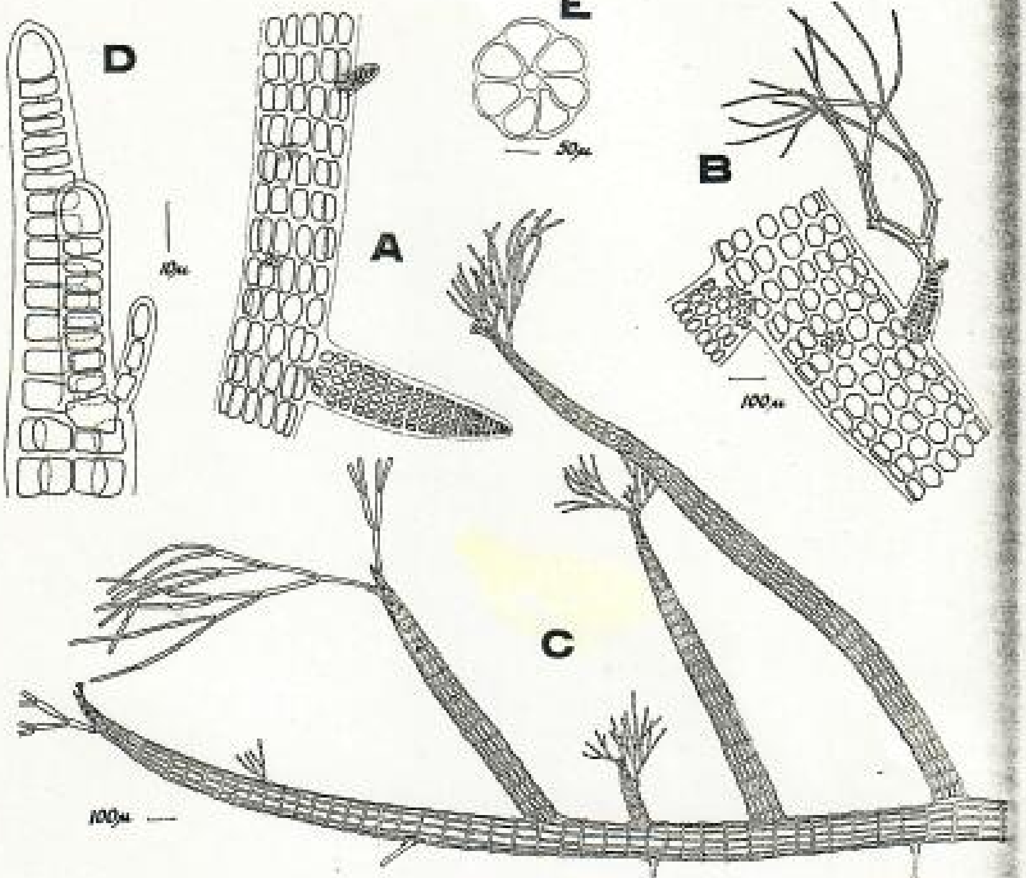

FIG. 3. *A* and *B*, *Polysiphonia?* sp. (scale for *B* applies to *A* as well). *C*, *Polysiphonia exilis*, prostrate branch and erect branches. *D* and *E*, *Polysiphonia sepida.*

Algae minutae, ramos prostratos 40–60μ diam. et segmenta aequa longa ac lata habentes, rami per rhizoidea unicellularia, ut cellulae discretae separata, affixi; rami erecti ad 4 mm alt., 40–50μ diam., plerumque non ramosi, segmentis plerumque ac longis ac latis aut brevioribus; cellulae pericentrales 4 in ramis prostratis et 6–9 in ramis erectis; trichoblastae rarae elementariaeque, primordiis vulgo uno in unoquoque segmento in ramis erectis prostratisque, in spira ordinatis nisi in ramis tetrasporangialibus; tetrasporangia in serie brevi non spirali; rami spermatangiales e primordio trichoblastae toto enascentes; cystocarpi non observati; plantae in collo testudinis marinae colentes.

TYPE: T. 609, tetrasporic, spermatangial, scraped from the neck of a sea turtle, *Chelonia mydas*. It was collected by Roy T. Tsuda at Laysan I., Hawaii (25°48′N, 171°44′W), Dec. 8, 1963. It is represented by a single glucose mount.

The spiral arrangement of trichoblasts and scar-cells, which are unilateral only on tetrasporangial branches, and the cicatrigenous origin of erect branches, are features which exclude this alga from the genus *Lophosiphonia*.

No additional collections are available for study, but no other species of *Polysiphonia* closely approximates the distinctive features of this alga, especially the epizoic habitat, the minute size, the variable number of pericentral cells, and the origin of spermatangial branches from the entire trichoblast primordium.

*Polysiphonia ?* sp.
Fig. 3*A*, 3*B*

Plants to 1 cm high with prostrate branches 200–220μ in diameter, attached by rhizoids which are cut off as separate cells from the distal end of the pericentral cells and which may have multicellular tips; erect branches similar and slightly larger in diameter, arising endogenously or mostly cicatrigenously at intervals of 6–8 segments, each erect branch mostly 2 segments and ¼ right-hand turn from another branch or a branch primordium, the latter usually composed of several cells; pericentral cells 8–(9?) ecorticate, composing segments mostly less than half as long as broad, with pericentral cells not in longitudinal rows but in offset position, resulting in a more or less hexagonal shape of the pericentral cells as seen in surface view; erect branches in turn bearing short, somewhat arcuate laterals and primordia; trichoblasts to 700μ long, with about 5 dichotomies; arising at intervals of mostly 2–3 segments and ¼ right-hand spiral, quickly deciduous, leaving scar-cells which quickly divide to form a cluster of small cells most of which remain as multicellular rudiments of potential branches; reproductive structures unknown.

A single collection, D. 17242.1, growing with a member of the Gelidiaceae, was collected by Jessie Kajimara at Ili Bridge, Halona, Oahu, Hawaii, Nov. 14, 1956.

This alga has very distinctive features, but the lack of reproductive structures makes its generic position uncertain.

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PROGRESS REPORT
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# A SURVEY OF NINE COMMERCIAL FISH PONDS

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The Fisheries Research Staff during the past few months made an effort to study as many commercial fish ponds as possible. The purposes of the studies have been (1) to gain some knowledge of the physical, chemical, and biological conditions of Hawaiian ponds (2) to discover one, or perhaps a group of conditions that might serve as indicators of the production possibilities of individual ponds; and (3) to search for means and methods of increasing production of commercial ponds. Early studies were preliminary and exploratory in nature but have provided information for systematizing and standardizing pond studies. Organized pond survey studies are still in progress and final reports on survey studies will not be available for some time. However, the survey studies are summarized from time to time as sections of the work are completed and the results of one section of the work is now available.

Nine ponds varying in size from 4 to 134 acres in area have been selected for seasonal survey studies. This progress report makes available to pond owners the results of a survey of the above ponds carried out cooperatively by members of the staff during the last week of August and the first week of September 1944.

Tables I and II present and summarize data collected on the nine ponds surveyed. Though each pond has an identifying Hawaiian name, the various ponds are identified only by Roman numerals in the tables and discussion to follow.

## PLAN OF SURVEY

General observations on the ponds as a whole were made but since conditions vary from place to place within ponds, representative areas of the ponds were selected for careful observation and collection of materials and samples. The number of collection areas, or stations, for the different ponds was determined by the size of the pond and by the number of recognizable ecological areas. The stations are identified by Arabic numbers in Table I and in the discussion. The appearance and depth of the water and the character of the bottom of the pond were noted at each station. The temperature of the surface layer of water of each station was taken with a Centigrade thermometer. Samples of the water of the stations were collected for chemical determination of chloride content and the chemical determinations later carried out in the laboratory. The potassium chromate-silver nitrate method for the

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determination of chlorides was employed and chlorinity, or quantity of chloride, of the water was recorded as parts chloride per thousand parts water. The quantity of plankton, or the minute plant and animal forms suspended or swimming in the water, was determined by pouring 25 gallons of water through a fine silk net and the net sample further concentrated by centrifuging. The quantity of plankton was recorded as cubic centimeters per 25 gallons, or approximately 100 liters, of water. Observations on the plant populations, including diatoms, were also made. Though quantitative measurements of the plant materials were not made, notes were made of the kinds and the relative abundance of plants.

## GENERAL CHARACTERISTICS OF PONDS

The water was fairly turbid in all but two of the ponds and varied in depth from a few inches along the shore to a few feet at the center. The maximum depth of the greater number of ponds was from three to four feet and only three ponds had limited areas of water up to ten or more feet in depth. In general, all were shallow ponds. The entire bottom area of seven of the ponds was covered by a deep layer of mud. One of the remaining ponds had a fair area of sandy bottom while the other had a fair area of hard coral bottom. Three of the ponds had walls equipped with gates that permitted a strong inflow of sea water at high tide. Five ponds had walls without gates or had gates not in operating condition so that sea water could enter only by seeping through the stone sea wall. The ninth pond had no direct connection with the ocean and, therefore, no change of water with rise and fall in tides.

## CHLORINITY

Chlorinity values, or the quantity of chlorides in parts per thousand parts water, are presented for all collection stations in Table I and are summarized in Table II. The average chloride value of 18.91 parts per thousand parts water for Pond IX when compared with the value of 19.00 parts per thousand parts water for sea water, indicates that that water of this pond was almost as salty as sea water. Ponds I and VII with average chloride values of 17.28 and 17.17 parts per thousand were quite salty but not as salty as the ocean. Ponds II, III, IV, V, and VI with chloride values of 13.80, 15.07, 11.92, 13.84, and 15.45 parts per thousand varied from a little more than one-half to three-fourths as salty as the ocean. Pond VIII with an average chloride value of 4.10 parts per thousand was only about a fourth as salty as the ocean. Pond VIII may be considered a fairly fresh pond, while all other ponds must be considered brackish or definitely salty.

A study of the chloride values for the water of the individual ponds recorded in Table I shows them to vary more or less markedly from station to station. In all instances the lowest chloride values for a pond were found to be near or at a region where fresh water entered a pond. For example, station 4 of Pond VI with a chloride value of 0.65 parts per thousand parts water received a strong inflow of fresh water from a spring. Station 9 of Pond VIII with a chloride value of 0.53 parts per thousand also received spring water. The low chloride value of 9.91 parts per thousand for station 11 of Pond IV bordered on a marsh which received spring water. Other examples of an inflow of fresh water lowering the chloride value of a station can be noted in Table I. It is interesting to note that in many instances the shore near the stations of low chloride value was marked by the presence of bulrushes.

The character of the sea walls and the surrounding land areas, by determining the water supply and the water exchange, determined the average chloride value of the ponds. Pond IX with an average chloride content of 18.91 parts per thousand received little or no fresh water. Three gates in operating condition in its sea wall permitted fairly free exchange of water with the ocean and its water was, therefore, about as salty as the ocean water. Though Pond I received spring water and surface water along its shore, its average chloride value was 17.28 parts per thousand. Its high chloride content was due to a great change of water of the pond with change in tide which resulted from the presence of gates in operating condition and the presence of low sections in the wall which permitted water to wash into the pond at high tide. Pond VII with a chloride value of 17.17 had no gates in the sea wall but the wall was in such poor condition that seepage of sea water through the wall at high tide was extensive enough to balance an inflow of a low volume of fresh water. Ponds II, III, and V with chloride values of 13.80, 15.07, and 13.84 parts per thousand received fresh water but had only limited exchange of water with the ocean since their wall either lacked gates or had gates so situated that very little inflow of water at high tide was permitted. Ponds IV and VI each had three operating gates in their wall but due to the placing of the gates the exchange of water with the ocean was greatest for pond VI. Both received fresh water, evidently in considerable quantity since in spite of a strong inflow of sea water their average chloride content was 11.91 and 15.45 parts per thousand. Pond VIII received spring water but had no direct exchange of water with the ocean though it did receive diluted sea water by seepage through a stone wall from a neighboring pond. Its chloride value of 4.10 parts per thousand was, therefore, the lowest for our series of ponds.

The above observations indicate that the water of some of the ponds was relatively stagnant and was freshened but little by sea water or fresh water. Ponds II, III, and V were of this type. Other ponds were freshened either by sea water with change in tide, or by fresh water, or by both types of water. Ponds I, IV, VI, VII, VIII, and IX were of this type. Ponds IV and VI were freshened by considerable volumes of both fresh and sea water while Pond VIII was freshened almost entirely by fresh water.

## WATER TEMPERATURE

The temperature of the water at each of the stations for all ponds is recorded in Table I and the average water temperatures for the various ponds are summarized in Table II. The average temperature for all ponds was 26.5° C. while the average temperature for the individual ponds ranged from 24.5° to 29.1° C. Ponds VI, VII, and IX with the highest average temperatures of 27.5°, 28.6°, and 29.1° C. were examined during the late morning and early afternoon hours. This observation indicates that the temperature of the water of the ponds tends to rise during the day. Further examination of the data on temperature of the water showed that the highest temperatures observed were for the shallower and more protected shore stations while the lowest temperatures were for central and more exposed stations and for areas where spring water entered the ponds.

## PLANKTON VALUES

One of the purposes of our studies has been to determine the relation of physical and chemical conditions to the biological conditions of ponds. Our data have been analyzed to determine the relation of the quantity of plankton to other pond conditions noted in our study. For our studies, the total plankton values show no direct relation to the time of day when the collections were made, or to temperature, chloride value, depth of the water, or location of the station within the ponds. The various plankton elements have not been enumerated and identified but it is possible that some one or more plankton forms may be directly related to some one or more of the physical or chemical conditions noted. The total plankton values of the present study may, however, become significant when compared to values obtained in later surveys.

## ALGAE

The kinds and numbers of plants were found to differ for the different ponds. Sea weeds, or algae, among them *Polysiphonia*, *Ceramium*, *Gracilaria*, *Cladophora*, *Enteromorpha*, and *Ulva*, were found in small numbers in most of the ponds. All were found attached to the stones of the sea walls or to rocks or other solid objects which projected above the surface of the mud of the bottom of the ponds. Except for the occasional patch of algae, the bottom of all but two ponds were found to be without plant growth. Pond VIII had a luxuriant growth of *Ruppia maritima*. It was fairly deeply rooted in the bottom mud and tended to hold the soil of the bottom. However, it showed the disadvantageous characteristics of growing to the surface and in growing in large impenetrable masses tending to "choke up" the pond. It should be noted that Pond VIII had the freshest water of the ponds investigated. A fairly luxuriant growth of *Halophila ovalis* was found only in Pond IX. It formed a good bottom plant and had the advantageous characteristics of growing only a few inches in height and in not "choking up" the pond. Because of its manner of growth, *Halophila* is a more desirable pond plant than *Ruppia* from the point of view of pond management.

## DIATOMS

Extensive studies of the diet of our commercially important pond fish have been carried out by members of our staff and the results of those studies will be published in detail later. However, it may be noted here that mullet (*Mugil cephalus*) are bottom feeders and that diatoms form about 90 per cent of their diet. Awa (*Chanos chanos*) are also bottom feeders but diatoms form a somewhat smaller percentage and larger algae and portions of higher plants form a greater percentage of their diet than for mullet. Since diatoms form the most important food forms of our pond fish, particular attention was paid to the presence and abundance of diatoms in the ponds. Before noting the occurrence and distribution of diatoms, some of the characteristics of these forms may be described. Diatoms are commonly classified as plants because of their power of photosynthesis, are microscopic in size, and characteristically possess a translucent covering shell of silicon. Many diatoms grow on the bottom while others grow on other plants or on animals, while still others are suspended in the water. In an abundant condition, diatoms form a brownish, silty layer of some thickness over the bottom of the ponds and may form layers over upright plants or other objects in the ponds. Frequently patches of the bottom diatom layer become detached and float on the surface of the water of the ponds. The presence of large or fairly large populations of diatoms in our ponds is, therefore, readily noted.

Diatoms were present, though not equally abundant, in all of the ponds investigated in this survey. Large bottom deposits were found in the shallower areas of the ponds, frequently in areas that were exposed at low tide. Large bottom deposits of that nature were found in Ponds I, III, IV, and V. Diatoms were most abundant in Ponds I and IV. Diatoms were less abundant in Ponds II, VI, VII, and IX, but Pond IX had large deposits in 4 of the 21 stations investigated. Diatoms were least abundant in Pond VIII.

Table I shows that the ponds which possessed large diatom deposits, namely, Ponds I, III, IV, and V, had average chloride values of 11.91 to 17.28 parts per thousand parts water. Diatoms, therefore, flourish under a considerable range of salinity. Though our studies are not extensive enough to yield definite proof, it appears that for the greater number of the ponds investigated, chloride content of the pond water was not the determining factor in diatom production. Neither does it appear that temperature alone determined diatom production. Depth of the water, and thereby the degree of exposure to sunlight, may be one of the factors that determines the formation of large diatom populations in the ponds. Water movements, such as the slow wash of the tides over the shallow shore areas, may also influence diatom production. Studies of the factors which stimulate and maintain diatom production are needed. It is possible that further survey studies may indicate the factors which stimulate formation of large diatom populations. Also, methods of artificially stimulating the development of diatoms in ponds must be devised if forced increase of fish production is to be attempted.

## RELATION OF FOOD SUPPLY TO FISH POPULATION

A census of the fish populations of the ponds was not attempted in this study. However, the number of fish noted during the course of the surveys was so small that a thorough census was not needed to conclude that the ponds were understocked. This conclusion was supported by information gathered on the management of the ponds which indicated that in recent years most of the ponds had not been stocked regularly. We believe that all of the ponds investigated can support a much larger population of fish. We also believe that ponds with large diatom populations can support larger populations of mullet and awa than has heretofore been supposed possible. This would be true particularly if the diatom populations remain large throughout the year. It also appears that Pond VIII could support a larger population of awa than of mullet because of the tendency of the former species to feed on larger plants and plant debris--the most abundant type of plant material found in this pond. Pond VI differed from the others in that iao (Hepsetia insularum) were present. If this species is found in considerable numbers throughout the year, Pond VI may be adapted to the cultivation of iao for sale as bait fish or to the cultivation of carnivorous species for which iao could serve as food.

The surveys of the nine ponds described above have yielded important information on the supply in the ponds of foods needed by mullet and awa. The surveys will be repeated from time to time during the period of a year for the purpose of determining whether food supplied are maintained at a constant level throughout the year or whether seasonal fluctuations in the abundance of foods occur. Recommendations on pond management will depend on which conditions our later surveys demonstrate for our ponds. Until the results of later surveys become available it can be concluded that ponds with large diatom populations are capable of supporting large populations of mullet and awa.

## ACKNOWLEDGMENT

The work of the survey described above was carried out cooperatively by Isabella Abbott, Charles J. Engard, Yoshinori Tanada, and the writer, who acknowledges his indebtedness to his colleagues for much of the material presented in this progress report. We are grateful to the Hawaiian Sugar Planters' Associatio for the privilege of living at its Mapulehu Experiment Station hous for the period of our study of the Molokai ponds.

## SUMMARY

1. The nine ponds included in the survey varied from 4 to 134 acres in area.

2. The temperature of the water of the ponds was found to average 26.5° C. and to range from 22.9° to 32.4° C.

3. The chloride content of the water of the ponds in parts chlorides per thousand parts water averaged 15.11 parts and ranged from 0.53 to 19.26 parts.

4. Total plankton values for the ponds averaged 0.12 cubic centimeters per 25 gallons of water and ranged from 0.01 to 1.20 cubic centimeters.

5. Algae, or seaweeds, were found in small numbers in the ponds investigated. Polysiphonia, Gracilaria, Ceramium, Ulva, Cladophora, and Enteromorpha were included in the collections.

6. Ruppia maritima was abundant in the pond with the freshest water while Halophila ovalis was abundant in the saltiest pond of the series. Each of these species was limited to one pond only.

7. Diatoms--the microscopic plants forming the greater part of the diet of mullet and awa--formed large deposits in four of the nine ponds, formed fairly large deposits in four others and were scarce in one pond.

| Number of pond | Station in pond | Time samples collected | Temperature of water in Centigrade | Chloride in parts per thousand | Plankton in cubic centimeters per 25 gals. water | Plants present |
|---|---|---|---|---|---|---|
| VI | 1 | 1:54 | 27.6 | 14.92 | 0.03 | Ulva, Cladophora; some diatoms. |
| | 3 | 2:10 | 28.5 | 16.83 | 0.15 | As for 1. |
| | 4 | 2:20 | 25.3 | 0.65 | 0.10 | As for 1. |
| | 5 | 2:38 | 30.2 | 17.04 | 0.20 | Very little plant material; very few diatoms. |
| | 6 | 2:50 | 27.2 | 17.69 | 0.05 | As for 5. |
| | 7 | 3:00 | 27.2 | 17.76 | 0.10 | Very little plant material. |
| | 8 | 3:05 | 27.4 | 16.74 | 0.10 | As for 7. |
| | 9 | 3:10 | 27.9 | 15.74 | 0.10 | Ulva and diatoms present. |
| | 10 | 3:22 | 27.1 | 17.04 | 0.05 | Ulva and Polysiphonia present. |
| | 11 | 3:30 | 27.1 | 17.77 | 0.04 | As for 10. |
| | 12 | 3:35 | 27.6 | 17.86 | 0.05 | As for 10; diatoms numerous. |
| VII | 1 | 12:35 | 28.9 | 17.31 | 0.40 | Diatoms fairly abundant; Polysiphonia present. |
| | 2 | 12:55 | 29.5 | 16.74 | 0.50 | As for station 1. |
| | 3 | 1:05 | 27.4 | 17.47 | 1.20 | Very few plants present. |
| VIII | 1 | 9:25 | 25.3 | 4.79 | 0.40 | Ruppia abundant; Spirogyra and Cladophora present; diatoms also present. |
| | 3 | 9:40 | 24.9 | 5.02 | 0.45 | As for 1. |
| | 5 | 9:53 | 25.5 | 5.23 | 0.30 | Very few plants of any kind. |
| | 8 | 10:20 | 25.7 | 4.93 | 0.05 | Ruppia abundant. |
| | 9 | 10:25 | 27.9 | 0.53 | 0.10 | Spirogyra, not abundant; few other plants. |

# GREEN SEA TURTLES RELEASED AT TURTLE BEACH, MAKAHA

by Sharon Hendrix

During September, 1981, the National Marine Fisheries Service Honolulu Laborarotory released a total of 165 green sea turtles (chelonia mydas) at various coastal sites on Oahu, Kauai, Maui, Hawaii and French Frigate Shoals. On Sept. 24, 15 of the green sea turtles were released at Turtle Beach on our Waianae coast. The released turtles were one year old, weighed about 8 lbs. and were involved in the "headstart" project. The project involved obtaining turtle hatchings at French Frigate Shoals (where green sea turtles go to breed) and transporting these turtles back to Sea Life Park for one year of rearing. The turtles were experimentally marked by surgically grafting small pieces of white tissue into the hatchling's black shells.


**Jeanine Ortogero and her daughter Makani carry one of the young turtles to its new ocean home.**

The "headstart" project offers potential for aiding the recovery of depleted turtle populations. According to Marty "Smitty" Smith and Wil Pickett and the Cabanas, green sea turtles were often seen at Turtle Beach, however, through man's over-exploitation and habitat encroachment, the green sea turtle population has declined here and throughout the islands.

The green sea turtle is currently protected under the U.S. Endangered Species Act and the wildlife regulations of the State of Hawaii. It is hoped that the turtles released in the "headstart" project will become part of the breeding colony when they mature into adults. Green sea turtles can take as long as 10-60 years to grow into adulthood, and are usually 36 inches in shell length, about 200 lbs. in weight and feed mostly on limu.

Scientists have much to learn about the green sea turtle and hope that the "headstart" project will demonstrate that restocking is a valuable conservation practice ("headstart" projects are currently in practice in several areas of the world). All of the young turtles that have been released are individually indentified with a small numbered metal tag attached to a front flipper. Information from the public on the sightings of these tagged turtles will be appreciated.

FOR FURTHER INFORMATION, TELEPHONE WILLIAM GILMARTIN OR GEORGE BALAZS AT NATIONAL MARINE FISHERIES SERVICE 946-2181.

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See page 12

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ISLAND BOY, A story of ancient Hawaii (1956)
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Lothrop, Lee and Shepard Company, Inc.
209 pp. illos

shallows until a huge circle was made. Paulo found that tugging at the awkward lines took all his strength. However, pulling and straining with a will, he felt that he belonged—the villagers accepted him as equal.

First and second settings of the net went well.

The fish were not yet running strong, but enough were caught to start things going. Everyone was hard at work hauling and tumbling the catch onto the sandy beach. Fires spurted thick clouds of smoke as green brush and leaves were piled high.

"More fish come!" Olu predicted enthusiastically. "We take home plenty!"

With the next cast of the net, Paulo knew his friend was right. Even as they formed a circle, a splashing school of feeding fish swam right into their great purse. Everyone stopped to let the net bob in the water. Soon all the fish were inside.

"What a fuss they make!" Paulo called to Olu.

Large fish and small streaked between his legs. Salt water splashed in his face as the fish rose to the surface. Soon a great circle was boiling with the catch; the whole school was trapped.

"Best haul yet!" Olu called. "When these are taken, we go home!"

Everyone shouted with happiness over their good fortune.

"Never have I seen such a netful!" one man called.

All those who heard answered with a cheer. Each man gave excited directions to the other.

Paulo hung onto the net rope with all his strength. Water here was over the boy's head. And the wiliwili floats were not sufficient to keep the net at the surface. He kicked hard with his legs and struggled to raise the rope.

The fish seemed to know they were trapped. They made long sweeps back and forth across the circle, frantically seeking a way of escape. A few leaped over the net and were gone. However, this was to be expected. They could not capture all the fish.

At the height of the excitement, Paulo's attention was caught by a huge, slow-swimming sea turtle. Deep in the green water, the lumbering creature was heading directly for the boy's section of the net. Through the clear swell, he could see brown and green splotches of the turtle's plated back. Clawed feet paddled water with graceful sweeps and long wrinkled neck stretched forward as beady eyes and sharp beak pointed the way.

"What a prize!" the boy thought with delight, knowing that sea turtle meat was a rare and tasty treat!

Paulo instantly decided that he must manage to trap the turtle. "A surprise for Olu!" he told himself, happily. But how could he manage to get the turtle to swim into a closed net? Dare he lower the edge just enough to allow the prize to swim past the barrier? It would be a risky thing to do, he fully realized. Yet, to capture such a prize without laying a hand on it!

Paulo watched as the turtle swam relentlessly and slowly forward. In an instant its sharp beak would come smack against the mesh of the net, or be lost as it swerved aside. The boy glanced toward the busy men. Olu was yards away. If he took time to call for help, the turtle would be gone before anyone could swim to his side.

Paulo looked deep into the water. "What shall I do?" he asked himself, helplessly. He could almost stare into the creature's gold-flecked eyes. Their lids winked in ludicrous slow motion. Dark lines on the turtle's horny-plated back were clearly visible. It was almost up to the net.

Paulo could not resist the temptation. In a swift dive, he carried the edge of the net deep into the water. He was none too soon! The bulky shape floated right past his face . . . one clawed foot just missing Paulo's nose. "It must weigh more than a man!" he calculated as it passed. In an instant, the sea turtle glided inside the circle of milling fish.

Greatly elated, Paulo tried to raise the net rope. But now, tension of the circle and surge of current made it unmanageable. He found the rope too heavy to lift to the surface. Desperately, his fingers slipped and strained at the meshes of the clumsy net. They were drawn taut as the string of a bow. Paulo's lungs began to labor—he must rise to the surface for air.

"Olu!" he gasped as his head bobbed out of water. "Help . . . Olu! The net!"

However, Paulo was too late; sharp-eyed fish had spotted the gap!

Silver streaks and splotches of brilliant colors flashed past the boy as the circling fishes started an escape over the net in a continuous stream. Paulo was helpless to stop them. A whole sea of rushing shapes seemed to be heading for him and open water. He kicked his feet, frantically fighting to stay afloat and escape the rush.

With eyes, nose, and ears filled with chop and flying spray, he listened as cries of alarm filled the air. Paulo knew the others now realized the catastrophe.

"What have I done? What have I done?" he thought in horror.

Olu's strong arm closed about his chest.

"What happened?" the big man choked as he flailed water and drew Paulo to one side. "Are you hurt?"

"No, oh no!" Paulo choked. "I . . . I tried to . . ."

"Wait!" Olu yelled in his ear, and Paulo felt himself being towed through the water by the man's powerful strokes.

Pandemonium had broken loose.

Everywhere in their path, men were struggling with the great net, trying to bring it back to the surface. Boiling fish spilled through the gaps in the circle as the largest catch of the day escaped toward the open sea.

On the beach, Olu and the boy sat catching their breaths.

"Now . . . tell me!" Olu's voice was urgent.

Between anguished gasps for breath, Paulo told about the sea turtle. How he had lowered the edge of the net . . . and could not lift it. Olu stared at him, unbelievingly.

"I . . . I wanted . . . to catch him . . . for you!" Paulo sobbed. "I thought . . . I could . . . lift the rope . . ."

"But we had plenty!" Olu said, dully. "Our biggest catch."

"I know . . . I know! I just thought . . . I wanted . . . Oh, Olu!"

The big man's features looked drawn and tired. "Well, little one, you meant no harm," he said, kindly. "All have to learn."

Villagers had gathered in a group about them. Paulo knew they must have heard his story. Knowledge of the certain disgrace burned his cheeks.

Olu rose slowly to his feet and turned to face the group.

"He's but a *keiki*!" he told them, warningly. "It was a man's job to tend the net. Some here," he looked at them, darkly, "shirked their duty!"

No one spoke as the group parted.

Olu gave the boy's shoulder a pat and strode heavily back to the water. Paulo was left sitting on the sand alone. A few more attempts were made with the net, but heart had gone from the task. Fish had now become wary. "We take what we have and go home," the men agreed. No one approached or scolded Paulo, nor mentioned the big haul. But the boy knew how they felt.

And the sea turtle? No one but Paulo ever saw it!

## CHAPTER SEVENTEEN

# The House-raising

TIME dragged for Paulo after the return from Kou. Again the village of Manoa seemed a strange place and the boy no part of its activity. He felt disgraced and lonesome.

True, the villagers treated him well. No one mentioned loss of the big haul in his presence, nor complained of the small stores of smoked fish in the storehouses. But Paulo knew he had committed a grave error with the net. He could see by their averted glances and studied politeness that many blamed him. He even imagined that they resented his presence in the village. Now he was not sure he should stay in Manoa. Even Olu seemed distant and less friendly.

Actually, ever since their return, Olu had been thinking of more important matters. Concern over his family's crowded quarters worried the big man.

Altogether, these were not happy days for Paulo. He kept to himself and roamed about the valley

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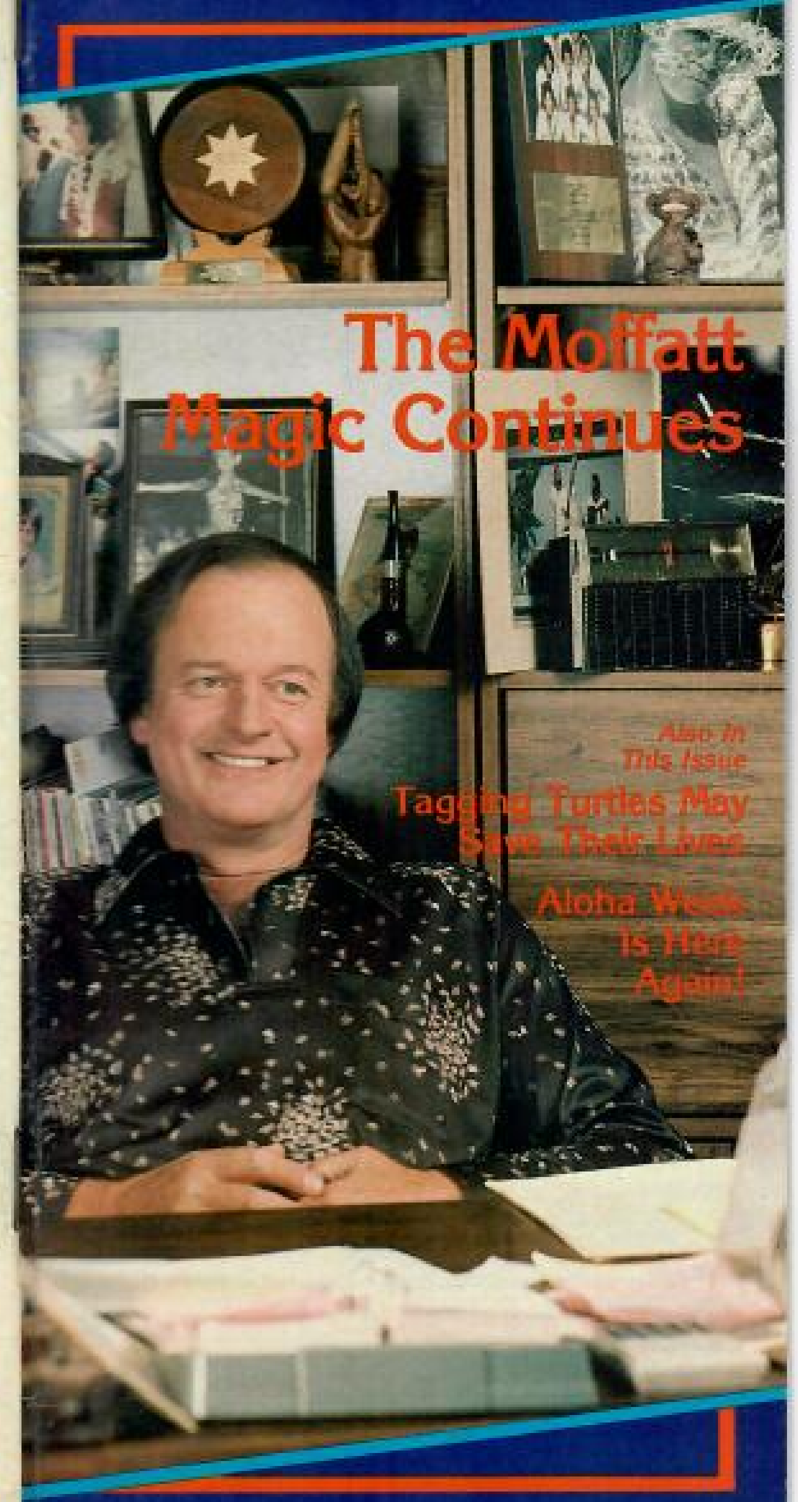

## The Moffatt Magic Continues

*Also In This Issue*

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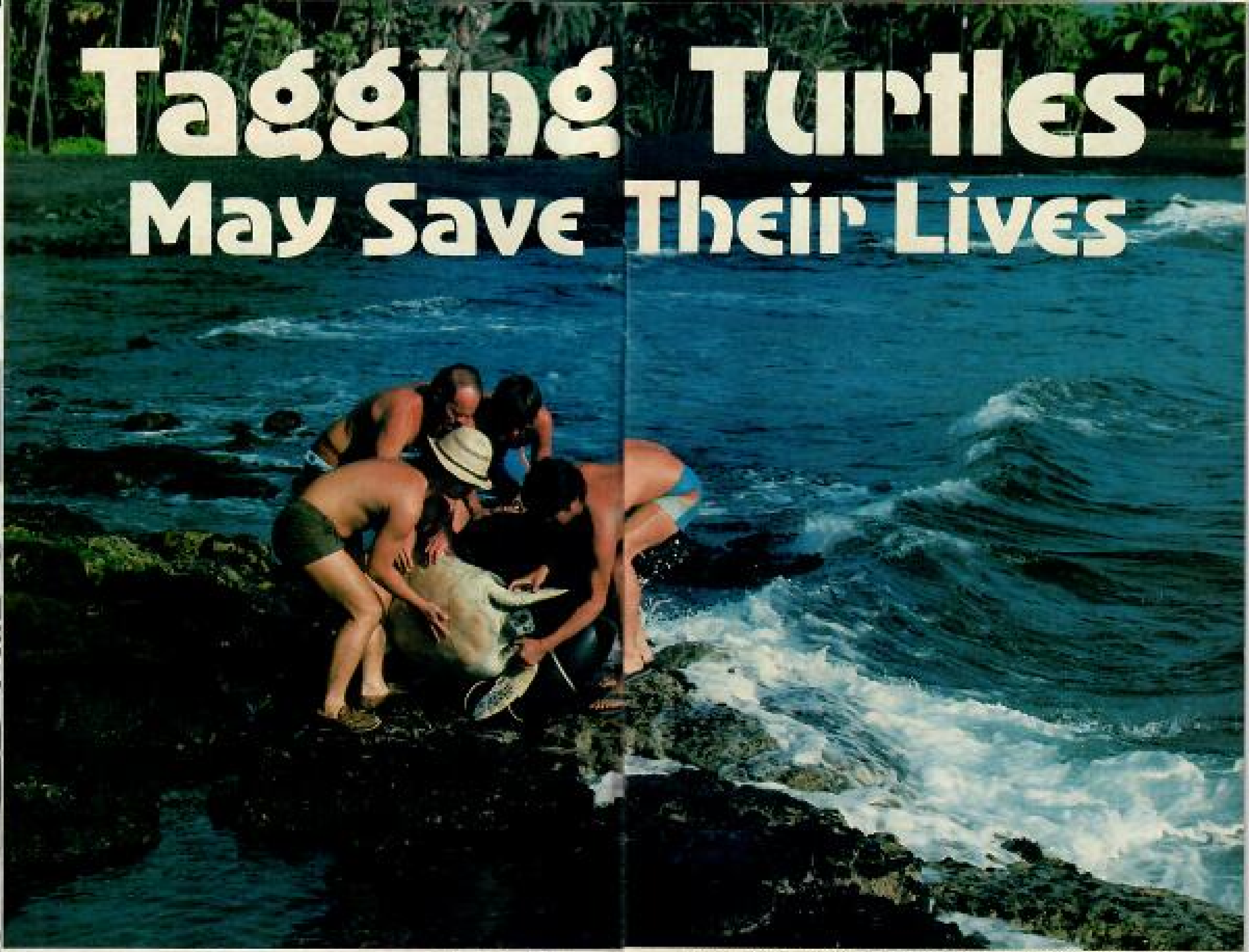
# MANULANI

# Tagging Turtles May Save Their Lives



—Photo by George H. Balazs

*The turtles are carried to and from the beach in innertubes. After tests and tagging are completed, they'll be released, none the worse for wear.*

**By Rick Klemm,**
*University of Hawai'i Sea Grant Extension Service*

The "Sea Turtle Research-University of Hawai'i" sign in front of the pavilion at Punalu'u County Beach Park attracts local residents and visitors alike, who have come by the busload to view the scenic cove. They all want to see the turtles, to "talk story," to ask turtle questions, and to get pictures of, with, and amid the creatures.

Researcher George Balazs and students from the Marine Option Program (MOP) at the Universtiy of Hawai'i-Hilo, on this weekend in February, are capturing and studying Hawaiian green turtles from the cove and nearby waters. Balazs, a wildlife biologist with the National Marine Fisheries Service in Honolulu, believes that gathering data about the green turtles is essential if they are to be properly managed for their benefit and ours. He explains that, while they are not an endangered species now, they are threatened, which means a dramatic change in their population might put them on the brink of extinction. As a threatened species, they are protected by federal and state laws.

Punalu'u is a sheltered cove with a black sand beach on the southeastern shore of the Big Island. The cove's name means "diving spring" and recalls a Hawaiian practice long ago of diving into the cove with gourds to obtain drinking water from an underwater spring.

Punalu'u and other areas along the Ka'u coast have probably been a favorite habitat of Hawaiian green and other turtles for centuries, judging from their mention in local mythology. A turtle named Kauila, according to legend, lived in the spring behind the beach and could assume human form out of water. She played with the children and watched after them as they fished in the spring.

With funding from the University of Hawai'i Sea Grant College Program, Balazs has been capturing and releasing turtles at Punalu'u since late 1983 to learn more about their feeding habits and growth rates. Growth rates among green turtles along the Ka'u coast appear to be more rapid than among green turtles elsewhere in the main Hawaiian Islands. Because of the faster growth rates, Balazs thinks the Ka'u turtle population may make up a large proportion of the breeding colony at French Frigate Shoals in the Northwestern Hawaiian Islands. It is believed that all Hawaiian green turtles go there to breed.

He was attracted to Punalu'u in 1974 when a local couple discovered a clutch of turtle eggs in the sand near their beach concession stand. Possibly because of a red *limu* (algae or seaweed) with the scientific name of Pterocladia capillacea and other underwater features, this area along the Ka'u coast may be one of the best feeding grounds for green turtles in the

(cont. on page 8)

## TURTLE TAGGING *(cont. from page 7)*

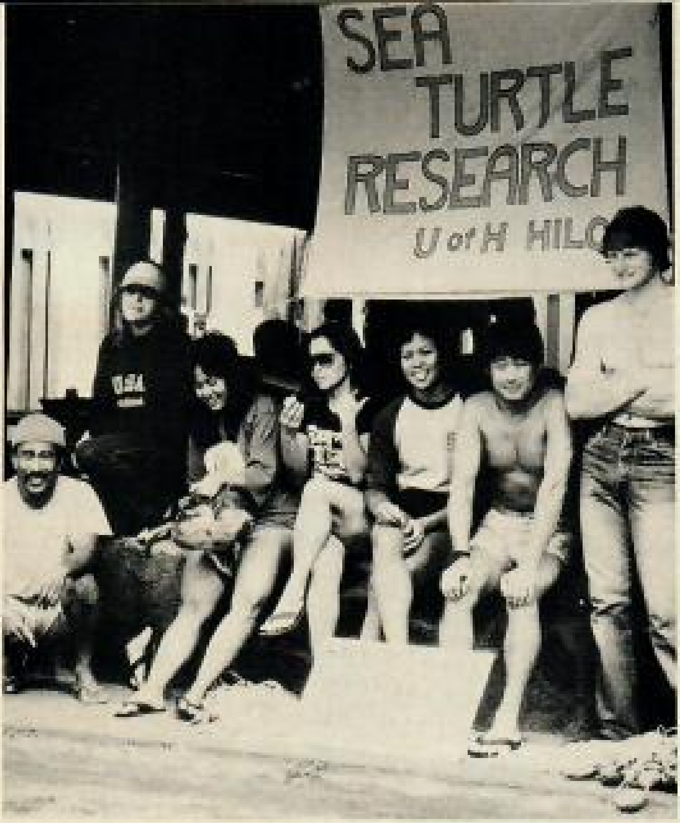
main islands. Not much is known about the feeding habits of these turtles because most research has been carried out at breeding and basking sites.

In 1982, 1,300 hatchling green turtles were tagged and released at French Frigate Shoals. Balazs expects some of these hatchlings to settle in feeding grounds along the Ka'u coast. If he is lucky, he may capture a few during his 12-month study at Punalu'u.

To capture turtles without harming them, Balazs and the MOP students use tangle nets laid across "traffic lanes" within the cove between the turtles' feeding and resting grounds. They come inshore at high tide to feed and rest in holes and cracks further offshore.

On the first night of this expedition, the team captured five green turtles, ranging from 30 to 202 pounds. Another was given them by two Filipino fishermen from Pahala, who earlier had talked with MOP student Diane Mazarakis about the research.

In the morning after breakfast, the first thing Balazs does is to "staple" a corrosion-resistant ID tag on the back edge of each front fin close to the body of each turtle. Large turtles are tagged in their rear fins, too. Then he and the students



*The dedication of teams such as this one from the University of Hawai'i-Hilo may spell the difference between life and death for the Hawaiian green turtle.*

—Photo by George H. Balazs

(cont. on page 33)

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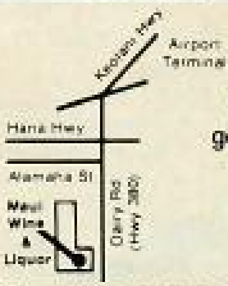

V 19 N12 DEC 1982 Natural History

# Transported Landscapes

*Long before Captain Cook discovered Hawaii, the islands and their flora and fauna had been transformed by Polynesian settlers*

### by Patrick V. Kirch

During the ten million years or more that the main Hawaiian Islands have existed as an archipelago, they have received a stream of colonists, ranging from passively dispersed seed plants and insects to migratory or wayward birds. From such progenitors evolved distinctive flora and fauna of marvelous and often bizarre forms. Because they evolved in isolation, however, these endemic life forms were extremely vulnerable to outside competitors. No more than about 1,600 years ago, some new colonists—Polynesians—arrived on the scene, culminating the greatest human dispersal of all time, the "conquest" of the Pacific by Oceanic peoples. This conquest went far beyond the discovery of the most isolated islands on earth. The story of Polynesia is one of interaction between people and island ecosystems that had for millions of years evolved in the absence of humans and other large terrestrial animals. While the Polynesians had to adapt to the conditions and challenges posed by island life, this was no passive adaptation. Rather, the Polynesians modified and at times drastically altered their island homes.

The impact of the prehistoric Polynesians on Hawaii has not always been appreciated by biologists and anthropologists. Biologists have often assumed that the major decline and extinction of native species occurred only in the past two centuries, following the advent of Europeans with their introduced weeds, insects, cattle, goats, sheep, and so on. Similarly, many anthropologists—intrigued by the conservation techniques sometimes practiced by Oceanic peoples, including the Hawaiians—assumed that there was a sort of harmonious relationship between the Polynesians and their environment.

Evidence that the early Polynesian settlers in Hawaii drastically altered their environment has slowly been accumulating for decades, but it was a serendipitous discovery in 1976 that startled archeologists and biologists into realizing that their data formed a coherent picture of prehistoric human impact. Bishop Museum archeologist Akihiko Sinoto found large quantities of well-preserved bird bones in several limestone sinkholes situated in an ancient elevated reef at Barbers Point, Oahu. Sinoto had been testing these sinks for evidence of human use, either for habitation or for agriculture. The surprise came when these semifossil bones were submitted to paleobiologists Storrs Olson and Helen James of the Smithsonian Institution, who determined that several unknown and bizarre species of birds were represented by this material, including a large, flightless goose. The Barbers Point material was unusual not only for the extent and diversity of the extinct species present but also because it showed that many of these birds had survived well into the period of human occupation of the islands. Had the Polynesians been in some way responsible for the reduction of this bird fauna?

In an effort to reconstruct the environmental context of these birds and any role that humans may have played in altering this environment, Carl Christensen, a Bishop Museum malacologist, and I began a study of the abundant fossil shells of terrestrial snails that had been observed in the same limestone sinks that contained the bird bones. Land snails are known to be good indicators of local environmental conditions, and in a manner analogous to pollen analysis, the relative frequencies of species through a sequence of sedimentary deposits may be used as evidence of environmental changes.

In analyzing our column samples from the Barbers Point sinkholes, we made several significant findings. First, in the upper levels of the sinks, where the extinct bird bones were concentrated, several endemic species of land snails declined greatly in abundance, while certain other species increased. Significantly, the species that became more abundant were those that continue to demonstrate that they are good competitors, surviving in the Hawaiian lowlands even in the face of a variety of more recently introduced species. Far more interesting, however, was the appearance in these same stratigraphic levels of *Lamellaxis gracilis*, a particular species of land snail known to have been transported by humans with soil and plants over much of the tropical world. Shells of *Lamellaxis* had been recovered from prehistoric archeological sites in the South Pacific dating to as early as 1200 B.C., and we suspected that the early Polynesians had also brought this species to Hawaii as a stowaway on plant stocks. We also found other clues—the bones of *Rattus exulans*, a small rat associated with Polynesian settlements, and of a gecko and a skink, two species frequently dispersed by humans.

A consistent picture thus emerged from the Barbers Point investigation: at the time that the now-extinct birds were dying and their bones were being deposited in large numbers, the local environment was undergoing a radical change. Not only did the land snails indicate changing vegetation conditions, but the *Lamellaxis*, rats, geckos, and skinks indicated that humans were present in the area and suggested that their actions were in some way responsible for these changes. The extinction of the birds was probably due to the alteration of their habitats rather than to direct predation by the Polynesians. Recent evidence, however, does suggest that now-extinct birds were also hunted and eaten by the early Hawaiians. During the past two to three years, additional major archeological projects—mostly under the aegis of the Bishop Museum—have provided more information concerning the past environment of various areas of Hawaii and the role of humans in changing the landscape and its life forms.

The Polynesian alteration of the Hawaiian ecosystem began with the initial human colonization of the archipelago early in the first millennium A.D. In their original state, the Oceanic islands—including Hawaii—offered little in the way of terrestrial food resources for human settlers. Certainly, rich shellfish beds, abundant fishes and turtles, and large populations of nesting sea birds would have provided a good supply of protein for the first colonists, but edible food plants, particularly farinaceous staples, were lacking (an exception was the indigenous tree fern, whose starchy pith was utilized by the Polynesians in times of famine). To establish themselves on the islands, the Polynesians transported with them a range of crop plants, domesticated species primar-

*On Captain Cook's third voyage of discovery, portraits of native Hawaiians were drawn by John Webber and later published as engravings. The man, below, wears a mask made from a bottle gourd, one of the plants that the Polynesians brought with them when they settled the islands.*

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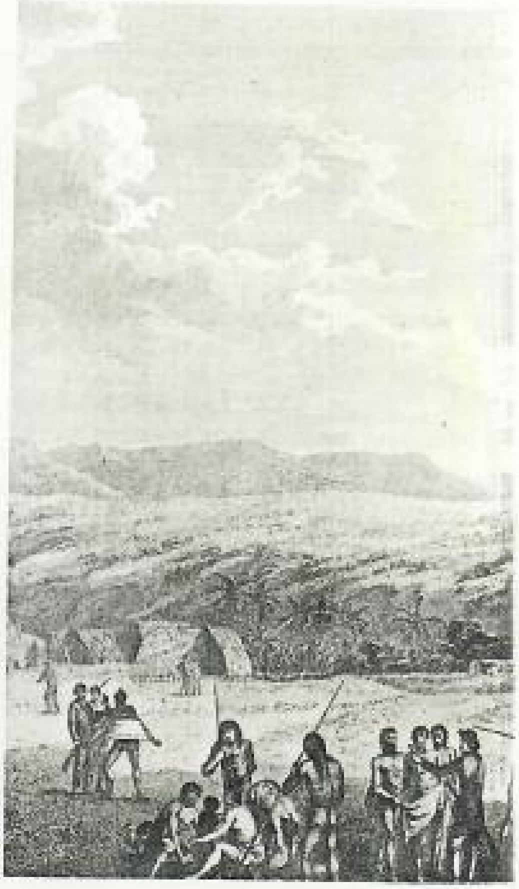
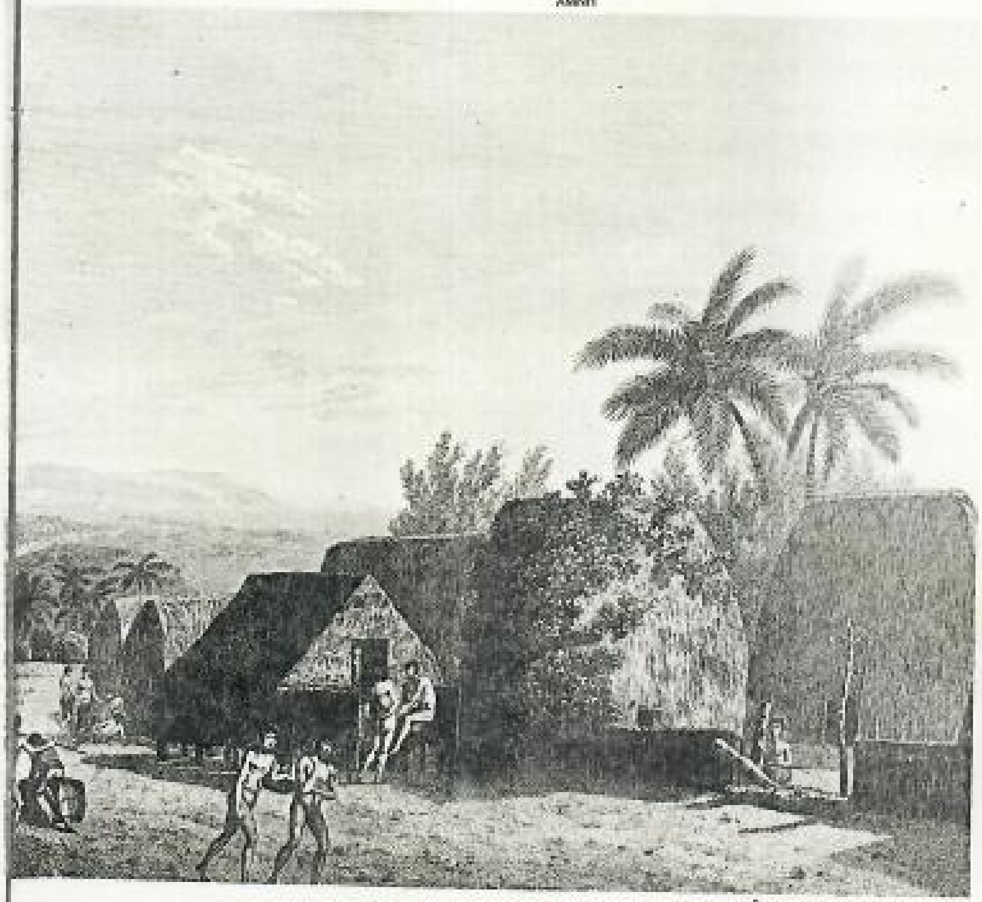
ily of Southeast Asian origin, such as taro, yams, bananas, and breadfruit. Breeding populations of the domestic pig, dog, and jungle fowl were brought along as well, to provide additional food sources in the new landfall. The introduction of these crop plants and animals (at least sixteen species in all), and the clearance of native forest to accommodate gardens and orchards, marked the beginnings of what, over several centuries, became a radical alteration of the Hawaiian environment.

In their double-hulled voyaging canoes, the Polynesians carried far more than a set of crop plants and domestic animals. We have already seen that land snails (not only *Lamellaxis*, but probably also *Lamellidea oblonga* and *Gastrocopta pediculus*) and a small rat, geckos, and skinks were introduced to Hawaii. These species were presumably all inadvertent stowaways on the voyaging canoes, and once released in their new island environment, they must have undergone rapid population expansion—particularly since the native fauna were unaccustomed to serious competition. We know also, from the records of botanist David Nelson, who accompanied Capt. James Cook on his third voyage of 1778 (the European "discovery" of Hawaii), that well established in the lowlands were a number of tropical weeds that also must have been dispersed by the Polynesians. These weeds included water purselane, which frequents wet habitats such as irrigated pond fields of taro, and crabgrass, which abounds around pigpens. Like snails, rats, and lizards, these weeds are powerful competitors; they must have immediately begun to replace endemic lowland plants wherever the Polynesians settled.

Both the purposeful and the inadvertent introductions to Hawaii of a range of competitive species by the Polynesians provide a classic example of what the botanist Edgar Anderson called "man's transported landscapes." Not only did the Polynesians surround themselves with an imported flora and fauna; they also undertook to actively modify and manipulate their insular environment according to cultural concepts that they had inherited from their ancestors in the South Pacific and, ultimately, Southeast Asia. Having arrived in this remote Pacific archipelago, the Polynesians did not simply adapt passively to its constraints and limitations, for like all human groups, they had their own ideas and values concerning how the world was to be ordered. As anthropologist Marshall Sahlins put it, the "action of nature is mediated by a conceptual scheme," a scheme that for the Polynesians included such concepts as the efficacy of fire in clearing forest for garden land, the feasibility of diverting streams to feed irrigated pond fields, and the suitability of broad coastal mudflats for the construction of large fishponds. In short, the Polynesians saw their island world as a plastic landscape to be molded to suit the needs and purposes of a growing human community.



As with other species that had preceded them to these shores, the Polynesians who colonized Hawaii underwent a rapid population explosion, growing from probably fewer than 100 persons at the time of first settlement to somewhere between 200,000 and 300,000 at the time of Captain Cook's first contact in 1778. During the first few centuries after settlement, the population remained small and the impact of human activities on the native environment was probably slight. But, as the population increased at a geometric rate, and the need for new agricultural land and the exploitation of wild food resources increased, this impact became correspondingly greater. By 1200 the population had multiplied to a point where the more marginal leeward coasts of the main islands were being permanently settled, and by 1400 large tracts of leeward parkland and forest were being cleared to make way for extensive field systems of cultivated sweet potato and taro. At the same time, valley bottoms were being converted to irrigated complexes, and the broad reef flats of Kauai, Oahu, and Molokai were modified by the construction of several hundred stone-walled fishponds for the husbanding of mullet fish. By 1600, probably 80 percent of all of the lands in Hawaii below about 1,500 feet in



*An inland view of Waimea, Kauai, by shipboard artist John Webber shows the dispersed settlement pattern that characterized the Hawaiian landscape at the time of Captain Cook's arrival in 1778. The early Hawaiians made extensive use of fire to clear forest for agriculture and to maintain grasslands.*

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elevation had been extensively altered by the human inhabitants. Today, only a few small areas of remnant dry or moderately moist forest hint at the former diversity of life in the lowland areas. Clearing of these habitats to make way for agricultural fields resulted in the extinction of untold numbers of species of plants, arthropods, land snails, and birds.

Like tropical agriculturists everywhere, the Polynesians made extensive use of one great tool, fire. Polynesian agriculture was essentially a form of shifting cultivation: tracts of forest or bush were cleared and burned to create garden plots; after several years of cultivation, these would be abandoned to secondary vegetation, and new plots would be cleared. As the population of the islands increased, however, many areas were gradually converted to more or less permanent cultivation, either dry-field systems on the leeward slopes or irrigated pond fields in valley bottoms.

Fire was also used to maintain tracts of grasslands created through removal of forest. Archibald Menzies, who was with the explorer Capt. George Vancouver in 1792, observed a great fire that burned off thousands of acres of dry tanglehead (*pili*) grass. Menzies reported that the Hawaiians purposely set such fires every year or so, as "the next crop of grass grew up clear and free of stumps, and was therefore better adapted for thatching their houses."

The clearance of large tracts of leeward slope and valleys, and the replacement of native forest with cultivations and secondary-growth shrubs and grasses, had an impact not only on the life forms of the islands but also on the physical landscape itself. Removal of native vegetation had the effect of exposing hillsides and slopes to erosion, and it now appears that the rate of erosion in some areas increased significantly after the human colonization of Hawaii. On Molokai Island, extensive alluvial deposits at the base of the Halawa Valley have been dated to the thirteenth century and are believed to reflect erosion caused by forest clearance on the valley sides. Charcoal in the erosional deposits indicates that fire was used in the forest clearance. The deposits also contain—in the lower levels—thousands of shells of endemic land snails that testify to the diversity of the original forest habitat prior to clearance.

The increased erosion and deposition of alluvial sediments in valley bottoms certainly had consequences for the Polynesians themselves. In the upper Makaha Valley on Oahu, forest clearance on steep ridges caused a major mudslide that buried the fields and ditches of a complex of irrigated taro fields under thousands of cubic yards of sediment. Archeological excavations in this field complex revealed this major geomorphic event and further showed that the valley's occupants had laboriously dug themselves out of the mud and rebuilt the irrigation complex. Probably not all erosion had such deleterious effects. In some areas, such as Kahana Valley on Oahu, increased deposition of sediments may have helped create alluvial flood plains more suited to the construction of irrigated fields than the original valley bottoms.

In the past decade, archeological investigation in Hawaii has disproved the old assumption that the Polynesians did not have a major impact on their island environment. We now have evidence that at the time of initial settlement by Polynesians from the South Pacific, the Hawaiian Islands supported a much more diverse flora and fauna than were recorded by the early European naturalists some fourteen centuries later. The impact of the Polynesians was, naturally, strongest in the lowlands, where they transformed vast areas of native forest into a cultural landscape of agricultural fields, grasslands, and habitations. While we are still just beginning to understand the scale of this human modification of a remote oceanic archipelago, the Hawaiian case serves to remind us once again that the study of nature is in many ways inseparable from the study of culture. □

F. Wayne King

Animal Kingdom
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FEB/MARCH 1975

# Research Reports

New York Zoological Society conservation researchers in the field.

**Nicolaos Papageorgiou** has completed research on the population ecology of the agrimi (*Capra aegragus cretica*), native to Crete. He focused his study on the Theodorou Wildlife Reserve—a small (168 acres) island just offshore from Crete. The agrimi were established there with the release of one pair of goats in 1928, another pair in 1937, and a third in 1945.

One of four subspecies of the wild goat, *Capra aegragus*, the agrimi is now seriously endangered. In the White Mountains of western Crete, where it still occurs naturally, interbreeding with domestic goats may lead to its extinction through hybridization. Today the Theodorou reserve alone offers any security; and even that is uncertain. Without natural predators on the island to control their numbers, the goats have multiplied to the point where they are over-grazing their food supply. Papageorgiou's study clearly documents the serious effects this is having on the island's vegetation. To preserve the agrimi on Theodorou, it will be necessary to reduce their numbers and to stimulate the recovery of food plants presently disappearing before the hungry animals.

**James N. Layne** has found a promising increase in the number of Audubon's caracara (*Polyborus plancus auduboni*) in Florida. The bird's slow disappearance there had prompted the Florida Committee on Rare and Endangered Plants and Animals to list it as a "threatened" species in that state.

This beautiful, vulture-like falcon also occurs in southern Texas, Arizona, Baja California, through Mexico south to Panama, and in Cuba. In south-central Florida, it is a characteristic inhabitant of open prairies, where it may be seen perching on fence-posts or pacing along roadsides in search of food. It feeds on a variety of prey including insects, amphibians, snakes, birds, and mammals, and frequently on carrion.

Though no more than 100 caracaras were thought to remain in Florida four years ago, Layne's preliminary survey indicates that as many as 140 may live there today. Future surveys will confirm or deny this potential signal of population stabilization.

Black caiman

Over-exploitation of reptiles in the Amazon and Putomayo Rivers in Colombia has led **Roger W. Foote** to survey the caimans and side-neck turtles there. Specifically, he will document the geographic and seasonal abundance of black, common, dwarf, and smooth-fronted caimans, as well as yellow-spotted, six-tubercled, and giant side-neck turtles in parts of both rivers and their tributaries.

For many years the caimans have supplied hides to commercial hunters, and the turtles meat and eggs for the cooking pot, to the point where both have virtually ceased to exist in the region. Foote will collect data on their reproductive cycles, behavior, and reproductive success; their population composition; and their continued use by people in the area. He is coordinating his work with a survey that NYZS Conservation Fellow Federico Medem is conducting on South American crocodilians.

**Leslie Garrick,** of the NYZS Center for Field Biology and Conservation, is initiating a study of the ecology and behavior of the American crocodile (*Crocodylus acutus*). Extinction threatens this reptile over most of its range—southern Florida, the Greater Antilles, Central America, Colombia, Peru, and Venezuela.

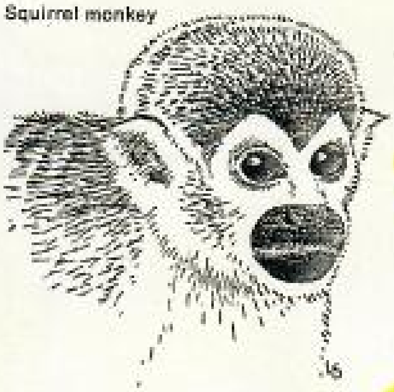
The American is one of the most variable of crocodile species. Earlier researchers described several subspecies based on geographic variation in morphology. And striking behavioral differences have been observed between populations. For example, females of some populations lay eggs in hole-nests dug in the sand, while others deposit them in mounds of vegetation or earth that they scrape together. Better understanding of the species will permit the design of sound management practices to assure its continued survival.

**Charles A. Ross'** nearly completed project will contribute to the improved management of American alligators (*Alligator mississippiensis*). Working under NYZS contract to the U.S. Fish and Wildlife Service, Ross is defining the morphological variations within individual alligator populations and comparing them to the variations found throughout the species' range. He has examined large numbers of specimens in Louisiana, Florida, and Georgia. One unexpected finding to date is an apparent morphological difference between captive-reared and wild alligators.

Results of this project will be extremely useful in federal or state plans to translocate alligators. Such shifting of populations sometimes leads to interbreeding and loss of genetic variability. Ross will also compile an extensive bibliography on the American alligator.

**Thomas Struhsaker,** Research Zoologist for the NYZS Center for Field Biology and Conservation, spent July and August, 1974, researching primates and their habitats in northern Colombia. He and a team of zoologists—Norman J. Scott, Hernando Chirivi, Kenneth

Squirrel monkey



Glander, and Jorge Fuentes—had intended to clarify some of the primate conservation problems there. They found conditions worse than expected. Not only had agricultural development already destroyed most of the rain forest, but heavy hunting threatens the few patches that remain.

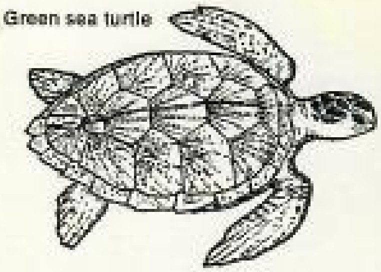
In September, Struhsaker surveyed the 1,481,482-acre Macarena National Park. It is Colombia's largest park and the home of many rainforest animals including howler, capuchin, spider, woolly, and squirrel monkeys, tapirs, brocket deer, peccaries, and numerous birds. Unfortunately, squatters are destroying this spectacular sanctuary as they invade its boundaries in search of farmland.

The logbooks of New England whalers from 1800 to 1860 are being tapped for new information about the decline of sperm whales (*Physeter catodon*). **George W. Schuster** is using the records to show the decline in sightings—their extent, nature, and timing—of, first, the large sperm whale bulls, and then entire pods. He also hopes to learn more about the whales' rate of decrease in size, as well as their behavioral reaction to the approach of whale boats.

The Society's first director of the New York Aquarium, Charles H. Townsend, used old logbooks in his 1935 study of whales' seasonal movements; and data for this century have been gathered by other researchers. Schuster aims to present more detail than the earlier studies. Further, his compilations will permit comparison between analyses of recent records and those of the earlier hunters.

French Frigate Shoals in the western Hawaiian Islands harbors the last remaining green turtle rookery in United States waters. The large numbers once prominent in Florida succumbed to the nets of the turtle fishermen in the last century. During the past two years, **George Balazs** has been making observations in Hawaii on the natural predators of hatchling turtles, egg fertility, and embryo and hatchling mortality. He also collected evidence of illegal poaching, and censused the population.

Green sea turtle



The French Frigate rookery is unique in all the world, since it is the only place where adult male green turtles come ashore to bask in the sun. Regrettably, this recent study—performed under contract to the U.S. Fish and Wildlife Service—indicates that the total population of green turtles (*Chelonia mydas*) nesting in the Hawaiian Islands includes fewer than 200 females.

**The Bahamas National Trust,** with Society support, has constructed a barricade across an estuary of Great Inagua Island in an attempt to protect and confine a group of green sea turtles being raised there. It is hoped that, once these turtles mature, they will nest on the estuary beach, thereby re-establishing a rookery for the species in the Bahamas. Although the green turtle was once sufficiently plentiful throughout the West Indies to give its name to several cays, it is now in danger of extinction there. If this semi-captive propagation effort proves successful, the same technique may be used elsewhere to rebuild lost populations of these marine reptiles.

Also in the Bahamas, **Walter Auffenberg,** NYZS Conservation Fellow, is investigating the ecological and behavioral requirements of rock iguanas (*Cyclura* species). These large herbivorous lizards are vanishing from many areas where they were once abundant: Several species already have become extinct in the Virgin Islands, Puerto Rico, and Navassa.

On Crooked, Watlings, and Andros Islands, and the Turks and Caicos Islands, Auffenberg has recorded the lizards' dietary components, growth rate, and reproductive cycles. Further, he has found that the rock iguana populations seem to be decreasing with the growing numbers of introduced pigs and dogs.

As part of his continuing study, **Dietrich Schaff** has completed an initial census of the endangered northern swamp deer (*Cervus duvauceli duvauceli*) in the Sukla Phanta Royal Shikar Reserve of Nepal. While 1,250 to 1,500 individuals were formerly estimated to be living in the reserve, the current census figure is considerably lower. This study is beginning to yield data on herd composition, foods, and interaction with other species, including man and his livestock. Schaff has also documented the fact that the deer in Nepal timidly flee at the sight of man, while those in northern India's Dudhwa Sanctuary—where poaching has been eliminated—are more tolerant of humans.

*—F. Wayne King*

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# Prehistoric Hawaiian Fishponds

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## Indigenous aquaculture influenced the development of social stratification in Hawaii.

William K. Kikuchi

Ever since the discovery of the Hawaiian Islands by Captain James Cook in 1778, Polynesian and Hawaiian specialists have been intrigued by the factors that caused the development of the highly stratified chiefdoms found in the Pacific. The cultures of Hawaii, Tonga, Samoa, and the Society Islands were structurally complex, with well-defined status separating the high chiefs, chiefs, advisers, stewards, and commoners. Of these island groups, Hawaii had the most highly stratified society. If we assume that all of the cultures of Polynesia are ancestrally related and that they all share a common linguistic, technological, and agricultural base, then the question arises of why a high level of complexity was achieved in only these four island groups.

Wittfogel (*1*) claims that irrigation systems had a direct influence on the emergence of political power and on the development of a statelike government. Fried (*2*) states that in Hawaii the control of water resources was used to bolster control over the land. According to Sahlins (*3*), the control of water resources was achieved by restricting access to irrigation water rather than to the land. Sahlins attributes the evolution of political stratification to technological and environmental factors. All of these authors imply that the development of bureaucracy in the Hawaiian Islands resulted in part from the control of water sources, specifically, irrigation systems, rather than from the direct control of land.

The word irrigation implies agriculture. Of the many theories concerning the development of Hawaiian culture, most center around the productivity of the agricultural system. The system of ditches that fed and drained the taro (*Colocasia esculenta*) plots is always seen as proof of engineering and agricultural skills. I suggest, however, that there is another important area in the study of the complexity of Hawaiian culture. This is the aquacultural system, which I do not see as an entity in itself but as one end of a continuum of food production technologies (Fig. 1). The fishpond system paralleled the agricultural irrigation system in many ways; that is, it dealt with the access to, restrictions on, and management of water resources. In this article I attempt to place the fishpond into such a context—to describe both its technological and political roles in culture.

Strung along the southern shore of the island of Molokai are a series of prehistoric fishponds whose remains can still be seen within the calm shoal waters. These remnants are only a fraction of the extensive aquacultural system that was evident on all of the major inhabited islands of the Hawaiian archipelago around the turn of the 20th century. Over the years, the ravages of high seas, tsunamis, floods, earthquakes, lava flows, and tectonic activities have greatly altered most such sites. Quite recently, fishponds have been filled and destroyed by commercial and industrial development. Some of the sites are now fringed with houses and industrial parks—foreign and incompatible environments that exhibit these sites as oddities, fossils of the past. Nonetheless, in isolated regions of the Islands a few fishponds can still be found in a relatively pristine environment.

### Origins

The date for the origin of Hawaiian fishponds will probably never be known. It certainly is not within the reach of traditional archeological dating techniques. Mythological and legendary sources are the only means currently available for gauging the antiquity and the nature of the origin of fishponds.

The builder of the first Hawaiian fishpond is traditionally acknowledged to be Kū-'ula-kai, who lived in an undated period of the Heroes and Gods. Kū-'ula-kai constructed the fishpond at Kaiwiopele in the district of Hana on the island of Maui (*4*). According to mythological sources (*5*), the fishponds of Alekoko and Nomilu on the island of Kauai were built during the period of the mythical Hawaiian dwarf-elves, the menehune. Associated with them is Chief Ola, whose historical placement remains unknown but who is alleged to have ruled in very ancient times. The fishpond is commonplace in legendary literature attributed to the 14th through the 19th centuries; therefore it can be conjectured that fishponds appeared in the Hawaiian Islands sometime prior to the 14th century A.D.

A survey (*6*) of aquacultural features in Oceania reveals a lack of true fishponds (that is, bodies of water primarily intended for the raising of fish), with the exception of ponds in the Gilbert Islands, where further study is needed. I propose that coastal fishponds in Hawaii evolved from irrigated agricultural plots, lo'i kalo, and became one end of a continuum of a basically agricultural, wet-plot system. On the basis of the barest and most questionable evidence from traditional material, I also propose that the fishpond was an independent Hawaiian innovation.

### Typology

Four basic types of fishponds were developed by the prehistoric Hawaiians: loko i'a kalo, loko wai, loko pu'uone, and loko kuapā (Fig. 2). The prefix loko refers to any pool, pond, lake, or other enclosed body of water (*7*), while the suffixes denote the specific type of fishpond. Although there were many variations within each type, the Hawaiians do not seem to have used separate names to identify subtypes.

Loko i'a kalo were irrigated agricultural plots for the growing of selected fish (i'a), such as aholehole (*Kuhlia sandwichensis*) and 'o'opu (*Eleotridae* and *Gobiidae* families), and of taro (kalo). Like other irrigated agricultural plots, loko i'a kalo were fed and drained through a system of ditches. Some of the fishponds were simply agricultural plots in inland areas or along the shore where both taro and fish could tolerate the varying degrees of water salinity.

Loko wai were inland ponds and lakes, usually found close to the shore. Since they most often had natural connections to the sea by way of ditches or

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streams, these fishponds, although called freshwater (wai) by the Hawaiians, would have been partially brackish because of tidal action. Aholehole; 'o'opu; amaama, or mullet (*Mugil cephalus*); awa (*Elops machnata*); and awa'aua, or milkfish (*Chanos chano*), all tolerant of both fresh and brackish water, were some of the fish raised in loko wai.

Loko pu'uone were coastal bodies of water that had been either stranded because of eustatic sea-level changes or isolated through the formation, by sea action, of loose, irregular walls (pu'uone) of sand and coral detritus. The permeability of the walls allowed seawater to percolate through, while freshwater springs along the shore provided internal seepage. Because of their proximity to the sea and because of their water salinity, loko pu'uone resembled natural estuarine habitats. Their fish were preferred as delicacies because the native Hawaiians believed that brackish to salt water produced a more savory fish than did freshwater.

Usually located in shallow shoal areas along the coast were loko kuapā, fishponds whose primary isolating feature was a wall of stone, coral blocks, or both as the backbone (kuapā). The kuapā core, usually of stone, was purposely made permeable in order to effectively absorb the forces of its containing body of water (either the sea or a river) while allowing a limited amount of water to flow through to reduce stagnation. Where the core was of earth, such as that found in loko i'a kalo or loko wai fishponds, other means of allowing water circulation were needed because the earth prevented water from entering or leaving the pond.

## Geomorphological Consideration

A positive correlation exists between the geography and geomorphology of an island and the type, size, shape, and location of a fishpond (*8*) (Fig. 3). The favorable geographical features sought by the ancient engineer-architects were shallow shore areas protected by long fringing reefs, natural bodies of water inland or along rocky rugged coastlines, barrier beaches with large bodies of water trapped behind them, and shore areas with seepage of freshwater through natural springs, streams, or rivers. A survey of the aquacultural system of prehistoric Hawaii (*6*) suggests that ancient Hawaiians utilized practically all sizable bodies of water for the construction of fishponds.

## Architectonic Features

Each of the fishpond types had some distinguishing architectonic feature, for example, a primary wall, secondary walls (pā), or ditches ('auwai) and their accompanying sluice grates (makahā). All of these were permanent and nonmobile in nature. In a recent study of selected fishponds (*6*), the mean width and height of 37 pond walls was computed to be 2.02 meters wide by 1.17 meters high, and the average length and volume of 90 pond walls was determined to be 487.68 meters and 954.9 cubic meters, respectively (*6*). The volume of the most massive seawall (kuapā), that of Kaloko fishpond on the island of Hawaii, was calculated as 4248.08 cubic meters. In comparison, secondary walls were small and crudely constructed. While seawalls were intended to withstand the forces of erosion and to hold the fishpond intact over long periods of time, secondary walls served to partition the calmer interior waters into aquatic pens.

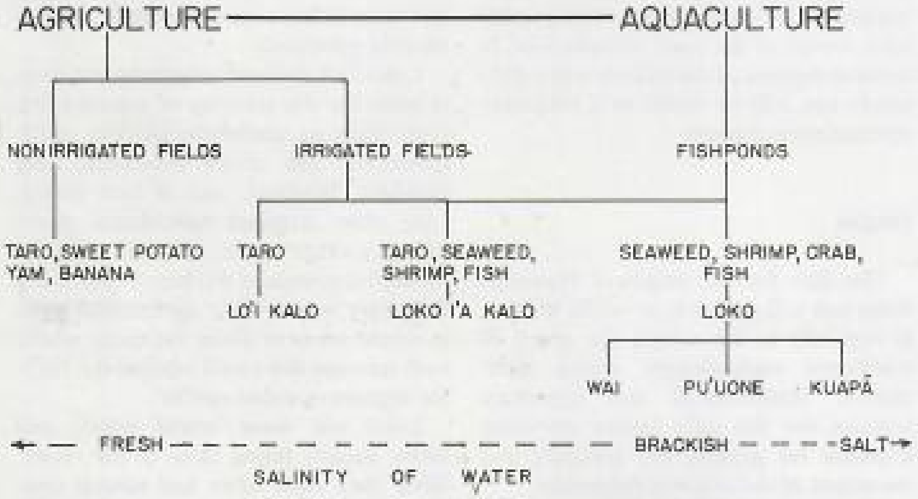


Fig. 1. Agriculture to aquaculture schematic of relationships without regard to chronology. The products of both systems are shown as a function of emphasis, with agriculture and aquaculture as extreme ends of resource management.

The Hawaiians made a distinction between ordinary ditches ('auwai) and those associated with the seawall ('auwai o ka makahā). 'Auwai were channels, usually a meter or two wide, that connected the fishpond with outside sources of water. These features served to allow circulation of water while introducing dissolved nutrients from without. 'Auwai o ka makahā, on the other hand, consisted of that short portion of the ditch that passed through the seawall; these were always associated with the makahā, or sluice grate. Sluice grates were stationary structures that consisted of spaced, vertically placed wooden sticks lashed to two or more horizontally placed sticks; these were placed in the ditch to act as a sort of filter for debris and large fish.

The number and location of sluice grates seems to have been a function of the size of the fishpond and of the prevailing current patterns. Most often there were two grates. A shelter for the caretaker, hale kia'i, was associated only with the loko kuapā type fishpond. These small rudimentary shacks were placed adjacent to the sluice grate area in order to provide the caretaker with some protection against the elements while he guarded against poachers.

## Cultural Significance

The prehistoric Hawaiian fishpond is an innovation not seen in other cultural areas of Oceania. Its evolution from a simple technological device into a symbol of status and power is significant from the vantage point of the development of stratified societies in the Pacific.

The universe of the native Hawaiian was a delicately balanced, tri-state system of the supernatural, the natural, and the cultural. Intertwined and integrated with one another, these three influences permeated every aspect of Hawaiian life. There were four "national" gods—Kū, Kane, Kanaloa, and Lono—who, with a multitude of demigods and guardian spirits, manifested themselves in every form of nature, from rocks and plants to atmospheric phenomena and running water. These served as constant reminders of the sanctity of all forms of earthly matter.

Complementing the gods were the

ali'i, or chiefs, whose status within the highly stratified order of nobility was determined by their genealogical proximity to the gods. Pedigree as well as privilege was correlated with individual linkage to both genealogy and the rights from conquest. Since each god had supernatural power, the human counterparts also possessed this mana, power bestowed directly or indirectly from a supernatural source (*9*), but in lesser degree.

There were two types of chiefs that were associated with fishponds: the ali'i-'ai-moku, or paramount chief, and the ali'i-'ai-ahupua'a, who were lower chiefs of land sections, or ahupua'a. All of the land with its resources and produce was owned by the paramount chief. Specific fishponds, in particular those noted for their antiquity or productivity, as well as all major temples, were also owned and controlled by the paramount chief as manifestations of his supreme rights, including his right of ownership and his right to rule. Other fishponds were feudalistically contracted to the chiefs of the various land sections, who, in turn, probably left control of the smaller fishpond-agricultural plots (loko i'a kalo) to the commoners. If this ownership pattern was in fact common in prehistoric Hawaii, a paucity of sites would be expected around fishponds.

A study (*6*, *10*) was made of the published archeological surveys of ten fishponds and their surrounding archeological remains to determine the nature of the settlement pattern around them. These sites (*11*) are the only ponds left in the Hawaiian Islands which have not been denuded of their archeological sites during the course of historical coastal development. The features that are directly associated with fishpond activity and that are consequently to be expected around ponds are canoe sheds, net-drying areas, the caretakers' house sites, and burial platforms. The number of sites expected is small, and they should be widely distributed over the landscape.

Canoe sheds were discovered only on the inland side of Kaloko fishpond on Hawaii Island and were diagnostic of other structures with stored canoes. Enclosures and mounds lined with stone, common structures for the cultivation of sweet potatoes and yams, never occurred in large numbers but were scattered where the bedrock allowed soil and humus to collect. A total of 24 house sites was found at seven fishponds, for an average of more than three per pond. The mode was two, while the largest number of house sites found at one fishpond was seven. This is a very small number, in view of the fact that a typical Hawaiian house site was a complex usually composed of two or three separate structures. Other features found near the fishponds were platforms, burial mounds, shelters, and walls. Such features ranged from 12 to 20 per fishpond. Although no chronological relationships have yet been established for these sites,

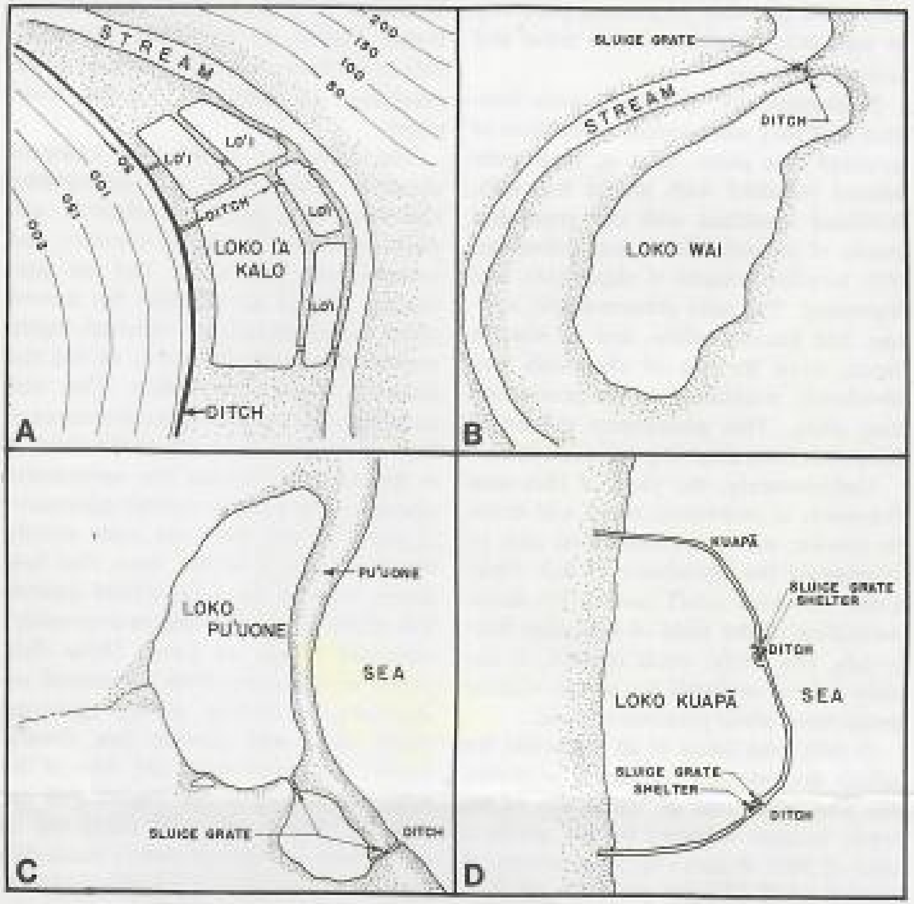
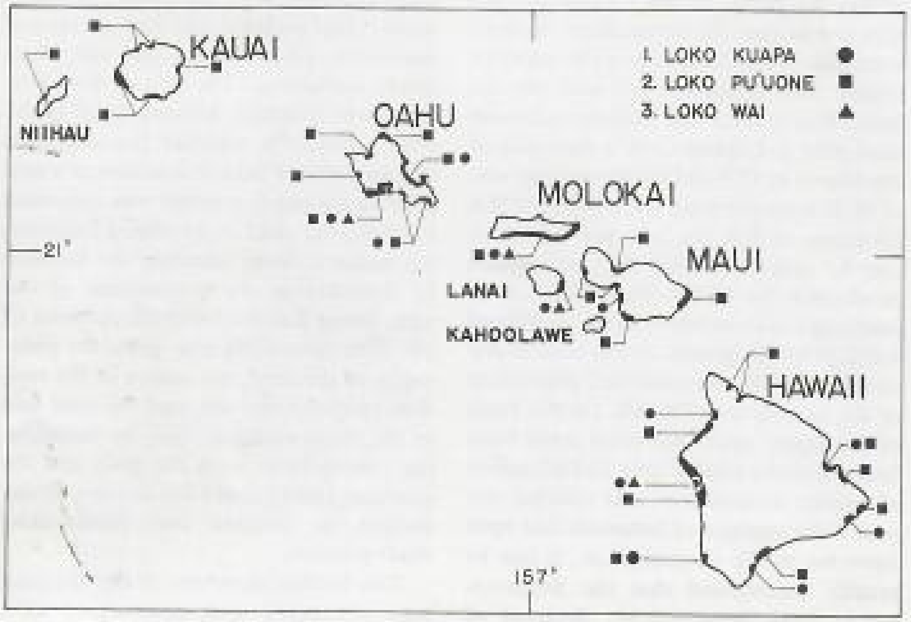


Fig. 2. The four basic Hawaiian fishpond types. (A) The loko i'a kalo, located in an inland area; (B) the loko wai, a natural lake artificially connected to a stream by a ditch; (C) the loko pu'uone, ponds created by coastal barrier beaches, artificially connected to each other, and drained by a ditch; and (D) the loko kuapā, two ditches and a seawall isolating a coastal body of water. No scale.



there are not enough of them to have supported any sizable portion of the population even if they were all in use simultaneously. I expect that an effort was made to discourage settlement around fishponds, possibly to prevent poaching as well as to eliminate undue noise and sewage pollution.

Philosophically, fishponds were handled as if they were simple extensions of irrigated taro plots. That is, they were seeded (stocked with mullet fry) (*12*), fertilized (mulched with cut grass and pieces of mussel, clams, and seaweeds) (*13*), weeded (cleared of algae) (*14*), and harvested. The gods abhorred filth, sewage, and kitchen refuse, and, in historic times, even the use of chemicals was absolutely prohibited in fishponds and taro plots. This philosophy prevented fishponds from attaining optimum yield.

Unfortunately, the yield of Hawaiian fishponds in prehistoric times will never be known; native accounts tend only to exaggerate the abundance of fish. Only Cobb (*15*) took exact care in his documentation of the yield of Hawaiian fishponds. His study, made in 1901, is the only source available for use in making projections about prehistoric yield.

A tally was taken of all fishponds for which documented acreage is available (*6*). Out of a total of 360 ponds of all types, acreage is known for 304, giving a total of 5608.48 acres for an arithmetical average of 18.44 acres per fishpond. According to Cobb's figures for historic yield on the islands of Kauai, Oahu, Molokai, and Hawaii, the yield of preferred fishes (which would have constituted the major part of the total) from 99 ponds was 307,900.4 kilograms of fish per annum. This averages to 3063.8 kilograms of fish per pond, or 166.1 kilograms per acre per annum. (In comparison, modern southeast Asian fishponds yield approximately 1800 kilograms per acre per annum.) If we assume that 360 fishponds were used prior to Captain Cook's discovery of the Islands in 1778 and use the average size of 18.44 acres per pond and a yield of 158.6 kilograms of fish per acre per annum, it can be calculated that the annual fish production for all the Hawaiian Islands amounted to somewhere in the vicinity of 1,052,518.3 kilograms. At the time of discovery in 1778, the estimated population of the Islands was 300,000. On the basis of this figure, each individual could have been allotted a total of only 3.62 kilograms of mullet, tenpounder, and milkfish per year if the produce of fishponds had been open for public consumption. It can be readily ascertained that the fishponds would have been quickly depleted of their produce if they had served the entire community. But if fishponds were not designed to provide a significant source of protein for the populace, what was their role in that prehistoric society? It seems very likely that selected fishponds played an important symbiotic role in the nature and development of the chiefdom, in particular, of the royal court.

The Hawaiian court was centered about its ruling chief, and surrounding him was a large retinue of relatives, servants, specialists, priests, warriors, and entertainers. The court had no permanent seat of government but moved about from area to area. Although highly mobile, the court still had to be fed and have its supplies furnished. This was accomplished by tapping local sources of food throughout the realm of the chief. It is known that, within the agricultural system of the Islands, certain agricultural plots, kō'ele, were set aside strictly for the chiefs. It seems, then, that fishponds became the aquacultural equivalent of the kō'ele, offering an ever-ready, sufficient supply of food. These fishponds were exempt from the coastal restrictions on fishing during spawning times and could provide fish, crustaceans, and seaweeds at any time of the year, regardless of the vagaries of the weather. The court could freely tap its own resources without unduly burdening the commoners or stripping them of their supplies. As the power of the chiefs increased, and as the size of the court grew, the political and economic roles of fishponds probably took on different meanings in meeting the needs of the royalty.

In order to effectively maintain control and organization of his lands, the paramount chief established a bureaucracy of specialists whose status and role were firmly spelled out. The first of these was the priest-architect, kahuna. In all of the chief's projects, whether the alteration of a taro plot or the construction of a new loko kuapā pond, a priest was consulted to advise the chief on all related engineering matters, from selecting the location to determining the dimensions of the site. These kahuna-kuhikuhi-pu'uone (*7*, *16*) were specialists who knew the geography of the land, the nature of the resident spirits of the site, and the total lore of the native religion. Only by maintaining concordance with the gods and the guardian spirits could the success of any project be ensured and productivity made possible.

Two further members of the bureaucracy connected with aquaculture were the land overseer, or konohiki, and the caretaker of a fishpond, the kia'i-loko. The land overseer was a male of chiefly status who served his superior by carrying out orders handed down to him. Superintendence duties surrounding aquacultural sites included instructing the tenants of the land when and where to construct, repair, and clean the different aquacultural structures. In many instances the konohiki also served as a warden to control poaching. Each loko kuapā fishpond apparently had one or more caretakers, kia'i-loko, who lived with their families at the site. These men patrolled the pond, cleaned it, and, when instructed to do so, harvested the fish.

In view of the statistics on the dimensions of fishpond walls, the amount of work involved in their construction and upkeep must have been considerable. Kamakau (*17*) estimates the manpower requirement for the reconstruction of several fishponds on the islands of Maui and Hawaii at around 10,000 men. The massiveness of even the shortest primary walls indicates that these construction projects were not based on the whim of commoners but were developed by individuals of status who could command and supply a large body of workers.

During interisland wars of conquest, invaders often destroyed the irrigation ditches that fed fishponds and agricultural plots (*18*) and tore down fishpond walls (*19*). The destruction of both agricultural and aquacultural systems effectively depleted the supplies of both commoners and elite for many years. Therefore, civil projects were necessary by both the conquered and the conquerors to reestablish their food sources. It was considered a commendable deed for conquering chiefs to spend time repairing breached fishponds.

### Cultural and Religious Sanctions

Fishponds were protected by both cultural sanctions and religious restrictions. The paramount chief, through his overseer and caretakers, physically operated and guarded the fishpond and its environment. Proclaiming the sanctity of all of the chief's property was the kapu, a taboo that was made visible by tying strips of white barkcloth to stakes along the property boundary or along the shore, whichever the case might be.

Pollution in the form of sewage, rubbish, and offal not only dirtied the physical environment of the fishpond but insulted and violated both the chief's taboo and the religious sanctions guarding the area. Religious controls in the form of traditional lore and mores were not directly manifested in the form of specific signs, such as taboo markers. Instead, their violation resulted in the disappearance of fish, crustaceans, and seaweeds and in sudden calamities such as floods, tsunamis, and storms.

All bodies of water, from the smallest pool to the largest fishpond, were the domicile of guardian spirits, mo'o, which manifested themselves in lizardlike or mermaid form. Their role was to protect their watery domain from man-made pollution in order to ensure an abundance and proliferation of aquatic foodstuffs. It was the duty of the caretaker of a loko kuapā to make offerings regularly to the guardian spirits at certain designated times of the lunar month; appeasement was likewise made through such offerings. Disrespect, in the form of verbal insults, of polluting the pond water with sewage, offal, or corpses, or of the presence of women in their menses, was considered sufficient cause for the spirits to denude a territory of its resources. Since famine was greatly feared, gross violation of cultural mores was punishable by death or by plucking out the eyes of the offender (*20*).

In order to restore a fishpond to a state of productivity, a ritual was performed to appease the guardian mo'o. This ceremony has been documented for Hanaloa (*21*) and Kuapā (*22*), fishponds on the island of Oahu. In each case, offerings were made at specific shrines near the ponds in the early dawn hours of the last phase of the moon. This night was the night of Kane, the god associated with life and with maleness, and thus with procreation.

## Decline of the Fishpond

Discovery of Hawaii by Europeans in 1778 initiated tremendous changes in all aspects of Hawaiian culture. The greatest barrier to change fell in 1819 with the abolition of the kapu system. This effectively destroyed the Hawaiian religion and with it the chief's supernatural right to rule and his once undeniable control of the land and all its resources. From that time on, Western acculturation accelerated at a rapid rate, and money became the standard of exchange in place of the barter system. The fishpond was no longer a symbol of chiefly power, but rather had to compete economically in the local market as well as with imports of foreign foods. Because of its inherent inefficiency, its low yield, and its requirement for frequent and extensive maintenance, the indigenous aquacultural system was doomed to decline during the population decline of the 19th century. Today, fewer than a dozen prehistoric fishponds are still in use throughout the Hawaiian Islands. The majority of these are operated by their owners, while a few are contracted out to lessees. Unless these ancient sites are physically altered, their economic impact on the local market will remain minimal. It is only through complete modernization that significant profits from fishponds can be foreseen.

## Summary

One of the important technological concepts that was developed in the Hawaiian Islands is that of the fishpond. From the 14th to the 19th centuries, these sites served as aquariums for the raising of selected fish. From its inception until the 1900's, the fishpond progressed little in design and function. Its rudimentary nature was a function of both technology and religion. Because of the open ditches, sluice grates, and permeable walls, neither the types nor the quantity of juvenile fish entering or leaving could be controlled. In addition, religious beliefs prevented experimenting with fertilization to increase yield. Although seemingly inefficient, the native aquacultural system was not intended to produce a great amount of fish but rather to yield selected fish on call. Fishponds became symbols of the chiefly right to conspicuous consumption and to ownership of the land and its resources. They were manifestations of the chief's political power and his ability to control and tap his resources. As soon as the native aristocracy changed to a Western-style kingdom, the fishpond's function changed, until, by the 1930's, the majority were simply archeological remains—mounds and walls of rock along a river or shore.

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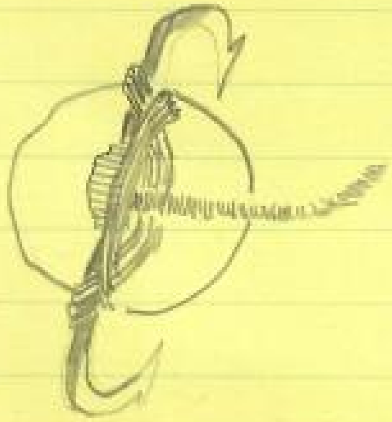
The aquatic resources of the Hawaiian Islands.
Section III. The Commercial Fisheries by J.N. Cobb.
Washington. Govt. Printing Office SH35
A6. H3

Spearing pg 734 Honu (turtle) are generally captured by means of spearing from the rocks along the shore where they congregate.

Line-fishing pg. 741 In fishing for honu (turtle) a flat stone is used, with two hooks lashed to the upper part and running out in opposite directions. This is attached to a long line. Hee also are occasionally caught with this apparatus.



Shark-catching pg. 741 mano-kihikihi (hammer-head)
lalakea (white-fin)

mano kanaka (man shark)
mano, a large white shark
niuhi, "largest and fiercest" "niuhi is said to be seen a long way off at night by the bright greenish light of its eyeballs

Pg. 743

The use of human flesh as bait was in great vogue among the Hawaiian chiefs It was cheaper than pig, was equally acceptable to the shark, and gave the chief an opportunity to kill anyone whom he disliked. The victim was cut up and left in a receptacle to decompose for two or three days. Kamehameha I was a great shark hunter and kept his victims penned up near the great heiau (temple) of Mookini, near Kawaihae, Hawaii.

Kay, E.A. et al. (1977) Hydrologic and ecologic inventories of the coastal waters of west Hawaii. Water Resources Research Center, UH. Honolulu, Hawaii 94pp.

(Figs. 24 and 25), a shoreline and inshore series of stations which also includes one station on the inner bay transect, and an offshore series of stations. Standing crop, species diversity, and species composition are shown in Table 18.

The inshore section of the bay consists of a broad, sandy flat which is succeeded some 30 m from the shore, at depths of 3 to 4 m, by a zone of isolated colonies of the coral, *Porites lobata*. Beyond the zone of *P. lobata*, coral cover increases and is dominated by *P. compressa* (see Coral Communities). Sediments of the bay floor are primarily calcareous.

The inshore stations (including the tidepools) are characterized by high proportions of *Bittium parcum* and *B. zebrum*, and relatively high proportions of the rissoid, *Rissoina ambigua*, and pyramidellids (Fig. 25, Table 19). Standing crop averages 7.1 shells/cm$^3$ and the species diversity index, H', averages 3.8.

The outer bay stations are clearly distinguished from those of the shoreline stations by high proportions of *Bittium impendens*, *Rissoina miltozona*, *Vitricithna marmorata*, and *Tricolia variabilis*. Standing crop is higher than in the shoreline sections of the bay ($\bar{x}$ = 41.8 shells/cm$^3$), and the species diversity index, H', also averages higher (4.2).

## Kīholo Bay

MACROMOLLUSCAN ASSEMBLAGES. The shoreline at Kīholo, like that at Wailua Bay, is formed by a continuous fringe of basalt. The northern terminus is steep, more than 3 m above sea level and there is a short, vertical intertidal zone. The mid-section of the bay consists of pebble beach and benches of smooth pāhoehoe. The southern terminus is formed by a low, flat pāhoehoe bench with a broad, horizontal intertidal zone. A prominent feature of the shoreline is Wainanali'i Pond, which intrudes into the bay on the northeast between the northern terminus of the bay and the central pebble beach. The pond is separated from the bay proper by a rubble shoal.

The dominant supratidal mollusks are the littorine, *Littorina pintado*, the nerite, *Nerita picea*, and, on the horizontal bench, the pulmonate limpet, *Siphonaria normalis*. The dominant mollusks of the intertidal and shallow subtidal waters are the gastropods, *Hipponix grayanus* and *Peristernia chlorostoma*, and the bivalve, *Isognomon perna*.

TABLE 18. STANDING CROP, SPECIES DIVERSITY, AND SPECIES COMPOSITION AT 'ANAEHO'OMALU

| | | | | | Station | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01A | 02 | 03 | 04 | In1 | In2 | In3 | ShA | ShB | ShC | TP |
| Depth, m | 8 | 8 | 8 | 18 | 6 | 5 | 8 | | | | |
| No. Specimens | 339 | 373 | 193 | 652 | 61 | 457 | 496 | 80 | 87 | 87 | 112 |
| No./cm$^3$ | 33.9 | 37.3 | 19.3 | 65.2 | 6.1 | 45.7 | 49.6 | 8 | 8.7 | 8.7 | 11.2 |
| H' | 4.0 | 4.5 | 4.3 | 4.4 | 3.3 | 4.2 | 4.1 | | 4.1 | | |
| Percent Composition | | | | | | | | | | | |
| Archaeogastropods | | | | | | | | | | | |
| *Leptothyra rubricincta* | 7 | 7 | 6 | 10 | 6 | 11 | 10 | -- | 2 | 5 | 3 |
| *Tricolia variabilis* | 10 | 5 | 11 | 7 | 1 | 7 | 9 | -- | -- | 1 | 3 |
| Rissoidae | 40 | 34 | 21 | 38 | 33 | 36 | 29 | 11 | 26 | 22 | |
| *Rissoina ambigua* | 1 | 3 | + | 1 | 13 | 2 | 1 | 2 | 7 | 11 | 15 |
| *R. miltozona* | 24 | 15 | 3 | 17 | 11 | 10 | 13 | 7 | 9 | 7 | 12 |
| *Merelina pisinna* | 3 | 6 | -- | 7 | 2 | 10 | 2 | 2 | 9 | 2 | -- |
| *Vitricithna marmorata* | 5 | 5 | 9 | 6 | -- | 7 | 7 | -- | -- | -- | -- |
| *Parashiela beetsi* | 2 | + | 3 | 2 | -- | 1 | 1 | -- | -- | -- | -- |
| Cerithiidae | 27 | 33 | 27 | 26 | 42 | 32 | 27 | 24 | 30 | 40 | |
| *Bittium impendens* | 23 | 25 | 22 | 20 | 11 | 22 | 25 | 1 | 6 | 1 | 3 |
| *B. parvum* | 2 | 2 | 4 | + | -- | 1 | + | 6 | 5 | 26 | -- |
| *B. zebrum* | 2 | 2 | -- | 2 | 31 | 7 | + | 16 | 19 | 10 | 12 |
| Dialidae | + | 3 | 17 | 3 | -- | 1 | 13 | -- | 1 | -- | -- |
| *Cerithidium perparvulum* | + | + | 11 | 2 | -- | + | 5 | -- | + | -- | -- |
| *Diala varia* | -- | + | 4 | + | -- | -- | 3 | -- | -- | -- | -- |
| Triphoridae | 6 | 6 | 3 | 2 | 5 | 1 | 1 | -- | -- | -- | |
| Pyramidellidae | 1 | + | -- | 1 | -- | 2 | 3 | | | | |
| Eatoniellidae | | | | | | | | | | | |

+ = amount too small to be counted.

## TABLE 19. STANDING CROP, SPECIES DIVERSITY, AND SPECIES COMPOSITION AT KĪHOLO BAY

| | | | | | | | | | | | Station | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 01 | 02A | 02B | 03 | 04 | 04B | 05 | In1 | In2 | In3 | 10.2A | 10.4 | 10.14 | 10.16 | 10.18 | 10.20 | 12.20 | 12.22 | 12.24 | 12.25 |
| Depth, m | 6 | 6 | 6 | 9 | 9 | 9 | 9 | 5 | 2 | 2 | | | | | | | | | | |
| No. Specimens | 194 | 585 | 344 | 541 | 668 | 359 | 318 | 135 | 305 | 228 | 248 | 640 | 153 | 93 | 225 | 228 | 58 | 87 | 127 | 231 |
| No./cm$^3$ | 19.4 | 58.5 | 34.4 | 54.1 | 66.8 | 35.9 | 31.8 | 13.5 | 30.5 | 22.8 | 9.9- | 32.4 | 6.1 | 3.7 | 9 | 9.1 | 2.3 | 3.5 | 5.1 | 9.2 |
| H' | 4.0 | 4.5 | 4.7 | 4.9 | 4.2 | 4.7 | 4.0 | 4.3 | 4.4 | 3.7 | 4.2 | 4.8 | 4.2 | 3.9 | 3.4 | 3.8 | 4.1 | 3.5 | 3.5 | 4.3 |
| Percent Composition | | | | | | | | | | | | | | | | | | | | |
| Archaeogastropods | | | | | | | | | | | | | | | | | | | | |
| *Leptothyra rubricincta* | 7 | 3 | 5 | 9 | 6 | 4 | 7 | 4 | 7 | + | 6 | 3 | -- | -- | -- | -- | -- | -- | -- | 4 |
| *Tricolia variabilis* | 15 | 11 | 7 | 6 | 13 | 11 | 11 | 3 | 6 | 3 | 4 | 5 | 6 | 3 | 2 | 5 | 5 | -- | 3 | 1 |
| Rissoidae | 22 | 37 | 42 | 37 | 32 | 36 | 13 | 43 | 33 | 29 | 30 | 23 | 23 | 38 | 20 | 17 | 33 | 9 | 13 | 26 |
| *Rissoina ambigua* | -- | -- | 3 | 2 | + | 1 | -- | 4 | 4 | 5 | 14 | 4 | 4 | 15 | 2 | 3 | 12 | -- | 5 | 8 |
| *R. miltozona* | 3 | 5 | 9 | 6 | 4 | 6 | + | 15 | 4 | 2 | 11 | 3 | 8 | 12 | 2 | 1 | 3 | 1 | -- | 5 |
| *Merelina pisinna* | -- | -- | -- | 2 | 4 | 4 | 2 | 10 | 9 | 1 | 1 | 4 | 2 | 1 | 2 | 4 | 2 | -- | + | 2 |
| *Vitricithna marmorata* | 5 | 14 | 15 | 15 | 12 | 14 | 6 | 4 | 5 | + | + | 2 | 5 | 5 | -- | -- | 10 | -- | + | -- |
| *Parashiela beetsi* | 8 | 10 | 7 | 6 | 7 | 4 | 2 | 1 | 1 | + | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- |
| Cerithiidae | 14 | 11 | 16 | 18 | 19 | 21 | 26 | 21 | 34 | 46 | 28 | 17 | 33 | 14 | 16 | 24 | 24 | 38 | 46 | 42 |
| *Bittium impendens* | 11 | 8 | 12 | 16 | 14 | 13 | 19 | 15 | 18 | 1 | -- | + | 3 | 4 | 2 | + | 10 | 22 | -- | 3 |
| *B. parcum* | 1 | + | + | + | 1 | 2 | 4 | 1 | 3 | 5 | 13 | 9 | 21 | 5 | 6 | 6 | 3 | 2 | 10 | 14 |
| *B. zebrum* | + | 2 | 2 | 1 | 2 | 3 | 1 | 3 | 11 | 23 | 12 | 6 | 8 | 3 | 8 | 16 | 9 | 14 | 36 | 24 |
| Diallidae | 22 | 16 | 10 | 9 | 13 | 7 | 9 | 3 | 1 | + | + | 1 | + | 3 | 3 | + | 2 | 2 | + | + |
| *Cerithidium perparvulum* | 15 | 10 | 7 | 7 | 12 | 6 | 8 | 3 | + | -- | + | + | -- | 1 | -- | + | -- | -- | -- | -- |
| *Diala varia* | + | 1 | + | -- | + | -- | -- | -- | -- | + | -- | + | -- | -- | -- | -- | -- | -- | -- | -- |
| Triphoridae | 2 | 4 | 5 | 4 | 4 | 5 | 6 | 4 | 1 | + | 2 | + | 1 | 2 | + | 1 | 2 | 2 | -- | -- |
| Pyramidellidae | + | -- | -- | + | + | + | -- | 2 | + | + | 2 | 9 | 15 | 5 | 8 | 14 | 2 | 21 | 6 | 6 |
| Eatoniellidae | -- | -- | + | 1 | 1 | -- | -- | -- | 5 | 3 | -- | 9 | 4 | 19 | 44 | 13 | -- | 13 | 2 | + |

+ = amount too small to be counted.

**MICROMOLLUSCAN ASSEMBLAGES.** Two assemblages of micromollusks are identified at Kīholo in the similarity analysis (Figs. 26, 27), one associated with a predominantly offshore cluster of stations (Group A, Fig. 27), the other characterizing predominantly inshore and shoreline stations (Group B, Fig. 27). Standing crop, species diversity, and species composition are shown in Table 19.

The inshore area at Kīholo is comprised largely of sediments of black sand studded with rubble at distances to 10 m offshore and at depths of less than 1 m. A variety of corals, such as *Porites lobata, Pocillopora meandrina,* and *Montipora verrucosa*, also occurs, although coral cover in the inshore area is sparse. A prominent freshwater lens is present along the northeastern sector of the shoreline, from Wainanali'i Pond to the central rubble beach, and the lens extends well into the mid-section of the bay, at least during the early morning hours. This lens causes considerable turbidity and reduced visibility, resulting in a rather uninviting prospect to a diver interested in clear water and colorful coral communities.

The dominant micromollusks of the inshore stations are *Bittium parcum* and *B. zebrum*. Two species associated with fresh water are also prominent, *Eatoniella* sp. and *Planaxis* sp., which occurred in 87% of the samples. Standing crop averages 9.3 shells/cm$^3$, and the diversity index, H', averages 3.7.

The dominant micromollusks of the offshore stations are *Bittium impendens, Vitricithna marmorata,* and *Parashiela beetsi*. The offshore stations are distinguished from those at 'Anaeho'omalu and Puakō by consistently lower proportions of *Rissoina miltozona* and higher proportions of *Parashiela* (Table 18). Standing crops average 31.9 shells/cm$^3$, and the mean of the species diversity index, H', is 4.4.

Three inshore stations occurring in the cluster of offshore stations include mollusks associated with fresh water, *Eatoniella* and *Planaxis*, as well as pyramidellids which may be associated with sessil invertebrates, such as oysters and sponges.

**WAINANALI'I POND.** Wainanali'i Pond is characterized by strong physicochemical gradients in the water column. These gradients primarily affect the fauna in the upper 0.5 m of the water column where a brackish to freshwater lens operates in conjunction with tidal flow and selects for euryhaline organisms. The dominant macromollusks in the pond are, thus, two species which are primarily associated with fresh water, *Isognomon californicum* and *Ostrea* *sandwicensis*. Details of the molluscan assemblages are described in the section on Wainanali'i Pond.

## Discussion

Benthic marine communities are traditionally separated into supratidal, intertidal, and subtidal zones on the basis of discrete faunal communities characterized by the regular occurrence of conspicuous, usually numerically dominant elements of the fauna within each of the zones. No community of organisms is continuous, however, and differences in topography, depth, water chemistry, and the presence or absence of substrates such as coral, algae, and sediment determine the occurrence of local, specialized assemblages of organisms. The Kona Coast of Hawaii is a case in point: in the four bays considered here, localized assemblages of organisms appear to be the rule rather than the exception, and although each of the bays is generally characterized by the traditional zonation pattern, there are also marked differences in assemblages of mollusks (and other organisms) among and within the bays.

At Puakō the shoreline is one in which topographic and biotic features are primarily determined by tides rather than wave action, and marine conditions generally predominate along the shoreline. The overhanging kiawe trees, the sparse intertidal biota restricted to a few boulders and basaltic outcrops, and the presence of a broad, shallow inshore zone with coral growth reaching the tide line reflect both the lack of wave energy and freshwater intrusions in the bay. At 'Anaeho'omalu where the shoreline vegetation is restricted to the berm shoreward of the shoreline, where a wide, calcareous sand beach forms a central feature of the bay, and where tidepools at the northern terminus are surrounded by boulders encrusted with a rich growth of *Porolithon*, the situation suggests that wave energy rather than tides is a predominant determinant of the configuration of the bay. As at Puakō, marine conditions generally predominate. At Waiulua and Kīholo, the basalt shorelines with pebble, rubble, and black sand beaches are suggestive of areas receiving even more wave energy than is effective at 'Anaeho'omalu. Freshwater influxes are noticeable features of the shoreline of both bays, indicated not only by freshets of groundwater which gush from crevices in the basalt but by the freshwater lens present in the inshore areas of both bays.

The assemblage of macromollusks associated with the shoreline and inshore areas of the four bays reflect the conditions cited above. The most consistently encountered assemblage of mollusks is that found in the rocky supratidal, the assemblage characterized by *Littorina pintado, Nodilittorina picta,* and *Nerita picea*. This assemblage is characteristic of all rocky supratidal substrates in the windward Hawaiian Islands. One supratidal mollusk, *Littorina scabra*, however, is found only at Puakō, on the kiawe trees overhanging the bay. This gastropod, which is widespread throughout the Indo-West Pacific, is unusual in the Hawaiian Islands, and found only in protected areas such as in bays and harbors (Whipple 1967).

In the intertidal there are two assemblages of macromollusks, a marine assemblage with *Hipponix grayanus, Morula granulata,* and *Isognomon perna* most frequently encountered, and a freshwater-associated assemblage of *Theodoxus neglectus, Isognomon californicum,* and *Brachidontes crebristriatus*. At Puakō *Theodoxus* was found only in one shoreward tidepool. At 'Anaeho'-omalu *Isognomon* and *Brachidontes* were similarly found in a single area. At Waiulua and Kīholo the four mollusks were consistently encountered the length of the shoreline. That the freshwater intrusions at Waiulua and Kīholo are permanent features of the shoreline is indicated by the distinct zonation exhibitied by these mollusks along the shoreline at Waiulua Bay and in Wainanali'i Pond at Kīholo.

Analysis of the micromolluscan assemblages of the four bays indicates even more subtle differences among and within the bays. Some of the differences are summarized in the similarity matrix which includes all stations sampled at Puakō, 'Anaeho'omalu, and Kīholo (Fig. 28). Two major groups and five subgroups of stations are distinguished. In one major group (Group A) are the offshore stations of Puakō, 'Anaeho'omalu, and Kīholo and the inshore stations at Puako; in the other major group (Group B) are the shoreline stations at 'Anaeho'-omalu and Kīholo. Standing crop and the species diversity index are generally lower at the shoreline and inshore stations than in the offshore stations (except for the high species diversity index calculated for the inshore stations at Puakō).

The distinguishing species of the shoreline stations at 'Anaeho'omalu and Kīholo are *Rissoina ambigua, Bittium parcum,* and *B. zebrum*. All three species are ubiquitous shoreline species in the Hawaiian Islands, *B. parcum* associated with frondose algae, *Rissoina ambigua* and *B. zebrum* with rubble. The Kīholo stations (subgroup B2) are distinguished from those at 'Anaeho'-

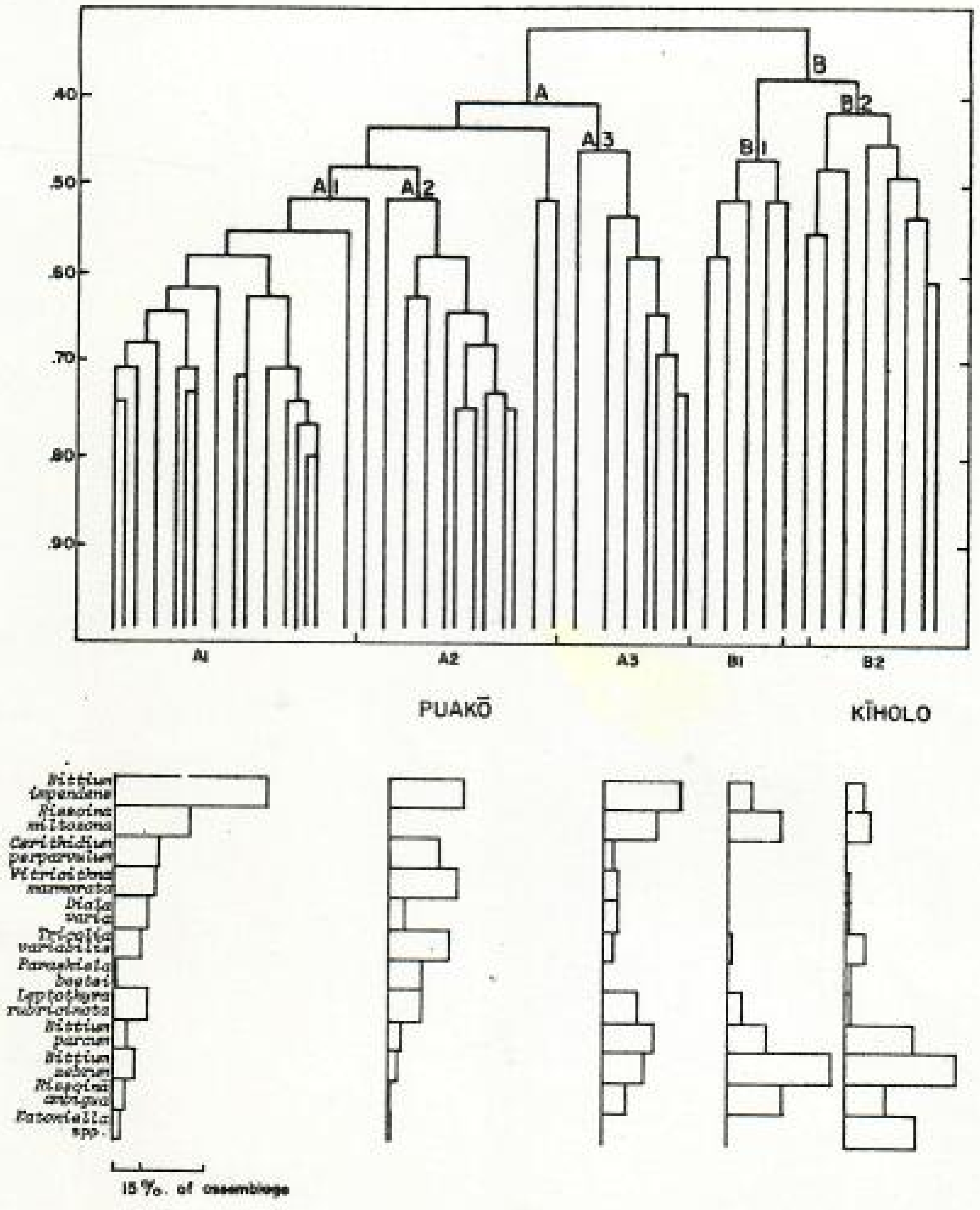


FIGURE 28. DENDROGRAPH, SHOWING SIMILARITY INDICES FOR PUAKŌ, 'ANAEHO'OMALU, AND KĪHOLO BAYS

omalu by the occurrence of *Eatoniella* sp. which is associated with fresh water. The effect of the freshwater intrusions on the benthic marine community at distances of some 30 m from shore is also indicated at Kīholo by the presence of *Eatoniella* sp. (and *Planaria*) at three offshore stations where the freshwater-associated species are admixed with marine species (Table 5). The admixture of species associated with freshwater and typically marine species at these stations suggests that although the freshening effect persists offshore, the low salinity water is mixed with the water mass of the bay.

Differences in species composition in the subgroups of the other major group (Group A) in the similarity matrix are more difficult to explain than are those of the inshore waters because we know less of the habits of subtidal mollusks than of intertidal forms. *Bittium impendens* which is a dominant component of these assemblages is peculiarly associated with the Kona Coast of Hawaii Island and with the leeward Hawaiian Islands of Midway, Laysan, and the like. It is found on Kauai, Oahu, Maui, but it forms a dominant component of micromolluscan assemblages only on Hawaii and in the leeward islands. The other dominant species include four ubiquitous subtidal species found elsewhere in the islands at depths of 10 to 100 m; *Cerithidium perparvulum*, *Diala varia*, *Vitricithna marmorata*, and *Parashiela beetsi*; and three species found from the intertidal to depths of about 50 m: *Leptothyra rubricincta*, *Tricolia variabilis*, and *Rissoina miltozona*. The Kīholo offshore stations (subgroup A2) are distinguished by higher proportions of *Tricolia*, *Vitricithna*, and *Parashiela* than occur at Puakō or 'Anaeho'omalu. *Tricolia* feeds and breeds on frondose algae, such as *Padina* (Wertzberger 1967); *Vitricithna* and *Parashiela* appear to be associated with substrates which have more rubble than coral cover (although no statistically significant correlation was found). It is tempting to suggest that their dominance at Kīholo is associated with the lesser coral cover characteristics of this bay than occurs in the others (see Coral Communities). The Puakō inshore stations (subgroup A2), with their admixture of deep and shallow species are consonant with the protected calm waters of the bay and the extensive inshore coral cover.

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# WAINĀNĀLI'I POND

Wainānāli'i Pond in Kīholo Bay represents a unique shoreline ecosystem among the four bays studied, and perhaps in the Hawaiian Islands, and is here described in detail.

Wainānāli'i Pond (Fig. 29) is an elongate lagoon formed by a cobble-and-sand bar lying along the 1859 pāhoehoe lava flow which constitutes the eastern boundary of Kīholo Bay. The bar connects with the lava at its seaward (northern) end, enclosing the head of the pond. At its landward end, the bar is crossed by two shallow passes which connect the pond with the inner part of Kīholo Bay.

The pond is roughly 457 m (1,500 ft) long by 30 m (100 ft) to 91 m (300 ft) wide, with an area of nearly 2 ha (5 acres). Detailed soundings were not made, but observations indicate steep sides and a relatively flat bottom at depth of 3 m (10 ft) to 4 m (12 ft). There is a partial barrier, about halfway along the pond, formed by a (submerged extension of the lava flow.) The gap between the end of this shoal and the cobble bar is about 3 m deep, so that while this feature restricts circulation, it does not form a sill behind which the deep water might tend to stagnate.

The main (northern) pass has a "channel" about 6 m (20 ft) wide with a sill depth of about 1 m (3 ft) at mean low water. The sides of the pass shoal very gradually, so that the total width varies with the stage of the tide between approximately 30 m (100 ft) and 61 m (200 ft). The small secondary pass, in which no measurements were made, has a maximum width of about 15 m (50 ft) at high water.

Freshwater springs enter the pond at several points along the edge of the lava flow. The most notable spring was observed at the head (northern end) of the pond.

The measured range of tide in the pond was 0.8 m (2.5 ft) at an extreme spring-tide maximum. More interestingly, a persistent 10- to 13-cm (4- to 5-in.) seiche, with a period of 6 to 8 min, was observed throughout the study period. The seiche was virtually undetectable on the open shoreline, but was easily visible within the quiet pond, and was strikingly evident in the passes over the bar, where the fairly strong current alternated in direction every few minutes. The mechanics of this seiche have not been investigated,

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Edward D. Stroup, David P. Fellows, and E. Alison Kay.

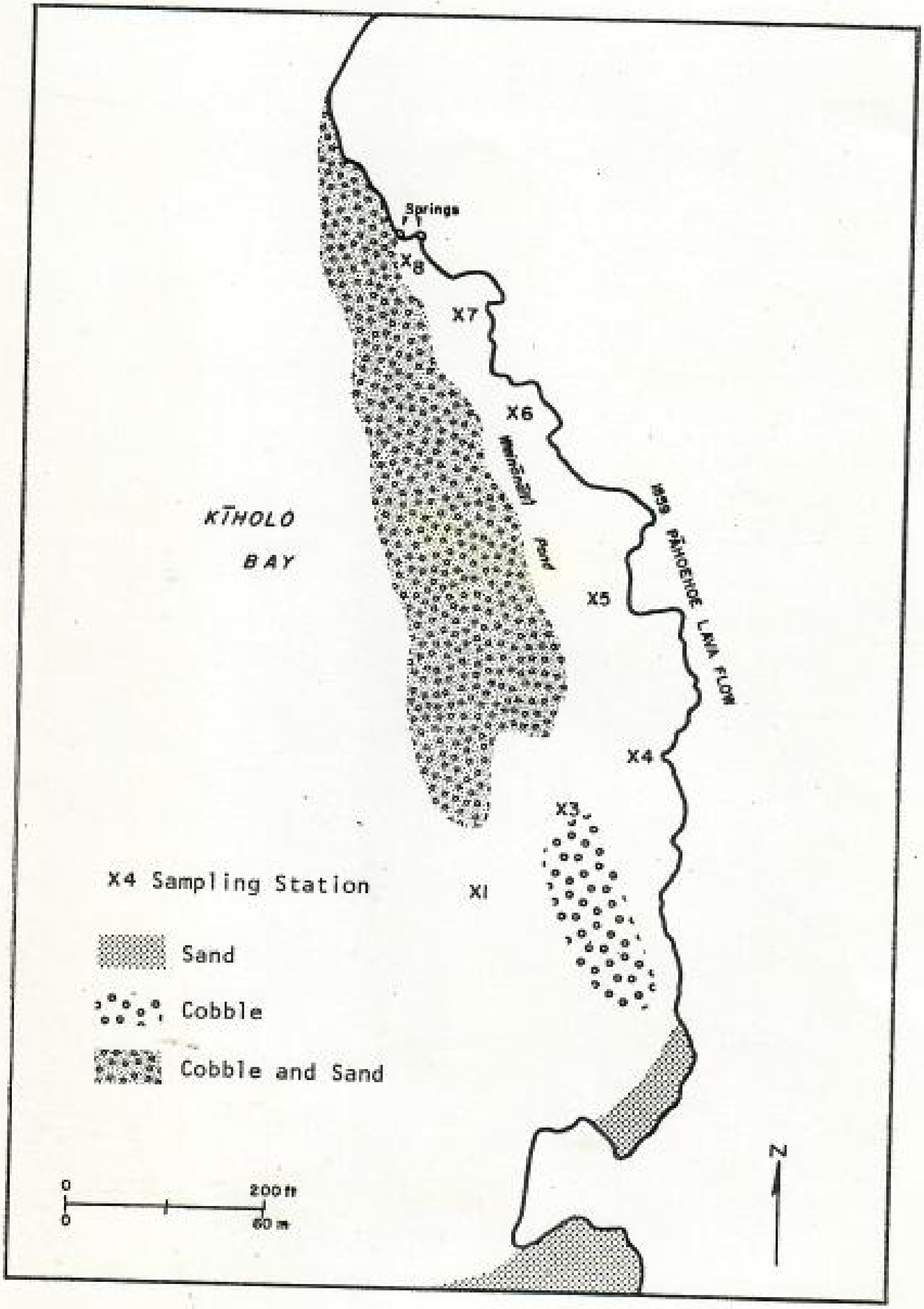

FIGURE 29. MAP OF WAINĀNĀLI'I POND ADJOINING KĪHOLO BAY

but the period would suggest a reflection of wave energy between the east and west sides of Kīholo Bay, that is, greater Kīholo Bay with a breadth of some 2.5 km. Other types of edge-wave effects may also be possible sources of this oscillation.

## Physical Measurements

Observations of temperature, electrical conductivity, and dissolved oxygen concentration were made at stations extending the length of the pond, on the entrance bar, and just outside the bar, as shown in Figure 30. At each station within the pond, measurements were made at the surface, 0.6 m (2 ft), 1.5 m (5 ft), and just above the bottom (usually about 3 m). At the station on and outside the bar, observations were made only at the surface and bottom.

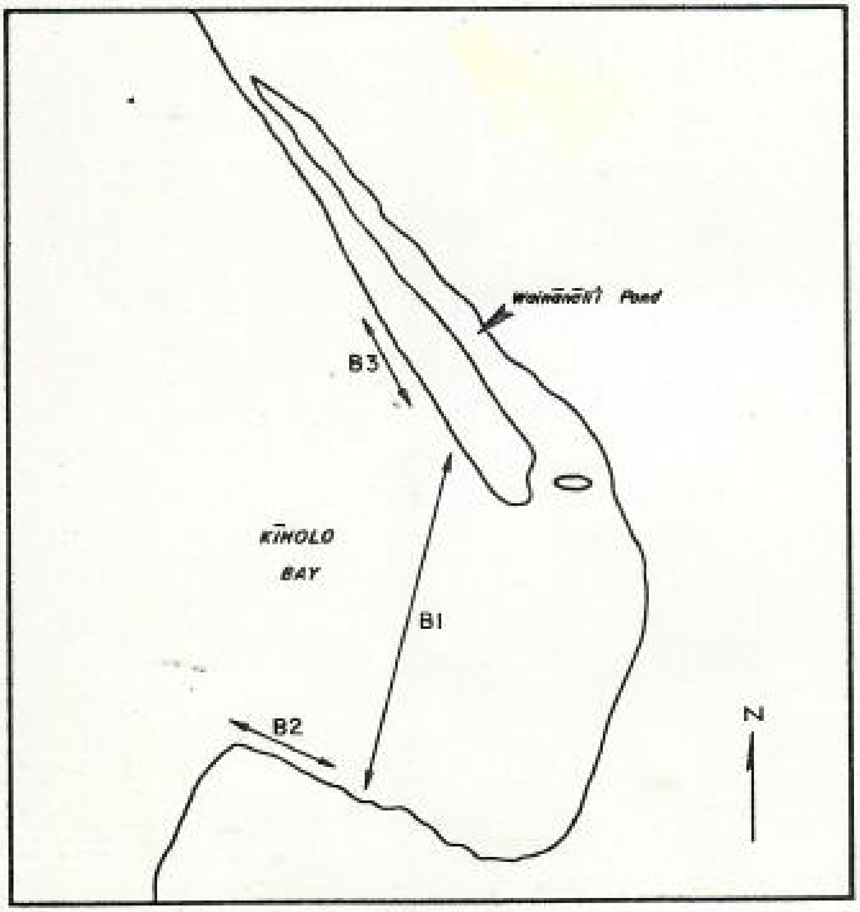

FIGURE 30. APPROXIMATE LOCATIONS OF KĪHOLO BAY TRANSECTS OUTSIDE WAINĀNALI'I POND, NORTH KONA

The stations were occupied near low water (0815 to 0950) on 10 August 1973, and again near low water (0930 to 1030) and near high water (1500 to 1540) on 11 August 1973. Only the data from 11 August are illustrated; there were no significant differences between the distributions at low water on this and the previous day.

TEMPERATURE. At low tide (Fig. 31-A) the cold, fresh (see below) outflow from the springs extended over the whole surface of the pond. The development of stratification was aided by calm or very light winds during the night. The cooling seen in the deeper pond near the bar may be caused by mixing generated at the bar by the seiche.

At high tide (Fig. 31-B), and after some hours of a brisk sea breeze from the WNW, the surface of the pond was 3 to 5°C warmer, with stratification very much reduced. The deeper layers have also been warmed by the sun, especially toward the inner end of the pond, where seiche-induced mixing would have least effect. The effect of the freshwater springs can be seen only in the slight cooling near the surafce at the very head of the pond.

SALINITY. Again, at low tide, the freshwater layer shows up clearly (Fig.32-A). Note that this layer mixes away rapidly as it crosses the bar into the bay. The station outside the bar show salinity lower than the usual oceanic value of near 35‰ in Hawaiian waters because there are many springs entering the ocean along this coast.

Salinity in the deeper pond is 28 to 29‰ during the low tide period. At high tide the stratification has nearly vanished, with surface salinities sharply increased and deep salinities somewhat reduced from the earlier values. Evidence of saltier water entering over the sill is indicated in Figure 32-B, since the observation at Station 3 was made during the inflowing phase of the seiche. During the outflowing phase, the bottom salinity on the bar dropped sharply.

OXYTY. The dissolved oxygen concentration (oxyty) distribution (Fig. 33) shows strong photosynthetic-respirational effects. In the early morning, at low tide, the deeper pond has depleted oxyty. The stable stratification has restricted downward mixing from the surface.

At high tide, in the late afternoon, oxyty has increased everywhere in the deeper pond, and also increased markedly in the water outside the bar. At the surface of the inner pond, the oxyty has decreased somewhat from the morning values, probably by a combination of mixing with deeper water and

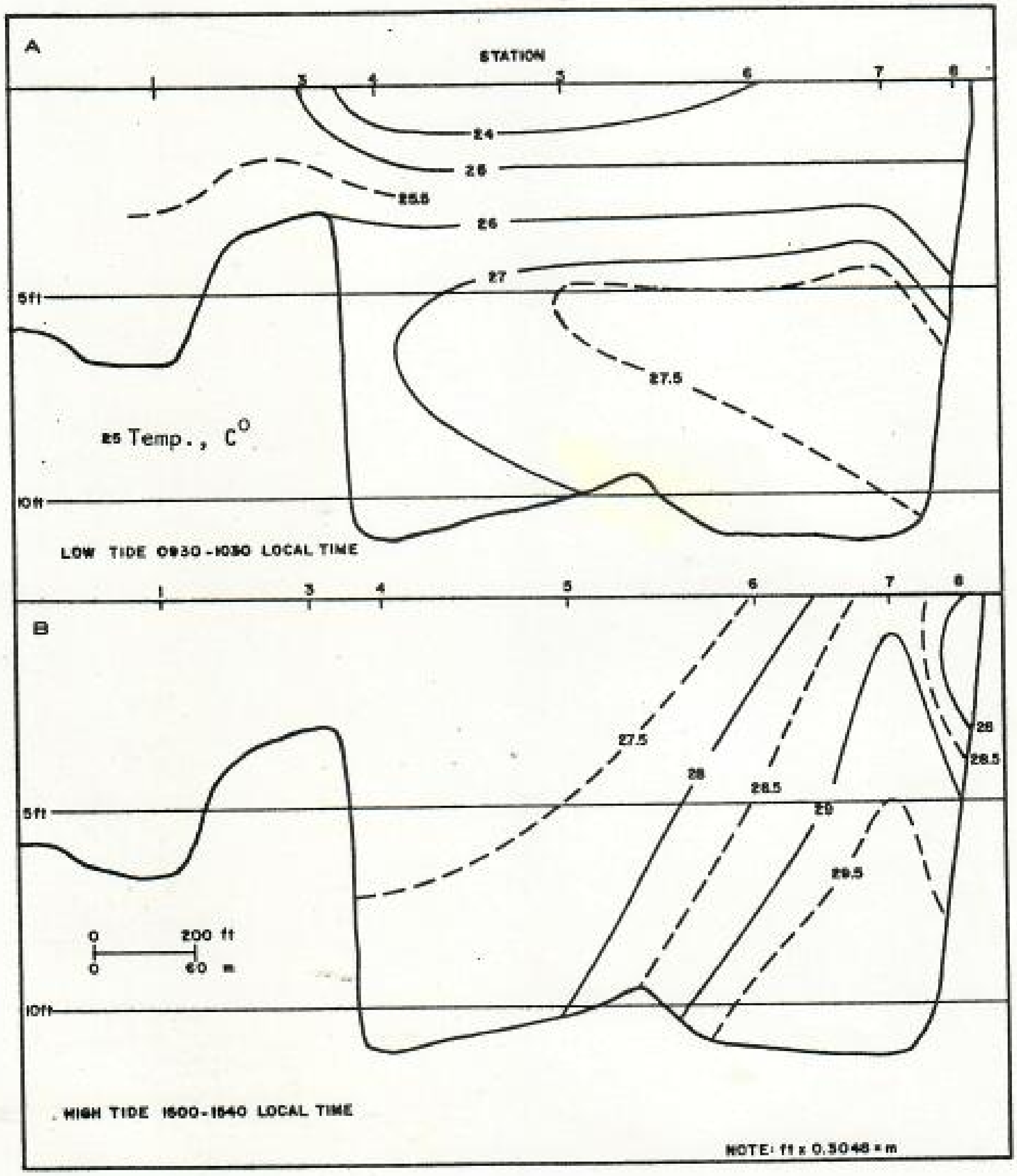

FIGURE 31. TEMPERATURE DURING LOW AND HIGH TIDES, WAINĀNĀLI'I POND

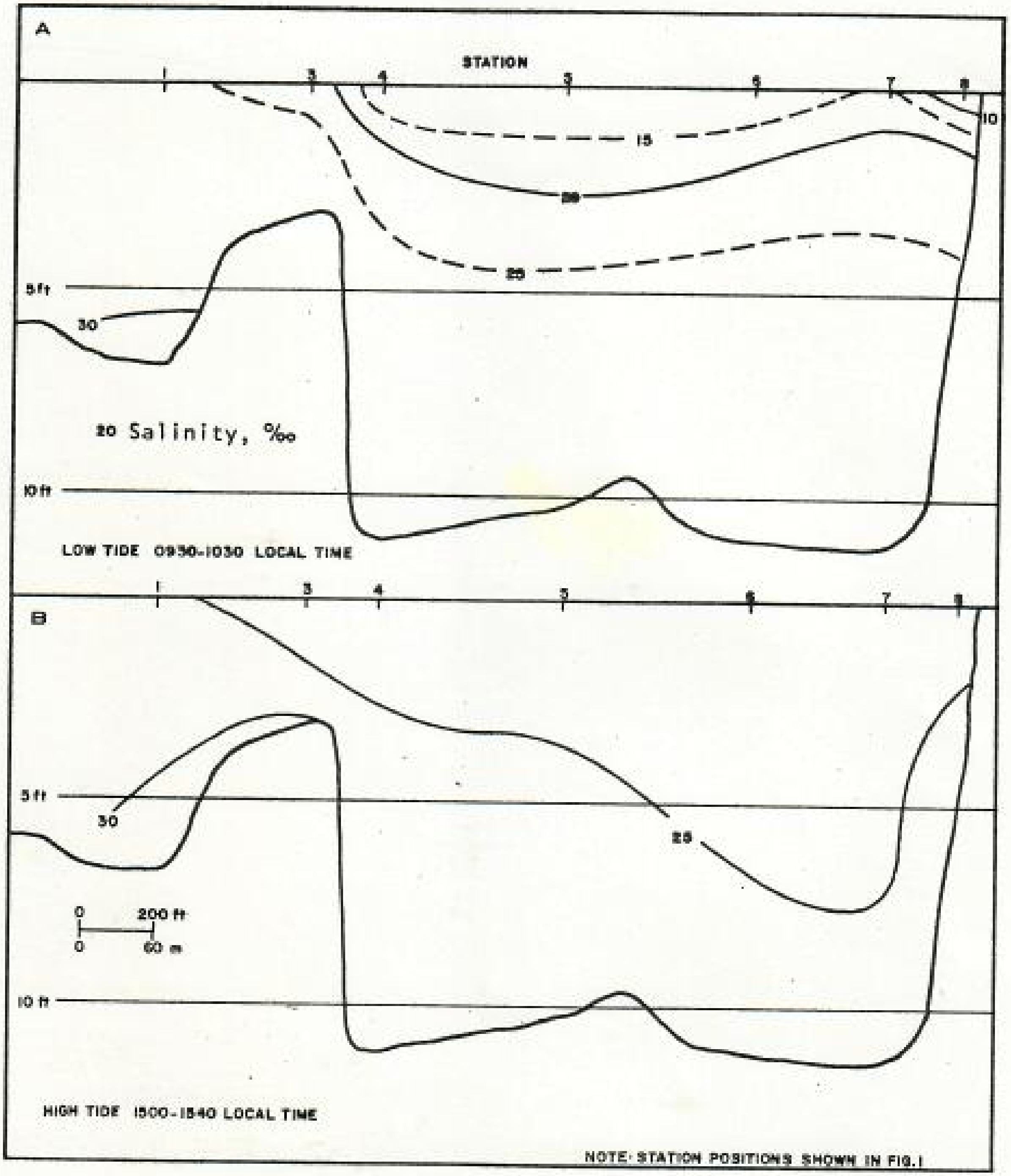

FIGURE 32. SALINITY DURING LOW AND HIGH TIDES, WAINĀNĀLI'I POND

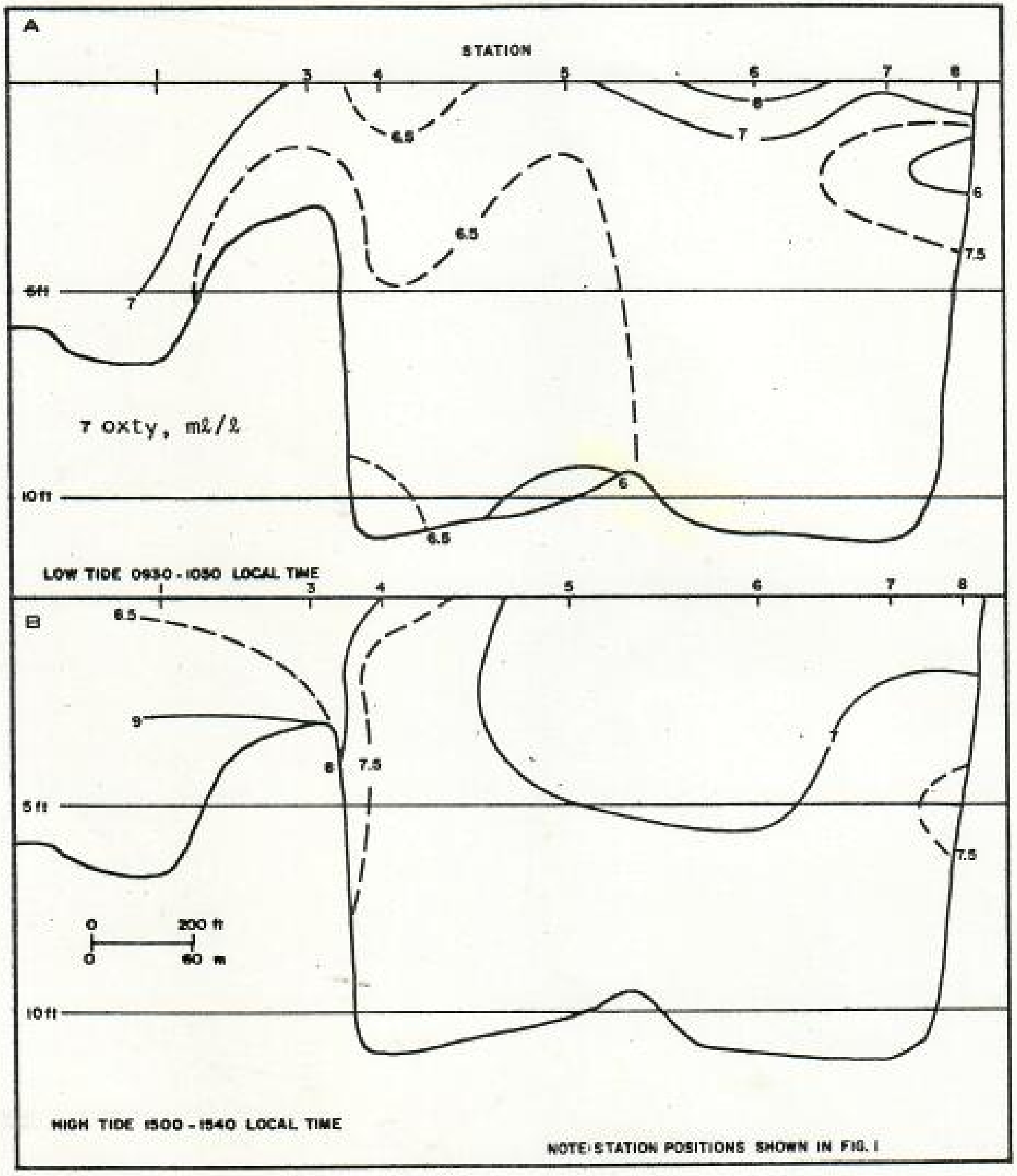

FIGURE 33. DISSOLVED OXYGEN CONCENTRATION DURING LOW AND HIGH TIDES, WAINĀNALI'I POND

loss to the atmosphere.

## Observations on the Biota

General turbidity in the pond, coupled with extensive silt deposits over most of the substrate surface, permitted only quantitative sampling of the benthic community. Five cross-sectional transects (P1 to P5, Fig. 34) were sampled at random to determine the composition of communities associated with the substrate in the pond. Based on the results obtained from the cross-sectional pond transects, a longitudinal transect was also established. This transect ran the length of the pond approximately 1 m below the low tide mark. Starting approximately 30 m from the pond entrance, samples were taken every 5 m for the first 100 m and thereafter at 10-m intervals. In all, 40 samples were taken over a distance of 300 m. Depending upon substrate composition, four double-handfulls of sand or four rocks (20- to 35-cm diameter) were examined at each sample point and the relative abundance of each organism characteristic of the pond habitat was noted.

Figure 35 illustrates a generalized cross section of the pond as determined by transects P2 and P5. The cross section is generally representative of all areas in the pond except: (1) the entrance, which consists of a shallow, predominantly cobble sill; and (2) a restricted beach area close to the entrance where Zones I and II consist of coarse angular black sand rather than cobble.

General substrate conditions and communities characteristic of each zone are summarized in Table 20. The strong physicochemical gradients reported above appear to have little effect on the fauna except in the uppermost 1.5 m where a brackish to freshwater lens operates in conjunction with tidal flow and strongly selects euryhaline organisms. Elsewhere, throughout the pond, community composition appears relatively consistent within a given substrate despite variations in water quality parameters.

The general, within-substrate faunal consistency noted above was more critically examined in Zone II by means of the longitudinal transect. Based upon a preliminary survey of organisms within this zone, each species encountered at a given sample point was rated either common or rare relative to its general abundance throughout the zone. The results of this survey are shown in Table 21 by groups of five successive sample points. The relative local abundance of each species is indicated and the number of sampling points

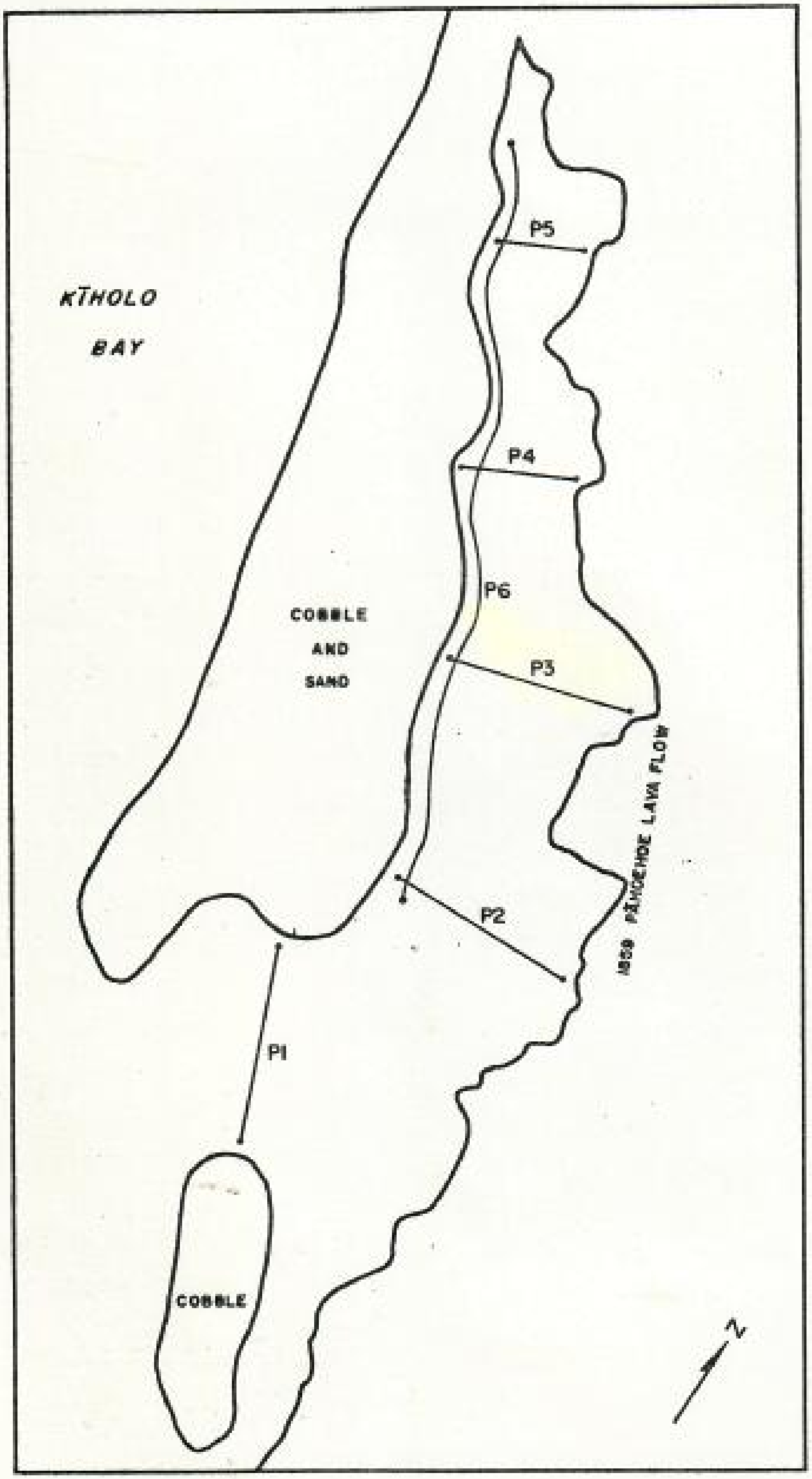

FIGURE 34. CROSS-SECTIONAL AND LONGITUDINAL TRANSECTS, KĪHOLO, NORTH KONA

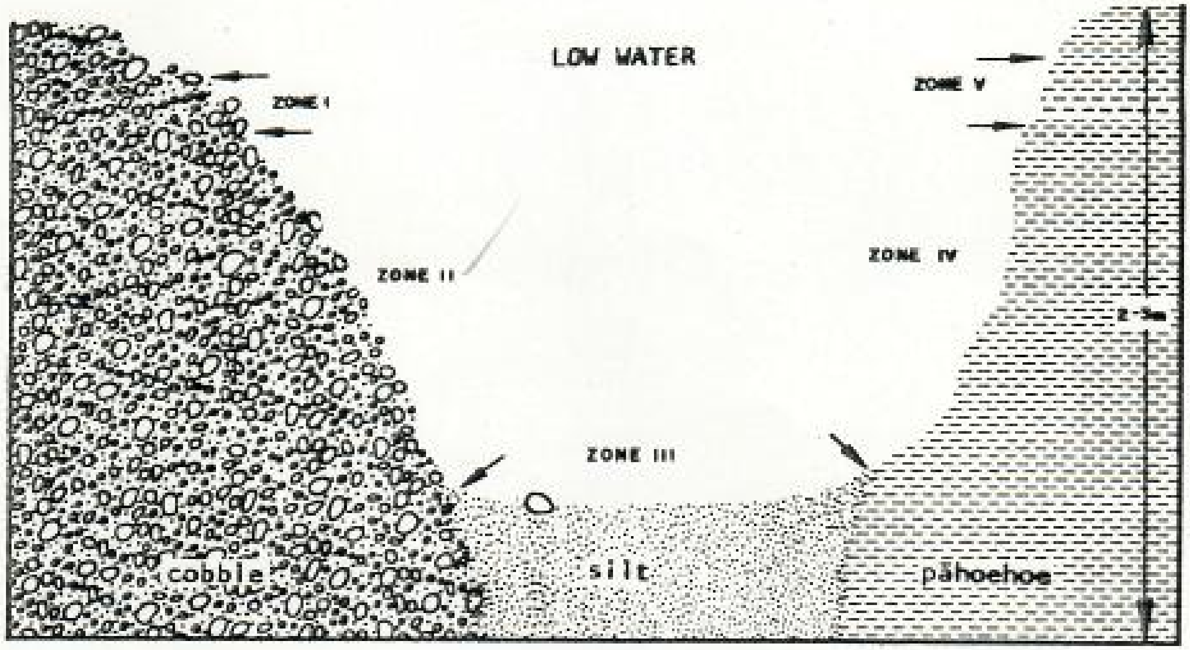

FIGURE 35. GENERALIZED CROSS SECTION OF WAINĀNĀLI'I POND, KĪHOLO, NORTH KONA

on which it occurred is shown for each segment of the transect. Also indicated in Table 21 is the relative abundance of species inhabiting the channel at the mouth of the pond as determined by transect P1.

From Table 21 is apparent that the majority of the Zone II cobble community is distributed throughout the length of the pond wherever suitable substrate occurs. This generalization does not, however, extend to the pond entrance where an ecotone community inhabits a substrate and depth commensurate with the cobble areas surveyed in Zone II. Moreover, within the pond, at least three species (*Eurythoe complanata, Isognomon californicum,* and *Ostrea sandvicensis*) and, possibly, a fourth species (*Hipponix* sp.) display longitudinal population gradients indicative of adverse selection in portions of the habitat. Efforts to determine factors limiting these organisms might prove them to be of value as indicator organisms.

## Micromollusks

Two distinctive assemblages of micromollusks were identified in the pond, one at the entrance, the other mid-way in the pond itself. In both assemblages, brackish-water or freshwater-associated mollusks predominate. At the entrance of the pond, the dominant species are *Eatoniella* (44.5%) and

TABLE 20. SUBSTRATES AND ASSOCIATED MACROBENTHOS OF WAINĀNĀLI'I POND

| Zone | Substrate | Community Composition | Other Observations |
|---|---|---|---|
| I | Bare clean cobble | Sparse pelecypod (*Isognomon perna*)-anthozoan (*Aiptasia*-like) community; infrequent small colonies of two species of demospongiae | Entirely within low salinity lens at low tide |
| | <u>OR</u> | | |
| | Clean coarse sand | Macrobenthos absent | |
| II | Vegetated cobble, silt content in- | Diverse pelecypod (*I. perna*; *I. californicum*; *Brachydontes cerebristriatus*; *Ostreasa hawaiiensis*)-gastropod (*Hipponyx* sp.)-anthozoan (*Aiptasia*-like)-polychaete (*Eurythoe complanata*)-holothurian (*Holothuria monocarida*)-poriferan community | *Acanthophora* and filamentous algae cover much exposed surface |
| | <u>OR</u> | | |
| | Coarse sand, silt content increasing with depth | Enteroptneust (*Ptychodera flava*)-annelid (*Cirratulus* sp.) community; burrows of unidentified Callianasid shrimp common, some of these occupied by gobies | Some filamentous algae present on sand surface, density increases with depth |
| III | Fine claylike silt | Similar to sandy section of Zone II, but *Ptychodera* less common. *Acanthophora* and *Aiptasia*-like anemone cover scattered rocks | Single specimen of gastropod-feeding crab, *Calappa hepatica* found |
| IV | Vegetated, lightly silted pāhoehoe lava | Anemone (*Aiptasia*-like) and *Acanthophora* cover virtually entire surface | |
| V | Bare, clean pāhoehoe lava | Scattered anemones (*Aiptasia*-like) only | Entirely within low saline lens at low tide |

TABLE 21. LONGITUDINAL DISTRIBUTION OF ORGANISMS IN ZONE II, WAINĀNĀLI'I POND, KONA COAST

| Species | Substrate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | cobble | sand | sand | cobble | cobble | cobble | cobble | cobble | cobble |
| | Distance from mouth of pond | | | | | | | | |
| | 0-5[*] | 30-50 | 55-75 | 80-100 | 105-125 | 135-175 | 185-225 | 235-275 | 285-325 |
| | (m) | | | | | | | | |
| Porifera | | | | | | | | | |
| Species 1 (red encrusting) | C | --- | --- | C-5 | C-3 | C-5 | C-2 | C-2 | C-4 |
| Species 2 (yellow branching) | - | --- | --- | C-3 | C-3 | C-1 | C-4 | C-4 | C-3 |
| Coelenterata | | | | | | | | | |
| *Aiptasia*-like | - | --- | C-1[†] | C-5 | C-5 | C-5 | C-5 | C-5 | C-4 |
| Annelida | | | | | | | | | |
| *Cerratulus* sp. | - | C-1 | C-1 | --- | --- | --- | --- | --- | --- |
| *Eurythoe complanata* | - | --- | --- | C-5 | C-5 | C-5 | C-3 | R-2 | R-1 |
| Mollusca | | | | | | | | | |
| *Planaxis labiosa* | C | --- | --- | --- | --- | --- | --- | --- | --- |
| *Isognomon perna* | R | --- | --- | C-3 | C-3 | C-2 | C-1 | C-5 | C-4 |
| *Isognomon californicum* | - | --- | --- | --- | --- | --- | --- | C-2 | C-5 |
| *Brachydontes cerebristriatus* | R | --- | C-1[†] | C-4 | C-2 | C-2 | C-3 | C-3 | C-2 |
| *Ostraea hawaiiensis* | - | --- | C-1[†] | C-1 | C-1 | C-3 | C-4 | C-5 | C-5 |
| *Theodoxus neglectus* | R | --- | --- | --- | --- | --- | --- | --- | --- |
| *Hipponyx* sp. | - | --- | --- | C-4 | C-4 | C-4 | C-5 | C-1 | --- |
| *Cypraea caputserpentis* | C | --- | --- | --- | --- | --- | --- | --- | --- |
| *Cypraea mauritiana* | R | --- | --- | --- | --- | --- | --- | --- | --- |
| Echinodermata | | | | | | | | | |
| *Holothuria monocaria* | C | --- | --- | C-2 | C-5 | C-5 | C-5 | C-3 | C-5 |
| *Actinopyga mauritiana* | R | --- | --- | --- | --- | --- | --- | --- | --- |
| *Echinometra mathaei* | R | --- | --- | --- | --- | --- | --- | --- | --- |
| *Asterina anomala* | - | --- | --- | --- | R-1 | R-1 | R-2 | --- | --- |
| Enteroptneusta | | | | | | | | | |
| *Ptychodera flava* | - | C-5 | C-5 | --- | --- | C-1[‡] | C-1[‡] | --- | --- |

NOTE: See text for details.

[*] Based on transect across mouth of pond.

[†] On isolated rock at one station.

[‡] In isolated sand pocket at one station.

C = common.

R = rare.

Numbers indicate number of sample stations in interval in which species occurred.

*Planaxis* and *Theodoxus* (10%) which are associated with brackish water, and marine-associated cerithids (*Bittium parcum, B. zebrum*), rissoids (*Rissoina ambigua, R. miltozona*), and pyramidellids. On the shoaling sill mid-way into the pond, *THeodoxus* and *Melania* which are associated with fresh water comprised 27% of the assemblages, and the remaining micromollusks consist of dead shells of marine species such as rissoids, *Tricolia*, cerithids, and the like. An interesting component of the micromolluscan assemblages in the middle of the pond is the endemic Hawaiian capulid, *Capulus tricarinatus*, which probably lives on the oyster *Ostrea sandvicensis*.

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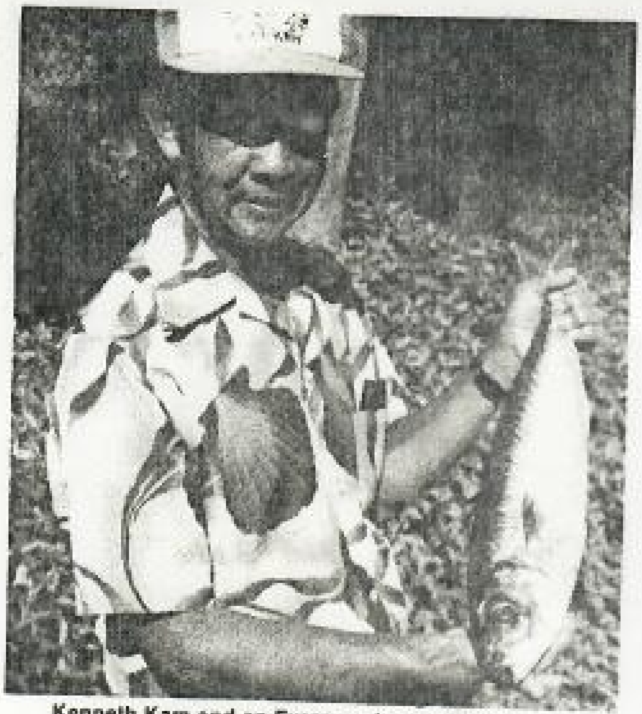

Kenneth Kam and an Evermann's nomeid fish.

Here is another interesting pull from the depths of O'ahu's waters. This catch was brought to our attention by a call from **Kenneth Kam.**

Ken brought the fish by the office so it could be photographed. Once again we found a fish we had never seen before.

According to Ken, he was fishing in 900 feet of water when he hooked his mystery catch. As you can see by the photo, the fish looks very similar to a mullet.

Ken's fish was later identified as an **Evermann's nomeid fish,** or *Ariomma evermanni.* According to the book *Fishes of Hawaii* by Spencer Wilkie Tinker, Evermann's nomeid fish is an uncommon fish found in the open sea. Two of its notable characteristics are its small mouth and its large eyes. Most fish of this species measure a foot in length, but some have been known to reach 24 inches. Distribution is the Hawaiian Islands and adjoining regions. The fish was first identified in 1923.

Here is a fish that is more common, however not with this particular coloration. Along with the photo, we received this letter about this unusual catch:

*Hi Chuck!*

*I have a rare prize here for you to set your eyes on: My husband, Clarence Ng, caught this fish on the Big Island at Hawaiian Beaches. As you can see, it's a "Bright Yellow Nenue."*

*People say it's rare, so I'd like to share this photo with you and your readers.*

*The nenue's weight was 4 lbs, and it was caught on 10-lb test line with a 4-lb test leader. Like they say, "Only in Hilo!"*

*Cynthia Ng*

Seen only occasionally, the **nenue pala** (golden yellow nenue) is actually a color phase of the adult fish that can grow to a length of 24 inches. Distribution of the nenue extends from Hawai'i southward into Polynesia and westward from Easter Island across the entire tropical Pacific and Indian Oceans to the coast of Africa and the Red Sea.

Clarence Ng and his nenue pala, or golden yellow nenue.

Chuck Johnston and his 200-lb sea turtle.

Lastly, I'd like to include one of my unusual catches—this huge sea turtle.

I was fishing with the **Atlapac Fishing Club** during our annual North Shore outing when my rod took a sudden dip and line started screaming off my reel in the direction of the outer reef. I put full pressure on the 40-lb test line to stop the initial run.

Hoping for a big ulua, but willing to settle for a kahala, I tightened the drag to the max. The battle lasted for 30 minutes, and I received lots of cheers and encouragement from the other club members. I'm sure I had an initial look of disappointment when this big bugger surfaced some 200 yards offshore.

This catch had a happier ending for Mr. Turtle than for Mr. Johnston. Being a protected species, the sea turtle did not qualify as the winning catch for the $200 club jackpot. But it did get the embedded hook carefully removed from its flipper and a chance to pose for photos before it was carried back to the edge of the reef and returned to freedom.

If someday you land an unusual catch, don't forget to take a picture and send it in to HFN. We'd like to share it with our readers.

**Fishin' Friends,**
**Chuck**

2777 Kalakaua Avenue
Honolulu, Hawaii 96815
January 10, 1977

Mr. George H. Balazs
Hawaii Institute of Marine Biology
P. O. Box 1346
Kaneohe, Hawaii 96744

Dear Mr. Balazs:

I am enclosing a copy of our January newsletter in which I wrote a synopsis of your lecture given at the SWASH November meeting.

As Editor of the Marine Aquarium Observer for 1977 this was my first attempt. It's quite a new experience for me, so I hope I got all the facts straight.

On behalf of the members of SWASH I would like to thank you for taking the time to speak to our group. There were many favorable comments and personally I found your lecture interesting. I recall seeing a film by Cousteau on sea turtle hatchlings elsewhere (but I don't remember where) and few survived as they were picked off by birds in the area.

Mahalo!

Sincerely,

Marion Kim

Marion Kim
Editor
Saltwater Aquarium Society
of Hawaii

# marine aquarium observer

JAN 1977
VOLUME VIII

THE SALT WATER AQUARIUM SOCIETY OF HAWAII

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SWASH

# Salt Water Aquarium Society of Hawaii

WAIKIKI AQUARIUM, 2777 KALAKAUA AVENUE, HONOLULU, HAWAII 96815

The SALT WATER AQUARIUM SOCIETY (SWASH) is a non-profit organization. The objectives of the Society are to promote an interest in the salt water fish hobby, to provide much needed encouragement and education in the art of collecting and keeping salt water fishes, to work together and develop techniques of increasing the longevity of salt water fishes through research, to introduce the hobby to the general public, and to provide community service through the application of the hobby.

Membership information and application in center of newsletter.

SWASH meets the second Wednesday of every month (except December) at the Waikiki Aquarium (address above). All visitors are welcome.

All general correspondence and exchanges should be sent to our Waikiki Aquarium address as given above.

Copy for the MARINE AQUARIUM OBSERVER (articles, questions, cartoons, information, etc.) should be sent directly to the Editor to avoid delay. (As should correspondence directed to the Editor.)
~~Address:~~ ~~Nancy Parker~~, ~~P.O. Box 7605~~, ~~Honolulu~~, ~~Hawaii 96821~~

Deadline for short items or ads 3 weeks before the next General Meeting. Deadline for articles 4 weeks before next General Meeting.

Members' personal ads run free of charge in the MAO. Call the Editor directly.

Commercial advertising Rates: $3.00/ ¼ page, $5.00/ ½ page, $10 per whole page--by the month. Advertisers who place ads for 11 months will receive the next month's ad free.

IMPORTANT--PLEASE NOTE THAT ALL COPY SHOULD BE TYPED UP ON OR DESIGNED FOR 8½ x 11 PAGES--these are reduced to the final size by the printer. This includes ads, articles, photos, etc., etc.

MOVING? YOU MUST GIVE US YOUR NEW ADDRESS AHEAD OF TIME. Call the Membership Chairman or drop us a postcard. No notice--no MAO. This is <u>your</u> responsibility.

Articles in the MARINE AQUARIUM OBSERVER may be reprinted in whole or in part (unless otherwise noted) provided proper credit is given to the Author and the Society and one copy is sent to the Society and one copy to the Author in care of the Society. (Lightning may strike you if you do not adhere to these courteseys!)

Views and opinions expressed in the MARINE AQUARIUM OBSERVER are those of the Author and not necessarily those of the Salt Water Aquarium Society of Hawaii. The Editor is the author of all unsigned comments. (The Editor is also typist and proof-reader--mistakes are just to keep you on your toes!)

SUPPORT OUR ADVERTISERS! Buy from them. Tell them you saw their ads in the MAO. Supporting them means more ads and more $$'s for the club.

SUPPORT YOUR CLUB. VOLUNTEER to work on a project, serve on a committee, help collate the MAO, write an article. It doesn't hurt a bit. The club needs everyones support. The club needs you.

# MARINE AQUARIUM OBSERVER

## January 1977

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OFFICERS OF THE SALT WATER AQUARIUM SOCIETY OF HAWAII

| | | |
|---|---|---|
| President | Joe Pickens | 373-4791 |
| Vice-President | Steven Leong | 531-6662 |
| Treasurer | Jim Schlais | 531-7827 |
| Recording Secretary | Dorothy Powell | 732-5896 |
| Board of Directors | Ken Chong | 947-1069 |
| | Rick English | 941-7107 |
| | Tom Nitta | 737-8460 |
| | Dale Varco | 261-3702 |
| Hawaii Council of Diving Clubs Rep. | Jim Watson | 672-9854 |
| Membership Chairman | Marilyn Green | 239-8793 |
| Librarian | --- | |
| Editor | Marion Kim | 941-6275 |

## *Preview .....*

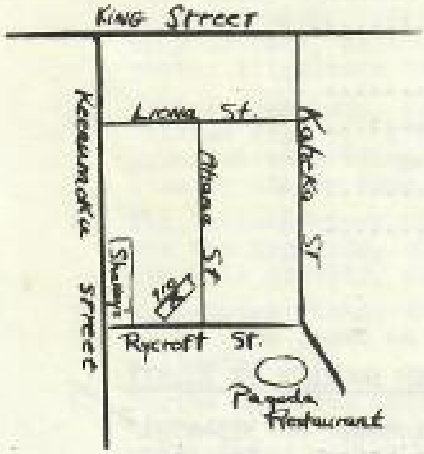
### JANUARY GENERAL MEETING

Wednesday, January 12, 1977 at 7:30 p.m. at the Waikiki Aquarium. Parking in the front of the building or on the street.

Vice-president, Steven Leong, will conduct the meeting, presenting an "Introduction to the Saltwater Aquarium." Bring a friend or if you know of someone contemplating starting a home aquarium, extend an invitation to our January meeting. Here is an excellent opportunity to get first hand information on the beginning of the saltwater hobby and the setting up of tanks from scratch. There will be a question-answer period as well.

Let's begin the new year by starting our meetings promptly at 7:30 p.m.

### JANUARY BOARD MEETING



Thursday, January 20, 1977 at 7:30 p.m. at 910 Ahana St., Apt. 608, at the home of SWASH Editor, Marion Kim. General members invited to attend - call Marion if you plan to attend (941-6275 evenings).

Street parking only and parking is somewhat limited. Park on Rycroft or Ahana St. There is a security locked elevator so phone Marion from the lobby (Number 41 on the board) to enter elevator. Apt. 608 on the 6th floor.

### OPEN HOUSE

If you are interested in holding an "Open House" please contact one of the officers and advise the Editor so an announcement may be made in the newsletter. Designate the day, time (2-3 hrs.) during a week night or weekend when you wish to have your tanks viewed and we shall include a map in order that members may find their way to your place.

# *The President's Message .....*

Here it is another brand new year and we're all set to make it a bigger and better year for the Salt Water Aquarium enthusiast.

Just a few reminders for old and new SWASH members. This is your club and anything you may think of to help make it more successful will not only be seriously considered being integrated into our programs but will be sincerely appreciated.

Don't forget that our board meetings are open to the general membership and everyone is invited to attend. A lot of new ideas come to light here and I'm certain your thoughts will be of help.

Bring a friend or aquaintance to our general meeting; they are potential members. Remember, this club is for more than those with established aquariums; it is also designed to serve those just starting and last but far from least those who are just thinking about starting a saltwater aquarium. It is the latter who should be encouraged and helped most for therein lies the future of SWASH.

Aloha,
Joe Pickens

## *From Your Editor .....*

As your new editor, I am finding this a new experience, for I am neither a marine biologist nor a journalist. What am I doing here, you ask? You might say I am being a martyr. It seems a few people had the confidence in me to ask that I take on this large order of being editor. My negative answers went unheeded and when I learned that SWASH minus one editor would equal no MAO and ultimately no SWASH, I decided to say yes and go full speed ahead. So bear with me for the coming year ...

There are a few things I would like you to think about. Number one is: How can we increase our membership, and more importantly, how to retain our long-time SWASH members who seem to be disappearing from the scene. It was noted at our last Board meeting that we are losing our old members and that includes our more experienced and more knowledgeable members. Are they getting tired? What is the reason for their lack of interest? Perhaps we have nothing to offer them.. whatever the reason, we would like to hear from those long-time members and find out what it is we are lacking. As editor I am concerned with this situation because if my newsletter can do anything to change this situation I shall earnestly try.

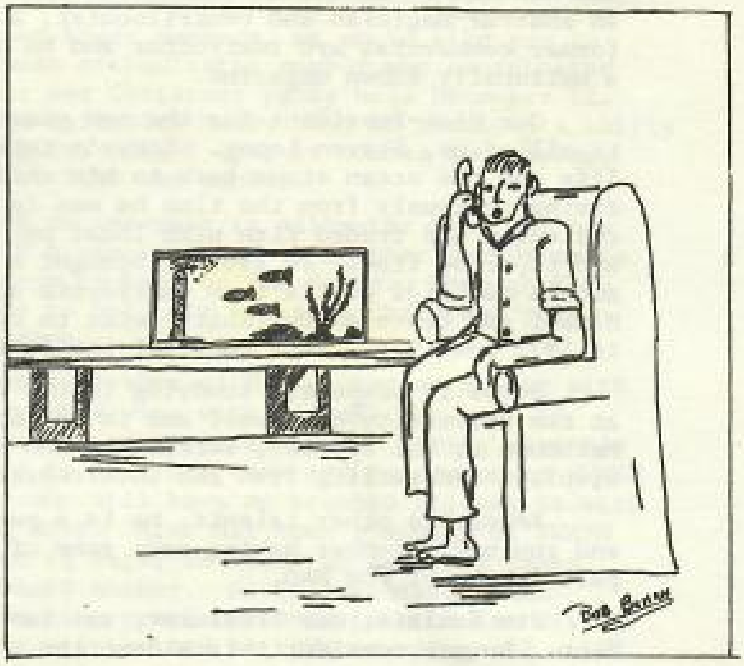
This brings us to number two: What would you like to see in the newsletter? There have been comments about lessening the number of reprints, but where are the original articles to take their place? Here's where you can help. If you have undergone some new experience with your tanks or have some news to share, let us hear about it. Send us whatever news or bits of news you can dig up and we shall try to put these all together and make one column. We used to have a "Problem Corner" in which member Fred Uggla answered the questions sent in by our readers. If you have problems send in your questions and if we have enough to work with, we'll find someone to answer them. If you have artistic inclinations, do send in your cartoons, pictures or illustrations. In any case, let us hear from you.

This is your publication and it is your responsibility as well as mine to keep the newsletter alive and informative. If you dislike a newsletter full of reprints, send in an original article for our next issue. Our treasurer will be only too happy to send you a check in the amount of $5.00 for your contribution. The success of this newsletter will depend on your cooperation .. I cannot do it alone.

It is gratifying to see our newer members with so much enthusiasm. You will see new faces serving on the Board and as officers of SWASH for the coming year. If "new blood" is what we need to keep our club alive, let's go out and recruit more new members.

Words of appreciation are in order .. thanks to Karon Chang, past editor, for her helpful hints in setting up the newsletter and to Marilyn Green for volunteering once again to help with the collating, stamping, stapling and mailing of the MAO. Also, thanks to my ten-year old son, Bobby Bohan, for his illustrations and cartoon in this issue. I'm trying to make this a sort of family project. All in all, I look forward to compiling the newsletter and can really appreciate the efforts put into this work by past editors.

Marion



" ... me, on the Board? Well.. thanks for calling but I'm awfully busy and ... "

## *Your Officers .....*

We have an excellent roster of officers and Board members for the coming year and I would like to introduce them to you.

First, meet our President for 1977, Joe Pickens. Joe is well known to most SWASH members, having been a member for about three years. Last year, he was a member of the Board.

He maintains one 85 gallon tank and three 20 gallon tanks, all housing various saltwater fish. If he holds an "open house" again this year, be sure to see his tanks; you will enjoy your visit.

Besides being a retired First Sargeant of the U.S. Army and presently employed at Postal Instant Press, Joe has many hidden talents. He may never forgive me for letting out these secrets he has kept well hidden for so long, but I would like our members to know what a talented officer we have. Joe is an amateur magician and ventriloquist, a former tatoo artist, former commercial art instructor and he drafted cartoons for a nationally known magazine.

Our Vice-President for the new year is also well known to all of us, Steven Leong. Steve's interests in saltwater life and the ocean stems back to his childhood but he started diving seriously from the time he was in 8th grade, when he collected and traded fish with local pet shops for equipment and imported fish. In 1963 he brought a pair of spotted cardinals and fiji devils from California all the way back to Hawaii and traveled to Tahiti twice to collect tropical fish in 1973 and 1974. Very enterprising fellow we have!

Steve is presently studying in the field of marine zoology at the University of Hawaii and is in partnership with Reginald Matsuura at Kai Systems, setting up and maintaining aquarium displays and selling fish and invertebrates.

Among his other talents, he is a part-time artist/sculptor and you may remember having seen some of his illustrations in past issues of the MAO.

Jim Schlais, our Treasurer, was last year's SWASH President. Do not consider this a demotion.. Jim is also a member with many talents but due to the enlargement of his family (Sandra presented him with a son) and his courses at the University, his time is at a premium. Rather than let Jim disappear from the scene, we elected him Treasurer to keep him close at hand.

The year before last, Jim was our HCDC Rep. and kept us well informed concerning their activities. In addition to his interest in experimental aquariums and tidepools, and the breeding of fish, he has contributed articles to the nationally known Marine Aquarist publication. At the Malacological show held in October 1975, he won the "Best in the Show" trophy for his tidepool setup.

Jim is also artistic and has contributed cartoons and illustrations for past issues of MAO. I hope we can count on him for future issues too.

Dorothy Powell, a newcomer to SWASH, is our new Recording Secretary and comes to us with excellent qualifications, being a secretary in the National Weather Service. Having joined SWASH about a year ago, she maintains two twenty gallon saltwater tanks and a twenty-nine gallon tank. Her interest in this hobby resulted from a course she took at the Waikiki Aquarium and a field trip sponsored by the University of Hawaii.

Among our four new Board members, we would like you to meet Tom Nitta, our most enthusiastic member who coordinated the potluck dinner for our Christmas party held December 12. Tom got started in the saltwater hobby when he received a thirty gallon aquarium as a gift. Right now, it houses two shrimp, an urchin, two squirrel fish and manini.

Ken Chong has had an interest in saltwater fish all his life. He joined SWASH a year ago and is another enthusiastic member whom we are happy to have on the Board. Through Ken, arrangements were made to hold our poolside Christmas party at his apartment building.

Rick English, former member of HCDC, started diving with Tiki Divers and also went diving with friends who were in the import/export business of tropical fish. Having recently moved he was compelled to sell his tank and equipment to SWASH member Odette Winkler who will have no trouble filling it with the ocean at her back door. Rick has been a member of SWASH about seven months and is eager to start up some new tanks and help SWASH as a Board member. He is associated with Franklin Optical Co. making prescriptioned inserts for diving masks. (SWASH members are invited to take advantage of a 10% discount he has to offer.)

Our fourth member is Dale Varco who hails from the L. A. area and began his collecting on the mainland. He used to have five tanks ranging from a twenty gallon to a hundred gallon. Dale enjoys diving and plans to begin collecting fish again. If you need a diving partner, give him a call.

Our Membership Chairman, Marilyn Green, has been a SWASH member of six years and this is her third as membership chairman. When MAO changed over to its present smaller format, she designed the original cover and also drew ads for MAO.

Yours truly, the Editor for the coming year, has been a member of SWASH over two years and became involved in the saltwater hobby as a result of having two young sons who like to snorkel, tidepool and fish. They catch the fish and I am the lucky one to maintain the tanks. I don't know which is more difficult; I tried my hand at catching fish and discovered that isn't easy at all.

Now that you have met our slate of new officers I do hope we can count on you to give them your full support, and help make this a successful year.

HAPPY NEW YEAR!

## CHRISTMAS PARTY .. 1976

Some twenty-one were in attendance at our Christmas party on December 12th. Thanks to Ken Chong who reserved the poolside area on the grounds of his apartment building and to Tom Nitta who coordinated the potluck dinner.

We must have had a hungry crew, for as Joe Pickens described it, "they ate everything but the dish."

Dinner was followed by a grab bag exchange which brought the party to a close with " A Merry Christmas to All and To All A Good Night."

# THE SALT WATER AQUARIUM SOCIETY OF HAWAII
## STATEMENT OF CASH RECEIPTS, DISBURSEMENTS & MEMBERS' EQUITY

January 1, 1976 through December 31, 1976

|  | Receipts | Disbursements | Excess of Receipts over Disbursements |
|---|---|---|---|
| INCOME |  |  |  |
| Membership Dues | $569.03 | --- | $569.03 |
| Newsletter | 16.50 | $346.27 | (329.77) |
| Raffles/Auctions | 195.53 | 4.68 | 190.85 |
| Donations for Waikiki Aquarium Fund | 30.93 |  | 30.93 |
| Advertisements | 5.00 |  | 5.00 |
| From Modern Pet for MAO | 20.00 |  | 20.00 |
| Copper Sulphate Sale | 8.00 | 14.97 | 6.97 |
| Uncashed check redeposited | 3.54 |  | 3.54 |
| Coffee Kitty | 2.35 |  | 2.35 |
| EXPENSES |  |  |  |
| Refunds |  | 14.00 | (14.00) |
| Stationery |  | 201.29 | (201.29) |
| Dues & Subscriptions |  | 21.00 | (21.00) |
| Articles for MAO |  | 15.00 | (15.00) |
| Social Activities |  | 77.51 | (77.51) |
| Gift Certificates |  | 40.00 | (40.00) |
|  | $850.88 | $734.72 | $116.16 |

Members' Equity as of January 1, 1976 $307.84

Members' Equity as of December 31, 1976 represented by: HAWAII NATIONAL BANK CHECKING ACCOUNT $424.00

Marion M. Kim

Marion M. Kim
Treasurer

December 31, 1976

# *Sea Turtles .....*

We were fortunate to have at our November general meeting, George Balazs of the Hawaii Institute of Marine Biology. For those members who missed his lecture and for our mainland and overseas readers, the following is a synopsis of this lecture on sea turtles.

Although our day to day problems are more involved with the maintenance of aquariums in the home, let us not disregard the greater problems of the sea which should be as much our concern and responsibility as it is the marine biologists'.

Marion Kim, Editor

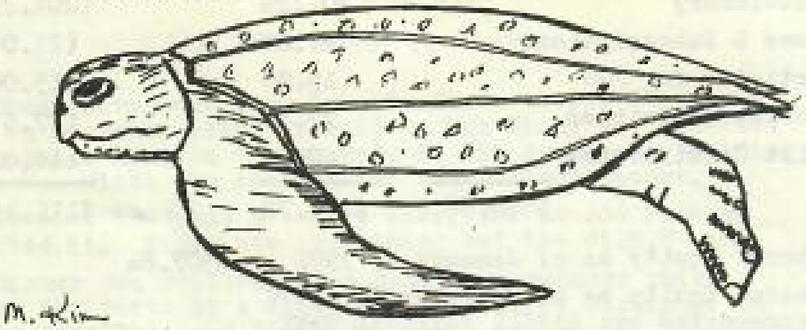
. . . . .

Of the seven species of sea turtles in the world, three of them are found in and around Hawaii. Two are native to Hawaii: the Hawk's-bill and Green turtle. The third, called the Leatherback, belongs to the open ocean but wanders throughout Hawaiian waters.

The Leatherback is the rarest turtle and its name comes from its tough leathery hide. The average leatherback weighs from six to eight hundred pounds and is found in the cold waters near Nova Scotia, but has been known to wander through warmer Southern waters.

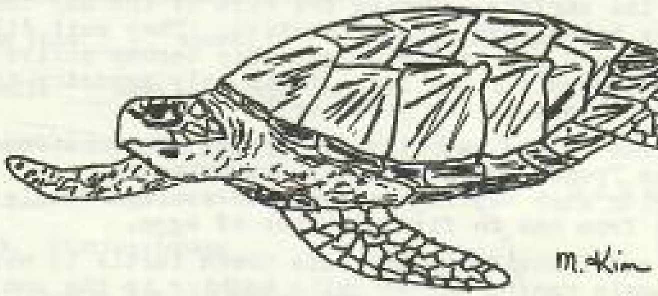
The leatherback has not been kept in captivity successfully as it bangs itself against the sides of the tank, not being used to living in confinement.

Leatherback turtle



The Hawk's-bill turtle appears in Hawaii in small numbers and is so-called because of its birdlike beak which is hooked, much like that of a hawk. The Hawk's-bill is a carnivorous turtle and feeds on marine invertebrates. The carapace of the young Hawk's-bill is covered with horny plates with a dark mottling, overlapping toward the back like shingles, a source of the much-desired tortoise shell. The shingle plated shell disappears as the Hawk's-bill grows older.

Hawk's-bill turtle



The third species is well known to most of us, the Green Sea Turtle and has been kept at the Waikiki Aquarium. Although it is not on the list of endangered species as the Hawk's-bill, it may well be on that list soon. Its cartilage is processed to make turtle soup, regarded as a delicacy and its hide used to make shoes, purses, etc.

Very extensive research has been made on the Green turtle and they have been found nesting in the French Frigate Shoals and from Kure-Midway southeast to the Hawaiian chain. The French Frigate Shoals is sixteen miles of shoal area and green turtles appear all along the small islands northwest of the Hawaiian chain. Of these islands, East Island is the most used. Approximately thirteen acres are used by Green turtles and the turtles share the island with approximately twelve hundred albatross and seals.

The breeding Green sea turtles begin migrating into the shoals around the month of March and copulation continues through July. During mid-May the females come out of the water, onto the sand. She scoops out a body pit, digging out an area about the size of her body and presto! - she has an egg chamber. Using her hind flippers, she is able to dig in 45 minutes to an hour, a large enough place to deposit eggs. Sometimes she will abandon the area and begin digging again in another area.

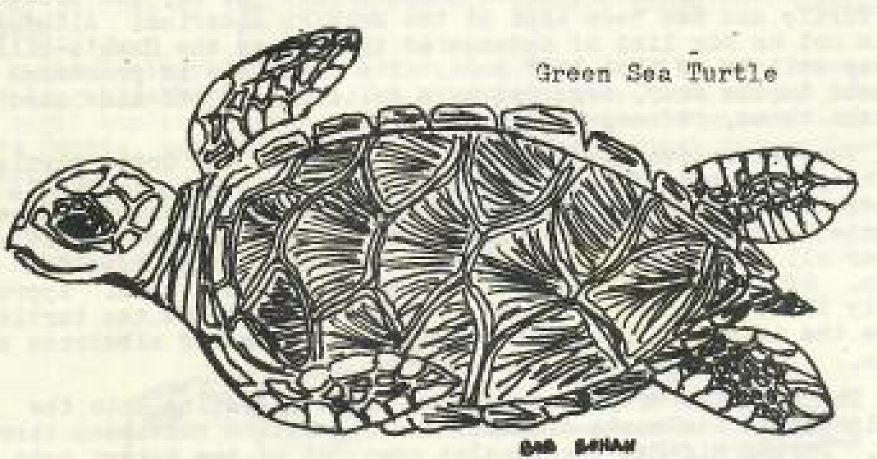
The number of eggs may range from 40 to 148, averaging around 105 in one clutch. The eggs are round and rubbery.

After the clutch is laid, her hind flippers pull the sand over to cover the eggs and she continues to knead the sand over the eggs. During this time, the turtle is immune to disturbance so it is the best time for turtles to be tagged or marked for identification.

After covering the eggs with sand, the female returns to the water. Two to four days later, the hatchlings prepare themselves to come to the surface. With a hundred or more hatchlings it becomes a group effort for them to come twenty-nine inches up to the surface. During the heat of the day the soil is hot and the hatchlings remain inactive. They wait 'til sunset, then between 9 p.m. and midnight they become active and all come up and head for the sea. Their only predator in the French Frigate Shoals is the ghost crab.

In the case of the majority of turtles the same female returns to the French Frigate Shoals approximately every four years and during each nesting season, the average female may have anywhere from one to five clutches of eggs.

Tagging and identifying the male Green turtle is more difficult. The male can be tagged while basking in the sun but this is not recommended as interference with his sleep is traumatic to the male.



Green Sea Turtle

(Editor's note: On the following page is a Sea Turtle Sighting report. If while fishing or on one of your dives you sight turtles, fill in the report and send to George Balazs.)

* * *

## SEA TURTLE SIGHTING REPORT

(Please return to: George H. Balazs;
Hawaii Institute of Marine Biology;
P. O. Box 1346; Kaneohe, HI 96744;
Tel. 247-6631)

Observation made by: ____________________

Address & Tel. No. (optional): ______________________________

Date: ________ Time: ________ Location (indicate on chart): ____________________

Observation made from: _____ shore; _____ boat; or while ____ skin ____ SCUBA diving.

Estimated size (shell length): ________

Turtle seen on: ____ surface; or at depth of approx. ______ ft. Distinguishing characteristics (species I.D. if known, long tail, shell color, tags, injuries, etc.):

______________________________

______________________________

Other comments: ______________________________

______________________________

THANK YOU FOR YOUR COOPERATION

### "THE MARKETPLACE"

This column will be available to members (free of charge) and to non-members (at a small fee of $1.00) who wish to advertise items for sale or items they wish to purchase whether it be an aquarium, piece of equipment, fish or even a non-aquarium item.

Are you moving? Do you have a non-member friend who wishes to purchase a tank or maybe you are searching for a long-desired article? Whatever you wish to sell, buy or just wish to know of its availability, give the editor a call (941-6275- evenings before 9 p.m.) and we shall write your request in this column.

# "REPRINT OF THE MONTH"

The following reprint was taken from Reef Reports, Vol 2, No. 5, a publication of the Mobile Marine Aquarists' Society.

With the availability of banded coral shrimp in our waters and tidepools, perhaps you will be fortunate enough to come up with a pair and the possibility of spawning them. If you are successful, let us hear from you also.

Below are some of George Muscat's observations in the spawning of banded coral shrimp.

## SPAWNING

## STENOPUS HISPIDUS

by
George Muscat

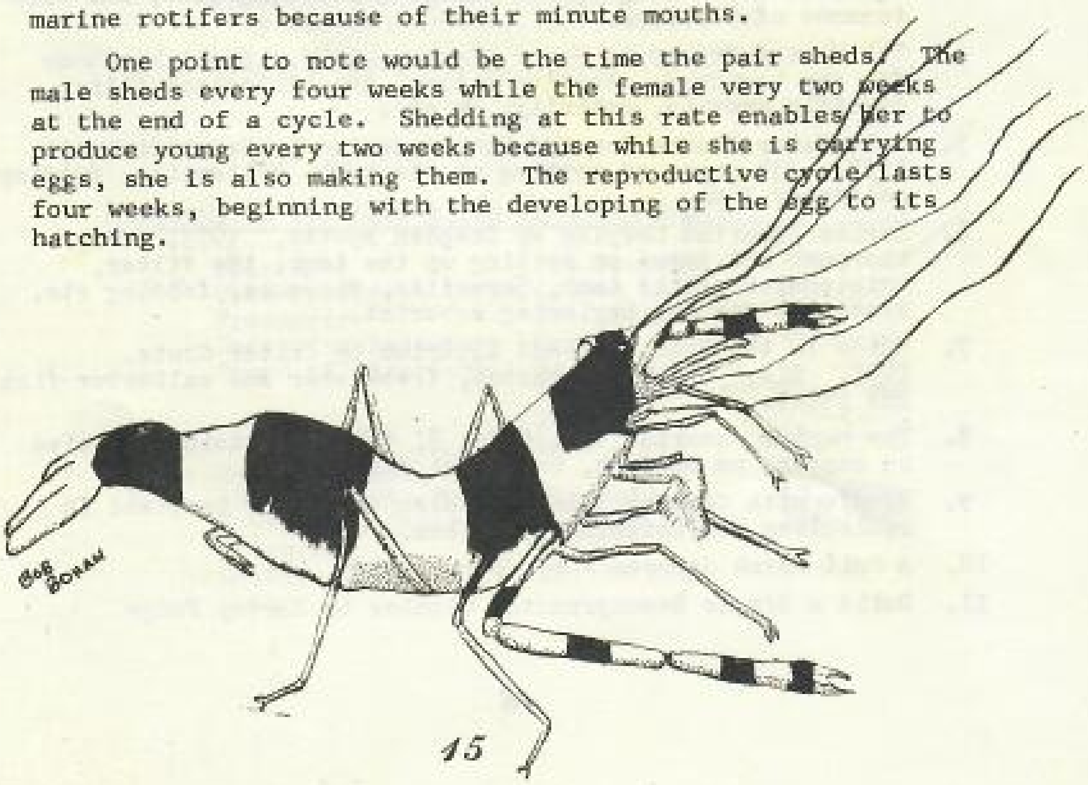
Stenopus hispidus, the red-banded coral shrimp, is a very beautiful and hardy specimen. Unlike many cleaning shrimp, this species is very aggressive and totally intolerant to smaller crustacea and invertebrates. My female has killed three arrow crabs and consumed a living rock. The rock was composed of four or five tube worms, several small crabs, and some clams. The female is the more aggressive of the two, though the male has been seen yanking the features off my feather duster. However, when separated, the male is peaceful.

The tank temperature is 75° - 78° with a salinity of 1.021 and pH of 8.2. The pair should be fed frozen brine shrimp to ensure good development of the eggs. At present, the only external sex characteristic is a heavier lower body in the female. This is due to the cavaties in her swimmerettes.

For a period of exactly fourteen days the female will begin producing and ripening eggs in a region located directly behind her head. The eggs are quite visible thru a clear section in her shell. The eggs first appear yellow in color and as they mature they change to a limegreen color. It is in the last few days of the ripening oyum which stimulates the male. He becomes quite aggressive and protective towards the female. He positions himself near her either in a head-to-tail position in which he is located directly behind her or a face-to-face position often embracing. On the fourteenth day the female sheds.

The male at this time uses his claws to ward off any fish or other organisms which might hurt the female. The pair continually cleans each other, however, in the head-to-tail position, the female gets more attention. The color of the female is now a steel blue with red bands. Within the next six hours the pair will spawn. Spawning is achieved by the female first moving the eggs from her reproductive organs to her cavaties located within the swimmerettes. The male then embraces the female face to face and fertilizes the eggs. Once having spawned, the female will carry the eggs for exactly fourteen more days. She is constantly shuffling and rearranging the eggs by passing water through her swimmerettes to keep the eggs clean. The male does not leave yet. He gathers food for the female until her shell has hardened and her natural color of white and red has returned. In the last five days the developing eggs go through rapid division and growth. This is noted by the color changes in the egg. The eggs once lime-green have now changed to a tan and then a brown color with the developing young being visible. On the fourteenth day, the female takes the eggs a few at a time from her swimmerettes to her mouth. Here she gently hatches the shrimp and spits them into the open. The baby red-banded coral shrimp are one half the size of adult brine shrimp, and white in color. They are not fully developed but do resemble the body shape of their parents. They are free swimming at birth and have a yolk sac which will last for three days. At this time the fry need marine rotifers because of their minute mouths.

One point to note would be the time the pair sheds. The male sheds every four weeks while the female very two weeks at the end of a cycle. Shedding at this rate enables her to produce young every two weeks because while she is carrying eggs, she is also making them. The reproductive cycle lasts four weeks, beginning with the developing of the egg to its hatching.



## SWASH LIBRARY ...

For new members who may not be aware of the few books we have in our library, let me fill you in.

Contact our Librarian (when we appoint one) or Joe Pickens, President, who is presently holding on to the books. Make the arrangements prior to the General Meeting and borrow the book until the next meeting.

If there is enough circulation to warrant the purchase of more books for our library, we shall look into the possibility of buying a book or two each year and increase the number of books available for your reading. If you know of an excellent book for the library pass on the name, author and publisher and we shall look into it.

The following books are for your borrowing:

1. Exotic Marine Fishes by Dr. Herbert R. Axelrod and Dr. Cliff Emmens, 1969. Introduction to setting up a home aquarium, followed by an alphabetical listing, brief descriptions and colored photos of various fish. 596 pages.
2. Salt-Water Aquarium Fish by Dr. Herbert Axelrod and William Vorderwinkler, 1965. Very briefly describes how to set up your tank, saltwater fish and invertebrates, colored photos illustrate the various species throughout the 348 pgs.
3. Marine Aquariums, Principle and Practice by John M. King and William Kelley, 1974. A 25 pg. manual for the beginning aquarist on setting up the tank, introducing fish, and maintenance of the tank.
4. The Marine Primer by Roger Klocek, 1975. Small handbook for the beginner, starting a tank, the biological filter, specific gravity, salinity, Ph etc.
5. Salt-Water Fishes for the Home Aquarium by Helen Simkatis, 1958. 234 pages on setting up the tank, collecting, feeding saltwater fish.
6. Marine Aquarium Keeping by Stephen Spotte, 1973. Very thorough 162 pages on setting up the tank, the filter, maintenance of the tank, parasites, diseases, feeding etc. Excellent for the beginning aquarist.
7. Guide to the John G. Shedd Aquarium by Walter Chute. 1953. Black and white photos, freshwater and saltwater fish 221 pages.
8. The Marine Aquarist Vol. 6 No. 8, 1975. Contains articles on copper, on batfish, on damsel fish.
9. Handle with Care by Deane Gonzalez - what is involved in collecting and shipping specimens.
10. A Salt Marsh Anemone - by John Lindsay
11. Build a Simple Decompression Chamber by Harvey Fudge

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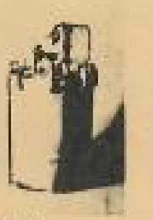

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