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PAPERS AND COMMENTS ON TROPICAL REEF FISH

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WORKING PAPER NO. 34

August 1978

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SEA GRANT COLLEGE PROGRAM

University of Hawaii
Honolulu, Hawaii

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PREFACE

The papers and comments on tropical reef fish included in this working paper are primarily the result of presentations made at the Tropical Reef Fish Conference which was held at the King Kamehameha Hotel, Kailua-Kona, Hawaii, on February 11, 1978. The purpose of the conference, which was coordinated by Peter L. Hendricks, University of Hawaii Sea Grant Marine Advisory Program Agent, was to provide those involved or interested in the tropical reef fish resource in West Hawaii and elsewhere a better understanding of this resource.

The presentations by conference panelists, as well as invited comments or papers on the coral reef system by resource persons are included as part of this publication.

We acknowledge the assistance and cooperation of Kela Holt, Marine Advisory Program Aide, and all the volunteers who helped to organize this conference.

We hope that this working paper will provide some common ground for the multiple users of the tropical reef fish resource to work toward its optimum management.

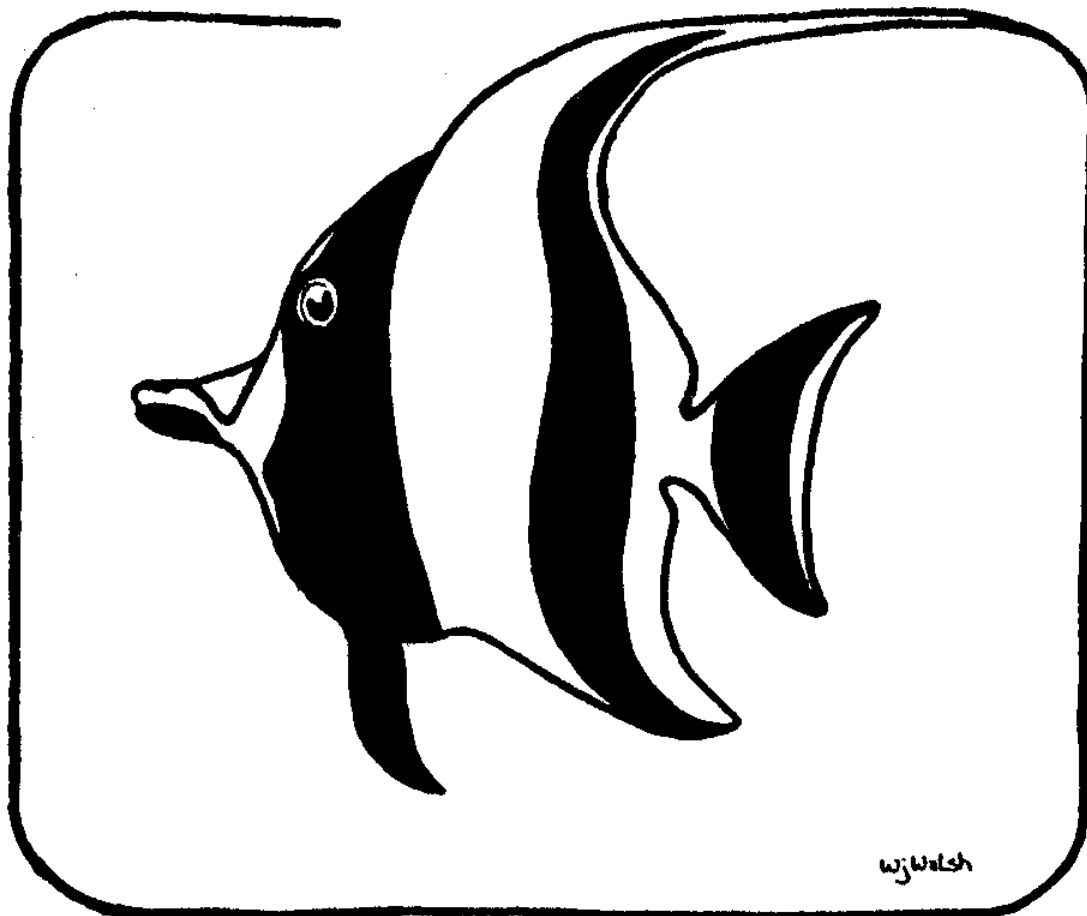


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REEF FISH COLLECTING--ISSUES AND POINTS OF VIEW

TROPICAL REEF FISH MANAGEMENT: ISSUES AND OPTIONS

Leighton R. Taylor
Director, Waikiki Aquarium

I'm very heartened to see so many people here today to discuss and learn about what some of us may consider a problem. Someone mentioned "sides" earlier and I think we are probably all on the same side in that we are interested in the dynamics of our reefs and the impact we as humans have on those reefs. Even while we sit in this room we have a big impact on the reefs out there. We're sitting here shivering in an over air-conditioned room that probably causes some water problems by the outflow from the cooling system. At least 10 of us went to the bathroom during the break and probably caused a significant ecological impact on the reef. So I think we're all on the same side when talking about an impact on the reef, whether it is an impact of a person swimming through the water, a person throwing a net, or a person collecting live aquarium fish.

What I would like to do is discuss briefly the testimony presented to the State Legislature a week or so ago. I took the opportunity to present the testimony because of a piece of legislation, HB 2072, introduced by Charles Toguchi, a representative from Oahu.

It is actually a short-form bill that was introduced to initiate a discussion about aquarium fishes. I want to point out to those of you who may not know that this legislation was introduced, and use the testimony as a spring board to talk about some of the problems that my colleague Ron Nolan and I have seen. It has already been pointed out that the collection of live reef fishes for the aquarium hobbyist constitutes a significant fishery in Hawaii. State licensed collectors, using principally scuba gear and hand nets, reportedly capture more than 85,000 individual fish belonging to 240 species annually.

The Division of Fish and Game panelist showed you that collecting is concentrated on a very small number of species. The wholesale value of the catch has been estimated at \$250,000 a year, which exceeds the wholesale value of mahimahi landed in Honolulu. As you know, most island mahimahi comes from the island of Taiwan and not the island of Hawaii. The majority of the catch is sold commercially to mainland aquarium dealers. In the spring of 1973 there was considerable public concern raised over the increase of aquarium reef fish collecting and the point was raised that such collecting might significantly alter Hawaiian reef communities. At that time, the State Division of Fish and Game temporarily suspended all aquarium fish collecting permits, then instituted increased reporting requirements. At a number of public hearings about reef collecting in those days some people were saying "You're over-collecting the reefs", and the collectors were saying "No, we're not", and some people in the middle were saying "Who knows?"

There were really no complete records until 1973 when Fish and Game instituted the catch report with which collectors are now only too familiar.

Coincident with these increased requirements, the University of Hawaii Sea Grant College Program responded to public concern by funding a two-year study (1974-76), conducted by myself and Dr. Nolan. The study was aimed toward analyzing the first 2 years to test data and to study the possible impact of reef fish collecting on reef communities. The Division of Fish and Game was very cooperative in presenting collection data for our study. The general conclusion of our study for five selected species (including some of the top 10 species) was that, at the collecting levels during the time of our study, in the Kona area and the North Kohala area, little impact was being made on Hawaii's reefs as a result of aquarium fish collecting.

Now there is renewed concern about tropical reef fish collecting, particularly in the Kona area. One thing that was not specifically pointed out in the Division of Fish and Game information was that, in 1973, about 12 percent of the state catch came from Kona. It was noted that currently about 25 percent comes from Kona, so there is obviously an increase in the catch from this area and in the effort in the Kona area.

I mentioned in my testimony to the State Legislature that this meeting would be held on February 11th and that a number of suggestions would probably come out of this meeting. I urge all of you, if you're interested, to make your feelings known to the House of Representatives, through Representative Toguchi's office.

Many studies of reef fishes indicate that it is extremely unlikely that a fishing activity at the level of fish collecting in 1973 and 1975 has deleterious, long-term effects on the fish species themselves. Overfishing of the resource by aquarium fish collectors will not result in the extinction of any Hawaiian species, but it does have some impact on the reef by reducing numbers of showy fishes in areas in which snorklers, divers, and underwater photographers may wish to see these animals.

I'd like to point out that terrestrial animals, like mammals, seals for example, are much more subject to extinction than marine fishes. The ability of reef fishes to reproduce themselves is exciting in its magnitude and it's really a housing shortage that limits the number of fishes on the reef rather than their ability to reproduce. Such activities as silt runoff and destruction of reefs by human disturbance increase the housing shortage and have much greater impact on the reef community than the collection of the adult animals themselves.

The management of any resource, such as reef fishes, is based on some predetermined objective. In the case of the ancient Hawaiians, their predetermined objective was to manage the resource to insure nutrition for their people. That's why they were actually forced into such rigid cultural restrictions as the kapu system. I often think that, if some local fishermen were put in a time machine and sent back into those ancient days with some of the gill nets they use today, they would be strangled by the kono-hikis. Other predetermined objectives are the harvesting of the resource

for food or other commercial use. Or, the predetermined objective may be leaving that particular reef community in a natural state so that it can be observed by snorklers, underwater photographers, etc. At the present time reef fish collecting at the levels we looked at during 1974 through 1976 seems, to me, to be properly managed. But, if the objective is to allow assemblages of reef organisms in a natural, non-harvested level, it's clear that reef fish collecting is having an impact. There does seem to be a conflict of objectives in some cases. One way to solve this conflict would be to exclude certain areas from any harvesting. This is already happening. The Division of Fish and Game, for example, has set aside Hanauma Bay on Oahu and Kealakekua Bay on the Big Island, and in the last couple of years they've been adding increasing numbers of sanctuary areas. They have a long list of areas that have been suggested to be set aside. The regulations for creating these sanctuary areas exist. It's my personal opinion that there must be strong public pressure in order for these sanctuaries to be set aside, however. It seems to me that the conflict of objectives can be avoided if every area's objectives were determined individually or according to what kind of management is needed.

There are, in many states, native American rights to certain fishing areas. That is not the case in Hawaii, but it could be, and perhaps should be. I would also like to suggest that in considering management of resources in Hawaii we're taking a shortsighted view by only considering the harvesting of reef fishes for aquarium purposes. There is some evidence that gill net fishing has considerable effect on the number and kinds of reef fishes and other organisms in certain parts of an area. If one compares the regulations imposed upon aquarium fish collectors with those imposed on non-commercial and commercial gill netters, you can see that the aquarium fishery is much more highly regulated than the gill net fishery. For example, a non-commercial fish collector, even a third grader with a red net, theoretically, has to register with Fish and Game to collect fishes. He has to report his catch on a monthly basis. A non-commercial gill net fisherman, on the other hand, does not require any sort of permit from the Division of Fish and Game and does not have to report the catch. In other words, we have one fishery, the aquarium fishery, whose impact can be analyzed and we have another fishery, the gill net fishery, from which we have no data, but which has, perhaps, a much greater impact on reef communities.

I would suggest that if increased management regulations are going to be considered for the aquarium fishery, we should certainly also look at other fisheries such as gill netting, rather than selecting only one fishery. I would also like to repeat that management of resources requires reliable test data and the timely analysis of such data. The Division of Fish and Game, at the present time does not have the staff nor the funds to analyze the aquarium fish data. In the 1974 through 1976 study, Sea Grant did provide money to analyze the catch statistics which were required by Dr. Nolan and myself. Thus, a computer program does exist. It's a simple matter once you have the money to pay someone to keypunch the cards. We could analyze the last 3 years of data relatively rapidly, but the Division of Fish and Game does not have the resource to do that. I would suggest that one need is money to pay for a keypuncher and computer rental.

MARINE PRESERVES--AN ANSWER

Dr. John E. Randall
Ichthyologist, Bishop Museum

Note: Dr. John E. Randall was unable to attend the Tropical Reef Fish Conference, but was asked to provide comments pertinent to the meeting. Dr. Randall is an authority on Pacific fishes.

Apparently there are some who feel that aquarium fish collecting in Hawaii should be banned. I don't agree with this view. But before I present my opinion let me say that I am very much a conservationist. I have served as a member of the Marine Steering Committee of the International Union for the Conservation of Nature and I am the marine fish specialist of the Survival Service Commission of the same organization.

Most of the fishes caught by commercial aquarium fish collectors are very common species, such as the yellow tang, long-nosed butterflyfish, and Potter's angelfish. As the research of Leighton Taylor and Ron Nolan has shown, the recruitment of these species is high. Furthermore, if an area is depleted, it is soon repopulated from the fish stocks of adjacent areas. The populations of these fishes are enormous, and the catch of the collectors is insignificant if we consider the populations as a whole, and not as an isolated sector. I just wish these fishes were important food fishes for man because of the great potential they represent.

It isn't fair to ask for a cessation of aquarium fish collecting while commercial fishing is permitted. The collector has just as much right to keep his job as the commercial fisherman. I believe commercial fishing has a more significant effect on the reef community than aquarium fish collecting. The concentration of effort to catch the larger fishes creates an imbalance in the community. More important is the destructive effect of some of the fishing techniques, particularly gillnetting and spearfishing (and all too often illegal procedures such as the use of small mesh nets and poisons).

I will admit that it is natural to be upset if you visit your favorite diving place after a professional fish collector has been at work and find some of the fishes you had observed on a previous visit missing. If you note damage to the corals as well, you become even angrier. I realize that some collectors break coral in their effort to catch fishes, but I'm sure they represent a small minority. Most learn that less shelter for fishes means fewer fishes the next time.

The answer for both sides--those who want to stop commercial aquarium fish collecting and those who wish to continue it--is the development of more marine preserves in Hawaii. Those favorite diving places should be set aside as complete sanctuaries where no manner of fishing, shelling, or coral collecting is allowed. The state of Hawaii has lagged behind most other maritime states in creating marine parks. This is difficult to understand in view of how superior Hawaii is to other states in the recreational potential of its marine environment, and especially difficult to comprehend when

we can see how successful our few marine parks are. I remember what Hanauma Bay was like before it became a preserve. Now it is a delight to go there and have the fishes crowd you, unafraid; and to witness the recovery of the corals.

Resistance to the establishment of marine preserves often comes from local fishermen who resent having areas closed for fishing. It is important to emphasize the role that such preserves play in maintaining breeding populations of commercial fishes which can "seed" adjacent areas subject to fishing pressure. Setting aside only 1 or 2 percent of a coastline, particularly if the selection is well made in terms of habitat, etc., would undoubtedly enhance the overall fishing of an island.

So my message to those who want to stop aquarium fish collecting is, direct your time and energy to the creation of more marine parks for the state of Hawaii instead.

AQUARIUM REEF FISH COLLECTING: PROMISE OR PROBLEM?

William J. Walsh
Reef Fish Research Foundation

The collecting of reef fishes and invertebrates for the commercial aquarium market is an activity which is increasing yearly in economic importance. The Department of Land and Natural Resources has estimated that wholesale revenues from the exportation of marine tropicals is at least \$250,000. This estimate must be considered a minimum figure as there presently is no way of verifying the accuracy of catch statistics submitted by the collectors to the department's Division of Fish and Game. With a substantial growth rate of up to 12 percent annually anticipated, this industry has the potential of becoming a significant economic factor in Hawaii. Likewise, it also has the potential of seriously affecting already threatened reef ecosystems.

Collecting in Hawaii is generally done with scuba, utilizing underwater barrier nets and small hand-held nets. The barrier nets of up to 100 ft in length are stretched out along the bottom and the reef fishes are herded into the net where they are trapped and captured by the divers with smaller hand nets. The fishes are then placed in underwater containers and eventually brought to the surface support boat. Fishes which are captured in this manner are generally those which flee rather than hide when danger threatens. Many of the butterflyfishes, surgeonfishes and wrasses which roam the reefs are caught in this way. Other fishes such as the triggerfishes and damsels, which retreat to cover when threatened, require other collecting techniques. With these, the collector must either flush out his quarry or reduce its cover until it is exposed and vulnerable to capture. This is a much more burdensome and time-consuming process and, by far, the largest number of fishes collected are those which can be herded into the barrier net. Hawaii, unlike many other tropical areas, prohibits the use of chemicals and explosives in the capture of marine animals.

Concern over the effect of collecting on the reef fish populations has been expressed for the past several years. This concern is justified, particularly in view of the laissez-faire attitude which the state has accorded this industry and other exploitative endeavors. At present there are few regulations controlling the numbers, size, or species which can be collected. Only freshwater species and the young of four foodfishes are kapu. They are the hahalalu (opelu or mackerel), o'ama (weke or goatfish), moi li'i (moi or threadfin), and hinana (o'opu or gobi). Except for possibly the o'ama, all of these species represent fishes which would otherwise not be sought by collectors. Collecting can be done by any number of persons in any area of the state, excepting marine conservation districts and certain other locations such as Hilo and Honolulu Harbors where collecting activity could possibly interfere with other commercial activities. All that is required of a would-be collector is that he obtain a permit from the Division of Fish and Game for the use of a fine meshed net and have some sort of facility to keep the fish alive and in "reasonable health." Permits are essentially issued to anyone who applies. Although submittal of monthly catch reports are required by the collectors, there is no way to ensure that these reports are accurate and reflective of collecting. Clearly, this state of affairs leaves the inshore marine areas open to both

willful abuse and exploitative ignorance, both of which could have serious deleterious consequences.

When the question of the depletion of reef fish populations by aquarium collectors was raised several years ago, the state took the stand that there was little hard evidence to support the contention that reef fish collecting was having a serious effect on reef communities. To help provide some answers, the University of Hawaii Sea Grant College Program funded a study to assess the impact of aquarium fish collecting on selected reef fish populations. The study was directed by Dr. Leighton Taylor, then with the Hawaii Cooperative Fishery Research Unit of the US Fish and Wildlife Service, and now director of the Waikiki Aquarium. The study, entitled "Reef Fish Populations of Hawaii and Their Commercial Exploitation," is in its final stages and will be released shortly. According to Dr. Taylor, the main finding of the study is that, "at current collecting levels, by responsible collectors, there is probably no threat to the most popular species taken by commercial collectors." It must be emphasized, however, that the study was limited to only the five most heavily collected species and Dr. Taylor's statement is predicated upon current collecting levels by responsible collectors. As the industry grows, it can be expected that the former will increase while the latter declines.

Once again public awareness over the possible harmful effects of aquarium fish collecting is increasing, at least on the Big Island, where collecting is becoming more and more widespread. Many longtime residents are convinced that aquarium collecting has had a pronounced effect on fish populations. Emotion over this issue is intense, with the anti-collectors strongly critical of the "reef rapers," referring to the collectors. Even former fish collectors are among those who are calling for some sort of action by the state to control this industry. Legal action to bring about a moratorium on all collecting activities is presently being considered by a group of Kona residents. The collectors themselves feel wrongly accused and, as a result of community criticism, have become secretive and defensive. Clearly, the time has come for the state to act upon this issue.

Is there, in fact, any hard evidence to support the contention that reef fish collection is causing substantial damage to reef communities? As Dr. Taylor's study is the first to be designed to specifically explore this question, we cannot rely solely on previous scientific work to provide the answer. There is a large number of unpublished personal observations on changes in reef fish populations, however. Many of the people reporting these changes--divers, fishermen, and tour boat operators--are intimately involved with the marine environment and quite a number have been residents of a particular area for quite some time. Almost without exception, they have noted significant declines in a variety of species. Most often, these species are fishes which are consumed as food, although there are several reports of declines in aquarium-type fishes. These observations cannot be dismissed lightly and no doubt do indeed reflect some real changes in community populations. Whether or not these changes were brought about or aggravated by aquarium collecting is problematical. More changes to the inshore environment have been brought about during the past 100 years than the thousands of years preceeding it. Increasing population, pollution, development, and exploitation have all had a detrimental

effect on the reef communities. In addition, natural changes in the abundance of various species is recognized by some ecologists as an integral part of the dynamics of the coral reefs. It is difficult, therefore, to single out aquarium collecting as being primarily responsible for the observed decline of various species. This is not to say that collecting has had no negative ecological effects, but rather that it is extremely difficult to document such effects and to accurately assign blame.

It is important to recognize that, as in any exploitative endeavor, the potential to cause serious damage to the resource being harvested always exists. It is the responsibility of those assigned with control over these resources to construct management programs and enforceable regulations to protect and conserve these resources, not only for the benefit of the exploiters, but for the public as a whole. In the case of inshore marine areas, the Department of Land and Natural Resources has been sorely negligent. It is not a justifiable excuse to refrain from action totally on the basis of incomplete information, especially when an activity, such as collecting, has the potential to cause serious depletions of an important resource. In instances like this it would appear to be sound policy to initially institute conservative measures while additional information is being gathered, rather than allowing almost totally unregulated activity with the possibility of serious ecological damage. To the consternation of many concerned citizens, the DLNR has chosen the second tactic.

Dr. Taylor's study must be regarded as only an initial step in answering some of the questions surrounding fish collecting. Aside from the physical difficulty of gathering data on reef fish populations, limitations in technique and scope make it necessary, indeed imperative, that further studies be conducted. Furthermore, it would be a serious dereliction to make a general statement regarding the effects of collection on the 250-odd species being collected on the basis of data concerned with only five or so of those species. This would be akin to trying to draw up a management plan for the birds of Hawaii solely on the basis of a study on house sparrows.

Unlike the temperate areas of the world where each fish species is generally represented by large numbers of individuals, the reefs have comparatively few members of each species. This is not to say that certain species are not abundant, but rather that there are relatively few of these and considerably more of those which are much reduced in numbers. Even the abundant reef species are generally low in numbers when compared with many of the species in more temperate areas. The relative scarcity of many reef species makes them particularly vulnerable to the effects of intensive collecting. Although 65 percent of the annual aquarium catch is composed of 10 relatively common species, the other 35 percent includes a number of species that could be classified as scarce or even rare. It is doubtful that, at present or even moderately increased levels of collecting, a serious depletion of these more common species would occur. The yellow tang (lau'i-pala) has been among the most heavily collected species for a number of years and, at present, constitutes approximately 18 percent of the total catch. Yet the numbers on the reef do not appear to have declined. In fact, there is some evidence that their numbers have increased in recent years, probably due to a natural fluctuation in population size. With these relatively abundant species, aquarium collecting can probably be

regarded in the same light as other commercial fishing activities and regulated accordingly.

This may not be the case, however, with other less common species. Although it would be difficult at present to state conclusively whether any Hawaiian reef species is an endangered species, it could be anticipated that collecting of a scarce or rare animal may have serious consequences for the well being of that species. There are a number of fish species presently being collected which fall into this category, such as the longnosed hawkfish and Tinker's butterflyfish. Continued collecting of these and other similar species could have profound consequences, perhaps even leading to local extinctions. The fact that rare species often command relatively high market prices make them an especially attractive target for collectors and further increases the threat to them. A counter argument to this line of reasoning is that, although several species appear to be rare in relatively shallow water (down to 150 ft), they may well be more common in deeper waters. Hence, collecting would not truly affect the species as a whole. The limited evidence, concerning deep water habitats which has been gathered so far, indicates that, while some species may be more common in deeper waters, others appear to have relatively restricted depth ranges. Tinker's butterflyfish, found only in Hawaii, is an example of a rare species which appears to occupy a relatively narrow depth range. With continued collection of this species, it is not improbable that virtual elimination of the species could occur. Collection of uncommon species which also inhabit deeper waters may not be harmful to the species. In this case, fishes which were once present in shallow waters are heavily collected until the only representatives of the species are found below diving depths. To the large and ever-increasing number of diving residents and tourists whose contribution to the economy of the state far surpasses that of the fish collecting industry, this would be a most unfortunate and unnecessary occurrence. To them, the reef environment would have been degraded just as surely as if the species had in actuality become extinct. For a state which depends so heavily upon the beauty of its natural resources to attract tourists, this development could have serious economic consequences.

It is not only with the uncommon or rare species that collecting could cause problems. Many fishes on the reefs hide in holes or crevices among the coral when threatened. In order for a collector to capture it he must either chase it out of its hole or destroy its shelter. Needless to say, this destruction of the reef habitat can undo in minutes what has taken nature years to build. The consequences of this sort of destructive activity can only be negative. Likewise, the collection of fishes which are strongly territorial and thus restricted in mobility could markedly reduce population numbers in areas which are heavily collected. This may not affect the species as a whole, but it most certainly would alter the community structure in localized areas, perhaps to the detriment of the entire community. This effect may be exaggerated if collectors remove certain species such as the cleaner wrasse. Concentration of collecting efforts in a relatively small number of localities by an ever-increasing number of collectors can similarly bring about severe ecological disruptions in these areas. For this reason, it is imperative that some sort of control be established over the number of collectors allowed

in an area and over the numbers and types of fishes they are collecting. Perhaps a lottery system or the issuance of permits on a first-come, first-serve basis would be an equitable way to apportion permits. Additionally, the state should look into the feasibility of closing heavily collected areas periodically in order to permit revitalization of collected stocks.

As previously mentioned there may be vast differences in the effects of collecting on the various species being sought. For this reason it is unrealistic to treat aquarium fish collection in broad general terms; individual species must be considered and afforded suitable protection. In some instances it may be warranted that certain species should not be collected under any circumstances by commercial operators. Collecting techniques should likewise be reviewed with the aim of eliminating those practices which could prove harmful to the reef habitat. A prohibition on destructive fish collecting techniques could achieve this goal. The state must abandon its policy of benign neglect toward its marine resources and begin to actively engage in meaningful research and enforcement. With regard to fish collecting, it would appear logical to institute a moratorium on the issuance of additional collecting permits until such time when a comprehensive management program can be implemented.

The primary aim of this article has been to point out some of the problems surrounding the tropical fish collecting industry as it relates to the ecology of Hawaii's reefs. Additionally, this article points out that potentially destructive practices are being allowed to continue--without proper review or concern by the state. Although aquarium fish collecting does pose a threat to certain selected species and localities and is in need of more rigorous control, it should not be made out to be an ecological "boogey man." There are many other activities presently being conducted which are no doubt causing as much, if not more, environmental harm as fish collecting. Gill netting, coral and shell collecting, and scuba-assisted spear fishing are among these activities, not to mention the notorious unenforcement of existing Fish and Game regulations. This article has focused only on one single area.

COMMERCIAL FISH COLLECTING

Geoffrey Daigle
Pacific Tropical Fish, Inc.

I'd like to give you an idea of why we began organizing this meeting some months ago. What we thought was that, in the West Hawaii area, there is a need for a lot more information to be readily available on the industry of tropical fish collecting. I think that anyone who works around the water, or who has seen skiffs coming in with buckets of fish, has wondered a little bit about what goes on before and after and perhaps during the diving, and exactly what takes place in the industry today. There's a lot of people here on the panel that have a great deal more information from a scientific standpoint than I can provide to you. But what I hope to do this morning is just to give you a little more insight into the way in which the industry itself works, at least here in Kona. And even though some of the things that I'll be suggesting are generalities--and techniques do vary between the individual stations and the individual collectors--what I hope to provide you with is something of a gross overview of the different types of collecting, and the holding and shipping methods that are used in this area.

As far as diving is concerned, most of the people that are diving around the coastline here work off of fairly small boats. The Boston Whaler is a fairly common boat used for collecting. We don't go quite as far out as the commercial fishermen do; we stay relatively close to shore --within 10 to 15 miles of town.

One very important factor is that the divers have a good collecting area and are able to get back to shore rather rapidly. We are mainly concerned about the care of the fish. That's how we make our living, by taking extremely good care of them. Therefore, we like to get them back to shore into some sort of holding facility as rapidly as possible. The small size and easy maneuverability of the boat make this possible.

The divers most often work in the 20 to 50-ft depth range. Contrary to popular belief, we don't usually use extremes--I can't think of a single extreme that we might use except an awful lot of hard work. We don't lay 500-ft seine nets and drag up the whole bottom. The collecting technique most used in Kona involves two divers usually working individually off their small boat in the same general area. The barrier net, or fence net, is the primary tool. It stands about 3 ft high, has floats across the top and lead weights along the bottom, and is a small-mesh, monofilament net, which does not damage the fish. A couple of hand nets made of the same kind of monofilament, which you have to change from time to time as it gets a little rough, are essential. The fish are stored underwater in small holding buckets which accommodate between four and eight fish each.

The length of the nets that we use varies, depending on the type of fish we're going for. The largest that I've ever used is about 50 ft in length. When stretched out underwater, it reduces down to about 30 to 35 ft of working length. Remember, the net and all of this equipment has to be carried by the diver.

You can't take a tremendous amount of gear with you, as you have to be very streamlined. You just take a minimum amount of equipment; basically just the fence net which I usually wrap up underneath my arm, two holding buckets--some people use larger buckets, which make it hard to swim underwater--and the hand nets.

To give you an appreciation of the way in which the collecting is usually done, (1) you bail out of the boat with your net tucked under your arm, (2) your two buckets in hand, and (3) your two hand nets in hand. Somewhere, if you can wiggle free two fingers to use to equalize the pressure in your ears on the way down, you're lucky. Your hands are pretty well tied up and it is cumbersome carrying this amount of gear around.

Diving often takes place in the 30 to 40 ft depth range where I like to work most of the time so I don't end up in decompression trouble. The normal procedure, if you find an area where there are some fish that you'd like to catch, is to set your net on the deep side of the fish, as they like to go downhill. You set what is for all intents and purposes a crescent shape to your net, which you feed along the bottom, making sure it covers the bottom fairly well so they can't duck underneath it. You then drop your buckets, and, with your hand nets, swim toward the shallows, and work on down toward the net.

Again, there are some misconceptions here. For the most part, you're not catching any more than one, maybe two fishes at a time per run. At least, that's the way that most of the collectors that I know in Kona work. You pick out an individual fish, say a long-nosed butterflyfish that looks to be about the right size--you don't want a very large fish as they tend not to adapt as well to tank life, so you take a reasonable medium-sized fish and you work on it, one on one. It can duck into rocks, or coral crevices or it can outrun you. There's an awful lot a fish can do to make you look really foolish. And when you're swimming with hand nets in the water it's like dragging a parachute with you. More often than not, it seems as though some of the faster species are looking over their shoulder and laughing at you as they swim away.

Sometimes fish like the pebbled butterfly who travel two at a time can be caught in pairs. You must be careful and move very, very slowly while "finessing" the fish on down toward the net. This is a kind of tracking procedure--you don't want to move them too fast or they'll duck into the coral or just spook out of the area, so you just move along very slowly, trying not to blow too many bubbles. With the edge of your net, tap along the coral to keep them moving toward the barrier net. Hopefully, if they're not too quick, they're going to bounce off the net and you should be able to scoop them up gently with your hand net. Or, they can duck into the coral and you'll never see them again.

It's a matter of training. A lot of people who have tried fish collecting just weren't able to make a living of it and have use to find other occupations. It's quite an art form, I think, but I'm very biased.

The fish are brought up in holding buckets and are put on a decompression line, something that the really good fish collectors have known

about for some time. Fish all have swim bladders unless they're bottom fish, like the hawkfish. The butterflyfishes and many others have swim bladders, and, therefore, you have to bring them up very, very slowly. When you've finished collecting, leave the fish on the decompression line at 20 to 30 ft, depending on the depth at which you first caught them, and bring them up about 10 ft every 30 or 40 minutes, so that by the time they reach your holding buckets on the surface they have had time to acclimate to the lower pressure. They can then be immediately transported back to the shop with no trouble.

If a fish shows any signs of distress, especially some of the deeper water fish that have some problems with decompression, it is either taken down manually, or, if it is able to swim on its own, it is released. There's no sense in bringing a fish back to the shop to put him in 3-ft deep water if he's having trouble in 10 ft of water. By releasing it, at least it'll be around to spawn more fish.

On the way back to the shop you should expect no mortality at all. The fish should absolutely not die by the time you get back to the shop. Usually it's just a matter of half an hour or an hour, and most often the collectors will have the buckets aerated and the water changed if necessary. Some boats have large holding capacities on board and are able to transport the fish in really excellent shape.

The main thing is to get the fish to a controlled environment right away. We take special care in the distribution of the fish throughout the shop and try to match them up in size and compatibility with other species as we put them in different tanks.

These tanks are all about 100 gallons or so in size, and altogether we have a few thousand gallons of holding capacity, as most of the shops in town do. The fish are tank-acclimated for anywhere from 2 to 5 days so that by the time we ship them, we are sure that they are capable of surviving in a tank on the other end. If at any time we feel that a fish really wasn't doing well in the shop, and this is the exception rather than the rule, we would treat them as we are best able to through the aid of such procedures as the Waikiki Aquarium has set down, and then we would release the fish in the best shape possible.

Of course, after all this trouble we'd like to make sure that they're going to do well and, for the most part, we're able to keep them in excellent shape.

The main thing that we watch while we're holding the fish is the water quality. By that I mean (1) we make sure that the fish are not crowded, (2) we give them sufficient aeration, and (3) we monitor the salinity and the pH of the water. These are all very important factors that have to be watched on a day to day basis. The temperature must be very carefully monitored and we always keep an eye on nitrates and ammonia. Once you have an established system it's usually easier, but if you're just getting set up, especially with small tanks, these things have to be watched pretty carefully. We're fortunate in that we have a system.

We have adequate filtration, as do the other shops in town. You can have the finest system in the world, or you can have a thousand gallons worth of 15-gallon tanks and have a tremendous inventory of fish, but it doesn't make a bit of difference if you don't have someone that really knows how to take care of the fish in the shop. The people must know what they're doing and take the time to watch and care for the fish. The personnel is all-important.

Moving on to shipping, the most important step. Everything else doesn't mean a thing if you can't ship the fish in good shape to the mainland. The fish, by the way, unlike some freshwater fish, are packed individually. Each fish gets its own bag, a double polyethylene bag (the type used in food storage), with a protective liner in between. After the fish is put into the bag, the air is pushed out and the bag is filled with pure oxygen. The water in the bag is filtered and pH, salinity, and temperature are checked so that they all match that of the tanks. The boxes used come in a couple of different styles and are marked "Live fish. Keep warm." We recently changed that label to "Live fish. Keep 70°," so someone doesn't put them out in the hot sun.

We try to take as much care as we can to make sure the fish are going to be in good condition on the other end. Most of the fish are going to arrive on the mainland in 16 hours maximum. Sometimes they get there in 8 to 12 hours. We've had fish that have been shipped to Europe from the mainland in the original bags and have reached there in about 26 hours in fine shape.

We have determined that the maximum time that should be allowed for a fish to arrive in really pristine shape is about 40 hours. We feel comfortable in shipping fish up to about 24 hours, but we'd sooner not send them beyond that time. To the mainland, 8, 10, to 12 hours is perfectly okay; the fish do very well.

We do guarantee live arrival on the other end. We don't send massive amounts of fish and hope that, by volume alone, some will arrive in good shape. For the most part we've been doing pretty well this year. Live arrival is about 98 to 99 percent. I think most of the shops in town have about the same average. The one or two percent that you do lose is probably the result of mishandling. I don't want to cast aspersions on the airlines, but in freight, the boxes do get bounced around. If you've got a fish that's got a heart condition, it might kick off and be the one in a hundred that will. We do have perfect shipments, although there are some shipments which lose three, four, or five percent--if they're left out in the cold in New York, for example. Mishandling by the airlines, I would say, is probable. We try to help the airlines as much as we can to avoid this type of problem.

To reemphasize what I've said, we do try to take extremely good care of the fish. We go through a lot of trouble to ship them in good shape because our livelihood is based upon it. We wouldn't be in business now, nor would anyone else in town, if we did not ship good quality fish. They have to be good to help the people on the other end. Otherwise you're just wasting your time.

The type of collecting of the reef that we do is designed to maintain a sustained yield type of harvesting. I intend on being here for a number of years and work in the same diving areas for a long, long time. Therefore, there are certain things I know that I'll have to do. For one, I have to rotate my areas of collecting. There are certain areas, of course, in which we don't collect--Kailua Bay, Kealakekua Bay--and we stay away from places where people like Bean's Cruises and Pacific Sail and Snorkel make their living. That's certainly reasonable.

We rotate our areas so that we're not diving in one area more than once every 2 months or so. We usually move about 50 yards away to a new area, giving us quite a bit of room along the coastline to collect. We try to protect the breeding population of the larger fish in the shallower water. By that I mean we're not taking large species. We're leaving them, hopefully to propagate the species and to keep things going. In any way we can we're trying to protect the reef as this is the mainstay of our business. This is where we make our living.

The only concluding thing that I would like to say is that, probably more than any other group in town, people in the fish collecting industry are concerned about the reef. As I mentioned, it's our primary source of living. If there is trouble on the reef, we're going to have trouble; if the reef is depleted, then we're going to go out of business.

We've got to make sure that the reef stays in the best possible shape. What we would like to do is to urge the community to help us if they can. The thing that we'd like to see looked into is protecting the coral reef habitats in any way possible. If people are destroying coral in any way, by breaking it up in any manner, or withdrawing it from certain areas, this is going to remove niches that fish and other food sources are living in. Harmful factors such as coastal pollution and even unnatural siltation--we can draw an example of Kaneohe Bay on Oahu--will wipe out a reef extremely fast.

Fish quite often will feed on living organisms, such as coral organisms, shrimp, or small crustaceans, inside the coral reef itself. If a layer of silt or an undesirable amount of pollution is present on the coral reef, the niche may still be there but the food source is gone for the fish and the fish will be gone.

Chemical poisoning--it's not supposed to happen in Hawaii. People in the Philippines and other areas are notorious for using chemicals such as Quinaldrine arsenic and Clorox. People here do use Clorox in shallow water. I've seen it done in tidepool areas for collecting assorted things. It wipes out everything indiscriminately in breeding areas.

AQUACULTURE OF TROPICAL REEF FISH

William Madden
Oceanic Institute

I would like to introduce and briefly describe an alternative to the wild collection of fishes--that is, the reproduction and rearing of marine ornamentals in captivity. For the past 10 years the Oceanic Institute has been involved with the reproduction and rearing of marine organisms, primarily fish. Most of our research has been concentrated on the mullet, *Mugil cephalus*, or ama. Currently we are working with milkfish, *Chanos chanos*, or awa. During the past several years I've done some preliminary work with marine ornamentals which suggests that, by applying what we know about raising mullet and milkfish, these, too, can be cultured in captivity.

The development of this technique offers an alternative, but not a replacement for collecting from the wild. It is, however, the next step up akin to the difference between a hunting-gathering operation and a farming operation. The hunter-gatherer goes out and collects food for whatever he needs from a wild population while the farmer plants, cultivates, sits still, and has some control over his product. The result can be a more uniform and consistent product which can be managed more efficiently, thereby providing a higher yield. Through genetic selection, faster growing or more tolerant varieties can be produced. Compare the freshwater tropical fish industry today with the marine ornamental industry and you can see the effects of culture. While the prices are lower per unit, a larger volume is possible along with hybrids and varieties which increase the desirability and demand of the product.

During the last year I looked at a number of marine fish as possible culture species, some of which are prominent in the collecting industry. These were the long-nosed butterflyfish, *Forcipiger flavissimus*; the damselfish or a'loi'loi, *Dacyllus albisella*; the mamo, *Abudefduf abdominalis*; the Potter's angelfish, *Centropyge potteri*; and the lemon butterflyfish, *Chaetodon miliaris*. These five species were decided upon after reviewing the potential of reproductive modes, spawning cycles, and resistance and adaptability to captivity of about 30 fish. The results of this work, while preliminary, are encouraging in that spawning and rearing for some of these fish has been accomplished in the laboratory. It is, however, a very imprecise operation at this time. With more time and opportunity, some fish species which are important in the aquarium trade can and will be cultured. In some instances it will not be possible, practical, or economical to reproduce certain species, thus collecting from the wild will still be necessary.

In other parts of the United States, particularly Florida and southern California, techniques have been developed for some species, such as the anemonefish or clownfish and the pomacanthids or angelfish from the Caribbean. These have been spawned and reared in captivity and a small number have actually entered the tropical fish market. To date, no cultured Hawaiian species are among these.

The problems related to the culture of marine tropicals are complex and are not generally comparable with those of freshwater ornamentals. The facts are that we know a lot less about the marine fish and find them much

harder to work with than freshwater species. Generally, the marine fish will not spawn in captivity. Since they do not, we must manipulate them through environmental changes and/or injection of hormones. While this can be accomplished, rearing the tiny and delicate larvae is very difficult. Last summer I was able to artificially spawn the long-nosed butterflyfish, *F. flavissimus*, in captivity for the first time. I was able to keep the larvae alive for only a week, however. The cause of death was the lack of food of the correct size during the critical first feeding period. This and other problems are now being worked on and ultimately I would expect that small quantities of the long-nosed butterflyfish will be produced. As I said before, I don't see this development as being competitive with collecting so much as an alternative to those times when divers cannot collect either through inclement weather or restrictive legislation.

In summary, I believe that the direction will, in the long run, be toward more product control through culture.

FOOD VALUE OF TROPICAL REEF FISH

John K. Spencer
Captain, *Fair Wind*

Actually I'm not prepared to do this but the gentleman who was supposed to do this is not here today. I'm going to do my best to say what needs to be said, not so much for the people that I represent, the *Fair Wind*, but more so for the real people that I represent, the indigenous people of the land, the Hawaiian people.

I see in the audience that there are just a few of us who were born and raised here and know about the changes we've gone through on this island, more so on the Kona coast of this island. I've been a lifetime resident here --except for the time I spent in the service--and most of that time has been spent in the water. By whatever testimony I can give, I hope I can shed better light on what our solution can be in trying to solve the present situation.

The ancient Hawaiian tradition or way of life was to preserve their needs, to keep what they had for later. There is a Hawaiian word for it which means "in harmony with nature."

The Kona coast is unique in its own way because we don't have much of it. I don't know how many people here actually go into the water, but, the Kona reef, or the reef along the shoreline, is only a fringing reef. It doesn't exceed or extend to 200 yards offshore. In a lot of places it only goes up to 40 or 50 ft offshore; deep blue water comes after that. But what I'm mainly trying to say is that there's not much room for a lot more collecting of any kind. We have to consider those people that make their living from catching tropical fish, not so much to sell it for aquarium use, but for food on their tables. I don't know how many of you folks know about this way of life, but there's not too many Hawaiian people who have the kind of job that can support themselves. We're still learning, trying to educate ourselves. Because there is this one block in front of us, everytime we need to survive--when we need to make ends meet--this is where we make it meet. When we can't feed the family, we go to the beaches. We take the family down there and that's where we eat what we need for that time.

In ancient times, the kapu system was established for the purpose of conservation and balance. There were some areas that you could fish only during certain times of the year. Even though everything wasn't written down --there wasn't a written language or history--there were the kahunas. They were not just kahunas of a religious sense, they were kahunas to watch out for the kapu system; not so much religion but conservation.

Not represented here today are a lot of those folks (Hawaiians) that go to the beach on weekends and throw net and catch fish, the kind of fish they're one for. One of those fishes, the Achilles tang, we call it pakukui, is one of the favorites of local people.

The area in which fish is being collected is right in our resort area. We, being in the tour business, are trying to promote the shoreline, and I

think the Kona coast is one of the finer places for the tourist industry to progress. It is visibly so. Eventually, it's going to be moving south, as the Kona coast is the lengthiest leeward, western coast in the state, and the waters here are very calm--probably one of the reasons you folks are attracted here--because of the water conditions, and the weather conditions as well.

Not so much by people collecting the fish, but just the population being here there is a danger to the fish. Everybody wants to be like a native. They want to go out and spear fish, throw net, and everything like that.

In the ancient times, everybody was educated in the sense of conservation and balance. That, I think, is our major concern. Even though I work for the *Fair Wind*, and the area that we operate in is a conservation area, Kealakekua Bay, we hand-feed the fish. And, to most of our folks, that's a really big thrill. Nobody's ever seen that before.

It is not a needed commodity for a local family to have an aquarium in the home. For us, it's just a luxury that's not needed. A fish is more practical to us if it's used for consumption.

We have, once or twice, gathered and tried to see how we could resolve this matter. There's a lot of people here that were at the other meeting, and everybody had a lot of thoughts as to how, later on, some of us could try to gather what is being said here today and put together a resolution.

My main concern, though, is for the indigenous people, those people that a law will eventually be made for--if there is a law passed about the certain size of the nets. These are the people that you're going to be hurting and they're the ones that are going to ignore the law. I know I might be one of them. They'll say, "I've been fishing here all the time, all my life, and I'm not going to stop now."

And how can you make these people stop? You cannot. I'm not just talking about young folks like me. I'm talking about older folks, like my mom and dad and my uncles. They're trying to support their families and are still hanging on to Hawaii as best as they can. The ocean is it. They feel, they've lost the land, in some sense, but the ocean, they'd like to hang on to.

If you have any ideas I can pass them on. I don't know whose side anybody is on, or whether there's any sides, or what. If anybody has any thoughts on the matter, I think that mainly what we're here for is to come to a solution where everybody will be happy. I understand the fish collecting industry brings in a lot of money. Well, unfortunately, it's probably something that nobody checks. I think that it really hasn't been checked. I'm in the water every day, and even on my day off I go to the beach, play around, and spear fish for my lunch.

Ten years ago, I could go to the old airport, just back about a mile or so. I could spear big pakukui, Achilles tang. Now, they're much smaller. This is not something recent; it's been this way for some time. And they're harder to get because of the increase in population--people are in the water all the time. What I used to catch is not like what it is now. It takes about three to four fish now to settle my ono.

What I'd really like to say is that a lot of people that would really be concerned about this are not here today, but their spirit is. I talked with a lot of them and I think that, if this thing gets to where there is a lot more pressure, there will be more reasoning from the people who are not here and whom I'm trying to represent--the Hawaiian people that live on the far outskirts of town. The places they fish, like the Kahaluu area, has been fished out. They have to go there earlier than usual. For sure, fishing is not like it used to be.

Hopefully, we can find a solution to this matter.

KONA CONFERENCE LOOKS AT HAWAII'S TROPICAL REEF FISH

Leigh E. Critchlow
Reporter, *Hawaii Tribune-Herald*

KAILUA - The University of Hawaii Sea Grant Marine Advisory Program will sponsor a tropical reef fish conference from 10 a.m. to 2 p.m. Saturday in the Hotel King Kamehameha.

The purpose of the conference is to provide those involved or interested in the tropical fish resource in West Hawaii a better understanding of that resource, whether they are dive charter operators, fish collectors, marine tour companies or private citizens.

"Around 1973 tropical fish collecting was growing as a commercial business. On Oahu some people felt reefs were being depleted of the popular fish and organized to try to stop collecting in the state," explained Pete Hendricks, marine advisory program agent for the Big Island.

"Permits were rescinded by the Division of Fish and Game for awhile but there was insufficient data to know one way or another what was happening," he said.

Sea Grant then funded a tropical reef fish research project, the report from which is now in draft form, Hendricks said.

The state's major tropical fish collection areas are the Waianae coast of Oahu and the West Hawaii coastline from Captain Cook Point north to Ke-ahole.

Participants in the conference will attempt to provide a look at the larger implications of reef fish collecting.

"There's got to be better resource management," said Kela Holt, marine advisory program aide. "The 1973 issue is surfacing again."

Hendricks said the national sea grant system is involved in working for the wise use of marine resources, and in research, education and extension activities in many universities throughout the U.S. The University of Hawaii is one of the specially-funded sea grant colleges.

Dr. Leighton Taylor, director of the Waikiki Aquarium, and Dr. Ron Nolan of Ocean Research Consulting and Analysis, were in charge of investigating for the sea grant program the possible overexploitation of reef fish communities by commercial aquarium collectors.

"Our analysis of catch statistics indicates that the aquarium fish fishery is of significant size in Hawaii," the two investigators said in a preliminary report.

They estimated that Hawaii provides U.S. markets with about 12 percent of its supply of the saltwater tank fish.

"We judge that the probability of Hawaiian fish collectors exceeding the maximum sustainable yield of a given species is less than the probability of them disturbing the balance of the reef community structure by over-collection of selected species," they suggested.

"Future goals will include determining methods of increasing yields in heavily collected areas using artificial reefs," they said. "These studies will involve experiments to determine the mechanisms by which key species return to reefs after larval existence in the plankton."

Nine members of the university Department of Zoology offered their opinion on the problem at a meeting called by the State Division of Fish and Game in 1973.

"Although we realize that the nature and degree of problems of over-collecting in coral reef communities in Hawaii have not yet been fully determined, we feel that it is essential to begin rational controls of the exploitation of these resources immediately.

"There appears to be a limited number of approaches to the regulation of collecting. One approach, the total ban of all collecting in all areas, is not acceptable to us. This solution is overly restrictive and would deny many people their livelihoods and recreation.

"On the other hand, we are also opposed to a continued policy of almost unlimited collection. We feel that this is overexploitative and will likely result in severe and unnecessary reduction in the kinds and varieties of marine species. Indeed, overcollecting might well have the same consequences as no collecting: i.e., the resulting rarity of animals will deny many people their livelihoods and recreation.

"We suggest a third, compromise alternative, and we stand willing to assist the Division of Fish and Game in the development and implementation of this solution.

"This plan involves the careful selection of specified 'Sanctuary' areas of limited extent, and the prohibition of collecting within their confines.

"These sanctuary areas can assure the preservation of native reef communities including populations of commercially popular animals; enhance collecting opportunities in adjacent open areas through the production of larvae by the resident animals; provide study areas for comparison with open areas and allow accurate assessment of the effects of collecting; and establish sites which can be developed into full-fledged marine parks."

The scientists suggested possible locations for the sanctuaries might be Kahe Point, the Pupukea reef and tidepool complex, and part of Kaneohe Bay on Oahu, Honaunau and Manuka Bays on the Big Island, and the Pali area on Maui.

"Collecting in open areas should be allowed by permit, the zoologists also urged, and detailed monthly records reporting the number of individuals and species captured, location and collecting efforts also would aid in assessing the effects of collecting.

"The selection of these sanctuary areas is crucial and should be made as soon as possible using the combined expertise and knowledge of fish and game biologists, professional collectors and university scientists," they said.

Taylor and Nolan were among those who signed the statement, along with Dr. Ernst Reese, professor of Zoology. The three will participate in Saturday's conference along with Dr. Alison Kay, chairman of the Department of General science at the University; Colin "Bud" Love, a member of the Kona Reef Conservation Council; Geoffrey Daigle, a partner in Pacific Tropical Fish Inc.; Bill Madden of Oceanic Institute; Al Katekaru of the Division of Fish and Game; and Mike Dant, president of Fair Wind Inc. Hendricks will moderate the panel discussion.

This conference is free and open to the public, but participants are asked to register with the university's Marine Advisory Program Kealakekua Office.

--Hawaii Tribune-Herald
February 7, 1978

REEF FISH COLLECTING: LEGAL AND REGULATORY ASPECTS

HAWAII TROPICAL REEF FISH STUDY

Dr. Ron S. Nolan
Ocean Research Consulting and Analysis, Ltd.

A complete environmental impact statement on aquarium fish collecting in Hawaii would be a formidable task. When Dr. Leighton Taylor and I began our study in 1974 we only had a modest budget from Sea Grant; therefore, we had to choose our objectives very carefully. We decided to station our investigation on the Big Island because Hawaii offers areas of heavy collecting pressure adjacent to areas with little collecting pressure--the Kona coast and the Kohala coast, respectively. Although the Kohala coast is now collected more heavily than at the time we began our study, we have had cooperation from the collectors to avoid entering our study sites.

The impact of commercial aquarium fish collecting is a complicated issue. The fish community members are highly dependent on one another. There is constant interaction between predators and competitors, as well as other members of the food web. There is a lot of variability in the system, even when it is not disturbed by man. Reefs seem to undergo natural cycles. At certain times there may be a scarcity of certain species while at other times they may be very abundant. There is also natural variation in the fish community at different locations. I've been diving in the waters of many of the major Hawaiian islands in the last few months, and it is amazing how much natural differences there are on reefs.

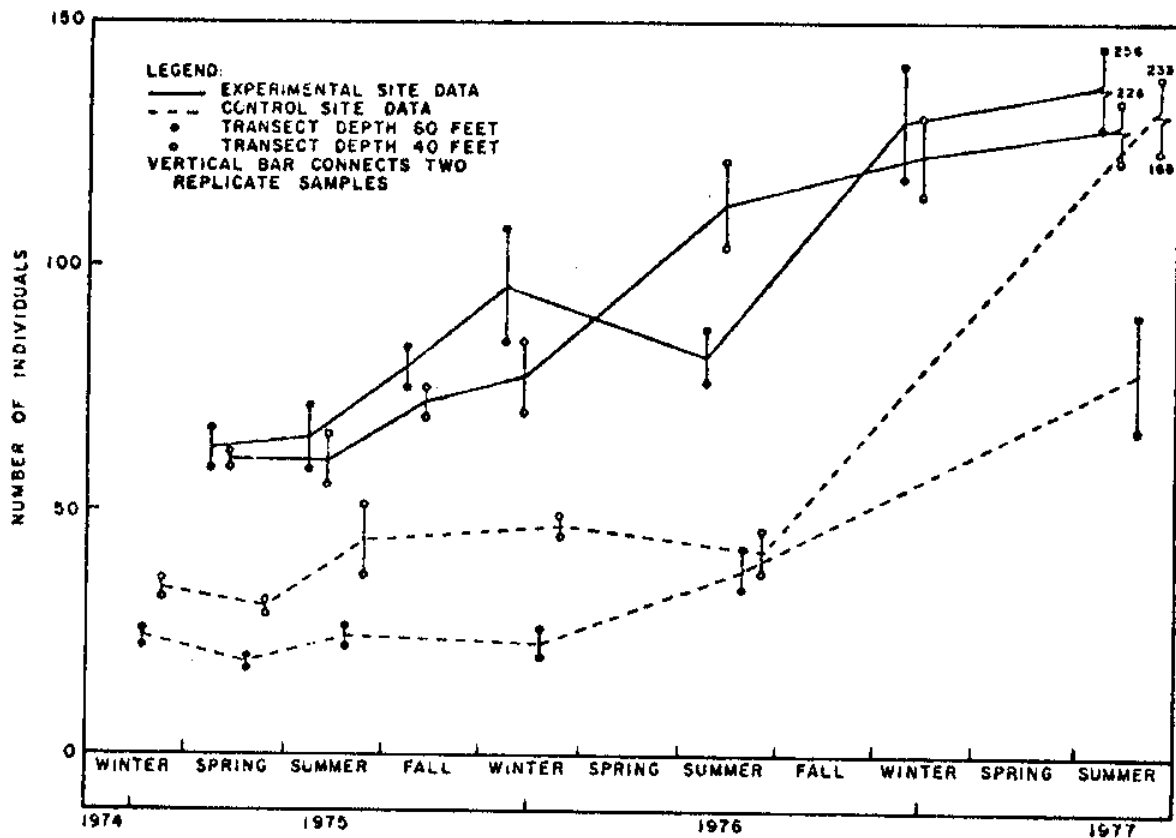
Since we had to limit our study to something that would fit within our budget and time constraints, we chose to look at the populations of the top five most heavily collected species in the two areas, Kona and Kohala. The Kona site was at Pine Trees, which is near the airport. We chose four transect areas at Pine Trees and four equivalent areas near Black Point, along the Kohala coast. We selected reef sites that had marginal coral cover. Collectors, at least the ones we've had experience with, prefer areas where sand is present between coral heads or coral rubble regions, so they can set up their fence nets and drive the fish in.

Our first step was to determine how to go about counting fish. People have used a method called visual transects for a number of years. We developed a transect standardization technique which we employed throughout the study. We limited our study to the top five most collected species. The reason fish are difficult to count accurately is because they move around. Some fish move around a lot more than others. For example, a Potter's angelfish may live in the same small area all its life, while roving fish like yellow tangs seem to move over considerable distances.

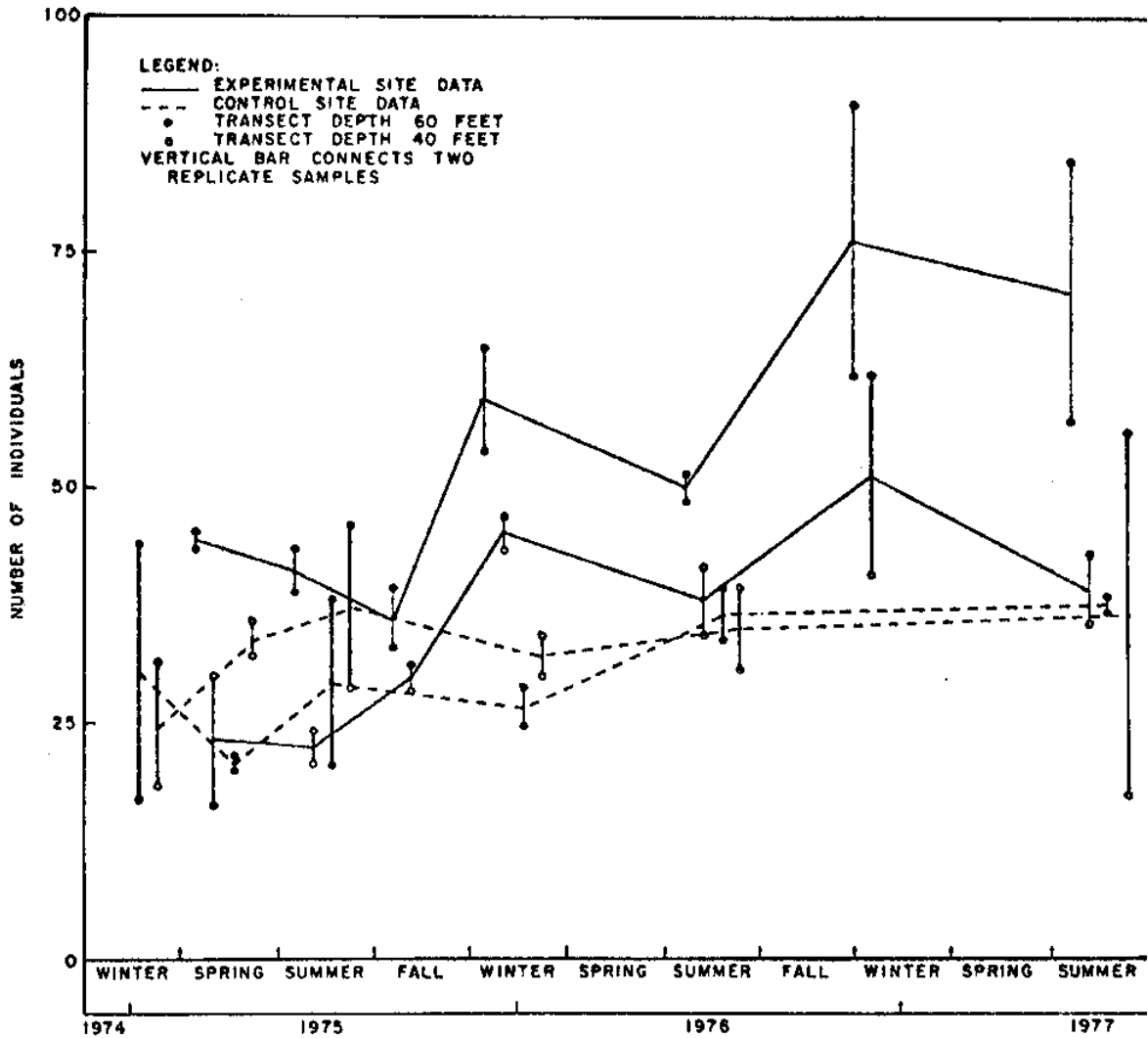
We standardized our techniques in order to get the most meaningful results. We did this by working at the same time of day in the same regions and using uniform transecting methods. The transects were 50 m long and we assessed the populations in an area 5 m wide on each side of the line. The transects were located at depths of 36 and 60 ft. The actual methodology is in a paper Dr. Taylor and I have written.

The following graphs present data obtained from our study.

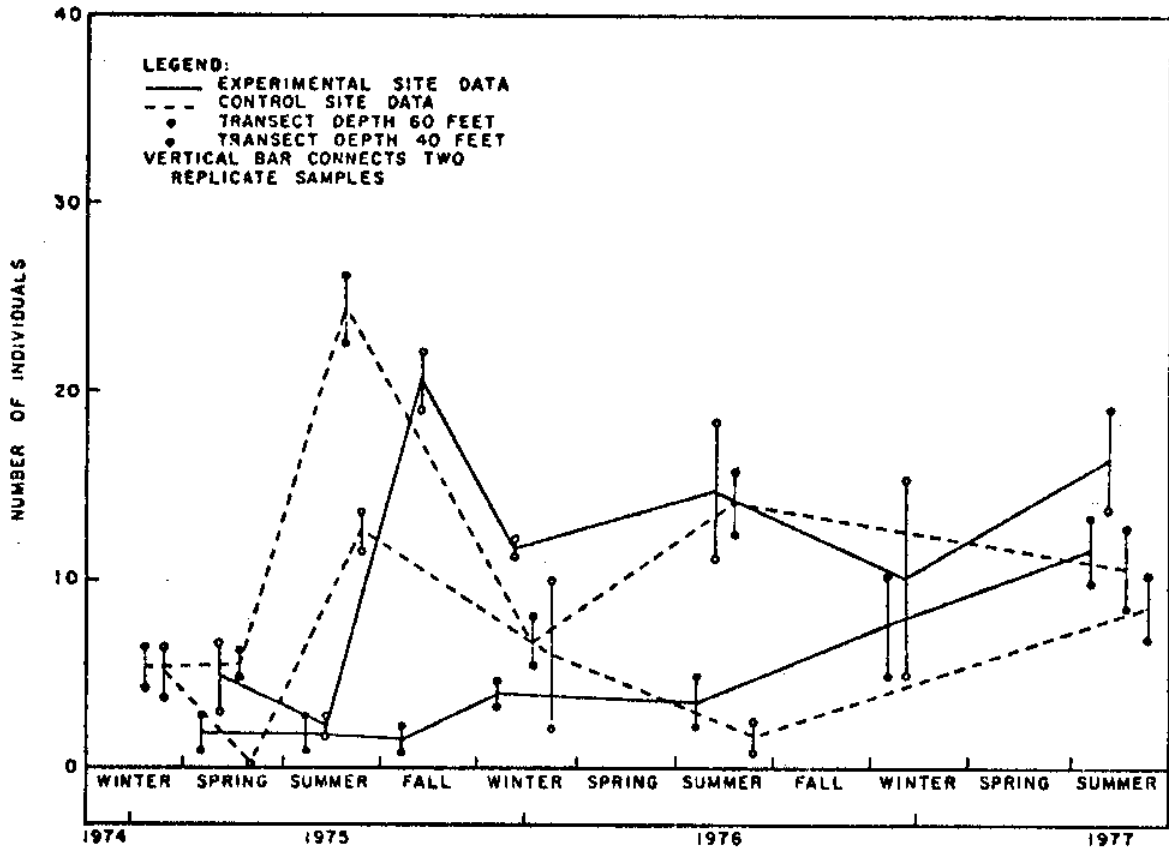
The graph below shows the population trends of *Zebrasoma flavescens* (yellow tang). The vertical axis gives the number of individual fish that were found on the study transect over a 3-year period (from winter of 1974 and 1975 to December of 1977). The solid lines represent the experimental (heavily collected) areas of Pine Trees. The broken lines represent the control reefs of Kohala. The bars intersecting those lines are the numbers of individuals from two samples. In other words, there were two replicate samples--counting the fish along the transect in the exact same place 2 days in a row, then repeating the procedure during another season. Actually, we have much more data than this, but I tried to simplify it. One should not mistake the continuity of these lines because these are actually point samples taken every month. They are connected artificially just to show you each study site: You can see a general trend here--the heavily collected reefs of Pine Trees always had a higher density of yellow tangs than was recorded on the non-collected reefs of Kohala. Yellow tangs are the most frequently collected fish. Collecting was well underway by the time Dr. Taylor and I began this study; therefore, we don't know whether at one time the experimental reefs had a density similar to that of the control reefs. I think there are two conclusions you might make from this and these may be subject to criticism. One, there hasn't been decimation of yellow tang stocks in the four sites we looked at in the Pine Trees area during this period and, two, the actual densities increased during the time of the study. [See graph below.]



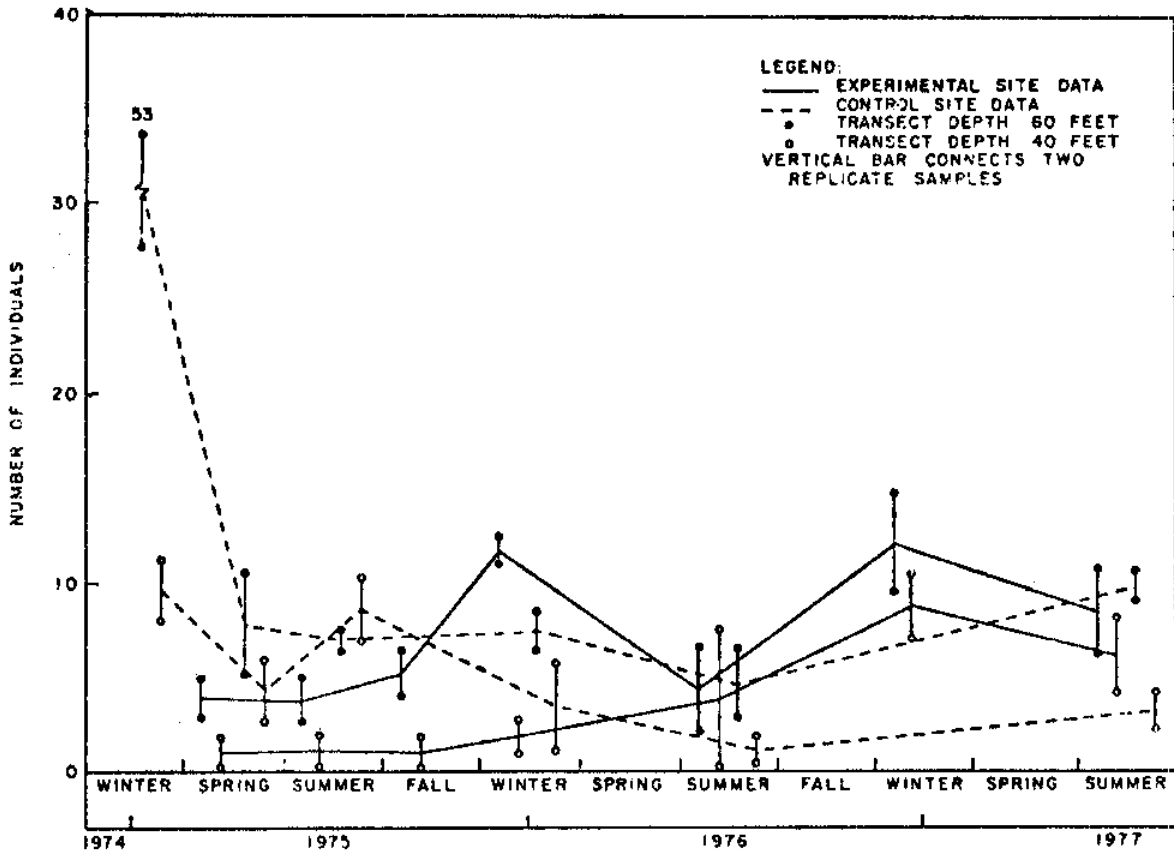
The graph below shows that the population of the pebbled butterflyfish, *Chaetodon multicinctus*, also increased both on controlled and collected reefs. This is explained by the tremendous larval fish recruitment during the summer of 1977. There has been a major recruitment of juveniles and an actual increase in the population of one of the most heavily collected areas in Hawaii.



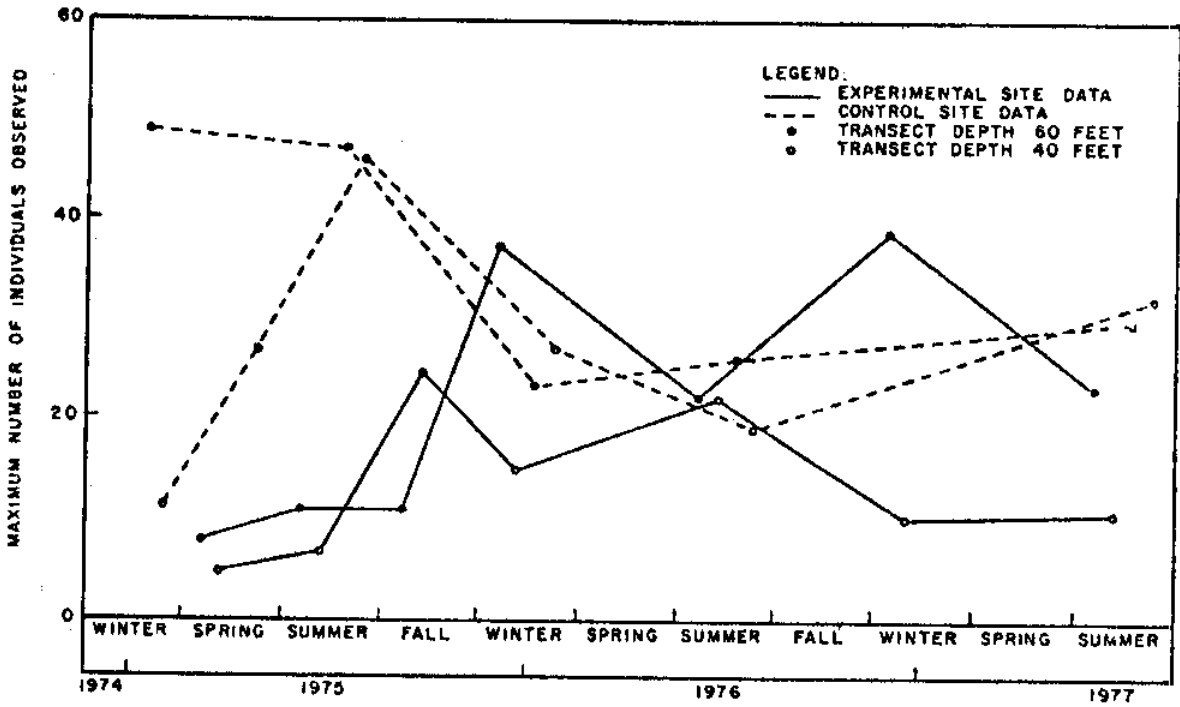
Forcipiger flavissimus, the long-nosed butterflyfish, was the second most heavily collected fish. There is a lot of variability in the populations of this fish. The scatter of the data in the graph below reflects the fact that these fish seem to wander over the reef. They may have a home range or home territory, but the chance of them uniformly occurring in the small area we looked at was slight. The populations were somewhat higher at the end of the study on both the experimental and control reefs.



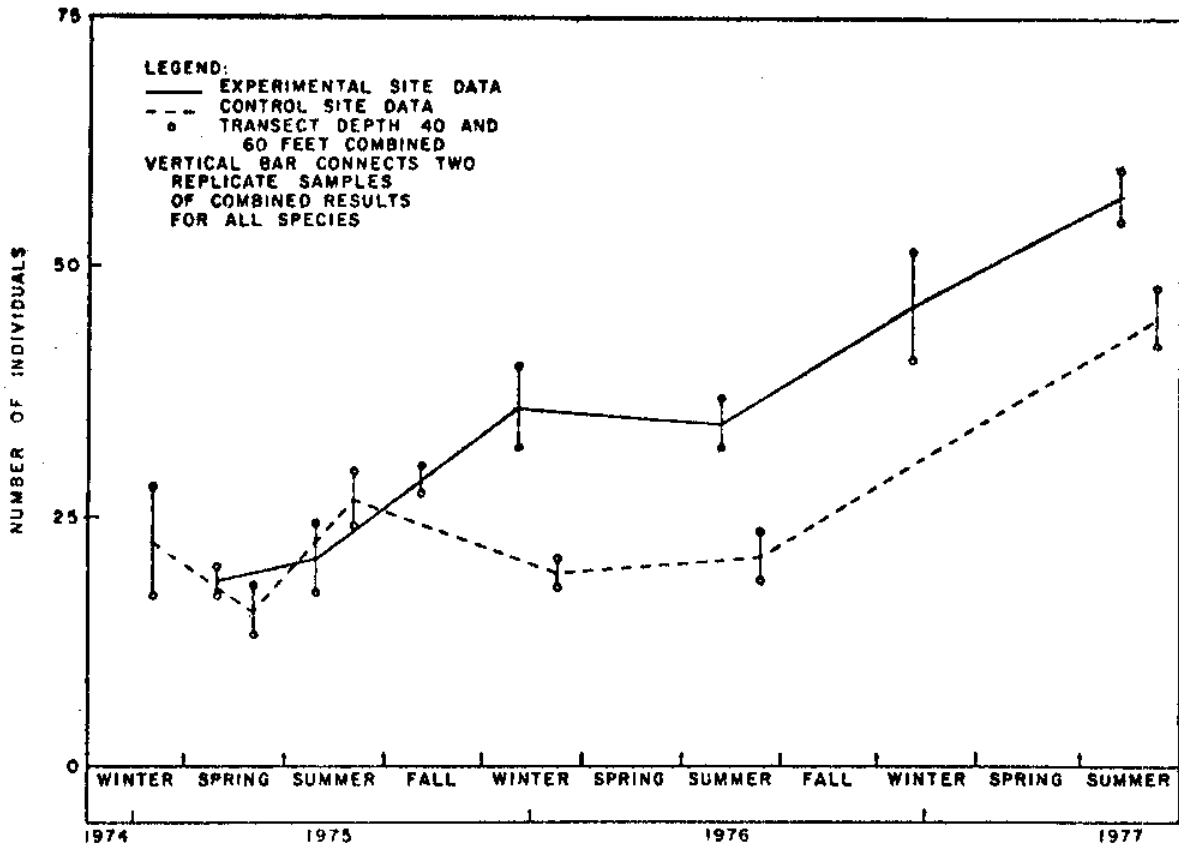
The graph below represents the population trends of *Naso lituratus*. It is very difficult to make any actual conclusions because of the considerable scatter in the data. However, there were slightly more *Naso* sp. on the collected reefs at the end of the observation period. This is one of the most prized fish among collectors because it commands a high market price.



Centropyge potteri, Potter's angelfish, is a species that might be susceptible to decimation because they have a limited home range and occur in relatively low densities on Hawaiian reefs. There seemed to be no major decimation of this species on collected reefs. [See graph below.]



The graph below represents the numbers of individuals of all five species combined. There was an increase in the abundance of all five species combined during the study period on both the controlled and experimental reefs. High recruitment rates on both collected and non-collected reefs seem to account for this trend. An increase due to fish collecting might occur if the fish removed, by monopolizing shelter sites or food resources, were inhibiting the recruitment of juveniles from the plankton.



Reef fishes have a unique life history. The adults usually mate in mid-water emitting sperm and eggs which, upon contact, become fertilized and float to the surface. On the surface, the eggs hatch within a few days into a transparent larval form which may drift in plankton for several months. No one knows the details. The reproductive strategy is for a few individuals to survive the larval stages, transform into juveniles, and invade a reef. Although many hundreds of thousands of eggs may be released by a female during the course of a year, most of this genetic or reproductive material is swept out to sea and is lost from the reef systems. Eventually, some larvae make it back to a reef to continue the population. The point is that the fish that are on the reef are the result of the reproductive activities of other fishes upstream of that reef, except for species which brood their young. A reef will re-populate itself as long as a reservoir of larvae is available. The availability of shelter seems to limit reef fish populations. This is shown to be true because when a habitat is provided, the number of reef fish is increased. If you do not disturb the shelter sites, but you remove the fish, the reef will re-populate as long as you don't exceed the capacity of the larval reservoir upstream.

In other words, if you collected all the fish from this island it might have an effect downstream on Lanai, Molokai, and Maui. I want to emphasize the need to protect living coral. Regulations should be adopted to encourage collectors not to disturb fish shelter sites. A lot of invertebrate collectors turn over dead coral heads; these should be returned to their original position. I realize enforcement will be a major problem, but perhaps education programs will help.

There are other means of sharing the sea among multiple users, e.g., Marine Life Conservation Districts. These areas provide the upstream reproductive potential which will seed collected reefs. Habitats might even be installed to attract reef fish larvae. Since there is an immense resource of larval reef fishes waiting for reef apartments, we might be able to capture the larvae efficiently and economically and raise them to large size in tanks. In the future, the fish collectors may initiate their own research and develop programs not only to increase their profits, but also to protect the reef environment.

REGULATIONS OF TROPICAL REEF FISH COLLECTING

Alvin Katekaru
State of Hawaii, Division of Fish and Game

As you know the Division of Fish and Game's role in aquarium fish management will understandably not be a popular one--strictly from the harvester's point of view or strictly from the non-harvester's point of view. Nonetheless, any proposed management scheme must be based upon reliable catch information and timely analysis of these data.

Allow me to go back a little to give you some background on the Division's involvement with aquarium fish activity.

In 1953 Act 154, forerunner of our present Hawaii Revised Statutes 188-31, was enacted to govern the use of fine mesh nets for aquarium purposes and also to establish a permit system as we know it today.

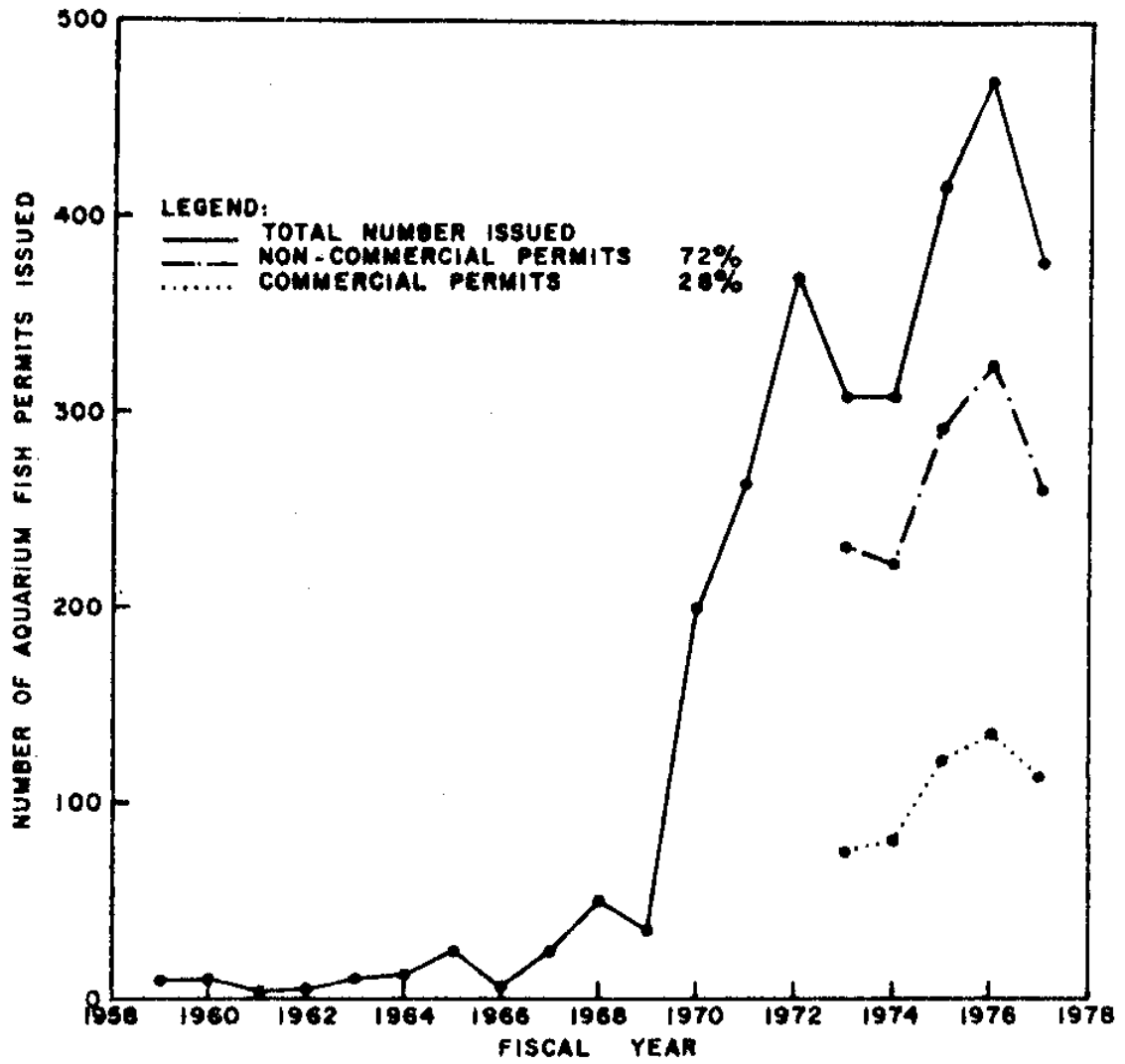
Two decades later, in 1973, a system was implemented by the Division, whereby all permittees had to submit a monthly aquarium fish catch report. Since 1973, we have been compiling aquarium fish catch data. The reliability of these data depends upon the sincerity of the permittees.

Our biggest hurdle to date, regarding the catch information, is the analysis of the data. Only adequate funding will allow us to make a complete evaluation of these data through computer data processing.

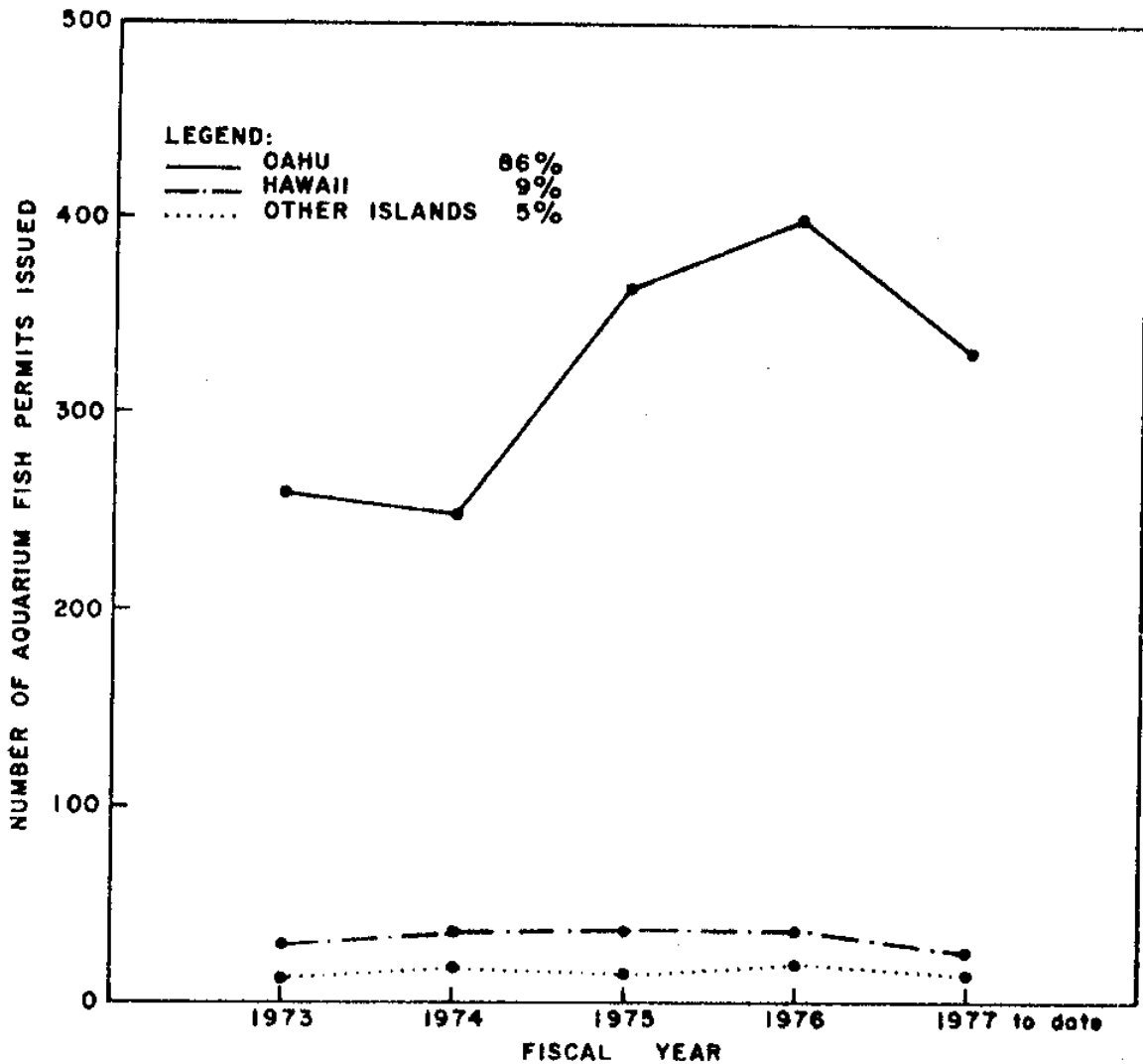
We are encouraged that current House Bill 2072, relating to the management of aquarium fish, proposes to provide some funds to the Department of Land and Natural Resources. We are also hopeful that supplemental federal funds will be forthcoming.

I would like to present some selected findings of the aquarium fish collecting activities based on available fish catch data obtained since 1973.

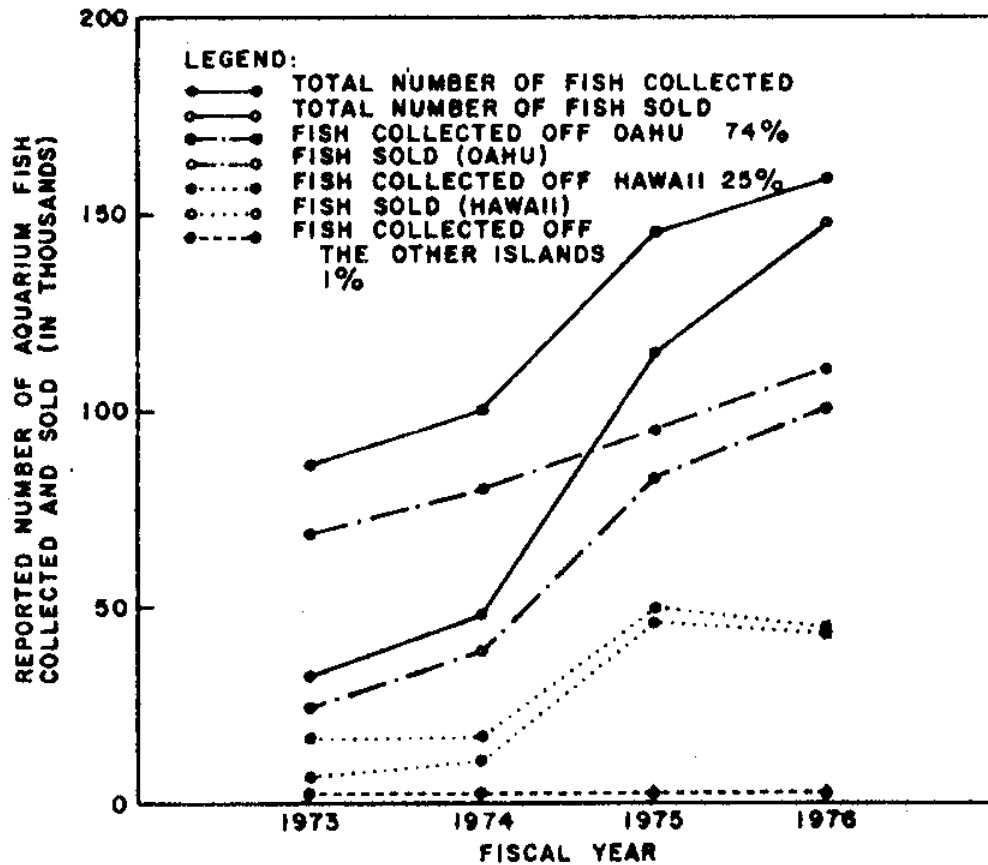
Since 1969 we have had a dramatic increase in the number of aquarium fish permits issued. The mean number of permits issued annually since 1973 has been 370. Seventy-two percent of the permits issued are for non-commercial purposes and 28 percent for commercial collecting purposes. [See following figure.]



In terms of which island has the most permittees, Oahu leads with 86 percent, followed by the island of Hawaii with 9 percent. The rest of the islands combined make up 5 percent. On Oahu, 75 percent of the permittees are non-commercial collectors and 25 percent are commercial collectors. On the island of Hawaii, 38 percent are non-commercial collectors and 62 percent commercial collectors. [See following figure.]

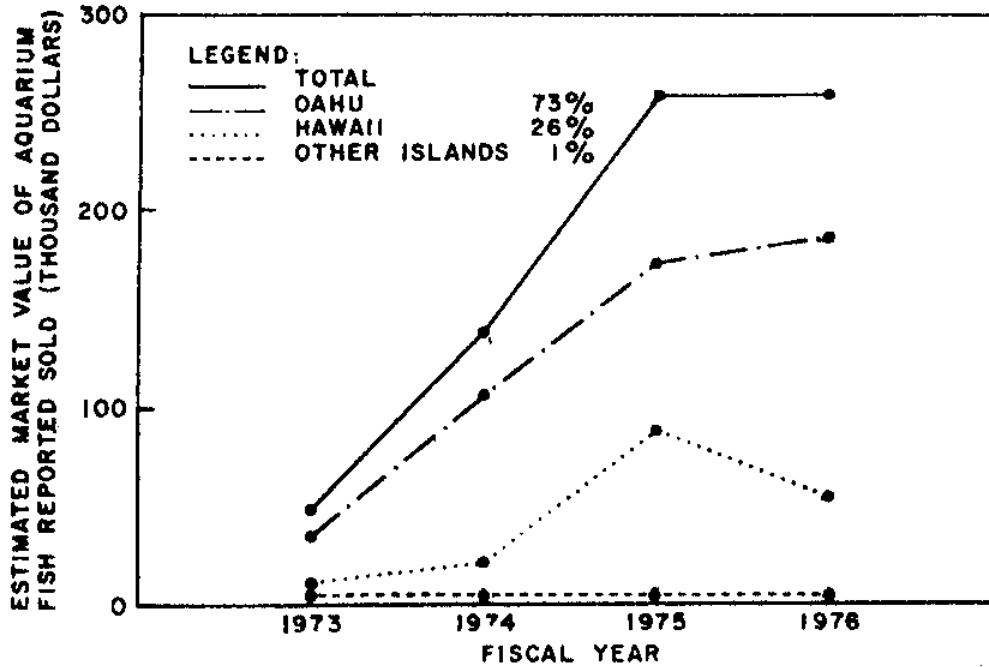


In terms of reported numbers of aquarium fish collected, since 1973, the total number has been 491,187. Of this number, 96 percent were collected commercially and 4 percent non-commercially. Since 1974, there has been a dramatic increase in the number of aquarium fish sold in relation to the number collected. The increase has primarily taken place on the island of Oahu which accounts for 74 percent of the total number collected. Hawaii accounted for 25 percent and the other islands combined for 1 percent. [See following figure.]



In 1976, the Kona area reported a commercial harvest of 49,560 fish, representing 67 percent of the total commercially harvested from the island of Hawaii and 19 percent of the total commercially harvested from the entire state.

With respect to the estimated market value of aquarium fish sold, since 1973, the total has been \$674,797 which represents a mean of \$168,000 per year. Oahu accounts for 73 percent of the total estimated market value and Hawaii 26 percent. In 1976, the Kona area accounted for \$36,926, which represents 71 percent of the estimated market value for the island of Hawaii and 15 percent of the total value for the entire state. [See following figure.]



There are four major areas of aquarium fish harvesting in the state; three located off Oahu and one off Hawaii. The most popular area in the state is the southwest corner of Oahu between Kepuhi Point and Kaena Point. This area accounted for 17 percent of the catch reported during fiscal years 1973 through 1975 with a mean catch per unit effort (the number of fish caught per manhour) of 12 fish. The second most popular area is located off the island of Hawaii between Hoopuloa Point and Keahole Point. This area accounted for 16 percent of the total state catch with a catch per unit effort of 10 fish. The third most popular area is located off the southwest corner of Oahu between Maili Point and Kepuhi Point. This area accounted for 16 percent of the total catch and a catch per unit effort of 13 fish. The fourth area is located between Kahe Point and Maili Point, Oahu, accounting for 12 percent of the total catch and a catch per unit effort of 15 fish. [See following table.]

MAJOR AREAS OF AQUARIUM FISH HARVESTING IN HAWAII
(Fiscal Years 1973-1975)

Island	Zone No.	Area	No. of Fish Collected	% of Total Catch	Average CPUE*
Oahu	34031	Kepuhi Pt.-Kaena Pt.	52,974	16.5	11.71
	34032	Maili Pt.-Kepuhi Pt.	49,789	15.5	12.98
	34021	Kahe Pt.-Maili Pt.	37,117	11.5	15.01
Hawaii	81010	Hoopuloa Pt.-Keahole Pt.	50,403	15.7	9.72
TOTAL			190,283	59.2	

*CPUE = catch per unit effort

In 1975, 72 percent of the fish collected commercially statewide was exported and 28 percent kept for local trade. The estimated market value of fish sold for the export trade was \$215,191 (83 percent), for the local trade, \$43,530 (17 percent).

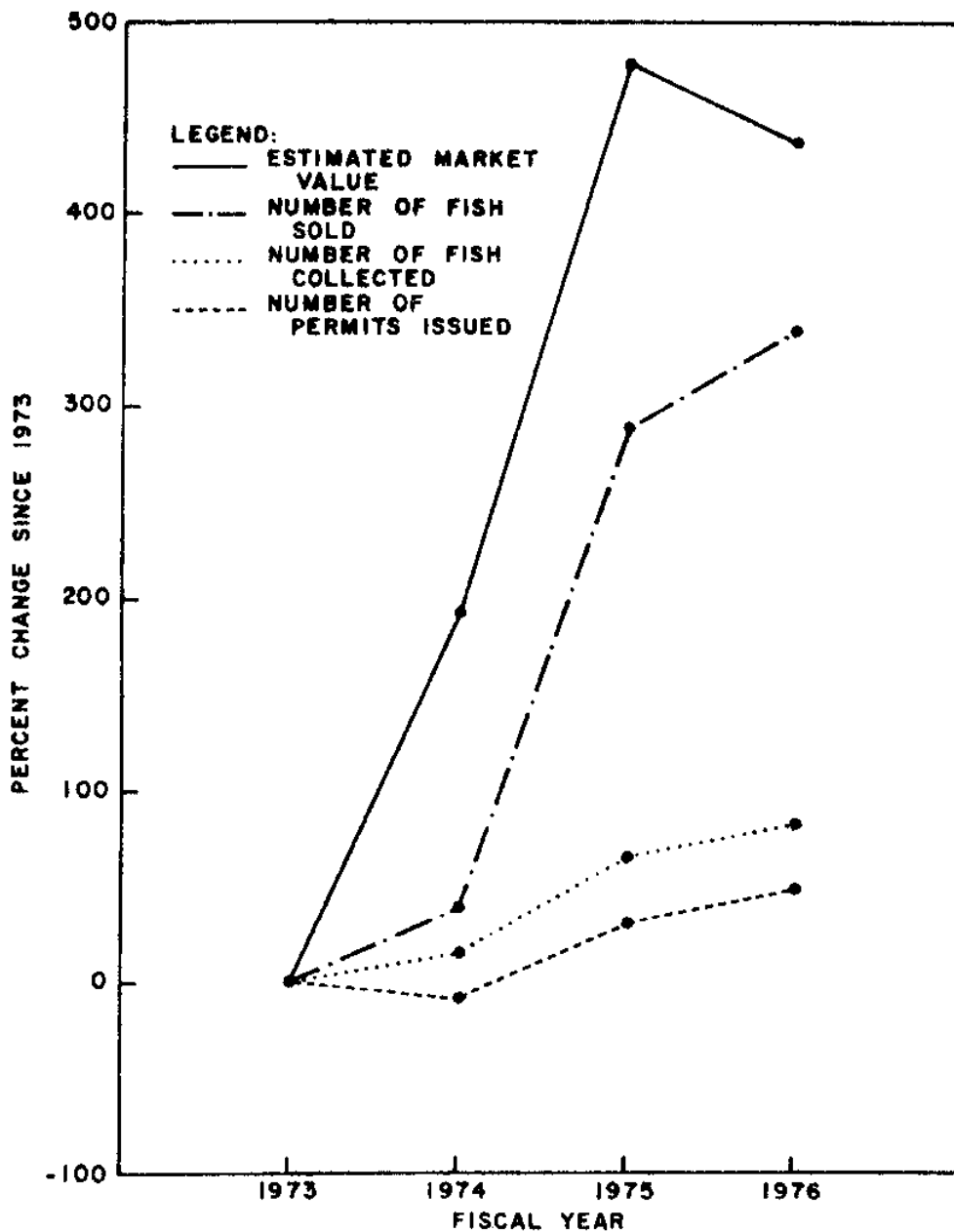
The ten top fish species reported as being most popularly caught in 1976 are first place, the yellow manini, accounting for 22 percent of the total catch, with an estimated value of \$43,325 and an estimated value per fish of \$1.24; second place, long-nosed butterflyfish, *Forcipiger longirostris*; third place, Potter's angelfish; fourth place, naenae; fifth place, kala--note that this fish commands a high estimated value per fish of \$2.24; sixth place, fourspot butterflyfish; seventh place, kihikihi; eighth place, teardrop butterflyfish; ninth place, the long-nosed butterflyfish, *Forcipiger flavissimus*; and tenth place, the copperband butterflyfish. [See following table.]

TOP TEN MARINE AQUARIUM FISHES COLLECTED IN HAWAII
(Fiscal Year 1976)

Species	Number	% of Total Catch	Estimated Value	% of Total Value	Estimated Value Per Fish
1. <i>Zebra flavescens</i> (Yellow manini)	35,006	22	\$ 43,235	18	\$1.24
2. <i>Forcipiger longirostris</i> (Long-nosed butterfly)	10,022	6	18,718	8	1.87
3. <i>Centropyge potteri</i> (Potter's angel)	9,299	6	17,919	7	1.93
4. <i>Acanthurus achilles</i> (Naenae)	9,233	6	18,920	8	2.05
5. <i>Naso lituratus</i> (Kala)	6,478	4	14,536	6	2.24
6. <i>Chaetodon quadrimaculatus</i> (Fourspot butterfly)	4,925	3	6,997	3	1.42
7. <i>Zanclus canescens</i> (Kihikihi)	4,520	3	8,763	4	1.94
8. <i>Chaetodon unimaculatus</i> (Teardrop butterfly)	4,496	3	6,502	3	1.45
9. <i>Forcipiger flavissimus</i> (Long-nosed butterfly)	4,259	3	6,914	3	1.62
10. <i>Chaetodon multicinctus</i> (Copperband butterfly)	3,623	2	3,343	1	.95
TOTAL: top ten	91,861	58%	\$145,938	61%	\$1.67 (avg.)

There may be some confusion between identification of the two long-nosed butterflyfish *F. longirostris* and *F. flavissimus*. I suspect that, as reported, both are *F. flavissimus*, and the supposedly rare *F. longirostris* should be ranked elsewhere. However, this is what the commercial fishermen report to us.

Since the base year 1973, some changes have taken place. The estimated market value for aquarium fish increased to almost 500 percent in 1975 and decreased to 420 percent in 1976. The number of fish sold, likewise, has gone up to over 300 percent since 1973. The number of fish collected has increased to about 80 percent and the number of permits issued to roughly 50 percent. Unfortunately, this evaluation is crude at best; more data must be obtained. [See following figure.]



I would like to emphasize that we need more information, and that we need the aid of the computer to make a complete and reliable evaluation of the data we receive. We get about 4,000 individual catch reports annually. Therefore, I would like to caution you on drawing any final conclusion from the data presented.

LEGAL ASPECTS OF TROPICAL REEF FISH COLLECTING

Colin Love
Private Attorney

At one time the taking of fish from the reefs in Hawaii was highly regulated. Numerous papers have been written and statements have been made about the ability of the old Hawaiians to conserve their fish to feed large populations. Current attempts by the state of Hawaii to regulate the taking of fish from the reef areas is found in Chapter 188 of the Hawaii Revised Statutes.

In 1859, the territorial government acknowledged the right of the konohikis to regulate the taking of fish from the areas under their jurisdiction. The konohikis had the right to designate fish that were taboo and, on consultation with their tenants, could prohibit the taking of any fish from their fisheries.

In 1925, the territorial government took jurisdiction over all of the fishing grounds appertaining to any government land except for ponds which were specifically left free for the equal use of all persons. Minimum net and trap sizes were established in 1929 and there have been numerous modifications since that time. In 1953, Section 188-31 of the Hawaii Revised Statutes was enacted, requiring a permit for the use of fine-meshed traps or fine-meshed nets, other than throwing nets, for the taking of marine or freshwater fish for aquarium purposes. Under that section a permit was to be issued only to persons who could satisfy the Board or its agents. The collectors had to have facilities to maintain fish alive and in reasonable health. The permit could be cancelled at the Board's discretion for any infraction of the terms of the permit when made evident to satisfaction of the Board.

In 1974, the State Legislature enacted a comprehensive scheme of environmental legislation. Contained within that legislation is Section 343-3 of the Hawaii Revised Statutes, which requires the filing of environmental impact statements for all actions proposing any use of the shoreline area as designated within Section 205-32 of the Hawaii Revised Statutes, or within 300 ft seaward of it. The environmental impact statement is required if it is probable that the proposed use will have significant environmental effects. Case law in Hawaii and other states has clearly established that the term "action" includes the act of issuing a permit. This is particularly true when the permit is being sought for an area specifically under contemplation by the environmental legislation.

In 1973, there was a great deal of concern over the effect the use of fine-meshed nets for taking non-game aquarium fish was having on the reef fish population around the island of Oahu. The result of that concern was a temporary moratorium on the taking of any fish by this means. The moratorium was subsequently lifted when it was determined that it was not possible to study the effect that the taking of non-game aquarium fish with fine-meshed nets was having on the reef fish population if no studies were run on the effects of such activities. It was not possible to run studies

without actually taking the fish; therefore, it was clearly necessary to allow netting to resume. But, presumably, the activities were to be monitored so that the short-range and long-range effects could be evaluated.

In September of 1977 I wrote to the Environmental Quality Commission and to the Director of the Department of Land and Natural Resources and asked where I might find copies of any environmental impact statements prepared prior to or concurrent with the issuance of the "Aquarium Fish Permit." Both responded to my letter. The Environmental Quality Commission concurred with my opinion that the area where the fishing activities are conducted is one where environmental impact statements may be appropriate. The Commission further stated, "We are presently making a determination as to whether appropriate action has been taken towards meeting the requirements of this statute."

The Director of the Department of Land and Natural Resources responded to my letter and made reference to the study entitled, "The Impact of Commercial Aquarium Fish Collecting Upon Selected Reef Fish Populations of the Kona Coast of Hawaii" and stated that, "Perhaps this report will provide some much less needed factual information pertinent to aquarium fish collecting activities and their impact upon the marine environment."

A review of the sequence of events set forth above indicates that, before the turn of the century, there was a comprehensive system for regulating the taking of all fish from the waters adjacent to the Hawaiian Islands. At a later date, the territorial government took over jurisdiction and then directed their attention specifically to the taking of non-game fish for aquarium purposes in 1953. Twenty-one years later, public concern was so great that a moratorium was placed on taking of all non-game fish for aquarium purposes. In 1974, the legislature enacted a comprehensive system of environmental law that required the filing of an environmental impact statement prior to any action in the shoreline area where such action would "probably have significant environmental effects." The moratorium on taking fish was later lifted. The state offices having the responsibility for protecting the environment are awaiting a research report by Drs. Taylor and Nolan, hoping that the report will provide some factual information on the problem.

Considering the chain of events in the manner set forth above it will appear that the state of Hawaii has not met its obligations. Drs. Taylor and Nolan presented some of the results of their study at the Tropical Reef Fish Conference in Kailua-Kona, and I believe that it can be fairly said that, at best, their results are inconclusive if not misleading. The state of Hawaii still does not have adequate information to determine if or to what extent the taking of non-game reef fish with fine-meshed nets is having a detrimental effect on the reef fish population.

The state of Hawaii has a number of alternatives open to it. They can accept the results of the recent study and decide that there is no adverse effect on the reef fish population and, therefore, no environmental impact statements are required and, hence, no further regulation is needed. On the other hand, they can hold that there is insufficient information available to make a determination and await further studies before deciding whether or not

environmental impact statements and further regulations are required. They could also cancel all of the permits and prevent all further fishing until the problem is solved or they can refuse to issue any new permits and, therefore, at least stabilize the problem until it can be analyzed. None of these solutions are really viable when it is recognized that there will be no answer except with further detailed analysis. Such analysis is going to require a considerable sum of money and as with any state government there is only a limited amount of money available. Even if the state were to completely analyze the problem and enact a comprehensive set of regulations, their actions would be futile without enforcement capabilities. At this time the reef fishermen are required to submit catch reports, but no effort is made to check the accuracy of the reports, nor has any effort been made to police the industry in any other way. Again, the problem is funding. The state simply does not have the funds available for addressing this particular problem when there are so many other problems that they must handle.

It would be easy to say that the blame for all of the problems rests squarely on the shoulders of the reef fishermen and, therefore, the reef fishermen should be the source of all revenues required for analyzing the problems and policing the industry. Placing such a burden on the industry would probably result in the elimination of the industry. That result would be totally unsatisfactory in that the reef fishing industry is a legitimate endeavor and a viable part of the economy of the state of Hawaii. It could well be that the reef fishing industry is only one of the many factors involved in the assumed decline of the reef fish population. Increasing population pressures and the generally unrestricted activities on the reefs are very possibly having a much greater effect on at least some portions of the declining population.

The basic key for solving complex problems, such as the one on hand, is money. Other states have had similar problems and have raised the money to find solutions through a variety of taxing and licensing schemes. No one likes to consider the possibility of having another tax burden placed upon himself, but when the alternatives are considered, it is sometimes the only logical solution. In Hawaii, the bounty of the ocean has always been considered to be free to the public. Only when commercial activities are involved are there licensing fees, and then those licensing fees are at best nominal. It may be time for us to start thinking in terms of a licensing requirement for all fishing activities. When the number of people taking fish from the ocean are considered, it should be possible to keep the licensing fee low and to give special consideration to the aged and still raise sufficient funds to pay for the studies that are clearly needed to insure the long-term survival of our reef population. It may be that, while the studies are being conducted, some limitations should be placed on the activities of reef fishermen. Those limitations should, however, be consistent with the needs of the industry, and they should not be so restrictive that they will result in the destruction of the industry.

MARINE REEF ECOLOGY

ENVIRONMENTAL STRESSES ON THE HAWAIIAN CORAL REEFS

Dr. S. Arthur Reed
Professor of Zoology, University of Hawaii

Note: Dr. S. Arthur Reed was unable to attend the Tropical Reef Fish Conference, but was asked to provide comments pertinent to the meeting. Dr. Reed specializes in marine invertebrates.

The shallow water coral reefs of Hawaii are composed of complex assemblages of organisms, the basic structure of which is formed by corals and coralline algae which precipitate calcium carbonate skeletons on the basaltic (lava) rock of the islands. Benthic filamentous or frondose algae also grow on the basaltic or reef rock in dense, carpeting masses or in waving clumps.

Due to various stresses, chunks of coral and algal skeletons break off the growing reef and, through abrasive action produced by the energy of moving water, are gradually pulverized to rubble and then into sand and mud which accumulate in depressions and pockets in the reef terrain. In regions near stream beds on the islands, freshwater runoff carries suspended terrigenous sediment which also settles into reef depressions and mixes with the sand and rubble.

The major types of reef substrata, then, are basalt, corals, coralline algae, benthic filamentous or frondose algae, rubble, sand, and mud. The coral and algal substrata may be vigorously growing and healthy, or only marginal. Each type may occur at varying depths and cover vast areas of the bottom or only in small patches, intermixed with other types.

Associated with each of these reef types is a large assemblage of invertebrates and fish which live and feed within, upon, and around the substratum. Each of these organisms has its own optimum growing conditions and tolerance to various physical and biological stresses. The benthic organisms, because they are permanently attached, are exposed throughout their life to stresses and must adapt to the limits of their capabilities or die. As the environmental stresses on a benthic community change, the assemblage of organisms able to withstand these changes is also altered. The freeswimming organisms associated with the benthic communities leave the zones of increased stress and seek more favorable areas. There is, therefore, a gradual succession of dominant reef substrate organisms and their associated infauna and epifauna in any given area of the reef, which is dictated by the environmental stresses places on the community.

Environmental Stresses on a Coral Reef

Light

The hermatypic (reef building) corals are dependent upon light for continued growth. Living within the endodermal cells of these corals are

one-celled dinoflagellate algae, zooxanthellae, *Gymnodinium microadriaticum*, which contribute photosynthetically produced molecules (largely glycerol) to the coral tissues (Muscatine et al., 1972). Calcification frequently has been shown to be light-dependent (Goreau, 1963; Buchsbaum-Pearse and Muscatine, 1971; and Muscatine, 1973). Corals kept in the dark secrete a calcium skeleton at only 1/10 the rate of corals exposed to light (Goreau and Goreau, 1959).

Vigorous coral growth and reef production is, therefore, limited to the upper euphotic zone of the ocean. In the Hawaiian Islands this zone is restricted to the depths of 50 m or less. Increased turbidity of the water column will reduce light penetration and restrict coral growth.

Sediments

Sediments are generally harmful to continued vigorous coral growth (Levin, 1970). Corals have a limited ability to remove small particulate sediments from their surface through secretions of mucus and ciliary activity on their cell surface. Water currents may also aid in flushing settled debris from the coral surfaces. But, if the sediment load increases, the corals will eventually be buried and die. Sediments also serve as substrates for bacterial populations which may produce anoxic conditions or attack the coral tissues directly. Increased sedimentation is a major factor in reducing coral growth in Kaneohe Bay (Smith et al., 1973; Maragos, 1972).

Loose, continually moving sediments can prevent the settlement of coral planula larvae and restrict the recolonization of a reef by a new generation of corals.

Suspended sediments, as indicated above, reduce light penetration (Verwey, 1930) and may also produce a serious damaging abrasion of coral tissues when moving across coral reefs with strong water currents.

Water movement

Moderate ocean currents supply corals and other benthic organisms with continued oxygen and suspended organic food and are responsible for dispersing planula larvae. However, high wave energy from storms can cause major damage to a coral reef--breaking off pieces of the more fragile species, causing abrasion through movement of suspended particles, and preventing the settlement of larvae (Maragos, 1972; Dollar, 1975).

On reef flats, especially at low tides, low rates of water movement may result in increased temperatures and possibly high salinity due to evaporation, both of which are detrimental to coral growth.

Temperature

Upper and lower temperature limits for continued coral growth and survival are about 36°C and 16°C to 18°C respectively (Stoddard, 1969),

and optimum growth occurs between 25°C and 29°C (Vaughn and Wells, 1943; Yamazato, 1966; Clausen, 1971). On Hawaiian reefs, open seawater temperatures are usually well within the range of optimum coral growth (Edmondson, 1928). However, on shallow reef flats, during low tides where water circulation is restricted, temperatures may approach the upper lethal limit for short periods of time (Maragos, 1972), which may be as low as 31°C for more thermal-sensitive corals such as *Pocillopora meandrina* (Jokiel and Coles, 1974). Thermal effluents from industrial power plants may also cause damage to restricted areas of the coral reef (Jokiel and Coles, 1974; Coles, 1975).

Salinity

Corals and many algae are marine organisms with limited ability to withstand salinities above or below that of open seawater. Exposure of corals to seawater diluted to 75 percent normal in the laboratory causes damage and is sometimes lethal (Edmondson, 1928). Corals do not grow at the point where rivers enter the ocean or in estuaries of reduced salinity such as Kahana Bay, Oahu and Kalihiwai Bay, Kauai. However, there probably are a combination of stresses operating in these areas including siltation, turbidity, and sandy substrate to prevent larval settlement, with reduced salinity playing only a minor part.

Torrential rainstorms and runoff in restricted watersheds of islands may result in deposits of large amounts of freshwater on the shallower coral reefs, causing major coral damage and destruction (Goreau, 1964) such as that which occurred in Kaneohe Bay in May 1965 (Banner, 1968). The potential danger of frequent repetition of this type of destruction is increased with extensive removal of water-retaining topsoil and vegetation, blacktopping and cementing, and channelization of watershed stream beds.

Groundwater seepage from the island freshwater lens probably does not greatly affect the growth of corals since, because of its lesser density, it remains near the ocean surface in a layer a few inches deep where it mixes gradually with ocean water through wave action.

Zones on a Coral Reef

The subtidal fringing coral reefs of the Hawaiian Islands can generally be divided into zones based on topography depth and characteristic assemblages of benthic organisms. The selection of these assemblages is strongly controlled by the intensity of various physical, chemical, and biological stresses at different depths.

The reef flat

The reef flat characteristically extends from shore as a wide, shallow platform to a depth of 1 to 3 m and to as much as 300 m seaward, usually terminating in a well-developed, wave-resistant ridge. Most of

this region is subtidal, but isolated areas may be exposed to air for short periods during low tide.

Good examples of the reef flat zone occur on the reefs between Hanalei Bay and Kalihiwai Bay on Kauai, along the windward coast of Oahu between Laie and Kaneohe Bay, and at Ala Moana, Waikiki, and Maunalua Bay. The bottom consists of patches of sand, rubble, algae, corals, and coralline algae. Crustose coralline algae are the dominant reef builders, covering 38.9 percent of the reef flat surface area on the Waikiki reef (Littler, 1973), secreting a compact skeleton that effectively resists the erosion of the wave energy and suspended particles. Zonation of the coralline algae was evident on the Waikiki reef with an unidentified form (melobesioid C) most abundant on the shallower shoreward reef flat; *Hydrolithon reinboldii*, reaching a maximum just before the crest of the seaward ridge; *Sporolithon erythraeum*, associated with dense patches of the frondose alga *Sargassum* sp. and other shaded spots; *Porolithon gardineri*, dominating the crest portion of the seaward ridge; and *Porolithon onkodes*, appearing as a thin crust on the seaward slope of the ridge and disappearing below a depth of 5 m.

Over 100 species of fleshy or frondose algae were also identified on the Waikiki reef flats (Doty, 1969), the more conspicuous ones being *Ulva fasciata* and *Ulva reticulata* in a shallow zone close to shore; *Dicetyosphaeria cavernosa*, *Acanthophora spicifera*, *Halimeda discoidea*, and *Padina japonica* on the middle reef flat; and *Sargassum echinocarpum*, *Sargassum obtusifolium*, and *Turbinaria ornata* on the algae ridge (Doty, 1973).

Small isolated patches of coral such as *Porites pukoensis*, *Porites lobata*, and *Pocillopora meandrina* may be present on the reef flat, but they represent a small fraction (less than 1.2 percent on the Waikiki reef flat) of the total cover and are relatively unimportant as contributors of limestone.

Because of the great variety of habitats, the distribution of epibenthic reef organisms is patchy and the most diverse found on any part of the reef complex. On solid reef substrate, the cone shells *Conus flavidus* and *Conus lividus* are common (Kohn, 1959). The snakehead cowrie, *Cypraea caputserpentis*, is very common under loose rubble and on the algal ridge. The most common shallow water echinoderm in Hawaii, *Echinometra matthaei* (Edmondson, 1946), is found on the outer reef flat, wedged in crevices in the reef rock. The most common fish on the Waikiki reef flat are the wrasse, *Stethojulis balteatus*, and the surgeonfish, *Naso unicornis* (Chave et al., 1973).

The seaward slope of the algal ridge is heavily populated by a number of grazing and detritus feeding fish species such as the damselfish, *Pomacentrus jenkinsi*, and the surgeonfish, *Acanthurus sandvicensis* (Gosline, 1965).

The seaward reef slope

Beyond the seaward algal ridge, the gradually sloping reef face is increasingly dominated by corals which may grow to depths of 50 m in clear water. The coral reefs along the Kona coast of Hawaii are better developed

island coasts--probably because it is protected from constant stress of tradewind-generated seas and is only rarely subjected to large swells from the west or south.

In shallower water the continuous action of high wave energy creates almost constant turbulent conditions with much suspended sediments and low water clarity, exerting a strong selection on the benthic community. The bottom may be covered with a thin algal turf, coral rubble, large and small basalt boulders, and occasional heads of *Pocillopora meandrina*, the dominant coral. Small colonies of other coral species often present are flat encrusting forms of *Porites lobata*, *Montipora verrucosa*, and *Leptastrea purpurea*. The ahermatypic olcyonarian, *Anthelia edmondsoni*, may also occur in small patches. Total live coral cover is typically low, 1.1 percent off Honouliuli, Oahu (Reed, 1974), to as high as 20 percent off the Kona coast of Hawaii (Dollar, 1975).

Pocillopora meandrina is the most common colonizing species on new lava flows, reaching a maximum colony size in 15 to 20 years. In areas of severe wave energy exposure, it remains the dominant species, but in quieter waters it may gradually be replaced by other coral species (Grigg and Maragos, 1974).

The basalt boulders and rubble are covered with an algal turf which is kept closely cropped by heavy grazing of many species of herbivorous fish (Randall, 1961) and the common sea urchins, *Echinometra matthaei* and *Tripneustes gratilla*, found in this zone (Reed, 1973, 1974).

At greater depths on the reef slope, where the effects of wave energy and turbulence are not quite as severe and light penetration is adequate, the coral *Porites lobata* is dominant. Coral cover may be relatively high, 40 to 70 percent, at depths of 6 to 14 m on the reefs off the Kona coast of Hawaii (Dollar, 1975). Other common corals in this zone are *Pocillopora meandrina*, *Porites compressa*, and *Montipora verrucosa*. Although not conspicuously visible, crustose coralline algae may also be abundant, growing at the bases of the live corals, over the surface of dead coral skeletons, and as loose aggregates (Littler, 1973). In shallow areas protected from heavy wave action, such as Keauhou and Kealakekua Bays, *Porites lobata*-dominated reefs may be found as shallow as a few meters. Other regions of prominent development in this zone are Ahihi Bay and Maalaea Bay, Maui (Maciolek, 1971) and Hanauma Bay and Kahe Point, Oahu. Common fish in this region of the reef are *Ctenochaetus strigosus*, kole; *Thalassoma duperreyi*, saddleback wrasse; *Acanthurus nigrofuscus*, lavender tang; and *Chromis verater*, black damsel (Kimmerer and Durbin, Jr., 1975). Heads of *Porites lobata* are sometimes heavily damaged by surgeonfish (*Acanthauridae*) and parrotfish (*Scaridae*) which browse on the coral polyps and skeleton. Common sea urchins are *Heterocentrotus mammillatus*, the slate pencil urchin, and *Echinothrix calamaris* and *E. diadema*, wana. The calcareous green alga, *Halimeda discoidea*, is also commonly found growing between the living coral colonies. The skeleton of this alga may contribute significantly to the production of sand in certain regions of the reef.

At a somewhat deeper depth, below the effect of major wave energy, the more delicate branching finger coral, *Porites compressa*, gains dominance.

Often only the upper 10 to 15 cm of the fingers are alive and possess polyps, the dead bases usually being covered with layers of coralline algae.

This zone is well-developed at depths of 14 to 25 m along the Kona coast (Dollar, 1975), and at depths of 10 to 20 m in Hanauma Bay and off Kahe Point, Oahu (Kimmerer and Durbin, Jr., 1975). At depths of 15 to 30 m, along the south coast of Molokai, *Montipora verrucosa*, the faster growing coral, was found to be overgrowing and replacing the dominant *Porites compressa* (Branham et al., 1971). In the calmer waters of the northern sector of Kaneohe Bay, where effects of increased sedimentation, sewage effluent, and algal growth have not severely damaged the patch reefs, *Porites compressa* dominates the entire reef slopes from 1 to 7 m in depth. The living coral on the reefs of the middle and southern sectors of the Bay have been almost completely lost and replaced by the bubble alga, *Dictyosphaeria cavernosa* (Banner and Bailey, 1970; Banner, 1974).

Common fish and sea urchins of this zone are quite similar to those in the *Porites lobata*-dominated zone.

At depths greater than 20 to 30 m the bottom is often sandy, with occasional low mounds of limestone covered with coralline algae or small heads of coral. Sand beds between 18 m and 90 m surveyed around Oahu are vast and expansive, estimated to contain more than 3.9×10^8 m² (520 million cubic yards) (Moberly et al., 1975). Clusters of the pen shell, *Pinna semicostata* are commonly found in the sand. Along the Kona coast, garden eels, *Gorgasia* sp., have been reported as common in the deeper sand region at Puako, Kealahou Bay, and Kooaie Cove (Kimmerer and Durbin, Jr., 1975).

Sand is the dominant substratum in many of the large embayments of the islands (Kahana Bay, Waimea Bay, Maunaloa Bay, and the inner region of Kailua Bay on Oahu)--from shore to great depths. No coral reef develops in these regions because of the constant movement of the sand particles, preventing larval settlement. Sand pockets, crevices, and channels are also common on the well-developed coral reefs.

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THE SOCIAL BEHAVIOR OF BUTTERFLYFISHES

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I'd like to talk about the kind of work that I've been doing in my research on coral reef fishes. I've just finished a short film aimed at creating an interest in looking at reef fishes and trying to understand a little bit about them. The film is available from the State Department of Education. It is entitled "The Social Biology of Butterflyfishes" and is a shorter version of an earlier film entitled "The Behavior and Ecology of Coral Reef Fishes."

The film will give you an idea of the kinds of things that my students and I have been interested in studying in coral reef fishes. Basically, we have studied their behavior and ecology, trying to find out what they're doing on the reef, where they live, what they feed on, and which species they compete with. These studies range all the way from field work to laboratory work. For example, I have a student at the University right now who is using a scanning electron microscope to study the fine details of the teeth of different species of butterflyfish. Their teeth, as you might guess, are adapted to the kinds of food that they eat, whether it's algae, coral polyps, or small invertebrate animals of the reef.

The purpose of the film, then, is to try to get people to ask questions about coral reef fishes and to become interested in their conservation through a better understanding and appreciation of them. They are a beautiful reef resource. We should not take them for granted.

COASTAL ECOLOGY: SHELLFISH

Dr. E. Alison Kay
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I'm sort of a fish out of the water because I'm going to be talking about opihi and shellfish, and the opihi that I'm going to be talking about are intertidal--they live between the tidemarks. There are, in Hawaii, four species of opihi, two of which are found primarily in the markets--the marketable species. A third species, found here on the Kona coast and elsewhere, is the very large, dinner-plate-sized thing, which is subtidal. But what I want to talk about are predominantly the two species, yellowfoot and blackfoot, which have been marketed for many years. The reason I'm talking about opihi is that they were utilized long before Cook arrived in Hawaii. The meat was a source of protein, and their shells were used as scrapers, tools, etc. In 1900, about 150,000 pounds of opihi were sold in the markets. Today, perhaps 15,000 pounds a year are sold, and, for a number of years, there has been an outcry that opihi are getting fewer and fewer and that something should be done.

In fact, 25 years ago, there was a resolution passed in the legislature that a study of opihi be made and that proper management measures be imposed so that there would be opihi for everybody.

Four years ago I bent somebody's arm sufficiently hard to get a little bit of money to start a study and, as a result of this study, the Division of Fish and Game has proposed some opihi harvesting regulations. There remain a couple more public hearings to get input on the proposed regulations and then perhaps they will be put into effect. We will be interested to see the results.

I don't know how much you know about opihi, except that they are very nice to eat. I've been studying them, more or less, for four years now. They occur primarily on black lava shorelines, and they are for the greater part--at least the marketable ones--found on windward shorelines. Eighty percent of the opihi in the markets come from the windward shorelines. This is not a new phenomenon. Just to check this, I had a chance to go through midden material in the Bishop Museum, and to see where they were collected in pre-Cook Hawaiian days. I found that in the middens from leeward shorelines, the shellfish remains are made up of two to three percent opihi shells but on windward shorelines, they're made up of 26 to 46 percent of opihi shells. So apparently, opihi naturally occurs more abundantly on windward shorelines than they do on leeward shores.

Opihi are neatly zoned. On the lower part of the shoreline are some of the yellowfoot opihi, and on the upper part, beyond the region on the pink limu, are the blackfoot. The Hawaiians recognized the two species--Maka 'ia'uli, the blackfoot, and alina'lina, the yellowfoot.

But Western scientists, in their wisdom, said there is only one species, a very variable species. But, I'm "Hawaiian." I know there are two species. They not only look different, they also taste different, and they live quite differently.

I've been working in an area where I've been able to have really neat experimental situations with isolated boulders. Opihi don't walk very far. The blackfoot won't walk down off the boulder to another one. Once they're on a boulder, they stay there. So I'm able to get a lot of very interesting data on their habits. Occasionally I'll find a yellowfoot on the lower part of a boulder.

On a more level shoreline, without boulders, the blackfoot is often found in crevices which is where most people see them. The yellowfoot is found lower, near the sea urchins. Quite often the yellowfoot has a tuft of limu on it. This seems to vary seasonally, but it usually has a little hat of limu and you can recognize them not only by their rough shell, but also by their limu.

What do opihi spend most of their time doing? They spend most of their time eating. They eat limu, grazing indiscriminately on the shoreline. The clear spot on the pig limu is a home scar of a blackfoot. What happens is that once the opihi settle on a spot on a rock--they settle from a free-swimming larval form--they will come back, in many cases, to that same spot. They will graze it first, and then when the tide comes in, and things get wet, they will move off of that space and move around and graze elsewhere. Then they will come back. One way in which you can tell whether a shoreline has been recently harvested is by the number of these bare spots. With the yellowfoot, sometimes these bare spots are really noticeable.

The opihi are good grazers. I scraped off some opihi in a section of coastline where I've been doing some of my work. Before I scraped them off there were little tufts of limu here and there and quite a number of opihi. When I checked the area a month later, the limu had really grown.

Bare spaces among the algae on a coastline are due both to the grazing activities of opihi as well as to the grazing of sea urchins.

One of the things that we wanted to find out is the period when opihi reproduce, because one of the ways, of course, that you can regulate or manage a fishery, is by closing seasons. We found that, in looking at the gonads--as do people who work with abalones and other such shellfish--the Hawaiian opihi don't fluctuate much in weight with the season.

Elsewhere, graphs of gonad weights with season fluctuate noticeably. Our graphs of gonad weight just sort of mosey along with slight ups and downs so that you can go out and find opihi with fairly well-developed gonads almost any time of the year. However, Hawaiian opihi are very seasonal when they settle on the shoreline. Their sexes are separate. After the sperm and eggs are released, the larvae swim around in the sea maybe for three or four days, and then a wave pushes them up on the shore where they settle and transform into small opihi. Most of the settlement seems to occur between January and late May or the beginning of June. Occasionally one finds a small settlement in August.

In May of 1976 I cleared a boulder which had something like 69 opihi on it. I took every opihi off the boulder, no matter what size it was. The mode of size range was around 25 to 30 mm. Between May 1976 and April 1977 I found only eight opihi on that boulder. There was literally nothing

on that boulder until the next April when there was a tremendous settlement. They grew at a rate of 5 mm a month until reproductive size, which is in the neighborhood of 25 mm--about an inch. And then they just sort of waffled around there from around June or July, until they began to spawn and settle again, beginning in January.

A second boulder wasn't cleared, but all the opihi on it were measured monthly. In January 1977 there was a little bit of recruitment and a little bit of settlement. In February there was a little more recruitment. In April, there was a lot of settlement that happened in March. The March settlement grew at 5 mm a month until the opihi reached 25 mm or so in length, then they slowed down and growth wasn't quite so rapid.

Just to show that--yes, it does happen in the field without our help--here is another story. On a holiday in November 1975, a good amount of the shoreline around Halape fell into the sea. My research assistant went along the shoreline about 2 or 3 weeks afterwards and found there were no opihi. The intertidal [area] in which both the yellowfoot and blackfoot occurred had fallen into the sea. The only opihi he could find were on the coconut trees that were now offshore. He also found that some opihi pickers had been there and, in their haste to get out, left behind their catch. We measured their shells. The mean and mode of the shell measurement was somewhere around 45 mm. In June, when we were back again, there were a lot of opihi on the shore. They had time to settle--between December and June is settling time--and they had grown to the right size. In October they had grown even more.

One of the things we want to find out is what happens to opihi besides sitting there and eating and growing gonads and reproducing.

There are a lot of factors which cause physical effects on shorelines. Besides the low tides on calm, collecting days, there is a tremendous amount of surf at times. There are other times when the low tides result in the shoreline drying out. These physical effects affect the opihi because they require a certain amount of moisture, etc. So the physical effects have something to do with the numbers of opihi found.

There are also biological effects. The opihi are often the prey of other organisms. If you think opihi is a nice, slow-moving organism neatly nestled on the shore or onto the substrate, you should put one of its predators beside it. Boy, will it run! It takes off! There are about three different things which feed on opihi. They have to live too!

So there are both physical and biological effects in nature which affect the opihi. But there are other things which happen which I'm not so sure about. What I've been doing is keeping track of the numbers and sizes of opihi on my experimental boulders.

In 1975 to 1976, the number of opihi varied between 25 and 100 on one particular boulder. They fluctuated just slightly over the 2-year period. Last year, there was a tremendous settlement on the boulder and, although they've fallen off somewhat, there's really a small amount of mortality. In other words, that boulder could have been worth about \$60 in the marketplace a couple of months ago.

But on the boulder right next, when I started out in 1973, were 200 plus opihi and I thought, "Gee, I'm really going to have fun watching them grow, what they're doing," and so on. However, since May of 1973, there has practically been no settlement on that boulder. I was out there on Thursday and there were 12 opihi on it. What's the reason for this? This is something I am interested in finding out because this is not a unique case. I have found a couple of other places along the shoreline where something like this happens. You'll go along for a while and there will be a tremendous amount of settlement. At other times you find a place where everything simply slows down.

Let me just end with something about man's effects on opihi. What I've shown you are the results of the work I have been doing in a non-fished area; that is, none of those effects decreases the numbers or things of that sort that have been due to the effects of man--unless, of course, the magic of my presence has had some effect on the opihi. However, if one measures the opihi that were in the marketplace 20 years ago and compares them with the marketplace opihi today, there is an obvious difference. Mean length of the opihi in the market today is 5 mm less in length than it was 20 years ago. That difference is quite striking. We are trying to figure out how many opihi can be supported on the shoreline that is not fished versus a fished shoreline. Less than 100 opihi can be picked on a fished shoreline. So man has had quite an effect on opihi.

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