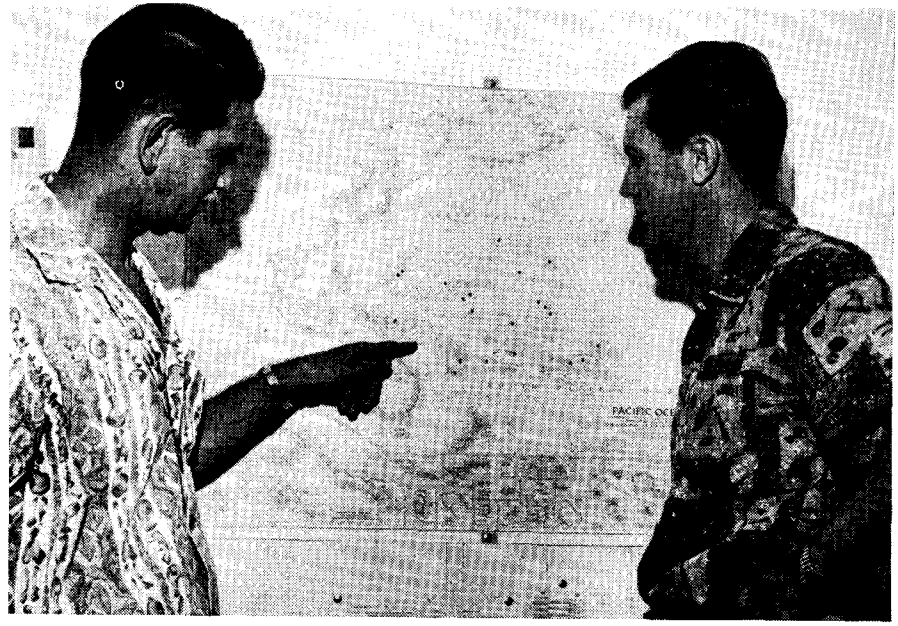


Prof. A. H. Banner and Dr. Philip Helfrich, biologists, discuss recently-received information of toxic fish on Rossel Island in the New Guinea area. The black pins on the map indicate recent reports of fish poisoning of the ciguatera type.

Fish Poisoning In The Tropical Pacific

For over three years, scientists at the Hawaii Marine Laboratory, University of Hawaii, have been investigating a common type of fish poisoning in the tropical Pacific which sometimes causes serious illness, and occasionally death. The National Institutes of Health of the United States and the South Pacific Commission are co-operating in this study.

By A. H. BANNER*

IF you anchored off the entrance to the lagoon at Palmyra Atoll, a small island about one thousand miles south of Honolulu, you could catch a large delectable red fish—the red snapper—esteemed as food in many parts of the Pacific, where it is variously known by the European names of the red bass, the red emperor, *l'anglais,* or by the scientific name of *Lutjanus bohar.* The fish are so abundant at that uninhabited atoll that your bait often cannot reach near the bottom before it is taken by a ten-pounder. And if you ate a sizable portion of one of these large fish, there is almost a one hundred per cent chance that you would be mildly to seriously poisoned thereby.

You would initially develop severe gastro-intestinal upset, with diarrhoea and vomiting; soon your skin would tingle and itch, especially around the mouth and on the palms of your hands; later you would notice an aching of the joints of the arms and legs, and a marked weakness in the legs. With a large enough serving you would develop paralysis, and perhaps drop into a coma and die. If you consulted a doctor he could give you no proven remedy for the disease—merely drugs that would alleviate the symptoms.

You would have developed the type of fish poisoning known as *"ciguatera* poisoning" in scientific literature, or popularly as *"la gratte"* in New Caledonia.

Yet if you went to Washington Island, of the same chain and only about 120 miles away, you would find the Gilbertese on the coconut plantation eating these fish as a large part of their usual diet, and never suffering from poisoning.

Similarly, throughout the tropical Pacific you will find areas where the fish are reported to be toxic. From one side of a bay on Moorea the Tahitians will eat no fish, but will eat those from the other side without harm; a portion of a reef south-east of Nouméa is avoided by fishermen; fish eaten with relish in the Solomon Islands are highly toxic in the northern New Hebrides.

In the toxic areas the red snapper

* Professor Banner is Director of the Hawaii Marine Laboratory.

Dr. Philip Helfrich, biologist, feeding a specimen of Ctenochaetus strigosus, a surgeon fish closely related to the toxic Maito (C. striatus) of Tahiti. This species, never toxic in Hawaii, is being fed over a period of months on the flesh of the toxic red snapper of Palmyra to see if it will develop toxicity.

Prof. A. H. Banner watching the feeding of a mongoose. The wild mongoose found in Hawaii has proved to be the most satisfactory animal available for initial screening of toxic fish. The mongoose, first starved for a day, is fed 10 per cent of its body weight of fish. If the fish is highly toxic, the mongoose will die in two days or less. If the fish is less toxic, the mongoose will be unable to walk or even stand.

is usually considered the worst of the fish, but the same symptoms may be produced by fish as diverse as the groupers (for example, *Serranus*), the barracuda (*Sphyraena*), the jack or trevally (*Caranx*), the moray eel (*Gymnothorax*), and even the little surgeon fish (*Ctenochaetus*).

Toxicity Pattern May Change

In any island group the pattern of toxicity may change over the years. The red snappers from Palmyra were imported by the ton to the Honolulu market previous to World War II.

More recently, the small "ulua" (jack or trevally, *Caranx cheilio*) that had been eaten by the U.S. Navy employees for years on Midway Island in the Hawaiian chain suddenly became toxic in October, 1959, and in two months, more than twenty-five individuals were poisoned.

Main Types Of Fish Poisoning

There are at least four distinct types of fish poisoning in the tropical Pacific, and probably several more.

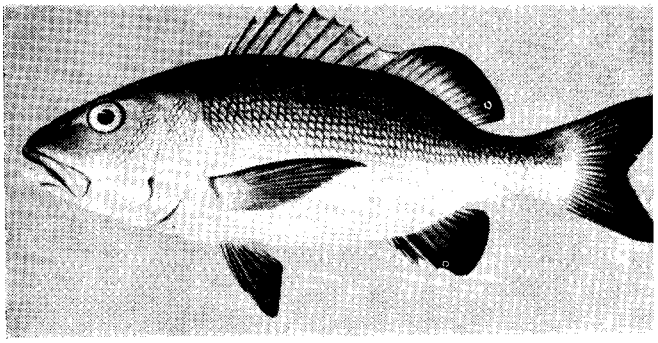
One is found in certain of the puffer fish (blowfish, toadfish—*Tetraodon* or *Arothron*). This poison has been studied by Japanese workers, who have isolated the toxin. It appears to be formed by the fish themselves, and the fish in all parts of its wide distribution are considered to be toxic unless great care is taken in preparing them for cooking.

Another type of toxicity is that found in the tuna and mackerel-like fish (Spanish mackerel, tuna or tunny, etc.). This also has been studied by the Japanese workers, and has been found to be the result of initial and minor decomposition by the bacterium *Proteus morganii* which occurs before the fish is "spoiled" in any obvious way.

The third type is that discussed in this article, the *ciguatera*-type of toxicity. Here the toxin is found in many types of unrelated fish in definite geographic regions; typically, it is not of seasonal occurrence, at least in the red snapper.

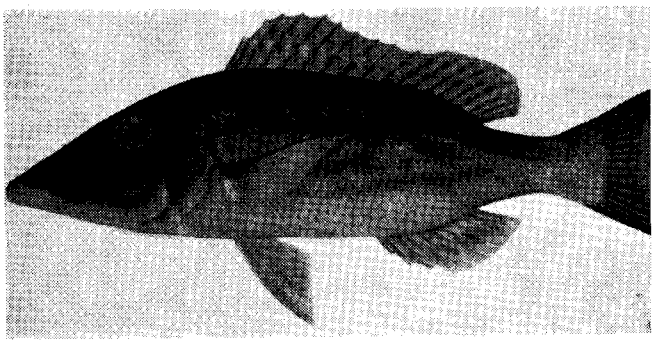
The fourth type of toxicity, almost unstudied, is an intoxication resulting from the eating of mullet (*Mugil*), surmullet (*Upeneus*) and related fish; it causes hallucinations and dizziness soon after eating if the person remains awake, or nightmares if the person falls asleep.

Other types of fish poisoning have been indicated, sometimes in medical papers, sometimes by cases reported only by the residents of the islands. These include poisoning by shark livers, by turtles, by certain sardines, by fish that are safe in most seasons but that are toxic when the balolo (or palolo) worms rise in Fiji and Samoa. There is even a crab that is reported to be toxic to eat.



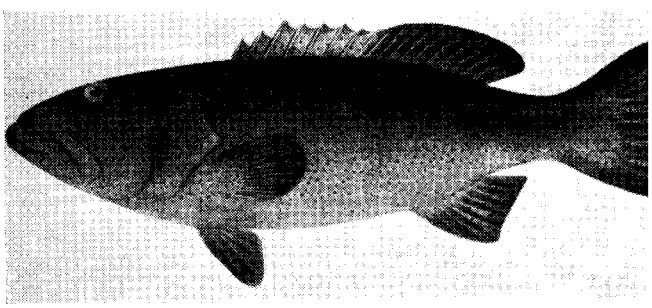
LUTJANUS BOHAR Forksal.

The red snapper, red emperor, l'anglais. This fish is probably the most consistently toxic fish in the tropical Pacific. In life it is a bluish hue above, and pink to red along the belly; however, soon after dying it turns brilliant red all over.



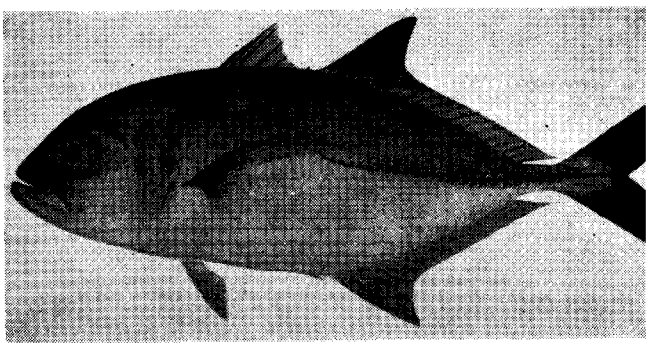
LUTJANUS MINIATUS (Shneider).

Scavenger fish, sweetlips. This is a silvery grey fish, and is often quite toxic in poisonous areas.



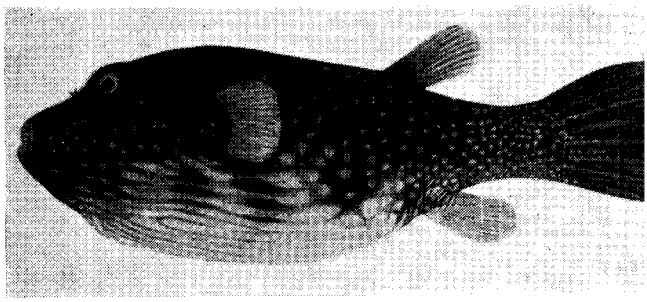
PLECTROPOMUS TRUNCATUS Fowler.

One of the groupers; this genus is known as Loche saumonee in New Caledonia. The fish is pink to red, with numerous blue spots. It is frequently violently toxic.



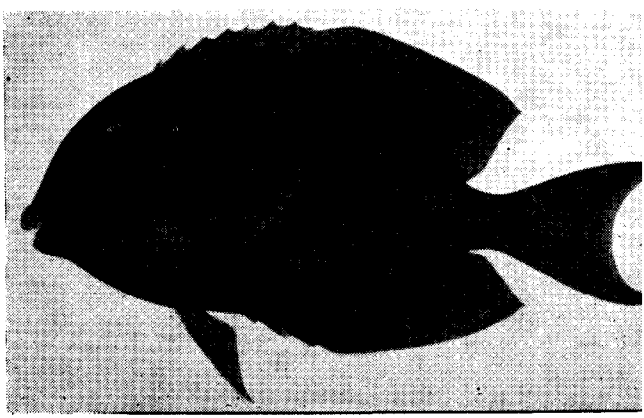
CARANX LESSONII Cuvier & Valenciennes.

One of the jacks, trevally or crevally. This fish, usually highly esteemed as food, becomes toxic in areas like Palmyra atoll, and a small related species caused an outbreak of fish poisoning at Midway Island. In Fijian waters, it is reported to be toxic only during the balolo season.



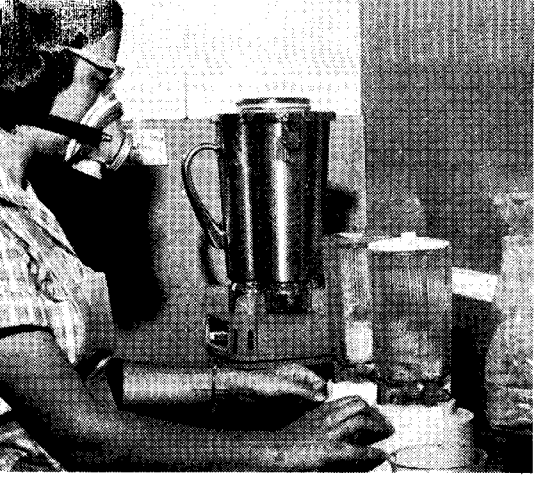
AROTHRODON HISPIDUS (Linnaeus): **also known as TETRAODON HISPIDUS**

One of the numerous puffers or toadfish which are characterized by their ability to inflate themselves into a balloon. These fish, in all parts of their range, are reputed to be highly toxic unless correctly prepared for cooking. Also related and also toxic is the balloon fish, with sharp spines, often known as porcupine fish (Diodon).



CTENOCHAETUS STRIGOSUS (Bennett).

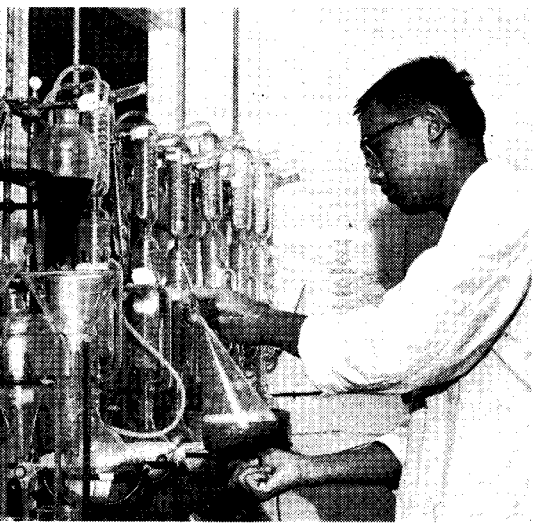
A black surgeon fish with stripes—known in Tahiti as the Maito. This is an herbivorous fish that becomes highly toxic in certain areas, and is fed upon by the larger snappers and groupers; it may be important in the transmission of the toxin along the food chain.



Miss Angeline Silva, assistant in biology, grinding a dried sample of the toxic fish in preparation for extraction. In processing the fish for the removal of the toxin, the fish are cleaned and filleted immediately after capture, and stored near 0° F. until they can be used. Then the fish is ground, dried in hot-air draft ovens at about 200° F., and repulverized. Boiling alcohol is used for the primary extraction. (A respirator is used because the fine dust of toxic fish irritates the respiratory tract.)

Only the type of fish poisoning known as *ciguatera*—the one that is limited geographically—is currently being investigated at the Hawaii Marine Laboratory of the University of Hawaii. For over three years our group of biologists and chemists have studied the problem intensively.

As is true with all scientific research, we must proceed slowly but meticulously. We use scientific "controls"—in this case, by contrasting the action of toxic fish with nontoxic fish of the same species—



Mr. Clifford Chang, an assistant in chemistry, preparing the toxic extract for further studies. The dark material in the separatory funnel is the crude extract from the initial extraction with 95% alcohol, here being washed with petrol ether to remove the fats.

and we carefully time the reactions of test animals to measured dosages of the toxic fish. To avoid confusion with possibly variable types of toxins from other species of fish and from the same species from other areas, we have used almost exclusively the large red snapper mentioned in the opening paragraph, and

Mrs. Lee Batty, chemist, holding a vial which contains the still-impure extract from Lutjanus bohar. The dark material in the test tube represents the toxin from about 45 lb. (20 kg.) of flesh—these few drops would be enough to kill about a thousand mice.

those only from the Palmyra and Christmas Atolls in the Line Islands.

For initial determination of the toxicity of any fish, we feed it to the Indian mongoose (*Herpestes mungo*), a small carnivore that has been introduced to Hawaii. For more precise assay we inject a partially-purified extract of the fish into the body cavity of a white

Dr. Philip Helfrich, biologist, injecting an extract of poisonous fish into the body cavity of a white mouse. The standard laboratory mouse provides an accurate test for the extracted toxin, and will die within a few minutes if injected with a strong toxin. Each mouse is weighed and given an injection proportional to its size; usually for each test the toxin is injected into several mice at each of several dosage-levels. By averaging the time to death at each level, and comparing the results with other tests, an appraisal of the toxicity of the particular sample is obtained.

mouse. A toxic fish may kill a mongoose in twelve hours or a mouse in seven minutes.

Evaluation Of Popular Beliefs

One of the first tasks in our studies was to evaluate the many beliefs held popularly in the islands because, if they were true, they would have speeded our investigations.

Fishermen reported, for example, that the larger fish were toxic while the smaller fish of the same species were usually safe to eat. This we found to be true at Palmyra, where ninety-five per cent of the snappers weighing over ten pounds would cause coma or death in our mongooses and the other five per cent would cause marked symptoms, while only twenty per cent of those weighing less than two pounds would produce at most only slight symptoms.

Other beliefs, however, were not supported by scientific tests. We could find no changes in external appearance nor internal structure correlated with toxicity; no method of preparation reduced the toxicity, whether it was immediate cleaning and skinning — some fish were filleted while they were still flopping—or any technique of washing or cooking. We found the toxin was not altered by any normal heat, as in cooking, nor by cold, as in a refrigerator near 0° F. for eighteen months.

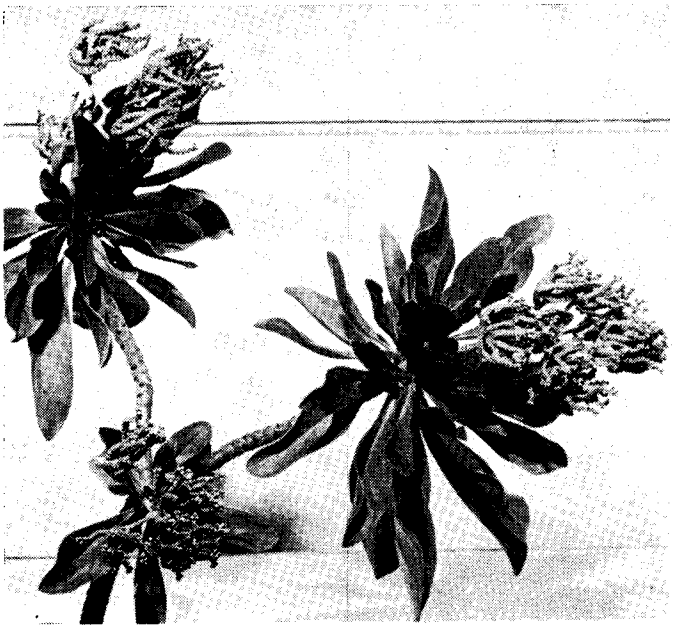
We also checked the belief that flies and ants are repelled by toxic fish, and that a toxic fish, when cooked with a silver coin, will discolour the coin. These beliefs were not true. Flies, for example, not only do not avoid the fish of proven toxicity, but can actually be raised upon the putrefying flesh of these fish. And an acid-cleaned American dime—we had no sixpence available—shows no difference whether it is cooked with a lethally toxic fish or with a perfectly safe control fish.

It is also contended that the head end of the fish is more toxic than the tail. At least for the muscles, this is not true. However, the viscera—the liver and the testes especially—may be up to fifty times as toxic as the muscles. While we have made no studies on the brain, it is likely that it may be more toxic than the muscles. Thus, if a person ate the nervous tissue of the head, he might receive more toxin than if he had eaten the muscles of the tail.

Main Work On Two Phases Of Problem

Our work to date has been primarily concerned with two phases of the problem: first, to isolate and to identify chemically the toxin, and, second, to determine why fish become toxic in only restricted areas.

The isolation of the toxin has been very difficult, the difficulty being caused at least in part by the extremely small



Messerschmidia argentea, also known as "false tobacco". This silvery leafed beach plant is widely used throughout the low islands of the Pacific as a cure for fish poisoning. Its effects have not been studied scientifically.

amounts of toxin found in the flesh of even lethally toxic fish. For from every ten-pound fish we start with, we can expect to recover less than 0.0003 lb. of the toxic extract; and even this extract is still not entirely pure. This toxin, even at its present level of impurity, is roughly comparable in potency to the venom of rattlesnakes. Like curare, the poison used by the Indians of the Amazon for their poison darts, this toxin appears to hit the vital pathways of the nervous system.

The method of extraction of the toxin has been reported in our scientific papers; here it will suffice to state that the lengthy process is carried on with a complex of various organic solvents, starting with boiling alcohol to extract the toxin and much else from dried flesh, and ending with selective flushing of the toxin from columns packed with specially-prepared absorbents.

At the time of writing a few crystals, presumably of the toxin, have been found in the most concentrated extract; yet the crystals are microscopically small, and float in a drop of oily residue. When sufficient amounts of the crystals are prepared, the chemical nature of the toxin will be investigated.

Many Theories For Regional Toxicity Pattern

Biologically, many theories have been offered as to the cause of the regional pattern of the toxicity. Some may be discarded on inspection. For example, the people who blame the toxicity on jettisoned war-surplus materials or on atomic fall-out do not remember that one of the first reports of fish poisoning of this type in the Pacific was made by Captain Cook from near Santo, New Hebrides, in 1774, or the German accounts of fish poisoning at Jaluit in the Marshalls in the last half of the nineteenth century. These somewhat predate the Bikini and Christmas Island bomb-testing. Similarly, the theory that the fish poisoning is caused by "coral in flower" can be discarded because coral, an animal, does not flower. In the Caribbean, the origin of the toxin is laid to the fruit of the manchineel tree (*Hippomane mancinella*), but this does not normally grow in the Pacific; further, it is difficult to imagine how—or why—a large carnivorous fish from the outer side of a barrier reef could, or would, feed on its apple-like fruit.

The theory that the toxin comes from the plankton—the microscopic drifting life of the sea—has a little more to support it, for the toxicity of shellfish in the North Pacific has been definitely traced to a microscopic plant that may be so abundant as to stain the water red. Yet none of the fish that show the *ciguatera* toxin are fish that feed directly or indirectly on the plankton, except incidentally. The herbivorous fish, like surgeon fish, feed primarily on the bottom plants or algae; the carnivorous fish feed upon the bottom-feeding fish like the surgeon fish. On the other hand, the fish that feed exclusively on plankton-feeding fish, like the tunas and the dolphin (MAHIMAHI in parts of Polynesia—*Coryphaena*) never show this type of toxicity.

Our hypothesis, yet unproven, is that the toxicity arises in some of the fine algae growing on the bottom. This algae is then eaten by various herbivorous fish like MAITO, the toxic surgeon fish of Tahiti (*Ctenochaetus strigosus*) which are not poisoned by the toxin, but instead accumulate it in their tissues. These small fish are in turn eaten by the larger carnivorous fish like our snapper, which also store the toxin. We have found that the snapper does indeed feed on the toxic surgeon fish, but we have not yet traced the toxin to an alga.

Wider Research Planned

In the coming years we hope to continue our present lines of research, and to expand them into other phases of the problem. One thing we hope to do is to investigate other species of fish and reef animals reported as toxic to see if they have the same toxin as that found in the red snapper from Palmyra Atoll.

Another extension of our work is the investigation of the reaction of the body to the purified toxin. As this is written during the summer of 1961, a member of our staff is working with a pharmacologist of the School of Medicine of the University of Southern California to determine the exact mode of action of the toxin upon the nervous system. From this we hope to develop a more sensitive and precise test for the toxin, and to obtain information so that the doctors may treat fish poisoning with drugs specific to it.

From our chemical studies we hope to be able to develop an accurate chemical test for toxic fish that may even be simple enough to be used by medical practitioners and nurses in isolated island communities.

Investigation Of Native Remedies

We also plan to extend our studies into an investigation of the native remedies developed by the island people during the thousands of years they have been treating this fish poisoning. These "home remedies" vary from island to island. Some, like the combination of coconut cream and lard, are emetics; others, like the juice from the Manila tamarind (*Pithecolobium dulce*), are purges. The obvious effects of these are to rid the digestive system of the poisonous fish before greater harm is done. Yet other plants, widely used for fish poisoning, like "false tobacco" (*Messerschmidia argentea*) or a salpiglossid (*Duboisia myoporides*), may contain drugs that are actually specific in their counteraction against the toxin. Native herb medicines should never be belittled without careful investigation—after all, it was the Inca Indians who discovered quinine as a specific against malaria.

Pacific Survey Planned

One of the major extensions of our studies will be a survey of fish poisoning in the Pacific. This will be done to provide us with clues as to the origin of the toxin, and to permit us and the health authorities to assess fish poisoning as a threat to public health. The study will be made in co-operation with the National Institutes of Health of the

(Continued on page 65)

Fish Poisoning In The Tropical Pacific

(Continued from page 21)

United States and the South Pacific Commission.

We have prepared a booklet with a technical discussion of fish poisoning; this, with questionnaires on which to record actual cases of fish poisoning, will be sent by the South Pacific Commission to all medical personnel in the whole of the central tropical Pacific. The Commission will also translate the booklet into French for personnel on the French islands.

If any of the residents of the islands wish to help us in our work, we would appreciate the following information in letters:

(i) Comprehensive accounts of toxic fish in any specific area.

(ii) Accounts of any cases of poisoning resulting from the eating of any marine animal, either recently or in the past, with as detailed information as possible on the fish causing the poisoning and the results of the poisoning.

(iii) Any information on locally-used cures, if possible with dried specimens of the plants used.

This information can be sent to the Director, Hawaii Marine Laboratory, University of Hawaii, Honolulu 14, Hawaii.

Two Common Questions

Finally, there are two questions always put by the residents of the islands: Which fish are always safe? What is an easy way to discover if any particular fish is safe to eat?

For the first; any fish that is caught in the open ocean, like the tuna, the flying fish, and the dolphin have never been known to cause poisoning when fresh. The second question is more difficult for, actually, there is no easy way to be assured that a fish is nontoxic. If the fish is doubtful, it would be best to feed the potentially highly-toxic liver and other viscera to a cat; if it does not show any ill effects in twelve to twenty-four hours, the fish is safe.

The Breadfruit Tree In Micronesia

(Continued from page 39)

ing breadfruit exist, but they differ only in some details.

As most of the breadfruit on Kapingamarangi Atoll ripens in February, there is a surplus of fruit at that time. A common method of preserving breadfruit on this atoll is the preparation of breadfruit "sheets", which are called TIPAK. For this purpose, skin, core and seeds are removed from nearly mature breadfruits. Seeds are immediately eaten after cooking or roasting. The fruit is then cut into small pieces