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Yoshiro HASHIMOTO, Shoji KONOSU, Takeshi YASUMOTO,
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Ciguatera in the Ryukyu and Amami Islands*

Yoshiro HASHIMOTO, Shoji KONOSU, Takeshi YASUMOTO,
and Hisao KAMIYA**

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Ciguatera is usually a nonfatal illness caused by ingestion of various reef and semi-pelagic fishes living in tropics and subtropics. This poisoning has not only been a serious problem in food supply and public health to inhabitants of islands in the South and South West Pacific but also an obstacle to utilizing fish as a protein source to the increasing population in the world. Among a number of reviews on this problem, the most exhaustive has been recently prepared by HALSTEAD[1].

A group in the University of Hawaii has been most actively studying the biology, chemistry, and pharmacology of ciguatera in the Central and South Pacific, and have clarified the characteristics of principal toxin named ciguatoxin[2~5]. We also made an approach on a small scale to the toxicity of ciguatoxic fishes[6,7] in the Ryukyu Islands which lie between Kyushu of Japan and Taiwan.

The increasing outbreaks of poisoning due to fishes brought into Japan from the southern sea led us to enhance the study and initiate joint research with the group from the University of Hawaii headed by Dr. A. H. BANNER under the Japan-United States Cooperative Science Program. At first, we made field surveys in order to grasp the general situation of ciguatera in the Ryukyu Islands and adjacent Amami Islands. The results obtained by the field survey were supplemented by an investigation with questionnaires distributed to many organizations in these islands.

Through these investigations occurrence of many ciguatera poisonings was found, which had not been indicated in official records. In the present report non-ciguatera fish poisonings, such as tetrodon poisoning, hypervitaminosis A due to livers of large-sized fishes, diarrhea due to castor oil fish, acute gastro-enteritis due to a halophilic bacterium *Vibrio parahemolyticus*, are excluded, though we came across several of these cases. Besides fish poisonings, outbreaks of poisoning from ingestion of turtles, crabs, or coconut crabs were also confirmed.

Intoxications by toxic crabs have been reported previously[8], and the present paper deals with the general pattern of ciguatera and poisonings due to turtles and coconut crabs in the Ryukyu and Amami Islands.

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* Studies on Marine Toxins. XX.

** Laboratory of Marine Biochemistry, Faculty of Agriculture, The University of Tokyo, Bunkyo-ku, Tokyo (橋本芳郎・鴻巣章二・安元 健・神谷久男, 東京大学農学部).

Investigation Methods and Results

Source of information

The information was derived from three different sources; from the organizations concerned with public health or fisheries, from interviews with many fishermen and individuals who had been poisoned, and finally from an investigation with questionnaires. Several field trips were made in 1966 through 1968 for the purpose of conducting interviews and for the procurement of test materials. Some of the interviews, especially in the southern Amami Islands, were made by Mr. K. SHIOMITSU, Technical Officer, Kagoshima Prefectural Fisheries Experimental Station.

The investigation with questionnaires was made in 1966 jointly with the U. S. group in order to collect information from areas not covered by survey trips and also to obtain additional information from the areas previously visited. The questionnaire adopted was the same one which had been used for many years by BANNER *et al.*[9] for a survey of ciguatera in the Central and South Pacific. In the Ryukyu Islands the questionnaire was distributed to 21 fishermen's associations selected at the suggestion of Department of Fisheries of Ryukyu Government, and recovered from 13 associations listed in the footnote of Fig. 1. In the Amami Islands, it was distributed through the Fisheries Section of Oshima Branch Office and the Oshima Branch of Kagoshima Prefectural Fisheries Experimental Station. The names and locations of the organizations are shown in Fig. 1.

Toxic species

The fishes reported to be poisonous in these areas are listed in Table 1. The species were identified by showing reporters the plates in the monograph edited by HIYAMA[10]. In the questionnaire, however, there were many local names which could not be clearly defined.

In Okinawa, toxicity of *Lutjanus bohar* was reported at all places, and *Gymnothorax flavimarginatus, L. monostigma, Variola louti,* and *Epinephelus fuscoguttatus* at many places. These five species are the most frequently implicated ciguatoxic fishes. Besides them, the following species were also reputed to be toxic in a few areas: *L. vaigiensis, L. fulviflamma, Plectropomus truncatus, Alutera scripta, Sphyraena picuda, Anyperodon leucogrammicus, Pogonoperca punctata, Lutjanus* sp., *Cheilinus* sp., *Siganus fuscescens,* and *Charcarhinus* sp. Unidentified fishes with the following local names, "Iyu-guchā", "Yamutobiya", "Kakū", "Akamī-mībai", "Akajimi", "Āra", and "Kuchiguāārā" were also reported as toxic.

In the Amami Islands, *L. bohar* is known to be toxic and has been prohibited from sale at Naze City market. As for the other toxic fish, the situations were slightly different from those in the Ryukyu Islands. For example, *V. louti* and *E. fuscoguttatus* were regarded as seldom toxic except in Yoron Island, which lies closest to the Ryukyu Islands. Especially in Amami-Oshima, there was no recent poisoning case from these two species. Fishermen reported that they frequently consumed moray eels, though there was a few sporadic out-

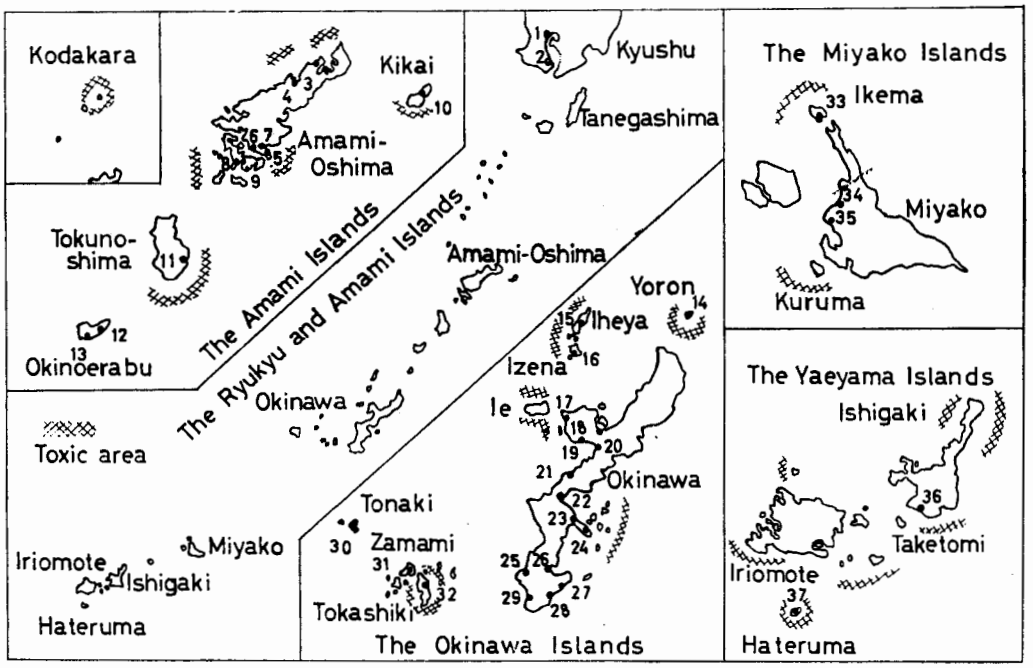

Fig. 1. The map of the surveyed areas and toxic regions

A Organizations visited

Kyushu and the Amami Islands: Faculty of Fisheries, University of Kagoshima; Section of Environmental Sanitation, Kagoshima Prefectural Office; and Section of Fisheries, Kagoshima Prefectural Office (1). Yamakawa Town Office (2). Section of Fisheries, Oshima Branch Office; Naze Health Center; and Naze Fishermen's Association (4). Kagoshima Prefectural Fisheries Experimental Station, Oshima Branch; and Setouchi Fishermen's Association (6). Tokunoshima Town Office; Tokunoshima Health Center; and Tokunoshima Fishermen's Association (11). Yoron Town Office; and Yoron Clinic (14).

The Okinawa Islands: Motobu Fishermen's Association (17). Haneji Fishermen's Association (18). Nago Health Center (20). Ishikawa Fishermen's Association (22). Union of Ryukyu Fishermen's Associations; Department of Fisheries and Department of Public Health, Ryukyu Government; Ryukyu Fisheries Research Laboratory; and Naha District Fishermen's Association (25). Itoman Fishermen's Association (29).

The Miyako Islands: Section of Economics, Miyako Regional Bureau; Miyako Health Center; Union of Ryukyu Fishermen's Associations, Miyako Branch; and Hirara Fishermen's Association (34).

The Yaeyama Islands: Yaeyama Health Center; Union of Ryukyu Fishermen's Associations, Yaeyama Branch; and Ishigaki Fishermen's Association (36).

B Regions investigated with questionnaire

The Amami Islands: Akiyaba (3), Sokaru (5), Agina (7), Ikomo (8), Osai (9), Onotsu (10), China (12), and Wadomari (13).

The Okinawa Islands: Iheya (15), Izena (16), Motobu (17), Yabe (19), Nago (20), Onna (21), Katsuren (24), Naha (25), Yonabaru (26), Tamagusuku (27), Gushichan (28), Tonaki (30), Zamami (31), and Tokashiki (32).

The Miyako Islands: Ikema (33), Hirara (34), and Hisamatsu District (35).

The Yaeyama Islands: Ishigaki (36) and Hateruma (37).

Table 1. Species reported to be toxic.

Scientific Name	Japanese Name	English Name	Local Name
Gymnothorax flavimarginatus	Doku-utsubo	Moray eel	Uji-unagi, Ujinnagi (Okinawa, Amami), Unagi (Tokunoshima), Uzu (Miyako)
Lutjanus bohar	Futatsuboshi-dokugyo	Red snapper	Akana, Akanā (Okinawa, Koniya, Tokunoshima, Yoron), Akairautsu (Miyako), Hāna (Naze), Āna (Tokunoshima, Yoron)
L. monostigma	Itten-fuedai	Snapper	Akashubi, Sukusubi, Sukushibi, Tokushibi, Hishiyamatobī (Okinawa), Subi (Okinawa, Amami)
L. vaigiensis	Akadoku-tarumi	Snapper	Inakū (Okinawa)
L. fulviflamma	Nisekurohoshi-tarumi	Snapper	Inakū (Okinawa)
Lutjanus sp.	Okifue-dai	Snapper	Kāshibi (Okinawa)
Variola louti	Bara-hata	Reef bass	Nagajyūmībai, Akazūmībai, Hingānakajyū, Akade, Akadē, Nagajyūakajin (Okinawa), Suwashin (Naze), Suwashimi (Koniya), Āre (Tokunoshima), Akajinnibara, Bunaganibara (Miyako), Dainupāādin (Yoron)
Epinephelus fuscoguttatus	Yodare-hata	Rock cod	Yudayāmibai, Akaāra, Akabanī (Okinawa), Nebari (Naze, Koniya, Yoron), Mebaru (Koniya), Nibai (Yoron)
Plectropomus truncatus	Akajin	Blue spotted grouper	Akajin, Agajin, Kurobanī (Okinawa)
Anyperodon leucogrammicus		Grouper	Yōrōmībai (Okinawa)
Cheilinus sp.	Hanabi-bera	Wrasse	Hirosā (Okinawa)
Alutera scripta	Sōshi-hagi	Filefish	Sensurū (Okinawa)
Sphyraena picuda	Doku-kamasu	Barracuda	Jikirukamasā (Okinawa), Kamasā (Miyako)
Siganus fuscescens	Aigo	Rabbitfish	Eiguwā
Zebrasoma veliferum	Raiden-hagi	Surgeonfish	Īgōgāsa (Okinawa)
Pogonoperca punctata	Ago-hata	Soapfish	Mībai, Yudayāgua (Okinawa)
Seriola sp.		Amberjack	
Charcarhinus sp.	Same	Shark	Fuka (Okinawa)

breaks of poisoning. In the Amami Islands intoxications by *Seriola* sp. and *Zebrasoma veliferum* were also reported.

At Yamakawa Machi in Kyushu Island, the northernmost place in this survey, neither ciguatoxic fish nor ciguatera poisoning case was reported.

The survey revealed an apparent decrease in both the numbers of species and toxicity of ciguatoxic fishes toward the northern areas from Okinawa.

Regionality of toxic area

The information we had received throughout the survey indicated that there was a great individual variation in toxicity even among the fish of a given species caught at the same fishing ground at the same time. On the other hand, it was also a general belief that there were some areas in which fishes were highly toxic. Such a pattern of narrow regionality has been recognized clearly by BANNER *et al.*[9] in the Central and South Pacific. It may be noteworthy that a sharp boundary between the toxic and non-toxic areas was indicated in some islands. For instance, *L. bohar* is believed to be toxic in the southern reefs of Kuruma Island, while non-toxic in the adjacent area in Miyako Island. The southern part of Toku-

noshima Island from Kametsu is reputed to be toxic, while the northern part is non-toxic. In Kin Bay in Okinawa, *S. fuscescens* was said to be poisonous when it settled on certain coral reefs. The suspected toxic areas are shown in Fig. 1 by shadows. In all of the areas pointed out as toxic, there are well-developed coral reefs, and this strongly suggests a close association of the toxic fishes with coral reefs.

General pattern of poisoning

It was easy to find out victims of poisoning in the Ryukyu and Amami Islands. A total of 93 persons who had experienced ciguatera were interviewed during the short survey trips and 99 case histories were collected: 11 in Amami-Oshima, 4 in Tokunoshima, 10 in Okinoerabu, 5 in Yoron, 42 in Okinawa, 4 in Miyako, and 23 in Ishigaki Islands. The separate record was prepared only for the latest case when a person interviewed had been poisoned more than twice by the same species of fish, but a record was prepared for each case when a person had been poisoned by different species.

The number of poisonings caused by each species are tabulated in Table 2. The poisoning from the ingestion of *L. bohar* comprises approximately 40% of the total and covers entire Ryukyu and Amami Islands. Poisonings due to *E. fuscoguttatus* were second and were recorded from Kamimotobu and Ie in northern district of Okinawa, Miyako, and Yaeyama Islands. In the Amami Islands two outbreaks were reported at Yoron Island. The reputation of this sea bass suggested latent poisoning cases in other regions. Outbreaks due to the moray eel, *G. flavimarginatus*, were rather few but covered the entire area investigated and involved many patients.

Table 2. Number of both outbreaks and patients and the parts eaten.

Toxic fishes	Outbreaks			Approx. no. of patients	Flesh	Flesh and head	Head	Others
	Ryukyu	Amami	Total					
L. bohar	22	17	39	230	28	7	2	Skin 1, Unknown 1
E. fuscoguttatus	10	2	12	45	3	3	1	Flesh and viscera 1, Flesh and skin 1, Stomach 1, Unknown 2
G. flavimarginatus	6	4	10	95	8	0	0	Unknown 2
V. louti	5	4	9	30	3	3	1	Flesh, liver, and head 1, Unknown 1
S. fuscescens	9	0	9	25	6	1	0	Unknown 2
L. monostigma	3	1	4	10	0	1	1	Flesh, head, bone, and viscera 1, Unknown 1
L. fulviflamma	1	0	1	5	0	1	0	
Cheilinus sp.	3	0	3	5	0	0	0	Flesh and skin 1, Viscera 1, Dorsal fin 1
S. picuda	1	0	1	1	1	0	0	
P. truncatus	1	0	1	4	0	0	1	
Serranus sp.	6	0	6	19	2	0	1	Flesh, head, and gill 1, Bone and skin 1, Unknown 1
Z. veliferum	0	1	1	1	1	0	0	
Charcarhinus sp.	2	0	2	2	0	0	1	Unknown 1
Seriola sp.	0	1	1	5	0	0	0	Viscera 1

The poisonings by *S. fuscescens* occurred at Ishikawa City and Katsuren Peninsula in the central part of Okinawa Island and at Ishigaki Island. In addition, there was unconfirmed information from Amami-Oshima on *S. fuscescens* intoxications.

Only three poisonings due to *L. monostigma* were found in Okinawa Island, though this species was considered by the local people to be much more toxic than the other species. Reputation of high toxicity of this species seemed to have kept people from eating it. Besides the fishes listed in Table 2, 6 outbreaks due to unidentified sea basses and 2 due to sharks were reported.

The number of poisonings over ten year periods, as shown in Fig. 2, suggests a slight increase of poisoning cases. It is evident that the occurrence of fish poisoning is not on the decrease and poisonings occurred since 1961 comprised about one third of the total.

A seasonal variation in outbreaks is shown in Fig. 3. Though there are many unknown cases, the poisonings by *L. bohar* and other species seem to be most frequent in the summer, especially in July to August. Further investigation seems necessary to decide whether this phenomenon reflects an increase of toxicity in summer or merely the increased catch of fish which consequently results in increased consumption of fish.

The poisonings by *S. fuscescens* centered in June and inhabitants in Ishigaki Island

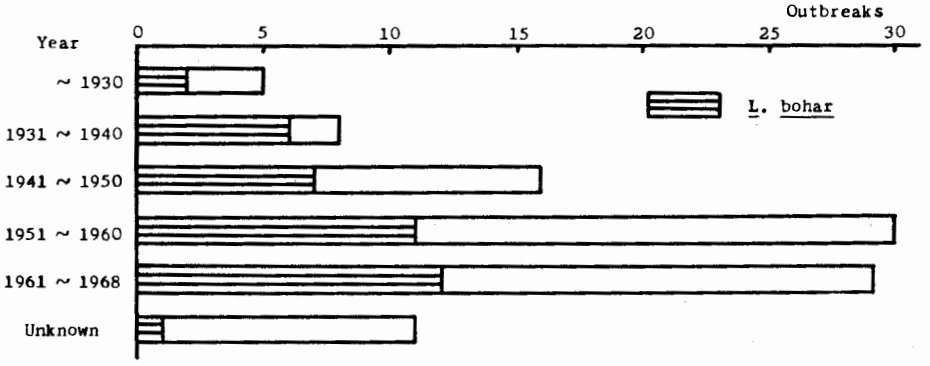

Fig. 2. Number of outbreaks over ten year periods in the Ryukyu and Amami Islands.

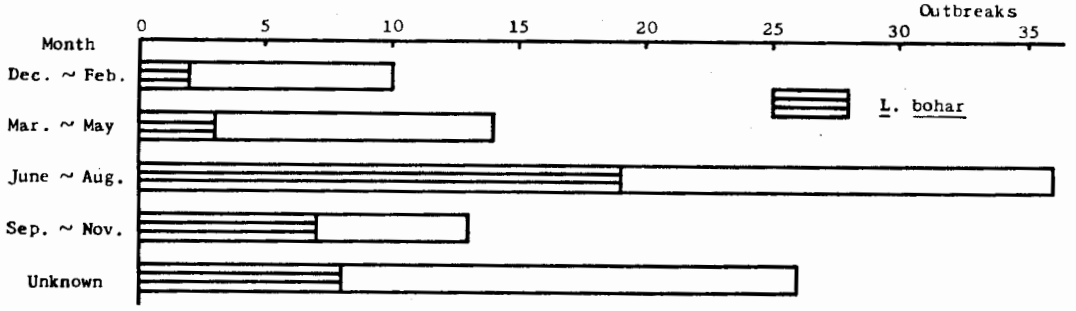

Fig. 3. Seasonal variation of fish poisoning occurred in the Ryukyu and Amami Islands.

insisted that the fish became toxic immediately after the heavy rainfall in the rainy season but soon became non-toxic.

The fact that the areas investigated were located at fish landing centers and that the causative fishes were consumed mostly by fishermen and their families suggested a short period of time from catching to consumption. Thus, the possibility that poisonings were due to putrefaction may be excluded.

Among the parts eaten by the patients, the flesh is first followed by the head only and finally flesh and head, as shown in Table 2. The viscera, especially the livers, were usually discarded and were involved only in a few cases because they were well-known to be strongly toxic. The flesh was consumed either raw or cooked, indicating that the toxin concerned is not destroyed during cooking.

It is a conspicuous feature of this poisoning that more than half the number of persons who ate the causative fishes became ill in 95 outbreaks with 4 exceptions. The reported symptoms were diarrhea, vomiting, dry-ice sensation, aching joints, fatigue, headache, and itching which appeared on the way to recovery. Besides these, abdominal pain, flushness of the face or body, numbness of hands, limbs and/or mouth, and fever were reported occasionally. The poisoning was rarely fatal. Most of the patients suffered from a tingling sensation when they touched water, and compared it to an electric shock. Because of the tingling sensation of the whole body, fishermen were forced to rest from labor for several days or even a few weeks and suffered a considerable economic loss.

Appearance of each symptom in the representative fish poisonings is shown in Table 3. There were some fishes for which only one case history was available. The following symptoms were reported on them: Dry-ice sensation and aching joints for *L. vaigiensis*; dry-ice sensation, aching joints, headache, flushness of the face, numbness, hypersalivation, and peeling off of mucosa in the mouth for *S. picuda*; aching joints and fatigue for *P. truncatus*. In 7 cases of poisoning due to other sea basses, dry-ice sensation and fatigue were observed in 3 patients, aching joints in 4, and diarrhea and vomiting in one, respectively. In 2 cases by sharks symptoms were ambiguous, except diarrhea and fatigue.

On the basis of symptoms observed, at least two different types of poisoning were apparent. The first type includes many species of fish such as *L. bohar, E. fuscoguttatus, G. flavimarginatus, V. louti, L. monostigma*, and others. The symptoms are characterized by acing joints, fatigue, and dry-ice sensation. The onset of poisoning varied from a few hours to a few days after ingestion. For complete recovery, a few days to a few weeks were required; even months in severe cases. The symptoms coincide well with those reported on ciguatera in the Central and South Pacific[11]. The second type is represented by *S. fuscescens*. The characteristic symptoms were headache and itching.

Legends for ciguatera

The following beliefs were reported as to origin of toxin, tests for toxic fish, and native

Table 3. Appearance of each symptom in percentage.

Toxic fishes	*L. bohar*	*E. fusco-guttatus*	*G. flavi-marginatus*	*V. louti*	*L. mono-stigma*	*S. fuscescens*
Diarrhea	28	50	50	33	75	11
Vomiting	23	17	10	33	25	11
Dry-ice sensation	74	17	10	89	75	0
Aching joints	90	83	100	89	100	11
Fatigue	77	75	70	44	50	22
Headache	21	17	20	33	50	67
Itching	41	8	50	33	25	67
Numbness around mouth and limbs	10	8	20	0	0	0
Flushing of face	10	8	20	0	0	22
Fever	5	0	10	11	25	11
Colic pain	15	8	0	22	25	0
Loss of appetite	10	8	30	22	25	0
Chills	0	8	0	11	0	0
Redness of skin	3	8	0	0	0	0
Others	Loss of hair 3, Flushing of whole body 3, Staggering 3	Dizziness 17				Hyperemia of eyes 22, abnormal sensation of mouth 33

remedies. Some of them are common with those collected by BANNER[12,13] in the tropical Pacific. 1) Fishes become toxic as a result of ingestion of toxic crabs, algae or corals. 2) A person who had experienced poisoning many times can distinguish a toxic fish by the taste test. 3) Especially in the case of *L. bohar* and *G. flavimarginatus*, small fishes are harmless. Lean fishes are harmful but fat ones are harmless. A fish with ripe gonads is not poisonous and the spent is poisonous. 4) Red snappers with pectoral fins not long enough to reach the proboscis are harmless. 5) The more black spots appear on the surface, the more toxic is *V. louti*. 6) Flies do not swarm on toxic fishes. 7) The viscera are the most poisonous and followed by the head and skin. The flesh is the least poisonous. 8) A drunk person is resistant to the poisoning. 9) Once poisoned, a man becomes more sensitive. 10) The flesh boiled with seasonings or cooked in soup is more toxic than "Sashimi", the raw flesh. 11) Toxicity of fish disappears during storage in frozen states. 12) The juice or infusion of leaves of "Suki", *Messerschmidia argentea* LINNÈ, is a good remedy for poisoning. At the onset of poisoning infusion of raw sugar is effective to lessen the severity of symptoms to some extent. The juice of balsam ("Shirotensagū" in Okinawa) is a good remedy for poisoning.

Turtle poisonings

During the survey four outbreaks of poisoning caused by ingestion of turtles were found[14]. One of them occurred in a research vessel of the Ryukyu Fisheries Research Laboratory at the Tōsa Islands. The symptoms were similar to those previously observed in Philippine[15], and included the erosion in the mouth, chills, nausea, headache, itching,

difficulty in swallowing, and loss of hair. It took a long time for complete recovery. Death occurred only in children, and in one case, an infant was affected through the breast milk. The inhabitants believed that the toxic species was a hybrid between the hawksbill turtle and another species. A photograph of the carapace of a turtle, which poisoned about 80 persons was obtained and sent to Dr. J. HENDRICKSON, Oceanics Institute of Hawaii, who identified it as a hawksbill turtle, *Eretmochelys imbricata imbricata* AGASSIZ. This toxic species was said to be caught only occasionally around the Yaeyama Islands, probably once in 4 or 5 years. As there was no poisoning case in northern areas, the Yaeyama Islands seemed to lie on the northernmost of the distribution of the toxic turtle.

Coconut crab poisoning

Sporadic outbreaks of coconut crab poisoning and some legends on the origin of toxin were found, which had not appeared in official reports. We obtained 5 case histories[16] although more could be collected easily in some districts. The symptoms were languor of the whole body, vomiting, and diarrhea which appeared within several hours after ingestion. Patients usually were forced to lie in bed for several days from exhaustion. Our investigation revealed that 4 out of 19 patients were killed. Pigs were involved in the poisoning by eating remnants of the crab, indicating that they are very sensitive to the toxin.

The coconut crab in question was called "Makkon" or "Makkan" locally and identified by Dr. S. MIYAKE, Zoological Laboratory, Faculty of Agriculture, Kyushu University, as *Birgus latro* LINNAEUS. The toxicity of coconut crab was reported to show a narrow regionality and to be related to the presence of some plants, locally called "Fubogi", "Gāna", or "Dōnattsu". "Fubogi" and "Gāna" were found to be identical. They were identified by Dr. S. KURATA, Department of Forestry, Faculty of Agriculture, The University of Tokyo, as *Diospyros maritima* BLUME BIJDR in the family Ebenacae and "Donattsu" as *Hernandia sonora* LINNAEUS in the family Hernandiacae. Coconut crabs were believed to become toxic when they feed on the fruits of "Fubogi" or dwell under "Dōnattsu".

According to Dr. BAGNIS, Institute of Medical Research "Louis Malardé", Tahiti (Private communication, 1968), a poisoning has recently occurred from the ingestion of coconut crabs in the Tuamotu Islands, French Polynesia. It was also reported by Mr. MOTE, World Life Research Institute, Palau (Private communication, 1968) that there is a belief on toxicity of coconut crabs in Palau. HOLTHUIS[17] referred in his recent paper to the following Balss' report that at Yap Island in the Carolines the native first leave the coconut crab for a few days before eating, so that the toxic substances by then have left its intestinal tract. These informations indicate that the coconut crab may cause poisonings within its range of distribution.

Discussion

The results obtained in the present survey, which was carried out on a rather limited scale, disclosed occurrence of a large number of fish poisonings in the Ryukyu Islands. Fishermen, fish dealers, and fish processors in the surveyed areas seemed to recognize the toxic species and toxic areas. They usually eliminate the suspected species before selling them at the fish market and take some precautions when they use the toxic fishes. For example, in Okinawa some of the ciguatoxic fishes are used as materials for fishcake "Kamaboko" after being stored for a long period in a freezer on the belief that the toxicity decreases during storage. We also confirmed experimentally that the water-soluble toxin which induced vomiting in cats disappeared gradually during storage in a freezer[6]. A process, involved in making "Kamaboko", which requires washing the minced meat with water, may effectively remove some of the water-soluble toxin. The toxicity of the product will be then reduced considerably by the addition of a large amount of non-toxic flesh. This precaution must have contributed toward diminishing outbreaks of poisoning to some extent. The fat-soluble toxin remains however unchanged during frozen storage for months and may not be leached out even if it is washed with water. Therefore, the use of toxic fish for "Kamaboko" still should be regarded as risky.

Among the patients interviewed during the survey, few had received medical treatment. This might have been related to difficulties in reaching medical aid, to high medical fees, or to a belief in both low mortality and mildness of ciguatera. These circumstances might have caused indifference of authorities to ciguatera, as evidenced by the fact that we could find out no official record on ciguatera. It seems urgent for the authorities concerned to be aware of the actual ciguatera situation and to prepare a counterplan as soon as possible.

Since poisonings due to both the turtle and coconut crab are known to occur occasionally in wide range of the tropical and subtropical regions and to cause deaths, a special precaution should be paid for these poisonings from the view point of public health. It may be noteworthy that the turtle is big enough to affect a large number of people at a time.

Summary

1. Frequent outbreaks of ciguatera poisonings in the Ryukyu and Amami Islands were disclosed, and 99 case histories were collected and analyzed.

2. Among about 20 species of fishes reported to be toxic, the followings were found to be the most frequently implicated: *Lutjanus bohar, L. monostigma, Gymnothorax* spp., *Epinephelus fuscoguttatus,* and *Variola louti.* Symptoms induced by these fishes were similar to each other and characterized by aching joints, languor, dry-ice sensation, diarrhea, and vomiting.

3. A rabbitfish, *Siganus fuscescens,* was reported to cause itching and headache in

a short period after a heavy rainfall in June.

4. Besides fish poisoning outbreaks of poisoning due to ingestion of toxic turtles and coconut crabs were confirmed.

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References

1) B. W. HALSTEAD: Poisonous and Venomous Marine Animals of the World, Vol. 2, U.S. Government Printing Office, Washington D. C. (1967).
2) P. HELFRICH, T. PIYAKARNCHANA, and P. S. MILES: Occasional Papers of B. Bishop Museum, **23**(14), 305–369 (1968).
3) P. HELFRICH and A. H. BANNER: *ibid.*, 371–382 (1968).
4) P. J. SCHEUER, W. TAKAHASHI, J. TSUTSUMI, and T. YOSHIDA: *Science*, **155**, 1267–1268 (1967).
5) K. M. LI: *Science*, **147**, 1580–1581 (1965).
6) Y. HASHIMOTO and T. YASUMOTO: This Bull., **31**, 452–458 (1965).
7) M. MORI, T. SAITO, Y. NAKANISHI, K. MIYAZAWA, and Y. HASHIMOTO: This Bull., **32**, 137–145 (1966).
8) Y. HASHIMOTO, S. KONOSU, T. YASUMOTO, A. INOUE, and T. NOGUCHI: *Toxicon*, **5**, 85–90 (1967).
9) A. H. BANNER and P. HELFRICH: Tech. Rep. No. 3, Hawaii Marine Laboratory, Univ. of Hawaii (1964).
10) Y. HIYAMA: Report of an Investigation of Poisonous Fishes in the South Sea, Nissan Fisheries Experimental Station, Japan (1943).
11) P. HELFRICH: *Hawaii Med. J.*, **22**, 361–372 (1963).
12) A. H. BANNER: *South Pacific Bulletin*, 18–45, Oct. (1961).
13) A. H. BANNER, S. W. SHAW, C. B. ALENDER, P. HELFRICH: South Pacific Commission Technical Paper, No. 141, 1–17, Sep. (1963).
14) Y. HASHIMOTO, S. KONOSU, and T. YASUMOTO: Tech. Rep. IV, Lab. of Marine Biochem., Fac. of Agr., Univ. of Tokyo, April (1967).
15) I. A. RONQUILLO *et al.*: IPFC Technical Papers, No. 47 (1964).
16) Y. HASHIMOTO, S. KONOSU, T. YASUMOTO, and H. KAMIYA: Tech. Rep. VIII, Lab. of Marine Biochem., Fac. of Agr., Univ. of Tokyo, Dec. (1967).
17) L. B. HOLTHUIS: *Crustaceana*, **15**(2), 215–222 (1968).