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Problems of Toxicants in Marine Food Products

1. Marine Biotoxins

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The expansion of marine fisheries into tropical waters, which is now occurring, will increase the risks of widespread poisonings because of the abundance of biotoxins in warm-water organisms. However, toxic marine organisms are not only a health hazard but also a possible source of new pharmaceutical products.

A classification of marine intoxicants is given in this paper with special reference to the oral biotoxins which will be of primary concern in the expansion of warm-water fisheries. The biotoxins are both invertebrate (e.g., molluscs, arthropods) and vertebrate (mostly fishes) in origin. Biotoxications of vertebrate origin may be caused by the muscles, the gonads or the blood of certain fishes or by special poison glands not equipped with traumagenic devices. (Venomous fishes, having poison glands and traumagenic spines, etc., are of no direct concern as oral intoxicants.)

The ichthyosarcotoxic fishes, in which the flesh is poisonous, appear to constitute the most significant health hazard. A list of fishes reported as causing ciguatera poisoning (one of the most serious and widespread forms of ichthyosarcotoxism) is included in this paper.

Marine fisheries comprise some of the world's most valuable protein food resources. It is generally recognized that an intelligent utilization of these resources is now urgently needed for the survival of the human species. The steady increase in world population, the resulting food demands and their associated logistic problems present some of the greatest technological challenges of our age. In recent years, the tremendous potential of the oceans to produce harvestable protein has become apparent and most nations are rapidly expanding their fisheries operations and are penetrating further into unexploited areas of the oceans. Recent studies indicate that the most rapidly growing fisheries are not in temperate seas but are in tropical waters (Chapman, 1965).[7] Moreover, there is a growing trend towards utilizing a greater variety of marine organisms, including invertebrate animals and seaweeds. Because of the abundance of biotoxins throughout the warm seas of the world, the expansion of fisheries operations in tropical seas, and the increased interest in utilizing a greater array of marine organisms for food, opportunities for human contacts with these poisons are becoming greater.

Although marine biotoxications have been known for many centuries, they have received only cursory attention by most health authorities because previously there was only limited opportunity for members of the public to come into contact with these poisons. However, this picture is now undergoing very rapid changes and in view of the current world food priorities, the entire subject of marine biotoxins is being given careful and critical consideration. Toxicologists, public health workers and food economists are becoming acutely aware of the dangers of environmental intoxicants. This awareness has been intensified by the discovery of the carcinogenic properties of mycotoxins, the newer knowledge of natu-

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[7] Chapman, W. M. (1965) *Food from the sea*, The Van Camp Sea Food Company (mimeographed document).

rally-occurring marine biotoxins and observations of the devastating effects of industrial contaminants in the marine biotope. As man attempts to harness ocean resources, toxic marine organisms will become increasingly important since they are an integral part of the biological economy of the sea. Toxic marine organisms are not only a health hazard, but they also constitute a vast, untapped supply of biodynamic agents that are only now beginning to be utilized and recognized as a valuable source of new pharmaceuticals.

The purpose of this paper is to review briefly some of the various types of marine biotoxins, to discuss their public health implications as they relate to future world food supply and to indicate the need for a more effective international surveillance programme in order to provide for optimum utilization of our marine resources.

CLASSIFICATION OF MARINE BIOTOXINS

Marine biotoxins are naturally occurring poisons derived directly from marine organisms. In the broad sense of the term, marine biotoxins include bacterial poisons, but as generally used by most biotoxicologists, the designation refers specifically to biotoxins produced by higher plants and animals. Biotoxins are of 2 major types: phytotoxins, or plant poisons, and zootoxins, or animal poisons. Although marine phytotoxins are known to exist, there is very little information concerning them. Marine zootoxins can be classified into 3 major groups: (1) oral biotoxins—those that are poisonous to eat; (2) parenteral biotoxins or venoms—poisons produced by specialized venom glands and injected by means of traumagenic devices (teeth or spines); and (3) crinotoxins—biotoxins that are produced by specialized poisons glands. Crinotoxic organisms lack a traumagenic organ; consequently, these biotoxins are usually released directly into the water. The degree to which crinotoxic organisms are involved in human oral intoxications is not known. Since this report is concerned solely with oral intoxicants, venomous and crinotoxic organisms will not be given further attention. Moreover, bacterial food poisoning will not be discussed.

The term " poisonous " may be used in the generic sense referring to both oral and parenteral poisons, but it is more commonly used in the specific sense to designate oral poisons. Thus, all venoms are poisons but not all poisons are venoms. Oral marine zootoxins are generally thought to be substances of small molecular size whereas most venoms are generally believed to have a large molecular size—a protein or a toxic substance in close association with a protein. Our knowledge of the chemistry of crinotoxins is too meagre, and the types of poisons too diverse, to permit generalizations to be made at this time.

In most instances, the chemical and pharmacological properties of these poisons are unknown. The rapidly growing literature on marine biotoxicology indicates that there is a vast array of these toxic substances, and it is estimated that probably less than 1% of the marine biotoxic species have been examined for their biodynamic activity.

Our present system of classification of marine zootoxins attempts to take into consideration the phylogenetic relationships of the etiological organisms, the clinical characteristics of the biotoxication and the chemical nature of the poisons involved. This classification can at this time be considered as only tentative, pending further elucidation of the chemical and pharmacological properties of these poisons.

ORAL MARINE BIOTOXICATIONS OF INVERTEBRATE ORIGIN

COELENTERATES

The consumption of sea anemones in some parts of the Philippines, New Guinea and Samoa has caused gastrointestinal and neurological disorders and these animals have sometimes been used for criminal purposes.

The toxicity arises from the nematocysts and from certain substances contained in the tentacular tissues that are harmful when eaten (Halstead, 1965).

ECHINODERMS

Poisoning by sea urchins, for example, *Paracentrotus lividus* in Europe, *Tripneustes ventricosus* in West Africa and *Diadema antillarum* in the West

Indies, during their reproductive period is comparable with the type described for coelenterates. It consists of digestive disorders with nausea, vomiting, diarrhoea and attacks of migraine. To explain these poisonings, it should be recalled that the gonads are essentially tissues whose physiological activity increases the nearer the sea urchin is to maturity. Rich in enzymes such as arginase, they contain many unstable ingredients which are very easily broken down to give rise to compounds that are in many cases toxic.

PARALYTIC SHELLFISH POISONING

This biotoxication is caused by the ingestion of toxic shellfish, i.e., clams, oysters, mussels, or various other molluscs that have been feeding on toxic dinoflagellates. Outbreaks have been reported in North America, Europe, Africa, Asia, and the Pacific islands, as shown in the following tabulation.

Reported Cases of Shellfish Poisoning

AFRICA
South Africa: 1948

AUSTRALASIA
New Zealand: 1951

CENTRAL AMERICA
Mexico, Pacific coast: 1939

EUROPE
Belgium: 1938
British Isles: 1827, 1857, 1872, 1888, 1890, 1904, 1909
France, North Sea coast: 1907
Germany: 1885, 1939
Norway, Baltic coast: 1901, 1939

NORTH AMERICA
Canada, Pacific coast: 1793, 1934
USA, Atlantic coast: 1936, 1945
USA, Pacific coast: 1903, 1915, 1917, 1927, 1929, 1930, 1932, 1933, 1936, 1937, 1939, 1942, 1944, 1946, 1948

Biotoxications are caused by a specific neurotoxin that has been designated as paralytic shellfish poison or saxitoxin ($C_{10}H_{17}O_4N_7 \cdot 2\ HCl$) (Schuett & Rapoport, 1962; Mosher, 1966). Neurotoxic symptoms usually develop within 30 minutes after ingestion of the shellfish. The symptoms consist of paraesthesias such as tingling, burning or numbness about the mouth, lips and tongue which then spread over the face, scalp and neck to the fingertips and toes. There may be disturbances in sensory perception, ataxia, incoherent speech,, dizziness, tightness of the throat, chest pains, weakness, malaise, headaches, hypersalivation, thirst, nausea, vomiting, loss of reflexes and muscular weakness. Death is usually attributed to respiratory paralysis. The case fatality rate is said to be as high as 10% (Halstead, 1965; Russell, 1965).

CALLISTIN SHELLFISH POISONING

This biotoxication is caused by ingestion of the Japanese callista clam, *Callista brevisiphonata*. The ovary of this clam contains a high concentration of choline during the spawning season. Intoxications have occurred only during the months of May to September in Japan. The onset of symptoms is rapid, usually less than 1 hour, and consist of itching, flushing of the face, urticaria, sensation of construction of the chest, epigastric and abdominal pain, nausea, vomiting, paralysis or numbness of the throat, mouth, and tongue, sweating, chills and fever. The victim usually recovers within a period of 2 days. No fatalities have been reported. The Japanese Government has prohibited the harvesting of these shellfish for a certain period after outbreaks have occurred. Cooking does not destroy the toxic properties of the shellfish and the degree of freshness of the organism is not a factor in the occurrence of the disease.

TRIDACNA CLAM POISONING

Giant clams of the species *Tridacna maxima*, commonly eaten in French Polynesia, may sometimes give rise to digestive disorders and serious disturbances of the nervous system, such as paraesthaesia, lack of motor co-ordination, ataxia and tremor. Such an outbreak occurred at Bora-Bora in the Society Islands in 1964 (Bagnis, 1967). About 30 persons were affected and there were 2 deaths. Numerous domestic animals which had eaten the remnants of the toxic products also died.

Toxicological study of the specimens taken at the time has not yet led to the isolation of a pure compound. The maximum concentration of the poison is in the mantle and viscera of the clam (Banner, 1967).

VENERUPIN SHELLFISH POISONING

This form of shellfish poisoning is due to the ingestion of toxic bivalve shellfish taken from certain regions of Japan during the months of December to April. Only 2 species of shellfish have been involved—the Japanese oyster (*Crassostrea gigas*) and the asari (*Tapes (Venerupis) semidecussata*). Symptoms usually develop within a period of 48 hours after ingestion of the molluscs and consist of gastrointestinal upset, headache, nervousness, bleeding of the gums, halitosis, jaundice, petechial haemorrhages, ecchymosis, leucocytosis, anaemia, retardation of the blood-clotting time and evidences of disturbances of liver function, enlargement of the liver, delirium, coma, and death in about 33% of the cases. The poison is believed to be derived from shellfish which have been feeding on the toxic dinoflagellate *Exuviaella mariae-lebouriae*. The Japanese Government has placed affected areas under quarantine during periods of danger. Ordinary cooking procedures do not destroy the poison (Akiba, 1943, 1949; Akiba & Hattori, 1949; Hattori & Akiba, 1952; Nakazima, 1965a, 1965b, 1965c; Halstead, 1965).

CEPHALOPOD POISONING

Intoxications resulting from the ingestion of toxic cephalopods have been caused by the ingestion of squid and octopus taken from certain specific areas in Japan. From 1952 to 1955, there were 779 outbreaks involving 2874 persons and 10 deaths. Routine bacteriological tests were negative. It was believed that the poisoning was due to a biotoxin of an unknown nature. Symptoms developed within a period of 10–20 hours and consisted of a gastrointestinal upset, abdominal pain, headache, weakness, paralysis and convulsions. Most of the victims recovered within a period of 48 hours. Ordinary cooking procedures apparently did not destroy the poison (Motohiro & Tanikawa, 1952a; Kawabata, Halstead & Judefind, 1957; Halstead, 1965).

WHELK POISONING

This form of poisoning is caused by the ingestion of whole whelks or ivory shells, i.e., molluscs of the genus *Neptunea*. The poison is found in the salivary glands of the mollusc and consists of tetramine. Human intoxications have occurred in Japan. Symptoms consist of intense headaches, dizziness, nausea, vomiting, visual impairment and dryness of the mouth. No deaths have been reported. Ordinary cooking procedures do not destroy the poison (Asano, 1952; Halstead, 1965).

ABALONE POISONING

Poisoning due to the consumption of the viscera of abalone (also called ormers) has been known for a very long time, particularly in the Island of Hokkaido in Japan where 2 highly prized species are allegedly responsible, namely, *Haliotis discus* and *Haliotis sieboldi*. The symptoms are a severe local reaction with urticaria, erythema, pruritus, subcutaneous infiltration and sometimes ulceration of the skin. The skin lesions are restricted to the parts of the body exposed to the sun. This is one of the rare disorders in which photosensitization is caused in man by the consumption of animal products.

The toxic product is said to be a photodynamic principle derived from the chlorophyll contained in the seaweeds on which the abalone feed.

CRAB AND LOBSTER POISONING

Lethal biotoxications due to eating crabs and lobsters have been reported from various tropical Pacific islands (Cooper, 1964; Hashimoto et al., 1967; South Pacific Commission, 1968 [1]) but very little research has been conducted so far on this group of arthropod poisons. One study on the nature of crab poisons, based on toxicology and thin-layer chromatography, has shown that the toxin in some of these crabs, is closely related to, or identical with, saxitoxin (Konosu et al., 1968). The clinical characteristics consist of gastrointestinal upset, anaesthesia of the mouth, numbness of the limbs, loss of motor co-ordination, unconsciousness, aphasia, muscular paralysis and death within a period of several hours. Ordinary cooking procedures do not destroy the poison.

ORAL MARINE BIOTOXICATIONS OF VERTEBRATE ORIGIN

Most marine biotoxications of vertebrate origin are caused by fishes, and a tentative classification of ichthyotoxic fishes follows (Halstead, 1967).

POISONOUS FISHES

Defined as fishes which, when ingested, cause a biotoxication in humans due to a toxic substance present in the fish. Fishes that may become accidentally contaminated by bacterial food pathogens are not included.

Ichthyosarcotoxic fishes

Those fishes that contain a poison within the flesh in the broadest sense, i.e., musculature, viscera,

[1] South Pacific Commission (1968) *Report of technical meeting on fisheries*, Nouméa, New Caledonia (mimeographed document).

skin or slime (mucus), which when ingested by humans will produce a biotoxication. The toxins are oral poisons believed to be substances of small molecular size that are generally not destroyed by heat or gastric juices. The various kinds of biotoxicity recognized among ichthyosarcotoxic fishes are as follows:

(1) Poisonous cyclostomes (lampreys and hagfishes) causing cyclostome poisoning.

(2) Poisonous elasmobranchs (sharks and rays) causing elasmobranch poisoning.

(3) Ciguatoxic fishes causing ciguatera poisoning.

(4) Tetrodotoxic fishes causing puffer-fish poisoning.

(6) Scombrotoxic fishes causing scombroid-fish poisoning.

(7) Hallucinogenic fishes causing hallucinatory fish-poisoning.

(8) Gempylotoxic fishes causing gempylid-fish poisoning.

Ichthyootoxic fishes

Those fishes that produce a poison which is generally restricted to the gonads of the fish. The musculature and other parts of the fish are usually edible. There is a definite relationship between gonadal activity and toxin production. Fishes in this group are mainly freshwater species, but a few marine species have been incriminated.

Ichthyohaemotoxic fishes

Those fishes having poisonous blood. The poison is usually destroyed by heat and gastric juices.

ICHTHYOCRINOTOXIC FISHES

Those fishes that produce a poison by means of glandular structures, independent of a true venom apparatus, i.e., poison glands are present but there is no traumagenic device.

VENOMOUS OR ACANTHOTOXIC FISHES

Those fishes that produce poisons by means of glandular structures and are equipped with a traumagenic device to transmit their venoms. The poisons are parenteral toxins, usually large molecules, and are readily destroyed by heat or gastric juices. Venomous fishes are of no direct concern as oral marine intoxicants, the most serious biotoxications of public health importance being produced by ichthyosarcotoxic fishes.

TYPES OF ICHTHYOSARCOTOXISM

Cyclostome poisoning

The slime and flesh of certain lampreys and hagfishes are reported to produce a gastrointestinal disturbance, nausea, vomiting and dysenteric diarrhoea. The slime and skin are said to contain a poison which is not destroyed by gastric juices or heat. The chemical and pharmacological properties of the poison are not known (Coutière, 1899; Pawlowsky, 1927; Halstead, 1958, 1964; South Pacific Commission, *op. cit.*; Russell, 1956) and no control measures exist. These fish could be used in the preparation of marine protein concentrates.

Elasmobranch poisoning

The musculature of some sharks, such as the Greenland shark (*Somniosus microcephalus*) is said to be poisonous to eat (Jensen, 1914, 1948), and the livers of several species of tropical sharks may cause severe intoxication (Coutaud, 1879; Coutière, 1899; Phisalix, 1922; Fish & Cobb, 1954; Halstead, 1959; Helfrich, 1961). While the musculature may cause symptoms of a mild gastroenteritis, ingestion of toxic shark livers may have very severe effects, with the onset of symptoms within a period of less than 30 minutes. Nausea, vomiting, diarrhoea, abdominal pain, headache, weak pulse, malaise, cold sweats, oral paraesthesia, and a burning sensation of the tongue, throat, and oesophagus may be present.

The neurological symptoms develop later and consist of extreme weakness, trismus, muscular cramps, a sensation of heaviness of the limbs, the loss of superficial reflexes, ataxia, delirium, incontinence, respiratory distress, visual disturbances, convulsions and death. The recovery period, if the victim recovers, varies from several days to several weeks. The mortality rate is not known. The severity of the symptoms varies with the amount of shark liver eaten, the species of shark, physical condition of the victim and other factors which are not clearly understood. The nature of the poison is unknown but it is not destroyed by heat or gastric juices. There are no control measures in existence. These fish could be used in the preparation of marine protein concentrates.

Chimaera poisoning

The musculature and viscera of some of the chimaeras or ratfishes have been found to be toxic. Unfortunately, very little is known concerning either the clinical characteristics of the biotoxication or the chemical nature of the poison. No control measures exist. These fish could be used in the production of marine protein concentrates.

Ciguatera fish poisoning

Ciguatera is one of the most serious and widespread forms of ichthyosarcotoxism. This biotoxication is caused largely by tropical shore-fishes, and more than 400 species have so far been incriminated (see Annex). Ciguatoxic fishes constitute a serious threat to the development of tropical shore-fisheries because many of the toxic species are generally regarded as valuable food fishes. In many instances, useful food fishes suddenly, and without warning, become poisonous, and it is believed that they do so because they have been feeding upon some noxious material such as toxic algae, invertebrates, fishes, etc. It is not known exactly how these fishes become poisonous, but an edible population can apparently become poisonous within a matter of hours or days and may remain toxic for a period of years. Ciguatera is most prevalent in subtropical and tropical latitudes, but the greatest concentration of ciguatoxic fishes seems to be around the tropical Pacific islands and in the Caribbean area.

Symptoms of ciguatera poisoning consist of paraesthesias of the lips, tongue and limbs; gastro-intestinal disturbances are generally present. Victims frequently complain of myalgia, joint aches and profound muscular weakness. The so-called paradoxical sensory disturbance in which the victim interprets cold as a "tingling, burning, dry-ice, or electric-shock sensation", or hot objects may give a feeling of cold, is said to be pathognomonic. Severe neurological disturbances consisting of ataxia, generalized motor inco-ordination, diminished reflexes, muscular twitching, tremors, dysphonia, dysphagia, clonic and tonic convulsions, coma and muscular paralysis may be present. The case fatality rate is said to be about 7%.

Ciguatera is a complex poison which appears to have several fractions. There is a fat-soluble fraction which is a light yellow, viscous oil having an empirical formula: $C_{28}H_{52}NO_5Cl$. It is thought to be a quaternary ammonium compound (Mosher, 1966). There is also a water-soluble fraction which is present in some ciguatoxic fishes, but it is not known which fraction or fractions is or are responsible for the ciguatera syndrome in humans. There is some evidence that at least one of the fractions of ciguatoxin is an irreversible anticholinesterase. Pharmacological studies show that ciguatoxin affects the neuromuscular, respiratory, cardiac and vascular systems, but all of the effects have not been delineated (Rayner, Kosaki & Fellmeth, 1968; Kosaki & Anderson, 1968; South Pacific Commission, op. cit). The treatment is largely symptomatic. Ordinary cooking procedures do not destroy the poison. No public health control measures exist except for those used in large Japanese fish markets, and those controls are based on samplings of suspect specimens which are tested by bioassay.

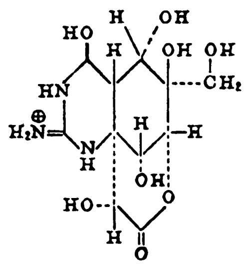
PUFFER-FISH POISONING OR TETRODOTOXISM

Tetraodon poisoning is one of the most violent forms of fish poisoning. It is produced by tetraodontoid fishes. The disease is characterized by rapidly developing violent symptoms. Tetrodotoxic fishes are most common in subtropical and tropical areas.

The biotoxication is characterized by paraesthesias of the lips and tongue which gradually spreads to include the extremities and later develops into severe numbness. The numbness may later involve the entire body. Gastrointestinal disturbances may or may not be present. Respiratory distress is a prominent part of the clinical picture, and the victim later becomes intensely cyanotic. Petechial haemorrhages, blistering and severe desquamation may develop. Ataxia, aphonia, dysphagia, muscular twitchings, tremors, incoordination, paralysis and convulsions are frequently present. The victim may become comatose, but in most instances remains conscious until shortly before death. Treatment is symptomatic. The case fatality rate is 61%. If death occurs, it usually takes place within the first 24 hours.

Pharmacological studies have shown that the primary action of tetrodotoxin is on the nervous system, producing both central and peripheral effects. Relatively low doses of the poison will readily inhibit neuromuscular function. Major effects include respiratory failure and hypotension. It is believed that puffer-fish poison has a direct action on respiratory centres; there is some evidence that tetrodotoxin depresses the vasomotor centre. The neuromuscular paralysis may be due to inhibition of conductivity (Iwakawa & Kimura, 1922; Yano, 1938; Murtha, 1960; Nagayosi, 1941, cited by Murtha, 1960; Katagi, 1927). The intraperitoneal LD_{50} for mice is said to be 0.02 g per g of body weight, killing the mice within 3.4–3.7 minutes. The empirical formula of tetrodotoxin is $C_{11}H_{19}O_9N_3$ and the molecular weight is 400. The probable structural arrangement is shown below (Goto, Kishi & Hirata, 1962a, 1962b;

Goto, Kishi et al., 1963a, 1963b, 1964a, 1964b, 1964c; Goto, Takahashi et al., 1964a, 1964b, 1964c; South Pacific Commission, *op. cit.*; Tsuda, 1963; Tsuda, Hayatsu et al., 1952; Tsuda, Ikuma et al., 1962a, 1962b, 1962c, 1962d; Tsuda & Kawamura, 1950, 1951, 1952a, 1952b, 1953; Tsuda, Kawamura & Hayatsu, 1958, 1960; Tsuda & Shan-hai, 1951; Tsuda, Tachikawa et al., 1964; Tsuda, Tamura et al., 1964; Tsuda & Umezawa, 1951; Woodward, 1964):



In Japan, the use of puffer-fish for human consumption is rigidly controlled by public health authorities. Ordinary cooking procedures do not destroy the poison.

Clupeotoxism

This is a form of ichthyosarcotoxism caused by fishes of the order Clupeiformes which includes the families Clupeidae (herrings), Engraulidae (anchovies), Elopidae (tarpons), Albulidae (bonefishes), Pterothrissidae (deep-sea bonefishes) and Alepocephalidae (deep-sea slickheads). The families most commonly incriminated in human clupeotoxications are Clupeidae and Engraulidae. Clupeotoxism is a sporadic, unpredictable public health problem of the tropical Atlantic Ocean, the Caribbean Sea and the tropical Pacific Ocean. Most poisonings have occurred in tropical island areas and were caused by fishes that had been captured close to shore. The viscera are regarded as the most toxic part of the fish. Tropical clupeiform fishes are most likely to be toxic during the warm summer months. There is no possible way to detect a toxic clupeiform fish by its appearance and the degree of freshness has no bearing on its toxicity. The clinical characteristics of clupeotoxism are distinct and usually violent. The first indication of poisoning is a sharp metallic taste which may be present immediately after ingestion of the fish. This is rapidly followed by a severe gastrointestinal upset which may be accompanied by a drop in blood pressure, cyanosis, and other evidences of a vascular collapse. Concurrently, or within a short period, a variety of neurological disturbances develop—nervousness, dilated pupils, violent headaches, numbness, tingling, hypersalivation, muscular cramps, respiratory distress, paralysis, convulsions, coma and death. Death may occur in less than 15 minutes. There are no accurate statistics on the case fatality rate, but it is reported to be very high. Treatment is symptomatic. There is no information available on the pharmacological or chemical properties of the poison and there are no public health control measures. These fish are likely to be involved in the manufacture of marine protein concentrates.

Scombrotoxism

This form of ichthyosarcotoxism is caused largely by fishes of the suborder Scombroidei, all of which are members of the single family Scombridae—the tunas and related species. Scombroid poisoning is generally caused by the improper preservation of scombroid fishes, which results in certain bacteria acting on histidine in the muscle of the fish converting it to saurine, a histamine-like substance. This is the only known form of ichthyosarcotoxism in which bacteria play an active role in toxin production within the body of the fish. The symptoms of scombroid poisoning resemble those of histamine intoxication. Symptoms usually develop within a few minutes after ingestion of the toxic fish and are intense headache, dizziness, throbbing of the carotid and temporal vessels, epigastric pain, burning of the throat, cardiac palpitation, rapid weak pulse, dryness of the mouth, thirst, inability to swallow, gastrointestinal upset, diarrhoea, abdominal pain, generalized erythema, urticarial eruptions, severe pruritus, swelling and flushing of the face, bronchospasm, suffocation and severe respiratory distress. There is danger of shock, and deaths have been reported. In rare instances, scombroid fishes have been involved in both scombroid and ciguatera poisoning in the same individual. The victim usually recovers within a period of 1 or several days. Treatment requires the use of antihistaminic drugs. On a world-wide scale, scombrotoxism accounts for the greatest overall morbidity rate of any single type of ichthyosarcotoxism. There are no public health control measures. Some scombroid species may be used in the manufacture of marine protein concentrate. The poison is not destroyed by ordinary cooking procedures.

Hallucinatory fish poisoning (ichthyoallyeinotoxism)

This form of ichthyosarcotoxism is caused by the ingestion of certain types of reef fishes which occur in the tropical Pacific and Indian Oceans. The families incriminated in ichthyoallyeinotoxism include the following: Acanthuridae, Kyphosidae, Mugilidae, Mullidae, Pomacentridae, Serranidae and Siganidae. Ichthyoallyeinotoxism may result from eating the flesh or the head of the fish where the poison is reputedly concentrated. This biotoxication is sporadic and unpredictable in its occurrence. The poison affects primarily the central nervous system. The symptoms may develop within a few minutes to 2 hours and persist for 24 hours or longer. Symptoms are dizziness, loss of equilibrium, lack of motor co-ordination, hallucinations and mental depression. A common complaint of the victim is that " someone is sitting on my chest," or there is a sensation of a tight construction around the chest. The conviction that he is going to die, or some other frightening phantasy, is a characteristic part of the clinical picture. Other complaints consist of itching, burning of the throat, muscular weakness and abdominal distress. No fatalities have been reported, and in comparison with other forms of ichthyosarcotoxism, hallucinogenic fish poisoning is relatively mild. There is no information available concerning the pharmacological and chemical properties of the poison. There are no public health control measures. Ordinary cooking procedures do not destroy the poison.

Gempylid-fish poisoning

Gempylotoxism is caused by ingestion of the flesh of fishes of the family Gempylidae—the escolars or pelagic mackerels—which contains an oil with a pronounced purgative effect. The purgative oil is present also in the bones, and sucking on the rich, oily bones may also result in diarrhoea. Gempylid poisoning is usually not a serious matter and many native groups esteem these fishes despite their purgative effects. Ordinary cooking procedures do not destroy the purgative effect of the oil.

POISONOUS MARINE TURTLES

Toxic marine turtles may cause a type of poisoning about which little is known. However, the cases reported bear witness to its serious nature. While most species may be eaten without fear, in the tropical parts of the Pacific, and particularly around the islands of Japan, some turtles may become extremely toxic.

Species known to have caused poisoning in man are the green turtle (*Chelonia mydas*), the leatherback turtle (*Dermochelys coriacea*) and, above all, the hawksbill turtle (*Eretmochelys imbricata*) found in the waters around the Philippines, India, New Guinea, Tahiti and Japan.

From the clinical point of view, the symptoms may become manifest in a few hours to several days after consumption of the turtle meat and consist of nausea, vomiting, diarrhoea, abdominal cramps, vertigo, a dry burning sensation in the lips and the tongue and irritation of the mouth and pharynx. Difficulty in swallowing, excessive salivation and a stomatopharyngitis may occur quite late but are all the more serious in that they bring about difficulty in breathing. Later still, red papules of the size of a pin-head appear on the tongue and finally ulcerate. If the poisoning is severe, the patient becomes somnolent and prostrate; this is a bad sign and precedes death from damage to the liver and kidneys. The case fatality rate is about 44%. Treatment is purely symptomatic.

MARINE MAMMALS

Several species have been blamed for poisonings. The polar bear (*Thalarctos maritimus*) is encountered throughout the Arctic regions and there have been numerous cases of poisoning due to ingestion of the liver. The main symptoms are intense formication, stabbing frontal headaches, nausea, vomiting, diarrhoea, apathy, giddiness, irritability, collapse, photophobia and convulsions. The condition is rarely fatal and the patient usually recovers in a few days. It is believed that the toxicity may be due to the large quantities of vitamin A present in some polar-bear tissues.

Certain species of seals, such as the bearded seal (*Erignathus barbatus*), sea-lions, such as Péron's sea-lion (*Neophoca cinerea*), whales and dolphins, have been blamed in various parts of the world for disorders of the same kind.

RÉSUMÉ

PROBLÈMES POSÉS PAR LA PRÉSENCE DE SUBSTANCES TOXIQUES DANS LES PRODUITS ALIMENTAIRES D'ORIGINE MARINE: 1. BIOTOXINES

L'apport de la pêche marine aux ressources alimentaires mondiales en protéines est considérable et on assiste actuellement à un essor de ce genre d'industrie, surtout dans les régions tropicales. Cette tendance, de même que l'incorporation dans l'alimentation humaine d'une variété toujours plus grande de produits de la mer, accroit fortement les risques d'exposition aux poisons (biotoxines) d'origine marine. En revanche, si les organismes marins toxiques sont une cause non négligeable de morbidité, ils constituent aussi un immense réservoir d'agents biodynamiques, dont l'étude est à peine entamée, qui présentent un intérêt certain en tant que source potentielle de nouvelles substances pharmaceutiques.

On distingue parmi les biotoxines deux types: les phytotoxines, d'origine végétale, sont très peu connues; les zootoxines sont d'origine animale. Ces dernières comprennent les biotoxines « orales », ingérées en même temps que le produit marin; les biotoxines « parentérales », produites par des glandes spéciales et inoculées par l'intermédiaire de certains organes (dents, épines); les crinotoxines, généralement libérées directement dans le milieu. Seules les biotoxines orales sont envisagées dans le présent article.

Des intoxications peuvent survenir après ingestion de divers organismes marins invertébrés: troubles gastro-intestinaux et neurologiques provoqués par les anémones de mer; paralysies causées par la neurotoxine de certains mollusques; troubles variés succédant à la consommation de palourdes, d'huîtres, de céphalopodes, de buccins, de crabes, de homards ou d'haliotides.

On reconnaît, parmi les intoxications dues à des organismes marins vertébrés (en majorité des poissons), huit types différents d'ichtyosarcotoxisme (empoisonnement par la chair du poisson), l'ichtyootoxisme (la substance toxique est concentrée dans l'appareil génital de l'organisme marin) et l'ichtyohémotoxisme (le sang du poisson est toxique). Il existe aussi des poissons ichtyocrinotoxiques (le poison est sécrété par certaines glandes) et des poissons acanthotoxiques (le poison est inoculé par l'intermédiaire de structures spéciales).

L'ichtyosarcotoxisme, intoxication de loin la plus dangereuse pour l'homme, doit retenir particulièrement l'attention au regard du développement des activités de pêche marine. Une de ses variétés les plus répandues est l'empoisonnement de type « ciguatera ». A ce jour, plus de 400 espèces de poissons, dont la liste est donnée en annexe, ont été reconnues responsables de troubles de ce genre. Dans beaucoup de cas, le poisson devient toxique après s'être nourri d'algues, d'invertébrés ou d'autres poissons qui renferment la toxine. D'autres intoxications humaines ont pour origine l'ingestion de la chair de tétrodons, de clupéidés ou de scombridés. Certains empoisonnements de type « hallucinogène » surviennent après consommation de la chair de certaines espèces coralliennes de l'océan Pacifique et de l'océan Indien. La symptomatologie clinique de ces manifestations est brièvement exposée dans chaque cas.

Pour la plupart des substances biotoxiques, les données chimiques et pharmacologiques font actuellement défaut. Leur présence éventuelle dans les préparations commerciales de farines ou de concentrés de protéines de poisson, dont la production est en constante augmentation, doit inciter à envisager d'urgence des mesures plus strictes de contrôle toxicologique de ces aliments.

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Annex

LIST OF FISHES REPORTED AS CIGUATOXIC[1]

Species	*Geographical distribution*
Family ALBULIDAE—ladyfishes	
Albula vulpes—ladyfish	Red Sea to Hawaii
Family CHANIDAE—milkfishes	
Chanos chanos—milkfish	Indo-Pacific
Family CLUPEIDAE—herrings	
Anodontostoma chacunda—shirt-finned gizzard shad	Indo-Pacific
Clupanodon thrissa—sprat	Indo-Pacific
Clupea sprattus—sprat	North-eastern Atlantic and Mediterranean
C. tropica—sprat	Indo-Pacific
Dussumieria acuta—round herring	Indo-Pacific
Harengula humeralis—sardine	Florida, Bermuda, West Indies to Brazil
H. ovalis—sardine	Indo-Pacific, Red Sea
H. zunasi—sardine	Indo-Pacific
Ilisha africana—herring	West coast of Africa from Senegal to Gulf of Guinea
Macrura ilisha—sablefish	Persian Gulf, India, Ceylon, Burma, Viet-Nam
Nematolosus nasus—gizzard shad	Indo-Pacific
Opisthonema oglinum—Atlantic thread herring	West Indies
Sardinella fimbriata—sardine	Indo-Pacific
S. longiceps—sardine	Indo-Pacific
S. perforata—sardine	Indo-Pacific
S. sindensis—sardine	Indo-Pacific
Family ELOPIDAE—tarpons	
Megalops cyprinoides—tarpon	Indo-Pacific
Family ENGRAULIDAE—anchovies	
Engraulis encrasicholus—anchovy	Eastern Atlantic and Mediterranean
E. japonicus—anchovy	China, Japan, Korea, Taiwan
E. ringens—anchovy	Coasts of Peru and Chile
Thrissina baelama—anchovy	Indo-Pacific
Family SYNODONTIDAE—lizardfishes	
Synodus variegatus—lizardfish	Indo-Pacific
Family CONGRIDAE—true eels	
Conger cinereus marginatus—conger eel	Indo-Pacific
C. conger—conger eel	Atlantic Ocean, Asia, Africa
Family MURAENIDAE—moray eels	
Echidna nebulosa—spotted eel	Indo-Pacific
Gymnothorax buroensis—moray eel	Indo-Pacific
G. flavimarginatus—moray eel	Indo-Pacific
G. funebris—green moray eel	Caribbean and south to Brazil
G. javanicus—moray eel	Indo-Pacific
G. kidako—moray eel	Japan
G. meleagris—moray eel	Indo-Pacific, Japan
G. moringa—spotted moray eel	Gulf of Mexico to Brazil
G. petelli—moray eel	Indo-Pacific
G. pictus—moray eel	Indo-Pacific
G. thyrsoideus—moray eel	Indo-Pacific

[1] All the species of fish appearing in this list are illustrated in Halstead (1967).

Species	*Geographical distribution*
Family MURAENIDAE—moray eels (*cont.*)	
G. tile—moray eel	Indo-Pacific
G. undulatus—moray eel	Indo-Pacific
Muraena albigutta—moray eel	Coast of Peru
M. argus—moray eel	Gulf of California to Peru
M. helena—moray eel	Eastern Atlantic and Mediterranean
M. insularum—moray eel	Eastern Pacific
M. lentiginosa—moray eel	Pacific coast of America
Family OPHICHTHYIDAE—snake eels	
Callechelys muraena—blotched snake eel	Florida
Echelus myrus—worm eel	Mediterranean
Leiuranus semicinctus—snake eel	Indo-Pacific
Myrichthys tigrinus—tiger snake eel	Oregon to Panama
Ophichthus ocellatus—pale-spotted eel	South Carolina to Brazil
O. ophis—spotted snake eel	West Indies
Oxystomus serpens—snake eel	Eastern Atlantic and Mediterranean
Family BELONIDAE—needlefishes	
Belone belone—garfish	Eastern Atlantic and Mediterranean
B. platyura—flat-tailed needlefish	Indo-Pacific
Strongylura acus—needlefish	Atlantic and Mediterranean
S. caribbaea—needlefish	West Indies
Family EXOCOETIDAE—flyingfishes	
Cypselurus callopterus—flyingfish	Panama and Galapagos Islands
Family HEMIRAMPHIDAE—halfbeaks	
Hemiramphus brasiliensis—halfbeak	Tropical Atlantic
H. marginatus—halfbeak	Indo-Pacific, Red Sea
H. saltator—longfin halfbeak	Mexico to northern Peru, Galapagos Islands
Hyporhamphus dussumieri—halfbeak	Indo-Pacific
H. laticeps—halfbeak	Indo-Pacific
H. unifasciatus—halfbeak	Gulf of California to northern Peru
Family AULOSTOMIDAE—trumpetfishes	
Aulostomus chinensis—trumpetfish	Indo-Pacific
Family SYNGNATHIDAE—seahorses	
Hippocampus hippocampus—seahorse	Eastern Atlantic and Mediterranean
Family HOLOCENTRIDAE—squirrelfishes	
Holocentrus diadema—squirrelfish	Indo-Pacific
H. lacteoguttatus—squirrelfish	Indo-Pacific
H. microstomus—small-mouth squirrelfish	Tropical Indo-Pacific
H. praslin—squirrelfish	Indo-Pacific
H. ruber—squirrelfish	Indo-Pacific
H. sammara—squirrelfish	Indo-Pacific
H. spinifer—squirrelfish	Indo-Pacific
H. tiere—squirrelfish	Indo-Pacific
Myripristis adustus—soldierfish	Indo-Pacific
M. argyromus—soldierfish	Indo-Pacific
M. berndti—soldierfish	Indo-Pacific
M. bowditchae—soldierfish	Indo-Pacific
M. chryseres—soldierfish	Indo-Pacific
M. microphthalmus—small-eye soldierfish	Indo-Pacific
M. murdjan—soldierfish	Indo-Pacific
M. occidentalis—soldierfish	Lower California to Panama
M. pralinius—soldierfish	Indo-Pacific

Species	*Geographical distribution*
Family ACANTHURIDAE—surgeonfishes	
Acanthurus achilles—surgeonfish	Indo-Pacific
A. bleekeri—surgeonfish	Indo-Pacific
A. chirurgus—surgeonfish	Tropical Atlantic
A. dussumieri—surgeonfish	Indo-Pacific
A. gahhm—surgeonfish	Indo-Pacific
A. glaucopareius—surgeonfishes	Indo-Pacific
A. leucosternon—striped surgeonfish	Indo-Pacific
A. lineatus—lined surgeonfish	Indo-Pacific
A. mata—surgeonfish	Hawaii
A. nigrofuscus—surgeonfish	Indo-Pacific
A. olivaceus—orange spot surgeonfish	Indo-Pacific
A. triostegus—convict surgeonfish	Indo-Pacific
A. triostegus sandvicensis—convict surgeonfish	Hawaii
A. xanthopterus—surgeonfish	Indo-Pacific
Ctenochaetus cyanoguttatus—surgeonfish	Indo-Pacific
C. striatus—surgeonfish	Indo-Pacific
C. strigosus—surgeonfish	Indo-Pacific
Naso brevirostris—unicornfish	Indo-Pacific
N. lituratus—unicornfish	Indo-Pacific
N. unicornis—unicornfish	Indo-Pacific
N. vlamingi—unicornfish	Indo-Pacific
Prionurus punctatus—surgeonfish	Baja California to Galapagos Islands
Zebrasoma flavescens—yellow tang	Indo-Pacific
Z. rostratum—tang	Indo-Pacific
Z. scopas—tang	Indo-Pacific
Z. veliferum—sailfin tang	Indo-Pacific
Family APOGONIDAE—cardinalfishes	
Apogon bandanensis—cardinalfish	Indo-Pacific
A. frenatus—cardinalfish	Indo-Pacific
A. robustus—cardinalfish	Indo-Pacific
Cheilodipterus macrodon—cardinalfish	Indo-Pacific
Paramia quinquelineatus—cardinalfish	Indo-Pacific
Family ARRIPIDAE—sea perches	
Arripis georgianus—tommy rough	Australia
A. trutta—sea perch	Australia
Family BLENNIIDAE—blennies	
Entomacrodus decussatus—blenny	Indo-Pacific
Ophioblennius steindachneri—blenny	Pacific coast of Mexico to Galapagos Islands
Family CARANGIDAE—jacks	
Carangoides ajax—jack	Hawaii
C. ferdau jordani—jack	Indo-Pacific
C. gymnostethoides—jack	Indo-Pacific
Caranx bartholomaei—yellowjack	West Indies
C. caballus—greenjack	Pacific coast of tropical America
C. cheilio—jack	Hawaii
C. crysos—jack	Tropical Atlantic
C. fasciatus—jack	West Indies
C. fulvoguttatus—jack	Indo-Pacific
C. hippos—jack	Tropical Atlantic
C. ignobilis—jack	Indo-Pacific
C. latus—horse-eye jack	Tropical western Atlantic
C. lugubris—jack	Circumtropical

Species	*Geographical distribution*
Family CARANGIDAE—jacks (*cont.*)	
C. melampygus—jack	Indo-Pacific
C. ruber—bar jack	West Indies
C. sexfasciatus—jack	Indo-Pacific
Elagatis bipinnulatus—rainbow runner	Circumtropical
Oligoplites saliens—leatherjack	West Indies
Scomberoides sanctipetri—leatherjack	Indo-Pacific
Selar crumenophthalmus—horse-eye jack	Circumtropical
Selene vomer—lookdown	Atlantic coast of tropical America
Seriola dumerili—amberjack	Indo-Pacific
S. falcata—almaco jack	West Indies
S. fasciata—lesser amberjack	West Indies
S. peruana—amberjack	Coast of Peru
S. zonata—banded rudderfish	Cape Cod to Hatteras
Trachinotus bailloni—pompano	Tropical Indo-Pacific
T. falcatus—permit	Atlantic coast of tropical America
T. glaucus—palmometa	Western Atlantic
Trachurus trachurus—horse mackerel	North Atlantic
Vomer setapinnis—Atlantic moonfish	Atlantic coast of tropical America
Zalocys stilbe—surge fish	Pacific coast of Mexico
Family CHAETODONTIDAE—butterflyfishes	
Chaetodon auriga—butterflyfish	Indo-Pacific
C. citrinellus—butterflyfish	Indo-Pacific
C. ephippium—butterflyfish	Indo-Pacific
C. falcula—butterflyfish	Indo-Pacific
C. lunula—butterflyfish	Indo-Pacific
C. nigrirostris—butterflyfish	Lower California, Panama Bay
C. ornatissimus—butterflyfish	Indo-Pacific
C. reticulatus—butterflyfish	Indo-Pacific
C. trifasciatus—butterflyfish	Indo-Pacific
C. unimaculatus—butterflyfish	Indo-Pacific
Heniochus acuminatus—butterflyfish	Indo-Pacific
H. permutatus—butterflyfish	Indo-Pacific
Holacanthus passer—angelfish	West coast of tropical America
Pomacanthus imperator—emperor angelfish	Indo-Pacific
Pygoplites diacanthus—angelfish	Indo-Pacific
Family CIRRHITIDAE—hawkfishes	
Paracirrhites cinctus—hawkfish	Indo-Pacific
Family CORYPHAENIDAE—dolphins	
Coryphaena hippurus—dolphin	Pelagic—all tropical and temperate seas
Family GEMPYLIDAE—oilfishes	
Ruvettus pretiosus—oilfish	Tropical Atlantic and Indo-Pacific
Family GERRIDAE—silverfishes	
Gerres baconensis—silverfish	Indo-Pacific
G. cinereus—silverfish	Both coasts of America
Family GOBIDAE—gobies	
Acentrogobius viridipunctatus—goby	Indo-Pacific
Ctenogobius criniger—goby	Indo-Pacific
Glossogobius giurus—white goby	Indo-Pacific
Oligolepis acutipennis—goby	Indo-Pacific
Zonogobius semidoliatus—goby	Indo-Pacific

Species	*Geographical distribution*
Family ISTIOPHORIDAE—sailfishes	
Istiophorus greyi—Pacific sailfish	Lower California to Peru
Family KUHLIIDAE—bass	
Kuhlia marginata—mountain bass	Indo-Pacific
Family KYPHOSIDAE—rudderfishes	
Doydixodon freminvillei—rudderfish	Galapagos Islands
Kyphosus cinerascens—rudderfish	Indo-Pacific
Family LABRIDAE—hogfishes	
Bodianus diplotaenius—hogfish	Gulf of California to Peru and Galapagos Islands
B. eclancheri—hogfish	Northern Peru and Galapagos Islands
B. iagonensis—hogfish	Coast of tropical West Africa
B. rufus—Spanish hogfish	Florida and West Indies
Cheilinus fasciatus—wrasse	Indo-Pacific
C. rhodochrous—wrasse	Indo-Pacific
C. trilobatus—wrasse	Indo-Pacific
C. undulatus—giant green wrasse	Indo-Pacific
Cheilio inermis—wrasse	Indo-Pacific
Coris gaimardi—wrasse	Indo-Pacific
C. julis—rainbow wrasse	Eastern Atlantic and Mediterranean
Ctenolabrus suillus—wrasse	Coasts of Europe
Epibulus insidiator—wrasse	Indo-Pacific
Halichoeres trimaculatus—wrasse	Indo-Pacific
Lachnolaimus maximus—hogfish	Florida and West Indies
Thalassoma lunare—wrasse	Tropical Indo-Pacific
T. purpureum—wrasse	Indo-Pacific
Family LUTJANIDAE—snappers	
Aphareus furcatus—snapper	Indo-Pacific
Aprion virescens—blue snapper	Indo-Pacific
Gnathodentex aureolineatus—snapper	Indo-Pacific
Gymnocranius griseus—snapper	Indo-Pacific
Lethrinus haematopterus—snapper	Indo-Pacific
L. harak—snapper	Indo-Pacific
L. kallopterus—snapper	Indo-Pacific
L. mambo—snapper	New Caledonia
L. microdon—snapper	Indo-Pacific
L. miniatus—grey snapper	Indo-Pacific
L. nebulosus—snapper	Indo-Pacific
L. ornatus—snapper	Indo-Pacific
L. rhodopterus—snapper	Indo-Pacific
L. variegatus—snapper	Indo-Pacific
Lutjanus apodus—snapper	Tropical Atlantic
L. aratus—snapper	Gulf of California to Ecuador
L. argentimaculatus—snapper	Indo-Pacific
L. argentiventris—snapper	Gulf of California to northern Peru
L. aya—red snapper	Western tropical Atlantic
L. bohar—red snapper	Indo-Pacific
L. coatesi—red snapper	Australia
L. cyanopterus—Caribbean red snapper	Florida and West Indies
L. gibbus—red snapper	Tropical Indo-Pacific
L. janthinuropterus—snapper	Indo-Pacific
L. jocu—dog snapper	Florida and West Indies
L. johni—snapper	Indo-Pacific
L. kasmira—snapper	Indo-Pacific

Species	*Geographical distribution*
Family LUTJANIDAE—snappers (*cont.*)	
L. monostigmus—snapper	Indo-Pacific
L. nematophorus—snapper	Australia
L. peru—snapper	Coast of Peru
L. rivulatus—snapper	Indo-Pacific
L. semicinctus—snapper	Indo-Pacific
L. vaigiensis—red snapper	Indo-Pacific
L. viridis—snapper	Gulf of California to Panama
Lythrulon flaviguttatum—snapper	Guaymas to Panama
Monotaxis grandoculis—snapper	Indo-Pacific
Ocyurus chrysurus—yellowtail snapper	Southern Florida to Brazil
Plectorhinchus lineatus—snapper	Indo-Pacific
P. nigrus—snapper	Indo-Pacific
P. pictus—snapper	Indo-Pacific
Family MUGILIDAE—mullets	
Chelon engeli—mullet	Indo-Pacific
C. vaigiensis—mullet	Indo-Pacific
Crenimugil crenilabis—mullet	Indo-Pacific
Mugil cephalus—common mullet	Cosmopolitan
Family MULLIDAE—goatfishes	
Mulloidichthys auriflamma—goatfish	Indo-Pacific
M. erythrinus—goatfish	Indo-Pacific
M. samoensis—goatfish	Indo-Pacific
Parupeneus bifasciatus—goatfish	Indo-Pacific
P. chryserydros—goatfish	Indo-Pacific
P. luteus—goatfish	Indo-Pacific
P. trifasciatus—goatfish	Indo-Pacific
Upeneus arge—goatfish	Indo-Pacific
U. prayensis—goatfish	Coast of tropical West Africa
Family PEMPHERIDAE—sweeperfishes	
Pempheris oualensis—sweeperfish	Indo-Pacific
Family POMACENTRIDAE—damselfishes	
Abudefduf glaucus—damselfish	Indo-Pacific
A. johnstonianus—damselfish	Indo-Pacific
A. saxatilis—damselfish	Gulf of California to northern Peru
A. septemfasciatus—damselfish	Indo-Pacific
A. sexfasciatus—damselfish	Indo-Pacific
A. sordidus—damselfish	Indo-Pacific
Dascyllus marginatus—damselfish	Indo-Pacific
D. trimaculatus—damselfish	Indo-Pacific
Pomacentrus arcifrons—damselfish	Cocos Island, Galapagos Islands
P. bifasciatus—damselfish	Indo-Pacific
P. leucorus—damselfish	Revilla Gigedo Islands to Galapagos Islands
P. lividus—damselfish	Indo-Pacific
P. nigricans—damselfish	Indo-Pacific
Family POMADASYIIDAE—grunts	
Anisotremus interruptus—grunt	Gulf of California to Ecuador
A. scapularis—grunt	Gulf of California to northern Peru
Orthopristis cantharinus—grunt	Galapagos Islands
Family PRIACANTHIDAE—snapper	
Priacanthus cruentatus—glasseye snapper	Circumtropical

Species	*Geographical distribution*
Family SCARIDAE—parrotfishes	
Chlorurus gibbus—parrotfish	Indo-Pacific
C. pulchellus—parrotfish	Indo-Pacific
Euscarus cretensis—parrotfish	Eastern Atlantic and Mediterranean
Scarops perrico—parrotfish	Mazatlan to Galapagos Islands
Scarus blochi—parrotfish	Indo-Pacific
S. brevifilis—parrotfish	Indo-Pacific
S. coeruleus—blue parrotfish	Florida, West Indies, Panama
S. croicensis—striped parrotfish	West Indies to Florida
S. dussumieri—parrotfish	Indo-Pacific
S. enneacanthus—parrotfish	Indian Ocean
S. forsteri—parrotfish	Indo-Pacific
S. ghobban—parrotfish	Indo-Pacific
S. guacamaia—rainbow parrotfish	Florida to Brazil
S. guttatus—parrotfish	Indo-Pacific
S. harid—pink parrotfish	Indo-Pacific
S. jonesi—blue parrotfish	Indo-Pacific
S. microrhinos—parrotfish	Indo-Pacific
S. noyesi—parrotfish	Gulf of California to Panama
S. perspicillatus—parrotfish	Hawaii and Johnston Islands
S. sordidus—parrotfish	Indo-Pacific
S. vermiculatus—parrotfish	Indo-Pacific
S. vetula—queen parrotfish	West Indies to Florida
Family SCATOPHAGIDAE—spade fishes	
Scatophagus argus—spade fish	Indo-Pacific
Family SCIAENIDAE—croakers	
Johnius umbra—croaker	Eastern Atlantic and Mediterranean
Nibea sina—croaker	Indo-Pacific
Odontoscion eurymesops—croaker	Galapagos Islands
Family SCOMBRIDAE—tunas	
Acanthocybium solandri—wahoo	Circumtropical
Euthynnus affinis—wavyback skipjack	Indo-Pacific
E. alletteratus—little tuna	Circumtropical
E. pelamis—oceanic skipjack	Circumtropical
Sarda sarda—Atlantic bonito	Atlantic Ocean
Scomberomorus cavalla—king mackerel	Tropical Atlantic
Family SCORPAENIDAE—scorpionfish	
Pterois volitans—zebrafish	Indo-Pacific
Scorpaena brasiliensis—barbfish	Atlantic coast of tropical America
S. grandicornis—lionfish	Atlantic coast of tropical America
S. plumieri—spotted scorpionfish	Tropical Atlantic
S. porcus—sea scorpion	Eastern Atlantic and Mediterranean
S. scrofa—hog scorpionfish	Eastern Atlantic and Mediterranean
Scorpaenopsis gibbosus—humped scorpionfish	Indo-Pacific
Sebastes marinus—redfish	Atlantic Ocean
Family SERRANIDAE—groupers	
Anyperodon leucogrammicus—grouper	Indo-Pacific
Cephalopholis argus—spotted grouper	Indo-Pacific
C. fulvus—coney	Florida and West Indies
C. leopardus—grouper	Indo-Pacific
C. miniatus—grouper	Indo-Pacific
C. urodelus—grouper	Indo-Pacific
Dermatolepis punctatus—grouper	West coast of Mexico to Cocos Islands

Species	*Geographical distribution*
Family SERRANIDAE—groupers (*cont.*)	
Epinephelus adscensionis—rock hind	Florida and West Indies
E. akaara—grouper	Ryukyus, Japan, China
E. areolatus—grouper	Indo-Pacific
E. corallicola—grouper	Tropical Indo-Pacific
E. elongatus—grouper	Indo-Pacific
E. fuscoguttatus—grouper	Indo-Pacific
E. guttatus—red hind	South Carolina to Brazil
E. hexagonatus—grouper	Indo-Pacific
E. labriformis—grouper	Gulf of California to Galapagos Islands
E. macrospilos—rock cod	Indo-Pacific
E. maculatus—grouper	Indo-Pacific
E. merra—grouper	Indo-Pacific
E. morio—red grouper	Western tropical Atlantic
E. morrhua—grouper	Indo-Pacific
E. socialis—grouper	Indo-Pacific
E. tauvina—black seabass	Indo-Pacific
Mycteroperca bonaci—blackfin grouper	Western tropical Atlantic
M. olfax—blackfin grouper	Mexico to Panama
M. tigris—tiger grouper	West Indies
M. venenosa—yellowfin grouper	Western tropical Atlantic
Paralabrax humeralis—grouper	Galapagos Islands
Paranthias furcifer—creolefish	Cuba to Brazil
Plectropomus leopardus—grouper	Indo-Pacific
P. maculatus—grouper	Indo-Pacific
P. oligacanthus—grouper	Indo-Pacific
P. truncatus—grouper	Indo-Pacific
Promicrops lanceolatus—giant seabass	Indo-Pacific
Rypticus saponaceus—soapfish	Tropical and subtropical Atlantic
R. saponaceus bicolor—soapfish	Baja California to Galapagos Islands
Variola louti—grouper	Indo-Pacific
Family SIGANIDAE—rabbitfishes	
Siganus fuscescens—rabbitfish	Indo-Pacific
S. lineatus—rabbitfish	Indo-Pacific
S. oramin—rabbitfish	Indo-Pacific
S. puellus—rabbitfish	Indo-Pacific
S. rostratus—rabbitfish	Indo-Pacific
S. spinus—rabbitfish	Indo-Pacific
Family SPARIDAE—porgys	
Calamus calamus—saucereye porgy	Florida and West Indies
C. taurinus—porgy	Galapagos Islands and Peru
Evynnis cardinalis—porgy	China and Japan
Pagellus erythrinus—porgy	Black Sea, Mediterranean and eastern Atlantic
Pagrus pagrus—porgy	Eastern Atlantic and Mediterranean
Sparus auratus—porgy	Eastern Atlantic
S. berda—porgy	Indo-Pacific
S. latus—porgy	Japan
S. sarba—porgy	Indo-Pacific
Stenotomus chrysops—scup	Southern USA, West Indies
Family SPHYRAENIDAE—barracudas	
Sphyraena barracuda—great barracuda	All tropical seas with exception of eastern Pacific
S. chinensis—barracuda	Indo-Pacific
S. forsteri—Forster's barracuda	Indo-Pacific
S. guachancho—guaguanche	Florida and south to Panama

Species	*Geographical distribution*
Family SPHYRAENIDAE—barracudas (*cont.*)	
S. idiastes—barracuda	Indo-Pacific
S. nigripinnis—barracuda	Japan
S. picudilla—southern sennet	West Indies to Brazil
S. sphyraena—barracuda	Eastern Atlantic and Mediterranean
Family XIPHIIDAE—swordfishes	
Xiphias gladius—swordfish	Temperate seas
Family ZANCLIDAE	
Zanclus cornutus—moorish idol	Indo-Pacific
Family BOTHIDAE—flounders	
Bothus mancus—flounder	Mexico and west to Indian Ocean
Scophthalmus rhombus—lefteye flounder	Coasts of Europe from Scandinavia to Mediterranean
Family ALUTERIDAE—filefishes	
Alutera monoceros—unicorn filefish	All warm seas
A. punctata—filefish	Senegal, Sierra Leone
A. schoepfi—orange filefish	Atlantic coast of tropical America
A. scripta—scrawled filefish	All warm seas
Anacanthus barbatus—filefish	Indo-Pacific
Pseudaluteres nasicornis—filefish	Indo-Pacific
Family BALISTIDAE—triggerfishes	
Abalistes stellaris—triggerfish	Indo-Pacific
Balistapus undulatus—triggerfish	Indo-Pacific
Balistes capistratus—triggerfish	Indo-Pacific
B. capriscus—triggerfish	Tropical Atlantic and Mediterranean
B. verres—triggerfish	Pacific coast of tropical America
B. vetula—triggerfish	Tropical Atlantic, Mediterranean and Indian Ocean
Balistoides conspicillum—triggerfish	Indo-Pacific
B. viridescens—triggerfish	Indo-Pacific
Canthidermis maculatus—rough or spotted triggerfish	Indo-Pacific, Tropical and subtropical Atlantic
C. sobaco—triggerfish	West Indies
C. viola—triggerfish	Philippines
Melichthys buniva—triggerfish	Indo-Pacific
M. vidua—triggerfish	Indo-Pacific
Odonus niger—triggerfish	Indo-Pacific
Pseudobalistes flavimarginatus—triggerfish	Indo-Pacific
P. fuscus—triggerfish	Indo-Pacific
Rhinecanthus aculeatus—triggerfish	Indo-Pacific
R. rectangulus—triggerfish	Indo-Pacific
R. verrucosus—triggerfish	Indo-Pacific
Family MONACANTHIDAE—filefishes	
Amanses sandwichiensis—filefish	Indo-Pacific
Monacanthus chinensis—filefish	Indo-Pacific
Navodon tessellatus—filefish	Philippines
Oxymonacanthus longirostris—filefish	Indo-Pacific
Paramonacanthus cryptodon—filefish	Indo-Pacific
Pervagor melanocephalus—filefish	Indo-Pacific
P. tomentosus—filefish	Indo-Pacific
Pseudomonacanthus macrurus—filefish	Indo-Pacific
Stephanolepis hispidus—planehead filefish	Tropical Atlantic
S. setifer—pygmy filefish	Indo-Pacific

Species	*Geographical distribution*
Family OSTRACIONTIDAE—trunkfishes	
Acanthostracion quadricornis—cowfish	Western Atlantic
Kentrocapros aculeatus—trunkfish	Indo-Pacific
Lactophrys trigonus—trunkfish	Western Atlantic
Lactoria cornuta—trunkfish	Indo-Pacific
L. diaphana—trunkfish	Indo-Pacific
Ostracion meleagris—trunkfish	Indo-Pacific
O. tuberculatus—trunkfish	Indo-Pacific
Rhinesomus bicaudalis—spotted trunkfish	Western Atlantic
R. gibbosus—trunkfish	Indo-Pacific
R. triqueter—smooth trunkfish	Atlantic coast of USA
Rhynchostracion rhinorhynchus—long-nosed trunkfish	Indo-Pacific
Family BATRACHOIDIDAE—toadfishes	
Coryzichthys gangene—toadfish	Indo-Pacific
Opsanus pardus—leopard toadfish	Gulf of Mexico
O. tau—oyster toadfish	Western Atlantic
Thalassophryne reticulata—toadfish	Panama
Family ANTENNARIIDAE	
Histrio histrio—sargassumfish	All tropical seas
Family LOPHIIDAE	
Lophiomus setigerus—goosefish	Indo-Pacific
Lophius piscatorius—goosefish	North Atlantic
Family OGCOCEPHALIDAE	
Ogcocephalus vespertilio—longnose batfish	West Indies