The Aquatic Biotic Environment and Its Biotoxins

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The aquatic world, together with its animal kingdom, is renowned for its enchanting beauty (Fig. 2.1). In particular, the vast tropical coral reefs offer a shimmering, glittering underwater panorama featuring an infinite variety of hues, sometimes clashing but always ultimately harmonising. In some cases, however, these beautiful shapes, elegant movements and profusion of colours seem to go hand in hand with disease and death. This is one of the great paradoxes of the aquatic world.

An analysis of the map of the hydrosphere shows that the centre of the world of potentially harmful aquatic animals is the great area of the Indian and Pacific Oceans, although aquatic animals of less aggressive type are present in all the seas. The defence and/or offence mechanisms of marine fauna can be of two different types, physical or chemical (Table 2.1). Some observations of the latter type have unveiled a fascinating sector of marine biology that is still largely a mystery.

Aquatic biotoxicology is the science that studies aquatic biological toxins, and as this book focuses above all on the skin damage that can be wrought by poisonous or venomous aquatic creatures, it seems wise to start off with an overall classification of poisonous aquatic animals [1–5].

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Fig. 2.1 *Hyppocampus guttulatus* (sea horse) (Courtesy of Drs. Pablo Helman and Susanna Volpe, "Il quaderno blu", Provincia di Imperia Ed., 1995)

Table 2.1 Aquatic animals and types of lesions they provoke

1. **Aquatic animals inducing mechanical injuries**
Sharks
Giant manta rays
Barracuda
Moray eels
Giant groupers
Sawfish
Piranhas
Alligators
Crocodiles
Gavials of the Ganges
Seals
Sea lions
Polar bears
Walruses
Killer whales
Giant squid

Table 2.1 (continued)

2. **Venomous aquatic animals: Invertebrates**
Porifera (sponges)
Coelenterates (hydroids, sea anemones, jellyfish, corals)
Annelidae (Polychaeta)
Molluscs (cone shells, cephalopods)
Echinoderms (starfish, sea urchins)
Arthropods (aquatic bugs)
3. **Venomous aquatic animals: Vertebrates**
Venomous fish
Stingrays
Catfish
Moray eels
Weeverfish
Scorpionfish
Surgeonfish
Flying gurnards
Venomous snakes
Sea snakes
Freshwater snakes
Venomous freshwater mammals
Platypus
4. **Poisonous aquatic animals: Invertebrates**
Protozoa
Coelenterates (sea anemones, corals)
Echinoderms (sea urchins, sea cucumbers)
Arthropods (crabs, lobsters)
5. **Poisonous aquatic animals: Vertebrates**
Ichthyosarcotoxic fish
Ciguatoxic fish
Surgeonfish
Triggerfish
Butterflyfish
Dolphins
Wrasses
Mullet
Morays eels
Parrotfish
Mackerel
Porgies
Barracuda
Clupeotoxic fish
Herrings
Anchovies
Scombrotoxic fish
Hallucinogenic fish
Sea chub
Tetrodotoxic fish
Puffer fish
Porcupine fish
Sunfish

(continued)

Table 2.1 (continued)

Ichthyotoxic fish
Sturgeon
Gars
Whitefish
Catfish
Codfish
Ichthyohaemotoxic fish
Freshwater eels
Crabs
Ichthyocrinotoxic fish
Lampreys
Hagfish
Pufferfish
Other poisonous vertebrates
Amphibians
Salamanders
Newts
Frogs
Toads
Reptiles
Turtles
Marine mammals
Dolphins
Porpoises
Whales
Polar bears
Sea lions
Walruses
Seals
6. **Aquatic animals with an electrical mechanism**
Torpedinidae

2.1 Toxic Aquatic Animals

The brief classification of poisonous aquatic animals listed below includes a large number of species living in enormously different geographical areas and habitats [2].

2.1.1 Invertebrates

Invertebrate poisonous aquatic animals, i.e., those with no backbone, can be subdivided into the following groups or phyla.

1. Protozoa

   This group includes single-cell planktonic organisms with which man can come in contact when eating molluscs or fish that feed on Dinoflagellates.

2. Porifera
   Some sponges produce chemical substances that are highly irritant to the skin.
3. Cnidaria (Coelenterata)
   Few species of Coelenterates are poisonous to eat but most of them are venomous.
4. Platyhelminthes
   Various species of Platyhelminthes are considered poisonous to eat.
5. Annelida
   Some Polychaetae worms are equipped with irritant hairs or spines, while others have venomous glands.
6. Mollusca
   Many bivalvular molluscs are transvectors of various toxic substances. The cone shell and the octopus are included in this class of molluscs with a venomous apparatus.
7. Arthropoda
   Some species of Asiatic crabs are poisonous to eat. There are also a few species of poisonous aquatic insects, belonging to five different families of bugs that inhabit freshwater.
8. Echinodermata
   Some species of sea urchins are poisonous because their eggs are toxic, and so are some sea cucumbers.

2.1.2 Vertebrates

1. Poisonous and venomous fishes
   Many fish can cause human bio-intoxication when eaten, due to the presence of toxic substances. This class does not include fish that have been accidentally contaminated by pathogenic bacteria. The largest category is that of ichthysarcotoxic fish, that contain poisonous substances in their muscles, viscera or skin, that obviously cannot be destroyed by heat or gastric juices. The second major category of poisonous fish is that of ichthyocrinotoxic fish, that release toxins through the skin by means of specialised secretory organs. The third category includes the various venomous fish with specialised secretory organs and a wound-producing apparatus, such as spines or teeth.
2. Venomous amphibia
   Some amphibians (salamanders, toads, newts) produce very strong poisons.
3. Poisonous reptiles
   Some species of sea turtles are considered to become poisonous through eating toxic plants, but the precise source of the poison is unknown. Water snakes make up the most numerous reptile category, and some of these contain very potent poisons.
4. Poisonous mammals
   The liver of some whales, polar bears, walruses, seals and sea lions can be toxic.

2.2 The Functions of Biotoxins

Biotoxins, i.e., "poisonous" organic products of bacterial, vegetable or animal origin, are substances that have various different biological actions, of variable severity, when introduced into other organisms. A substance, of animal or vegetable origin, is poisonous if it is harmful to eat (e.g., some mushrooms and some fish are poisonous). Instead, an animal is "venomous" if it produces substances that are harmful when they enter the bloodstream (e.g., the viper and some Coelenterates are venomous, but their secretions are innocuous when eaten). Obviously, the toxic products of a venomous animal can be harmful when injected [5].

As shown above, many species of marine Vertebrates and Invertebrates produce biotoxins. An animal will be described as "poisonous" or "venomous" according to the use it makes of its poison: when it is used as a defence or offence mechanism and to capture prey for food, the animal is said to be "venomous", or actively toxic. Instead, a "poisonous" or passively toxic animal produces or ingests substances that are harmful when the animal is eaten [5].

There are large volumes of data in the literature on the biotoxins of marine animals [6–17]. Some general notions are reported below, while the toxins inherent to each animal species will be dealt with in the relative chapters.

Most marine animal poisons serve to capture prey for food. However, not all marine animals use toxins just to procure food: microphagic animals feed on live or dead organisms and organic waste floating in the water or mingled with the sand, and therefore filter the water or ingest the sand to obtain the nourishing substances. For this reason, some of these animals may be toxin carriers because they act as filters, and so any toxic substances present in the micro-organisms or in the aquatic environment will accumulate in their organs and make them poisonous to eat.

Instead, macrophagic animals need to use defence and offence mechanisms to capture and immobilize their prey. Hence, while the mammalian salivary glands have only a digestive function, in many Invertebrates and some Vertebrates (snakes) these glands secrete substances that are actively toxic to the prey's nervous system or other organs. Cephalopod Molluscs, for instance, immobilize their prey with secretions from their posterior salivary glands, which contain both digestive proteolytic enzymes and biotoxins. Snakes also produce many poisons that are injected with their saliva into victims. Coelenterates capture their prey, such as fish, with their tentacles and immobilize them by injecting toxins through the nematocysts. Not all the action mechanisms of these immobilizing neurotoxins are known: some act on the brain centres or ganglial chains, and others on the peripheral nervous system by impeding the conduction or transmission of nerve impulses at the level of the neuromuscular sheath.

Biotoxins may be used purely as defence mechanisms. The scorpionfish (Scorpaena) defends itself from predators thanks to its venomous dorsal spines. The ray (Dasyatis) has a strong, well-developed sting apparatus in the tail which is thrust into the body of the predator. Not only does this organ provoke a painful, lacerating wound, but it also conveys the secretions of the potent poison glands situated at its base.

In short, when they are produced by the salivary glands, biotoxins serve above all to capture prey for food. The biotoxins in the nematocysts of Coelenterates have the same function. Instead, when they are secreted by glands at the base of the spine or radioles, they have a defensive function against other animals. The role of the toxins present in the muscles or ovaries of many marine animals is difficult to ascertain, but what is certain is that owing to these toxins, such animals are poisonous to other animals and man.

2.3 The Biochemistry of Biotoxins

Up to now, the biochemical make-up of only relatively few biotoxins has been identified, for various reasons: it is difficult to obtain sufficient material for extracting and purifying the poisons, while we have little knowledge of the environmental distribution of many pelagic or deep-sea animals, and no suitable means for capturing them.

The biotoxins whose chemical nature is known are of various types: some are simple amino or phenol derivatives with a low molecular weight, or choline esters, or derivatives of steroid or isoquinoline compounds; others are peptides formed by few amino acids or proteins with a high molecular weight.

Generally, a venomous gland produces various compounds with different functions and chemical structures: the nematocysts of the Coelenterates, for example, contain many active substances with high and low molecular weights.

Research on the synthesis and metabolism of biotoxins is still in its infancy. With a few exceptions, no antidotes to the various poisons have yet been discovered, even for those that can cause mortal epidemics, like mytilotoxin and tetrodotoxin.

References

1. Williamson JA, Fenner PJ, Burnett JW et al (1966) Venomous and poisonous marine animals. A medical and biologic handbook. University of New South Wales Press, Sydney
2. Halstead BW (1992) Dangerous aquatic animals of the world: a color atlas. The Darwin Press Inc/Mosby Year Book, Princeton/Saint Louis
3. Banister K, Campbell A (eds) (1993) The encyclopedia of aquatic life. Facts on File, Inc, New York
4. Kaplan EH (1982) Coral reefs. Houghton Mifflin Company, Boston
5. Ghiretti F, Cariello L (1984) Gli animali marini velenosi e le loro tossine. Piccin, Padova, p 7
6. Banner AM (1967) Marine toxins from the Pacific. I. Advances in the investigations of fish toxins. In: Russel FE, Saunders PS (eds) Animal toxins. Pergamon Press, Oxford, p 157
7. Der Marderosian A (1968) Current status of drug compounds from marine sources. In: Freudenthal HD (ed) Drugs from the sea. Marine Technological Society, Washington, DC, p 19
8. Baslow MH (1969) Marine pharmacology. The Williams and Williams Co, Baltimore
9. Bucherl W, Buckley EE (1971) Venomous animals and their venoms. Academic, New York
10. Humm HJ, Lane CE (1974) Bioactive compounds from the sea. M Dekker Inc, New York
11. Russell FE, Brodie AF (1974) Toxicology: venomous and poisonous marine animals. In: Mariscal RC (ed) Experimental marine biology. Academic, New York, p 269

12. Ruggieri GD (1976) Drugs from the sea. Science 194:491
13. Scheuer PJ (1978) Marine natural products. Academic, New York
14. Hashimoto Y (1979) Marine toxins and other bioactive marine metabolites. Japan Scientific Society Press, Tokyo
15. Eaker D, Wadström T (1980) Natural toxins. Pergamon Press, Oxford
16. Habermehl GG (1981) Venomous animals and their toxins. Springer, Heidelberg/New York/Berlin
17. Botana LM (ed) (2014) Seafood and freshwater toxins: pharmacology, physiology and detection, 3rd edn. CRC Press, Boca Raton