DEEP-SEA FOOD CHAINS

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In this paper we shall present an overview of the deep-sea food chains (mainly benthic) including some fish feeding strategies. This last subject will be based in part in our personnal experience, concerning the deep-sea benthic fishes of Northern Atlantic. Under the general designation of deep-sea we are considering the bottoms deeper than the continental shelf.

Scarcity of food is a rule is these bottoms and the first problem when dealing with such a subject is to know how organic matter can reach the bottom. Vinogradov (1953) suggested a scheme based on the zooplancton vertical migration. This scheme deals with overorlaps of several series of vertical migrations (diel or ontogenetic) at successive bathymetric levels. Through the trophic relations these series are responsible for the presence of organic matter at bottom level.

Animals may feed in the surface waters and migrate to deeper levels where undigested organic matter is excreted or where these animals may be eaten by others. Furthermore defecation means organic matter available to the organisms living on the water masses or on the sediments, including, microorganisms.

If vertical migrations are sufficiently known for the upper 1550 m (Longhurst, 1976, *in* Rowe & Staresinic, 1979) there is few data for the same kind of phenomena occurring below this depth. Sinking is perhaps then the most usual process by which particulate organic matter, reaches the bottom. The particulate organic material that sinks permanently in the sea has his main origin on the phyto and zooplanctonic organisms of the upper levels.

Bottoms nearer the continents (or under the influence of certain currents) are those presenting highest biomasses (those less than 2000 m deep) and 85% of the oceanic benthic oxygen consumption (Hinga *et al*: 1979). There are in fact indication (see Hinga *et al*, 1979) that the total amount of food available to the deep-sea benthos is probably closely related to the productivity of the surface waters. After Smith (1978, *in* Hinga *et al*, 1979) benthic respiration measurements from the northwest Atlantic show a decrease in oxygen consumption with increasing depth and with distance from land.

Sinking material is usually constituted by small particles, but fast sinkings carcasses of big fishes or other marine animals (mammals, for example) may represent another source of organic matter. It is obvious that the most nutritional parts of the sinking material are decomposed before reaching the bottom. Fast sinking is then an important factor for providing organic matter to the bottom animals. Nevertheless a certain amount of slow sinking particles reach also the bottom and are of course also important to the process.

Another important source of organic material is represented by debris of macroscopic plant material. As a matter of fact debris from several species of terrestrial and marine plants (including algae) were found at different depths (even in the hadal zone) and in several areas of the world ocean (dredged and directly observed from the DSRV Alvin). In the stomach contents of many benthic animals as ophiurans, sea-urchins and isopods, was found the above mentioned material. The conclusion is that either plant material or its associated epibiota are used for food (Rowe & Staresinic, 1979).

It is also know that wood is used as food by boring deep-sea mollusks (*cf.* Rowe & Staresinic, 1979). Pine pollen was also pointed as an organic food source (Hinga *et al*, 1979).

Heterotrophic organisms have in the deep-sea the above mentioned food sources and of course the posibility for several of them of catching preys.

Autotrophic organisms are also represented in the deep waters. As a matter of fact CO_2 fixation by chemosynthetic (or chemoautotrophic) bacteria is a primary source of organic matter. As was pointed by Rowe & Staresinic (1979) «reduced compounds such as ammonia, hydrogen sulphid, methane and elemental sulphur are oxidized, each by a specialized group of bacteria to obtain energy used in the primary synthesis of particulate organic matter».

Sometimes organic particles that reach the bottom are not used directly by benthic organisms (suspensivores or detritivores). It is generally accepted that they are converted into bacterian living matter, and after that ingested by several benthonts. As a matter of fact bacteria are also an important food source for benthic invertebrates (Pérès, 1961 *in* Saldanha 1974) mainly detritivores. Nevertheless we do not exclude suspensivores as behaving in the same way.

Deep-sea mobile animals present a series of feeding strategies enabling them to face a stressing environment. For us the most striking feature is the "opportunistic" character of these strategies.

Geistdoerfer (1975) when dealing with the diet of Macrouridae fishes wrote about the feeding habits of several invertebrate groups. It is known that polychaetes, that are an important part of most fish diets may eat not only particles in suspension but also those deposited on the sediment. They may also be carnivorous like many crustaceans.

Most crustaceans (amphipods and others) feed on several types of material even on dead material, being scavengers. Shrimps feed on almost everything — plancton, nektonic and benthic invertebrates, dead organisms.

With some exceptions euryphagy is undoubdtely one of the main characteristics of the deep-sea fishes diet. In the deep-sea food chain fishes are generally placed in a high trophic level — they are carnivorous predators of carnivorous.

Macrourids for example (*cf.* Geistdoerfer, 1975) feed on near 10 to 20 kind of animals of different groups, crustaceans being dominant in this material.

The anguilliform fish *Synaphobranchus kaupi* presents also a broad diet: cephalopods, shrimps, fish and amphipods (Saldanha, 1979).

It is difficult sometimes to access food preferences as fishes catch the most abundant material. This is what we call an «opportunistic» feeding strategy. This broad diet as several authors have pointed is a good adaptation to the depths where scarcity of food prevails.

In what concerns benthic or benthopelagic fishes this adaptation includes the possibility of catching preys not only on the bottom but also in the water column.

The presence of pelagic organisms in the gut contents of benthic and benthopelagic fishes is due to two different reasons — concentration of pelagic animals near the bottom (migrations of different kinds, concentrations connected with the nepheloid layers, etc.) or feeding activity at a certain distance from the bottom.

Even the species classically considered as benthic may feed actively some meters above the bottom and then rest on it. Alternative stages of activity and dormancy gave the animals the possibility of regulate energy expenditure (Jannasch, 1978). Development of sensory organs (neuromasts, fin filaments, etc.) as we can observe in several deep-sea fishes help a better location of preys and are another advantage to those animals living in a stressing environment.

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