SHRIMPS AND KRILL

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Contents

Summary

Shrimps and krill species are crustaceans. Although they belong to two different orders, their differences are not very important. Morphologically, they are roughly alike; and are both swimming animals.

The key characteristics of the main commercial species are described (distribution, general ecology, behavior, reproduction, growth and feeding); and an overview of their exploitation is given (main fisheries, fishing gears and landings).

Finally, management strategies are reviewed, and specific concerns are discussed.

1. Shrimps

1.1 Introduction

Shrimps (or prawns - the terms “shrimp” and “prawn” are used interchangeably -) constitute a large group in which about 2500 species have been identified. Twenty years ago, 343 of these (Holthuis, 1980) were considered of interest to fisheries, including not only those already exploited for human consumption or bait, but also those thought to be of potential commercial value, because they met the following criteria: sufficiently abundant, large enough in size, and accessible to fishing gear.

At the turn of the twenty-first century, only a hundred species make up the exploited shrimp stocks, and contribute to World shrimp captures.

1.2 Taxonomy

Shrimps belong to the class Crustacea, order Decapoda, suborder Natantia. Those of commercial interest are subdivided into two sections: the Penaeidea and the Caridea.

Penaeidea and Caridea can be easily distinguished by morphological and biological characteristics.

Morphological characteristics (Figure 1):

- In the Penaeidea:
  - the second abdominal segment never overlaps the first one;
  - the first three pairs of legs end with pincers; and
  - the sixth abdominal segment shows a keel dorsally.

- In the Caridea:
  - the second abdominal segment always partly overlaps the first;
  - the first two pairs of legs end with pincers; and
  - the cross-section of the sixth abdominal segment is rounded.

Biological characteristics:

- In the Penaeidea, eggs are directly released into the water just as they are laid. There are never egg-bearing females.
- In the Caridea, after being laid and fertilized, eggs are strongly fastened to the abdominal appendages (pleopods), where they remain during incubation until they hatch out. Egg-bearing females may often be found in the field.

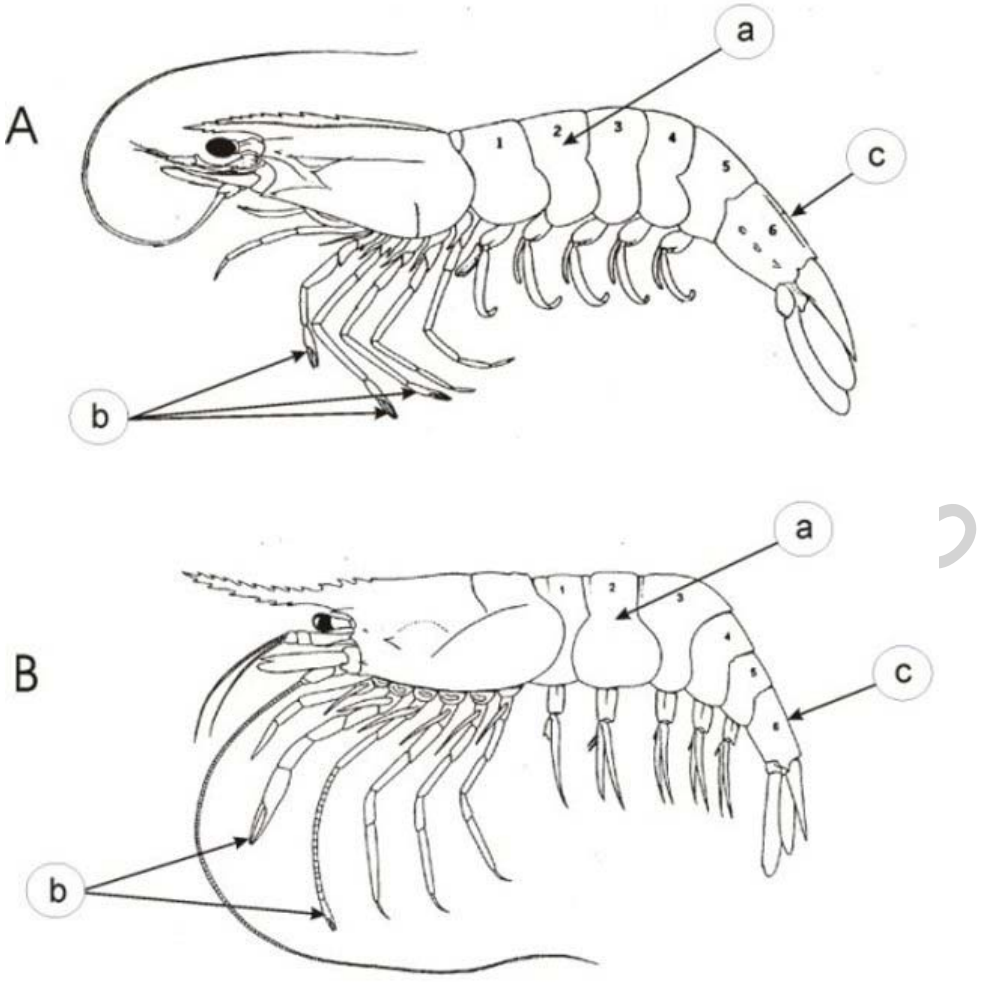

Figure 1. Morphological characteristics of shrimps.
A: Penaeidea; B: Caridea.
a: second abdominal segment; b: legs with pincers; c: sixth abdominal segment

Eight families (five penaeideans and three carideans) comprise all commercial species:

- Penaeidea
  - Solenoceridae
  - Aristaeidae
  - Penaeidae
  - Sicyonidae
  - Sergestidae

- Caridea
  - Palaemonidae
  - Pandalidae
  - Crangonidae

1.3 General Distribution

Marine shrimps are widely distributed throughout the world, from equatorial to Polar Regions.

Among the commercial carideans, the Palaemonidae are coastal species living in seaweed and seagrass areas, mainly in brackish waters, and exploited from the tropical to the temperate zones; Pandalidae are deep shrimps found as deep as 500 to 800 meters and exploited in temperate and cold seas; and Crangonidae are coastal species living on soft bottoms (sand and mud) and exploited in temperate seas.

The peneideans are mainly exploited in tropical, subtropical, and warm temperate waters, and represented at all depths and in almost all environmental conditions. However, most of commercial species live in coastal areas, and occupy shallow or moderately deep waters on continental shelves. Solenoceridae, Aristaeidae, Sicyonidae and Sergestidae are exclusively marine; while in the Penaeidae, most of coastal species are amphibiotic. That means that they carry out migrations during their living cycle, spending the juvenile stage in inshore brackish waters of marshes, mangrove swamps, lagoons or estuaries, and the adult stage in offshore marine waters. There are nevertheless a few exceptions; in the regions where brackish water areas are rare, as in the Arabic-Persian Gulf, coastal penaeid nurseries are located in marine waters, but always close to the coasts.

1.4 Biology

1.4.1 Habits

When adults, the majority of commercial shrimps by far are benthic or demersal. They live on the bottom, or close to it. Only the species of Sergestidae are entirely pelagic. Most of shrimps are gregarious. Some, such as *Penaeus merguiensis* (in Australia) and *P. semisulcatus* (in Madagascar), can form shoals when the population density is high.
When active to feed, shrimps are the most vulnerable to fishing gear, and give rise to the largest catches. In the Sicyonidae, *Sicyonia brevirostris* is active at night (nocturnal). In the Penaeidae, some species are active at any time (nocturnal and diurnal), such as *Penaeus indicus* and *P. penicillatus*; while a few of them, such as *Xiphopenaeus kroyeri*, are diurnal. However, most of penaeids are nocturnal (*Penaeus semisulcatus, P. latisulcatus, P. japonicus, P. aztecus, P. duorarum, P. monodon, P. notialis, P. brasiliensis, Trachypenaeus curvirostris*). During the daytime, they bury themselves in the substrate, from which they emerge at night in search of food.

Although benthic or demersal, some shrimp species have a more or less pronounced pelagic behavior, and realize diurnal vertical migrations of more or less importance, in order to feed, especially at night. These species include *Pandalus borealis* (Pandalidae), *Aristeus antennatus* (Aristaeidae) and the Penaeidae *Parapenaeus longirostris*, *Penaeus chinensis*, and *P. setiferus.*

Some species are sedentary, such as *Crangon crangon*, which is found in estuarine areas, buries itself during low tide, and emerges at high tide. In contrast, some species

carry out either seasonal inshore-offshore migrations (e.g., *Palaemon serratus*, which moves offshore in the winter, probably to a more constant temperature regime, and can achieve changes of location of 8 to 12 miles in less than four days), or migrations along the coast (e.g., *Penaeus setiferus*, which can carry out migrations up to 580 km along the US Atlantic coast

1.4.2 Reproduction

All shrimps have separate sexes, unlike exploited pandalids which are protandrous hermaphrodites. This means that male pandalids change their sex at a certain time during their life. One example is *Pandalus borealis*, in which species the male animals function as male for 2–5 years before changing sex (the sex change occurring later at higher latitudes), and spend the remainder of their life cycle as females. Populations of *P. borealis* nevertheless contain a varying percentage of primary females, which remain females throughout their life; this percentage decreases at higher latitudes. In a *P. borealis* population in the North Sea, the proportion of primary females is about 30%.

In the carideans, it is difficult to distinguish males and females when the latter are not carrying eggs, while in the penaeideans, there are easily noticeable sexual differentiations: males have a copulatory organ, the petasma, joining the base of the first pair of pleopods, and used to transfer spermatophores (where sperm is stored) during mating; females have a seminal receptacle for spermatophores (the thelycum), located on the ventral side between the last pair of legs.

Most shrimps of the genus *Penaeus* reach sexual maturity in under one year: for example, *P. indicus* from Madagascar reaches maturity at 4 months, *P. duorarum notialis* (a sub-species of *P. duorarum*) from the Côte d'Ivoire at 6.7 months, and *P. monodon* from the Philippines at 10 months. Compared with penaeids, the carideans have delayed maturity; *Palaemon serratus* and *Crangon crangon* are mature at about 1 year; while *Pandalus borealis* reaches sexual maturity at 1 year in short life cycle populations, and at three or four years in longer life cycle populations.

In mature females, egg production depends on the size of the animal. Penaeids are the most fecund shrimps and can release between 100 000 and 1 000 000 eggs at a single spawning (100 000-800 000 in *Penaeus japonicus*; 500 000 in *P. setiferus*). In the Caridea, female fecundity is lower; and only a few thousands of eggs are released at each spawning (900–5000 in *Palaemon serratus*; 3000–8000 in *Crangon crangon*; 600–3600 in *Pandanus borealis*; 1700–3300 in *Heterocarpus reedi*).

At spawning time, eggs are released and fertilized as they pass over the stored sperm. In carideans, fertilized eggs become attached externally beneath the abdomen of the female, where they will remain during the incubation period, until they hatch at advanced larval stages or as juveniles. The incubation duration depends on water temperature; for example, it lasts 3.5 to 10 weeks in *Crangon crangon*; 5 to 6 months in *Pandanus borealis* on the Pacific coast of North America, and about 1 year in populations from Spitzberg. In penaeideans, on the contrary, fertilized eggs are released directly into the seawater. Generally, spawning occurs several times a year (in *Aristeus antennatus* and *Palaemon serratus*, older females can spawn up to three times). The

reproduction process can be spread out over several months, and even be nearly continuous in tropical species.

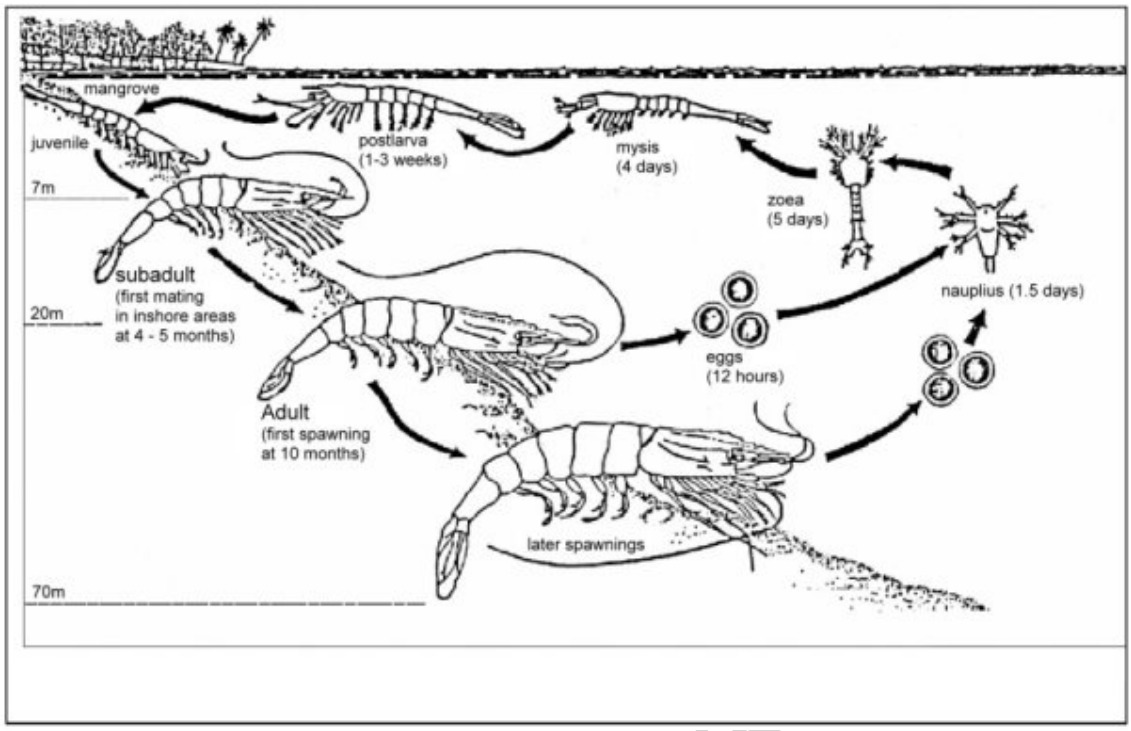

Figure 2. Life cycle of *Penaeus monodon* (Motoh, 1981).

In the Penaeidae, incubation lasts only a few hours after spawning; and eggs hatch into nauplii which represent the first of usually 11 larval stages (5 nauplii, 3 protozoeae and 3 mysis). The larvae are planktonic. After about three weeks of pelagic life, they reach the postlarval stage (about 6 to 14 mm long) and are shrimp-like in appearance. At that time, they begin the process of entering into inshore waters, generally brackish. In these nursery grounds, they gradually acquire a benthic behavior, grow rapidly, and develop into juveniles which have a complete rostrum set of teeth. As they grow, increasing in size, they move progressively towards deeper zones, becoming subadults when external sexual organs are formed, then adults when they can breed. Finally, they reach the spawning grounds where mature females spawn to repeat the cycle. As an example, the reproduction cycle of *Penaeus monodon* is represented in Figure 2.

1.4.3 Growth

In shrimps, as in all Crustacea, growth occurs through successive molts, and appears to be discontinuous at individual levels. The molting process is controlled by two hormones: the first one, which accelerates it, is secreted by the Y organs; the second one, which inhibits it, is secreted by the complex X organ-sinus gland. Environmental factors also stimulate molting. For instance, in the Penaeidae, the number of molting individuals often increases at the time of the full moon.

The growth rate results from two components: molt frequency and increase in size at each molt. Molting frequency decreases regularly when age increases, and becomes

practically nil in old individuals. Increase in size at molting is closely related to the condition of the individual, and can be negative in starving animals.

As in all exploited species, knowledge of growth and age structure of the population is very important to fisheries management. The age of a shrimp is difficult to determine. Two methods have been usually used to estimate growth parameters, which give reliable results on age structure. They are tagging, and modal progression analysis on length frequency distribution.

Penaeids have high growth rates and grow very fast. Most of the coastal amphibiotic species reach their maximum size in about two years. For instance, in *Penaeus japonicus*, the mean daily increase in size is between 0.7 and 1 mm in subadult and adult females; the mean daily increase in weight in individuals of 15–20 g is 0.8% for females and 0.5% for males; so in six months, females can reach 40 g and males 20 g.

Compared with penaeids, caridean shrimps have slower growth rates. For instance, in *Palaemon serratus*, the maximum weight is 7 g for males and 15 g for females.

In all species, females grow at a faster rate than males, and are larger at any given age. Growth rates show seasonal variations, which are particularly outstanding in temperate and cold seas. Growth decreases during the cold season in *Palaemon serratus,* and is very linked to environmental temperature in *Pandalus borealis*. In this species, individuals reach 10 cm in less than two years in the gulf of Maine, and in about four years in Greenland and Spitzberg.

Generally, fast growth corresponds with short life species and populations, and the converse also applies. Longevity is 3 to 4 years in *Aristeus antennatus*, 2 to 3.5 years in *Parapenaeus longirostris*, 18 to 20 months in *Penaeus kerathurus*, and 4 years in *Palaemon serratus*. In *Pandalus borealis*, the life span is 3 years in the North Sea, 4 years in New Scotland, 5 to 6 years in Labrador, and 6 to 7 years in Iceland and West Greenland.

1.4.4 Feeding

Adult shrimps feed on a great diversity of prey in accordance with their availability, and can be called opportunist. The diet consists mainly of invertebrates: bryozoans, mollusks (bivalves and gastropods), polychaetes (bristle worms), echinoderms (brittle stars), and small crustaceans (euphausiids, amphipods). However, foraminifera, as well as fragments of seaweed, seagrass and fish, can be found in stomach contents (*Parapenaeus longirostris*, *Penaeus kerathurus, Palaemon serratus*).

In deep shrimps, interesting trophic relationships generally exist. On the Atlantic continental slope of Morocco where there are high densities of shrimp populations in spite of the fact that the food resources provided by benthic invertebrates are poor, the main constituents of the diet are euphausiids which carry a high-energy supply of plankton—euphausiids carry out diurnal vertical migrations, feeding during the night on surface plankton and becoming prey during the day to most of the benthic deep shrimps living on the continental shelf.

1.5 Harvesting

Shrimp is a product of high commercial value, and its exploitation is stimulated by a strong demand in international markets, particularly in the US, Japan and the countries of the European Union (mainly France and Spain), where steadily rising incomes have contributed significantly in increasing the demand for shrimp.

At the same time, the generalization of the use of cooling and freezing systems in handling and processing shrimps has removed the technical constraints hindering the development of the consumption of this product which requires delicate preservation Shrimp fisheries have been developing outstandingly since the early 1950s, especially in tropical areas with the exploitation of penaeids, and present (at the turn of the twenty-first century), wherever there is catch potential, the resource is almost always undergoing an increase in fishing pressure.

For many developing countries, shrimp production is an important source of foreign currencies (often by far, the leading source), as the major part of the catches is exported to industrialized countries.

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Biographical Sketch

Jean Marin, D.Sc., has a Ph.D. in the biology and dynamics of marine populations. He is fishery biologist at the Mediterranean and Tropical Fishery Center (Fishery Resource Laboratory of IFREMER) in Sète (France), and in charge of scientific cooperation with Mediterranean African countries in the field of fisheries, a fisheries research project in Brazil (in cooperation with the States of Bahia, Espirito Santo and Rio de Janeiro), and Vice-Chairman of the Scientific Advisory Committee (SAC) of the General Fisheries Commission for the Mediterranean (GFCM). Before his assignment at IFREMER, J. Marin was head of the IFREMER Aquaculture Laboratory in La Trinité-sur-mer (Brittany) from 1972 to 1975, head of the IFREMER Fisheries Resources Laboratories in Corsica, La Martinique (FWI), and in French Guyana (1978 to 1992), responsible for scientific international cooperation in the field of living resources at IFREMER from 1992 to 1995, and head of the Fisheries and Aquatic Living Resources Unit in the Agriculture Division of the United Nations Economic Commission for Africa (UNECA) in Addis Ababa (Ethiopia) from 1995 to 1997. He has been involved in various research programs and field missions: biology and ecology of the European flat oyster, coastal fishery resources of the West Channel and of the Gulf of Biscay, fishery resources of the North West Indian Ocean, biology and dynamics of the red spiny lobster in Corsica, assessment of the fishery resources in the continental slope off the east coast of Corsica, assessment of the small-scale fisheries in La Martinique, assessment of the shrimp and red snaper fisheries in French Guyana, assessment of small coastal pelagic fish in Tunisia, and assessment of small pelagic and demersal resources off the States of Bahia, Espirito Santo, and Rio de Janeiro. He has experience of research projects in developing countries, mainly in Africa (Algeria, Morocco, Tunisia, Cameroon, Chad, Côte d'Ivoire, Djibouti, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Madagascar, Mauritius, Senegal, Seychelles, Tanzania, Togo, Uganda), and in Latin America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama; Brazil, Guyana, Surinam, Venezuela), and also in Asia (Iran, Pakistan, Vietnam).