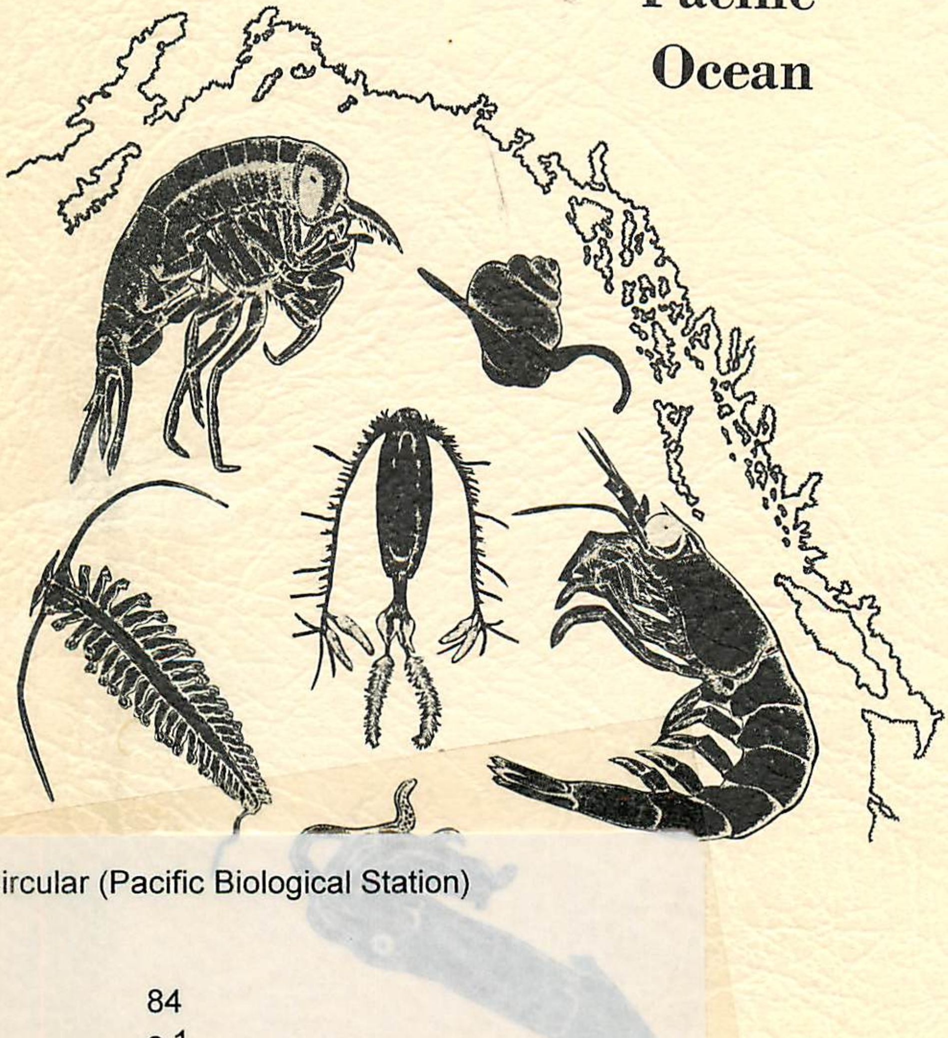
A Guide to Zooplankton of the Northeastern Pacific Ocean



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A Guide to Zooplankton

of the

Northeastern Pacific Ocean

by

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and

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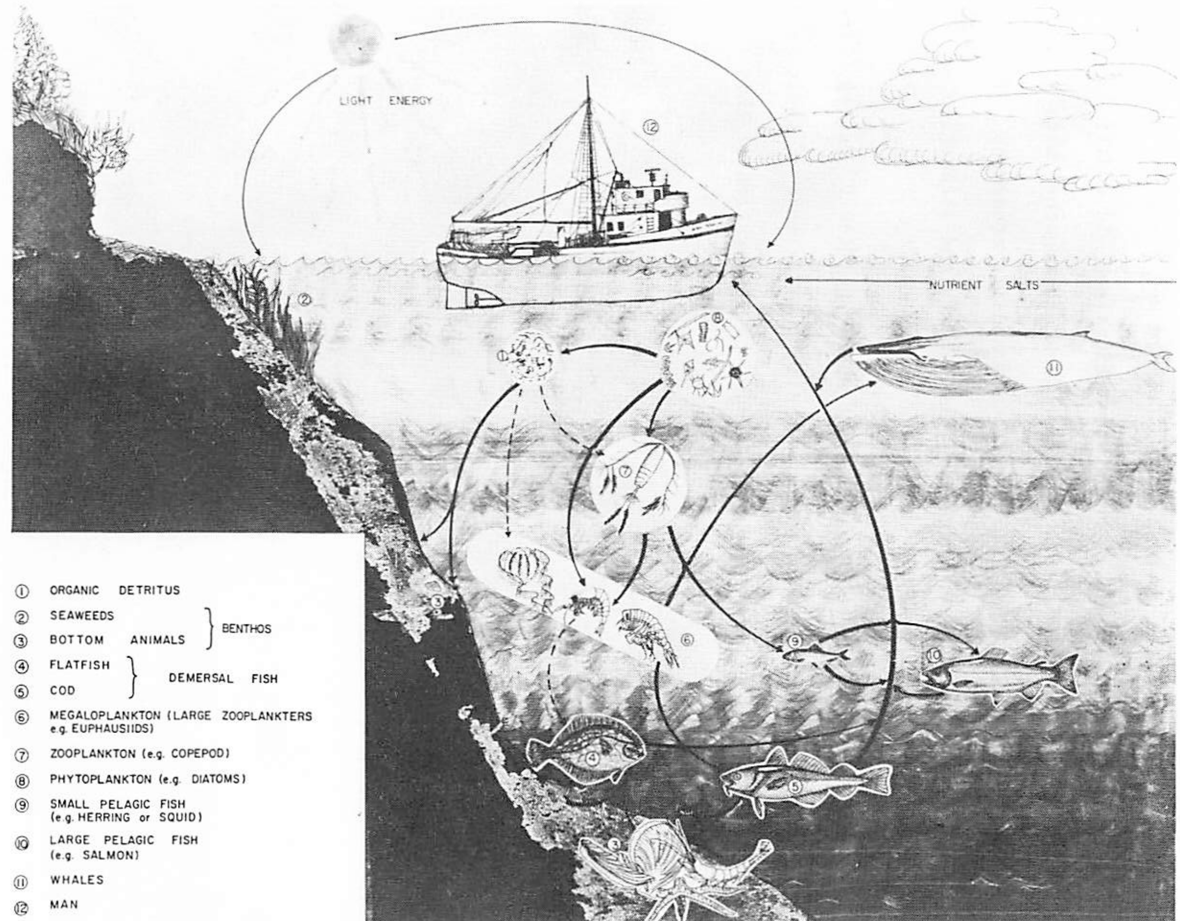
This guide has been prepared in response to requests from schools and from ship's personnel for information on, and pictures of, the multitude of local marine zooplankton. A simple key and brief descriptions have been prepared to assist in their identification. In addition, directions are included for collecting zooplankton, together with a list of books written for the public about the sea and its creatures. These books should in turn lead to more specialized texts and scientific publications.

The drawings for this guide were prepared by Miss V. Davies. The authors also gratefully acknowledge the critical assistance of their colleagues at Pacific Oceanographic Group in the preparation of this report.



SCHEMATIC FOOD WEB SHOWING SOME OF THE PATHWAYS LINKING VARIOUS PLANTS AND ANIMALS.

Marine organisms may be grouped, according to their mode of life, as benthos (plants and animals crawling on, or attached to, the ocean floor), as nekton (swimming, freely migrating animals) or as plankton (floating or drifting plants and animals). Plankton is of importance because all but a very small fraction of animal life in the oceans is ultimately dependent upon it for existence. Planktonic life ranges in size from minute one-celled bacteria and plants such as dinoflagellates and diatoms to highly developed animals such as shrimp, larval fish and squid. Plankton are found in all waters - from the surface to the ocean depths, and from the tropics to the polar seas. They may live for several days or as long as 2 or 3 years, depending upon their rate of development. Some forms live all their lives as plankton, while others, such as larval stages of shore animals and fish, remain a part of the plankton for relatively brief periods only. All plankton are dependent upon the sea for distribution and for survival.

The simplest life in the sea comprises the planktonic plants, the phytoplankton, which utilize the sun's energy to convert the basic elements and nutrients in the water into new plant material containing proteins, fats and carbohydrates, without which there could be no marine animals.

The phytoplankton float in countless millions in the sunlit euphotic zone, the upper 50 to 300 feet of water. Under optimal conditions they may double their numbers daily, occurring at times in great concentrations or "blooms" which color the water. Small and numerically abundant animals, the zooplankton, graze upon the phytoplankton. The zooplankton are the basic source of food for juvenile stages of most fish species as well as for a variety of other animals. The latter, in turn, form the food of even larger animals, the nekton, such as fish, porpoise, and whales. Thus there is a transfer of energy or food in the form of living and decaying material, which may be regarded as passing from one group of organisms or trophic level to another. Intermediate between the various groups of organisms are the bacteria. Bacteria are directly utilized by some animals but their most important role is to break down the wastes and dead bodies of plants and animals into useful compounds.

This process of energy exchange is schematically illustrated on page 2. Because of the complexity of the predator-food relationship between trophic levels, the term "food web' rather than "food chain" has been sometimes used. Even in this simplified food web it can be seen that the relationships between organisms may be exceedingly complex. This is further emphasized when it is realized that many groups of zooplankton assume different roles in the utilization of and the transfer of energy during their life cycle. The earlier stages of most zooplankton graze on phytoplankton and are termed herbivores; later stages may feed upon smaller zooplankton as well as phytoplankton and are termed omnivores; and adult stages may be completely carnivores. At each level the amount of food, or energy available as food, diminishes due to a variety of life processes such as metabolism and excretion. The energy lost through these processes may amount to 75% or more of the food which has been eaten, leaving 25% or less for growth and reproduction. For example, it could take between 250 and 1000 pounds of phytoplankton to make one pound of salmon depending upon whether the salmon ate herbivores or organisms further along the food web. Consequently, if man is to harvest the sea efficiently, he should do so as near to the level of primary production as is economically feasible. At present, fishing is largely confined to the collection of animals at the third and fourth trophic levels such as the planktivore fish (e.g. herring) and the carnivore fish (e.g. salmon). In future, as the demands for food from the sea increase, greater efforts will be directed towards catching fish and other organisms at the third trophic level and even, in some circumstances, the herbivores at the second trophic level. However, to achieve greater efficiency in harvesting the sea it will be necessary to develop new fishing and culturing techniques, and new ways of processing fishery products, and also to study the processes by which food energy is transferred from one group of organisms to another.

Although the zooplankton consist of a wide variety of dissimilar animals, they do exhibit some common forms of behaviour. As mentioned previously, they have relatively weak swimming powers and must rely on ocean currents for movement from one area to another. However, by moving a short distance in a vertical rather than in a horizontal direction, these animals are capable of moving from one type of environment to another, and of transferring to different current systems, thereby enhancing their opportunities of finding optimal growing conditions. Many zooplankton migrate vertically twice a day, moving towards the surface at nightfall and returning to deeper waters before sunrise. This daily migration brings the animals into the euphotic zone, where phytoplankton production takes place, therefore where feeding conditions are likely to be the best.

Sampling for zooplankton at the surface at night invariably produces a larger and more varied catch than does sampling in daylight. In the daytime, many species of zooplankton maintain a position in discrete layers at different depths, the depth of a layer being dependent upon the species, its stage of development, and its response to such environmental factors as the light intensity, and the pressure,density and temperature of the water. This behaviour pattern leads to the concentration of organisms in areas where current systems converge, e.g. along tide lines. Another characteristic common to many zooplankton is swarming, which, for a variety of reasons such as breeding or feeding, results in dense accumulations of a species in discrete patches. Predators, such as fish or whales, often tend to gather in areas where dense concentrations of zooplankton frequently occur. Such areas include coastal waters and regions where ocean currents meet, e.g. in the western north Pacific, where the Oyashio and Kuroshio current systems converge. Examples in coastal waters are common to most people who spend time along the sea shore, and sports fishermen are well aware of the increase in the feeding activity of fish at daybreak or at nightfall.

KEY

To recognize the different organisms it is best to try to work through the following key, successively eliminating unlikely organisms, and then comparing the likely specimen with the most appropriate drawing and description.

Major Group	Character	Example	
<u>Coelenterate</u> (Medusae and jellyfish)	Gelatinous Transparent *Radially symmetrical Saucer or bell-shaped Unsegmented 5-150 mm (and larger)	<u>Aglantha</u> <u>Philidium</u>	pp. 21 pp. 21
<u>Ctenophore</u> (Combjellies or sea gooseberries)	Gelatinous Transparent Radially symmetrical, pear or ball-shaped, with 8 rows of comb plates Unsegmented 5-80 mm	<u>Pleurobrachia</u>	pp. 22
<u>Chaetognath</u> (Arrow worms)	Transparent *Bilaterally symmetrical, body elongate, arrow or torpedo-shaped Unsegmented Eyes not evident 5-45 mm	<u>Sagitta</u>	pp. 23
<u>Annelid</u> Polychaete worms	Conspicuous segmentation Bilaterally symmetrical Body elongate with paired swimming appendages and tentacles Eyes inconspicuous 5-30 mm	<u>Tomopteris</u>	pp. 24

Major Group	Character	Example	
<u>Molluscs</u>	Unsegmented Bilateral symmetry may not be apparent in some forms		
Pteropods	Eyes not evident Coiled, snail-like shell 1-15 mm	<u>Limacina</u>	pp. 25
	No visible shell, globular or triangular shape with wing-like fins 5-20 mm	<u>Clione</u>	pp. 25
Cephalopods	No visible shell Eyes well developed Well developed arms or tentacles 6-60 mm (and much longer)	<u>Squid</u>	pp. 26
<u>Crustacea</u> (water fleas, shrimps, etc.)	Segmented Bilaterally symmetrical, paired appendages Strong exoskeletons or tunics covering animal		
	Eyes absent or poorly developed, sausage-like body 1-10 mm	<u>Copepod</u>	pp. 27 to 29
	Well developed compound eyes fused to head Body laterally compressed 3-20 mm	<u>Amphipod</u>	pp. 30
	Well developed stalked compound eyes Body shrimp-like Legs for swimming 10-20 mm	<u>Euphausiid</u>	pp. 31
	Well developed stalked compound eyes Body crab-like or shrimp-like Legs for walking or grasping 1-20 mm	<u>Crab larvae</u>	pp. 32
	1-50 mm	<u>Sergestes</u>	pp. 33

Major Group	Character	Example
Pisces (Fish larvae)	Segmented Transparent Eyes well developed 4-50 mm	Larval rock sole pp. 34

*Radial symmetry: Having similar parts arranged around a common central axis, as in jellyfish.

*Bilaterally symmetrical: Capable of being halved by one plane into equivalent right and left halves, as in fish.

1 inch = 25.4 millimetres = 2.54 centimetres

39.4 inches = 100 centimetres = 1 metre

1 fathom = 6 feet = 1.8 metres

NOTES

Coelenterates

The coelenterates, or "jelly fish", are very abundant in the summertime along the beaches and in shallow bays. Most jelly fish exhibit a life cycle referred to as an alternation of generations. At one stage the animal is a free-swimming jelly fish or medusa, while at another stage it is a colony of plant-like animals living attached to the bottom in shallow water - the hydroid stage. One species which spends its entire life-history as a free-swimming medusa is _Aglantha digitale_ (pp.21). _Aglantha_ is often captured in the open ocean and sometimes is present in the deep water of the Strait of Georgia. Another species, _Philidium_ (pp. 21), is commonly found near the sea surface. Jelly fish are generally carnivorous, feeding upon the small animals which come within the grasp of the numerous tentacles which line the edge of the bell.

Ctenophores

These animals are commonly called comb-jellies or sea gooseberries. The most abundant form on this coast is _Pleurobrachia_ (pp.22) which is generally found in the warm surface waters in late summer. It has eight rows of comb-like structures made up of minute hair-like organs called cilia, which are used to propel it through the water. Unlike the coelenterates, the comb-jellies entangle their food in a sticky substance secreted by two long trailing tentacles. After the prey is captured the tentacles contract and pass the food to the mouth.

Annelids

In the Strait of Georgia the polychaete worm, Tomopteris, (pp.24) is present in considerable numbers below 100 m. The deeper plankton tows during fall and winter contain up to 25% by weight of Tomopteris. The role of Tomopteris in the food chain is that of a carnivore. It has been observed to feed voraciously on Sagitta and larval fish; it has sometimes been found in stomachs of oceanic fish.

Chaetognaths

The Chaetognaths are a group of animals which bear little resemblance to any other animal group. They are sometimes called "glass worms" because of their transparency, or "arrow worms" because of their shape. The most abundant chaetognath locally is Sagitta elegans (pp.23). It is a voracious carnivore, capturing large numbers of copepods, with paired chitinous hooks on either side of the mouth. It usually swallows its prey whole. It is also reported to prey upon the early larval stages of fish. Studies of the food of juvenile salmon show that fish 50 to 70 mm long, can eat chaetognaths.

Molluscs

Pteropods are related to the snail. The most common species in this area, Limacina helicina (pp.25) has a coiled shell like that of a snail, but the part analogous to the snail's "foot" is enlarged into a "wing" which it uses to swim through the water. It lives in the surface waters, grazing upon phytoplankton, and is preyed upon by a wide variety of fish including chum salmon, cod, and rock sole.

When eaten in quantity by a fish, Limacina give an objectionable odor to the flesh which may result in the fish being classed as unfit for human consumption. When found in fish stomachs, Limacina appear similar in size and color to coffee grounds.

Another member of the same family, Clione limacina (pp.25) has no external shell, and is commonly called a "sea butterfly". Unfortunately, when the animal is preserved, the "wings" contract and much of its beauty is lost. They are carnivores.

The Cephalopods are comprised of squids (pp.26) and octopods which, in their larval and juvenile stages, are sometimes captured in plankton tows. Juvenile squid are reported to feed on small fishes and crustaceans, particularly copepods. Squid occur in great abundance, providing a major source of food in oceanic waters for fish such as salmon as well as supporting commercial fisheries in some areas. In British Columbia squid are not commercially exploited, although they are purse seined and canned in California.

Crustaceans

Copepods

Copepods are one of the most abundant groups of animals in the world. They are present in all the oceans and seas of the world, at all depths and during all seasons. They are usually the most abundant animal in any zooplankton sample, and can occur in dense concentrations giving the water a reddish color. This phenomena is referred to as "red feed" or "red rice". Like other crustaceans, such as crabs or lobsters, the copepods have an external skeleton of chitin, and must moult or shed their skeleton in order to grow. In its lifetime each copepod moults twelve times. The first six stages or moults are called nauplius stages and do not resemble the adult. Although very small, the nauplii are an important source of food for many larval fish. The next five stages are called copepodite stages, and look similar to the final adult except for size and number of swimming legs. Adults may range between 0.5 and 7 mm long, depending on the species.

One of the most abundant copepods of the North Pacific is Calanus plumchrus, (pp. 27) so named because many of its spines bear ornate feathery structures. The adults lay eggs in the early spring. The young feed and grow rapidly in the surface waters, reaching copepodite Stage V before midsummer. The later stages of this copepod are large, rich in fat, and sometimes abundant enough to color the surface water, forming an important source of food for many species of fish. The large fat-laden Stage V C. plumchrus are believed to cease feeding in midsummer, when they descend to depths greater than 250 m. They spend the winter at this or greater depths, using their fat reserve to mature. In spring they ascend to shallower depths, lay up to 500 eggs, and die without having fed since the previous summer. C. plumchrus is a particularly important food source for juvenile, as well as for some adult, fish and whales.

In the open ocean, as distinct from the coastal inlets and waterways, Calanus cristatus (pp. 28) has a life history similar to C. plumchrus. It may be recognized by its larger size (the adult is about

7 mm long) and by a prominent crest on its head end. It is an important source of food in the diet of whales.

Other copepods which are abundant in the North Pacific include _Calanus pacificus_, _Pseudocalanus minutus_, _Oithona plumifera_ (pp.29) and _Acartia longiremis_. These smaller copepods breed several times a year and generally remain near the surface. _Metridia pacifica_, another small copepod, lives in the deeper water during the day (usually deeper than 100 m) and migrates to the surface each night to feed.

The copepods considered so far are predominately herbivores and therefore must spend part of their lives in surface waters rich in phytoplankton. _Euchaeta japonica_ (pp.29) is a carnivore which spends its entire adult life in the deeper waters. Its large mouth parts are used for grasping prey which usually consists of other copepods.

Amphipods

Most amphipods live in shallow water, either on the bottom or clinging to weeds. One group, the Hyperids, is planktonic. The Hyperids have very large compound eyes which take up most of the head, similar to those of insects. _Parathemisto pacifica_ (pp.30) is the most abundant amphipod in the North Pacific. It is easily recognized in a sample since the head is usually pigmented a bright red or purple. _P. pacifica_ is often captured during the night in surface plankton tows. It forms an important part of the diet of small oceanic fishes and of squid.

In the deeper more southern waters of the North Pacific, the large (as big as 20 mm) transparent Hyperid amphipod Phronima sedentaria (pp.30) are occasionally encountered. This species is notable in that it makes itself a barrel-like house from gelatinous bodies of pelagic tunicates.

Euphausiids

After copepods, the euphausiids are the most important zooplankton group in the world oceans (pp.31). They are largely omnivorous in their feeding habits. On this coast they are common in the stomach contents of most larger fish, as well as being the most important food of whalebone whales. The widely-used Norwegian term "Krill" refers to swarms of euphausiids.

Euphausiids have luminous organs at the base of the 7th thoracic leg and at the base of the first four abdominal legs. The animal gives off short, sharp flashes of light when disturbed. The tiny flashes of light seen at night in the wake of a ship are often made by euphausiids.

The most common species of euphausiids in our waters, Euphausia pacifica, feeds in the surface water at night but migrates to deep water during the day. This daily migration is often greater than 150 m.

Decapods

Few decapods, other than larval stages of crabs and shrimps, are caught in the plankton. The exceptions are all pelagic shrimps, such as Pasiphaea or Sergestes (pp.33), which occur in deep samples during the day and in surface samples during the night. They frequently form part of the incidental catch of pelagic trawl nets. Little is known of their feeding habits or of their importance to fish, although they are known to form part of the diet of fur seals.

Temporary plankton

Many animals which live on the bottom of the ocean or on the shores (benthos) have larval stages which live briefly as zooplankton. For example, the early life history of shore crabs takes place in the plankton as a zoea stage (pp.32) which moults into a megalops stage (pp.32) before settling on the bottom as juvenile crabs.

Another example are the early nauplii stages of the barnacle. Barnacle nauplii may live as plankton from one to four weeks and then settle on rocks or other substrates. Other benthic animals which have planktonic larval stages include teredos, clams, oysters, starfish, sea-cucumbers, and shrimps.

Larval fish (pp.34) form an important focal point for broad studies of the food resources of the sea. All factors which influence their survival require thorough study. As soon as the larvae are ready to commence feeding, zooplankton of the appropriate size, kind and quantity are essential. As the fish grow, they may fast for long periods or may bypass low food concentrations to search out high concentrations. As they grow they generally prey upon increasingly larger forms. For example, larval and juvenile fish studies in the

Strait of Georgia show that the eggs and nauplii of crustaceans are important sources of food for newly-hatched fish larvae. With an increase in size and mobility, the fish may feed successively upon Pseudocalanus, C. pacificus, and C. plumchrus. However, at the same time there is also an increased ability to take a broader size spectrum of prey. The stomach contents of juvenile fish, 30 to 70 mm in length, may consist of organisms ranging from the size of Oithona to euphausiids. Adult fish show similar feeding pattern, but the size spectrum of their prey may range from large copepods to squid and small fish.

Observing plankton -

During the spring and early summer, plankton is often very abundant in the Strait of Georgia. On calm days it is possible to look down into the water and see tiny animals swimming about. At night, planktonic animals and small fish may be attracted by a strong light aimed downward into the water from a wharf or boat. When plankton is very abundant it is possible to capture a few in a bucket or a small aquarium dip net. Larger samples may be collected by towing a conical net with very small mesh openings through the water at 1 to 2 knots for 5 to 10 minutes. A nylon stocking towed or held in a current will also catch zooplankton. The size of the plankton caught will depend on part on the mesh size of the net. The most common mesh used locally to catch zooplankton has openings of about 1/3 of a millimetre.

The amount of zooplankton caught is usually greatest in the spring and early summer; night catches are usually larger than day catches. Samples may be preserved by the addition of about 10% formaldehyde.

Recommended reading -

Books -

Berril, N.J. 1966. The Life of the Ocean. McGraw-Hill, Toronto, pp. 1-232.

Hardy, A.C. 1956. The Open Sea: Its Natural History: The World of Plankton. New Naturalist Series, Collins, London. pp. 1-335.

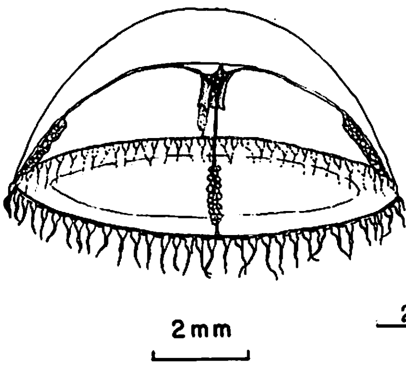
Fraser, J. 1962. Nature Adrift. The story of marine plankton. Foulis, London, pp. 1-178.

Russel, F.S., and M. Yonge 1963. The Seas. F. Warne and Co., London, pp. 1-376.

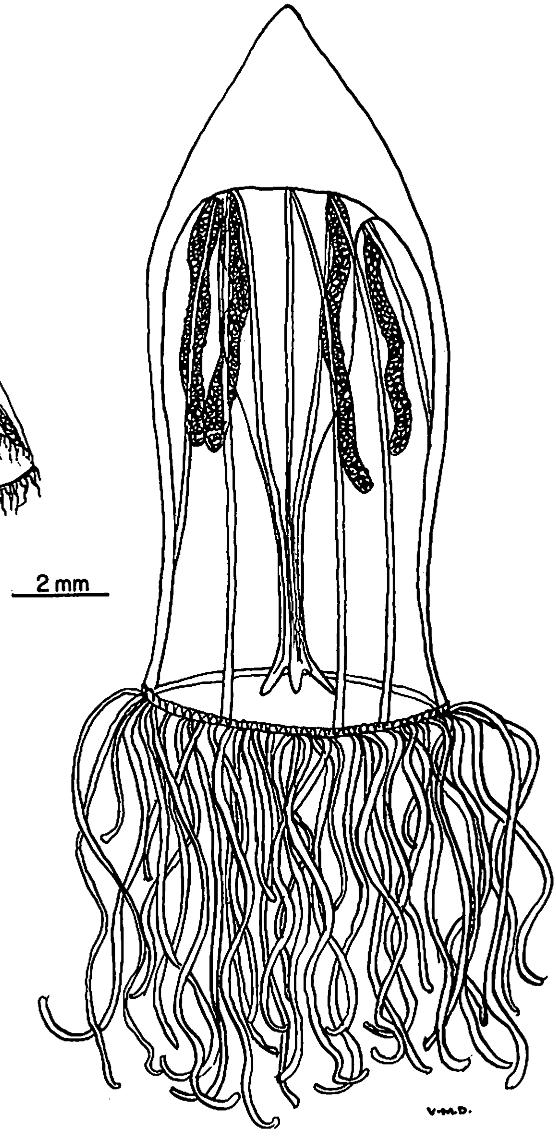
Wimpenny, R.S. 1966. The Plankton of the Sea. Faber and Faber Ltd., London. pp. 1-426.

Manuals -

Newell, G.E. and R.C. Newell. 1963. Marine Plankton, a practical guide. Hutchinson Educational, London. pp. 1-207.



Philidium

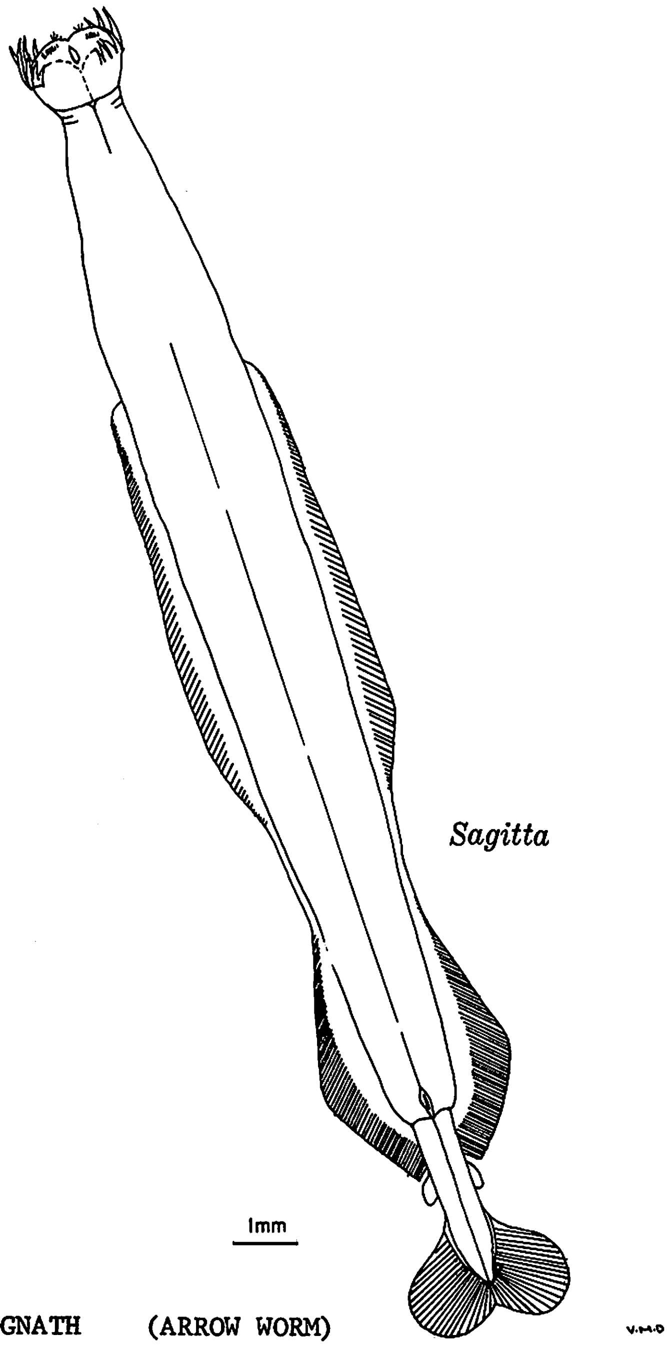


Aglantha

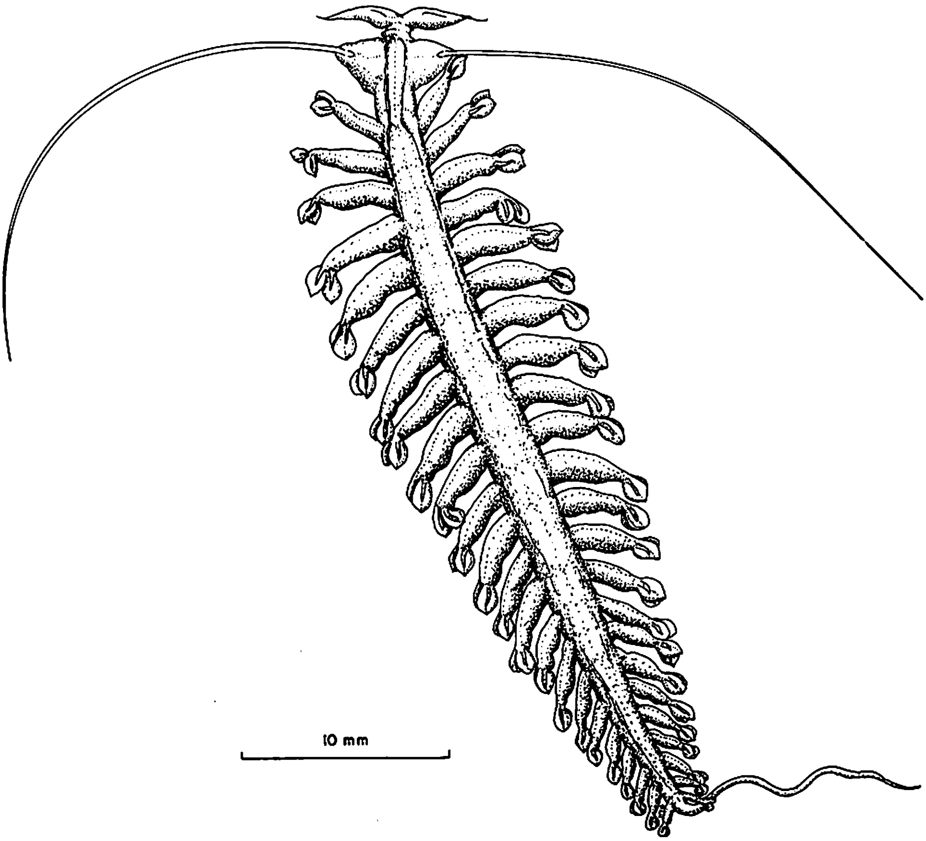
COELENTERATE (JELLYFISH)

Pleurobrachia

CTENOPHORE (SEA GOOSEBERRY)

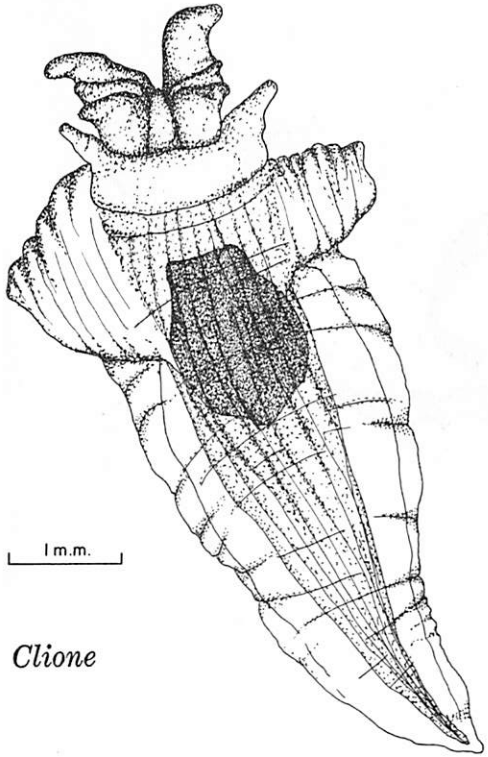


CHAETOGNATH (ARROW WORM)

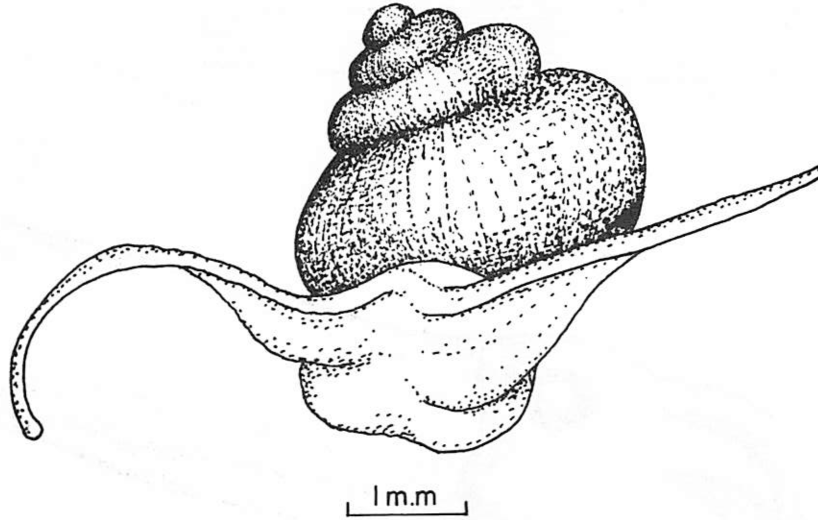


Tomopteris

ANNELID (POLYCHAETE)

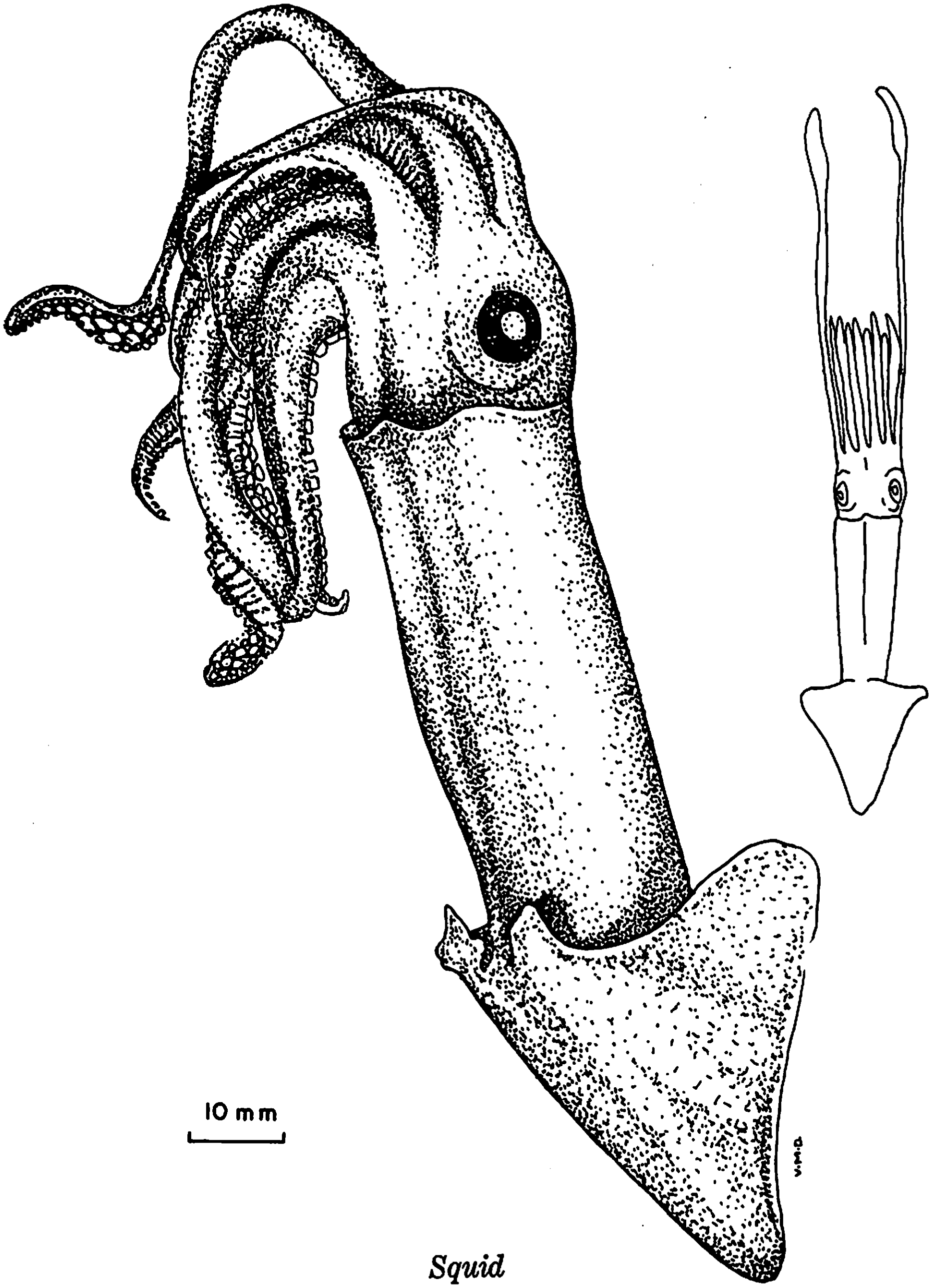


Clione



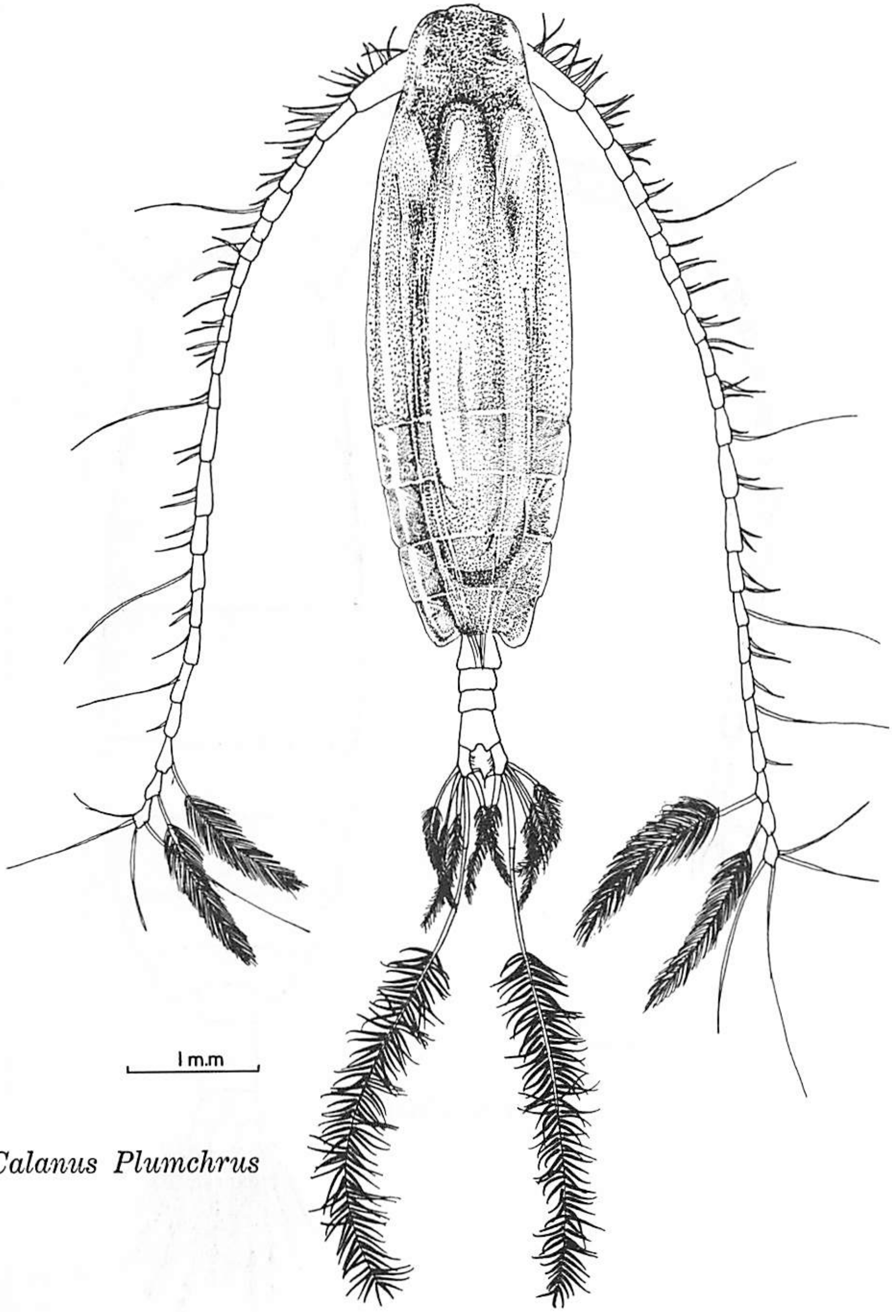
Limacina

MOLLUSC PTEROPOD (SEA BUTTERFLY)



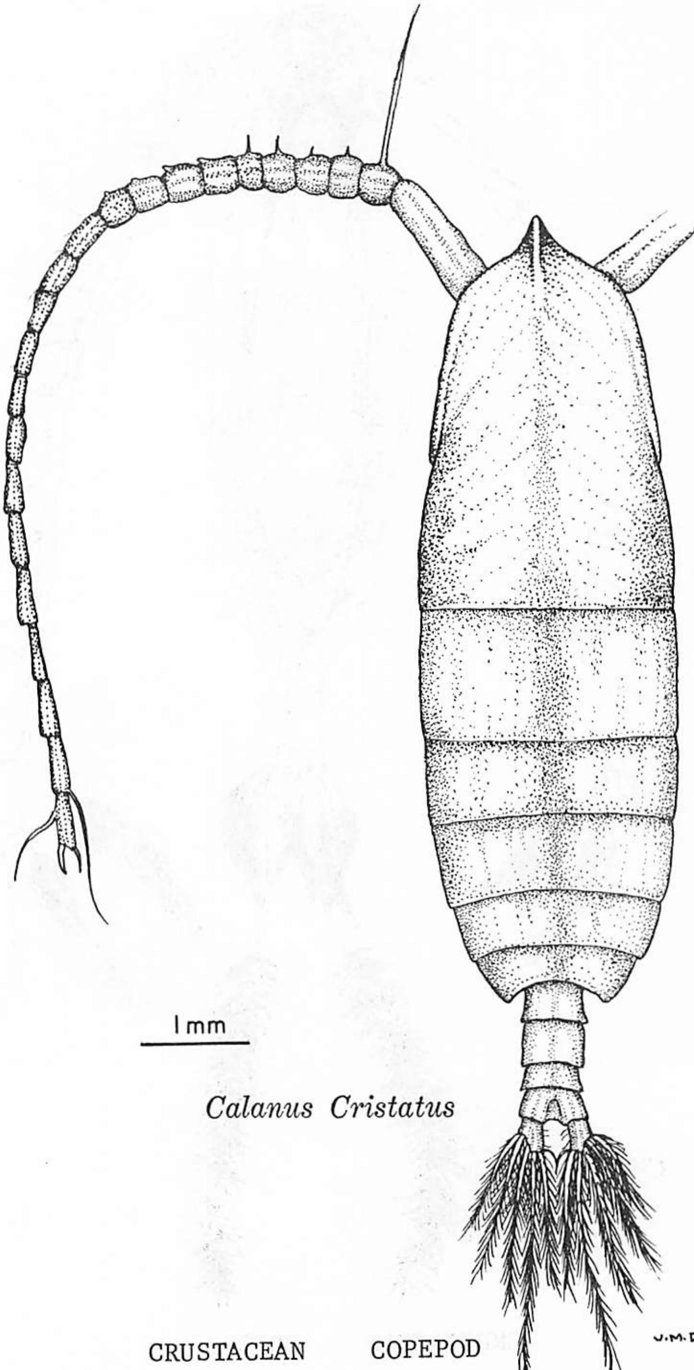
Squid

MOLLUSC CEPHALOPOD



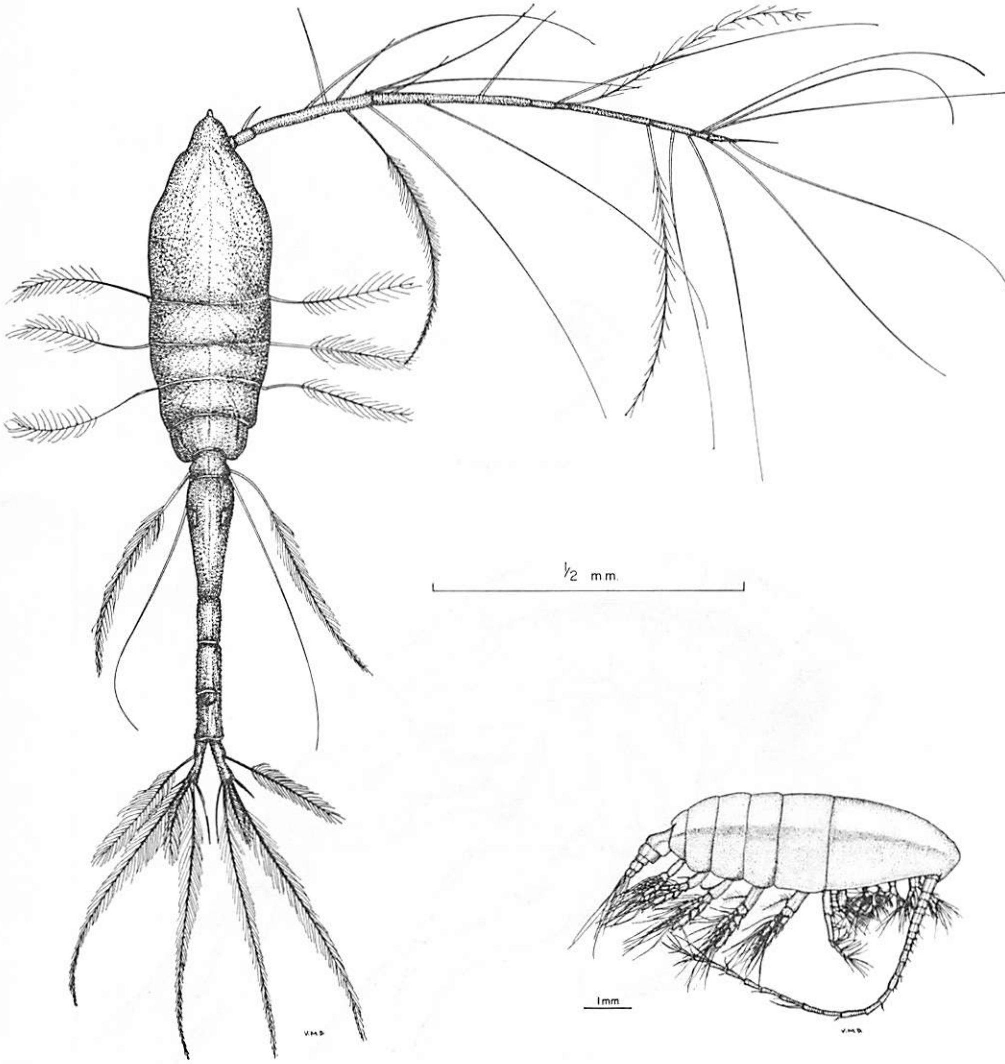
Calanus Plumchrus

CRUSTACEAN COPEPOD



Calanus Cristatus

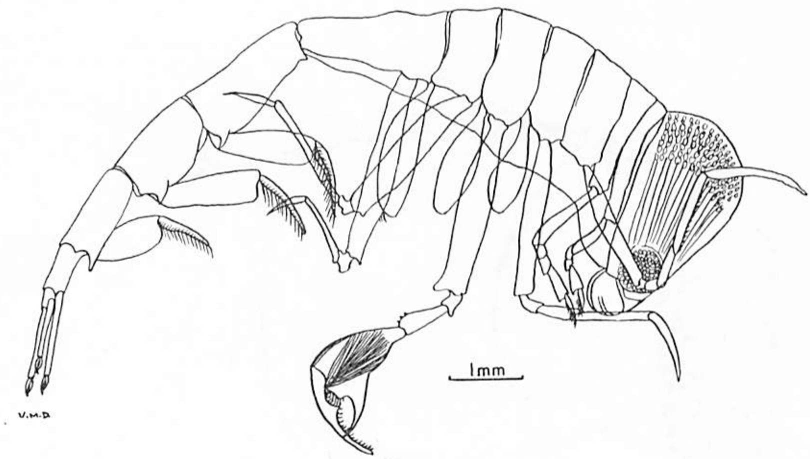
CRUSTACEAN COPEPOD



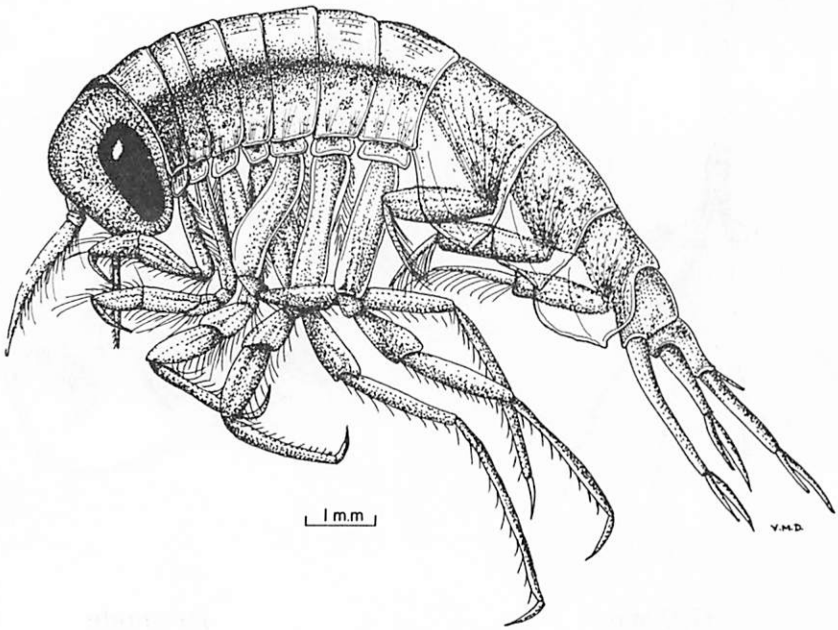
Oithona

Euchaeta

CRUSTACEAN COPEPOD

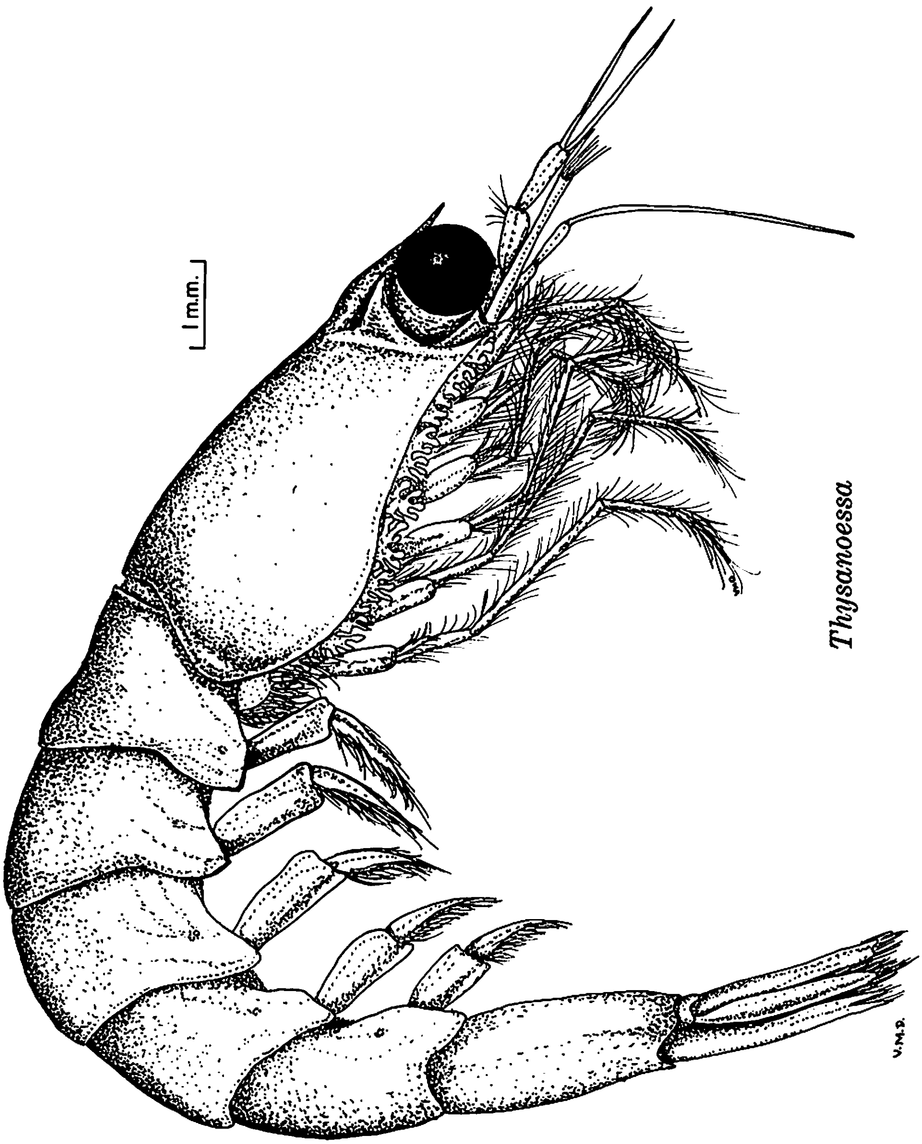


Phronima



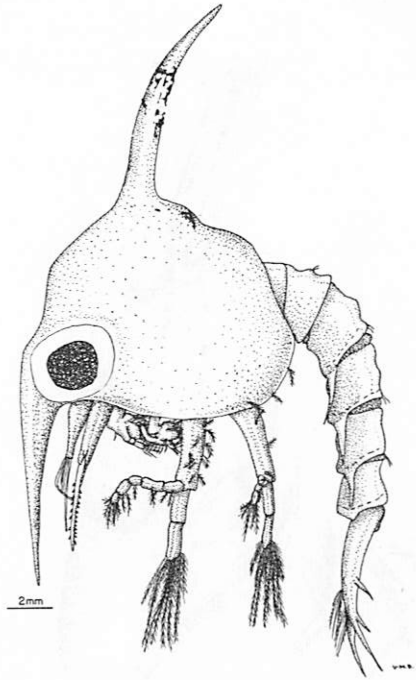
Parathemisto

CRUSTACEAN AMPHIPOD (SEA FLEAS)

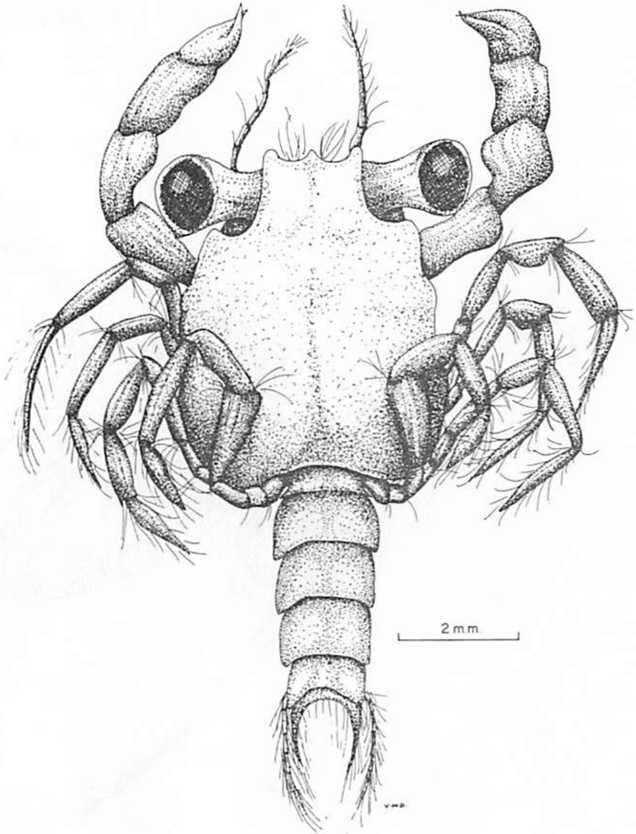


Thysanoessa

CRUSTACEAN EUPHAUSIID (KRILL)

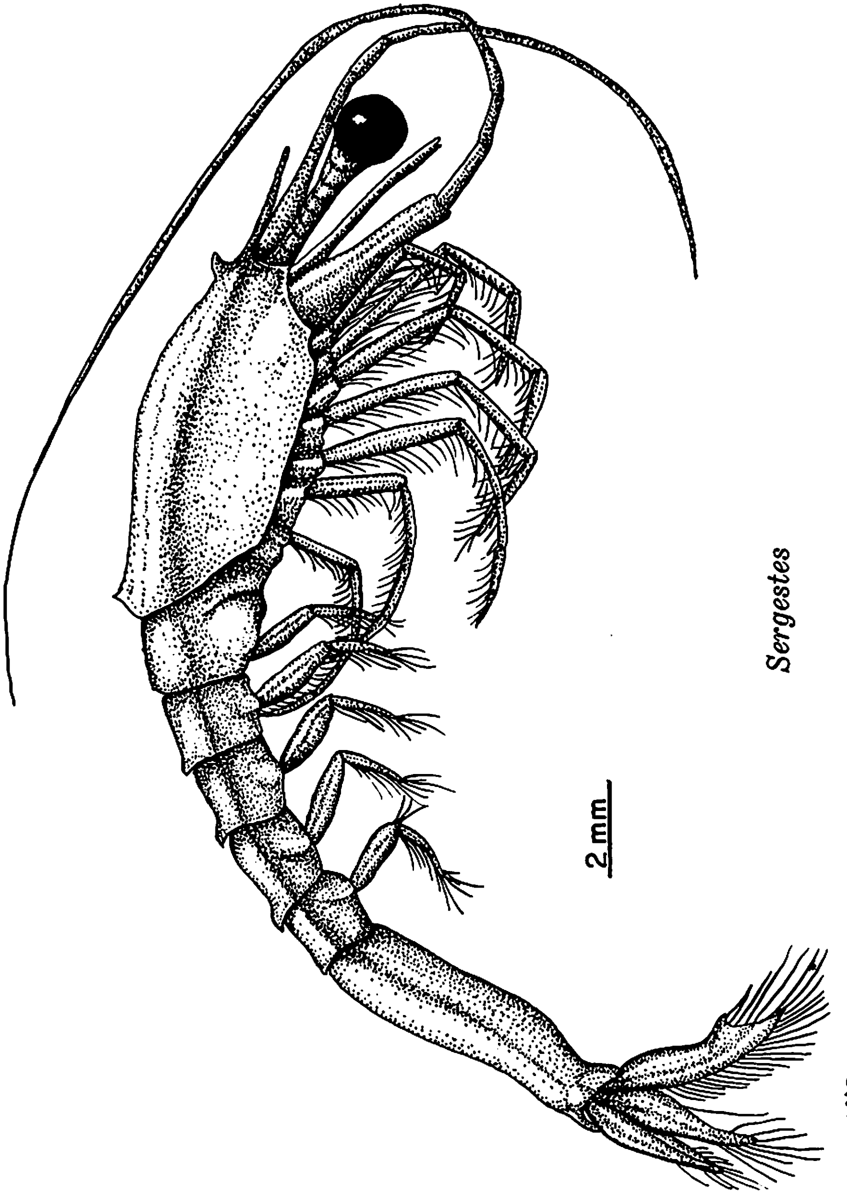


Zoea



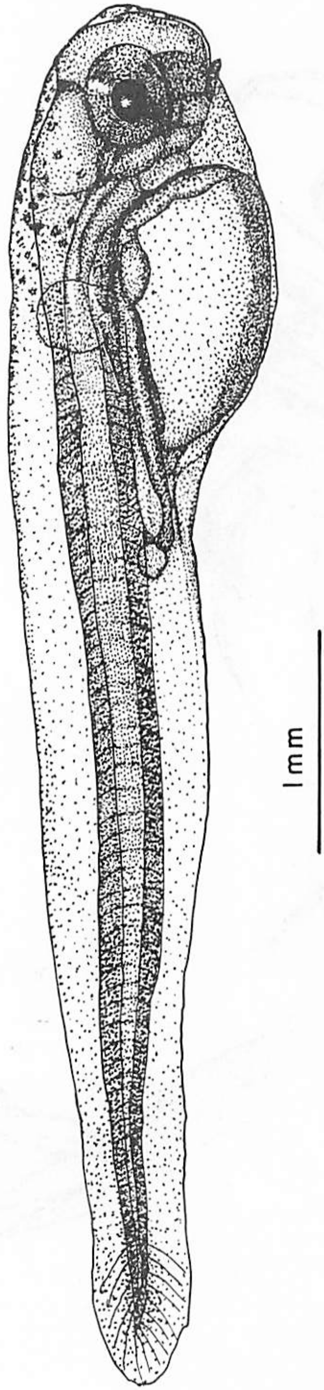
Megalops

CRUSTACEAN CRAB LARVAE



Sergestes

CRUSTACEAN SHRIMP



Rock Sole

LARVAL FISH