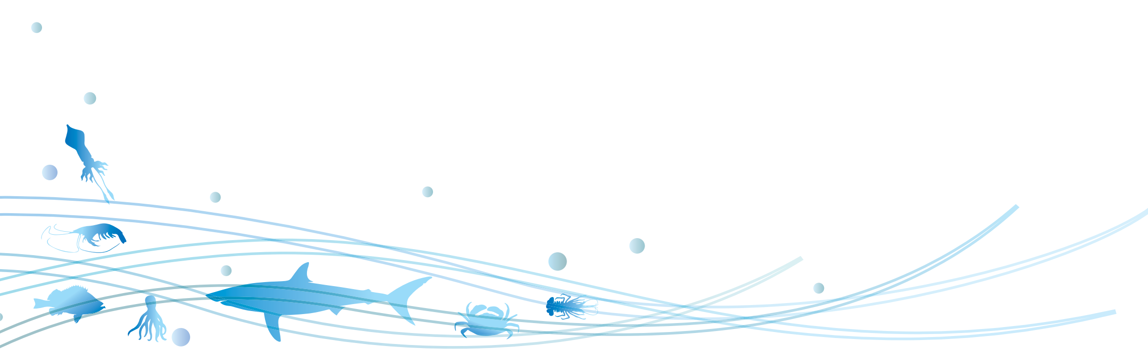
Methodologies for studying finfish & shellfish biology

Compiled and edited by
A.P. Dineshbabu
Geetha Sasikumar
Prathibha Rohit
Sujitha Thomas
K.M. Rajesh
P.U. Zacharia



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Dr. A. Gopalakrishnan
Director

Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)

Ernakulam North P.O., No. 1603 Cochin – 682 018, Kerala, India.

www.cmfri.org.in

Email: director@cmfri.org.in
Tel. No. +91-0484-2394867 Fax No. +91-0484-2394909

Preface

Global warming and consequent increase in seawater temperature are likely to play key roles in the distribution, abundance, phenology and recruitment success of marine and freshwater fishes. Migration and changes in abundance will alter species composition; structure and function of aquatic ecosystems. These changes may significantly alter production from seas. Though the marine fish production in India has shown steady increase over the years, it is now facing several sustainability issues such as the production approaching potential yield, overcapacity in the fishing sector, degradation of habitats and changes in migration patterns. Climate change will exacerbate these situations. Central Marine Fisheries Research Institute (CMFRI) has been assessing the impact of climate change on marine fisheries in order to develop strategies for climate change migration by continuously monitoring the biological characteristics of the exploited marine fishery resources of the country under the Indian Council of Agricultural Research(ICAR) project National Initiative on Climate Resilient Agriculture (NICRA).

This handbook on suggested methodologies for studies in fishery biology of finfishes and shellfishes of Indian waters prepared for use in the NICRA project by A.P.Dineshbabu and team is a compilation of existing methodologies right from estimation of fish catch at the landing centre to the analysis of biological aspects of finfishes, crustaceans and molluscs; supplemented with illustrations and drawings for easy understanding. This initiative is an outcome of the rich experience of the CMFRI researchers in the field of marine fisheries and will certainly help to improve the technical skill of researchers and their capabilities in undertaking mitigation measures and adaptation strategies associated with climate change.

This handbook is prepared as a reference guide for carrying out biological studies of exploited finfish and shellfish resources. I am sure that this handbook will be of immense help as a guiding tool in fishery biology studies for students and also as a teaching aid for researchers and teachers in universities and colleges as well.

A. Gopalakrishnan
Director
Central Marine Fisheries Research Institute

Contents

1

MARINE FISH CATCH ESTIMATION

Commercial fishing along the Indian coast is a dynamic and complex process with several types of crafts, gears exploiting more than 500 species of finfishes and shell fishes. Further to this, changing fishing patterns, practice of innovative fishing methods, improvisation of existing fishing methods, add to the already complex nature of fishing. Estimation of catch landed along the coast is thus a mammoth task.

Systematic, regular and unbiased sampling is an integral vital aspect of fishery biology. Biological processes like growth, maturation, feeding patterns, follows regular patterns. Long term studies are generally carried out on subsamples collected from the landing centres to get information on the different aspects of the life cycle of fish. These results are then extrapolated to get a clear picture of the fish population in the commercially fished area. To obtain, a subsample, one has to initially estimate the total catch available. Such sampling can be done only by following a statistically valid sampling design.

Estimation of the total marine fish catch of the country is one of the important mandates of the Central Marine Fisheries Research Institute. The institute has developed and adopted a reliable sampling methodology to estimate resource-wise/region-wise landings based on stratified multi-stage random sampling technique. In this, the stratification is over space and time. Over space, each maritime state is divided into suitable, non-overlapping zones on the basis of fishing intensity and geographical considerations. The number of centres may vary from zone to zone. These zones have been further stratified into substrata, on the basis of intensity of fishing. There are some major fisheries harbours/centres which are classified as 'single centre zones' for which there is an exclusive and extensive coverage. The stratification over time is a calendar month. One zone and a calendar month is a space-time stratum and primary stage sampling units are landing centre days.

Example: In Karnataka, 14 zones have been identified. Of these seven of them namely- Mangalore, Malpe, Gangolli, Bhatkal, Kesarkodi, Tadri and Karwar fishing harbours are single centre zones. The remaining seven zones have multiple centres ranging from 10-12 landing centres. Kn-I zone include the following 10 centres – Talapady, Someshwara, Ullala, Panambur, Baikampady, Hosabettu, Suratkal, Mukka, Lachhil and Sasihitlu. The centres included under a zone are reviewed regularly and changes made if required based on the latest fishing status of the centre. Within a zone if there are 20 landing centres, there will be 20 x 30 = 600 landing centre days in that zone for that month (of 30 days). For observation purpose, a month is divided into 3 groups, each of 10 days. From the first five days of a month, a day is selected at random, and the next 5 consecutive days are automatically selected. From this, three clusters of two consecutive days are formed. For example, for a given zone, in a given month, from the five days, if the date (day) selected at random is 4, then the following clusters are formed, namely, (4, 5); (6,7) and (8, 9) in the first ten day group. In the remaining ten day groups, the clusters are systematically selected with an interval of 10 days. In the above case, the cluster of observation days in the remaining groups are (14, 15), (16, 17), (18, 19) (24, 25), (26, 27) and (28, 29). Normally, in a month there will be 9 clusters of two days each.

From among the total number of landing centers in the given zone, 9 centres are selected with replacement and allotted to the 9 cluster days as described earlier. Thus in a month 9 landing centre days are observed. The observation is made for six hours (1200 - 1800 h) on the first day and six hours (0600-1200 h) on the second day, in a centre. For the intervening period of these two days, the data are collected by enquiry from 1800 hrs of the first day of observation to 0600 hrs of the 2nd day of observation of a landing centre-day, which is termed as 'night landing '. The `night landing' obtained by enquiry on the second day covering the period of 1800 hrs of the first day to 0600 hrs of the next day are added to the day landings so as to arrive at the landings for one (landing centre day) day (24 hours). It may not be practicable to record the catches of all boats landed during an observation period, when the number of boats/craft landings is large. Then a sampling of the boats/crafts becomes essential. When the total number of boats landed is 15 or less, the landings from all the boats are enumerated for catch and other particulars. When the total number of boats exceeds 15, the following procedure is followed (table.1) to sample the number of boats (Alagaraja, 1984):

Table 1. Sampling procedures for fishing boats based on their numbers landed at landing centres.

Number of units landed	Fraction sampled
Less than or equal to 15	100 %
Between 16 and 19	First 10 and the balance 50 %
Between 20 and 29	1 in 2
Between 30 and 39	1 in 3
Between 40 and 49	1 in 4
Between 50 and 59	1 in 5

The basic information collected from the samples units are type of craft, craft material, fish hold capacity when present, gear used, fishing duration, area of operation, direction of wind, depth of operation, no. of hauls per day, species composition and estimated wet weight of the different species. Catch from the boat is generally removed in baskets or crates. The weight of fish per basket/crate is known and form this total weight of the particular fish landed by the unit is estimated.

Estimation procedure

The unit sampled is based on the type of craft, gear used, fishing days per trip and status of mechanization. For instance, when a trawler is being monitored; the sampled unit can be a traditional non-mechanized hand trawl, a motorized canoe operating the small trawl net, a single day mechanized trawler, a multiday mechanized trawler or a multiday deep water trawler. The catch observed in the sampled unit is added to get the total catch made by the sampled units at the observed centre. The catch by all the units (sampled type) during the observation is estimated. By adding the catch during the two six hour periods of observation and the catch during the twelve hour duration (night landings), the total quantity for a centre day is estimated. Catch during the sampling days are added to get an estimation of catch for all the sampling days for the centre. This data is then used to estimate the monthly catch for a particular type of unit from a sampled centre. The monthly estimates are added to get the annual estimates. The procedure for estimating the catch for different centres, zones and states to arrive at the National catch estimates has been discussed in detail by Srinath *et al.* (2005).

Effort is generally given as actual number of units or as actual fishing hours. The use of hours is relevant especially when fishing operation is carried out for more than one fishing day and also when the fishing operation is active. In the case of trawlers, the actual time taken for trawling per haul is taken into account. Appropriate weightage is given while estimating the catch made by single day and multiday trawl, based on the actual time used per haul and number of hauls made during 24 hours.

Development process in the fishing industry has been very rapid and with the advent of multi-day/night fishing, use of combination gears and introduction of high speed engines for fishing, sampling and catch estimation are becoming even more complex. However, the stratified

multi-stage sampling technique used by CMFRI is the best to estimate catch by species / by gear for different centres, States and for the country over space and time. The FAO has recognized this method as a model sampling design which can be followed by all developing nations.

2

MORPHOMETRIC MEASUREMENTS

Meristic and morphometric characteristics are important to identify fish species and their habitat peculiarities as well as ecological criteria. Variety of morphological, physiological, behavioral and biochemical characteristics are used to identify and classify fishes. Though morphometric measurements are used directly they are usually presented as a proportion of standard or total length. Shape and structure of marine organisms vary greatly among fishes, crustaceans and molluscs therefore the morphometric measurements used for biological studies are different for the three groups. For stock related studies length measurements forms basic input data and in fishes. Generally total length is measured to the nearest 0.1 centimeter (total length/fork length for fish, total length/ carapace length for shrimps and lobsters, carapace width for crab and dorsal mantle length for cephalopods).

Finfishes

Several characteristics based on morphology and meristic such as body shapes, length, depth position of mouth and fins, nature of fish spine, scales and colour are used for identification of the fish. The principal length measurements used in fish taxonomy are body shape, body covering, mouth structure barbels and flaps, colouration, fins and their shapes, gill apertures/gillrakers and sensory organs.

Body shape

Generally, the fish body is torpedo shaped (fusiform) and most often slightly to strongly ovoid in cross section. These body shapes range from globe shapes (Pufferfishes, Tetradontidae) to thread like in outline (snipe eels, Nemicthyidae). Some fishes are strongly flattened from side to side (butterfly fishes, Chaetodontidae, flounders and Pleuronectidae) flattened laterally and greatly elongated (Trachipteriformis, ribbonfishes. Pomacanthidae, Chartodontidae), dorso-ventrally flattened (skates, rays) and some are having combination shapes as in the case of seahorse and sunfish.

Fins

Median fins: The median fins include the dorsal fins, caudal fins, and anal fins. In general all these fins are present on the fish with exceptions of one of the fins absent in some fishes.

Dorsal fin: The number of dorsal fin varies from 1-3. It is usually one and soft rayed in lower teleosts, two and spiny rayed in higher teleosts (separate, slightly united or united). Presence of three dorsal fins is characteristic of cod and haddock. In Gymnotiformes the dorsal fin is absent. Fatty adipose fins (lizardfishes) or fins reduced to a few disconnected spines (sticklebacks) are also are some of the modification of fins.

Caudal fins: The caudal fin type is also characteristic feature for the classification and evolution of fishes.

The tails of fishes reflect changes that have taken place through the ages. In sharks, as in early fossil fishes, the upper part of the tail contains the backbone and extends to a point. This asymmetrical fin type is called heterocercal. In modern bony fishes, the tail is more balanced and the backbone ends where the tail begins. This type of caudal fin is called homocercal. Another type of tail is called diphycercal or isocercal. In this type of caudal fin, the vertebrae extend all the way to the end of the tail. It is present in coelacanth and lungfish, where it is three-lobed.

The pectoral fins: The pectorals are supported by the pectoral girdle that joins the skull and in spiny rayed fishes, are situated higher on the sides of the fish rather than near the pelvics. Pectorals are absent in lampreys and hagfishes, enlarged in flying fishes and flying gurnards, modified into claspers in some cyprinodontiformes and into holdfast organs (suckers) in clingfishes and loaches.

The pelvic fins: The pelvic fins vary substantially in position. In most soft rayed fishes the pevics are abdominal in position but they may be positioned anteriorly just below the pectorals (thoracic) or under the throat (jugular). Pelvics are absent in lampreys and hag fishes and become lost in some fishes like eels. In sharks and rays they are modified into claspers, and as holdfast organs in some gobies.

Mouth structure

The position of the mouth opening, structure of mouth, width of the gape is some of the important considerations taken into account during taxonomic studies of the fish. The mouth position may be terminal, inferior or superior.

Jaws and teeth

The jaws and teeth exemplifies many evolutionary trends and adaptations and largely determines the facial appearance. The jaws of fishes have evolved into many different types, both as to position and details of structure. One extreme variation is the protrusion of the jaws.

Gill apertures/ gillrakers

In bony fishes there is a single gill opening on each side of the head, with an operculum. Normally this opening is in front of the pectoral fin base the exception being fished of the family Ogocepahlida where the gill opening is in front of gill opening. The openings are a single pair in chimaeras and some hagfishes. In other hag fishes they vary from 5-14 on each side, the lampreys have seven and most sharks have five openings. The position and number of gill apertures thus form an important taxonomic tool in the identification.

The gill membranes connect the branchiostegals and enclosing the gill chamber ventrally; the membrane below the operculum often attached to the isthmus supported by branchiostegals and helping to enclose the gill chamber ventrolaterally.

The presence, absence of gill rakers, their position and number are important identification tools in most fish identification upto species level. The filter feeders have several gill rakers whereas in carnivore fishes, the gill rakers are limited and easily countable.

Sensory organs

Nares: One or two nares on each side of the snout leading to a blind sac represent the organs of smell externally among fishes. The fleshy, valvular tissue in the nostrils have some value in the classification of fishes.

Eyes: Lidless eyes that cannot be closed are situated in orbits, one on each side of the mid line of the head. Generally the eyes are lateral but in bottom dwellers, the eyes are dorsal. The eyes are variously reduced or absent in cave fishes.

Lateral line: A lateral line is a sense organ fish use to detect movement and vibration in the surrounding water. The shape of lateral line, the length and curvature position, etc. are useful tools in identification and classification of fishes into families and species.

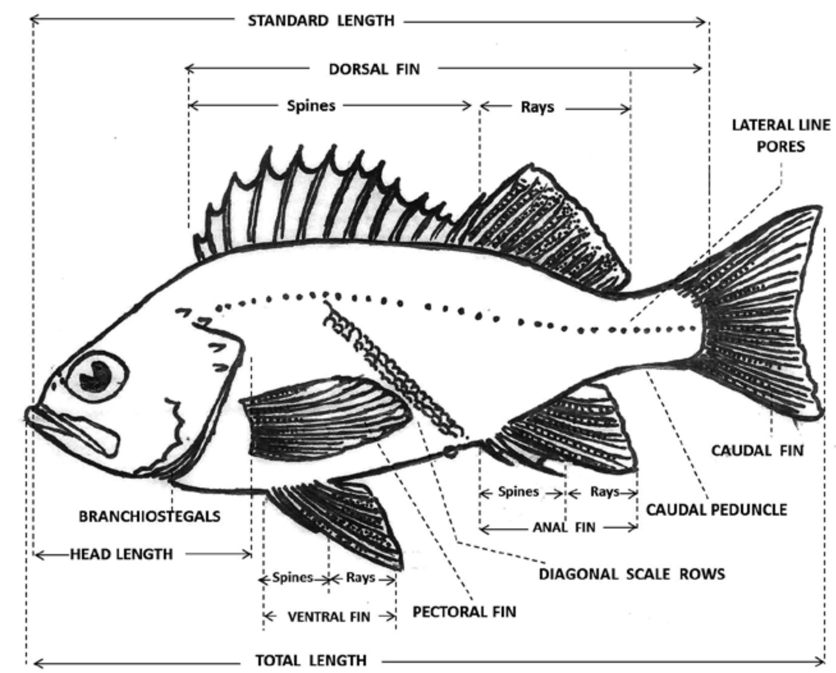


Fig. 1. Morphometric features of a teleost fish

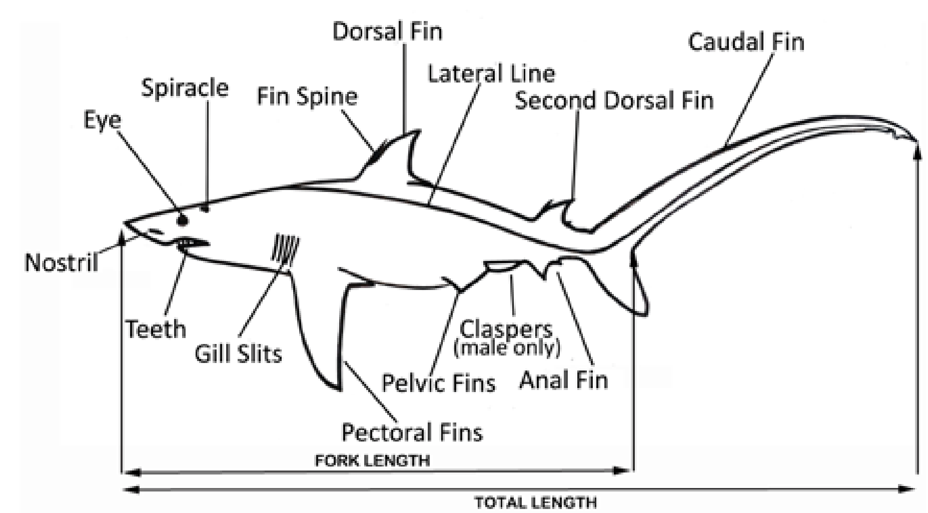


Fig. 2. Morphometric features of features of shark.

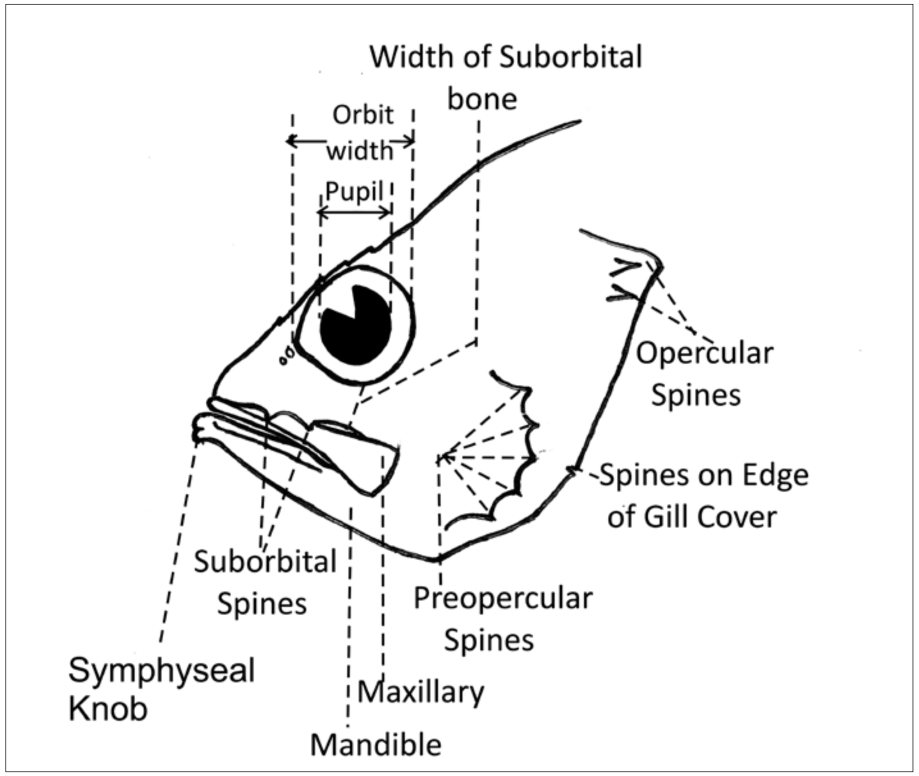


Fig. 3. External measurements of a teleost head.

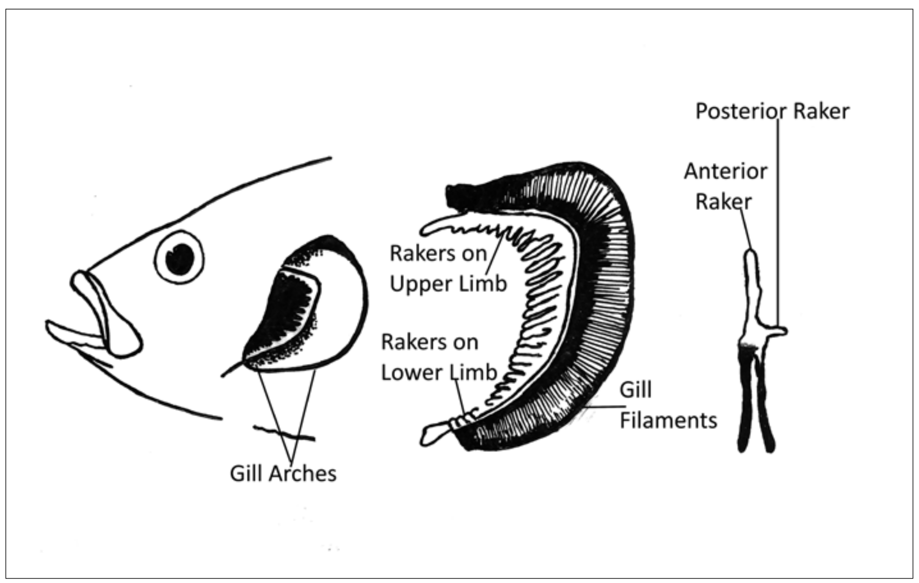


Fig. 4. a. Position of Gill arches inside gill cavity of bony fish (gill covers removed); b. sideview of the gill arch; c. section of the gill arch.

Crustaceans

Shrimp/prawn

The shrimps constitute a large group of crustaceans varying in size from microscopic to about 35 cm long. The body of the shrimps is almost always laterally compressed, the rostrum usually compressed and toothed, and the abdomen long, longer than the carapace or head. The antennules, or first pair of feelers, in most species bear a small scale or spine, the stylocerite, at their bases, and the antennal scales of the second pair of feelers, the antennae, are generally large and plate-like. The pereopods or legs are usually slender, but in some a single leg or pair of legs may be stout and some pereopods (the chelipeds) end in pincers or chelae. The pleopods or abdominal appendages used for swimming are well developed and, except in a few species, are present on all five anterior abdominal segments.

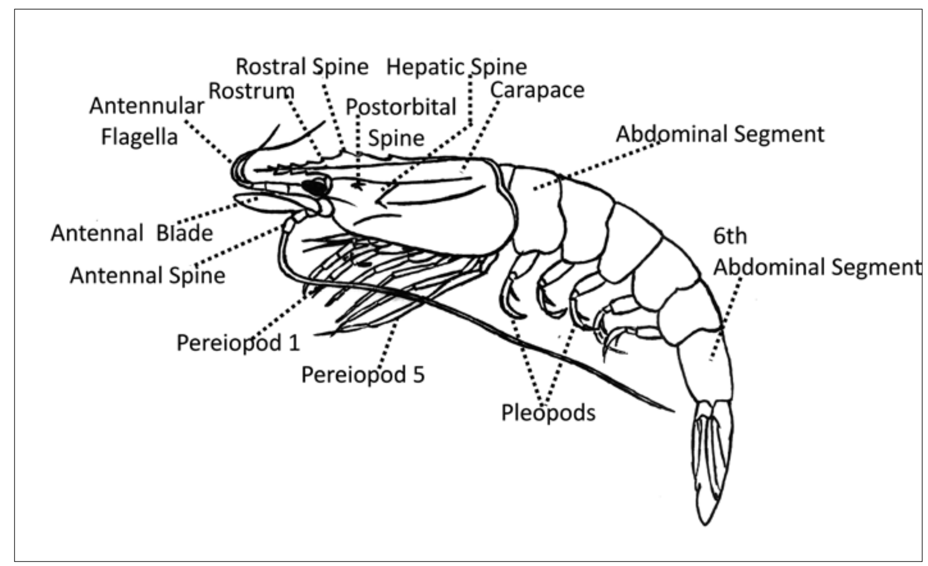


Fig. 5. Morphometric features of prawn

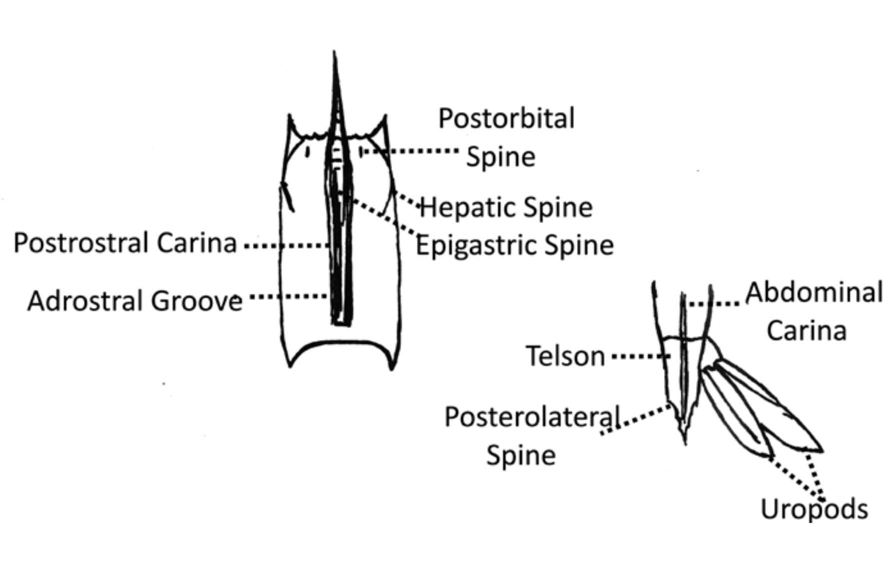
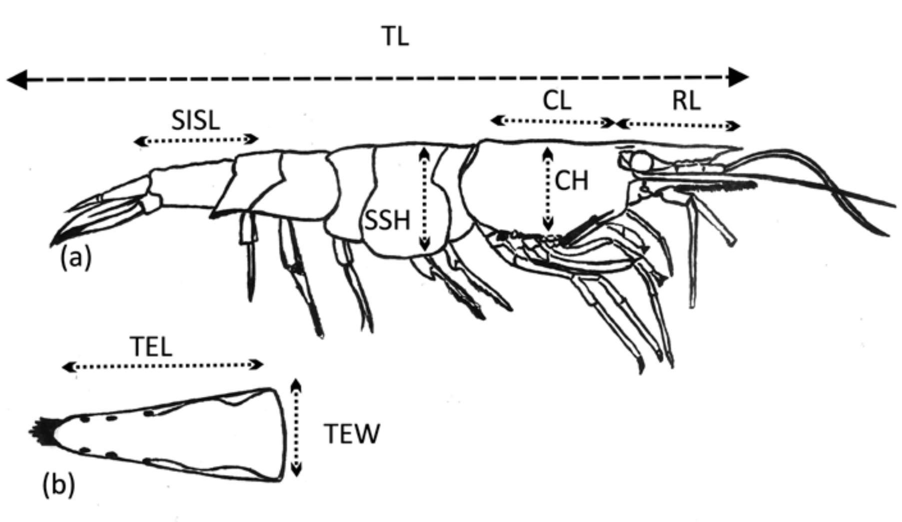


Fig. 6. Parts of carapace and tail of the prawn



telson. TL: total length, CL: carapace length, CH: carapace height, RL: rostral length, SSH: second pleon segment height, SISL: sixth pleon segment length, TEL: telson length and TEW: telson width.

Fig. 7. Morphometric measurements of prawn

Crab

The true crabs (brachuran crabs) have a depressed carapace or cephalothorax and a much reduced, straight, and symmetrical abdomen which is closely bent under the cephalothorax. Abdomen lacks biramous uropods as in prawns. In the female, during the spawning season, the eggs are attached to the abdominal appendages (berried crabs). The cephalothorax has 5 pairs of walking legs, the first of which is chelate (ending in pincers) and nearly always much stronger than the other legs.

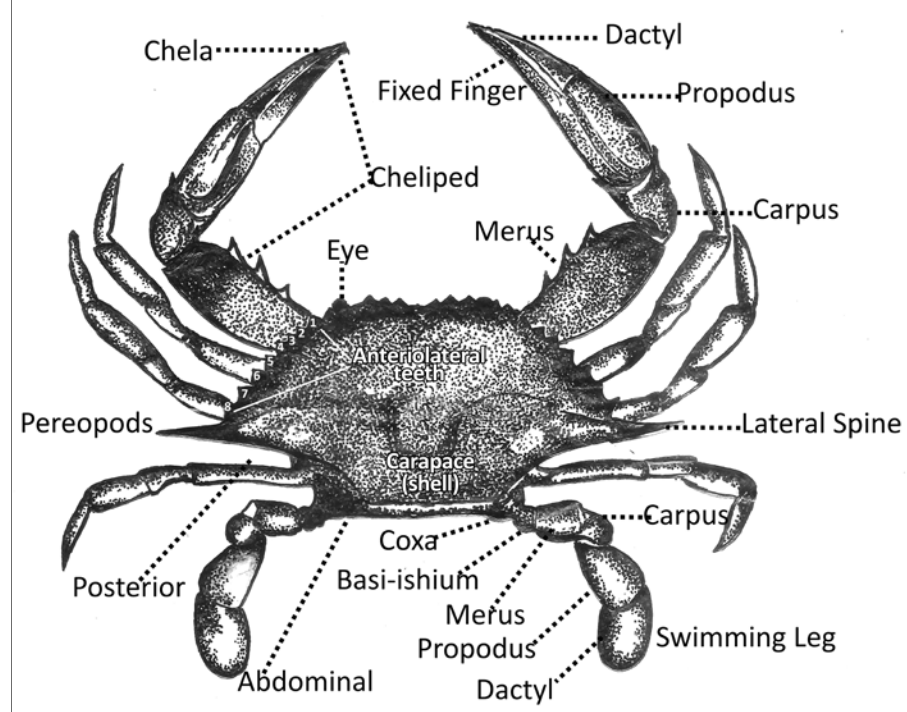


Fig.8. Morphometric features of crab

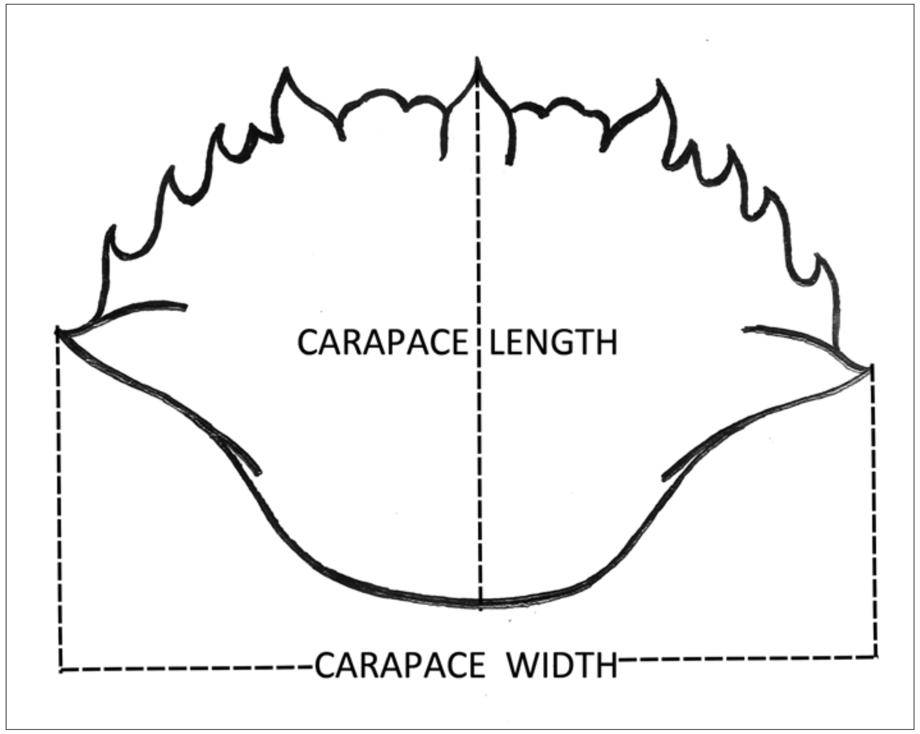


Fig. 9. Morphometric measurements of crab

Lobster

The lobsters are more or less elongate animals with cylindrical or flattened bodies and a prominent tail or abdomen consisting of 6 movable segments and a terminal fan, which is usually about as long as the rigid and often spiny or tuberculate head or carapace. The eyes are stalked and usually movable in the sockets of the carapace. The most conspicuous of the appendages of the anterior part of the body, under the carapace, are a pair of usually small, slender antennules, a pair of more robust antennae (long and cylindrical in most families, scale-like in the slipper lobsters or Scyllaridae) and 5 pairs of legs (pereopods or thoracic legs). The abdominal appendages are short and biramous reduced abdominal legs or pleopods.

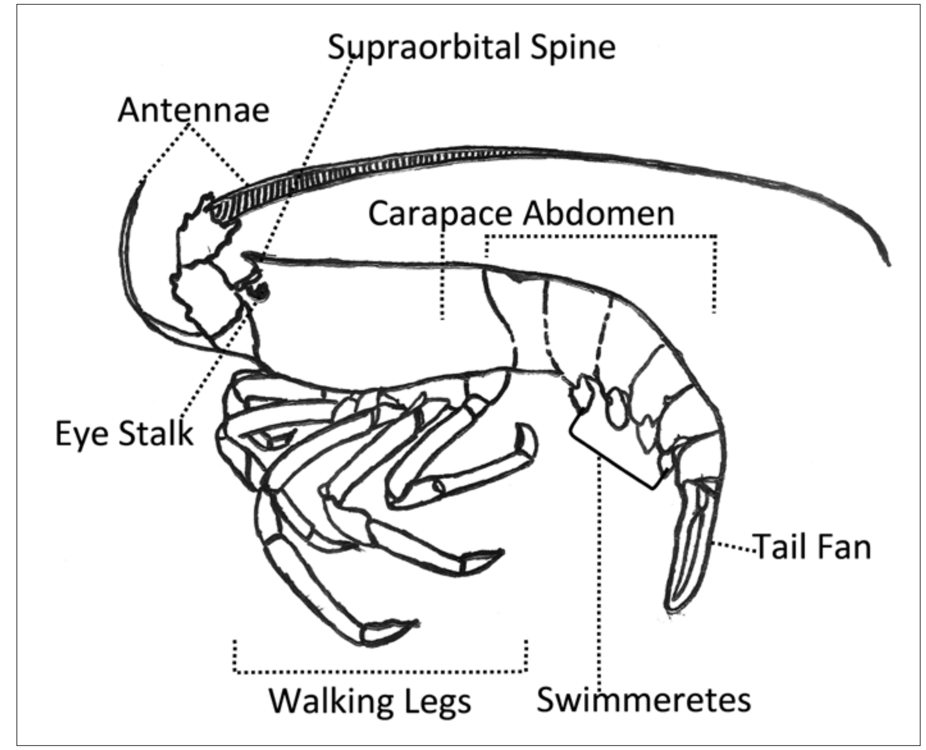


Fig. 10. Morphometric features of of lobster

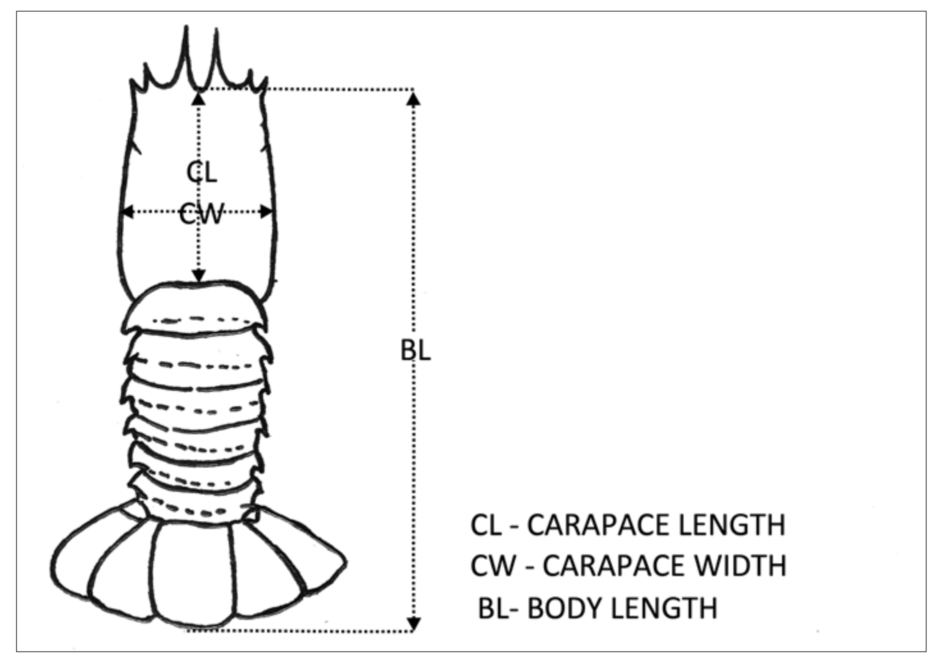


Fig. 11. Morphometric measurements of lobster

Cephalopods

Cephalopods are represented by the squids, octopuses and cuttlefishes. The body form is characterized by the fore-shortening of the anterior-posterior axis and elongation of the dorso-ventral axis. Size of adult cephalopods ranges from less than 1 cm to the giant squid at approximately 20 m in total length, including the tentacles. The largest specimens may weigh well over 500 kg, but the average size of commercial species is 20 to 40 cm mantle length and about 0.1 to 2.0 kg total weight.

Cephalopods are soft-bodied, bilaterally symmetrical animals with a well-developed head and a body that consists of the muscular mantle, the mantle cavity that houses the internal organs, and, when present, the external fins. The head bears an anterior circumoral (surrounding the mouth) crown of mobile appendages (arms, tentacles). Arms and tentacles bear suckers and/or hooks, which are powerful tools to seize prey. The mouth has a pair of chitinous jaws (the beaks) and, as in other molluscs, a chitinous tongue-like radula (band of teeth) occurs in most cephalopod species. The ancestral mollusc shell is variously modified, reduced, or absent in living coleoids. It is a calcium carbonate structure in cuttlefishes (the cuttlebone of sepiids and the ram's horn shell of Spirula), reduced to a rigid structure composed of chitin in squids (the gladius or pen, sometimes quite flexible) and to a cartilaginous structure in finned octopods. In some sepiolids no vestige of shell is found.

In squids and cuttlefishes, the measurement is made along the dorsal surface from the posteriormost point to the anteriormost point of the mantle. In octopuses, mantle length is measured from the midpoint between the eyes to the posterior tip of the mantle along the dorsal surface.

Squid

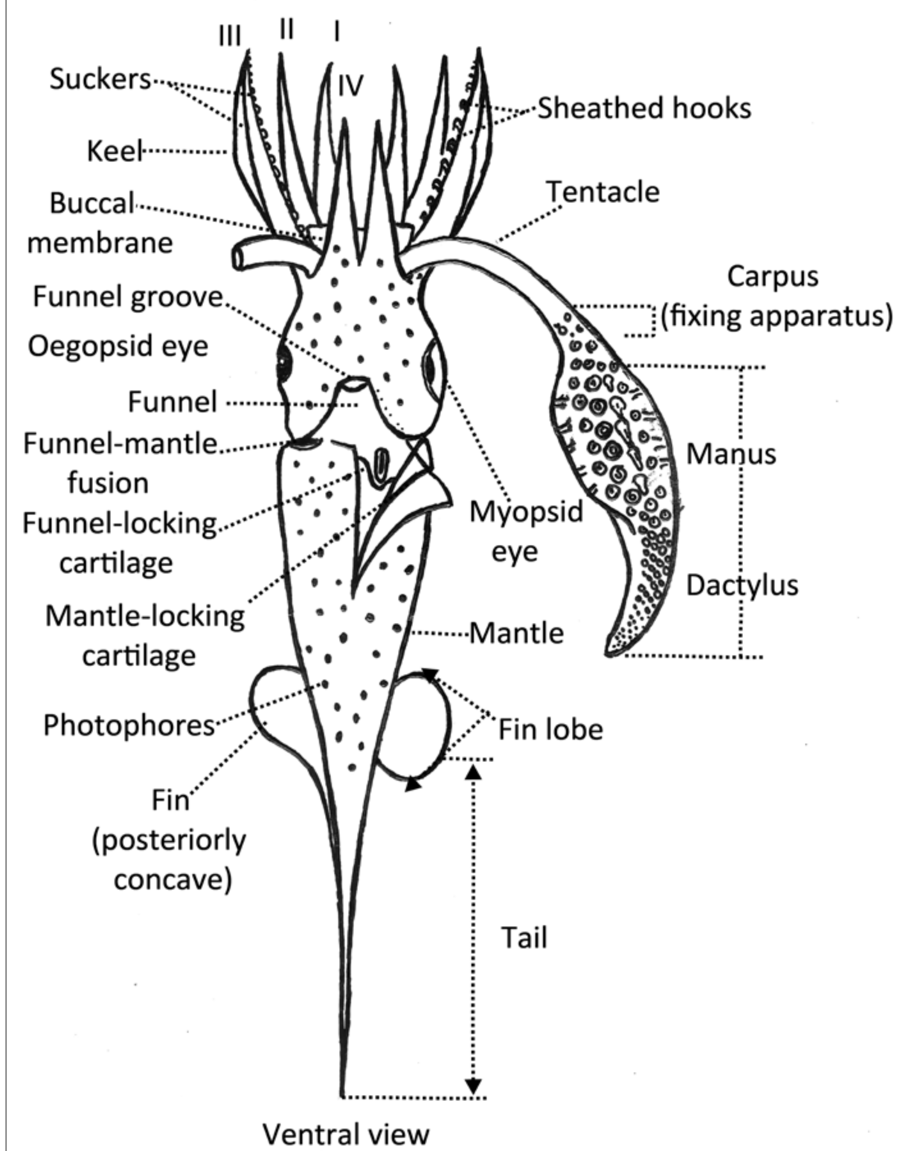


Fig. 12. Morphometric features of squid (Ventral view)

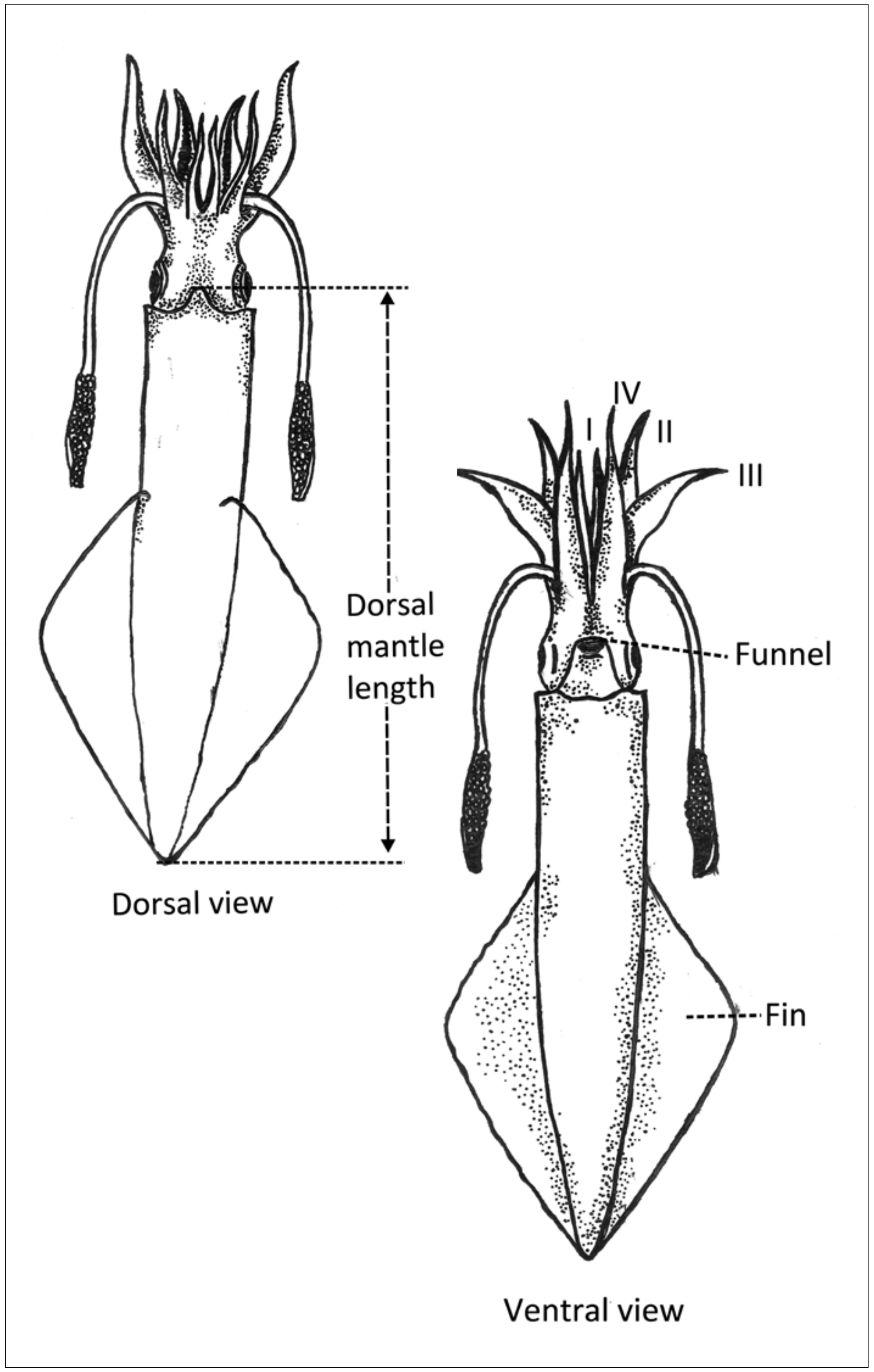


Fig. 13. Dorsal view of squid representing basic features

Cuttlefish

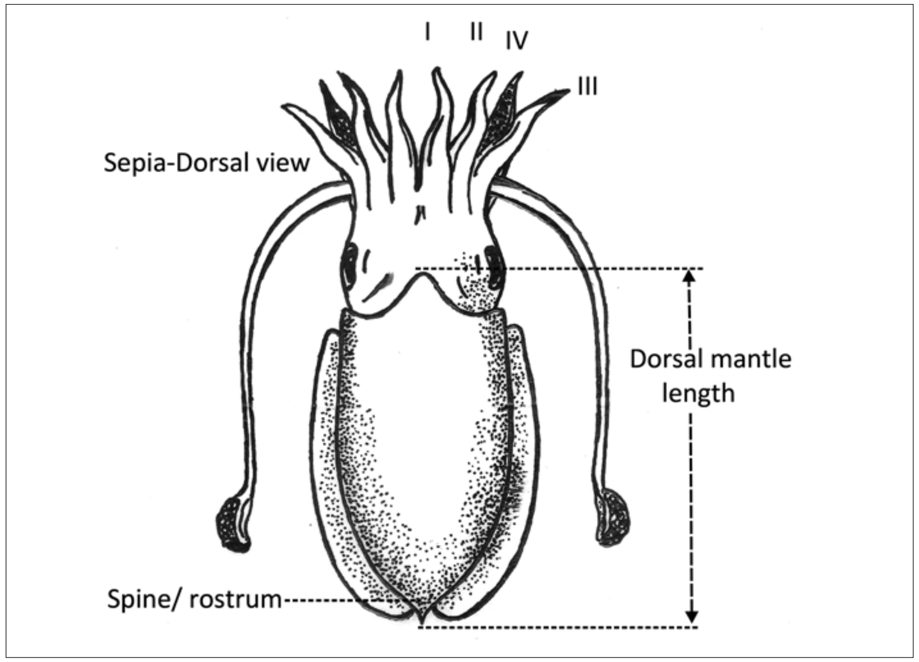


Fig. 14. Dorsal view of cuttlefish – *Sepia*

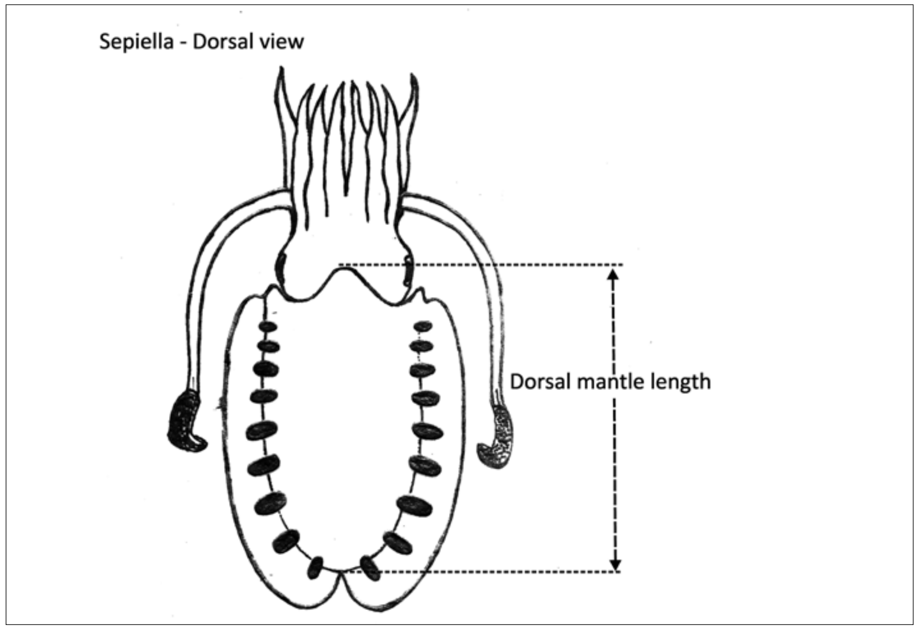


Fig. 15. Dorsal view of cuttlefish – *Sepiella*

Octopus

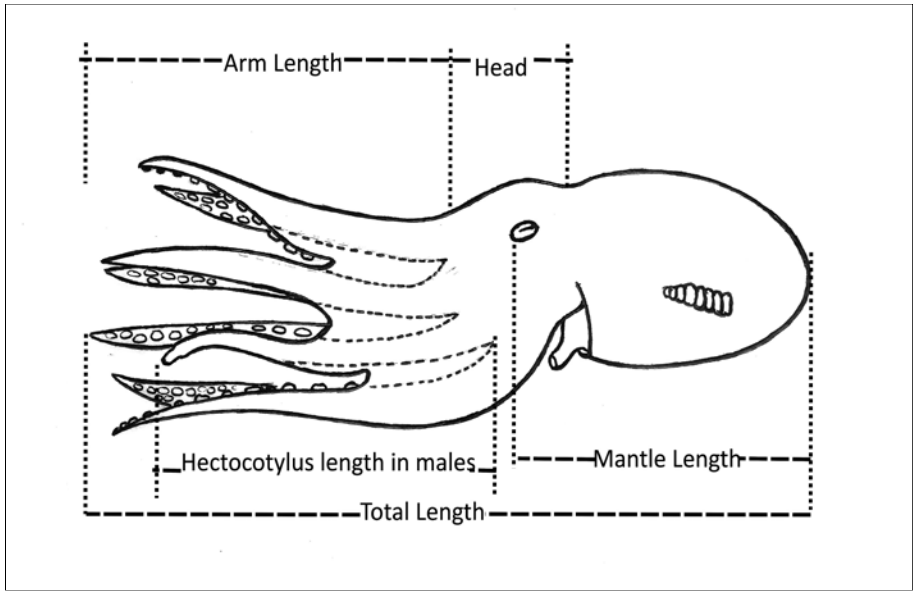


Fig. 16. Morphometric measurements of octopus

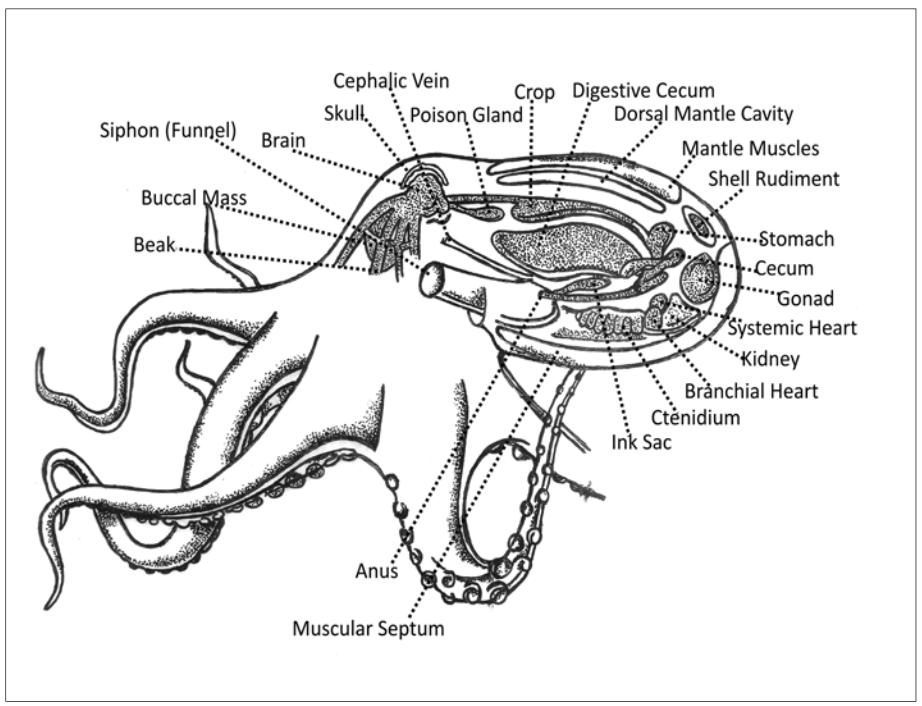


Fig. 17. Schematic representation of external and internal body parts of octopus.

Bivalves

Bivalves have a soft unsegmented body protected within the two calcified valves of their shell, lying on the right and left side. They have a thin layer of tissue called a mantle that covers their internal organs. The two valves are connected along the dorsal margin at the hinge by ligaments. The shells are closed by the pulling action of adductor muscles, fixed to the inner side of the valve.

Shell height in bivalves is measured as the distance between two planes parallel to the hinge axis and perpendicular to the plane of commissure, which just touches the most dorsal and most ventral parts of the shell. The shell length is the distance between two planes perpendicular to the cardinal axis and just touching the anterior and posterior extremities of the shell.

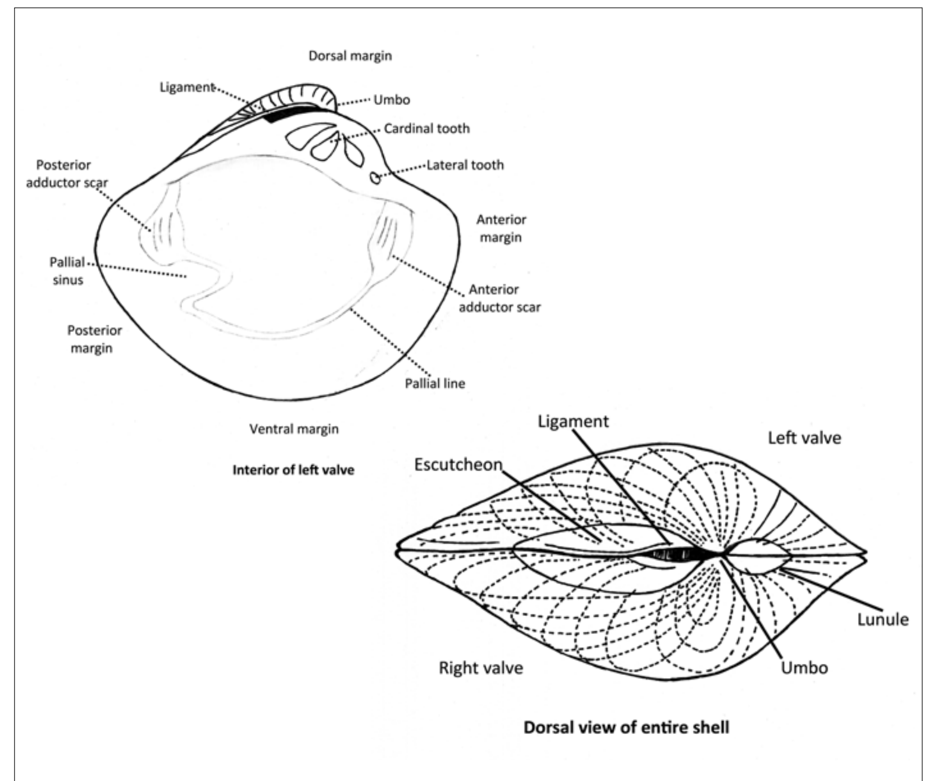


Fig. 18. Morphometric features of bivalves

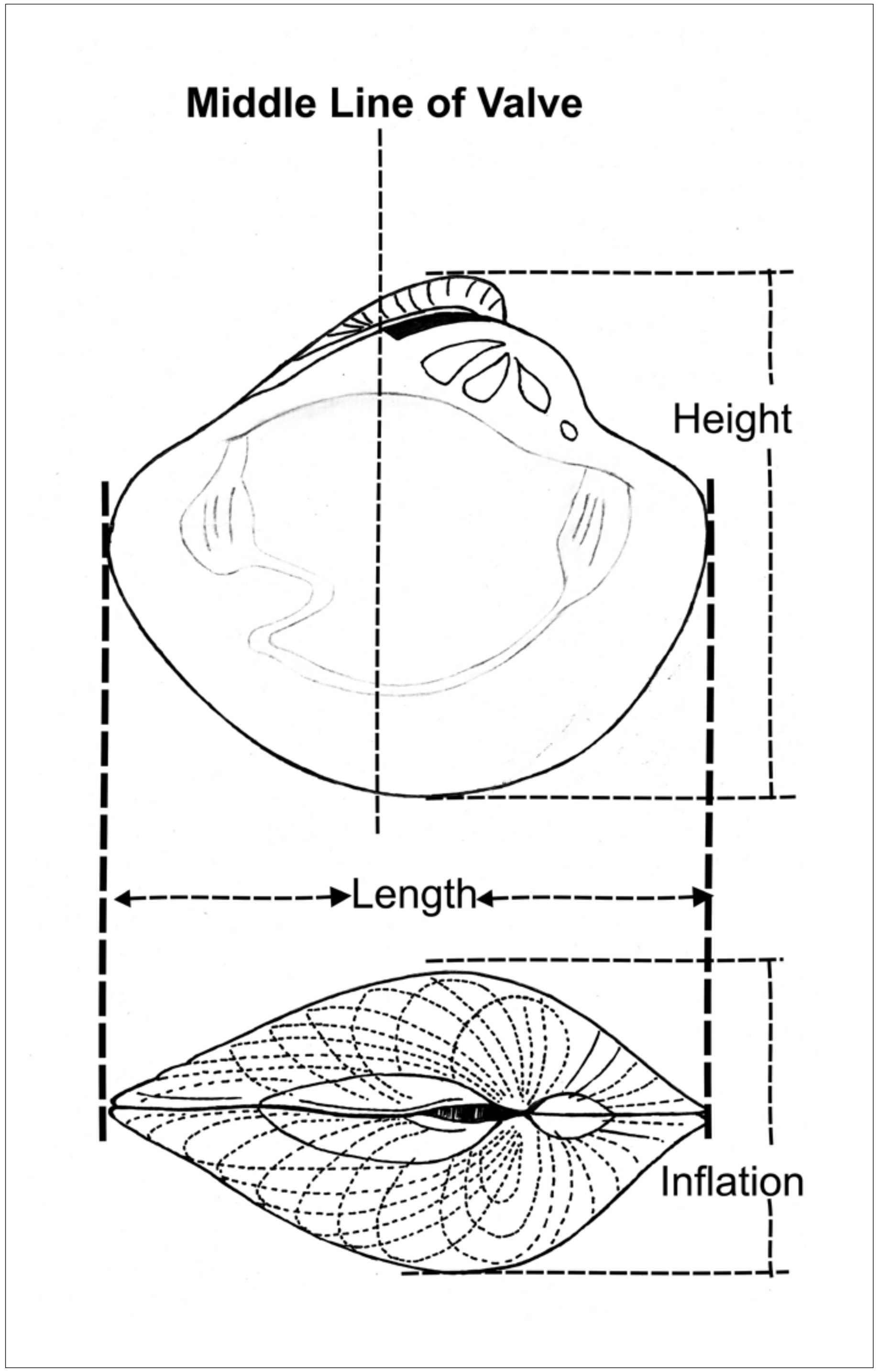


Fig. 19. Morphometric measurements of bivalves

Gastropods

A univalve, generally spirally coiled shell is present in the majority of gastropods, although the shell may be poorly developed or lacking in the opisthobranchs. Gastropods are torted, asymmetrical molluscs, usually with a spirally coiled shell. Their soft body is divided into 4 main regions: the head, which normally protrudes anteriorly from the shell; the foot, a muscular ventral organ with a flattened base used for locomotion (creeping or burrowing); the visceral mass, which fills dorsally the spire of the shell, and contains most organ systems; the mantle, a collar-like tegument which lines and secretes the shell, and forms a mantle cavity normally provided with respiratory gills in aquatic species. The noteworthy asymmetry of the internal anatomy of gastropods results from a twisting through 180° called the "torsion", which occurs in the first few hours of larval development. Part of the paired organs of the visceral mass cease developing, and the animal begins to be asymmetrical. This internal asymmetry persists in the adult, even when a subsequent detorsion occurs.

Body whorl lengths are made by measuring the large, final coil (most recently formed) of a mollusc shell that contains the body of the snail, i.e. from the aperture to approximately one whorl back. Spire length includes all the coils (whorls) of a shell above the body whorl. Height is measured as the distance from the apex to the anterior tip of a gastropod shell, also called length.

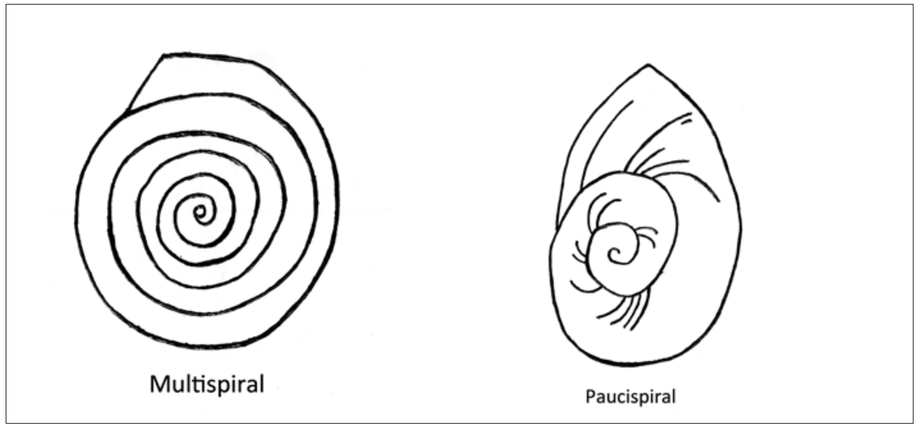


Fig. 20. multispiral and paucispiral shapes of gastropod operculum

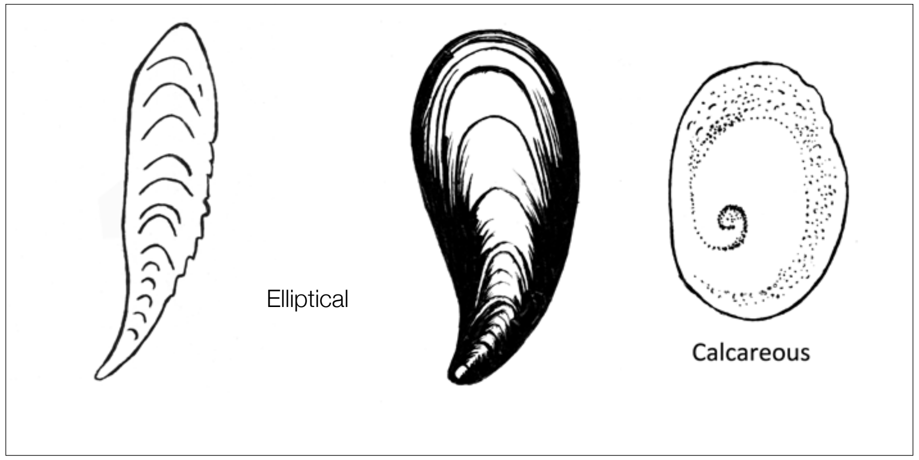


Fig. 20a.Elliptical and calcareous shapes of gastropod operculum

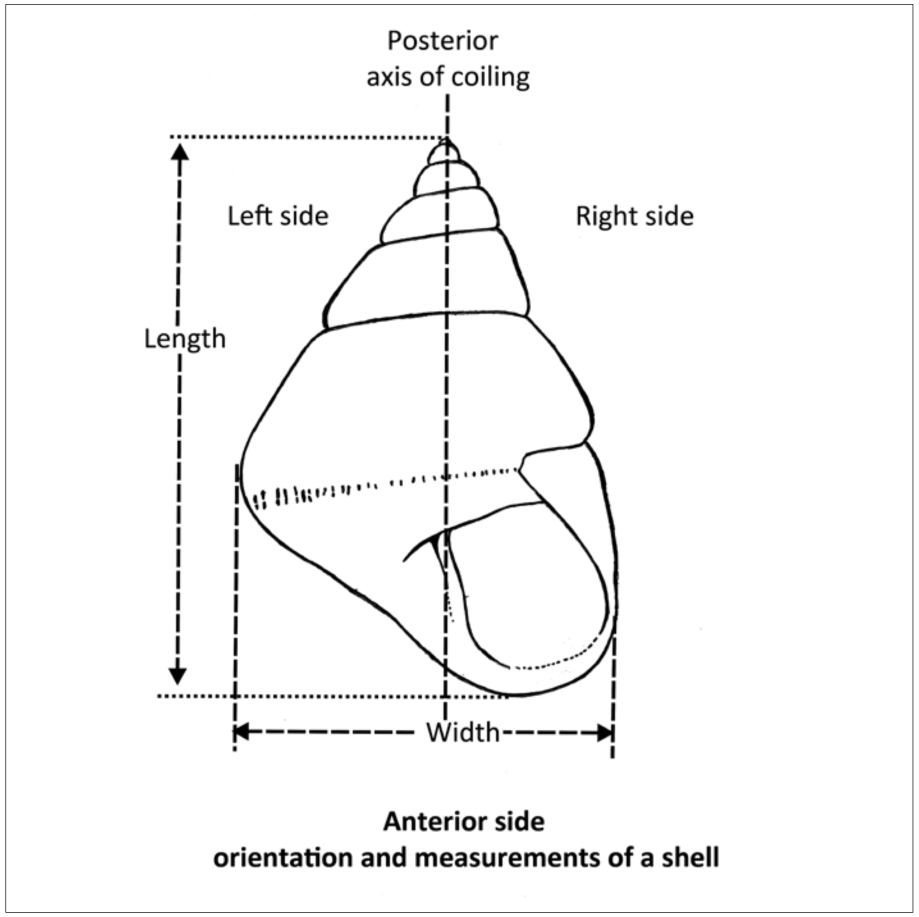


Fig. 21. Measurement of gastropod shell .

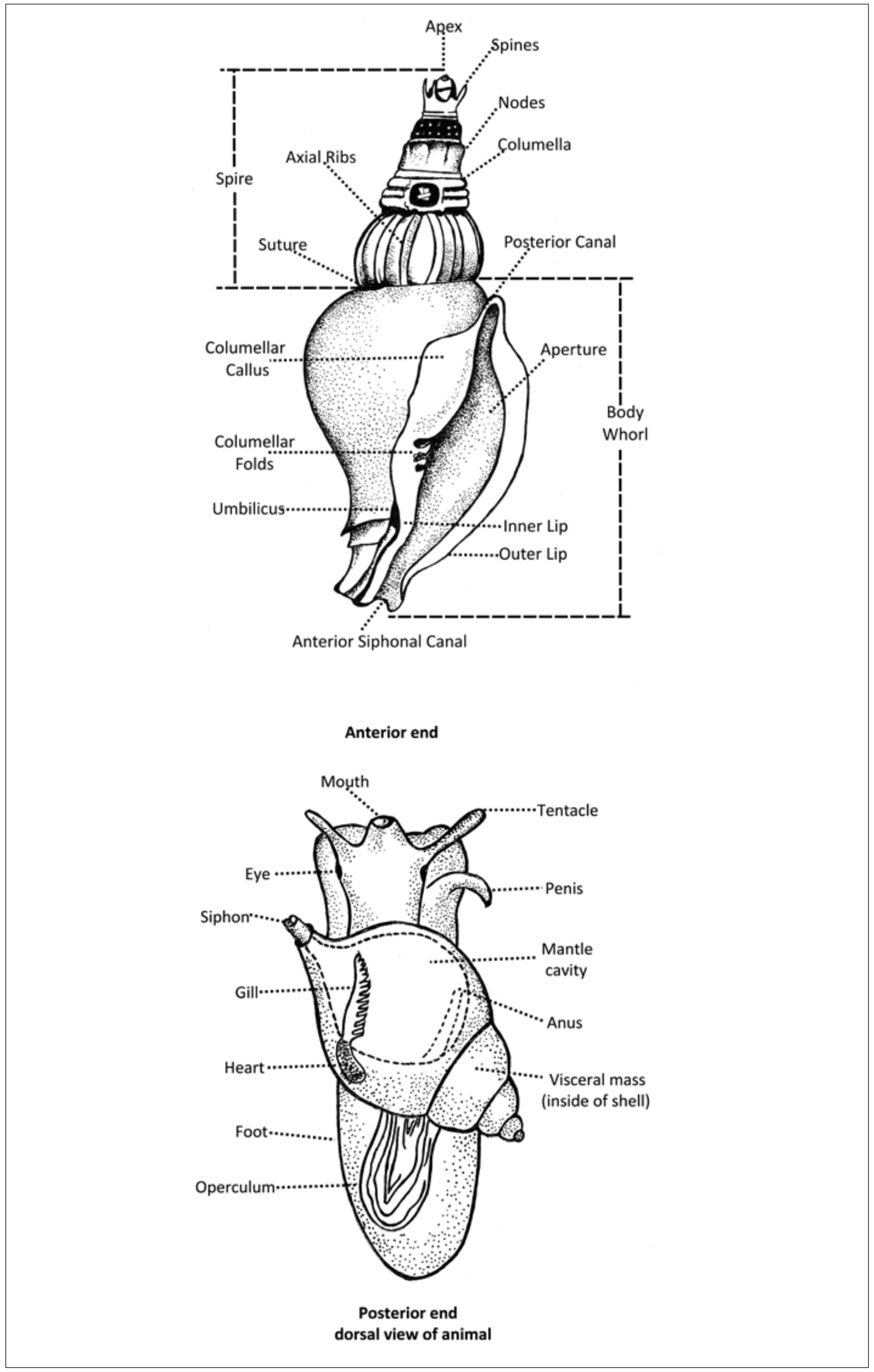


Fig. 22. Morphometric features of gastropod

3

LENGTH-WEIGHT RELATIONSHIP

Every animal in its life grows both in length and weight and the relationship between these two has both theoretical and practical importance. It has been mathematically proved that there is a fairly constant relationship between total length and weight of the individuals of the species. It helps to establish a direct mathematical relationship between the two variables, namely length and weight, so that if one is known the other could be easily computed. Length-weight relationship is also needed for studies on maturity and yield estimates by analytical models.

Biotic factors such as reproductive state of the animal, population density, physical and biological variables of habitat are known to effect the growth and can change the allometry. Growth and shape are also influenced by abiotic (exogenous/ environmental) and biotic (endogenous/ physiological) factors. Information on allometry helps to understand the ideal conditions under which animal show proportionate growth and also to determine the size at which harvest can be intensified so as to maximize production. Of the different relationships, length-weight is the most important, since it helps inter conversion of variables. Thus, in computation and analysis of catch statistics it helps to convert the sample weight to numbers in order to obtain the abundance of stock in space and time. Moreover, the information would allow for comparison between species from different geographical areas, and could also be used both in fishery models and in improving fishing gear selectivity. Thus, a thorough knowledge of allometric relationships of commercially important species is imperative for successful exploitation of its fishery potential.

The weight of the animal is considered a function of length and since length is a linear measure and weight is a measure of volume, the relationship between the length and weight of an animal could be expressed by the hypothetical cube law, $W = CL^3$, where W (g) and L (cm) are the weight and length respectively and C a constant. This expression holds good when the specific gravity and the form of the animal remain constant. However, in aquatic organisms the growth is not always isometric and therefore does not exactly follow the cube law. Le Cren (1951) modified the equation into a non- linear equation as $W= aL^b$, where a and b are constants to be derived empirically. This equation explains the relationship between length and weight of a fish better than cube law. The exponent value of b in the equation varies from 2.5 to 4 (Hile, 1936) depending on the shape of the fish. However, significant variation from the isometric growth ($b = 3$) is not always common in fishes (Beverton and Holt, 1957) and b will be equal to 3 in an ideal situation where the animal maintains its body proportion throughout (Allen, 1938) its life.

This non-linear equation can be transformed into a linear equation of the form, $Y = a + b X$ by taking logarithms on both sides as,

$$Log\ W = Log\ a + b\ Log\ L$$

i.e., $Y = A + BX$, *where* $A = log\ a$, $Y = log\ W$ *and* $X = Log\ L$

Log a represents the point at which the regression line intercepts the log W axis and b represents the slope line. Subsequently, the comparison

between the obtained value of the t-test and tabled critical value of the t-test, allows the determination of the statistical significance of the b value and its inclusion in the isometric or allometric ranges (b =3 or b =1 for isometric or b < 3 or b < 1 for negative allometry or b>3 or b>1 for positive allometry). The Student's t test is to be carried out to find out whether the b values for males, females and sexes pooled are significantly different from 3, using the formula.

$t = \frac{b - \beta}{S_b}$ where β is equal to 3.

4

GUT CONTENT ANALYSIS

Information on food and feeding habits of fishes is essential for better understanding of their growth, breeding and migration and also for improving the harvest of the commercially important fisheries resources. Information on food and feeding will add to the existing knowledge needed for better management of fish stocks. Study of seasonal variation in diet and dietary comparison between different sub-groups of the species like year-class will help to understand whether there is competition for food. Study on the diet of marine organisms also gives a clear indication of prey-predator relationship and feeding migration if any. Diets of fishes represents an integration of many important ecological components that include behavior, condition, habitat use, energy intake and intra/interspecific interactions.

Finfish

Stomach contents can be collected either from the live or from well preserved fish. Regardless of the method, investigators should ensure that the removal technique effectively samples all items in the gut. Otherwise data will be skewed toward items that are more easily displaced from the stomach. Alternatively, live fish can be sacrificed and stomach contents removed for analysis. If fish are to be sacrificed, they should be preserved immediately either by freezing or by fixing in formalin. Stomach contents will continue to digest, rendering rapid preservation of the fish or removed contents necessary to prevent loss of resolution. As in most fish groups feeding behavior of juveniles and adults vary distinctly, care should be taken to encounter more samples which will include all size groups of the particular fish. The specimens either live or preserved should be measured for total length to the nearest 1mm and weight to the nearest 0.1 g. Cut open the fish and record the sex and maturity stage of the fish. Remove the stomach and preserve in 10% neutralized formalin for further analysis. For analysis, a longitudinal cut must be made across the stomach and the contents are transferred into a Petri dish. The contents must be then kept for five minutes to remove excess formalin and then examine under binocular microscope. Identify the gut content up to the genus and if possible up to species level depending upon the state of digestion. Various taxa digest at different rates. As such, all recently consumed taxa may be present in the foregut but only resistant items remain in the hindgut. To avoid bias when both easily digested prey and resistant prey are present, only the immediate foregut (e.g., stomach) should be sampled.

Methods of gut contents analysis are broadly divisible into two, viz., qualitative and quantitative. The qualitative analysis consists of a complete identification of the organisms in the gut contents. Quantitative methods of analysis are three types, viz., numerical, gravimetric and volumetric.

The fullness of fish stomachs are classified as 'gorged', 'full', '¾ full', '½ full', '¼ full', trace and 'empty'. The stomachs of fishes are removed, weighed and preserved in 5% buffered formalin for further analysis.

The index of preponderance method (Natarajan and Jhingran, 1961) suitable for carnivorous fishes is adopted by good number of workers. The index of preponderance was worked out by the following formula:

$$I = \frac{V_i O_i}{\Sigma V_i O_i} \times 100$$

where Vi and Oi represent the percentage of volume and percentage of occurrence indices of each food item respectively and I the index.

Another method , the Index of Relative Importance(IRI) proposed by Leo Pinkas et (1971) is an integration of measurement of number , volume and frequency of occurrence to assist in evaluating the relationship of the various food items found in the stomach. It is calculated by summing the numerical and volumetric percentage values and multiplying with frequency of occurrence percentage value.;

Index of relative importance, $IRI_i = (\% N_i + \% V_i)\ \% O_i$

Where N_i, V_i and O_i represent percentage of number, volume and frequency of occurrence prey respectively.

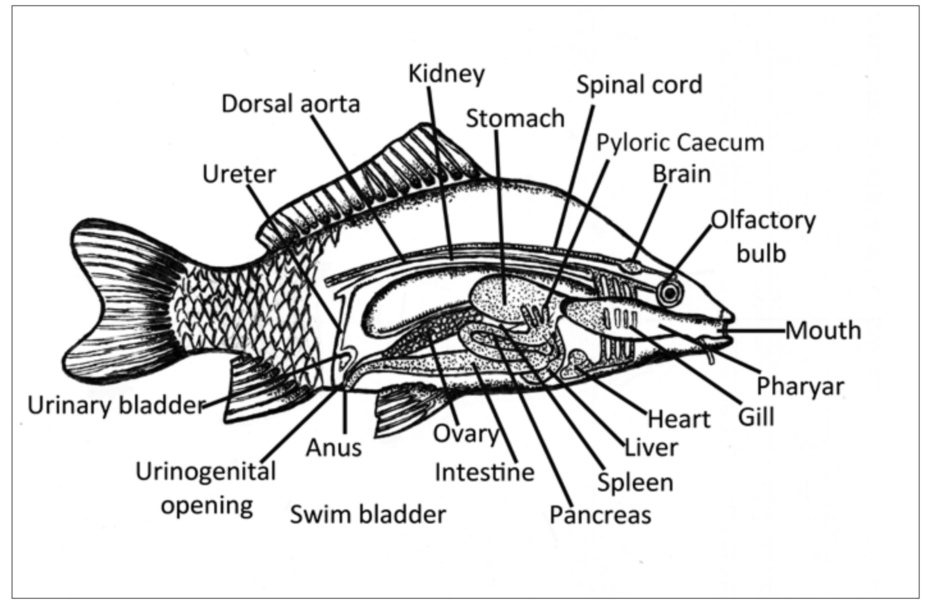
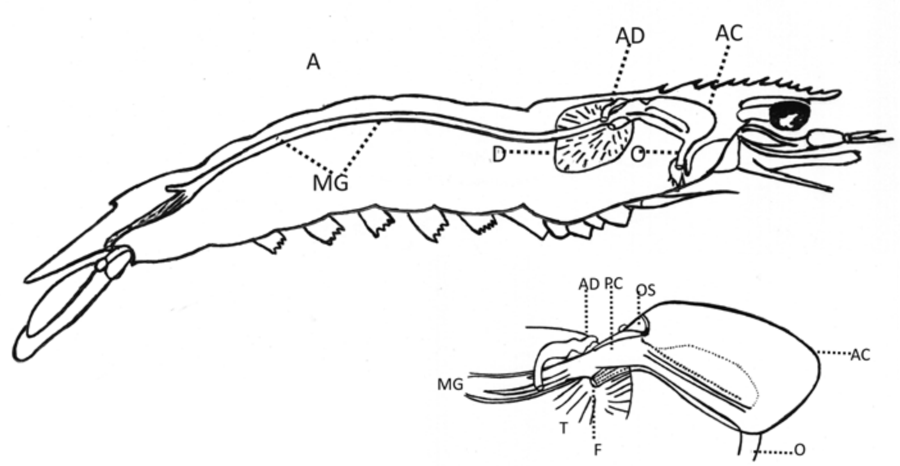


Fig. 23. Digestive system in fish

Crustaceans

Due to the nibbling action of mandibles on the food and mastication of food inside the stomach by the action of gastric mill, identification of the food organisms is based mainly on broken shell remains spines and cetae. The stomach contents can be grouped as follows: decapod crustaceans (mostly shrimps), fishes, molluscs, polychaetes, crustaceans other than decapods, foraminiferans, sand, detritus and unidentifiable digested matter (decomposed plant , animal matter and their remains mixed with mud) Since the quantity of food in the stomach of shrimps are very little, the 'points method' is generally used for food content study. The intensity of feeding is determined by the degree of distension of the stomach due to the quantity of food inside the anterior and posterior chambers of the proventriculus. The condition of feeding is expressed as full, ¾ full, ½ full, ¼ full, trace and empty and each one is assigned, 100, 75, 50, 25, 10 and 0 points respectively



Digestive system in shrimps

A, anus; AC, anterior chamber of proventriculus ("stomach"); AD, anterior diverticulum of mid-gut (this is a paired structure); D, digestive gland; F, opening (paired) from "filter press" of posterior diverticulum into digestive gland; M, mouth, MG, mid-gut; O , oesophagus, OS, ossicles of gastric mill; PC, posterior chamber of proventriculus; PD, posterior diverticulum of mid-gut; R, rectum; T, tubules of digestive gland.

Fig. 24. Digestive system in shrimp

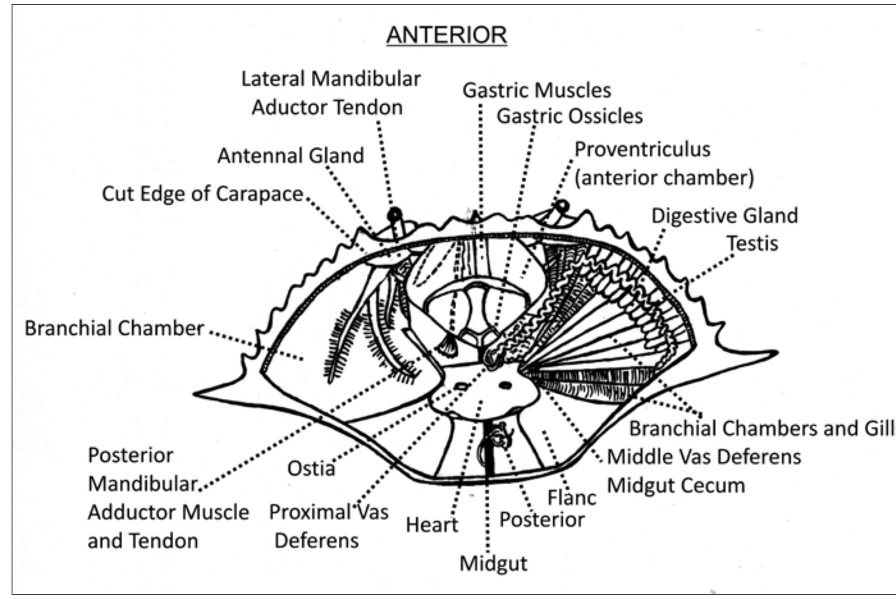


Fig. 25. Anatomy of crab

Cephalopods

All cephalopods are active carnivores feeding on live prey during their entire life cycle. They are generally considered as night-time feeders, but some species feed during the day. The range of prey organisms in the gut content of cephalopods are wide and include representatives of crustaceans, molluscs and fish. They are opportunistic feeders, switching easily from one prey to another, though distinct preferences seem to exist for some species. For example, the main prey for the coastal octopus species are generally crustaceans and shelled molluscs.

The captured prey is brought to the mouth by the arms where it is killed or paralysed. The dorsal beak, or the 'upper' beak is inserted within the 'lower' (ventral) beak to tear tissue of the prey with a scissors-like cutting action. The gut has spontaneous peristaltic activity. The chopped food passes from the buccal cavity through the oesophagus to the stomach, where most of the digestion takes place. The digestive tract except for glandular area, is chitin lined from the buccal mass to the stomach. The cuticular ridges in the stomach aid in grinding food. The food is broken down with enzymes in the stomach from the digestive gland. The stomach may be greatly expandable in size and serve as a storage area until food can be fully processed.

The degree of fullness of the stomach is visually assigned and recorded as 'completely full', 'half full', 'one-fourth full', 'trace remains' and 'empty'. For gut content analysis, the individual stomach is cut opened, examined under dissecting microscope, prey items identified and separated for weighing. In cephalopods the advanced degree of digestion of stomach contents generally impeded the exact and complete separation of prey for weighing. Undigested cephalopod tissue remains, indicative of cannibalism need to be considered apart from natural prey. Crustaceans are identified by their exoskeleton. The number of fish or cephalopods consumed may be estimated based on fish otoliths or of upper or lower cephalopod beaks. Frequency of occurrence and numeric and gravimetric (volumetric) methods are used to quantify the diet. Frequency of occurrence (%FO) is calculated as the percentage of cephalopod that fed on a certain prey, %number (%N) is the number of individuals of a certain prey relative to the total number of individual prey, and %weight (%W) is defined as the weight of a certain prey relative to the total weight of all prey, expressed as a percentage.

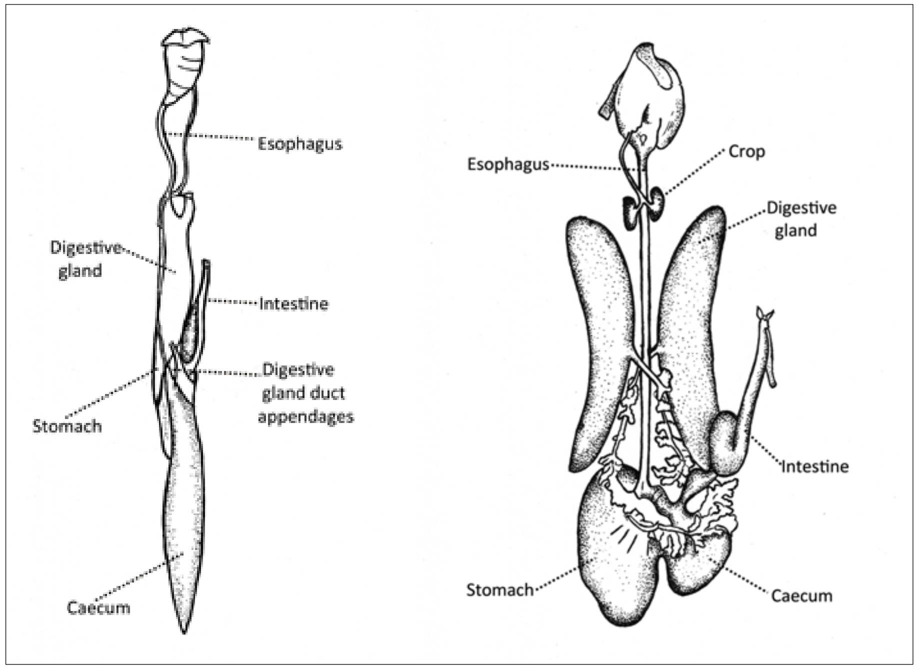


Fig. 26. Digestive system of (a) squid and (b) cuttle fish

5

REPRODUCTIVE BIOLOGY

An understanding of the reproductive biology of any given species is an essential prerequisite for stock assessment in wild populations and for their sustainable exploitation.

Fishes

Development of the Ovary

The stages of ovary development can be examined by visual observation or histological examination. Fish gonad development may be divided into seven stages according to appearance, colour, size, weight, blood vessel distribution, and maturity of Ova. However, the classification of ovary developmental stages varies from country to country. Five stages are recognized in India, Japan, and the United States of America; several countries recognize seven stages; and, in China, six stages are defined.

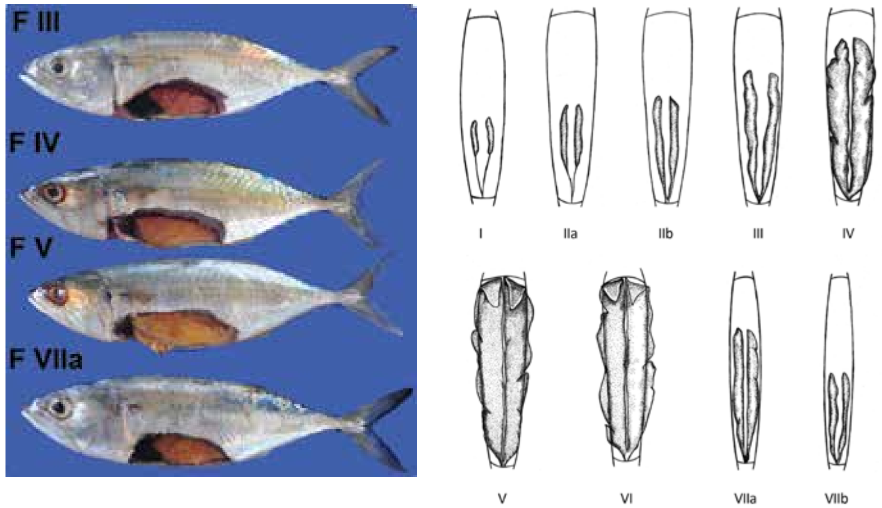


Fig. 27. Maturity stages of female onads of fish

Stage I ovary

The gonads are located at the lower part of the air bladder, closely attached to the coelomic membrane, and are lineal in shape, transparent, and white in colour. It is impossible to distinguish the sexes with naked eye.

Tissue section — Cells are tiny; diameter, 12–22 μm. The nucleus is rather large, occupying more than half of oocyte of diameter. There are few nucleoli in the centre of the nucleus.

Stage II ovary

Ribbon-shaped, white, semitransparent gonads are observed. With the naked eye, it is impossible to distinguish one ova from another; however, small eggs are visible when the tissue is examined under a magnifying glass; when fixed, the eggs are petal shaped. At this stage, it is possible to distinguish visually the sexes. The gonad index (percentage of gonad weight to body weight) is 1–2%.

Tissue section — Cells are multiangular or sphere-shaped; diameter 90–300 μm. A thin layer of flat follicle cells surrounds the oocyte. The nucleoli are closely attached to the nuclear membrane.

Stage III ovary

The size of the ovary is conspicuously enlarged. Due to the appearance of melanotic pigment, colour of the ovary changes to greenish grey or orange. Eggs are visible with the naked eye but not easily separable. The distribution of blood vessels is clear. The gonad index is 3–6% in this stage.

Tissue section — The follicular membrane surrounding the oocyte is a bilayer. The egg yolk begins to form. One or two layers of vacuoles appear on the edge of the cell. The cell is 250–500 μm in diameter. The nucleus in the centre is irregular or oval-shaped. Most of the nucleoli are distributed along the edge of the nuclear membrane; a small number is scattered in the centre of the nucleus.

The gonads of mature brooders are generally at stage III in the winter.

Stage IV ovary

The ovary is now long and saclike, occupying one-third to one-half of the coelomic cavity. Eggs are plump, greenish grey or light yellow or bright orange, and can be easily separated. The ovary is fully distributed with blood vessels, and the gonad index is 12–22 %

Tissue section — Egg yolk granules fill almost all the space outside the nucleus, with only a little cytoplasm spreading around the nucleus and near egg membrane; diameter 800–1580 μm. The nucleus edge is wavy, with a few nucleoli inserted in the troughs; most of the nucleoli are seen toward the centre of the nucleus.

This stage can be further divided into three substages based on oocyte diameter and nucleus location. Early stage IV: egg diameter, 800 μm; nucleus in the centre. Middle stage IV: egg diameter, 1000 μm; nucleus in the centre or slightly toward the animal pole. Late stage IV: egg diameter, 1580 μm; nucleus at the animal pole (polarization).

Stage V ovary

In this stage, oocytes enter the ovarian cavity as follicular membranes break, and the eggs are flowing freely. Ovary and belly of the fish are very soft. A slight pressure on the belly would cause the eggs to flow through the only in clamo branches opening.

Tissue section — Yolk granules begin to fuse. The cytoplasm and the nucleus have moved to the animal pole. The nucleoli concentrate in the centre of the nucleus, the nuclear membrane dissolves and the nucleus looks transparent.

As the oocytes proceed to maturity, the follicle epithelial cells secrete a substance that dissolves and absorbs tissues between the follicular and egg membranes; thus, the eggs can easily be released from the follicles and flow freely in the ovary (ovulation). During spawning, the eggs are released from the body through the cloacal opening.

Stage VI ovary

At this stage, most of the eggs have been released. There still some stage IV oocytes in the ovary. The ovary is slack and noticeably smaller, and blood vessels have become enlarged with lump-shaped extravasated blood.

Tissue section — After ovulation, there are abundant follicular membranes and some undischarged mature eggs in ovary. The undischarged eggs soon degenerate and are absorbed, forming a semi-transparent, irregular, orange-yellow structure. Many interim oocytes can still be seen.

Structure of the testes

Testis

The testes are paired, tubular and are situated on both sides of the air bladder, attached to the coelomic wall. The mature testes are inside

white and with many irregularly arranged ampullae The spaces between ampullae are full of connective tissues. The ampullae are composed of many spores (seminal vesicle sacs). Spore sacs are separated by a thin layer of follicular cells. Each spore sac contains synchronously developing germ cells, and germ cells in various stages of development can be seen in different spore sacs. At the centre of the ampullae, there is a hollow cavity. After the formation of sperm cells, the spore sacs dissolve and the sperms enter this cavity. The terminal end of the testis is connected to a short seminal duct with opening to the exterior of the body.

Development of the testis

The development of testis may be divided into seven stages.

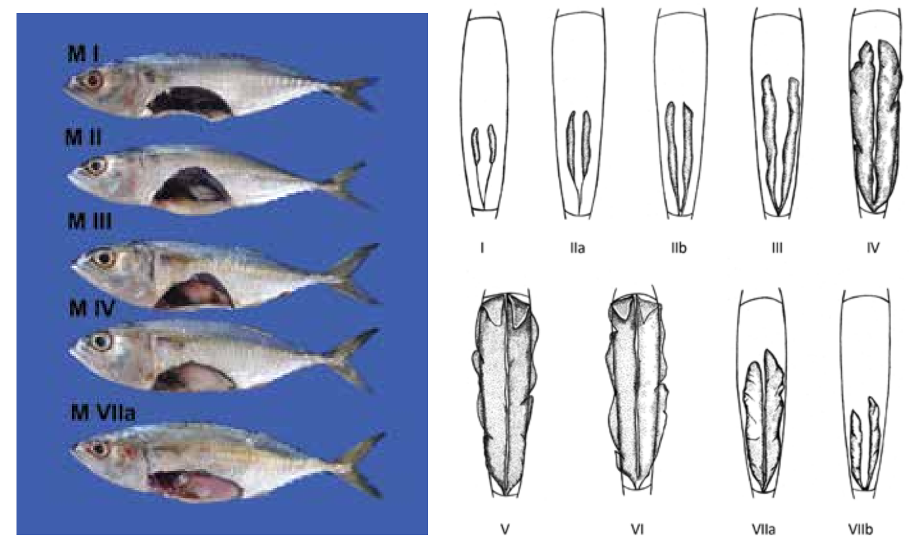


Fig. 28. Maturity stages of male gonads of fish

Stage I testis

Testes are lineal in shape, transparent, and closely attached to the coelomic wall. At this stage, it is impossible to distinguish between the sexes. On the tissue slice, scattered spermatogonia, 16 μm in dia, may be observed. The nucleus is big and round, 9 μm in diameter. Ampulli and seminal vesicles are still forming; therefore, there is no clear, fixed arrangement of sperm cells.

Stage II testis

Testes are lacelike and either translucent or opaque. Blood vessels are not clearly visible. Characteristic of this stage are the multiplication of spermatogonia and the formation of seminal vesicles, which are arrayed in bundles. At this stage, ampulli are solid and separated by connective tissue.

Stage III testis

Testes are rod-shaped, pink or yellowish, and elastic on the surface, with a clear distribution of blood vessels. On the tissue slice, a hollow cavity may appear in the middle of the solid ampullae, with one or several layers of seminal vesicles on the ampullar walls.

Stage IV testis

Testes are milky white with a clear distribution of blood vessels on the surface. It is impossible to squeeze out milt early in this stage, but becomes possible later in stage IV. On the tissue slice, large primary spermatocytes, small secondary spermatocytes, and spermatids can be observed; all of these cells congregate on the walls of the seminal vesicles with a small number of sperms.

Stage V testis

Testes are white with full of milt. Raised with oozing milt when belly is slightly pressed. A large number of sperms, both mature and in various stages of development, can be seen inside the ampulli on the tissue slice.

Stage VI testis

The volume of testes greatly reduced after milt is released and is become yellowish white or pink in color. Only spermatogonia, some primary spermatocytes, and connective tissue remain in the seminal vesicles. After milt exudation, the testes revert to stage III and redevelop.

Shrimp/Prawn

Reproductive organs

Structure of male reproductive system

The male reproductive system in shrimps consists of a pair of testes, vas deferens, terminal ampoules and a petasma.. The testes consist of four lobes located in the cardiac region dorsal to hepatopancreas. The narrow tube which follows this portion is the vas deferens that traverses through muscle of cephalothorax and opens at the base of 5th pereopod through the terminal ampoule. The petasma is formed by the fusion of endopods of first pair of pleopods.

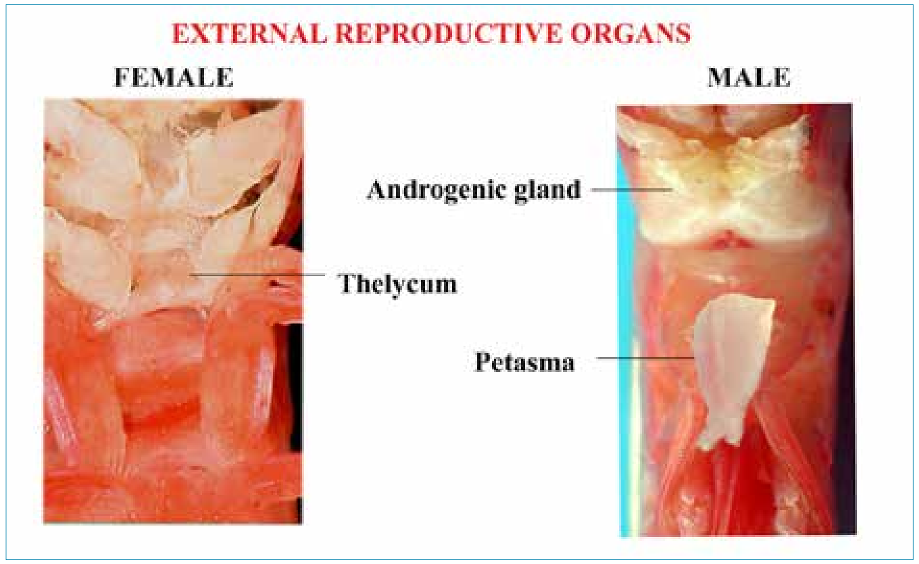


Fig. 29. External reproductive organs in male and female shrimp

Structure of female reproductive system

The female reproductive system in shrimps consists of ovaries, oviducts and a single thelycum. The mature ovaries are paired organs, situated dorsally extending from the base of rostrum to the last abdominal segment.

They are bilaterally symmetrical and partly fused. Each half of the ovary consists of three lobes of which the slender anterior lobe occupies the cephalic region and lies in close proximity with the oesophagus and cardiac region of the stomach. The middle lobe has six finger-like lateral lobules. The lateral lobules are located dorsally to the large mass of hepatopancreas and ventrally to the pericardial chamber. The posterior lobes of the ovary extend the entire length of the abdomen. The two halves of the ovary are united, one at the base of the anterior lobe and other at the tip of the posterior lobe in the 6th abdominal segment. The thin oviducts start from the tip of the penultimate lobules of the middle lobe on both side and run downwards to the external gonophore on the 3rd pereopod.

Maturity stages in females

Based on the coloration and size of the ovary and ova-diameter variations,

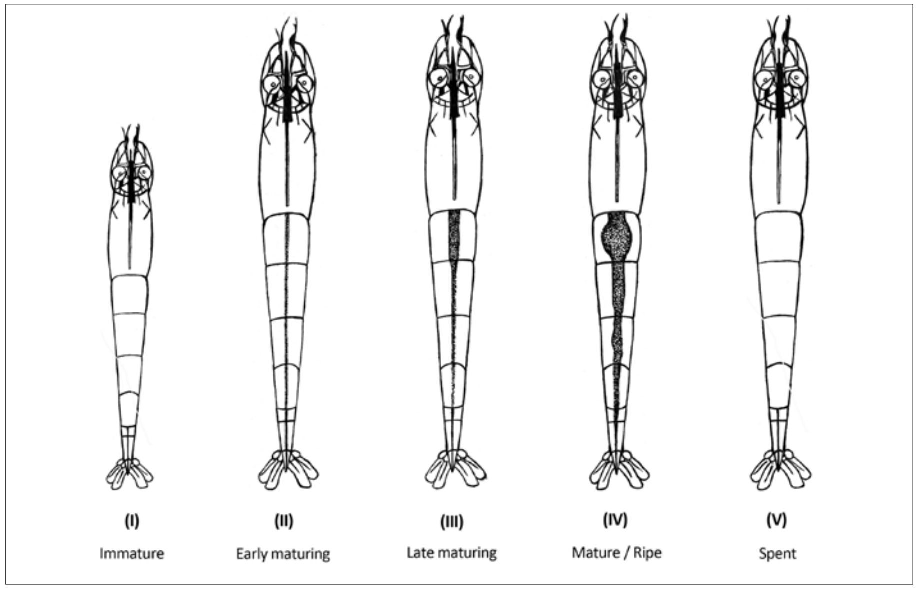


Fig. 30. Different maturity stages of gonads in shrimp

five stages of maturity in females of shrimps were identified: immature, early maturing, late maturing, mature and spent-recovering.

(I) Immature stage: The ovary is thin, translucent and unpigmented confined to posterior part of cephalothorax and abdomen.

(II) Early maturing stage: Size of the ovary increases, anterior lobes further develop and extend forward in the cephalothorax; the middle lobes and rudiments of their lobule develop. The posterior lobe increases in girth. The general colour of the ovary is yellowish.

(III) Late maturing stage: The ovary develops further, the anterior, middle and posterior lobes fill the cephalothorax completely. The ovary is generally orange in colour, some times with branched brownish chromatophores distributed over the surface. Ovary is clearly visible through the exoskeleton.

(IV) Mature stage: The ovary is very clearly visible through exoskeleton. The anterior and middle lobes are well developed. The colour of the ovary is brownish orange. Due to the fullness of the ovary, the lateral lobules of the middle lobe get folded and occupy the entire space available in the cephalothorax.

(V) Spent recovering stage: After extrusion of ova, the gonad reverts

Fig. 31. Maturity stages based on the colouration of ovary

almost immediately to immature condition. The ovarian lobes are flaccid and appear whitish. The ovary contains ova which are similar to those in immature stage.

Fecundity and size at maturity

For the study of reproductive biology, total length and weight of males and females are recorded. After recording length and weight, ovaries from females are dissected. The colour and size of the ovary are recorded before preserving them in 5% formalin. The maturity stages could be differentiated from fresh specimens based on the colour and thickness of ovary. However, the different maturity stages can be confirmed later by microscopic examination.

The size at maturity is found out by plotting the percentage of immature males and females against the matured ones with respect to the total length of the shrimp. For the size at maturity (50%) studies in females, the specimens with early maturing ovary is rated as immature and females having late maturing, mature and spent ovaries are considered as matured ones. Shrimps with petasma with presence of spermatophores in the terminal ampoule are taken as matured males.

Preserved ovary after four or five days should be washed and dried by placing it between two blotting papers. The weight of ovary is recorded and a sub-sample of ovary segment is taken out and weighed to the nearest 0.001, using an electronic balance. The mature ova present in the sub-sample are counted by using a counting slide. From the number of ova in the weighed sub-sample, fecundity is calculated using the formula

$$\text{Fecundity} = \frac{\text{total weight of the ovary}}{\text{weight of the sample}} \times \text{number of ova in the sample}$$

The relationship of fecundity on total length, total weight and ovary weight is found out by fitting regression on logarithms of observed values by least square method (Snedecor and Cochran, 1968).

$$F = aX^b$$

where, F = Fecundity, a = constant, X = variable (total length, body weight or ovary weight) and b = correlation coefficient. The exponential relationship is transformed into a straight line logarithmic form based on the equation:

$$\log F = \log a + b \log X$$

For gonado-somatic index (GSI) estimation, females are weighed individually after wiping it dry. The gonad is dissected out carefully and weighed by using an electronic balance. The GSI is calculated by using the formula:

$$\text{GSI} = \frac{\text{Weight of the gonad}}{\text{Weight of the fish}} \times 100$$

The sex ratio may be studied based on the monthly estimated numbers as to get an actual representation of males and females in the population. Homogeneity of the sex ratio (based on observed numbers) over months in two years are to be tested using Chi-square test (Snedecor and Cochran, 1968).

This is computed as follows:

$$\chi^2 = \frac{\sum (O - E)^2}{E}$$

where, O = observed number of males and females in each month/length group E = expected number of males and females in each month/length group. Significant test at a probability level of p = 0.01 is to be carried out. Homogeneity also can be tested for 1:1 ratio and for common ratios as observed from the data.

Crabs

The adult male crab can be easily identified from the female by its narrow abdomen which is 'T' shaped instead of triangular in female. In females, gonads vary in colour, shape, consistency and volume as it matures. The colouration changes from white through orange to dark brown. White-coloured ovaries are cylindrical, slender and flaccid and extend to the first abdominal segment. Orange-coloured gonads are cylindrical and slightly compressed dorsoventrally, but are firmer to touch and reach the second or third abdominal segment. Dark brown ovaries are considerably larger and compressed dorsoventrally; the anterior lobes cover the entire hepatopancreas, while the posterior lobes may extend as far as the extremity of the third abdominal segment.

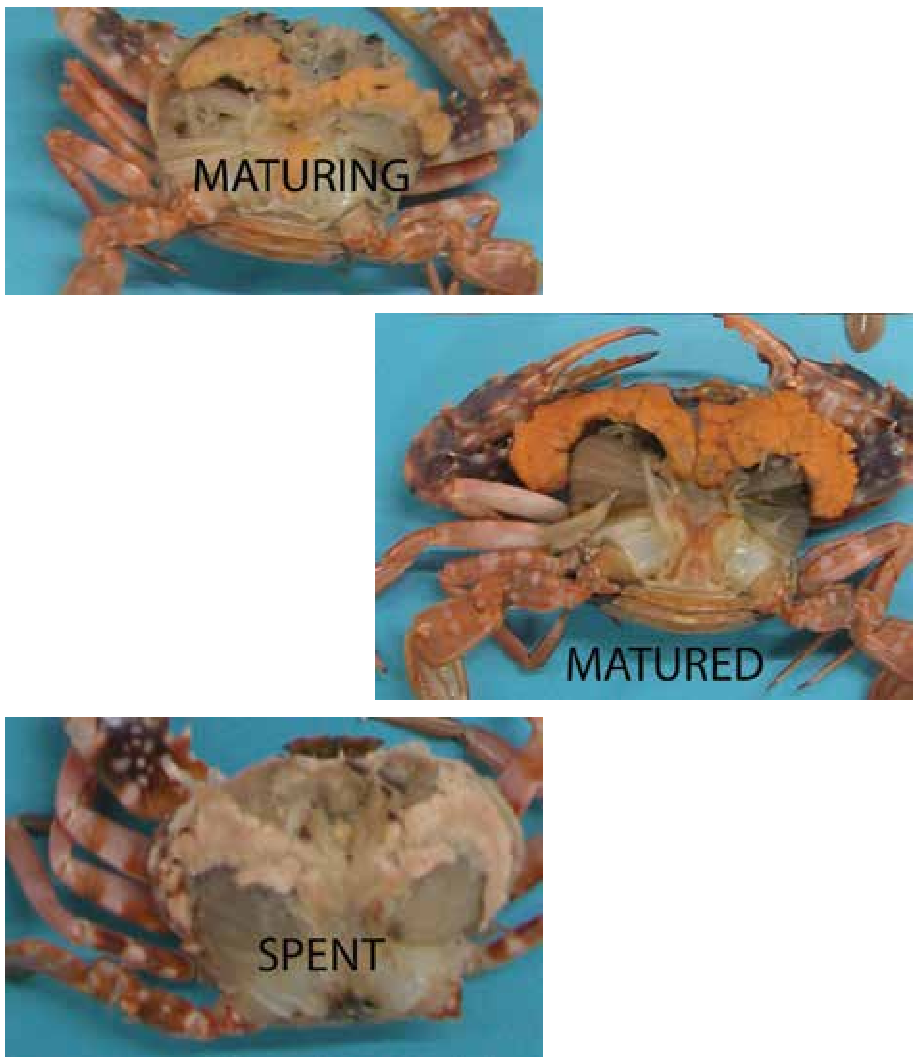


Fig. 32. Maturity stages in female crabs

Visual identification of maturity stage of female crabs

Immature: Ovary lobes are slender and flaccid. Lobes are in tubular form and white in colour.

Maturing: Anterior lobe is compressed dorso-ventrally, with almost covering the hepatopancreas, colour turn to yellow and later to orange. Maturing stages can be divided into two; early maturing and late maturing.

Matured: Anterior lobe is compressed dorso-ventrally, with entirely covering the hepatopancreas, colour turn into brown.

Spent: Ovary lobes are flaccid and slender. Coloration of the ovary is white or light yellow.

Squids and Cuttlefish

In squids and cuttlefishes, the gonads form a single mass at the posterior end of the mantle cavity. Reproductive systems are highly complex structures with ducts, glands and storage organs. In males, the sperms are produced in the testis located in the posterior end of the mantle, which are then picked by the ciliated funnel of the vas deferens that joins the multi-unit spermatophoric organ. While passing through this organ the sperm are formed into a spiral mass and coated with the various membranes and tunics to form the spermatophores (sperm packets). The vas efferens takes the fully mature spermatophores and transfer them one at a time into the spermatophoric sac or the Needham's sac and stored until copulation. Female reproductive system consist of a single ovary, the single oviduct having thin walled as well as glandular portions, the paired nidamental glands and the paired accessory nidamental glands. Once shed, the ova pass into the funnel in the oviduct, where they are stored in the proximal thin walled portion of the oviduct until mating and egg laying. The ova in the more posterior-dorsal ovary are opaque when immature and less clear when still surrounded by the follicular epithelium. From the thin-walled lightly muscular, proximal portion of the oviduct, the eggs are passed during laying through an opaque glandular portion of the oviduct on the left side of the mantle, where they are coated with a layer of egg jelly. The oviducal gland is connected to two large nidamental glands, which contains thick white gelatinous material which is used to embed each ovum into an individual protective capsule. The cuttlefish ovary grows rapidly during sexual maturation. The eggs growing in the same string of germinal epithelium in ovary grow at different rates and vary considerably in size. All eggs in the ovary will not reach maturity at the same time due to the limitation in the physical capacity of the ovary. Therefore the mature eggs in cuttlefish are spawned in different batches.

During mating, the male uses a modified arm, the hectocotylized arm, to transfer the spermatophores into the female's buccal area. The spermatophores are stored in the buccal area until fertilization of the eggs. When the female is ready to deposit the eggs in protected areas under rocks or in discarded shells, the female uses the arms to wipe the stored spermatophores onto each egg.

Cuttlefish eggs are individually enclosed in a tough protective external coating, often pigmented black from the ink-sac secretions. These egg clusters are attached to rocky crevices and disguised among many encrusting organisms.

Maturity stages of female squids and cuttlefish

Immature-Stage I

Ovary small in size, appear as whitish or transluscent, does not have a granulate structure in squids. Ovary very small, occupying the posterior mantle as a whitish patch in cuttlefish. Nidamental glands appear as very fine transparent strip, small in size, accessory nidamental gland not apparent. Oviduct meander not visible.

Maturing/ Developing-Stage II:

Ovary occupies nearly half of posterior body cavity. Individual ova visible. Ovary with uniform sized developing white oocytes. This stage is very brief. Nidamental glands larger and thicker, lobe-like in squids and pearl-shaped in cuttlefish; accessory nidamental gland small and creamy white in cuttlefish. Oviducts fully developed but empty in squids.

Mature -Stage III

Ovary very prominent with plenty of translucent eggs in oviducts and occupies entire posterior mantle cavity. Oviduct (not paired in neretic squids) with mature ova. Nidamental glands large, whitish cream and attain maximum size in squids. In cuttlefish nidamental glands thick and white, with distant anterior pore; yellowish to orange accessory nidamental glands. The proximal oviduct in cuttlefish with smooth transparent mature eggs, the distal part of ovary with striated eggs and small eggs.

Spawning/ spent-Stage IV

Decrease in gonad volume/ degenerating eggs in oviduct/ or ova absent. Nidamental glands flaccid or diminished, noticeably smaller in volume and weight in squid. Ovary with few striated loose eggs and few medium to small eggs attached to the connective tissue core of the ovary. Nidamental glands flabby, accessory nidamental glands orange red in cuttlefish.

Maturity stages of male squids and cuttlefish

Immature-Stage I

Testis small thin and elongate in squid and small and triangular in cuttlefish. Spermatophoric (Needham's) sac small with not visible vas deferens. Spermatophores are absent.

Maturing/ Developing-Stage II:

Spermatophoric (Needham's) sac with visible vas deferens and few spermatophores. Testis larger and thicker. Hectocotylization is apparent.

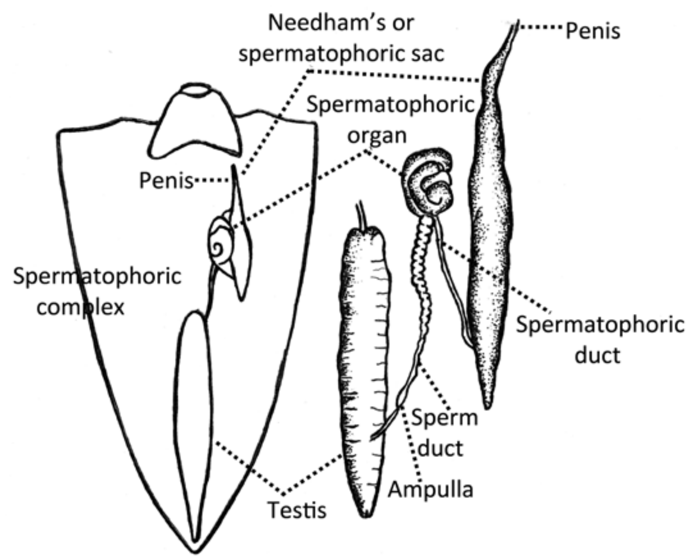


Fig. 33. Reproductive organs of male squid

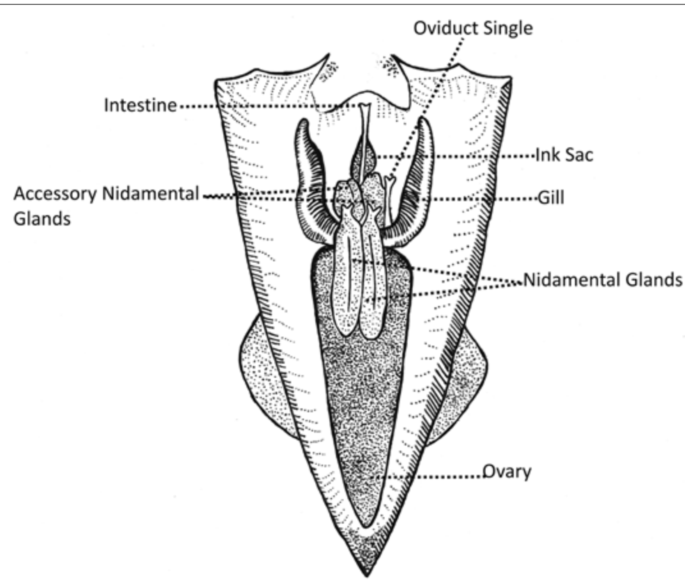


Fig. 34 a. Reproductive organs of female squid

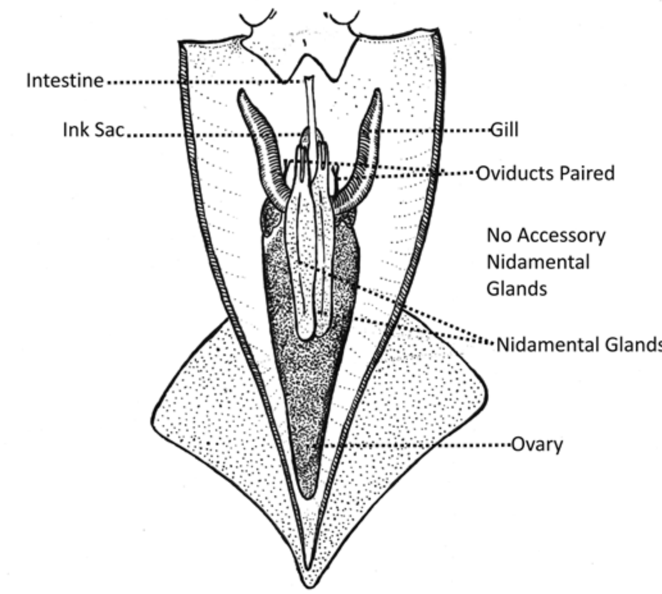


Fig. 34 b. Reproductive organs of female squid

Fig. 34 c. Reproductive organs of female squid

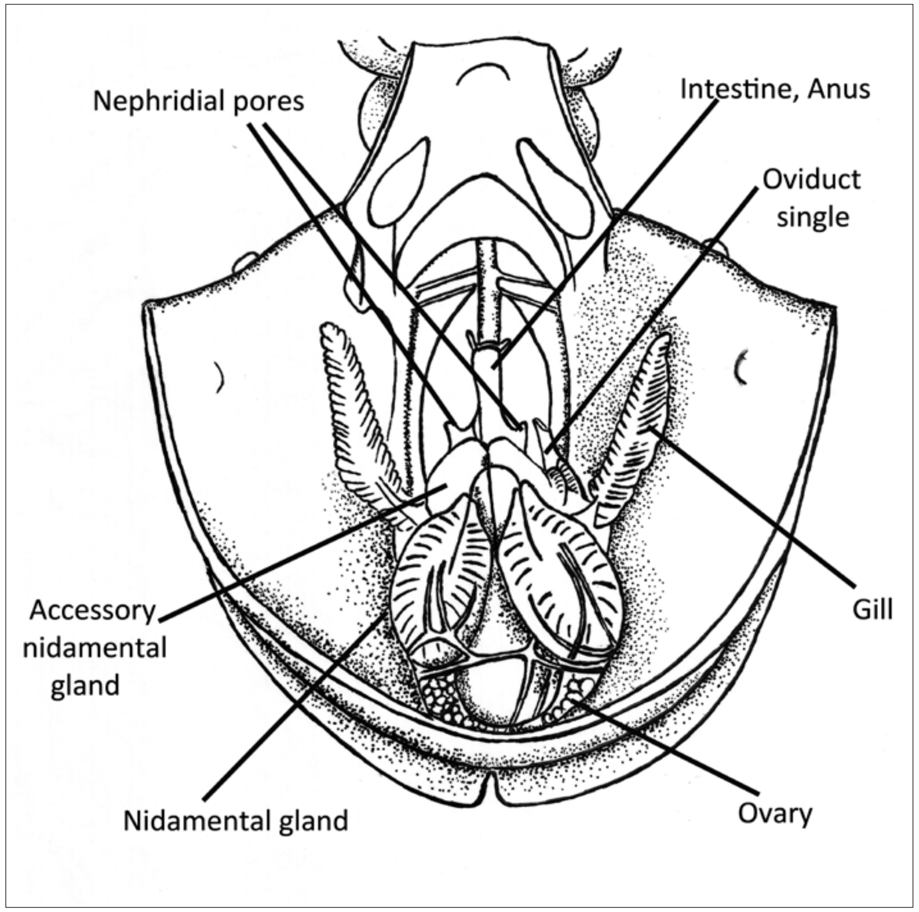


Fig. 35. Position of reproductive organs in cuttlefish

Mature -Stage III

Needham's sac completely packed with plenty of well-developed spermatophores; spermatophores occur in the penis. Testis large and fully developed.

Spawning/ spent-Stage IV

Spermatophores in gonoduct. Needham's sac flaccid with degenerating spermatophores. Testis small.

Octopus

Maturity stages of female octopus

Immature

Ovary semi-transparent and lacking granular structure. Oocytes not visible to naked eyes. Oviducal glands small and translucent.

Developing

Ovary with granular structure clearly visible, not reaching the posterior half of mantle cavity. Oviducal gland developing.

Mature/ spawning

Large ovary containing high percentage of large reticulated oocytes. Well-developed oviducal glands.

Spent

Shrunken flaccid ovary, with only immature oocytes attached to the central tissue and a few loose large oocytes in the coelom

Maturity stages of male octopus

Immature

Testis small, thin and translucent. Spermatophoric complex with vas deferens not visible. Absence of spermatophores.

Developing

Developing and whitish testis. Spermatophoric complex transparent with visible vas deferens. A white streak may appear. Absence of spermatophores.

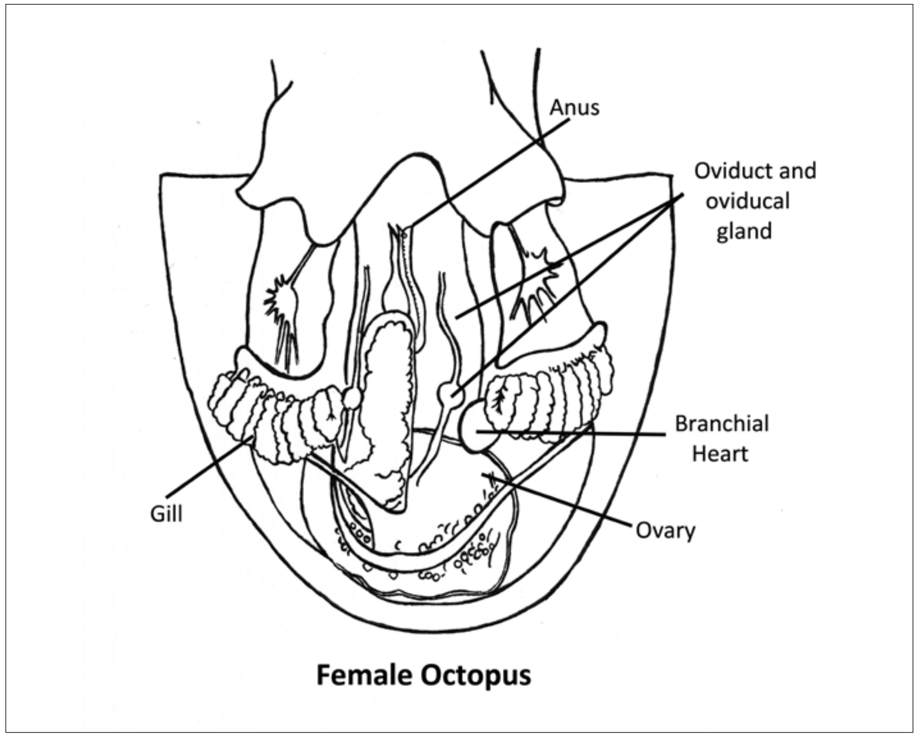


Fig. 36. Position of Reproductive reproductive organs in female octopus

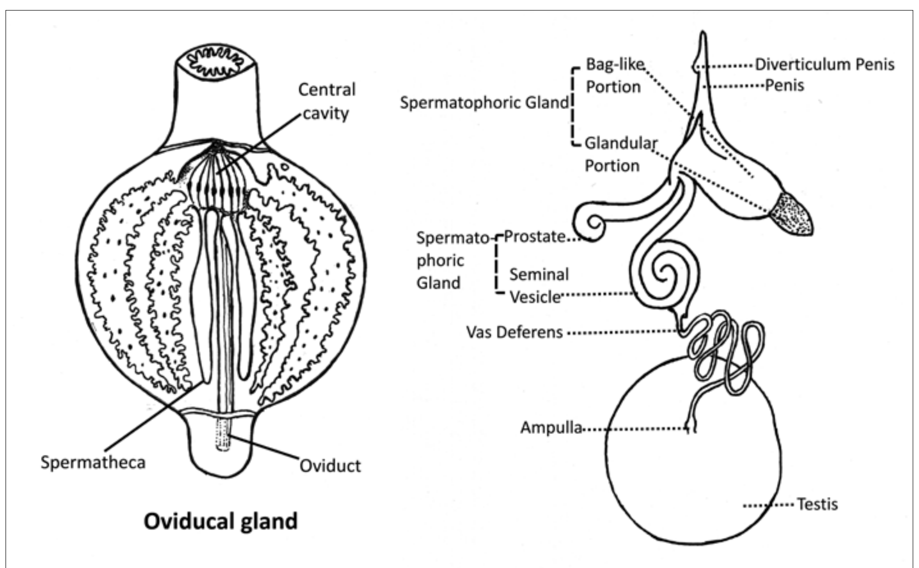


Fig. 37. Male and female organs in octopus

Mature/ spawning

Testis whitish with large and white vas deferens. Large Needham's Sac full of packed spermatophores.

Spent

Testis flaccid. Needham's Sac empty or with few spermatophores.

Bivalves

Reproductive activities of molluscs are mainly controlled by an interaction of exogenous and endogenous factors. For classification of the condition of gonad, fresh gonad smears are examined under microscope in 15 x 40 magnifications. Sex and stages of maturity were ascertained from fresh smear of gonad from individual clam. Following are the different stages in bivalves

Indeterminate:

This stage is unique because of the shrunken follicles, without any differentiation of cells and demarcation of sex. The gonad area is white. The wall of the gonad appears with much connective tissue. The follicles are completely shrunk and collapsed. At this stage the gonad is quiescent without trace of any germinal cells. Differentiation of sex is difficult at this stage.

Stage I. Maturing:

In this stage, gonad of the female is somewhat thick, pale yellowish with underlying genital ductules more prominent. It has small oocytes, which proliferate from genitial cells of the follicle wall, while in male, gonad tissue is thick, firm and white, with follicles occupying the entire area of gonad, and only sperm mother cells and spermatids are present, indicating the commencement of gametogenesis.

In male on the onset of active phase, the follicle increase in size and the periphery contains numerous spermatogonia and a few spermatids radiating towards the lumen of the follicle. As the maturing phase advances, the secondary spermatocytes appear in large numbers along with the primary spermatocytes. The primary and secondary spermatocytes can be differentiated only by size and staining intensity.

In the female gonad, the primary germ cells undergo mitotic division and give rise to oogonia in this stage. The onset of oogenesis is indicated by the appearance, growth and spreading of follicles and the occurrence of oogonia and oocytes in the premeiotic stage. The cytoplasm is small and the nucleus is not distally visible. In the late maturing phase a rapid increase in the size of the follicle is seen along with the secondary oocytes. The follicle occupies more area among the connective tissue.

Stage II. Mature

In Stage II, gonad of the female is full, plumpy, and creamy in colour and free oocytes were more in the follicle. The fully yolked ova was perfectly spherical with round nuclei. As the male gonad attains the ripe condition, the spermatids differentiated into spermatozoa and lie as a core in the lumen of the follicle. A ripe gonad is characterized by bunches of spermatozoa arranged more or less radiating with their tails facing towards the centre of the follicular lumen. The lumens of the follicle were full of spermatids.

Stage III. Partially Spent

In this stage, some follicles were empty due to the discharge of gametic material. In female clams, the follicle shows varying degree of emptiness. The vesicular tissue, the connective tissue cells and free oocytes are found scattered on the lumen. The ripe ova were present in some follicles and other follicles empty. In male gonad residual sperms and spermatids were seen in the partially empty follicles. The follicle cells ruptures and become empty with a few residual gametes. The vesicular connective tissue increases.

Stage IV Spent

In this stage, the follicles were greatly shrunken with few residual sperms in males and oocytes in females, in addition to the connective tissues. Vesicular and connective tissue increases and occupy the space between the follicle.

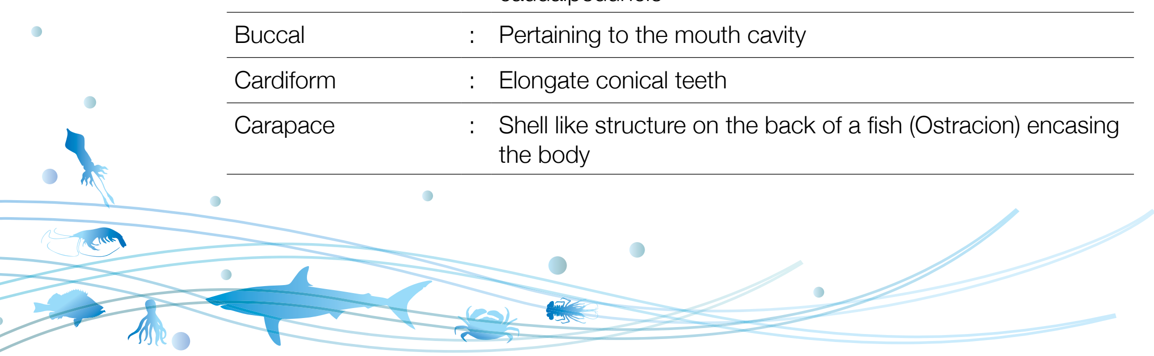
6

GLOSSARY OF TECHNICAL TERMS

Fish

Abdomen	:	Belly
Abdominal	:	Pertaining of the belly
Acute	:	Sharp pointed
Adipose eyelids	:	Transparent membranes covering partly the surface of eye
Adipose fin	:	Fin which is fleshy or fatty and present behind dorsal fin
Adnate	:	One part adhering to the other
Anal	:	Pertaining to vent; abbreviation for anal fin
Anastomosing	:	Inter joining
Anterio-inferior	:	That which is situated below anterior end of head
Anterio-transverse	:	That which is situated in the middle of anterior end of head
Antrorse	:	Directed forward
Anus	:	External opening of the intestine often referred to as the vent

Apical	: At the tip or apex
Auxiliary scales	: Small scales superimposed on or along hind edges of larger ones
Asperites	: Rough bony excrescences
Axil I Axial I Axilla	: Angle between pectoral fin and bod y-pertaining to pectoral axilla or pelvic axilla
Axillary	: Pertaining to the axil or upper angle of pectoral fin
Axillary process	: An accessory, enlarged scale attached to the upper or anterior base of the pectoral or pelvic fins
Air bladder	: A membraneous gas filled sac lying just beneath the back bone either open or closed
Ankylosed	: Grown firmly together
Asymmetrical	: Lacking symmetry
Back	: The dorsal side of a fish
Barbel	: Elongate fleshy tentacular projection - usually around the mouth
Basal	: Pertaining to the base; at or near the base; used with reference to fins
Bicuspid	: Having two lobes
Bifid	: Cleft into two
Bifurcate	: Forked into 2 parts generally pertaining to caudal fin
Bilaterally symmetrical	: Capable of being halved in one and only one plane in such a way that the 2 halves are approximate images of each other
Bilobate	: Having 2 lobes
Bony plates	: Hard plate like structures. which are modified from scales (see carapace) which encase body
Bony rings	: Hard ring - like structureswhich are modified from scale which encase body
Branched ray	: A soft ray which forks into 2 or more parts distally
Branchial	: Pertaining to the gills
Branchiostegals	: Bony rays supporting the gill membrane
Buckler	: A bony shield often with a spinousprojection on caudalpeduncle
Buccal	: Pertaining to the mouth cavity
Cardiform	: Elongate conical teeth
Carapace	: Shell like structure on the back of a fish (Ostracion) encasing the body



Cardiform	: Coarse and sharp small teeth
Carinate	: Having a keel or ridge along the midline
Cartilaginous	: Composed of cartilage
Caudal	: Pertaining to the tail; abbreviation of caudal fin
Caudal fin (Shapes)	: Pointed, truncate, emarginated, forked, lunate, wedge shaped
Caudal peduncle	: The narrow terminal part of body between the end of dorsal fin and the base of caudal fin
Cephalic	: Pertaining to the head
Cephalic pit	: Pore like structures present on lateral side of gill cover
Clasper	: Extensions of the pelvic fins in male sharks
Clef	: Split; divided; pertaining to fish mouth
Conical teeth	: When blunt are called - obtuse; long and sharp called Acute - Fang like – caniniform
Continuous	: On contact or closely adjoining
Crenulate	: With the edge slightly scalloped
Ctenoid	: With spiny (comb like) hind margin - refers to scales
Deciduous	: Which is shed easily or rubbed off
Dendritic	: Resembling a tree
Depth	: Vertical height of bod
Distal	: Distal Remote from the point of origin or insertion
Dorsal	: Pertaining to the back. abbreviationfor dorsal fin
Dorsal origin	: The apex of an angle which is formed by the dorsal ridge of the body and the anterior most or spine of the dorsal or first dorsal fin
Edentulous	: Without teeth
Emarginate	: With definitely the margin slightly hallowed; Notched forked. Shallow notch in the tail
Entire	: Not serrated; pertains to undivided dorsal ray; with a smooth margin. Refer to scales. Operculum and fin
Epibranchial	: A bone forming upper part of the gill arch
Exserted	: Fin rays much projecting beyond the fin membrane
Eractile	: Capable of being raised or erected
Falcate, falciform	: Long, narrow, curved, scythe - shaped
Filamentous	: Thread - like, filiform

Fimbriate	:	Fringed at the margin
Finlet	:	Small fins in series behind the dorsal fin and ventral; Division of fin into series of smaller units
Finrays	:	Horny supports of fins; usually called soft rays and generally though not always, flexible and bilaterally paired and segmented; may also refer to spiny rays
Forked	:	Connected basally but separated distally. Furcate
Fossa	:	A pit or depression
Furcate	:	Forked
Gill arch	:	The skeleton supporting gills
Gill rakers	:	A series of bony projection along the anterior edge of the gill-arches
Gular plate	:	A plate covering the upper part of the throat
Hipural	:	The modified terminal bone of the vertebral column. Supporting the rays of caudal fin
Heterocercal	:	Caudal fin with longer upper lobe
Hyaline	:	Transparent. devoid of pigment
Illicium	:	Modified isolated first ray of the dorsal fin in angler fish
Imbricate	:	Having parts overlaying each other
Imperforate	:	Not pierced
Incisors	:	Flattened front cutting teeth, which is chisel shaped
Infraorbital	:	Small bones along lower side of eye; pertaining to the area below eye
Integument	:	A covering or coating layer
Intermaxilla	:	Anterior bone in the upper jaw and situated between the maxillaries; premaxilla
Interopercle	:	Membrane bone between preopercle and branchiostegale
Iris	:	The round, pigmented membrane surrounding the pupil of the eye
Isthmus	:	The narrow fleshy projection of the chest below the gill openings
Jugular	:	Pertaining to the throat
Keel	:	A ridge extending longitudinally and laterally along the middle (of the side)
Labial	:	Pertaining to the lips
Labial - fold	:	A skin flap surrounding corners of the mouth

Lamellae	:	Thin layers of tissue
Laminae	:	Thin layers of bone, skin or other tissue
Lanceolate	:	Lance – shaped, gradually tapering towards the extremity: spear shaped
Lingual	:	Pertaining to the tongue
Lobate	:	Divided into lobes or having rounded divisions
Lunate	:	Shaped like a cresent
Luminiscent	:	Pertaining to the production of light
Mandible	:	The bone or bones forming the lower jaw
Mandibular pores	:	Small openings along a tube (usually hidden) on the lower side of each jaw
Maxilla	:	The principal side bone of the upper jaw
Maxillary	:	Pertaining to the upper jaw
Median. Mesial	:	Pertaining to the middle
Median fins	:	Combined terms of dorsal, caudal and ventral fins
Melanophore	:	A cell containing melanin or black pigment
Mental barbel	:	On chin
Molar	:	A blunt and rounded grinding tooth
Spiracle	:	A respiration opening behind the eye in sharks and rays
Trilobate	:	With three lobes or divisions
Tubiform	:	Tube - like
Vestigeal	:	Pertaining to remnant; rudimentary
Villiform teeth	:	Small s lender teeth forming velvety bands
Vomer	:	A bone forming the front part of the roof of the mouth
Vomerine	:	Pertaining to the vomer bone; especially teeth bar on this bone

Prawns, Crabs and Lobsters

Abdomen	:	Posterior region of body consisting of six (prawns and lobsters) or less (crabs) well defined somites, carrying equal or less number of paired appendages
Antenna	:	Appendage of the third cephalon somite
Antennule (Antennula)	:	Appendage of the second cephalon somite

Anterolateral teeth	:	Teeth on anterolateral border of carapace between orbit and lateral spine in crabs and teeth on lateral margin of carapace in front of cervical incision in sand lobsters
Appendix interna	:	Small separate branch on medial side of pleopodalendopodite tipped with hooks which interlock with opposite member in swimming
Appendix masculina	:	Accessory male organ located medially on second pair of pleopods between endopodite and appendix interna
Branchiocardiac groove regions	:	Groove separating branchial and cardiac
Branchiostegal spine	:	Spine on anterior edge of carapace. or near it. immediately below branchiostegal groove
Branchium	:	Gill
Buccal cavity	:	Cavity on ventral surface of body in which the mouth parts are situated; it is bounded anteriorly by the epistome. laterally by the free edges of the carapace
Carapace:	:	Shield like covering of the cephalothorax
Carpus (carpopodite)	:	Third article from the distal end of a leg
Cephalon	:	Head. It is formed by the first six somites of the body and is fused with the thoracic region of cephalothorax. The first cephalic somite carries the eyes, the second the antennulae, the third the antennae, the fourth the mandibles, the fifth the maxillule and the sixth the maxillae
Cervical groove	:	Complex groove or series of grooves running across carapace
Cephalothorax	:	Part formed by the anterior 14 somites including the first 6 somites of cephalon and the rest 8 thoracic somites
Chela	:	Arrangement of the distal two articles of a crustacean limb by which the terminal element is opposed to the element which precedes it t so that the appendage is adapted for grasping
Chelate	:	Carrying a chela or pincer
Chelipeds	:	Pair or pairs of thoracic legs immediately behind the Maxillipeds
Maxillipeds	:	They bear chelae or pincer, claws and are often stouter, sometimes much stouter than the succeeding walking legs
Cornea	:	The distal part of eye that carries the visual elements and is usually pigmented
Coxa (coxopodite)	:	First or proximal article of a leg or maxilliped
Dactyl (dactylus or dactylopodite)	:	Terminal or distal article of a leg or maxilliped
Efferent channels	:	Channels through which water passes out from the gills
Endopodite	:	Medial ramus of a biramous appendage
Epipodite	:	Outgrowth of the first seven thoracic coxae
Exopodite	:	Lateral ramus of a biramus appendage
Frontal teeth	:	True frontal teeth: those teeth originating on the front but exclusive of the inner orbital teeth
Gastric region	:	Large median area, in the crab carapace, bounded behind by the cervical suture, laterally by the hepatic regions, and anteriorly by the fronto-orbital regions. It is divisible into the following subregions or lobes: epigastric, protogastric, mesogastric, metagastric and urogastric
Hand (chela)	:	Propodus and dactyl of the cheliped
Hepatic region	:	A small (paired) subtriangular, anterolateral region, wedged between branchial and gastric regions, and either margin of carapace or margin of orbit in crabs
Hepatic spine	:	Spine on hepatic region in prawns
Merus (meropodite)	:	Fourth article from the distal end of a leg or maxilliped. It is sometimes called the arm of a cheliped
Orbit	:	Cavity in the carapace containing the eye
Orbital region	:	Narrow space bordering upper margin of orbit;not always distinguishable
Palate	:	Roof of buccal cavity in crabs
Palm	:	Proximal portion of propodus of chela
Pereopod	:	Thoracic appendages behind the mouth parts, i.e. the appendages of somites 10 to 14
Petasma	:	Endopodite of the first pleopods in male penaeid prawns. It takes the form of a complicated membranous plate bearing coupling hooks medially which interlock with the member of the opposite side. The petasma may terminate distally in various combinations of complex-shaped lobes. Additional complex processes may also be present
Pleopod	:	Appendage of any of the first five abdominal somites
Pleurobranchia	:	Gills attached to lateral wall of body dorsal to the articulation of an appendage
Podobranchia	:	Gills attached to the coxa of an appendage
Pterygostomiaa region	:	Triangular space on ventral surface of carapace, on either side of buccal cavity in crabs. Region at anterolateral corner of carapace in prawns
Scaphocerite	:	Antennal scale

Stylocerite	: Spine or rounded lobe on lateral aspect of basal article of antennules
Subhepatic region	: Area below the hepatic region and below the anterolateral border of the carapace
Suborbital spine	: Spine on lower rim of orbit
Supra orbital spine	: Spine above and behind orbit
Telson	: Terminal somite of the abdomen in prawns and lobsters, carrying no appendages
Tergite	: Dorsal plate of a segment
Thelycum	: External seminal receptacle. Variously developed, lying on sternum of the thorax and formed by outgrowths from the last two thoracic somites
Uropod	: Appendage of the sixth abdominal somite

Cephalopods

Aboral	: Away from or opposite to the mouth
Accessory nidamental glands	: Glands of unknown function; consist of tubules containing symbiotic bacteria. Found in all decapodiformes except oegopsid squids
Anal flaps	: A pair of fleshy papillae involved in directing releases of ink, one flap situated at each side of the anus
Anterior	: Toward the head-end or toward the arm-tips of cephalopods
Anterior salivary glands	: Glands on or in the buccal mass that aid in preliminary digestion
Arm	: One of the circumoral appendages of cephalopods. Arms are designated by the numbers I to IV, starting with I as the dorsal (or upper) pair
Arm formula	: Comparative length of the 4 pairs of arms expressed numerically in decreasing order: the largest arm is indicated first and the shortest last, e.g. IV>III>II>I. If IV>III=II>I, then arm IV is the longest, followed by arm III which is the same size as arm II and both are longer than arm I. In octopods, the non-hectocotylized arm III is used in this formula
Beak	: Two chitinous jaws of cephalopods, bound in powerful muscles
Branchial	: Pertaining to the gills

Brooding	: Incubation of eggs by the female. A characteristic feature of incirrate octopods, but also found in some squids (e.g. Gonatidae)
Buccal	: Pertaining to the mouth
Buccal connective	: Thin muscular band that attaches the buccal support of the buccal membrane to the base of the adjacent arm. The position of attachment of the connective on the fourth arms was recognized in the early twentieth century as an important character for phylogenetic relationships among decapodiformes
Buccal membrane	: The muscular membrane that encircles the mouth like an umbrella. It connects to the buccal supports to form the buccal crown. The pigmentation of the buccal membrane often differs from that of the adjacent oral surfaces of the arms
Caecal sac	: The sac-like, thin-walled posterior portion of the caecum in the digestive tract that lacks the internal, ciliated leaflets characteristic of the anterior portion of the caecum
Caecum	: Region of the digestive tract of all cephalopods between the stomach and intestine. It is the primary site of food absorption
Calamus	: The conical papilla or projection at the base of the ligula on the hectocotylus of octopods, at the distal terminus of the sperm groove, distal to the last sucker
Cornea	: Smooth, thin, turgid, transparent skin without muscles that covers the eyes to protect the eye lenses of incirrate octopods and some decapods (myopsids and sepioids)
Crop	: Expansion (i.e. a broadening or a side pocket) of the oesophagus for storing ingested food, prior to entering stomach. Present in nautiluses and most octopods
Cuttlebone (= sepion)	: The calcareous (chalky) oblong, supporting protective and buoyancy shield in the dorsal part of the mantle of cuttlefishes
Dactylus	: The distal, terminal section of the tentacular club, often characterized by suckers of reduced size
Digestive gland	: Primary organ in cephalopods that secretes digestive enzymes. It is also important in absorption and excretion
Digestive gland duct appendages	: Outpockets of the ducts leading from the digestive gland that are covered with glandular epithelium
Dorsal	: The uppermost or back surface of a cephalopod, opposite the ventral surface where the funnel is located

Fin length	Length from anterior lobe, or anterior most attachment of lobe, to posterior most attachment of fin to mantle or tail. Extremely long, spike-like tails usually do not include fin tissue
Fin lobe	The portion of a fin that extends anteriorly from the fin's anterior point of attachment, or posteriorly from the fin's posterior point of attachment of the fin, to the mantle. This often is called the 'free' lobe
Fin position	Fins are located anterior to the termination of the muscular mantle (subterminal position) or mostly posterior to it (terminal position) or in an area of overlap between the two.
Fin shape	Fins are classified, somewhat arbitrarily, by their shape as sagittate, rhomboid, circular/ elliptical, lanceolate, ear-shaped, ribbed, lobate or skirt-like
Funnel	The ventral, subconical tube through which water is expelled from the mantle cavity during locomotion and respiration (reproductive and waste products and the ink also pass through the funnel). Archaic term: siphon
Funnel groove	The depression in the postero-ventral surface of the head in which lies the anterior portion of the funnel
Funnel-locking cartilage	The cartilaginous groove, pit, pocket or depression on each ventrolateral side of the posterior part of the funnel that joins with the mantle component to lock the funnel and mantle together during locomotion and respiration, so that water is expelled only through the funnel and not around the mantle opening
Funnel organ	The glandular structure fused to the internal surface of the funnel, generally a single W-shaped form in octopodiformes and a dorsal inverted V-shaped component with opposed ventral oblong components in decapodiformes
Gill lamellae	The leaf-like convoluted individual components of the gill through which gas exchange occurs
Gladius(= pen)	The feather or rod-shaped chitinous supporting structure in the dorsal midline of squids; the homologue of the shell of ancestral forms
Gladius length (GL)	Sometimes used as a measurement of the body (= mantle) length when direct measurement of the mantle is unreliable (usually due to deformation)
Head length (HL)	A standard measurement within species growth stages and for species comparisons; measured from posterior limit to V-notch at base of Arms I

Hectocotylus	One (or more) modified arm in male cephalopods used to transfer spermatophores to the female; modifications may involve suckers, sucker stalks, protective membranes, trabeculae
Ink sac	The structure that manufactures and stores the ink of cephalopods; it lies parallel with the intestine and empties via a duct into the rectum
Ligula	The spatulate to spoon-shaped, terminal structure of the hectocotylus of many incirrate octopods, that contains the calamus basally (proximally) and usually a series of transverse ridges and grooves on the oral surface (see Calamus, Hectocotylus). Spermatophores transferred along the sperm groove of the hectocotylized arm are presumably gripped by the ligula. Details of the function of the ligula are unknown
Mantle	The fleshy (muscular) tubular or sac-like body of cephalopods; provides propulsion through jet-like expulsion of water; contains the viscera
Mantle cavity	Space enclosed by the mantle. In cephalopods the mantle cavity contains the visceral sac, gills, anus, openings of the gonoducts, nephridial pores and various muscles and septa
Manus	Central or 'hand' portion of club between the dactylus distally and the carpus proximally
Needham's sac (spermatophore/ spermatophoric sac) –	The elongate, membranous organ of males where completed functional spermatophores are stored. It opens into the mantle cavity or directly into the water through the penis
Nidamental glands	Large glandular structures in females of most decapods and nautiluses that lie in and open directly into the mantle cavity. The glands are composed of numerous lamellae that are involved in secretion of egg cases or the jelly of egg masses
Ocellus	Apigmented spot or patch that usually consists of a central locus of concentrated chromatophores with one or more outer concentric rings of chromatophores. Ocelli occur on some octopuses, and their normally vivid iridescence and pigmentation cause them to stand out against the background coloration of the skin. Also called 'false eyespot'
Oviduct	Female gonoduct(s). The oviduct conducts eggs from the visceropericardial coelom, that encompasses the ovary, to the mantle cavity and often is used to store eggs. In some argonautid octopods eggs are fertilized and undergo either partial (Argonauta) or complete (Ocythoe) embryonic development within the oviduct

Oviducal gland	:	Glandular structure that surrounds the anterior end of the primary oviduct and secretes some of the external coatings around spawned eggs
Penis	:	The long, muscular terminal section of the male gonoduct that serves to transfer spermatophores to the female. Apparently, in species with a hectocotylus, the penis transfers spermatophores to the hectocotylus which in turn transfers them to the female
Pocket, tentacular	:	An open depression in the anteroventral surface of the head between the bases of arms III and IV of decapods, except myopsid and oegopsid squids, into which the ejectable feeding tentacles are retracted when not in use
Rostrum (= spine)	:	A spike-like posterior projection of the gladius or cuttlebone, exterior to the conus
Semelparous	:	A reproductive strategy in which females spawn once then die. Sometimes called terminal or 'big-bang' spawners. Many cephalopods are semelparous but in some species reproduction is prolonged (up to 50% of the ontogenesis). Nautiluses are iteroparous and spawn repeatedly over a period of years
Sperm duct (= seminal duct)	:	The duct of males which joins the testis with the spermatophoric organ
Sperm mass	:	The mass of sperm held within the spermatangia of evertedspermatophores
Sperm receptacle	:	A bulbous structure in the buccal region or at the openings of the oviducts in females of certain cephalopods for deposition of spermatangia
Spermatangium(pl. spermatangia)	:	Extruded, exploded, evaginatedspermatophore/s, often in the form of a round bulb
Spermathecae	:	Specialized sperm-storage structures found in the skin of some female decapodiformes or as pockets of the oviducal gland in octopods
Spermatophore	:	A tubular structure manufactured by male cephalopods for packaging sperm; capable of holding millions of sperm, it is transferred and attached to the female until fertilization begins. It forms a spermatangium after the spermatophoric reaction occurs and the spermatophore has everted
Spermatophoric complex	:	The unit formed by the sperm duct, the spermatophoric organ, the spermatophoric sac, the spermatophoric duct and the penis
Spermatophoric duct	:	The duct of males through which the spermatophores, once formed, pass from the spermatophoric organ to the spermatophoric sac

Spermatophoric organ	:	Male organ where the spermatophores are formed
Spermatophoric reaction	:	The evagination of a spermatophore with the extrusion of the sperm mass, caused by the penetration of water inside the spermatophoric cavity, where the osmotic pressure is higher.
Stomach	:	The muscular organ of the digestive system where primary digestion occurs
Sucker/s	:	Muscular, suction-cup structure/s on the arms and tentacles (occasionally on the buccal membrane) of cephalopods. It consists of a cup-shaped portion, the acetabulum, and a flat, distal ring, the infundibulum, that contacts the substrate. They usually are counted either in longitudinal rows or in transverse (oblique) series
Sucker ring	:	Chitinous, often serrated or toothed, ring that encircles the opening of suckers of squids and cuttlefishes
Tentacles	:	Modified fourth pair of appendages in decapods, used for prey capture and capable of considerable extension and contraction
Tentacular club	:	The distal, terminal, usually expanded, part of the tentacle that bears suckers and/or hooks. Used for capturing prey
Total length (TL)	:	Length measured from the posterior tip of the mantle to the anterior tip of the outstretched tentacles (squids and cuttlefishes) or arms (octopuses)
Web	:	A membranous sheet of greater or lesser extent that extends between the arms of many octopods, giving an umbrella-like appearance when the arms are spread out, e.g. on cirroteuthids. It is reduced or absent in most decapods

Gastropods

Albino	:	Shell lacking normal pigmentation
Anterior	:	Region situated near the head. In gastropods: in front
Anterior canal	:	Expansion looking like a groove or a tube and serving to protect the siphon in gastropod shells
Aperture	:	Opening in gastropod shells
Apertural	:	Position relative to the aperture of gastropod shells
Apex/ Top of the shell	:	Extremity of a gastropod shell opposite to the anterior region; part of the shell built in earlier life
Apical	:	Situated at or near the apex of a gastropod shell

Axial	Direction forming a plane with main shell axis in gastropods
Basal	Position relative to shell base
Base	Part of the gastropod situated in opposition to the apex
Bottom of the shell	Same as base
Body whorl	Most anterior whorl of the gastropod shell, last and largest whorl
Callus	Thickening of the shell, secondary, smooth, sometimes glazed, usually secreted on the parietal region of the columella
Cancellate	Feature of cross-barred sculpture of some gastropod shells consisting of axial and spiral elements of same intensity crossing at right angles
Columella	Column or pillar located on the centre of a gastropod shell
Cord	Element of gastropod shell sculpture, usually spirally oriented, thicker than line
Cordlet	Narrow cord, thicker than line
Corrugated	Appearance of surfaces forming wrinkles
Crenulated	Appearance of surfaces that are delicately notched or corrugated. Term usually applied to wrinkled shell margin or edge
Crenulations	Notches, or wrinkles that are small and delicate
Denticles	Features of sculpture elements looking like small teeth-like projections.Term usually applied to features seen on the internal part of the aperture
Depressed	Outline of low, pressed-down gastropod shells. Term usually applied to some top shells
Dorsal	Region opposite to the foot in gastropods
Elongate	Shell with length significantly larger than width
Excavated	Appearance of a hollow, concave surface
Fold/ Plication	Ridge spiralling on columella
Foliated	Characteristic of being leaf-like
Foot	In gastropods, fleshy, sole-like, muscular part of body involved in locomotion
Furrow	Groove in longitudinal direction found on the dorsal region of, among other shells, cowries and Triviidae
Fusiform	Characteristic of being spindle-shaped
Glassy	Surface resembling glass, vitreous, transparent

Globular / Globose	Shape resembling a sphere or a ball
Granulated	Surface covered with minute grains, pustules, or beads
Growth lines	Lines on shell surface indicative of alternating periods of growth and rest; sometimes corresponding to seasonal changes
Horny	Substance that is hardened and proteinaceous; present in or completely forming the gastropod operculum and shell periostracum
Incised lines	Features of shell sculpture represented by cuts or narrow grooves on the shell surface
Indentation	Cut or notch on shell edge or parietal region
Indented	Surface bearing an indentation
Interspaces	Spaces between sculptural features, such as ribs, costae, or cords
Juvenile	Characteristic of being young, immature, not fully grown
Keyhole	Apical orifice in some limpets
Knob	Large nodule, rounded projection
Knobbed	Surface bearing knobs
Lamella (pl. lamellae)/ Lamellation	Thin plate or blade-like projection
Ligament	Structure that is horny and proteinaceous, acting as a spring tending to keep the valves opened in bivalve shells. Usually situated in the region of the hinge, either internally or externally
Line / Thread	Sculptural feature narrowly incised on shell surface
Lip	Edges of the outer surface of the aperture in the gastropod shell
Longitudinal	Direction parallel to the largest dimension of the shell or mollusc
Nacreous	Characteristic of being iridiscent, like mother-of-pearl
Nodules	Projections that are rounded as tubercules
Nodulose	Surface bearing nodules
Notch	Cut or depression on any margin, canal, or on the gastropod aperture
Opalescent	Characteristic of being whitish, but with nacreous luster

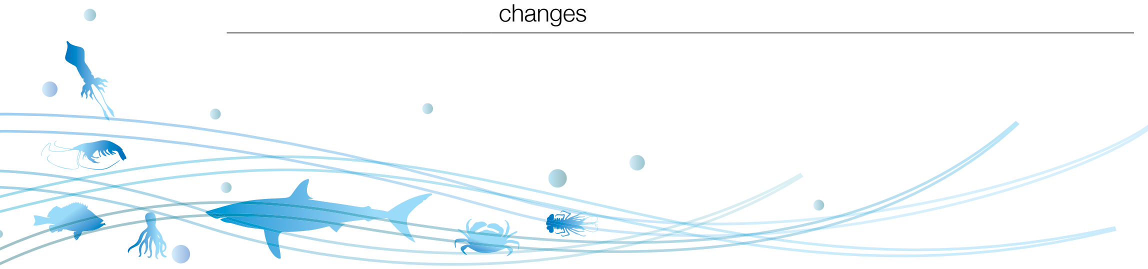
Operculum	:	Trapdoor or plate which closes the aperture of gastropod shells and isolates the snail from its surrounding environment. Opercula can be horny ('soft', brownish) or calcareous ('hard', usually whitish)
Outer lip	:	Edge of the external part of the aperture away from the shell axis
Ovate/ Oval	:	Characteristic of having the form of an egg
Parietal	:	Region of the internal part of the aperture, usually set apart by differences in surface texture and/or coloration
Parietal shield	:	Parietal region when markedly different from the remainder of the adjacent shell area
Periphery	:	Region of the outermost part of any given whorl on the gastropod shell. The shell periphery is therefore the greatest circumference of the gastropod shell
Periostracum	:	Layer of the outside part of the shell. It is horny and sometimes hair-like
Peristome	:	Aperture rim or periphery
Posterior	:	Region away from the siphonal canal, near the apex, in gastropods; in bivalves, the region of the shell sinus, away from the foot
Posterior canal	:	Canal of small size or notch opposite to the siphonal canal on the aperture of the gastropod shell
Protoconch	:	Larval shell remaining on the apex of well-preserved gastropod shells
Radial / Radiating	:	Structures that are directed away from the apex toward the shell margin, in limpets
Reticulate	:	Feature of shell sculpture consisting of criss-crossed, net-like texture formed by the intersection of lines at right angles
Ribbon / Egg-ribbon	:	Surface consisting of an aligned sequence of egg-cases
Ribs	:	Strucutural elements forming a well-defined, narrow ridge in gastropod shells. Term usually applied to those elements forming a plane with (or slightly oblique to) shell axis
Riblets	:	Diminutive of ribs
Scales	:	Sculptural elements that are small, raised, and plate-like
Septum	:	Partition found in the internal side of gastropod shells; characteristic of slipper-shells
Serrated	:	Resembling tiny saw teeth
Shoulder	:	Angled region of the whorls of gastropod shells
Siphon	:	Prolongation of the gastropod mantle used to convey water into the mantle cavity

Siphonal canal	:	Projection of the anterior region shell in tubular form protecting the anterior siphon
Snails	:	Common name of gastropods
Spiral	:	Direction following the coiling of the gastropod shell. Term usually applied as a modifier to sculptural terms such as 'spiral cords'
Spire	:	Series of successive whorls in a gastropod shell, with exception of the last one
Spire angle	:	Angle formed by the lines defined by the outermost points on both sides of the spire
Striation	:	Fine, repeated lines or furrows on shell surface
Suture	:	Line or region of junction between two adjacent whorls in the gastropod shell
Synonym	:	A scientific name applied to a species that has received an earlier name. Obs: usually, the earlier name is the valid one
Turbinate	:	Form that looks top-shaped, tapering evenly from base to apex
Turreted	:	Form that looks tower-shaped, elongate
Umbilicus	:	Cavity at base of gastropod shells
Uncoiled	:	Gastropod shell that lacks coiling
Varix	:	Axial sculptural element that is more prominent than a costa, and usually more widely spaced; evidence of a growth halt during which a thickened lip develops (plural: varices)
Ventral	:	Region of the animal opposed to the dorsal region; region of the foot in gastropods
Whorl	:	A complete turn or coil of the gastropod shell

Bivalves

Anterior	:	Region situated near the head. In bivalves: region opposite to the siphons, consequently, opposite to the shell sinus
Beak/ Umbo (pl. umbones)	:	Projected portion of the hinge. First-formed part of the bivalve shell
Bivalve	:	Molluscs that have, among other features, shell comprised of 2 halves, or valves
Byssal	:	Position relative to byssus
Byssal gap	:	Gap or opening sometimes present on the ventral margin of bivalve shells for passage of byssus

Byssus	:	Bundle of fibers secreted by some bivalves attaching the animal to the bottom. Mussels, some arks, and pen shells are attached to the substrate by byssus
Cancellate	:	Cross-barred sculpture. In bivalves, radial and concentric elements will cross to produce a cancellate sculpture
Chondrophore	:	Depression in spoon-like form housing the internal ligament of some bivalve shells
Chomata	:	Marginal crenulations in Ostreidae and Gryphaeidae, occurring all around the inner side of valves or only near the hinge, composed of small tubercles or ridgelets on the right valve, and corresponding pits on the left valve
Compressed	:	Outline of bivalves which are flattened laterally
Concentric	:	Feature of sculptural elements curving about the umbo in bivalves
Cord / Cordlet	:	Element of gastropod shell sculpture, usually spirally oriented, thicker than lines
Corrugated	:	Appearance of surfaces forming wrinkles
Crenulated	:	Appearance of surfaces which are delicately notched or corrugated. Usually applied to wrinkled shell margin or edge
Crenulations	:	Notches, or wrinkles which are small and delicate
Depressed	:	Outline of low, pressed-down gastropod shells. Obs: term usually applied to some top shells or baby ear
Dorsal	:	In bivalves, the region of the hinge
Equivalve	:	Characteristic of bivalves that have the 2 valves or halves of same size
Escutcheon	:	An area of the posterior-dorsal shell surface near a ligament that is differentiated by sculpture and frequently demarcated by a marginal ridge or furrow
Excavated	:	Appearance of a hollow, concave surface
Foliated	:	Characteristic of being leaf-like
Foot	:	In bivalves, hatchet-like, expandable structure involved in burrowing
Glassy	:	Surface resembling glass, vitreous, transparent
Granulated	:	Surface covered with minute grains, pustules, or beads
Growth lines	:	Lines on shell surface indicative of alternating periods of growth and rest; sometimes corresponding to seasonal changes



Hinge	:	Region of the bivalve shell where the two valves are joined together, usually including interlocking teeth and the ligament
Hinge teeth	:	Projections that interlock on the inner side of the bivalve shell hinge helping to prevent the two valves from sliding sideways past each other
Horny	:	Substance that is hardened, proteinaceous; partially or completely forming the ligament, shell periostracum, and possibly other structures
Incised lines	:	Features of shell sculpture represented by cuts or narrow grooves on the shell surface
Indented	:	Surface bearing an indentation
Inequivalve	:	Characteristic of having the two valves (halves) of different size
Inflated	:	Characteristic of being 'fat', rotund, and frequently lightweight
Interspaces	:	Spaces between sculptural features, e.g., ribs, costae, or cords
Knob	:	Large nodule, rounded projection
Knobbed	:	Surface bearing knobs
Lamella	:	Thin plate or blade-like projection
Ligament	:	Structure that is horny, proteinaceous, acting as a spring tending to keep the valves opened in bivalve shells. Usually situated in the region of the hinge, either internally or externally
Line	:	Sculptural feature narrowly incised on shell surface
Lunule	:	Impression on the external side of the hinge, anterior to the umbo, usually heart-shaped
Mantle	:	Fleshy sheet surrounding vital organs and composed of 2 lobes, one lining and secreting each valve
Margin	:	Edge of shell
Nacreous	:	Characteristic of being iridiscent, like mother-of-pearl
Nodules	:	Projections which are rounded as tubercules
Nodulose	:	Surface bearing nodules
Notch	:	Cut or depression, as on a shell margin
Opalescent	:	Characteristic of being whitish, but with nacreous luster
Ovate / Oval	:	Characteristic of having the form of an egg

Pallial line	:	Fine scar-like impression present internally; in bivalve shells produced by the edge of the mantle
Periostracum	:	Layer of the outside part of the shell. It is horny and sometimes hair-like
Posterior	:	In bivalves, the region of the shell sinus away from the foot
Prodissoconch	:	Shell in larval state remaining on the umbonal region of well-preserved bivalve shells
Radial / Radiating	:	Structures that are directed away from the umbo toward the shell margin in bivalve shells
Reticulate / Reticulated	:	Feature of shell sculpture consisting of criss-crossed, net-like texture formed by the intersection of lines at right angles
Ribs	:	Strucutural elements forming a well-defined, narrow ridge in gastropod shells. Term usually applied to those elements forming a plane with (or slightly oblique to) shell axis
Riblets	:	Diminutive of ribs
Scales	:	Sculptural elements that are small, raised, and plate-like
Septum	:	Partition found in the internal side of gastropod shells; characteristic of slipper-shells
Serrated	:	Outline resembling tiny saw teeth
Shell sinus	:	Embayment on the pallial line of bivalve shells that correspond to the position of the siphons
Siphon	:	Prolongation of the mollusc mantle used to convey water into or out of the mantle cavity
Spiral	:	Direction following the coiling of the gastropod shell. Usually applied as a modifier to sculptural terms such as 'spiral cords'
Striation	:	Fine, repeated lines or furrows on shell surface
Varix (pl. varices)	:	Axial sculptural element that is more prominent than a costa, and usually more widely spaced; evidence of a growth halt during which a thickened lip develops
Valve	:	One half of the bivalve shell
Ventral	:	Region of the animal opposite the dorsal region; usually region of the foot in bivalves

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REFERENCES AND MATERIALS FOR FURTHER READING

Alagaraja, K (1984) Simple methods for estimation of parameters For assessing exploited fish stocks. *Indian J. Fish.* 31 (2). pp. 177-208.

Allen, R. K (1938) Some observation on the biology of the *Salmo trutta* in windmere. *J. Anim. Ecology* .4: 333-349.

Beverton Raymond J. H., and Sidney J. Holt. (1957) On the Dynamics of Exploited Fish Populations. Gt. Britain, Fishery Invest., Ser. II, Vol. XIX. 533 pp.

Carpenter, K.E.; Niem, V.H. (eds) (1998) FAO Species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, corals, bivalves and gastropods. Rome, FAO. pp. 1-686.

Chan, T.Y., (1998) Shrimps and Prawns. In: FAO identification guide for fishery purposes – The Living Marine Resources of the Western Central Pacific, Vol.2, Cephalopods, Crustaceans, Holothurians and Sharks. K.E. Carpenter and Niem V. H., (eds): 827-1155pp.

Fischer, W. and G. Bianchi (eds), (1984) FAO species identification sheets for fishery purposes. Western Indian Ocean; (Fishing Area 51). Prepared and printed with the support of the Danish International Development Agency (DANIDA). Rome, Food and Agricultural Organization of the United Nations, vols 1-5.

George, M.J., (1969) Systematics, taxonomic considerations and general distribution: Prawn Fisheries of India. *Bull. Cent. Mar. Fish. Res. Inst.*, 14: 5-48.

Hile, R. (1936) Age and growth of *Leucicthys artedi* inthe lakes of the northeastern high lands. *Wisconsis. Bull, us. Bur. Fish.* 48: 211- 317.

Holthuis, L.B., (1980) FAO species catalogue. Vol. 1. Shrimps and prawns of the world. An annotated catalogue of species of interest to fisheries. *FAO Fisheries Synopsis*, 125 (1): 261 pp.

http://www.niobioinformatics.in

Jereb and Roper (2005) CEPHALOPODS OF THE WORLD *An annotated and illustrated catalogue of species known to date.* FAO Species Catalogue for Fishery Purposes No.4, Vol.1.

Le Cren E D (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in the perch *(Perca fluviatilis). J. Anim. Ecol.* 20: 201-19.

Mathur V. and Rajvanshi A. (2001) The Integration of Biodiversity into National Environmental Assessment Procedures National Case Studies India. UNDP/UNEP/GEF BPSP- Komex, September 2001. 59 p.

Miquel, J.C., (1984) Shrimps and Prawns: *In*: FAO Species identification sheets for fisheries purposes. Western Indian Ocean (Fishing area 51), Edited by W. Fisher and G. Bianchi. FAO, Rome.Vol.5, (unpaginated).

Natarajan, A.V. and V.G. Jhingran (1961) Index of preponderance - A method of grading the food elements in the stomach analysis of fishes. *Indian J. Fish.*, 8 (1): 54-59.

Radhakrishnan, E V and Josileen, Jose (2013) Taxonomy-Marine Prawns of India. In: Handbook of Marine Prawns of India. Rao, G Sudhakara and Radhakrishnan, E V and Josileen, Jose,(eds.) Central Marine Fisheries Research Institute, Kochi, pp. 9-37.

Snedecor, G.W and W.G. Cochran (1967) Statistical methods. Oxford and IBH Publishing Co., New Delhi, Sixth edition, 539 pp.

Srinath, M and Kuriakose, Somy and Mini, K G (2005) Methodology for the Estimation of Marine Fish Landings in India. CMFRI Special Publication, 86 . pp. 1-57.

Van Bruggen, A.C. Wells, S.M. and Keperman T.C.M. (Eds.) (1995) *Biodiversity and Conservation of the Mollusca*: Proceedings of the Alan Solem Memorial Symposium on the Biodiversity and Conservation of the Mollusca. Backhuys Publishers, Oegstgeest-Leiden.

Zacharia, P U and Abdurahiman, K P (2004) Methods of stomach content analysis of fishes- Winter School on Towards Ecosystem Based Management of Marine Fisheries – Building Mass Balance Trophic and Simulation Models. [Teaching Resource] http://eprints.cmfri.org.in/view/creators/Zacharia=3AP_U=3A=3A.html

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