TAXONOMY AND DIVERSITY OF JELLYFISHES

Dr. R. Saravanan

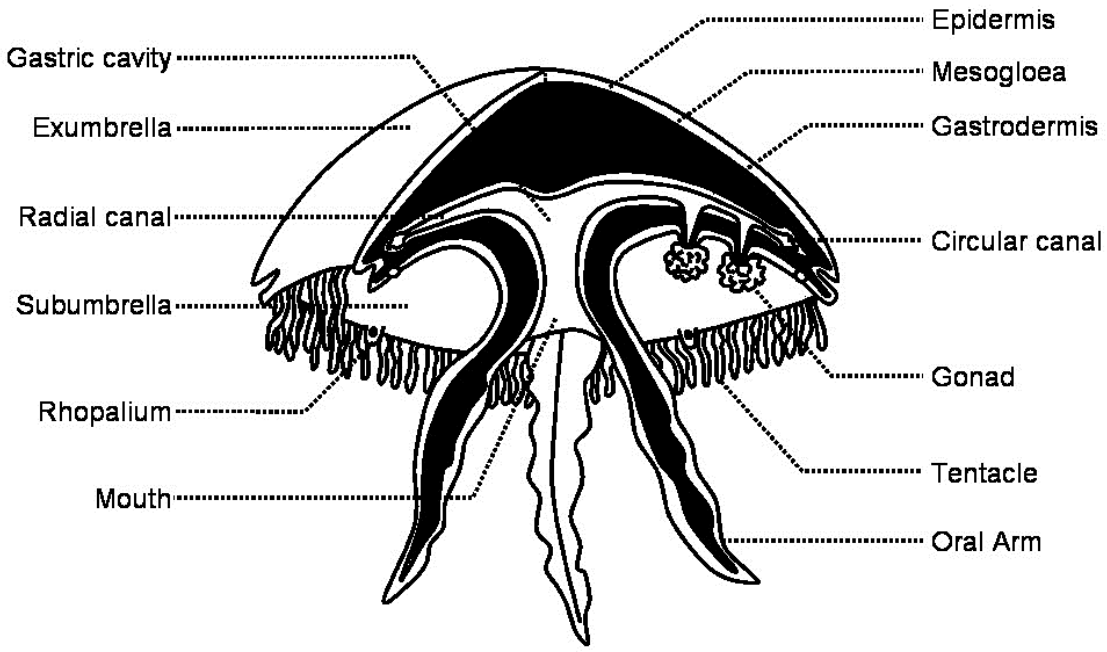
Senior Scientist, ICAR-CMFRI, Mandapam Regional Centre

1. Introduction

Jellyfish is a common term used for any gelatinous animal in marine waters. These include a wide variety of stinging and non-stinging jellyfishes. Jellyfish are the oldest animal on planet Earth, dating from the pre-Cambrian period, and have passed through 500 million years of natural selection. The word "jellyfish" is usually used for a group of jelly-like zooplankton that includes planktonic members of the phylum Ctenophora, Salps and Pyrosomes, and medusae from the phylum Cnidaria (scyophomedusae, hydromedusae, cubomedusae, and siphonohores). The true jellyfish come under the three Cinidarian classes, viz., Hydrozoa, Scyphozoa, and Cubozoa, and seasonally swarm in the coastal waters. Among the three classes, representatives of Scyphozoan and Cubozoan jellyfish range in size from 2 mm to 2 m in bell diameter, however, most of the hydrozoan jellyfish are smaller than 2 mm in bell diameter and belong to the mesoplankton. The biodiversity of pelagic scyphozoan jellyfishes and cubozoan jellyfishes is largely ignored in India, other than a few works in this line. The first work on scyphozoan medusae was published way back in 1930, in which the scyphomedusae of Madras were described with illustrations (Menon, 1930). Subsequent to this publication, the above author has brought out the scyphomedusae of Kurusadai Island (Menon, 1936). These are the two classic works that describe the taxonomic features and distribution of scyphomedusae along the south-east coast of India. Since then, there has been a long gap in the study of scyphomedusae in India. The scyphomedusae available in India were listed as 34 by Chakrapany (1984). The Medusae of the Travancore waters was studied by Nair (1951) and assessed for its impact on fisheries.

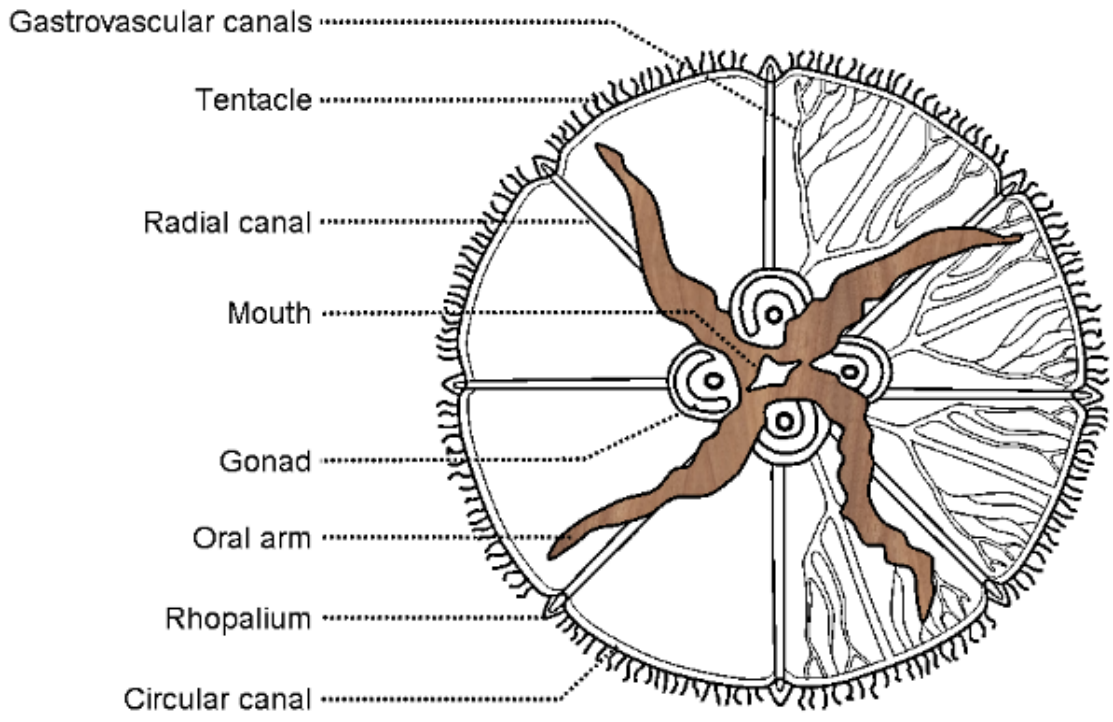
2. Morphometric features of Jellyfishes

Jellyfishes are simple organisms with three layers of tissue, viz., endoderm, ectoderm, and mesoderm. The body is composed of over 90 percent water. The umbrella shaped body, which is called the bell, and the underside are covered with oral arms, or tentacles. In jellyfish, differences in the bell margin are used as a differentiating characteristic between different groups. The members of the order Semaeostomeae have tentacles on the bell margin, whereas the members of the order Rhizostomeae have tentacles on the tip of their oral arms. Jellyfish are 97% water and are semi-transparent.



Aurelia medusa – cutaway diagram

Image based on: https://cronodon.com/BioTech/Jellyfish.html



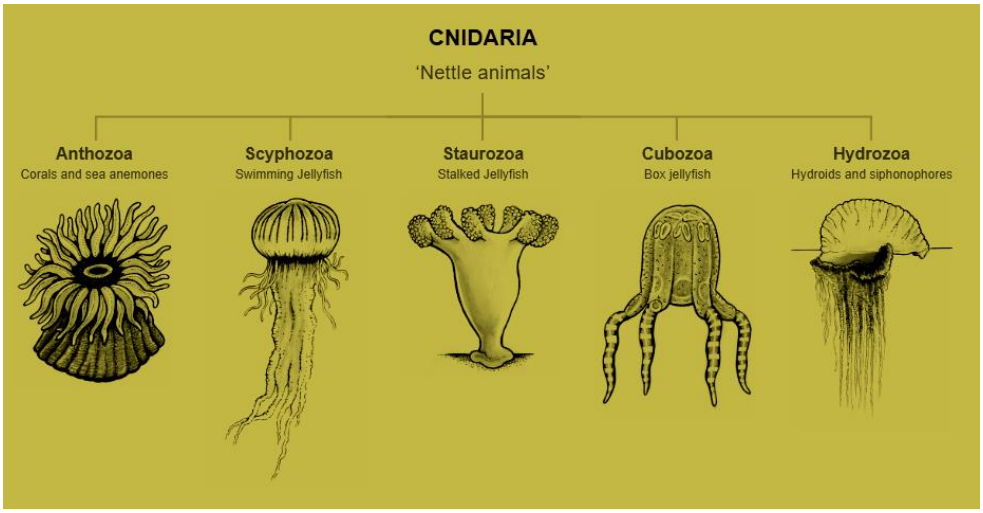
Aurelia medusa – subumbrella view

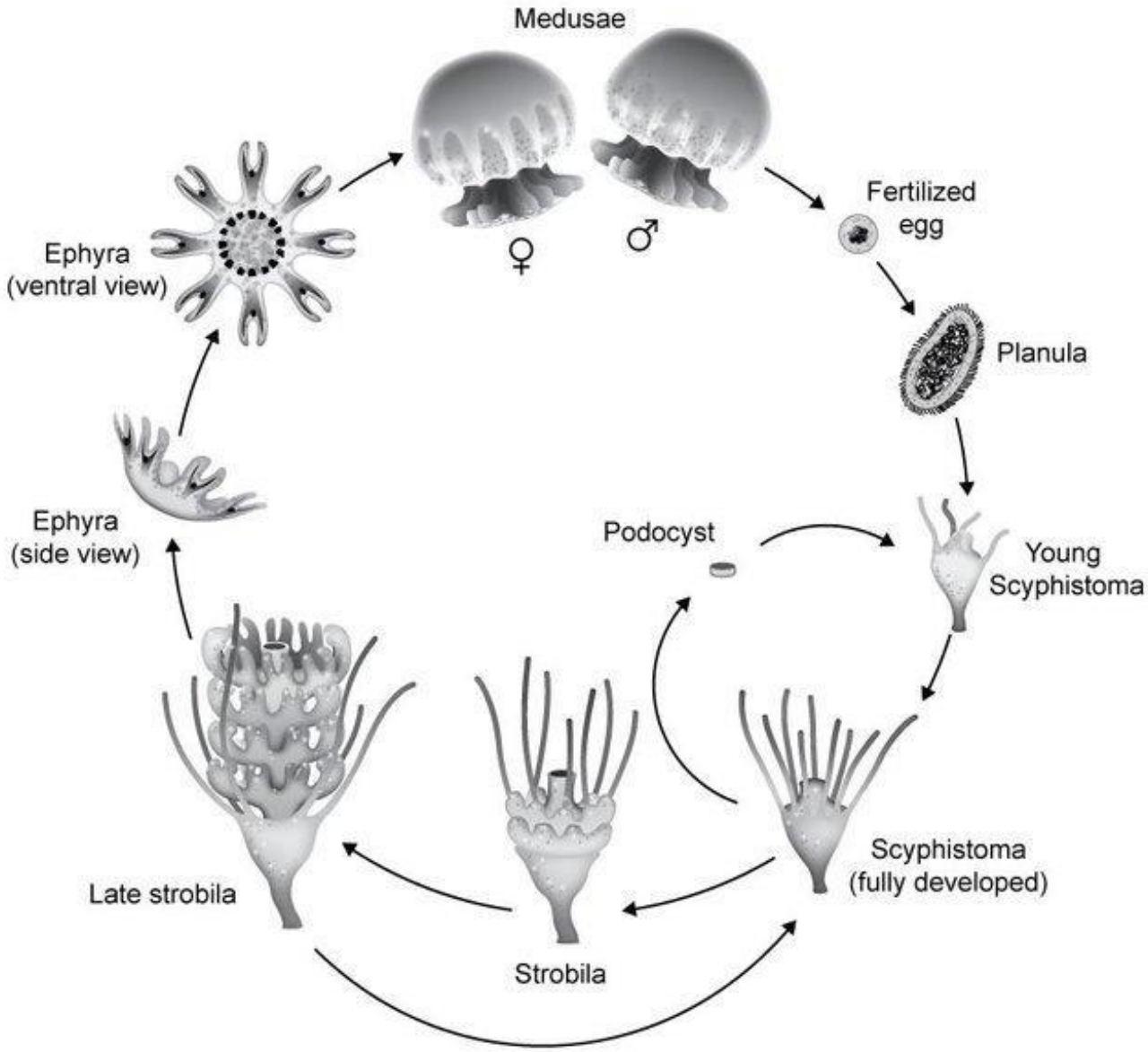
Image based on: https://cronodon.com/BioTech/Jellyfish.html

Jellyfish have two body layers: the outer layer, the epidermis and the interlayer, the gastrodermis. Between both layers is a thick layer of mesoglea, which consists of fibres embedded in a hydrated matrix that contains cells. These layers of tissues make up the umbrella of the jellyfish, which is usually bell-shaped; thus, the umbrella is also known as the bell. The scyphozoan jellyfish are tetraradially symmetrical, meaning they have many structures in multiples of four. It contains a simple gastrovascular cavity that acts as the stomach. They are also characterised by having gastric filaments in the stomach. Some scyphozoan jellyfish, such as Semaestomeae, contain an opening, or mouth, at the subumbrella. There are four to eight oral arms near the mouth, which function as arms to capture and transport food to the gastrovascular cavity. Jellyfish lack eyes but possess many sensory receptors capable of detecting light, pressure, temperature, and gravity. These sensory receptors are concentrated in the marginal sense organ that contains the rhopalium (Nakanishi, 2015). Not all jellyfish possess tentacles. For Semaestomeae jellyfish, tentacles can be found at the margin of the bell or at the subumbrella, whereas tentacles are absent from the Rhizostomeae jellyfish. Jellyfish contain a network of canals that usually anestomose with each other and form various patterns.

3. Life cycle and biology

Cnidarian jellyfish, also called medusae, have complex life cycles that often involve a benthic stage: the polyp and the pelagic stage: the medusae or jellyfish. This bipartite life cycle alternates between an asexual, benthic polyp and a sexual, pelagic medusa. Medusae typically are produced asexually in abundance and grow rapidly in seasons (Russel, 1970).





Life cycle of the cannonball jellyfish *Stomolophus meleagris*; based on Calder (1982)

4. Diversity and distribution of jellyfishes in India

Class Scyphozoa is ascribed to four orders, namely Stauromedusae, Coronatae, Semaeostomeae, and Rhizostomeae, with 65 genera and over 187 species globally. The diversity of scyphozoan jellyfish along the Indian coastal waters has been reported at 29; however, given the poor research attention given to this group, there may be more species to be recorded in the coming years.

Order Semaeostomeae

The order Semaeostomeae composed of three families, four subfamilies, 18 genera and 56 species (Kramp, 1961). Semaestommeae jellyfish are characterized by four oral arms around the mouth. Tentacles are found at the umbrella margin. (Arai, 1997). The two important families of Semaeostomeae are Cyaneidae and Pelagiidae.

Order Rhizostomeae

The order Rhizostomeae is composed of two suborders, 10 families, 25 genera, and approximately 89 species (Kramp, 1961). Rhizostomeae jellyfish are characterised by having a bell margin cleft into a lappet, with no tentacle on the bell margin, without a central mouth, and with eight oral arms extended from the subumbrella, where each oral arm bears numerous secondary mouths. A network of canals is found beyond the stomach. (Kramp, 1961; Arai, 1997). The important orders of this family are Mastigiidae, Versurigidae, Lychnorhizidea, Catostylidea, Lobonematidae, and Rhizostomatida.

5. List of Scyphozoan jellyfishes Occuring in Indian waters

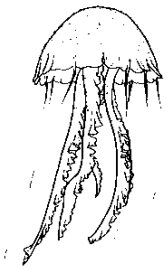
- *Atolla wyvillei Haeckel, 1880*
- *Nausithoe punctata Kölliker, 1853*
- *Periphylla periphylla (Péron & Lesueur, 1810)*
- *Cyanea nozakii Kishinouye, 1891*
- *Pelagia noctiluca (Forsskål, 1775)*
- *Aurelia aurita (Linnaeus, 1758)*
- *Acromitus flagellatus (Haeckel)*
- *Acromitus maculosus Light, 1914*
- *Catostylus mosaicus (Quoy & Gaimard, 1824)*
- *Crambionella orsini (Vanhöffen)*
- *Crambionella annandalei Rao, 1931*
- *Lobonema smithii Mayer, 1910*
- *Lobonemoides robustus Stiasny, 1920*
- *Lobonemoides sewelli Rao, 1931*
- *Lychnorhiza malayensis Stiasny, 1920*
- *Rhopilema hispidum (Vanhöffen, 1888)*
- *Cassiopea andromeda (Forsskål, 1775)*
- *Cassiopea xamachana Bigelow 1892*
- *Cephea cephea (Forskål, 1775)*
- *Marivagia stellata Galil & Gershwin, 2010*
- *Netrostoma coerulescens Maas, 1903*
- *Netrostoma setouchianum (Kishinouye, 1902)*
- *Mastigias papua (Lesson)*
- *Versuriga anadyomene (Maas)*
- *Phyllorhiza punctata Lendenfeld, 1884*
- *Thysanostoma loriferum*
- *Thysanostoma thysanura Haeckel, 1880*

6. List of Cubozoan Jellyfishes occurring in Indian waters

- *Alatina alata (Reynaud, 1830)*
- *Alatina madraspatana (Menon, 1930)*
- *Tamoya gargantua Haeckel, 1880*
- *Chiropsalmus quadrumanus (F. Muller, 1859)*
- *Chiropsoides quadrigatus (Haeckel, 1880)*
- *Chiropsoides buitendijki (van der Horst, 1907)*
- *Chironex indrasaksajiae Sucharitakul, 2017*

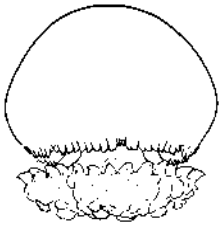
Morphology of different jellyfishes- taxonomic family-wise

Cyaneidae

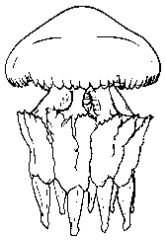


Pelagiidae

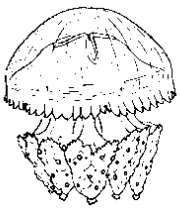
Ulmaridae



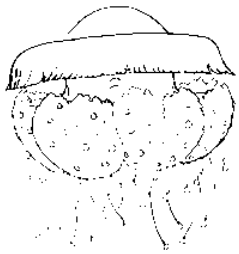
Rhizostomatidae



Rhizostomatidae



Mastigiidae



Cepheidae

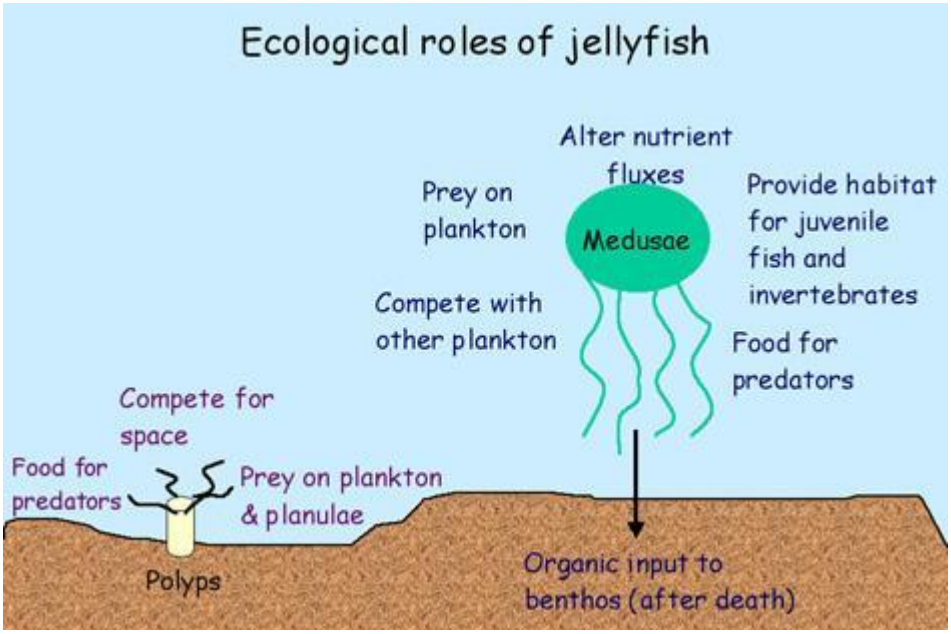
Catostylidae

Physaliidae

7. Ecosystem importance of Jellyfishes

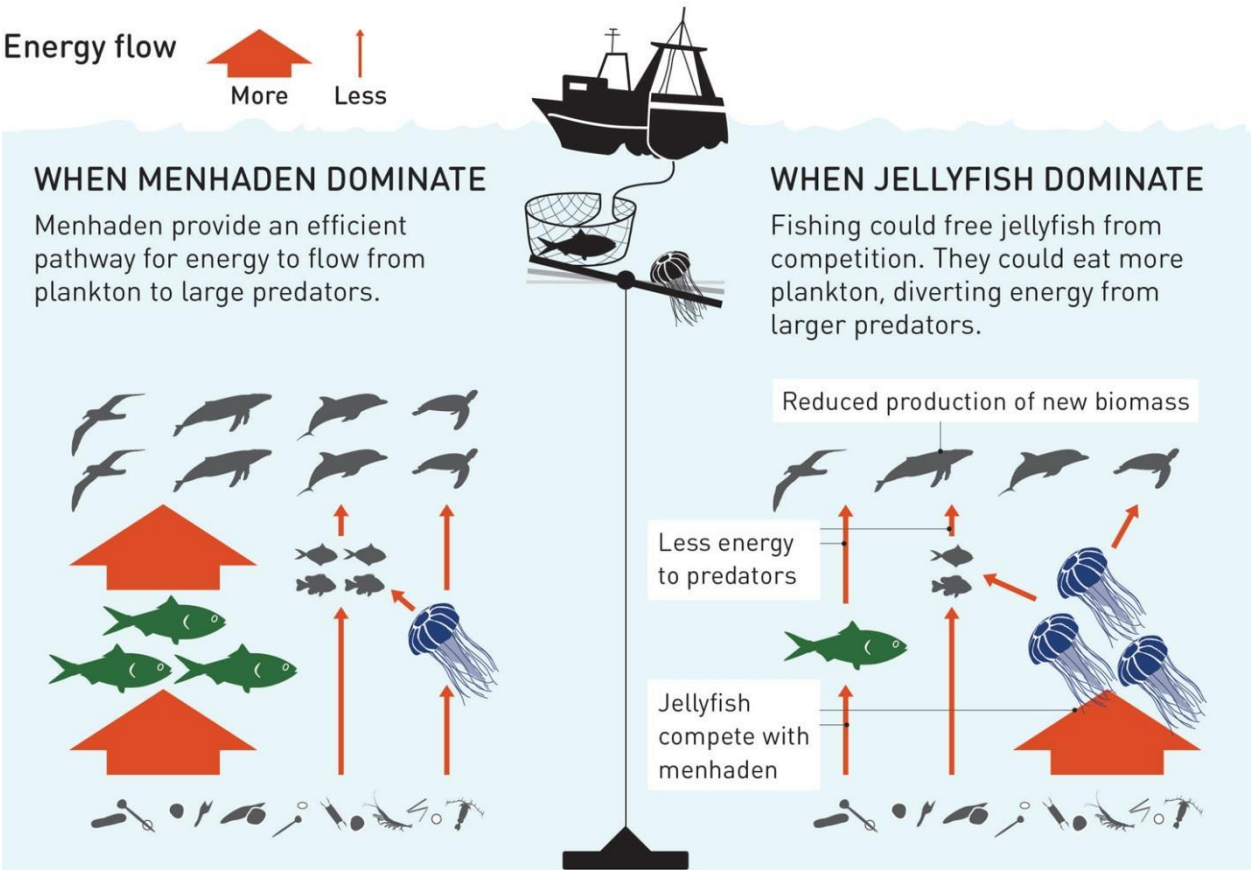
Jellyfishes are distributed globally and often form swarms under favourable conditions that last for weeks to months before they collapse. Though jellyfish population swarms occur in many places at an increasing trend, the lack of time series data on their distribution and abundance along the Indian coast prevents us from concluding their population dynamics. Establishing time series data around the Indian subcontinent and island territories on jellyfish abundance is difficult due to the fact that, in most cases, these jellyfish get damaged in bottom trawls and zooplankton tows

and are not properly recorded. Jellyfish directly interfere with many human activities (reviewed by Purcell et al., 2007; Richardson et al., 2009), specifically through stings (beach closures, tourism impacts, injuries, deaths), clogging intakes (coastal power and desalination plants, mining and military operations, shipping, aquaria), interference with fishing (clogged and split nets, spoiled catch, stung fishers, damaged gear, capsized boats), aquaculture (fish deaths, pens fouled by polyps), and marine biological surveys (interference with trawls and acoustic surveys). Jellyfish also have ecosystem impacts with indirect effects on fisheries resources that are difficult to quantify, such as their roles as predators of zooplankton, fish eggs, and ichthyoplankton, as vectors for parasites, as food for fish, and as refugia and food for some species of juvenile fish.



Ecological roles of medusae and polyps. Adapted from Kingsford et al. 2000

Invasive species of jellyfish are reported in 21 of 45 LMEs. For the most part, invasive species were not responsible for the observed increases reflected in the results; however, the widespread detections demonstrate that jellyfish are truly global invaders of significant concern. Thriving populations of invasive jellyfish in systems like the Mediterranean and Black Seas should serve as warnings for other ecosystems around the globe, and it is likely that far more invasions have occurred than are reported (Holland et al., 2004). It is considered that the drivers of the change in jellyfish population, including overfishing, aquaculture, climate change, habitat modification, and the introduction of alien species, suggest that human-caused coastal deterioration may have benefited jellyfish and led to their increasing populations.



Potential ecosystem shifts due to fishing - From fish dominated to jellyfish dominated

(Robinson et al. 2015)

8. Gut content studies of Jellyfishes

In order to study the gut content of jellyfish, their gastric pouches are excised, opened, and the contents rinsed through a 100-µm mesh sieve. This is a common procedure for concentrating gut contents and handling samples of large medusae. The collection of jellyfish for gut content studies should be preferably done in the night. All medusae should be studied within 35 minutes of collection, which is less than published prey digestion times (Arai 1997).

9. Global Jellyfish Fisheries

Dried jellyfish is considered a delicacy in many Asian countries. Jellyfish are also purported to have beneficial medicinal properties and are traditionally used to treat ailments such as arthritis, hypertension, and back pain (Hsieh et al., 2001). Jellyfish

have been harvested off the coast of China for more than 1700 years (Omori & Nakano, 2001).

Only jellyfish belonging to the order Rhizostomeae are harvested for food. The rhizostomes are preferred because they are typically larger and have more rigid bodies than other scyphozoan orders. When processed, the rhizostomes produce a product that has a desirable, almost crunchy texture. Some species considered to be edible are:

Cepheidae	*Cephea cephea*
Catostylidae	*Catostylus mosaicus, Crambione mastigophora,Crambionella orsini, Crambionella annandalei*
Lobonematidae	*Lobonema smithi,Lobonemoides gracilis*
Rhizostomatidae	*Rhopilema esculentum,Rhopilema hispidum,Rhizostoma pulmo*
Stomolophidae	*Stomolophus meleagris,Stomolophus nomurai*

10. Indian Jellyfish fisheries

There are active jellyfish fisheries along Kerala, Gujarat, and Andhra Pradesh, and four species support jellyfish fisheries in India, viz., *Crambionella annandalei*, *C. orsini*, *Catostylus perezi,* and *Rhopilema hispidum*, which are processed and exported to overseas markets.

11 Guidelines for Jellyfish studies

11.1 Preservation Method

Scyphozoans are typically preserved for morphological analyses in a solution of 4% formalin in seawater with the appropriate label (i.e., 4 parts formalin [37% w/v] and 96 parts seawater). Place the jellyfish in a plastic container with a label (waterproof paper) and pour formalin until the organism is completely covered.

If you are using a plastic bag, place the organisms in a bag, fill it with formalin, twist the bag, and use a rubber band to wrap the plastic bag. When it is tight enough, fold the tip of the plastic bag, and with the last part of the rubber band, secure the folded part of the bag. An excess of 4% formalin solution is used, and it can be renewed after two weeks to ensure successful fixation.

11.2 Tissue storage for DNA studies

1. Flush the oral arms or bell margin with tap water. Repeat several times to displace all the debris.

2. Using clean forceps or scissors, cut a half-fingernail-sized piece of tissue from the oral arm or bell margin.

3. Preserve the tissue in one vial of preservative. (Make sure there is excess preservative; guard against diluting the preservative with too much water.)

4. With forceps, hold a piece of oral arm and cut it with clean scissors or razor blades.

5. Place the piece of tissue in a vial with 95% ethanol.

11.3 Specimen Information to be collected

Geographic location

Depth

Date (of collection)

Collector (e.g. your name)

Photograph

Whole jellyfish preserved? (yes/no; where)

Conditions

11.4 Photograph of the following features

Bell

Differences in the bell margin can be useful to distinguish orders of medusae. For example, the semaeostomeae, in contrast to the rhizostomeae, have tentacles on the bell margin.

Canal

Canal structure inside the bell

Cnidae

In jellyfish, most cnidae are located in and around the tentacles and/or oral arms. Their shape is used for identification.

Mouth-arms

Differences in the form of the mouths distinguish orders of scyphomedusae. The Rhizostomeae have many small mouths distributed over their oral arms in contrast to semaeostomes, for example, which have a single, much larger, central mouth. The form and distribution of mouths over the oral arms can also be useful for distinguishing taxa within the Rhizostomeae.

Rhopalia

Rhopalia (singular rhopalium) are the most obvious sensory structures of scyphozoan jellyfish. They include specialised structures for sensing light (eyespots) and movement or direction with respect to gravity (statoliths).

Table .1 Checklist to study the Morphological features of Scyphozoan and Cubozoan Jellyfishes

1	Tentacles present on umbrella (on margin or underside) (or) Tentacles lacking on umbrella	
2	Umbrella almost spherical (or) Umbrella not spherical	
3	Umbrella without prominent white spots (or) umbrella with numerous prominent white spots	
4	Mouth-arms with stout finger-like appendages (or) Mouth-arms with long and slender fi laments basally	
5	Tentacles on underside of umbrella (or) Tentacles on margin of umbrella	
6	Tentacles in a wide band around underside of umbrella; medusae large (or) Tentacles in 8 U-shaped clusters on underside of umbrella	
7	Colour of the Umbrella	
8	Umbrella cuboid or not cuboid	
9	Umbrella higher than a hemisphere (or) Umbrella decidedly flattened.	
10	Tentacles round noodles like or pasta like flattened	

Rhopilema hispidum

Crambionella orsini

Chrysaora sp.

Chiropsoides sp.

Lobonemoides robustus

Mastigias papua

Cyanea sp.

Cassiopea xamachana

First aid kit developed by ICAR-CMFRI

Jellyfish sting advisory board at tourist beaches

Terminology

- **Adradius, adradial**: four body axes that lie mid-way between the perradius and the interradius; do not run through opposite rhopalia.
- **Anastomose**: joining and fusing.
- **Bell**: the umbrella or body of the medusa.Maybe saucer-shaped, cuboidal or hemispherical.
- **Bell Diameter** (Scyphozoa): distance between opposite rhopalia or lappets of Scyphozoa and opposite margins of Hydrozoa.

- **Bell Height** (Scyphozoa and Cubozoa): vertical height from apex of umbrella to bell margin. Precise measurements may be taxon specific.
- **Bell Width** (Cubozoa): distance between opposite pedalia on a flattened specimen,at the height where the pedalium joins the exumbrella of the bell.
- **Circular canal**: canal running around bell margin of hydrozoans, linking the distal ends of radial canals.
- **Cnida (s), Cnidae (pl)**: the explosive organelle found within cnidocytes, which protective or predatory purposes. Often uncritically referred to as a nematocyst.
- Envenomation: the process of being stung. A jellyfish can stings you causing an envenomation.
- **Ephyra (s), ephyrae (pl)**: the freeswimming product of asexual reproduction that will develop into a medusa. Ephyrae are typically released following the strobilation of polyps, but may be released by viviparous medusae or through changes from the planula larva.
- **Exumbrella**: upper surface of bell, often strongly pigmented and eventually with warts.
- **Gastric filaments**: fine, thread-like filaments of endodermal tissue responsible for the secretion of digestive enzymes into the gastric cavity. May occur in clusters interradially, or on gastric septa. Usually lost on collection and ironically most conspicuous on ephyrae.
- **Gastric ostia**: subgenital ostia
- **Gastric pouch**: in Coronamedusae/Pelagiidae the peripheral parts of the gastrovascular system divided by the radial septa forming a series of relative discrete areas or pouches.
- **Interradius, interradial**: two body axes, at 45° to the perradius, again running through opposite rhopalia.
- **Lappets**: scalloped flaps of ectodermal tissue at bell margin. The number of lappets per octant, their relative size and shape, pigmentation and internal canal extensions can provide useful information for separating taxa at the species level. Those lappets that flank the rhopalia tend to have a different character to the balance and are referred to as rhopalial lappets, as opposed to velar lappets. All are regarded as marginal lappets.
- **Manubrium**: mouth tube; frequently with a thick mesoglea; of variable length and supporting oral arms distally
- **Medusa:** free swimming cnidarian – classical jellyfish
- **Oral arms**: extensions of the mouth tube or manubrium; effectively long, thin and often coiled-lips bearing cnidae in the case of Semaeostomeae that surround an open mouth centrally; or, in the case of Cepheida and Rhizostomida, much thickened and supporting numerous mouthlets externally, and with a branching gastrovascular network internally.
- **Pedalium**: interradial extensions of the bell margin in which tentacles are attached. It has an internal pedalial canal which is connected to the

gastrovascular cavity. In its upper part some species present a knee-bend which has taxonomic value.

- **Polyp**: the generally sessile phase in the life cycle of cnidarians, resembling a sea-anemone, typically with tentacles around its mouth. In hydrozoans, polyps may occur in colonies of clones that display polymorphism. The polyp may be protected by a chitinous tube (some Hydrozoa and Coronamedusae), or be naked. Also known as a scyphistoma in Scyphozoa.
- **Rhopalium**: collection of sense organs (ocelli, light; statocysts, "balance") into a single body, generally at or close to the bell margin.
- **Ring canal**: see gastrovascular system.
- **Scapulets**: eight short, rigid, pairs of mouthlet-bearing outgrowths at the base of manubrium in some Rhizostomeae.
- **Strobilation**: the process of asexual reproduction by a polyp that gives rise to ephyrae (through transversal fissions of the body).
- **Subumbrella**: lower surface of bell.
- **Tentacles**: threads (hollow or solid) of ectodermal tissue arising from the bell margin/subumbrella surface (Hydrozoa,Scyphozoa), or from pedalia (Cubozoa),which are laden with nematocysts and used for prey capture. Generally retractile; of variable length. The number and arrangement of tentacles are useful characters in taxon identification, though it should be remembered that they are frequently lost on rough collection. The designation primary, secondary, etc. refers to the order in which tentacles develop in some Semaeostomeae, with the primary tentacles forming first from between velar lappets at the centre of each octant.

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