



## CHAPTER 37

# Taxonomy of Cephalopods

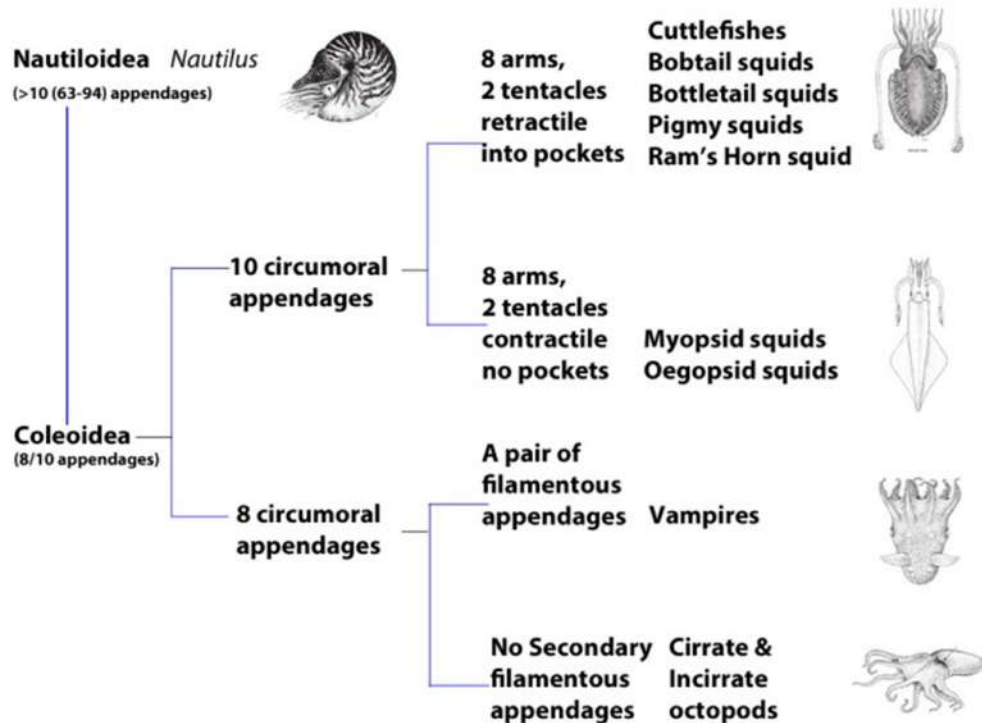
### Introduction

Cephalopods are ecologically and commercially important invertebrates with a wealth of extant marine taxa spanning from neritic continental shelf to the abyssal plains. The class Cephalopoda includes two, distantly related, extant subclasses, the primitive Nautiloidea, represented by the externally shelled nautilus; and Coleoidea, which includes the ten-armed squids & cuttlefishes and the eight-armed octopuses.

The commercial importance of this exclusive marine mollusc has risen in the last six decades remarkably across a highly diverse set of cephalopod taxa. The positive trend in cephalopod abundance has been attributed to a range of coastal and oceanic environmental changes, together with the potential release of cephalopods from predation and competition pressures (Doubleday et al., 2016). The fishery mainly targets the coastal species of squid, cuttlefish and octopus besides the oceanic squids when encountered within the operational range of commercial fleets while undertaking migration (Rodhouse et al., 2014).

### Classification

The systematics and classification of the Recent Cephalopoda are under considerable discussion (Jereb and Roper, 2016). The higher classification above the family level is still not resolved, but species-level taxa can be placed in well-defined families. Early in their evolution, cephalopods emerged in the fossil record in Cambrian, later, the extant lineages which arose in the late Silurian, diverged into the two sub-classes, Nautiloidea, with external shell and Coleoidea, without external shell (internalized shell), in the mid-Palaeozoic. The living cephalopods (~ 800), notable for their many arms and soft bodies, are at present not the most successful of the molluscan groups, while, there is fossil evidence to suggest that they were once a much more important group (17,000). The ancient cephalopods were mostly known from their shells as they are well preserved as fossils. In cephalopods, the taxonomic efforts can be quite challenging in comparison to finfish due to the lack of fixed meristic characters.



Cephalopod classification (Modified from Jereb and Roper, 2005)

### I) Sub-class Nautiloidea

Nautiluses are unique from other extant cephalopods by having a distinctive, ornate, coiled shell. They are considered as living fossils since they retained the external chambered shell and simple “pinhole camera” eyes (without a lens) similar to their Palaeozoic ancestors. The nautilus shell has chambers that are interconnected and the animal lives in the outermost chamber with its body attached to the sides of the chamber by the adductor muscles. Nautilus regulate its buoyancy through the control of fluid and gas in the chambers. Nautiluses have two pairs of gills and up to 47 pairs of circumoral arm-like appendages, also called ‘tentacles’, arranged in 2 rings around the mouth and 2 pairs lateral to the eyes. Above the tentacles is a large fleshy wedge, called the ‘hood’. This is used as a trapdoor to seal the shell closed if the animal is attacked. They are known to occur in the tropical Indo-Pacific region, where they live close to the bottom, primarily over reef slopes, from near the surface to about 500-750 m depth. Their optimal range seems to be from 150 to 300 m. Although their taxonomy is poorly resolved, the family Nautilidae is currently considered to include seven species in two genera, *Nautilus* and *Allonautilus*. The Umbilicus is small, or moderate, about 5-16% of shell diameter in *Nautilus* and the whorl cross-section is oval, compared to a larger Umbilicus (20% of shell diameter) and quadrate cross-section in *Allonautilus*.

The systematic position of important species under the Class Cephalopoda in Indian Seas

Sub-class	Super order	Order	Family	Species	
Nautiloidea		Nautilida	Nautilidae	<i>Nautilus pompilius</i>	
Coleoidea	Decapodiformes	Spirulida Ram's horn squid	Spirulidae	<i>Spirula spirula</i>	
		Sepiida Cuttlefishes	Sepiidae	<i>Sepia pharaonis</i> <i>Sepia elliptica</i> <i>Sepia trygonina</i> <i>Sepia omani</i> <i>Sepia prashadi</i> <i>Sepia vecchioni</i> <i>Sepia aculeata</i> <i>Sepia brevimana</i> <i>Sepia prabahari</i> <i>Sepia arabica</i> <i>Sepia ramani</i> <i>Sepiella inermis</i>	
		Sepiolida Bob-tailed squids and bottletailed squids	Sepiolidae	<i>Euprymna spp.</i>	
		Myopsida Neritic squids	Loliginidae	<i>Uroteuthis (Photololigo) duvaucelii</i> <i>Uroteuthis (Photololigo) edulis</i> <i>Uroteuthis (Photololigo)</i> <i>singhalensis</i> <i>Loliolus (Nipponololigo) uyii</i> <i>Loliolus (Loliolus) hardwickei</i> <i>Sepioteuthis lessoniana</i>	
		Idiosepiida Pygmy squids	Idiosepiidae		
		Oegopsida Oceanic squids	Thysanoteuthidae	<i>Thysanoteuthis rhombus</i>	
			Ommastrephidae	<i>Sthenoteuthis oualaniensis</i>	
			Enoploteuthidae	<i>Abralia (Heterabralia) andamanica</i> <i>Abraliopsis (Micrabralia) lineata</i>	
		Bathyteuthida Squids	Bathyteuthidae	<i>Bathyteuthis bacidifera</i>	
		Octopodiformes	Vampyromorphida	Vampyroteuthidae	<i>Vampyroteuthis infernalis</i>
			Octopoda	Octopodidae	<i>Amphioctopus neglectus</i> <i>Amphioctopus marginatus</i> <i>Amphioctopus aegina</i> <i>Amphioctopus rex</i> <i>Cistopus indicus</i> <i>Cistopus platinoideus</i> <i>Octopus cyanea</i> <i>Octopus vulgaris</i>

### *Nautilus pompilius*

The umbilicus is small, visible as shiny silver and black patch, closed; callus usually present (with rare exceptions). No inner coils are visible. Shell colour patterns variable: irregular brown to reddish-brown stripes radiates from the umbilicus to venter in the usual colouration, but this striping can be reduced to various degrees, leaving the umbilicus and even much of the flanks white. The chambered nautilus, *Nautilus pompilius*, is a highly vulnerable species because of its life history characteristics, including low reproductive rates, slow growth, and late maturity. Chambered nautilus are primarily targeted for their shells, which are sold commercially and traded internationally for use in art, furniture, jewellery, and other items. *Nautilus pompilius* is listed under the Schedule I Part IV-B of the Wildlife Protection Act, 1972.

### II) Sub-class Coleoidea

Eight or ten circumoral appendages; suckers (and/or hooks) present; no external shell.

### Superorder Decapodiformes

Decapodiformes comprises about 500 recent species in between five and seven orders depending on taxonomic opinion (Allcock, 2015). The relationships among orders of Decapodiformes are not well understood, and molecular systematics has failed to provide much resolution, although there is some evidence for a sister-taxon relationship between Spirulida and Sepiida

- **Family Spirulidae:** The ram's horn squid have an internal calcified coiled, chambered shell. It is represented by a single extant species, *Spirula spirula*. A spirally coiled internal shell comprising of over 30 chambers is located in the posterior end of adults. Fins narrow, ovate, attached dorsolaterally on the posterior end of the mantle (almost perpendicular to the longitudinal axis of the body). Arms increase in length dorsally to ventrally, with arms I short, arms IV longest. All arms except the fourth pair are united by broad webs. All arms except the fourth pair united by broad webs; arm suckers tetraserial, or in 6 rows. Hectocotylus present, both ventral arms modified: right hectocotylized arm grooved, concave, with spoon-like expansion, pointed tip and 2 finger-like outgrowths; left hectocotylized arm round in cross-section with 2 spoon-like and one finger-like outgrowth with soft papillae at the distal tip. Tentacular club straight, slender; not expanded, the same width as stalk; with 12 to 16 suckers in transverse rows; all suckers of similar small size
- **Family Sepiidae** (for a detailed description see Reid et al. 2005): Cuttlefishes have an internal calcified cuttlebone. There are three genera in the family Sepiidae namely *Metasepia*, *Sepiella* and *Sepia*.
  - 1) ***Metasepia*:** Cuttlebone is diamond-shaped in outline and much shorter than the mantle, located in the anterior 1/2 to 2/3 of the mantle; dorsal anterior edge of mantle without tongue-like projection.
  - 2) ***Sepiella*:** A gland and gland pore located on the ventral side of the posterior end of the mantle; mantle-locking apparatus with triangular projection; cuttlebone inner cone with very short limbs; outer cone a wide, spatulate, chitinized border around the posterior end of cuttlebone.

- ***Sepiella inermis***: Posterior gland and gland pore pigmented reddish. Club with 12 to 24 suckers in transverse rows. Cuttlebone outline oval, broad; cuttlebone width 33 to 43% cuttlebone length; strongly convex in lateral view; granulose dorsally; dorsal median rib distinct. Spine absent. Striated zone and last loculus convex; sulcus extend the entire length of cuttlebone. Inner cone limbs are uniform width, narrow, inner cone U-shape posteriorly, thickened, raised in the centre as a rounded knob; outer cone chitinous, spatulate, expanded. The dorsal mantle has more than 7 reddish patches adjacent to the base of fins.
- 3) ***Sepia***: Mantle-locking apparatus semicircular, without triangular projection. Cuttlebone inner cone with relatively long limbs; outer cone usually calcareous, not spatulate posteriorly.

***Sepia pharaonis***: Tentacular club sucker-bearing surface flattened, with 8 suckers in transverse rows; suckers differ markedly in size: 5 or 6 median suckers enlarged (3 or 4 of these are greatly enlarged). Cuttlebone outline oblong; bone bluntly rounded anteriorly; acuminate, acute, posteriorly; dorsal surface creamy white; dorsal surface evenly convex; texture smooth; dorsal median rib distinct, rib broadens anteriorly; lateral ribs indistinct. Chitin borders lateral and anterior margins of cuttlebone. The spine is short, pointed, curves dorsally, keel absent. Striated zone concave; last loculus flat; sulcus deep, wide, extends the entire length of cuttlebone; sulcus flanked by rounded ribs. Anterior striae are inverted U-shape; limbs of the inner cone extend anteriorly to the end of the striated zone. Inner cone limbs are narrow anteriorly, broad posteriorly with distinctive thick bulbous swelling; outer cone calcified; narrow anteriorly, broadens posteriorly. Dorsal mantle with series of elongate papillae along each side, adjacent to the base of each fin, or covered with numerous small papillae.

***Sepia elliptica***: Tentacular club sucker-bearing surface flattened, with 10–12-minute suckers in transverse rows; suckers all similar size. Cuttlebone outline oval; bone very angular, V-shape anteriorly; bluntly rounded posteriorly; dorsal surface creamy white; dorsal surface evenly convex; texture smooth; dorsal median rib indistinct, broadens anteriorly; lateral ribs indistinct. Spine is short, pointed, curves dorsally, keel(s) absent. Striated zone concave; last loculus convex; sulcus deep, wide. Anterior striae are inverted U-shape. Inner cone limbs are narrow anteriorly, broaden posteriorly; outer margin of inner cone raised into flat posterior ledge; ledge whitish (sometimes with a thin rim of chitin on outer margin); ledge not thickened; outer cone calcified.

***Sepia prabahari*** Mantle broad, ovate and broadest at the anterior end. Dorsal mantle, head and arms zebra stripe pattern occurs, which is more prominent in males. Arms I and IV elongate, robust, whip-like in males and females arms approximately subequal in length. Tentacular club short with 6 suckers in transverse rows; all suckers are minute without any enlarged suckers. Cuttlebone elliptical in shape; broader in females than males; rugose dorsally, with indistinct median and lateral ribs. Spine curved dorsally, without keels. Anterior striae are inverted V-shape. Inner cone limbs are narrow anteriorly, broaden posteriorly, then are raised into a thick, round ledge.

- **Family Sepiolidae**: The members of the family have rounded posterior mantle with internal gladius present, rudimentary, chitinous, or absent. Fins wide; rounded, semicircular, or kidney-shaped, with pronounced anterior lobes, or 'earlets'; attached about

midway along mantle; fin attachment short, fin length exceeds attachment length. Large eyes covered by corneal membranes.

***Euprymna* sp.:** Dorsal mantle fused to head by the cutaneous occipital band; anterior edge of ventral mantle not forming a ventral shield. Arm suckers usually tetra serial; left dorsal arm hectocotylized; distal suckers on male hectocotylized arm greatly modified, with closely packed fleshy papillae formed from enlarged and elongate swollen sucker pedicels; male third arms not bent inward.

- **Family Loliginidae** (Jereb et al.,2010): Internal shell straight, chitinous; tentacles contractile, mantle edge near mantle cartilages with small projections. Eye covered by a transparent membrane. Four longitudinal rows (series) of suckers on manus of tentacular clubs; fins united at the posterior end of the mantle; medial posterior border of fins concave.

***Uroteuthis (Photololigo) duvaucelii:*** Fins gently rhombic, broad, approximately 50% of mantle length (up to 60% of mantle length). Tentacles long; tentacular clubs expanded, large, up to 45 to 50% of mantle length; large median manal suckers, (<2 times diameter of marginal suckers), with 14 to 22 short, sharp teeth, subequal in size, regularly spaced around the entire margin. Arm suckers with 5 to 9 broad, large, square teeth on the distal margin in females and up to 18 teeth around the entire ring in males. Mantle moderately long, slender, cylindrical for about half its length; it tapers gently into a blunt tip. Anterior margin with a small rounded lobe in the dorsal midline.

***Uroteuthis (Photololigo) edulis:*** Fins rhombic, attain 70% of mantle length in adults, anterior margin slightly convex, posterior margin gently concave, lateral angles rounded; fins slightly longer than wide in adults, width 60% of mantle length (usually slightly larger in females). Mantle moderately stout, elongate, slender in mature males. Arm sucker rings with up to 12 (more often 6 to 8) long, slender, square-cut (bluntly-pointed) teeth on the distal margin; the proximal margin smooth or only irregularly denticulate with inconspicuous teeth.

***Sepioteuthis lessoniana:*** Mantle long, robust, width about 40% of length. Fins very large, broadly oval in outline, fin length over 90% up to nearly 100% of mantle length, their width up to 75% of mantle length; the greatest width occurs posterior to the midpoint of the fins. Tentacular clubs long expanded.

- **Family Thysanoteuthidae:** Funnel free from mantle; funnel-mantle locking apparatus present. Funnel-locking cartilage with a longitudinal groove from which a shorter groove branches medially, † shaped; fins more than 80% of mantle length.

***Thysanoteuthis rhombus*** is monotypic, so the characters detailed at the family level are diagnostic.

- **Family Ommastrephidae:** Funnel-locking cartilage with a longitudinal groove crossed by a transverse groove at its posterior end, † shaped; fins less than 60% of mantle length

***Sthenoteuthis oualaniensis:*** Based on size differences of mature squid, as well as dorsal photophore and gladius morphology, 5 forms of undetermined status are distinguishable.

- **Family Enoploteuthidae:** Funnel-mantle locking apparatus straight. Hooks are present on all arms. Photophore present on mantle, funnel, head, eyeballs, and arms. Nuchal folds are present.

*Abralia andamanica:* Five photophores (two large terminal opaque organs and three intermediate silvery organs) on the ventral side of the eyeball. The arm formula was 4<2<3<1. The mantle apex (tail) is long.

*Abraliopsis lineata:* The mantle is weakly muscular, short conico-cylindrical, terminating in a blunt-ended short tail. The ventral surface of the mantle, funnel, head and arms III and IV are ornamented with photophores. Three longitudinal photophore rows are present on the arms IV. The ventral side of the eyeball has five photophores.

- **Family Bathyteuthidae:** Photophores absent on eyes; buccal membrane with 7 lappets or less. Buccal membrane connectives attach to the dorsal sides of IV arms. The surface of mantle and head without photophores. Minute suckers are present on the oral surface of the buccal membrane.

*Bathyteuthis bacidifera:* The animal is dark brown in colour. Protective membranes on arms reduced or absent; trabeculae free, elongate, finger-like; arm suckers numerous; sucker rings with 18 to 34 protuberances; gills long, broad.

### Superorder Octopodiformes (for a detailed description see Reid et al., 2005)

Octopodiformes comprises ~300 species in two orders. The relationships among Octopodiformes are better understood among cephalopods. The vampire squid is placed in a separate order (Vampyromorphida), and all other octopods are placed in the order Octopoda. Within Octopoda there are two major forms, the deep-sea cirrate octopods and the incirrate octopods.

**Incirrate octopods:** The incirrate octopods contain the greatest number of species including the familiar, muscular, bottom-dwelling (benthic) octopuses that are popular as fisheries targets (family Octopodidae). They are found in intertidal habitats to the deep-sea floor. This group also includes seven less familiar families of pelagic octopods of the open ocean, such as the argonauts and the Glass octopus (*Vitreledonella richardi*). Mature animals range in size from pygmy octopuses at under one gram to the Giant Pacific octopus (*Enteroctopus dofleini*) (Jereb and Roper, 2016). They are united by 8 arms with 1 to 2 rows of sessile suckers and the absence of fins or cirri. Females of all members of this order brood their young, tending and remaining with the eggs until hatching.

- **Family Octopodidae:** Eyes lateral, round to oblong, not telescopic; body and arms muscular or semi-gelatinous; funnel free from the ventral mantle. Body and arms muscular, transparent only in smallest juveniles. Distinct locking apparatus joining inner edge of the lateral mantle to funnel base absent. Male octopuses possess a modified third arm, typically the third right arm. This arm, the hectocotylus, typically has a spoon-like tip ligula and a curved gutter or groove along its length.



***Amphioctopus neglectus***: It is one of the major commercial species in the Indian Seas, usually caught in large quantities by bottom trawls. Moderate-sized species with oval mantle and relatively slender arms. Numerous small, rounded white spots are distributed on the dorsal mantle. A narrow, small, slightly U-shaped transverse bar is present between eyes. False-eye spots (ocelli) are present, containing a simple blue/ purple iridescent ring. Lateral or ventral arms longest (typically  $4=3>2>1$ ).

***Amphioctopus marginatus***: Moderate sized, arms 2 to 3 times mantle length, two rows of suckers on each arm. Slightly enlarged suckers present in mature males, 4 to 5 on arms 2 and 3, starting around the 7<sup>th</sup> proximal sucker. False-eye spots (ocelli) absent. The typical pattern of orange-brown to the purple background with dark purple-brown reticulations, defining distinct patches in irregular longitudinal rows. Suckers white to pink, contrasting against dark brown to the black border along the leading edge of arms 1 to 3. Narrow transverse "head bar" visible in live animals. The white triangle below each eye. Dark vein-like reticulations are distinctive on lateral arm crown in the same position as false eyespots in ocellate species. Transverse pair of white spots present on the dorsal mantle, slightly anterior to midpoint of the mantle. The diamond shape of four longitudinal skin ridges on the dorsal mantle

***Cistopus indicus***: Moderate-sized species. Arms long, length around 6 times mantle length. Dorsal arms longest ( $1>2>3>4$ ). Water pouches present in the oral surface of webs close to mouth; pores located adjacent to the level of 3rd to 4<sup>th</sup> proximal sucker. Two rows of suckers on each arm. The right third arm of males hectocotylized, length around 75% of the opposite arm. Ligula tiny and blunt, 0.5 to 0.7% of arm length. Calamus absent. Hectocotylized arm with 116 to 123 suckers.

***Octopus cyanea***: Large, robust, muscular species. Mantle round to oblong with a few large tubercles. Arms robust and long, 4 to 6 times mantle length, arms IV slightly longer. Lateral arms longest (typically  $4=3=2>1$ ). Deepest web on lateral arms and shallow webs between the dorsal arms. Interbrachial web pouches are absent. Arms with two rows of suckers. Large size animal has 450 to 500 suckers on each normal arm. Ocellus present as dark oval patches within a dark narrow outer ring; located at the base of arms III and IV. Ocellus without an iridescent ring. Arm tips with 3 to 7 longitudinal rows of small white spots, often pronounced against the dark base colour. Mantle mottled, reticulate, arms with purple-brown blotches. Four large primary papillae in diamond arrangement on the dorsal mantle.



**Conclusion:**

The morphological traits in cephalopods are not well-delineated as their body forms differ so widely; most of them lack a shell; possess few hard structures; and often gets distorted in size, colour and shape on preservation, thus hindering their identification. In some species, hectocotylus morphology (which varies to a great extent across genera and species), is recognised for species-level classification. This may limit identification of female cephalopods, without the support of other identification tools in such groups.

**References:**

- Allcock, A. L. (2015). "Systematics of Cephalopods" In Gopalakrishnakone, P.; Malhotra, A. (eds.). *Evolution of Venomous Animals and their Toxins*. Springer Science. pp. 415-434. doi:10.1007/978-94-007-6727-0\_8-1. ISBN 978-94-007-6727-0
- Allcock, A. L., Lindgren A. & Strugnell J.M. (2015). The contribution of molecular data to our understanding of cephalopod evolution and systematics: a review. *Journal of Natural History* 49(21-24):1-49. DOI: 10.1080/00222933.2013.825342
- Doubleday, Z. A., Prowse, T. A. A., Arkhipkin, A., Pierce, G. J., Semmens, J., Steer, M., et al. (2016). Global proliferation of cephalopods. *Curr. Biol.* 26, R406–R407. doi: 10.1016/j.cub.2016.04.002
- Jereb, P. & Roper, C.F.E. (2016). General remarks on cephalopods. In P. Jereb, C.F.E. Roper, M.D. Norman & J.K. Finn eds. *Cephalopods of the world. An annotated and illustrated catalogue of cephalopod species known to date. Volume 3. Octopods and Vampire Squids*. FAO Species Catalogue for Fishery Purposes. No. 4, Vol. 3. Rome, FAO. pp. 3-5.
- Jereb, P., Vecchione, M. & Roper, C.F.E. (2010). Family Loliginidae. In P. Jereb & C.F.E. Roper, eds. *Cephalopods of the world. An annotated and illustrated catalogue of species known to date. Volume 2. Myopsid and Oegopsid Squids*. FAO Species Catalogue for Fishery Purposes. No. 4, Vol. 2. Rome, FAO. pp. 38–117.
- Reid, A., Jereb, P. & Roper, C.F.E. (2005). Family Sepiidae. In P. Jereb & C.F.E. Roper, eds. *Cephalopods of the world. An annotated and illustrated catalogue of species known to date. Volume 1. Chambered nautilus and sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae)*. FAO Species Catalogue for Fishery Purposes. No. 4, Vol. 1. Rome, FAO. pp. 57–152
- Rodhouse, P. G., Pierce, G. J., Nichols, O. C., Sauer, W. H., Arkhipkin, A. I., Laptikhovskiy, V.V., et al. (2014). "Environmental effects on cephalopod population dynamics: implications for management of fisheries," in *Advances in Marine Biology*, Vol. 67, eds E. A. G. Vidal (Oxford: Academic Press), 99–233

