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Deep-water marine shrimps from the Indian coast: A review

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In recent years, there has been a noticeable expansion of commercial fishing operations into the deeper waters, resulting in a increased global identification of novel deep-sea shrimp species. The biological and ecological traits characterizing these deep-sea organisms render them notably susceptible to exploitation compared to their shallower-water counterparts. A prevailing challenge in addressing this matter pertains to the paucity of comprehensive ecological insights into the majority of deep-sea species, thereby impeding the formulation and execution of effective management strategies. In light of the aforementioned concerns, endeavors have been undertaken to systematically organize the available data concerning deep-sea shrimp resources and the extant condition of fisheries within the geographical context of India. A contemporary and updated inventory of deep-sea shrimp taxa has been meticulously compiled, encompassing a total of 156 distinct species. These species are taxonomically categorized into 18 families within the suborder Pleocyemata and 6 families within the suborder Dendrobanchiata, all of which fall under the overarching order Decapoda. This study intricately amalgamates a compendium of pertinent literature, drawn from diverse sources including research articles, monographs, books, species checklists, technical reports, and a repository of knowledge maintained by researchers along the Indian coastline.

[**Keywords**: Checklist, Decapoda, Deep-sea, Fishery, India, Shrimps]

Introduction

Within the taxonomic hierarchy, the Subphylum Crustacea stands as a prominent entity, occupying the fourth position in terms of biological diversity among the various animal groups. However, when focusing on the specific context of deep-sea shrimps in the Indian waters, available data pertaining to their diversity and geographical distribution remain notably constrained. Furthermore, recent times have witnessed notable shifts in the taxonomical classification of deep-sea species. This evolution is attributed to the rectification of misidentifications that were previously encountered and the subsequent emergence of new records. The expansion of fishing territories has significantly contributed to this dynamics, leading to an increased awareness of previously overlooked or misclassified and misidentified species.

Information regarding the presence of numerous deep-sea shrimp species within the Indian maritime domain, primarily documented through surveys conducted aboard the Royal Indian Marine Survey vessel 'INVESTIGATOR' spanning the years 1884 to 1925, is at our disposal. Subsequent to 1999, the ICAR-Central Marine Fisheries Research Institute has undertaken the responsibility of systematically monitoring the commercial exploitation of deep-sea shrimp resources through extensive surveillance[1-3]. The economic significance of deep-sea shrimps is profound, boasting substantial export value[4-7]. Beyond their economic value, these organisms assume a pivotal ecological role within the marine ecosystem, constituting a crucial component of the marine trophic structure[8]. They demonstrate a broad distribution, particularly prevalent along the southwest and southeast sectors, chiefly occupying at depths ranging between 200 to 800 meters.

In the contemporary epoch, a substantial escalation in the exportation of shrimps from India has become evident, primarily attributed to elevated consumer demand. This surge has, however, engendered a concomitant issue of over-fishing. The time frame spanning 2014 to 2016 witnessed notable fluctuations in catch quantities. The pursuit of conserving and sustainably harnessing marine biodiversity has confronted impediments stemming from the absence of a comprehensive, intricate taxonomic, phylogenetic, and biogeographic database pertaining to various taxa. This information gap is particularly pronounced in the domain of deep-sea shrimps within the Indian context.

Therefore, the present research endeavor is oriented toward furnishing an extensive and meticulous overview encompassing fishery dynamics, species composition, and distribution patterns of deep-sea shrimps along the southern Indian coastline. A central facet of this study involves the provision of an updated checklist delineating the deep-sea shrimp fauna, which is anticipated to bridge the existing knowledge gaps in this domain.

Taxonomy

The taxonomic classification of the order Decapoda has been traditionally demarcated into two distinct suborders: the ancestral Dendrobranchiata (Prawns) and the Pleocyemata (comprising Shrimps, Crabs, and Lobsters). This differentiation is primarily based on the structural characteristics of their gills; Dendrobranchiata exhibit branched gill structures, in contrast to the non-branched configuration observed in Pleocyemata. The Pleocyemata subgroup exhibits diverse synapomorphic traits, with a pivotal feature being the retention of fertilized eggs by females, which are incubated until hatching, often accumulating within the pleopods until the emergence of zoea larvae. Within the Pleocyemata, a classification into eleven infraorders prevails: Stenopodidea, Caridea, Astacidea, Glypheoidea, Axiidea, Gebiidea, Achelata, Polychelida, Anomura, Procarididea, and Brachyura[9]. Nevertheless, discrepancies in opinion persist regarding the taxonomy of the order Decapoda.

Significant contributions concerning the taxonomy and spatial distribution of deep-sea crustaceans in the Indian context have emanated from the works of Alcock[10] and Suseelan[11]. Noteworthy summaries have been compiled by George & Rao[12], elucidating the various deep-sea decapod crustaceans inhabiting the Southwestern coast of India. Thomas[13], in a distinct study, has concentrated on species frequently encountered along the shelf edge and upper continental slope of the Gulf of Mannar, situated on the Southeastern coast of India. Pertaining to the variability in distribution and richness within the deep-sea shrimp populations, analyses have been conducted on samples obtained from research vessels such as RV Conch, Kalava, Varuna, Klaus Sunnana, Velameen, and Tuna, traversing the western coastal expanse of India. These investigations were undertaken by John & Kurien[14], George & Rao[12], Rao & Suseelan[15], Mohamed & Suseelan[4], and Suseelan[5]. Suseelan[16] provided a taxonomic exposition focusing on deep-sea pandalid shrimps, notably *Plesionika williamsi*, *Plesionika ensis*, and *Heterocarpus sibogae* within the Indian waters. Bhargava *et al*.[17] delved into the distribution and abundance of deep-sea shrimps along the southwestern Indian coastline, gleaned from foreign fishing vessel operations during the period spanning 1990 to 1994. Jayaprakash *et al*.[18] extended their study to delineate the distribution patterns and abundance profiles of deep-sea fishes and decapod crustaceans along the Southwestern coast of Indian. Further, Ganga *et al.*[19] provided an account of the occurrence and taxonomic characteristics of the deep-sea aristeid shrimp, *Aristaeopsis edwardsiana*, off the Trivandrum coast. In the period spanning from 2015 to 2021, an assemblage of thirteen deep-sea caridean shrimp species was documented. These species encompassed *Plesionika narval*, *Plesionika semilaevis*, *Plesionika reflexa*, *Plesionika persica*, *Plesionika bifurca*, *Heterocarpus chani*, *Acanthephyra fimbriata*, *Pasiphaea alcocki*, *Parapontocaris bengalensis*, *Parapontocaris levigata*, *Pontocaris affinis affinis*, *Pontocaris propensalata*, *Glyphocrangon investigatoris*. Additionally, two new distributional records of penaeid shrimps, namely *Solenocera barunajaya* and *Solenocera rathbuni*, were reported along the Southern coast of India[20,28].

Taxonomic status of deep-sea shrimps from the Indian coast

The deep-sea shrimp biodiversity within the Indian subcontinent, encompassing the Andaman and Nicobar Islands as well as the Lakshadweep Islands, comprises a comprehensive total of 156 distinct species (Table 1). Within the suborder Dendrobranchiata, there exist 68 species distributed across 6 families, while the suborder Pleocyemata encompasses 93 species spanning 18 families (Tables 1 & 2). Particularly, the family Penaeidae, comprising 6 genera and encompassing 15 species, holds prominent significance within the penaeoid group. Numerous members of this family constitute valuable resources for commercial fisheries, and some also hold relevance for aquaculture endeavors.

The precise enumeration of caridean species within the realm of deep-water shrimps of Indian waters remains uncertain, as ongoing discoveries continue to contribute to marine ecosystems. Among the representatives, a singular species belonging to the family Palaemonidae, situated within the subfamily Pontoniinae, stands as *Periclimenes laccadivensis*. Notably, 20 novel records have been appended to the

Table 1 — Checklist of deep-sea marine shrimps from Indian waters

Sl no	Species	Distribution
	Family: Aristeidae Wood-Mason in Wood-Mason & Alcock, 1891 (13)	
1	*Aristaeomorpha foliacea* (Risso, 1827)	Arabian Sea, Bay of Bengal, Andaman Sea
2	*Aristaeomorpha woodmasoni* Calman, 1925	South west and Southeast coast, Andaman Sea Holthuis, 1980[ref. 46]
3	*Aristaeopsis edwardsiana* (Johnson, 1868)	Southwest, Southeast, Lakshadweep Sea, Andaman Sea Alcock & Anderson, 1894[ref. 47]
4	*Aristeus alcocki* Ramadan, 1938[#]	Southwest, Southeast, Lakshadweep Sea, Kerala Holthuis, 1980[ref. 46]
5	*Aristeus semidentatus* Spence Bate, 1881	Southwest & Andhra Pradesh coast Alcock & Anderson, 1894[ref. 47]
6	*Aristeus virilis* (Spence Bate, 1881)	Andaman Sea Alcock, 1906[ref. 48]
7	*Cerataspis coruscans* (Wood Mason in Wood-Mason & Alcock, 1891)	Andaman Sea Wood-Mason & Alcock, 1893[ref. 49]
8	*Cerataspis monstrosus* Gray, 1828	Bay of Bengal
9	*Hemipenaeus carpenter* Wood Mason & Alcock, 1891	Minicoy, Bay of Bengal Alcock & Anderson 1894[ref. 47]
10	*Hepo madustener* Smith, 1884	Bay of Bengal
11	*Pseudaristeus crassipes* (Wood-Mason in Wood-Mason & Alcock, 1891)	Lakshadweep Sea, Southwest coast, Andaman Sea Alcock & Anderson 1894[ref. 47]
12	*Pseudaristeus kathleenae* Pérez Farfante, 1987	
13	*Pseudaristeus protensus* Pérez Farfante, 1987	East and west coast Pérez Farfante & Kensley, 1997[ref. 50]
	Family: Benthesicymidae Wood-Mason in Wood-Mason & Alcock, 1891 (12)	
14	*Altelatipes carinatus* (Smith, 1884)	Lakshadweep Sea
15	*Bentheogennema intermedia* (Spence Bate, 1888)	
16	*Bentheogennema pasithea* (de Man, 1907)	Arabian Sea
17	*Benthesicymus armatus* Mac Gilchrist, 1905	
18	*Benthesicymus bartletti* Smith, 1882	
19	*Benthesicymus investigatoris* Alcock & Anderson, 1899	Gulf of Mannar, Andaman Sea Alcock, 1901[ref. 51]
20	*Gennadas bouvieri* Kemp, 1909	Bay of Bengal
21	*Gennadas parvus* Spence Bate, 1881	Arabian Sea Karuppasamy *et al*., 2006[ref. 52]
22	*Gennadas propinquus* Rathbun, 1906	Southwest and Southeast
23	*Gennadas scutatus* Bouvier, 1906	Southwest coast Karuppasamy *et al*. 2006[ref. 52]
24	*Gennadas sordidus* Kemp, 1910	Goa and Arabian Sea Karuppasamy *et al*. 2006[ref. 52]
25	*Gennadas tinayrei* Bouvier, 1906	-
	Family: Penaeidae Rafinesque, 1815 (15)	
26	*Funchalia danae* Burkenroad, 1940	Arabian Sea Karuppasamy *et al*. 2006[ref. 52]
27	*Funchalia villosa* (Bouvier, 1905)	Southwest coast &Andaman Sea Rao, 1984[ref. 53]
28	*Metapenaeopsis andamanensis* (Wood-Mason in Wood-Mason & Alcock, 1891)[#]	Southwest, Southeast, Andaman Sea, Kerala Thomas, 1979[ref. 13]; Kurup *et al*. 2008[ref. 54]
29	*Metapenaeopsis coniger* (Wood-Mason in Wood-Mason & Alcock, 1891)[#]	Southwest, South, northeast, Andaman Sea Alcock,1901[ref. 51]; Thirumilu & Rajan, 2003[ref. 55]
30	*Metapenaeopsis difficilis* Crosnier,1991	Andaman Sea
31	*Metapenaeopsis philippi* (Spence Bate, 1881)	Southwest coast Kurian, 1965[ref. 56]
32	*Metapenaeopsis toloensis* Hall, *1962*	Chennai, Southeast coast Pillai, 2013[ref. 57]

(*Contd*.)

Table 1 — Checklist of deep-sea marine shrimps from Indian waters (*Contd*.)

Sl no	Species	Distribution
33	*Parapenaeus fissuroides fissuroides* Crosnier, 1986	Southeast coast Dineshbabu, 2004[ref. 58]
34	*Parapenaeus fissures* (Spence Bate, 1881)	Orissa, Andaman Sea Alcock, 1901[ref. 51]; Aravindakshan *et al*., 1997[ref. 59]
35	*Parapenaeus investigatoris* Alcock & Anderson, 1899#	Southwest, southeast, Andaman Sea Alcock, 1901[ref. 51]; Mohamed & Suseelan, 1973[ref. 4]
36	*Parapenaeus lanceolatu* Kubo, 1949	Southeast coast
37	*Parapenaeus sextuberculatus* Kubo, 1949	
38	*Pelagopenaeus balboae* (Faxon, 1893)	Southwest coast Karuppasamy *et al*., 2006[ref. 52]
39	*Penaeopsis jerryi* Pérez Farfante, 1979#	Southwest, Southeast and Andaman Sea Purushothaman *et al*., 2019[ref. 32]
40	*Penaeopsis rectacuta* (Spence Bate, 1881)	Southwest, Southeast and Andaman Sea Kurian, 1965[ref. 56]
	Family: Sicyoniidae Ortmann, 1898 (3)	
41	*Sicyonia fallax* de Man, 1907	-
42	*Sicyonia longicauda* Rathbun, 1906	-
43	*Sicyonia parajaponica* Crosnier, 2003	Southwest and Southeast Vaitheeswaran, 2017[ref. 60]
	Family: Solenoceridae Wood-Mason in Wood-Mason & Alcock, 1891 (17)	
44	*Gordonella villosa* (Alcock & Anderson, 1894)	Karwar and Minicoy
45	*Hadropenaeus lucasii* (Spence Bate, 1881)#	Southwest coast Purushothaman *et al*., 2019[ref. 32]
46	*Haliporus taprobanensis* Alcock & Anderson, 1899	Gulf of Mannar and Kanyakumari
47	*Haliporus thetis* Faxon, 1893	
48	*Haliporus taprobanensis* Alcock & Anderson, 1899	Andaman Sea
49	*Hymenopenaeus equalis* (Spence Bate, 1888)#	Southeast and Southwest, Andaman Sea Mohamed & Suseelan, 1973[ref. 4]
50	*Hymenopenaeus laevis* (Spence Bate, 1881)	Lakshadweep
51	*Hymenopenaeus neptunus* (Spence Bate, 1881)	Bay of Bengal
52	*Hymenopenaeus sewelli* Ramadan, 1938	
53	*Solenocera alfonso* Pérez Farfante, 1981	Southeast coast Chakraborty, 2017[ref. 61]
54	*Solenocera alticarinata* Kubo, 1949	
55	*Solenocera annectens* (Wood-Mason in Wood-Mason & Alcock, 1891)#	Andaman Sea Alcock, 1901[ref. 51]; Purushothaman, 2019[ref. 32]
56	*Solenocera halli* Starobogatov, 1972	East and west coast, Andaman Sea
57	*Solenocera hextii* Wood-Mason & Alcock, 1891#	East and west coast Thomas,1979[ref. 13]
58	*Solenocera koelbeli* de Man, 1911	Kerala, Andhra Pradesh and Gujarat George, 1966[ref. 62]
59	*Solenocera barunajaya* Crosnier, 1994	Southwest coast
60	*Solenocera rathbuni* Ramadan, 1938#	Southwest coast
	Super family: Sergestoidea Dana, 1852; Family: Sergestidae Dana, 1852 (8)	
61	*Deosergestes rubroguttatus* (Wood-Mason in Wood-Mason & Alcock, 1891)	
62	*Deosergestes seminudus* (Hansen, 1919)	Karuppasamy *et al*., 2006[ref. 52]
63	*Neosergestes orientalis* (Hansen, 1919)	Karuppasamy *et al*., 2006[ref. 52]
64	*Neosergestes semissis* (Burkenroad, 1940)	Karuppasamy *et al*., 2006[ref. 52]
65	*Parasergestes armatus* (Krøyer, 1855)	
66	*Sergestes hamifer* Alcock & Anderson, 1894	Arabian Sea, Andaman Sea
67	*Sergia bisulcata* (Wood-Mason & Alcock, 1891)	Arabian Sea
68	*Sergiainoa* (Faxon, 1893)	Karuppasamy *et al*., 2006[ref. 52]
	Family: Callianassidae Dana, 1852; Subfamily: Callianassinae Dana, 1852	
69	*Callianassa lignicola* Alcock & Anderson, 1899	Andaman Sea Alcock & Anderson, 1899[ref.63].

(*Contd*.)

Table 1 — Checklist of deep-sea marine shrimps from Indian waters (*Contd*.)

Sl no	Species	Distribution
	Infra order: Caridea Latreille, 1817; Super family: Alpheoidea Rafinesque, 1815; Family: Alpheidae Rafinesque, 1815	
70	*Alpheus macroskeles* Alcock & Anderson, 1899	Bay of Bengal, Andaman Sea
71	*Alpheus paralcyone* Coutière, 1905	Lakshadweep Sea
72	*Alpheus samudra* De Grave, Krishnan, Kumar, & Christodoulou, 2020	Arabian Sea
73	*Synalpheus neomeris* (de Man, 1897 in [de Man, 1895-1898])	Gulf of Mannar
	Super family: Alpheoidea Rafinesque, 1815; Family: Hippolytidae Spence Bate, 1888	
74	*Merhippolyte calmani* Kemp & Sewell, 1912	Southwest coast
	Family: Ogyrididae Holthuis, 1955	
75	*Ogyrides orientalis* (Stimpson, 1860)	
	Super family: Crangonoidea Haworth, 1825; Family: Crangonidae Haworth, 1825	
76	*Aegaeon lacazei* (Gourret, 1887)	Southeast coast
77	*Parapontocaris andamanensis* (Wood-Mason in Wood-Mason & Alcock, 1891)	Andaman Sea Alcock, 1901[ref. 51]
78	*Parapontocaris bengalensis* (Wood-Mason in Wood-Mason & Alcock, 1891)[#]	Bay of Bengal Alcock, 1901[ref. 51]
79	*Parapontocaris levigata* (Chace, 1984)*	Southwest coast
80	*Parapontophilus abyssi* (Smith, 1884)	Alcock, 1901[ref. 51]
81	*Parapontophilus gracilis* (Smith, 1882)	East coast Alcock, 1901[ref. 51]
82	*Pontocaris affinis affinis* (Alcock, 1901)[#]	Southwest and northwest coast Alcock, 1901[ref. 51]
83	*Pontocaris pennata* (Spence Bate, 1888)	South & North east coast Kemp, 1961[ref. 65]
84	*Pontocaris propensalata* (Spence Bate, 1888)[#]	Southwest and Andaman Sea
85	*Prionocrangon ommatosteres* Wood-Mason in Wood-Mason & Alcock, 1891	Alcock, 1901[ref. 51]
	Family: Glyphocrangonidae Smith, 1884	
86	*Glyphocrangon andamanensis* Wood-Mason in Wood-Mason & Alcock, 1891	Andaman Sea
87	*Glyphocrangon caeca* Wood-Mason in Wood-Mason & Alcock, 1891	Bay of Bengal Alcock, 1901[ref. 51]
88	*Glyphocrangon caecescens* Wood-Mason in Wood-Mason & Alcock, 1891	Bay of Bengal Alcock, 1901[ref. 51]
89	*Glyphocrangon cerea* Alcock & Anderson, 1894	Lakshadweep Sea Alcock & Anderson, 1894[ref. 47]
90	*Glyphocrangon gilesii* Wood-Mason & Alcock, 1891	Andaman Sea
91	*Glyphocrangon investigatoris* Wood-Mason & Alcock, 1891[#]	East & West coast Alcock, 1901[ref. 51]
92	*Glyphocrangon prionono*ta Wood-Mason & Alcock, 1891	Lakshadweep Sea Alcock, 1901[ref. 51]
93	*Glyphocrangon regalis* Spence Bate, 1888	Kerala, Southwest coast
94	*Glyphocrangon smithii* Wood-Mason in Wood-Mason & Alcock, 1891	Bay of Bengal Alcock, 1901[ref. 51]
95	*Glyphocrangon unguiculata* Wood-Mason & Alcock, 1891	Arabian Sea Alcock, 1901[ref. 51]
	Super family: Nematocarcinoidea Smith, 1884; Family: Nematocarcinidae Smith, 1884	
96	*Nematocarcinus cursor* A. Milne Edwards, 1881	Alcock, 1901[ref. 51]
97	*Nematocarcinus gracilis* Spence Bate, 1888	Arabian sea
98	*Nematocarcinus tenuirostris* Spence Bate, 1888	Arabian sea, Andaman Sea
99	*Nematocarcinus undulatipes* Spence Bate, 1888	Lakshadweep Sea
	Super family: Oplophoroidea Dana, 1852; Family: Acanthephyridae Spence Bate, 1888	
100	*Acanthephyra armata* A. Milne Edwards, 1881	Alcock, 1901[ref. 51]
101	*Acanthephyra curtirostris* Wood-Mason & Alcock, 1891	Alcock, 1901[ref. 51]
102	*Acanthephyra eximia* Smith, 1884	Alcock, 1901[ref. 51]

(*Contd*.)

Table 1 — Checklist of deep-sea marine shrimps from Indian waters (*Contd*.)

Sl no	Species	Distribution
103	*Acanthephyra fimbriata* Alcock & Anderson, 1894[#]	Bay of Bengal and Arabian Sea
104	*Acanthephyras anguinea* Wood-Mason [in Wood-Mason & Alcock, 1892][#]	Kerala, west coast Alcock, 1901[(ref. 51)]
105	*Ephyrina hoskynii* Wood-Mason & Alcock, 1891	Bay of Bengal Alcock, 1901[(ref. 51)]
106	*Heterogenys microphthalma* (Smith, 1885)	
107	*Hymenodora gracilis* Smith, 1886	West coast
108	*Meningodora vesca* (Smith, 1886)	Bay of Bengal Karuppasamy *et al*., 2006[(ref. 52)]
109	*Notostomus sp.* A. Milne Edwards, 1881	West coast Karuppasamy *et al*., 2006[(ref. 52)]
	Family: Oplophoridae Dana, 1852	
110	*Oplophorus gracilirostris* A. Milne-Edwards, 1881[#]	Southwest coast and southeast coast Chakraborthy, 2013[(ref. 66)]
111	*Oplophorus spinosus* (Brullé, 1839)	Southwest coast
112	*Oplophorus typus* H. Milne Edwards, 1837 [in H. Milne Edwards, 1834-1840]	West coast Karuppasamy, 2006[(ref. 52)]
	Family: Palaemonidae Rafinesque, 1815; Sub family: Pontoniinae Kingsley, 1879	
113	*Periclimenes laccadivensis* (Alcock & Anderson, 1894)	Lakshadweep Sea
	Super family: Pandaloidea Haworth, 1825; Family: Pandalidae Haworth, 1825	
114	*Chlorotocus crassicornis* (A. Costa, 1871)	Andaman Sea Alcock & Anderson[(ref. 47)]
115	*Dorodotes reflexus* Spence Bate, 1888	Bay of Bengal Shanis *et al*., 2012[(ref. 67)]
116	*Heterocarpus dorsalis* Spence Bate, 1888	Arabian Sea, Andaman Sea, Bay of Bengal Shanis *et al*., 2012[(ref. 67)]
117	*Heterocarpus ensifer* A. Milne Edwards, 1881	Southeast and west coast
118	*Heterocarpus chani* Li, 2006[#] [Misidentified as: *Heterocarpus gibbosus* Spence Bate, 1888]	Southwest coast and southeast coast Suseelan,1974[(ref. 5)]; Kuberan *et al*., 2015[(ref. 20)]; Yang *et al*., 2017[(ref. 68)]
119	*Heterocarpus laevigatus* Spence Bate, 1888	Arabian Sea, Bay of Bengal Alcock & Anderson, 1894[(ref. 47)]
120	*Heterocarpus longirostris* Mac Gilchrist, 1905	Bay of Bengal, Andaman Sea Shanis *et al*., 2012[(ref. 67)]
121	*Heterocarpus sibogae* de Man, 1917	Southwest coast, Andaman Sea Shanis *et al*., 2012[(ref. 67)]
122	*Heterocarpus tricarinatus* Alcock & Anderson, 1894	Arabian Sea, Lakshadweep Sea, Andaman Sea Shanis *et al*., 2012[(ref. 67)]
123	*Heterocarpus woodmasoni* Alcock, 1901[#]	Southeast, west coast, Andaman Sea Shanis *et al*., 2012[(ref. 67)]
124	*Plesionika longicauda* (Rathbun, 1901)	Kakinada Devi, 1980[(ref. 69)]
125	*Plesionika adensameri* (Balss, 1914)	Arabian Sea, Bay of Bengal
126	*Plesionika alcocki* (Anderson, 1896)[#]	Arabian Sea and Bay of Bengal Shanis *et al*., 2012[(ref. 67)]
127	*Plesionika bifurca* Alcock & Anderson, 1894	Andaman Sea, Arabian Sea, Bay of Bengal Alcock & Anderson[(ref. 47)]
128	*Plesionika ensis* (A. Milne Edwards, 1881)	Southwest and East coast Shanis *et al*., 2012[(ref. 67)]
129	*Plesionika martia* A. Milne Edwards, 1883	Andaman Sea Shanis *et al*., 2012[(ref. 67)]
130	*Plesionika semilaevis* Spence Bate, 1888[#]	Southwest and southeast Shanis *et al*., 2012[(ref. 67)]
131	*Plesionika ocellus* (Spence Bate, 1888)	Andaman Sea, Arabian Sea Shanis *et al*., 2012[(ref. 67)]

(*Contd*.)

Table 1 — Checklist of deep-sea marine shrimps from Indian waters (*Contd*.)

Sl no	Species	Distribution
132	*Plesionika quasigrandis* Chace, 1985[#]	West and southeast coast Alcock,1901[(ref.51)].
133	*Plesionika sindoi* (Rathbun, 1906)	Andaman Sea, Arabian Sea Shanis *et al*., 2012[(ref. 67)]
134	*Plesionika unidens* Spence Bate, 1888	Andaman Sea Shanis *et al*., 2012[(ref. 67)]
135	*Plesionika williamsi* Forest, 1964	Southwest coast Shanis *et al*., 2012[(ref. 67)]
136	*Plesionika persica* (Kemp, 1925)	Southwest coast
137	*Plesionika reflexa* Chace, 1985[#]	Southwest coast
138	*Plesionika narval* (Fabricius, 1787)[#]	Southwest coast
139	*Plesionika richardi* (Coutière, 1905)	Bay of Bengal
	Family: Thalassocarididae Spence Bate, 1888	
140	*Thalassocaris obscura* (GopalaMenon & Williamson, 1971)	Arabian Sea
	Super family: Pasiphaeoidea Dana, 1852; Family: Pasiphaeidae Dana, 1852	
141	*Eupasiphae gilesii* (Wood-Mason, 1892)	Andaman Sea Alcock,1901[(ref. 51)]
142	*Eupasiphae latirostris* (Wood-Mason & Alcock, 1891)	Arabian sea Alcock,1901[(ref. 51)]
143	*Glyphus marsupialis* Filhol, 1884	Arabian Sea
144	*Leptochela (Leptochela) aculeocaudata* Paul'son, 1875	East and West coast, Andaman sea Karuppasamy *et al*., 2006[(ref. 52)]
145	*Leptochela (Leptochela) robusta* Stimpson, 1860	Southwest coast Karuppasamy *et al*., 2006[(ref. 52)]
146	*Pasiphaea alcocki* Wood-Mason & Alcock, 1891[#]	Southwest, southeast coast Alcock, 1901[(ref. 51)]
147	*Pasiphae aunispinosa* Wood Mason, 1892	Andaman Sea Alcock, 1901[(ref. 51)]
148	*Psathyrocaris fragilis* Wood-Mason in Wood-Mason & Alcock, 1893	
149	*Psathyrocaris infirma* Alcock & Anderson, 1894	Southwest coast Karuppasamy *et al*., 2006[(ref. 52)]
150	*Psathyrocaris platyophthalmus* Alcock & Anderson, 1894	Lakshadweep Sea
151	*Psathyrocaris plumose* Alcock & Anderson, 1894	
	Super family: Processoidea Ortmann, 1896; Family: Processidae Ortmann, 1896	
152	*Hayashidonus japonicas* (De Haan, 1844 [in De Haan, 1833-1850])	
	Super family: Psalidopodoidea Wood-Mason [in Wood-Mason &Alcock, 1892]; Family: Psalidopodidae Wood-Mason [in Wood-Mason & Alcock, 1892]	
153	*Psalidopus huxleyi* Wood-Mason [in Wood-Mason &Alcock, 1892]	West coast, Southeast coast, Lakshadweep Sea, Andaman Sea Alcock, 1901[(ref. 51)]
	Infra order: Stenopodidea Spence Bate, 1888; Family: Spongicolidae Schram, 1986	
154	*Engystenopus palmipes* Alcock & Anderson, 1894	Bay of Bengal Alcock, 1901[(ref. 51)]
155	*Spongicola andamanicus* Alcock, 1901	Andaman Sea Alcock, 1901[(ref. 51)]
	Family: Stenopodidae Claus, 1872	
156	*Odontozona spongicola* (Alcock & Anderson, 1899)	Andaman Sea Alcock & Anderson, 1899[(ref. 63)]

Number given in bracket refers to number of species belongs the corresponding family; [#]Deep-sea penaeid and caridean shrimp from India have sequences deposited in the NCBI GenBank

checklist within the family Solenoceridae, of which two species, *Solenocera barunajaya* Crosnier, 1994, and *Solenocera rathbuni* Ramadan, 1938, emerged as notable deep-water shrimp species. The family Hippolytidae incorporates *Merhippolyte calmani* Kemp & Sewell, 1912, while the family Crangonidea encompasses in total 10 species spread across five genera: *Aegaeon*, *Parapontocaris*, *Parapontophilus*,

Table 2 — Number of families and deep-sea species under the suborder Pleocyemata in Indian waters

Sl no	Family	Species (No.)
1	Alpheidae	4
2	Hippolytidae	1
3	Crangonidae	10
4	Glyphocrangonidae	10
5	Nematocarcinidae	4
6	Oplophoridae	3
7	Pandalidae	26
8	Thalassocarididae	1
9	Pasiphaeidae	11
10	Psalidopodidae	1
11	Stenopodidae	1
12	Spongicolidae	2
13	Axiidae	5
14	Callianassidae	1
15	Acanthephyridae	10
16	Ogyrididae	1
17	Pontoniinae (Subfamily)	1
18	Processidae	1

Pontocaris, and *Prionocrangon*. These encompass the entirety of marine deep-sea shrimps. Within the family Pandalidae, a set of 5 species are identified, including *Heterocarpus chani* Li, 2006 (initially misidentified as: *Heterocarpus gibbosus* Spence Bate, 1888), *Plesionika semilaevis* Spence Bate, 1888, *Plesionika persica* (Kemp, 1925), *Plesionika reflexa* Chace, 1985, and *Plesionika narval* (Fabricius, 1787). These deep-water shrimp species have been documented within the Indian coastal context.

Molecular taxonomy

Molecular phylogenetics, an innovative method, synergistically merges molecular and statistical techniques to elucidate the evolutionary interconnections among organisms. This approach capitalizes on the molecular structure and functional attributes of biomolecules, as well as their temporal changes, to deduce evolutionary relationships. Employing the genetic makeup of individuals, populations, or species through their DNA sequences, molecular phylogenetics furnishes a robust mechanism for discerning distinctiveness and characterizing the evolutionary lineage of individual species, thereby resolving taxonomic intricacies.

DNA barcoding has been harnessed for species differentiation and the identification of cryptic species[29]. However, within the domain of deep-sea shrimps belonging to the order Decapoda, the application of molecular methodologies has been relatively limited[30]. Investigating the phylogenetic relationships up to the familial level within approximately 30 families of deep-sea shrimps, Bracken *et al.*[10] employed mitochondrial (16S) and nuclear (18S) markers. Additionally, Chu[31] conducted a study focusing on the intricate *Heterocarpus* complex.

The ambiguity between *Aristeus alcocki* and *A. semidentatus* was studied by using morphological and molecular markers *viz*., mitochondrial (16S rDNA, COI) and nuclear (*NAK*, *PEPCK*) protein coding genes. The results of the study indicated the presence of *A. alcocki* along the Indian coast[32]. *Aristeus alcocki* from southwest coast of India exhibited morphometric variability, revealing existence of two groups; while the samples collected from Kalamuku lying on the south west coast of India, clustered separately in group-I, and the samples collected from other four locations were clustered in group-II(ref. 23). Further, the genetic diversity and stock structure of *A. alcocki* using nine microsatellite markers with 203 individuals collected from five locations along the Indian coast revealed the presence of single stock for adopting fishery management and conservation of the species[33]. Studies on the population dynamics of *A. alcocki* signified that the species has remained stable during the study period, in terms of its life span, size frequency distribution and biological parameters, such as growth and mortality[34].

The integrative taxonomy of deep-water penaeoid shrimp species along the Indian coast was undertaken using three mitochondrial genes (cytochrome oxidase subunit I (COI), cytochrome b, 16S rRNA), in combination with 54 morphological characters. This assessment revealed significant molecular divergence (ranging from 3.3 to 33.0 %) among nine species from three Solenoceridae genera, four species from three Penaeidae genera, and one species from Aristeidae, particularly in relation to COI markers[32].

Deep-sea shrimp studies encompassed the integrative taxonomy of deep-sea shrimps along the southern coast of India. This study resulted in the deposition of sequences (63 COI, 55 16S, and 29 Cytb) from various deep-sea penaeid shrimp species into the NCBI. Similarly, 57 COI and 64 16S sequences of deep-sea caridean shrimp species were also deposited (Table 1) and the corresponding accession numbers for the deposited sequences were acquired from GenBank.

Trawling operations

The initial investigations on deep-sea shrimp fishery, predicated upon trawl landings from

commercial trawlers along the Kerala coast, delineated the composition of deep-sea penaeid and caridean species. Their relative dominance was ranked as follows: *Metapenaeopsis andamanensis*, *Aristeus alcocki*, *Penaeopsis jerryi*, and *Solenocera hextii*, along with pandalid shrimp species such as *H. woodmasoni*, *H. gibbosus*, and *Plesionika quasigrandis*[35]. The eminent fishing harbors on the southwest coast encompass Kalmuku (KAL), Sakthikulangara (SAK), and Colachel (COL). Correspondingly, deep-sea fishing vessels are operated from the fishing harbors of Tuticorin (TUT), Nagapattinam (NAG), and Chennai (CHE) on the southeast coast (Fig. 1). Detailed particulars encompassing the fishing grounds, depths, gear dimensions, duration of fishing voyages, hauling speeds, landing time frames, and the count of vessels per port are elucidated in Table 3. The predominant proportion, approximately 80 %, of deep-sea shrimp trawling endeavors are concentrated along the southwest coast, marked by two distinct modalities of trawling operations, each targeting specific groups of shrimp species. One modality exclusively targets *Aristeus alcocki* (locally known as "red ring") at depths exceeding 300 m. The other mode encompasses a comprehensive target of diverse deep-sea shrimps (including pandalids and other penaeid shrimps) within a depth range of 170 – 300 m. Conversely, along the southeast coast (Chennai and Nagapattinam), fishing activities are predominantly directed towards the red ring species, at depths ranging from 250 – 800 m. Notably, fishing trips along this coast extend up to 15 days, surpassing durations observed at other ports. The timing of trawling operations varies; on the southwest coast, it spans from September to May, except during the monsoon ban period (10th June to 31st July). Conversely, along the southeast coast, seasonal deep-sea operations transpire from December to March, with a monsoon ban extending from 15th April to 30th May.

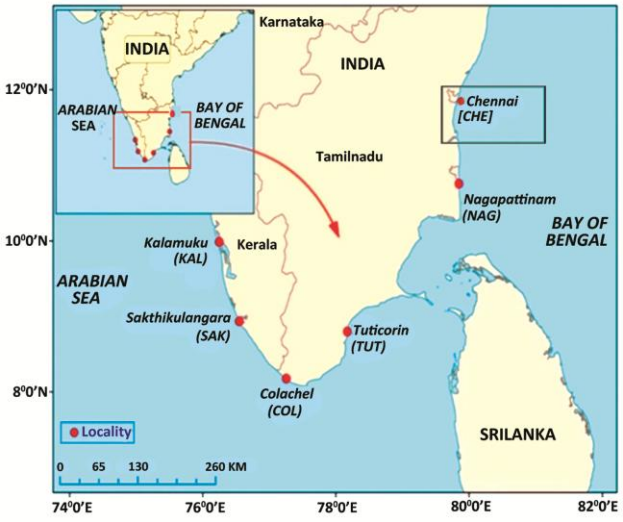

Fig. 1 — Deep-sea fishing harbours along the Southern Coast of India

Species composition from the southern coast of India

Southwest coast (Kerala)

The Quilon Bank (Latitude 8° N – 9° N, Longitude 76° E) emerges as a pivotal contributor to the deep-sea shrimp fishery, accounting for a significant portion of the catch. Specifically, during the period spanning 1999 – 2003, Quilon Bank contributed for approximately 72.8 % of the catch landed at the Sakthikulangara fishing harbour. This trend persisted

Table 3 — Details of fishing operations for deep-sea shrimps in Indian coast

Landing centres	KAL	COL	SAK	TUT	NAG	CHE
Area of operations	9°59' – 01 60' N 76°14' – 32°16' E	9°31' – 11°02' N 75°50' – 75°05' E	7°41' – 9°24' N 76°45' – 75°38' E	8°30' – 8°60' N 78°20' – 78°42' E	10°22' – 11°58' N 80°22' – 79°58' E	12°33' – 13°32' N 80°38' – 79°30' E
Depth (m)	180 – 250	180 – 450	200 – 600	250 – 500	250 – 800	250 – 600
Gear size (mm)	20 – 24	20 – 24	20 – 24	25 – 35	20 – 35	24 – 35
Voyage days	5 – 7	5 – 7	5 – 10	1	7 – 14	7 – 15
Hauling speed (nm/hr)	2 – 3	2 – 2.5	2 – 3	3	2 – 4	2 – 3
Catch/trawl (tons)	0.5 – 1	0.5 – 2	1 – 3	0.15 – 0.5	1 – 3	1 – 3
Landing available	Oct – Mar	Oct – May	Sep – May	Nov – Mar	Nov – April	Jan – Mar
No. of vessels involving	10 – 15	50 – 100	100 – 250	6 – 15	15 – 20	10 – 15

KAL: Southwest coast – Kalamuku; COL: Southwest coast – Colachel; SAK: Sowthwest coast – Sakthikulangara; TUT: Southeast coast – Tuticorin; NAG: Southeast coast – Nagapattinam; and CHE: Southeast coast – Chennai

through 2003 – 2006, encompassing 84.2 % of the catch, and persisted into 2007 – 2017, with exceptions observed during 2008 – 2010. Concurrently, the Cochin fisheries harbour accounted for 15 % of the landings during the period encompassing 2007 – 2017.

An ecological perspective on the major species landings spanning 2007 to 2017 highlights the contribution from both harbours situated along the Arabian Sea. These landings encompass 11 species within the family Pandalidae, 10 species in Solenoceridae, 4 species in Crangonidae and Penaeidae, 2 species each under Acanthephyridae and Sergestidae, and one species each in Aristeidae, Glyphocrangonidae, Hippolytidae, Oplophoridae, Pasiphaeidae, Sicyoniidae, and Stylodactylidae. Noteworthy amongst these, the *Plesionika* genus comprises species such as *Plesionika adensameri*, *P. alcocki*, *P. bifurca*, *P. narval*, *P. persica*, *P. quasigrandis*, *P. reflexa*, and *P. semilaevis*. Similarly, the *Heterocarpus* genus is represented by *Heterocarpus chani*, *H. woodmasoni*, and *H. sibogae*. Additionally, minor species include *Acanthephyra fimbriata*, *A. sanguinea*, *Oplophorus gracilirostris*, *Pontocaris affinis affinis*, *P. propensalata*, *Parapontocaris bengalensis*, *P. leavigata*, *Glyphocrangon investigatoris*, *Parastylodactylus sulcatus*, *Merhippolyte calmani*, *Pasiphaea alcocki*, *Aristeus alcocki*, *Metapenaeopsis andamanensis*, *M. coniger*, *Penaeopsis jerryi*, *Parapenaeus investigatoris*, *Solenocera alfonso*, *S. annectens*, *S. barunajaya*, *S. hextii*, *S. koelbeli*, *S. rathbuni*, *Hymenopenaeus equalis*, *Hadropenaeus lucasii*, *Sicyonia parajaponica*, and representatives from the *Deosergestes*, *Neosergestes*, *Sergestes*, and *Sergia* genera. Within this diverse array, a subset of species emerges as dominant in landings, encompassing *Heterocarpus chani*, *H. woodmasoni*, *Aristeus alcocki*, *Metapenaeopsis andamanensis*, *P. quasigrandis*, *P. semilaevis*, and *S. hextii*. Conversely, the remaining species manifest sporadic occurrences in landings, thus being excluded from catch estimations.

Southeast coast (Tamil Nadu)

Deep-sea shrimp landings have been observed within Tuticorin, Nagapattinam, and Chennai fishing harbours situated along the southeastern coast of India. Within this context, a total of twenty-five shrimp species have been documented in the deep-sea shrimp landings, among which a select group of seven species emerges as dominant contributors to the catch. This group includes *H. chani*, *H. woodmasoni*, *A. alcocki*, *M. andamanensis*, *P. quasigrandis*, *P. semilaevis*, and *S. hextii*, mirroring the species composition evident in the southwestern coast. Conversely, the remainder of the species contributes in minor quantities to the overall deep-sea catch. Notably, an examination of species composition across three distinct harbours (Tuticorin, Nagapattinam, and Chennai) underscores the prevalence of *H. chani*, *M. andamanensis*, *P. quasigrandis*, and *A. alcocki* as primary contributors, collectively accounting to over 90 % of the total landings. Of particular significance, *M. andamanensis* emerges as the predominant species, constituting 59 % of the catch from Chennai and 75 % from Nagapattinam. The combined landings from these harbours amount to 15,544 tonnes within the time frame of 2007 – 2017. Notably, peak landings were achieved during 2015 – 2016, reaching 3,241 tonnes and 3,661 tonnes with corresponding peak catch per unit values of 11 and 10 kg/unit, respectively. However, a decline ensued in 2017, resulting in a reduced catch of 498 tonnes with a catch per unit of 3.1 kg/unit (CMFRI, Annual Reports). It is noteworthy that *M. andamanensis* displayed consistent size ranges (Carapace Length, CL 20 – 21 mm) from 2015 to 2017.

Within the caridean group, the primary species contributing to the deep-sea shrimp fishery encompass *H. chani*, *H. woodmasoni*, and *P. quasigrandis*. On the other hand, the penaeid group is characterized by major contributions from species such as *A. alcocki*, *M. andamanensis*, *M. coniger*, *S. hextii*, and *P. jerryi*. Additionally, *H. chani* and *P. quasigrandis* constitute significant portions of the caridean catch[36]. Detailed composition data from Chennai reveals the dominance of *M. andamanensis* (59.8 %), followed by *A. alcocki* (24.6 %), *H. chani* (8.4 %), and *H. woodmasoni* (6.9 %) within the deep-sea shrimp landings.

Distinct patterns emerge in the context of Tuticorin's deep-sea shrimp catch, primarily featuring *P. quasigrandis*, *H. chani*, and *M. andamanensis* as dominant contributors over multiple years. Other species such as *A. alcocki*, *A. fimbriata*, *A. sanguinea*, *O. gracilirostris*, *Pontocaris affinis affinis*, *Parastylodactylus sulcatus*, and *Metapenaeopsis coniger* were noted to have occasional presence in the fishery. Howevere, *P. quasigrandis* emerged as the most prevailing species, demonstrating variation from 1,407 tonnes in 2013 to 4 tonnes in 2017, thereby contributing 58.2 % to the landings. *Heterocarpus chani* followed as the subsequent dominant species,

presenting fluctuations from 533 tonnes in 2013 to 1.1 tonnes in 2017. Moving to Nagapattinam, the deep-sea shrimp landings are characterized by *M. andamanensis* (76.2 %), *A. alcocki* (12.8 %), and *H. woodmasoni* (10.2 %) as prominent contributors. Other species such as *S. hextii*, *P. jerryi*, and *M. coniger* occasionally contribute to the shrimp landings. Notable catches of *A. alcocki* were primarily observed in 2016 and 2017, amounting to 1,277 and 874 tonnes, respectively[37,38].

An overview of deep-sea shrimp biology

Investigations regarding the reproductive biology of deep-sea shrimps *Heterocarpus gibbosus* and *H. woodmasoni* were carried out by Radhika[39], focusing on the Southern Arabian Sea. Preliminary insights into the reproductive aspects encompassing sex ratio, fecundity, and egg size among deep-sea shrimps were reported by Rao & Suseelan[40], Rajan *et al*.[41], and Thirumilu & Rajan[42], stemming from research within the Indian waters.

Length-weight relationship investigations concerning shrimps sourced from Indian waters primarily hinge on the total length[7,43]. Nonetheless, the utilization of carapace length as a determinant for establishing length-weight relationships has found extensive application, particularly in the context of *Plesionika* species[44]. Within this realm, Radhika[39] conducted an empirical analysis encompassing seven deep-sea shrimp species, namely *P. quasigrandis*, *P. martia*, *P. ensis*, *H. gibbosus*, *H. woodmasoni*, *A. alcocki*, *S. hextii*, and *M. andamanensis*. This study was conducted using samples obtained from both commercial landings and exploratory surveys conducted off the southwestern coast of India. Through this research, the total length-weight parameters and condition factor were ascertained, contributing to a comprehensive understanding of these species' morphometric relationships.

Plesionika spinipes Spence Bate, 1888, a commercially significant shrimp in trawl fisheries, was initially a misidentification of *P. quasigrandis*[7]. However, Chakraborty *et al*.[27-28] undertook a detailed taxonomic investigation employing molecular barcoding data to rectify this misidentification. Their study contributed to a comprehensive understanding of *P. quasigrandis* taxonomic status. The fishery, biology, and population dynamics of this species unveiled an exploitation rate lower than the E_{max}, indicating a potential for sustainable resource utilization[26].

In the case of *H. chani*, the relationship between total length-weight and carapace length-weight was studied across different groups, including males, ovigerous females, and non-ovigerous females, sourced from five major fish landing centers along the southern coast of India. The analyses indicated negative allometric growth across all populations, as revealed by the total length-weight and carapace length-weight relationships[45]. Recent approaches in population morphological differentiation have embraced the utilization of truss network or geometric methods. Employing the truss network system, the existence of three distinct *H. chani* populations along the southern coasts, spanning the Arabian Sea and Bay of Bengal, has been substantiated. Morphological differences were identified in the first four abdominal pleuron characters within the populations[45].

The feeding ecology of the deep-water shrimp, *A. alcocki* from the Arabian Sea revealed that the species consumes highly diversified diet, the dominant items being invertebrates, crustaceans (amphipods, euphausiids), foraminiferans and mollusks[34]. The reproductive biology studies on red ring indicated synchronous oocyte development and continuous spawning activity with a peak during January to April[23].

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Conflict of Interest

All authors of this manuscript are declaring that no conflict of interest is present in this manuscript.

Ethical Statement

This article does not contain any experimental studies with live animals by any of the authors.

Author Contributions

RDC: Acquiring fund from DST-SERB, India, conceptualization, sample collection, methodology, original draft preparation, investigation, and supervision**;** GK: Sample collection, draft editing of manuscript, methodology, and measurements; PP: Sample collection and measurements; EVR: Draft editing of manuscript and checklist; PTS: Draft editing and sample collection; GM: Draft editing and methodology; and APG: Formatting and references.

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