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CONTENTS

An updated checklist of planktonic Copepods from the major estuaries of Kerala (Vembanad and Ashtamudi), south-west coast of India

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ABSTRACT: We present an updated checklist of planktonic copepods from Ramsar sites of Kerala *viz*., Vembanad and Ashtamudi estuary, situated along the Southwest coast of India. Data available in the published records were compiled and updated with data generated from our recent study conducted from 2018 to 2019 from both the estuaries. The combined list includes 105 species of copepods under 42 Genera in 22 Families and 3 Orders; namely Calanoida, Cyclopoida, and Harpacticoida. Common families recorded were Pontellidae (15 species), Acartiidae (13 species), Corycaeidae (12 species), Oithonidae (12 species), Pseudodiaptomidae (9 species), Centropagiidae (8 species) and Paracalanidae (7 species). 67% of species recorded were marine inhabitants and 20% recorded both in marine and estuarine habitats whereas only 10% of species recorded in marine, estuarine and freshwater habitats. True estuarine (*Acartia tropica*) and true freshwater inhabitants (*Heliodiaptomus cinctus* and *Allodiaptomus mirabilipes*) were also recorded during the study. Fifty-three recorded species were common to both the estuaries. In comparison, the Vembanad estuary sustained a higher number of species (100 nos.) than the Ashtamudi estuary (58 nos.). *Calanopia metu*, a Mediterranean calanoid copepod is also included in the list as it is the first time reported from the Indian waters. Historical studies report the presence of 91 species of copepods under 39 genera of 20 families and 3 orders from both the estuaries. It is also observed that six new species of copepods such as Acartia *(Acartiella) keralensis, Pseudodiaptomus malayalus, Acartia bilobata, Archidiaptomus aroorus, Isias cochinensis* and *Acartia bowmani* were added to the science from the Vembanad estuary. Vembanad estuary reports more species of copepods than the Ashtamudi estuary because, Vembanad estuary is more exploited than the Ashtamudi estuary in terms of copepod studies.

Key words: Calanoids, Cyclopoids, Harpacticoids, marine, freshwater, Vembanad and Ashtamudi estuary

Copepods are the most abundant aquatic crustaceans on the earth, forming the bulk of the zooplankton community (Ohtsuka and Nishida, 2017). They are one of the most diverse groups of animals on the planet, with over 13,000 different species (Ohtsuka and Nishida, 2017). The newly and widely accepted classification made by Huys and Boxshall (1991) and Humes (1994), divides the subclass Copepoda into ten orders *viz.,* Platycopioida, Calanoida, Misophirioida, Cyclopoida, Gelyelloida, Mormonilloida, Harpacticoida, Poecilostomatoida, Siphonostomatoida, and Monstrilloida. Among which the dominating orders are Calanoida, Cyclopoida, and Harpacticoida (Conway *et al*., 2003). Generally, Order Calanoida includes pelagic forms with marine (~ 75%) and freshwater inhabitants (~25%) (Sanu, 2018). Species under the Order Cyclopoida are pelagic, commensal or parasitic forms and are distributed between marine and fresh waters habitats. Order Harpacticoida includes benthic, pelagic, and commensal forms distributed mostly in marine and freshwater (~10%).

Vembanad (VE) and Ashtamudi (AE) are the largest and second-largest estuaries of Kerala, located along the Southwest coast of India. They were designated as Ramsar sites in 2002 with international importance. The Vembanad estuary, also known as Cochin estuary is relatively studied on its biological resources including Copepods compared to Ashtamudi estuary. A comprehensive study on Copepods from the Vembanad estuary was published in 1958 (George) whereas an almost similar study from the Ashtamudi estuary was published in 1982 (Divakaran *et al*.) after three decades. Even though both the estuaries are equally important as Ramsar sites, most of the studies were concentrated in to the Vembanad estuary (Madhupratap and Haridas, 1975; Madhupratap, 1979; Haridas, 1982; Madhu *et al.,* 2007; Vineetha *et al.,* 2015; Jyothibabu *et al.,* 2016). Information on copepods was limited in the case of Ashtamudi estuary. A comprehensive list of planktonic copepods of coastal Ramsar sites of Kerala is still lacking. In this background, the present study was done to collate all the available information on copepods in order to produce a comprehensive checklist of copepods of both the estuaries.

MATERIALS AND METHODS

Monthly samples were collected from the down stretch of Vembanad (9.97^0 N-76.23^{0}E) and Ashtamudi (8.93^{0}N-76.54^{0}E) from February 2018 to December 2019 (Fig 1). Zooplankton samples were collected during morning hours between 6 am to 8 am at low tide period by employing the standard conical zooplankton net from the upper water column. The net was hauled horizontally for 10 minutes by maintaining a speed of the boat at 2 knots/hr. The net was made up of 200 µm bolting silk (60 cm diameter) fitted with a Calibrated flow meter (Hydrobios model - 438110) to estimate the volume of water filtered. The filtered samples were washed out and preserved with 4-5% Formaldehyde solution and stored into plastic bottles. Copepods were sorted out manually from the sample for analysis. The taxonomic identification of copepods was done by using a stereo zoom trinocular microscope (Model Magnus MSZ-TR). The confirmation of the species was done by dissecting and mounting the 5th Pleopods of the specimens and observed under the Compound microscope (Leica DM500 fitted with Camera). Species identification was done with the help of taxonomic keys/manuals such as Kasturirangan (1963), Conway *et al.* (2003). Online resource the Marine planktonic copepod database (https://copepodes.obs-banyuls.fr/en/) (Razouls *et al.,* 2005-2022) was also used for species conformation. Information on the accepted species names, habitat of Copepods were collected from the website WORMS (https://www.marinespecies.org) (Horton *et al.,* 2022) Extensive review of literature (online and offline resources) was carried out in order to collect the previous records of copepods from the Vembanad and Ashtamudi estuary. Based on this, checklists of planktonic copepods were prepared and the same was updated with the records from our study which was conducted in both the estuaries from 2018 to 2019.

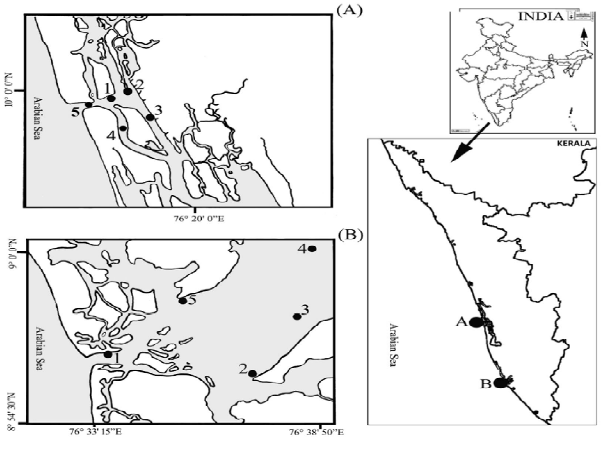

Fig. 1: Map of the study area; A) Vembanad estuary B) Ashtamudi estuary

RESULTS AND DISCUSSION

A total of 58 (56 species from Vembanad estuary and 52 species from Ashtamudi estuary) species of copepods under 32 genera and 22 families were recorded during the present study (Table 1). Forty-six species of Calanoids, 9 species of Cyclopoids and 6 species of Harpacticoids were observed from both the estuaries. Among which, 42 species of Calanoids noticed in VE whereas only 38 species of Calanoids observed from AE. Nine species of Cyclopoids and 5 species of Harpacticoids reported from VE during

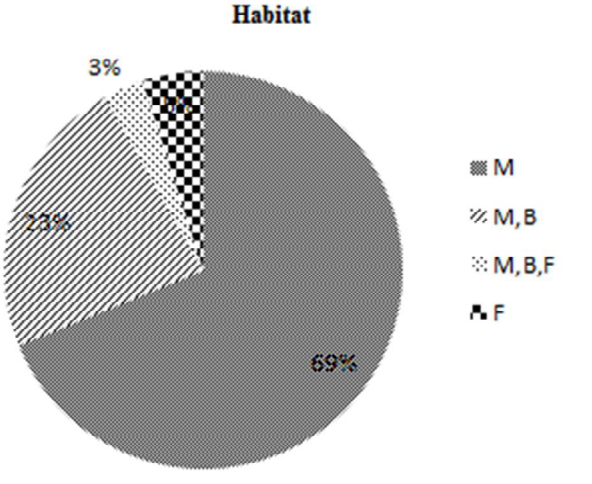

Fig.2: Habitat preferences of copepods in the estuaries during present study (M=Marine, B=Brackish, F=Freshwater)

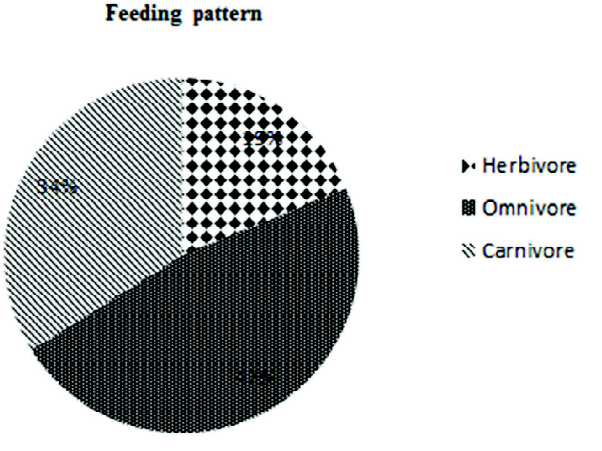

Fig. 3: Feeding pattern of copepods in the estuaries during present study

Table 1: Comparative assessments of copepod species available from historical studies and present study with systematic position, habitat preference (M=Marine, B=brackish water, F= Fresh water) and preferred feeding type from the estuaries (AE=Ashtamudi Estuary, VE=Vembanad Estuary, B= both Ashtamudi and Vembanad)

Sub phylum: Crustacea Brünnich, 1772
Class : Maxillopoda Milne - Edwards, 1840
Sub class: Copepoda Milne Edwards, 1840

Order: Calanoida Sars G. O., 1903

Family	Name of species	Habitat (M/B/F)	Preferred Feeding type	Occurrence (VE/AE/B)	Reference of records
Calanidae	*Canthocalanus pauper* Giesbrecht, 1888	M	Herbivore	B	George, 1958; Pillai,1971; Madhupratap,1979; Haridas *et al.,* 1982; Vineetha *et al*., 2015; **Present study**
	Nannocalanus minor Claus, 1863	M	Omnivore	B	**Present study**
	Undinula vulgaris Dana, 1849	M		VE	Madhupratap, 1979; Haridas, 1982; Vineetha *et al*., 2015
Subeucalanidae	*Subeucalanus subcrassus* Giesbrecht, 1888	M	Herbivore	B	Pillai *et al*., 1973; Silas and Pillai, 1975; Madhupratap, 1979; Vineetha *et al*., 2015; **Present study**
	Subeucalanus crassus Giesbrecht, 1888	M	Herbivore	B	George, 1958; Pillai *et al*., 1973; Madhupratap and Haridas, 1975; Madhupratap, 1979; Vineetha *et al*., 2015; **Present study**
	Subeucalanus monachus Giesbrecht, 1888	M	Herbivore	VE	Madhupratap, 1979, Haridas *et al,,* 1982
Eucalanidae	*Pareucalanus attenuates* Dana, 1849	M		VE	Haridas *et al.,* 1982
Paracalanidae	*Calocalanus pavo* Dana, 1852	M		VE	Madhupratap and Haridas, 1975
	Acrocalanus gibber Giesbrecht, 1888	M	Herbivore	B	Haridas, 1982; **Present study**
	Acrocalanus monachus Giesbrecht, 1888	M		VE	George, 1958; Rao *et al*., 1975; Madhupratap and Haridas 1975; Vineetha *et al*., 2015
	Paracalanus aculeatus Giesbrecht, 1888	M	Herbivore	B	George, 1958; Wellershus, 1969; Rao *et al*., 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap, 1979; Madhu *et al*. , 2007; **Present study**
	Paracalanus parvus parvus Claus, 1863	M		VE	Jyothibabu *et al.,* 2016; Nagarathinam *et al.,* 2021
	Parvocalanus crassirostris (Dahl F., 1894)	M		VE	Wellershus,1969;Rao *et al*., 1975; Pillai, 1973; Wellershus, 1974; Pillai *et al*., 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap, 1979; Haridas, 1982; Madhu *et al*., 2007
	Bestiolina similis Sewell, 1914	M	Herbivore	B	Wellershus, 1969; Pillai *et al*., 1973; Wellershus, 1974; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Rao *et al*., 1975; Silas and Pillai, 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; Santu *et al*., 2016; **Present study**
Centropagidae	*Centropages alcocki* Sewell, 1912	M	Omnivore	VE	Wellershus, 1970; Pillai and Pillai, 1973; Rao *et al*., 1975; Pillai *et al*., 1973; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Silas and Pillai, 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap 1980; Haridas, 1982; Madhu *et*

					al., 2007; Vineetha *et al*., 2015
	Centropages calaninus Dana, 1849	M	Omnivore	VE	Vineetha *et al*., 2015; **Present study**
	Centropages furcatus Dana, 1849	M	Omnivore	B	Pillai, 1971; Pillai and Pillai, 1973; Pillai *et al*., 1973; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Rao *et al*., 1975; Silas and Pillai, 1975; Haridas *et al*., 1982; Vineetha *et al*., 2015; **Present study**
	Centropages orsinii Giesbrecht, 1889	M	Omnivore	B	Pillai and Pillai, 1973; Pillai, 1971; Pillai *et al*., 1973; Silas and Pillai, 1975; Vineetha *et al*. 2015; Jyothibabu *et al.,* 2016; **Present study**
	Centropages tenuiremis Thompson I.C. & Scott A., 1903	M	Omnivore	B	Rao *et al*. 1975; Pillai *et al*. 1973; Madhupratap and Haridas, 1975; Silas and Pillai, 1975; 35Madhupratap *et al*. 1975; Madhupratap, 1979; Haridas, 1982; Vineetha *et al*., 2015; **Present study**
	Centropages trispinosus Sewell, 1914	M	Omnivore	B	Pillai 1971; Rao *et al*., 1975; Pillai *et al*., 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Haridas, 1982; **Present study**
	Isias cochinensis Pillai, 1975	M		VE	Pillai, 1975; Silas and Pillai, 1975
	Limnocalanus macrurus macrurus Sars G.O., 1863	M		VE	Nagarathinam *et al.,* 2021
Pseudodiaptomidae	*Pseudodiaptomus annandalei* Sewell, 1919	M,B,F	Herbivore	B	George, 1958; Wellershus, 1969; Pillai, 1971; Pillai and Pillai, 1973; Rao *et al*., 1975; Pillai *et al*., 1973; Wellershus 1974; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap & Rao 1979; Madhupratap, 1979; Madhupratap 1980; Haridas *et al*., 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; Jyothibabu *et al*., 2016; Nagarathinam *et al.,* 2021; **Present study**
	Pseudodiaptomus aurivillii Cleve, 1901	M,B	Herbivore	B	Wellershus, 1969; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Haridas *et al*., 1982; Madhu *et al*., 2007; **Present study**
	Pseudodiaptomus malayalus Wellershaus, 1969	M,B,F	Herbivore	VE	Wellershus, 1969; Rao *et al*., 1975; Pillai *et al*., 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap, 1979; Haridas, 1982; Madhu *et al*., 2007; Nagarathinam *et al.,* 2021; Vineetha *et al*., 2015
	Pseudodiaptomus tollingerae Sewell, 1919	M,B,F	Herbivore	VE	George, 1958; Pillai *et al*., 1973; Silas and Pillai, , 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap, 1979; Haridas, 1982; Madhu *et al*., 2007
	Pseudodiaptomus mertoni Früchtl, 1924	M,B,F	Herbivore	VE	Wellershus, 1969; Pillai, 1971; Rao *et al*., 1975; Pillai, 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Haridas, 1982; Vineetha *et al*., 2015
	Pseudodiaptomus serricaudatus Scott T., 1894	M,B	Herbivore	B	Wellershus1969; Pillai and Pillai, 1973; Pillai 1971; Pillai *et al*., 1973; Rao *et al*. 1975;Silas and Pillai, , 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975;Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; Nagarathinam *et al.,* 2021; **Present study**
	Pseudodiaptomus ardjuna Brehm, 1953	M,B	Herbivore	VE	Wellershus, 1969

	Pseudodiaptomus jonesi Pillai, 1970	M,B	Herbivore	VE	Wellershus, 1970; Pillai, 1973; Silas and Pillai, , 1975; Madhupratap and Haridas, 1975; Madhupratap *et al.* 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al.*, 2007
	Archidiaptomus aroorus Madhupratap &Haridas, 1978		M		VEMadhupratap and Haridas, 1978; Madhupratap, 1979; Haridas, 1982
Temoridae	*Temora discaudata* Giesbrecht, 1889	M	Omnivore	VE	Pillai *et al.*, 1973; Silas and Pillai, 1975; **Present study**
	Temora stylifera Dana, 1849	M	Omnivore	VE	Madhupratap and Haridas, 1975; Haridas, 1982; **Present study**
	Temora turbinata Dana, 1849	M	Omnivore	B	Pillai, 1971; Pillai and Pillai, 1973; Pillai, 1970; Pillai *et al.*, 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Haridas, 1982; Vineetha *et al.*, 2015; **Present study**
Candaciidae	*Candacia bradyi* Scott A., 1902	M	Carnivore	VE	Pillai *et al.* 1973; Madhupratap and Haridas, 1975; Silas and Pillai, , 1975; Haridas, 1982; Vineetha *et al.*, 2015; **Present study**
Pontellidae	*Calanopia elliptica* Dana, 1849	M	Carnivore	B	George, 1958, Pillai, 1971; Madhupratap, 1979; Haridas *et al.,* 1982; **Present study**
	Calanopia aurivilli Cleve, 1901	M	Carnivore	VE	**Present study**
	Calanopia seymouri Pillai, 1969	M	Carnivore	AE	**Present study**
	Calanopia thompsoni Scott A., 1909	M	Carnivore	AE	**Present study**
	**Calanopia metu Uysal & Shmeleva, 2004*	M	Carnivore	B	**Present study**
	Calanopia minor Scott A., 1902	M	Carnivore	VE	Pillai and Pillai, 1973; Madhupratap, 1979
	Labidocera acuta Dana, 1849	M	Carnivore	VE	Madhupratap and Haridas, 1975; Haridas ,1982; Vineetha *et al.*, 2015; Nagarathinam *et al.,* 2021
	Labidocera bengalensis Krishnaswamy, 1952	M	Carnivore	VE	**Present study**
	Labidocera kroyeri gallensis ThompsonI. I.C. & Scott A., 1903	M	Carnivore	B	George, 1958; Pillai *et al.*,1973; Silas and Pillai, 1975; Madhupratap, 1979
	Labidocera minuta Giesbrecht, 1889	M	Carnivore	VE	Pillai *et al.*, 1973; Silas and Pillai, 1975
	Labidocera pavo Giesbrecht, 1889	M	Carnivore	B	Pillai *et al.*, 1973; Silas and Pillai, 1975
	Labidocera pectinata Thompson I.C. & Scott A., 1903	M	Carnivore	B	George, 1958; Wellershus, 1969; Pillai, 1971; Pillai *et al.*, 1973; Pillai and Pillai, 1973; Rao *et al.*, 1975; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap, 1979; Madhupratap, 1980; Haridas *et al.*, 1982; Madhu *et al.*, 2007; Vineetha *et al.*, 2015
	Pontella danae Giesbrecht, 1889	M	Carnivore	VE	**Present study**
	Pontellopsis herdmani Thompson I.C. & Scott A., 1903	M	Carnivore	AE	**Present study**
Acartiidae	*Acartia (Odontacartia) bowmani* Abraham, 1976	M,B	Omnivore	B	Abraham,1976; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Madhu *et al.*, 2007; Vineetha *et al.*, 2015; **Present study**
	Acartia (Acanthacartia) bilobata Abraham, 1970	M	Omnivore	B	Abraham, 1970; Tranter and Abraham, 1971; Rao *et al.*, 1975; Pillai *et al.*, 1973; Silas and Pillai, 1975; Madhupratap and Haridas;1975; Madhupratap *et al.*, 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al.*, 2007; Santu *et al.*, 2016
	Acartia (Odontacartia) centrura	M,B	Omnivore	B	Wellershus,1969; Pillai, 1971; Tranter and Abraham, 1971; Pillai and

Giesbrecht, 1889				Pillai, 1973; Rao *et al*., 1975; Pillai, 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Pillai, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; Santu *et al*., 2016; Nagarathinam *et al.,* 2021; **Present study**
*Acartia (Odontacartia) erythraea*Giesbrecht, 1889		M,B	Omnivore	BWellershus, 1969; Pillai, 1971; Pillai and Pillai, 1973; Tranter and Abraham, 1971; Pillai *et al.* 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Haridas, 1982; Vineetha *et al*., 2015; Jyothibabu *et al.,* 2016; Nagarathinam *et al.,* 2021; **Present study**
Acartia (Acartia) danae Giesbrecht, 1889	M	Omnivore	B	Jyothibabu *et al.,* 2016; **Present study**
Acartia (Odontacartia) pacifica Steuer, 1915	M,B	Omnivore	B	Wellershus, 1969; Madhupratap and Haridas, 1975; Madhupratap, 1980; Haridas, 1982; Madhu *et al*., 2007; **Present study**
Acartia (Acanthacartia) plumosa Scott T., 1894	M,B	Omnivore	B	Wellershus, 1969; Tranter and Abraham, 1971; Rao *et al*., 1975; Pillai *et.al.,* 1973; Wellershus, 1974; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas *et al*., 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; Santu *et al*., 2016; Nagarathinam e*t al.,* 2021; **Present study**
Acartia (Euacartia) southwelli Sewell, 1914	M,B	Omnivore	B	Tranter and Abraham, 1971; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al*. 2007; Santu *et al*. 2016; Nagarathinam *et al., 2021*; **Present study**
Acartia (Odontacartia) spinicauda Giesbrecht, 1889		M,B	Omnivore	BWellershus, 1969; Pillai, 1971; Tranter and Abraham, 1971; Rao *et al*., 1975; Pillai and Pillai, 1973; Pillai *et al*. 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*. 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; **Present study**
Acartia (Acanthacartia) tropica Ueda & Hiromi, 1987		B	Omnivore	BMadhu *et al*., 2007; Santu *et al*., 2016
Acartia (Acartia) negligens Dana, 1849	M	Omnivore	VE	Haridas, 1982; Nagarathinam *et al.,* 2021
Acartiella gravelyi Sewell, 1919	M,B		B	George, 1958; Pillai, 1969; Wellershus, 1969; Tranter and Abraham, 1971; Rao *et al*., 1975; Pillai *et al.* 1973; Wellershus, 1974; Silas and Pillai, , 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*. 1975; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al.* , 2007; Vineetha *et al*., 2015; Jyothibabu *et al.,* 2016; Nagarathinam *et al.,* 2021; **Present study**
Acartiella keralensis Wellershaus, 1969	M,B		VE	Wellershus, 1969; Tranter and Abraham, 1971; Rao *et al*., 1975; Pillai *et al.* 1973;Wellershus, 1974; Silas and Pillai, , 1975; Madhupratap and Haridas,1975; Madhupratap *et al*., 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas *et al*. 1982; Madhu *et al*., 2007; Vineetha *et al.* , 2015

Tortanidae	*Tortanus (Tortanus) gracilis* Brady, 1883	M	Carnivore	B	Wellershus, 1969; Tranter and Abraham, 1971; Rao *et al.* 1975; Pillai *et al.* 1973; Wellershus, 1974; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap *et al*., 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu *et al*., 2007; Vineetha *et al*., 2015; **Present study**
	Tortanus (Tortanus) forcipatus Giesbrecht, 1889	M		VE	Vineetha *et al*., 2015
1. Euchaetidae	*Euchaeta sp. Philippi, 1843*	M		VE	**Present study**
Lucicutiidae	*Lucicutia flavicornis* Claus, 1863	M		VE	Haridas, 1982
Diaptomidae	*Allodiaptomus mirabilipes* Kiefer, 1936	F		B	Abraham, 1972; Madhupratap and Haridas, 1975; Rao *et al.* 1975; Silas and Pillai, 1975; Madhupratap, 1979; Haridas *et al*., 1982; Vineetha *et al*., 2015; Nagarathinam *et al.,* 2021; Jyothibabu *et al.,* 2016; **Present study**
	Heliodiaptomus cinctus Gurney, 1907	F		B	Pillai, 1971; Abraham, 1972; Rao *et al*. 1975; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap, 1979; Haridas, 1982; Vineetha *et al*., 2015; Jyothibabu *et al*., 2016; **Present study**
Order: Cyclopoida Burmeister, 1834					
Oithonidae	*Dioithona rigida* Giesbrecht, 1896	M	Omnivore	B	Wellershus,1970; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Thompson and Easterson, 1977; Madhupratap and Rao, 1979; Madhupratap, 1979; Haridas, 1982; Thompson, 1991; Vineetha *et al*., 2015; Jyothibabu *et al.,* 2016; Nagarathinam *et al.,* 2021; **Present study**
	Dioithona oculata Farran, 1913	M	Omnivore	VE	Silas and Pillai, 1975; Thompson, 1991
	Oithona brevicornis Giesbrecht, 1891	M,B	Omnivore	B	Wellershus, 1969; Wellershus, 1974; Madhupratap and Haridas 1975; Silas and Pillai, 1975; Thompson and Easterson, 1977; Madhupratap, 1979; Haridas, 1982; Thompson, 1991; Madhu *et al*., 2007; 2009;Vineetha *et al*., 2015; Jyothibabu *et al.,* 2016; Nagarathinam *et al.,* 2021; **Present study**
	Oithona hebes Giesbrecht, 1891	M,B,F	Omnivore	VE	Wellershus, 1969; Wellershus, 1974; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Thompson and Easterson, 1977; Madhupratap, 1979; Haridas, 1982; Thompson,1991
	Oithona nana Giesbrecht, 1893	M,B,F	Omnivore	VE	Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap, 1979; Thompson and Easterson ,1977;Haridas, 1982; Thompson, 1991
	Oithona plumifera Baird, 1843	M,B,F	Omnivore	B	Silas and Pillai, 1975;Haridas, 1982;Thompson, 1991; **Present study**
	Oithona attenuata Farran, 1913	M,B,F	Omnivore	VE	Thompson and Easterson, 1977; Thompson, 1991
	Oithona setigera setigera Dana, 1849	M	Omnivore	B	**Present study**
	Oithona similis Claus, 1866	M,B,F	Omnivore	VE	Thompson and Easterson, 1977; Thompson, 1991
	Oithona simplex Farran, 1913	M,B,F	Omnivore	VE	Thompson and Easterson, 1977; Thompson, 1991
	Oithona linearis Giesbrecht, 1891	M,B,F	Omnivore	VE	Thompson and Easterson, 1977
Oncaeidae	*Oncaea venusta* Philippi, 1843	M	Omnivore	B	Silas and Pillai, 1975; Thompson, 1991; Vineetha *et al*., 2015; **Present study**
	Oncaea clevei Früchtl, 1923	M		VE	Thompson, 1991

	Oncaea media Giesbrecht, 1891	M		VE	Silas and Pillai, 1975; Thompson, 1991
	Oncaea mediterranea Claus, 1863	M		VE	Thompson, 1991
Corycaeidae	*Triconia conifera* Giesbrecht, 1891	M		VE	Silas and Pillai, 1975; Thompson, 1991
	Corycaeus crassiusculus Dana, 1849	M,B	Carnivore	B	Thompson, 1991; Jyothibabu *et al.,* 2016; **Present study**
	Corycaeus speciosus Dana, 1849	M,B		VE	Thompson, 1991
	Ditrichocorycaeus andrewsi Farran, 1911	M,B		VE	Silas and Pillai, 1975; Thompson, 1991
	Ditrichocorycaeus dubius Farran, 1911	M		VE	Silas and Pillai, 1975; Thompson1, 991
	Ditrichocorycaeus affinis McMurrich,1916	M		VE	Thompson, 1991
	Ditrichocorycaeus asiaticus Dahl F., 1894	M,B		VE	Thompson, 1991
	Ditrichocorycaeus subtilis Dahl M., 1912	M,B		VE	Thompson, 1991
	Ditrichocorycaeus dahlia Tanaka, 1957	M		VE	Thompson, 1991
	Farranula gibbula Giesbrecht, 1891	M		VE	Thompson, 1991
	Onychocorycaeus pacificus Dahl F., 1894	M		VE	Thompson, 1991
	Onychocorycaeus catus Dahl F., 1894	M	Carnivore	B	Vineetha *et al*., 2015; **Present study**
	Onychocorycaeus agilis Dana 1849	M		VE	Thompson, 1991
Cyclopidae	*Mesocyclops Sars G.O., 1914*	F		B	Vineetha *et al*., 2015; **Present study**
Sapphirinidae	*Sapphirina sp.Thompson J., 1829*	M		VE	**Present study**
Order: Harpacticoida Sars G.O, 1903					
Miraciidae	*Macrostella gracilis*	M	Herbivore	B	Haridas, 1982; Jyothibabu *et al.,* 2016; **Present study**
Ectinosomidae	*Microsetella norvegica* Boeck, 1865	M,B	Omnivore	B	Jyothibabu *et al.,* 2016; **Present study**
	Microstella rosea Dana, 1847	M	Omnivore	AE	**Present study**

the study and only 8 species of Cyclopoids, 6 species of Harpacticoids reported from AE during the present study. Among the families, Pontellidae (13) and Acartiidae (9) represented the maximum number of species followed by Centropagidae (5) and Oithonidae (4) from the estuaries. In VE, Acartiidae (9) represents maximum number of species followed by pontellidae (8), centropagiidae (5) and Oithonidae (4). Whereas in AE, family pontellidae and Acartiidae (9) represents maximum number of species followed by Centropagidae and Oithonidae (4). An addition of common coastal species such as *Calanopia aurivillii, Calanopia saymouri, Calanopia thompsoni, Labidocera bengalensis, Pontellopsis herdmani, Pontella danae, Microsetella rosea, Oithona setigera, Longipedia sp., Pontella sp. Euchaeta sp.* were added to the list during the study. *Calanopia metu***,** a mediterranean calanoid copepod also collected during the study from the estuaries and the species reported for the first time in Indian waters. The samples were deposited in the national zoological collection of crustacean division ZSI/FPS of Zoological Survey of India, Kolkata and the reference ID issued is C8930/2.

During the present study, nearly 68% of the copepod species recorded from the AE was truly marine inhabitants followed by 24% of marine and brackish water forms and only 5% freshwater inhabitants (fig. 2). Only 3% of the species found in a wide habitat range from marine, brackish to freshwater habitats. Most of the species recorded were marine inhabitants which emphasize the expansion of distribution of such species to the estuarine waters. Salt water incursion from Arabian Sea to the estuarine waters attributed the presence of coastal species into the estuaries (Vineetha *et al.,* 2015). Also, marine species were migrated to the estuarine waters for breeding and spawning activities (Pillai, 1971). Higher diversity of marine copepods which directly indicates the conducive condition prevailed in the estuary for the successful survival of the copepod community in the estuary.

Generally, the feeding pattern of Copepods recorded from the VE and AE ranged from herbivores, omnivores to carnivores. Omnivores contribute 48% of the sample followed by carnivores (33%) and herbivores (19%) from the estuary (fig.3). Most of the copepod species in the estuaries prefers omnivorous food in their daily diet. This indicates that the estuary supports plenty of both plant and animal matter as food which ultimately provides nutritionally enriched environments for copepod species irrespective of larvae and adult population. And also, the ability to eat different types of food (omnivore feeding) may enrich the chance of getting a nutritionally complete

Table 2: List of families reported from the Vemband (VE) and Ashtamudi (AE) estuaries during the study

Family	Number of species recorded from both the estuaries (1958-2021)	Number of species recorded (1958 - 2021)		Number of species recorded from both the estuaries (2018-2019)	Number of species recorded (2018-2019)	
		VE	AE		VE	AE
Calanidae	3	3	2	2	2	2
Subeucalanidae	3	3	3	2	2	2
Eucalanidae	1	1	-	-	-	-
Paracalanidae	7	7	3	3	3	3
Centropagidae	8	8	5	5	5	4
Pseudodiaptomidae	9	9	4	3	3	3
Temoridae	3	3	1	3	3	1
Candaciidae	1	1	1	1	1	1
Pontellidae	15	11	8	13	8	9
Acartiidae	13	13	12	9	9	9
Tortanidae	2	2	1	1	1	1
Lucicutiidae	1	1	1	-	-	-
Diaptomidae	2	2	2	2	2	2
Euchaetidae	1	1	-	1	1	-
Oithonidae	11	11	6	4	4	4
Oncaeidae	5	5	1	1	1	1
Corycaeidae	12	12	2	2	2	2
Ectinosomatidae	2	1	2	2	1	2
Miraciidae	1	1	1	1	1	1
Tachidiidae	1	1	1	1	1	1
Canuellidae	1	1	-	-	-	-
Ameiridae	1	1	1	1	1	1
Tegastidae	1	1	-	-	-	-
Longipediidae	1	1	1	1	1	1

ration for the species (Kleppel, 1993).

Review of literature collected from 1958-2021 reports the presence of 91 species of copepods under 39 genera of 20 families and 3 orders viz., Calanoida, Cyclopoida and Harpacticoida (Table 1). Among the three orders, Calanoida represents relatively higher number of species (63% from VE and 74% from AE) than Order Cyclopoida (30% from VE and 16% from AE) and Order Harpacticoida (7% from VE and 10% of species from AE). Family Acartiidae and Corycaeidae represents the maximum number of species (13) followed by Oithonidae (10), and Pontellidae (7). In the Vembanad estuary order Calanoida, Cyclopoida and Harpacticoida were represented by 13 families, 3 families and 5 families respectively. Family Acartiidae and Corycaeidae (13) have the maximum number of species followed by Oithonidae (10), Pseudodiaptomidae (9) and Centropagidae (8). In the case of Ashtamudi estuary, Calanoids, Cyclopoida and Harpacticoida are represented by 10, 3 and 3 families respectively. Among the families, Acartiidae (12) reports the maximum number of species followed by Oithonidae (6), Pseudodiaptomidae (4), Pontellidae (4) and Centropagidae (3) (Table 2). About the 91 species of copepods, 41 species were common in both the estuaries. Vembanad estuary reports 90 species of copepods whereas only 41 species were recorded from the Ashtamudi estuary. From previous studies it is observed that six new species of copepods such as Acartia *(Acartiella) keralensis, Pseudodiaptomus malayalus, Acartia bilobata, Archidiaptomus aroorus, Isias cochinensis* and *Acartia bowmani* were added to the science from the Vembanad estuary. Vembanad estuary reports more species of copepods than the Ashtamudi estuary because, Vembanad estuary is more exploited than the Ashtamudi estuary in terms of copepod studies.

CONCLUSION

Analysis of copepod diversity from the major estuaries of Kerala during 1958-2021 revealed the presence of 105 copepods with an addition of new recorded species. Higher number of marine migrant species of copepods in the estuary shows the potential of the estuary to serve as a

feeding and nursery ground for many species. On comparison with historical studies, diversity of copepods in the estuarine waters was increased during the present study. The present study reports more species of copepods with an addition of common coastal species such as *Calanopia aurivillii, Calanopia saymouri, Calanopia thompsoni, Labidocera bengalensis, Pontellopsis herdmani, Pontella danae etc.* and a new recorded species *Calanopia metu* and also some species were not recorded from the estuaries. The diversity and abundance of copepods in the estuarine waters were dependent on ecological and environmental conditions prevailing in the estuary. Copepods are highly sensitive to the environmental changes and the changes can be reflected through its composition, abundance, distribution and diversity. For the past decades, the estuaries have changed a lot as it is the active site for many activities including mining, dredging, tourism activities, husk retting, trafficking etc. For understanding the ecosystem changes in the copepod community, continuous monitoring and study need to be conducted.

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