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### 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° N-76.23°E) and Ashtamudi (8.93°N-76.54°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

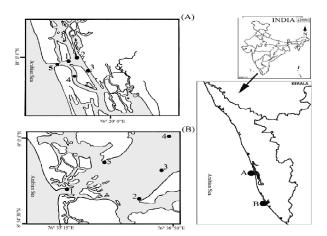


Fig. 1: Map of the study area; A) Vembanad estuary B)
Ashtamudi estuary

prepared and the same was updated with the records from our study which was conducted in both the estuaries from 2018 to 2019.

#### 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

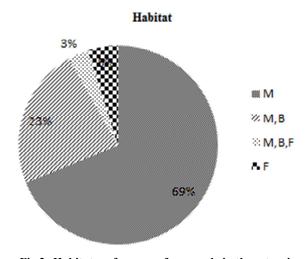


Fig.2: Habitat preferences of copepods in the estuaries during present study (M=Marine, B=Brackish, F=Freshwater)

Feeding pattern

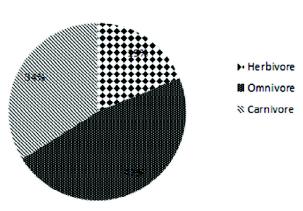


Fig. 3: Feeding pattern of copepods in the estuaries during present study

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: C Class: Maxillo Sub class: Cope	Sub phylum: Crustacea Brünnich, 1772 Class: Maxillopoda Milne - Edwards, 1840 Sub class: Copepoda Milne Edwards, 1840				
Order: Calanoi	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	В	George, 1958; Pillai,1971; Madhupratap,1979; Haridas et al., 1982; Vineetha et al., 2015: <b>Present study</b>
	Nannocalanus minor Claus, 1863 Undinula vuloaris Dana 1849	ΣΣ	Omnivore	B	Present study Madhumatan 1979: Haridas 1982: Vincertha et al. 2015
Subeucalanidae		×	Herbivore	B :	Pillai et al., 1973; Silas and Pillai, 1975; Madhupratap, 1979;
	Subeucalanus crassus Giesbrecht, 1888	M	Herbivore	В	Vineetha et al., 2015; <b>Present study</b> George, 1958; Pillai et al., 1973; Madhupratap and Haridas, 1975; Madhupratap 1979. Vineetha et al., 2015. <b>Present study</b>
	Subeucalanus monachus Giesbrecht, 1888	M	Herbivore	VE	Madhupratap, 1979, Haridas <i>et al.</i> , 1982
Eucalanidae	Pareucalanus attenuates Dana, 1849	M		VE	Haridas et al., 1982
Paracalanidae	Calocalanus pavo Dana, 1852	Σ		VE	Madhupratap and Haridas, 1975
	Acrocalanus gibber Giesbrecht, 1888	M	Herbivore	В	Haridas, 1982; Present study
	Acrocalanus monachus Giesbrecht, 1888	M		VE	George, 1958; Rao et al., 1975; Madhupratap and Haridas 1975; Vincarba at al., 2015
	Dangalanie amilanie Giechracht 1888	Σ	Harbiyora	α	VIII.Court et al., 2013 George 1058: Wellarchus 1060: Beo et al. 1075: Medhumraten and
	i aracaianas acaicatas Orosonecia, 1000	TAT		۵	Haridas, 1975; Madhupratap et al., 1975; Madhupratap, 1979;
	Paracalanus parvus parvus Claus, 1863	∑ ;		VE	Jyothibabu et al., 2016; Nagarathinam et al., 2021
	Parvocalanus crassirostris (Dahl F., 1894)	${\sf Z}$		۸E	Welershus 1969; Kao
					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	В	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;
					Madhiuptarap, 1980, 17a1thas, 1982, Madhiu <i>et al.</i> , 2007, Vincetha <i>et al.</i> , 2015; Santu <i>et al.</i> , 2016; <b>Present study</b>
Centropagidae	Centropages alcocki Sewell, 1912	×	Omnivore	<b>VE</b>	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

	Centropages calaninus Dana, 1849	Σ	Omnivore	VE	al., 2007; Vineetha et al., 2015 Vineetha et al., 2015; <b>Present study</b>
	Centropages furcatus Dana, 1849	Σ	Omnivore	В	Pillai, 1971; Pillai and Pillai, 1973; Pillai <i>et al.</i> , 1973; Madhupratap and Haridas, 1975; Madhupratap <i>et al.</i> , 1975; Rao <i>et al.</i> , 1975; Silas and Pillai, 1975; Haridas <i>et al.</i> , 1982; Vincetha <i>et al.</i> , 2015; <b>Present</b>
	Centropages orsinii Giesbrecht, 1889	M	Omnivore	В	study Pillai and Pillai, 1973; Pillai, 1971; Pillai <i>et al.</i> , 1973; Silas and Pillai,
	Centronages tenuiremis Thomnson 1C	Σ	Omnivore	22	1975; Vineetha et al. 2015; Jyothibabu et al., 2016; <b>Present study</b> Rao et al. 1975: Pillai et al. 1973: Madhumanan and Haridas. 1975:
	& Scott A., 1903	!		1	Silas and Pillai, 1975; 35Madhupratap et al. 1975; Madhupratap, 1979; Haridas, 1982; Vineetha et al., 2015; <b>Present study</b>
	Centropages trispinosus Sewell, 1914	M	Omnivore	В	Pillai 1971; Rao et al., 1975; Pillai et al., 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap et al., 1975; Haridas, 1989: Present endy
	Isias cochinensis Pillai, 1975	M		VE	rialidas, 1962, <b>riesent suuy</b> Pillai, 1975; Silas and Pillai, 1975
	Limnocalanus macrurus macrurus Sars GO., 1863	$\mathbb{Z}$		VE	Nagarathinam <i>et al.</i> , 2021
Pseudodi aptomidae	Pseudodiaptomus annandalei Sewell, 1919	M,B,F	Herbivore	В	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; Vincetha et al., 2015;
	Pseudodiaptomus aurivillii Cleve, 1901	M,B	Herbivore	В	Jyothibabu <i>et al.</i> , 2016; Nagarathinam <i>et al.</i> , 2021; <b>Present study</b> Wellershus, 1969; Silas and Pillai, 1975; Madhupratap and Haridas,
					1975; Madhupratap <i>et al.</i> , 1975; Haridas <i>et al.</i> , 1982; Madhu <i>et al.</i> , 2007; <b>Present study</b>
	Pseudodiaptomus malayalus	M,B,F	Herbivore	VE	Wellershus, 1969; Rao et al., 1975; Pillai et al., 1973; Silas and Pillai,
	Wellershaus, 1909				1975, Madnupratap and Haridas, 1975, Madnupratap et at., 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	$\Lambda E$	George, 1958; Pillai et al., 1973; Silas and Pillai, , 1975; Madhupratap and Haridas, 1975; Madhupratap et al., 1975; Madhupratap, 1979;
	Pseudodiaptomus mertoni Früchtl, 1924	M,B,F	Herbivore	VE	Haridas, 1982; Madhu <i>et al.</i> , 2007 Wellershus, 1969; Pillai, 1971; Rao <i>et al.</i> , 1975; Pillai, 1973; Silas
					and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap <i>et al.</i> , 1975; Haridas, 1982; Vineetha <i>et al.</i> , 2015
	Pseudodiaptomus serricaudatus Scott T., 1894 M,B	94 M,B	Herbivore	В	Wellershus 1969; 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 <i>et al.</i> , 2007; Vincetha <i>et al.</i> , 2015; Nagarathinam <i>et al.</i> , 2021; <b>Present</b>
	Pseudodiaptomus ardjuna Brehm, 1953	M,B	Herbivore	VE	stuay 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, 1979; Madhupratap, 1980; Haridas, 1982; Madhu et al., 2007
	Archidiaptomus aroorus Madhupratap & Haridas, 1978	as, 1978	M		VEMadhupratap and Haridas, 1978; Madhupratap, 1979; Haridas, 1982
Temoridae	Temora discaudata Giesbrecht, 1889 Temora stylifera Dana, 1849	∑ ≥	Omnivore	VE	Pillai <i>et al.</i> , 1973; Silas and Pillai, 1975; <b>Present study</b> Madhunratan and Haridas 1975; Haridas 1982; <b>Present study</b>
	Temora turbinata Dana, 1849	M	Omnivore	В	Fillai, 1971; Pillai and Pillai, 1973; Pillai, 1970; Pillai et al., 1973;
					Silas and Piliai, 1973; Madhupratap and Haridas, 1973; Haridas, 1982; Vineetha <i>et al.</i> , 2015; <b>Present study</b>
Candaciidae	Candacia bradyi Scott A., 1902	M	Carnivore	VE	Pillai <i>et al.</i> 1973; Madhupratap and Haridas, 1975; Silas and Pillai, , 1975; Haridas, 1982; Vineetha <i>et al.</i> , 2015; <b>Present study</b>
Pontellidae	Calanopia elliptica Dana, 1849	M	Carnivore	В	George, 1958, Pillai, 1971; Madhupratap, 1979; Haridas et al., 1982; Present etudy
	Calanonia aurivilli Cleve, 1901	Σ	Carnivore	VE	Present study
	Calanopia seymouri Pillai, 1969	×	Carnivore	AE	Present study
	Calanopia thompsoni Scott A., 1909	$\mathbb{Z}$	Carnivore	AE	Present study
	*Calanopia metu Uysal & Shmeleva, 2004	M	Carnivore	В	Present study
	Calanopia minor Scott A., 1902	$\mathbb{Z}$	Carnivore	VE	Pillai and Pillai, 1973; Madhupratap, 1979
	Labidocera acuta Dana, 1849	$\mathbb{M}$	Carnivore	$\Lambda E$	Madhupratap and Haridas, 1975; Haridas, 1982; Vineetha et al., 2015;
	Lahidocera henoalensis Krishnaswamy 1952	Σ	Carnivore	VF	Nagarathinam <i>et at.</i> , 2021 <b>Present study</b>
	I ahidocera troweri aallensis Thompson!	€ ≥	Carnivore	<u>,</u> u	George 1058: Pillai et al 1073: Silas and Pillai 1075: Madhumatan
	I.C. & Scott A., 1903	į		i .	1979
	Labidocera minuta Giesbrecht, 1889	M	Carnivore	$\Lambda$ E	Pillai et al., 1973; Silas and Pillai, 1975
	Labidocera pavo Giesbrecht, 1889	M	Carnivore	В	Pillai et al., 1973; Silas and Pillai, 1975
	Labidocera pectinata Thompson	$\mathbb{Z}$	Carnivore	В	George, 1958; Wellershus, 1969; Pillai, 1971; Pillai et al., 1973; Pillai
	I.C. & Scott A., 1903				and Pillai, 1973; Rao <i>et al.</i> , 1975; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap, 1979; Madhupratap, 1979; Madhupratap, 1979; Madhupratap, 1979; Madhu <i>et al.</i> , 2007; Vineetha <i>et al.</i> , 2015
	Pontella danae Giesbrecht, 1889	M	Carnivore	VE	Present study
	Pontellopsis herdmani Thompson I.C. & Scott A., 1903	M	Carnivore	ΑE	Present study
Acartiidae	Acartia (Odontacartia) bowmani Abraham, 1976	M,B	Omnivore	В	Abraham, 1976; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Madhu et al., 2007; Vincetha et al., 2015;
	4 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	7		þ	Present study
	Acarha (Acanthacarha) bilobata Abraham, 1970	Σ	Omnivore	m m	Abraham, 1970; Iranter and Abraham, 1971; Kao <i>et al.</i> , 1975; Pillal <i>et al.</i> , 1973; Silas and Pillai, 1975; Madhupratap and Haridas;1975; Madhupratap <i>et al.</i> , 1975; Madhupratap and Rao, 1979; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu <i>et al.</i> , 2007; Santu
	Acartia (Odontacartia) centrura	M,B	Omnivore	В	et al., 2016 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 <i>et al.</i> , 2007; Vineetha <i>et al.</i> , 2015; Santu <i>et al.</i> , 2016; Nagarathinam <i>et al.</i> , 2021; <b>Present st</b> ndv
Acartia (Odontacartia) erythraeaGiesbrecht, 1889	M,B	Omnivore	BWellershus, 1969; Pillai, 1971; Pillai and Pillai, 1973; Tranter and Abraham, 1971; Pillai <i>et al.</i> 1973; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap <i>et al.</i> , 1975; Haridas, 1982; Vineetha <i>et al.</i> , 2015; Jyothibabu <i>et al.</i> , 2016; Nagarathinam <i>et al.</i> , 2021;
Acartia (Acartia) danae Giesbrecht, 1889 M Acartia (Odontacartia) pacifica Steuer, 1915 M,B	Omnivore Omnivore	ВВ	Jyothibabu et al., 2016; Present study Wellershus, 1969; Madhupratap and Haridas, 1975; Madhupratap,
Acartia (Acanthacartia) plumosa Scott T., 1894M,B	Omnivore	В	Wellershus, 1969; Tranter and Abraham, 1971; Rao <i>et al.</i> , 1975; Pillai
			et.at., 1975; Weltershus, 1974; Shas and Pilla, 1975; Madnupratap 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; Naggarathinam et al., 2021: Present study
Acartia (Euacartia) southwelli Sewell, 1914 M,B	Omnivore	В	Tranter and Abraham, 1971; Madhupratap and Haridas, 1975; Madhupratap et al., 1975; Madhupratap and Rao, 1979; Madhupratap, 1980; Haridas, 1982; Madhu et al. 2007; Santu et al. 2016: Nagarahinam et al., 2007; 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; Vincetha et al., 2015; Present et al., 2015;
Acartia (Acanthacartia) tropica Ueda & Hiromi, 1987 Acartia (Acartia) negligens Dana, 1849 M Acartiella gravelyi Sewell, 1919 M,B	B Omnivore	Omnivore VE B	Frescin study  BMadhu <i>et al.</i> , 2007; Santu <i>et al.</i> , 2016  Haridas, 1982; Nagarathinam <i>et al.</i> , 2021  George, 1958; Pillai, 1969; Wellershus, 1969; Tranter and Abraham, 1971; Rao <i>et al.</i> , 1975; Pillai <i>et al.</i> 1973; Wellershus, 1974; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap <i>et al.</i> 1975; Madhupratap, 1979; Madhupratap, 1980; Haridas, 1982; Madhu <i>et al.</i> 2017. Vincetha <i>et al.</i> 2015: Evorhibabu <i>et al.</i> 2016.
Acartiella keralensis Wellershaus, 1969 M,B		VE	Nagarathinam et al., 2021; <b>Present study</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

Tortanidae	Tortanus (Tortanus) gracilis Brady, 1883	Σ	Carnivore	В	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, 1970; Wadhu, et al., 2007; Vinesaha, et al., 2017; Present et al., 2007; Vinesaha, et al., 2007; Vinesa
1. Euchaetidae Lucicutiidae Diaptomidae	Tortanus (Tortanus) forcipatus Giesbrecht, 1889 M Euchaeta sp. Philippi, 1843 M Lucicutia flavicornis Claus, 1863 M Allodiaptomus mirabilipes Kiefer, 1936 F	889 M M M F		VE VE B	Vincetha et al., 2015  Present study  Haridas, 1982  Abraham, 1972; Madhupratap and Haridas, 1975; Rao et al., 1975; Silas and Pillai, 1975; Madhupratap, 1979; Haridas et al., 1982; Vincetha et al., 2015; Nagarathinam et al., 2021; Jyothibabu et al., 2016.
,	Heliodiaptomus cinctus Gurney, 1907	ĹŦij		В	Pillai, 1971; Abraham, 1972; Rao <i>et al.</i> 1975; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Madhupratap, 1979; Haridas, 1982; Vincetha <i>et al.</i> , 2015; Jyothibabu <i>et al.</i> , 2016; <b>Present study</b>
Order: Cyclope Oithonidae	Order: Cyclopoida Burmeister, 1834 Oithonidae Dioithona rigida Giesbrecht, 1896	Σ	Omnivore	В	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; <b>Present study</b>
	Dioithona oculata Farran, 1913 Oithona brevicornis Giesbrecht, 1891	M M,B	Omnivore Omnivore	VE B	Silas and Pillai, 1975; Thompson, 1991 Wellershus, 1969; Wellershus, 1974; Madhupratap and Haridas 1975; Silas and Pillai, 1975; Thompson and Easterson, 1977; Madhupratap, 1979; Haridas, 1982; Thompson, 1991; Madhu <i>et al.</i> , 2007; 2009; Vincetha <i>et al.</i> , 2015; Jyothibabu <i>et al.</i> , 2016; Nagarathinam
	Oithona hebes Giesbrecht, 1891	M,B,F	Omnivore	$\Lambda E$	Wellershus, 1969; Wellershus, 1974; Silas and Pillai, 1975; Madhupratap and Haridas, 1975; Thompson and Easterson, 1977; Madhupratan, 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 Oithona attenuata Farran, 1913 Oithona setigera setigera Dana, 1849 Oithona similis Claus, 1866	M,B,F M,B,F M M,B,F	Omnivore Omnivore Omnivore	$\begin{array}{c} B \\ VE \\ VE \end{array}$	Silas and Pillai, 1975; Haridas, 1982; Thompson, 1991; <b>Present study</b> Thompson and Easterson, 1977; Thompson, 1991 <b>Present study</b> Thompson and Easterson, 1977; Thompson, 1991
Oncaeidae	Oithona simplex Farran, 1913 Oithona linearis Giesbrecht, 1891 Oncaea venusta Philippi, 1843	M,B,F M,B,F M	Omnivore Omnivore Omnivore	$\begin{array}{c} VE \\ VE \end{array}$	Thompson and Easterson, 1977; Thompson, 1991 Thompson and Easterson, 1977 Silas and Pillai, 1975; Thompson, 1991; Vineetha et al., 2015;
	Oncaea clevei Früchtl, 1923	M		VE	Present study Thompson, 1991

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

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)	re	er of species corded (8 - 2021)	Number of species recorded from both the estuaries (2018-2019)	rec	of species orded 3-2019)
		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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