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Biochemical composition of wild copepods, *Acartia spinicauda* and *Oithona similis*, from Parangipettai coastal waters in relation to environmental parameters

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Abstract: *Percentage composition of protein, lipid, carbohydrate and amino acids of copepods, Acartia spinicauda and Oithona similis collected from Parangipettai coastal waters were estimated following standard methodologies. Of the principal biochemical constituents, protein formed the major component followed by lipid and carbohydrate. Biochemical composition analysis of wild copepods indicated their nutritional rank. The ranges of protein, lipid and carbohydrate (%) contents (of A. spinicauda and O. similis) were 67.33-75.45; 12.42-16.58; 6.69-7.98 (Stn 1); 68.10-74.62; 12.65-17.81; 4.41-7.34 (Stn 2); 68.65-74.93; 14.55-17.69; 4.01-7.90 (Stn 3) and 59.53-69.61; 10.76-17.68; 3.43-6.59 (Stn 1); 62.39-67.09; 10.26-15.65; 3.78-5.85 (Stn 2) and 59.57-67.60; 9.89-15.44; 3.71-5.72 (Stn 3) respectively. Totally 16 amino acids were observed in these wild copepods, with threonine, glutamic acid, alanine, aspartic acid, serine, valine and methionine as the dominant ones. The minimum and maximum values of atmospheric and surface water temperatures (°C), salinity (‰), pH and dissolved oxygen (ml* l^{-1}*) were 28.5-35; 28.7-34.2; 14.5-35.7; 7.4-8.6 and 3.0-7.2 respectively. The ranges (µM) of nitrate, nitrite, phosphate and silicate were 7.9-52.9; 0.6-9.6; 0.5-7.5 and 8.2-140.5 respectively. The results supported the view that protein may function as a metabolic reserve in copepods and that the availability of a constant supply of food may render large amount of lipid storage unnecessary in tropical copepods.*

Key words: *Copepods, Acartia spinicauda, Oithona similis, Biochemical composition, Physico-chemical characteristics*
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Introduction

Copepods (Crustacea: Arthropoda) are the most abundant and probably the most ecologically significant zooplanktonic animals of the first consumer level of the marine food-chain. They are considered to be "nutritionally superior live feeds" for commercially important cultivable species, as they are valuable source of proteins, lipids, carbohydrates and enzymes all of which play an important role in digestion and also enhance the metamorphosis of larvae (Nanton and Castell, 1999; Stottrup *et al*., 1999; Stottrup, 2000; Cutts, 2001; Hernandez Molejon and Alvarez-Lajonchere, 2003; Lee *et al*., 2005; Rajkumar and Kumaraguru Vasagam, 2006; Rajkumar *et al*., 2008). Most of the fish and crustacean species mainly depend on zooplankton (copepods) throughout their life stages and some species even feed exclusively on copepods during their entire life. Studies on proximate composition of various zooplankton groups imply that the composition values may have an important role in the ecological, physiological functions, metabolism, nutritive value besides reproductive and energetic aspects of the marine ecosystem (Maruthanayagam and Subramanian, 1999; Nageswara Rao and Krupanidhi, 2001; Ashok Prabhu *et al*., 2005; Ikeda *et al*., 2006; Ashok Prabhu and Rajkumar, 2007; Rajkumar *et al*., 2008).

Some reports are available on the general quantitative aspects of proximate composition of wild zooplankton (Goswami *et al*., 2000; Ashok Prabu *et al*., 2005; Ashok Prabu and Rajkumar, 2007; Rajkumar *et al*., 2008). Although the amino acids of copepods are utilized as energy substrate by the fish larwae, only limited information is available (Santhanam and Perumal, 2001; Rajkumar and Kumaraguru Vasagam, 2006; Ashok Prabu and Rajkumar, 2007; Rajkumar *et al*., 2008). Hence the present investigation on the seasonal variations in the biochemical composition *viz*. protein, lipid, carbohydrate, moisture, ash content and amino acid profiles of copepods, *Acartia spinicauda* and *Oithona similis* collected from the Parangipettai coastal waters in relation to environmental parameters from October 2002 to September 2003.

Materials and Methods

For the present investigation, three sampling stations , situated in the Vellar estuary and the neritic region of Bay of Bengal near Parangipettai along the Southeast coast of India were chosen (N. Lat. 11° 29'; E. Long 79° 46'). The Station 1 is in the neritic zone, Station 2 is 3 km away from the Vellar estuarine-mouth and the Station-3 is situated 1.5 km west of Vellar-mouth, just opposite to the Marine Biological Station of Annamalai University.

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Field data like temperature, salinity, dissolved oxygen and pH were measured during forenoon. Atmospheric and surface water temperatures were measured using standard mercury filled centigrade thermometer. Salinity was estimated with the help of a hand refractometer (Atago, Japan) and pH was measured using Elico pH meter (Model LC-120). Dissolved oxygen was estimated by the modified Winkler's method, described by Strickland and Parsons (1972). For the analysis of nutrients, surface water samples were collected in clean polyethylene bottles and kept in an ice box and transported immediately to the laboratory. The water samples were filtered using a Millipore filtering system (MFS) and analyzed for dissolved inorganic phosphate, nitrate, nitrite and reactive silicate by adopting the standard methods described by Strickland and Parsons (1972).

Collection and Isolation: Zooplankton samples were collected fortnightly in every month and hence the results are given in I and II from the study areas by horizontal-surface towing of a plankton net (0.35 m diameter opening), made up of bolting silk cloth (No. 10, mesh size 158-µm) for 30 min. The zooplankton samples were immediately transported to the laboratory and thoroughly rinsed to reduce contamination by unwanted organisms and the copepods were identified under the microscope using the key provided by Kasturirangan (1963). After collection, the zooplankton was screened to isolate the size fraction containing predominantly adult copepods and later-stage copepodids of *A. spinicauda* and *O. similis.* This was achieved by a first coarse screening through a 500-µm mesh to remove the fish and prawn larvae. Then the samples were rinsed for 2 hr in a zooplankton washer (Schipp *et al*., 1999) fitted with a 190-µm mesh screen used to remove rotifers and nauplii of copepods and barnacles. After rinsing, the remaining adult copepods and larger copepodids were used for the analysis of biochemical composition.

Biochemical composition: Biochemical composition analysis was done for protein, dry matter and ash content following standard methods (AOAC, 1995). Carbohydrate and lipid were analysed following the methods of Dubois *et al*. (1956) and Folch *et al*. (1956) respectively. Triplicate samples were analysed and average values were taken.

Amino acid estimation: The protein bound amino acids were separated from free amino acids using 6% TCA solution (Finn *et al*., 1995). Amino acids were analysed by sealed tube hydrolysis with 6N HCL for 22 hr at 110°C (Spackman *et al*., 1958; Finlayson, 1964). After hydrolysis, the acid was evaporated in vacuum oven and the sample was kept in a NaOH desiccator to remove traces of acid. The residue was brought into 1 ml of sample diluent (pH 2.20). Amino acids were analysed using Shimadzu HPLC model LC-10A (Shimadzu corp., Japan). Separation of amino acid was performed in a column (Shimpack ISC-07/S 1504 Na) packed with a strongly acidic Na^+ type cation exchange resin (Styrene-divinyl benzene copolymer with sulfinic group) under gradient elusion. The amino acids were detected and quantified using a fluorescent detector (FLD-6A) after post column derivitization with O-pthaladehyde and 2-mercaptoethanol. Amino acid standard solution (Sigma-aldrich Inc., USA) for fluorescent detection was used as external standard. For every ten-sample injection, one standard run was carried out. The n mole units of amino acids were converted to µg units by multiplying with its molecular weight X 1000.

Statistical analysis: Simple correlation coefficient (r) was made for the statistical interpretation of the physico-chemical characteristics and two-way analysis (ANOVA) was employed to find out variations in all hydrographic parameters between stations and seasons. The collected data were subjected to standard statistical analysis for PRIMER – 6.0. A suite of statistical analyses were carried out using statistical packages Origin Pro (Version 7.5) and SPSS (Version-16) to elucidate the inter and interannual variations among the physico-chemical parameters. Biochemical compositions were compared by one way ANOVA. Duncan's multiple range test (Duncan, 1955) was applied to ascertain any significant differences between treatment means. All the above mentioned statistical analyses were performed using SPSS statistical software (Version 16 for Windows, SPSS, Chicago, IL, USA). Limits of significance for all critical ranges were set at $p<0.05$.

Results and Discussion

Atmospheric and surface water temperature varied from 28.5°C to 35°C and 28.7°C to 34.2°C respectively for all the three sites, with a minimum and maximum mean values (±SD) of 30.97±1.80 (Stn. 1) and 31.78±1.63 (Stn. 3) and 31.08±1.43 (Stn. 1) and 31.59±1.36 (Stn. 2) (Fig. 1, 2). Salinity values varied from 14.5 to 35.7‰ for all the three sites, with a minimum and maximum mean values (±SD) of 31.50±4.0‰ (Stn. 3) and 34.47±1.38‰ (Stn. 1) (Fig. 3) pH in water ranged between 7.4 and 8.6 for all the three sites, with a minimum and maximum mean values (±SD) of 7.93±0.29 (Stn. 3) and 8.24±0.27 (Stn. 1) (Fig. 4). Variation in dissolved oxygen content was from 3.0 to 7.2 ml l^{-1} for all the three sites, with a minimum and maximum mean values (±SD) of 3.66±0.35 ml l^{-1} (Stn. 1) and 4.62±1.05 ml l^{-1} (Stn. 3) (Fig. 5). Nitrate values varied from 7.9 to 52.9 µM for all the three sites, with a minimum and maximum mean values (±SD) of 21.01±11.18 µM (Stn. 1) and 26.35±12.68 µM (Stn. 3) (Fig. 6). Nitrite values ranged between 0.6 and 9.6 µM for all the three sites, with a minimum and maximum mean values (±SD) of 3.30±1.92 µM (Stn. 1) and 5.08±2.47 µM (Stn. 3) (Fig. 7). Phosphate concentration varied from 0.5 to 7.5 µM for all the three sites, with a minimum and maximum mean values (±SD) of 1.75±1.15 µM (Stn. 1) and 3.25±1.65 µM (Stn. 3) (Fig. 8). Silicate values ranged between 8.2 to 140.5 µM for all the three sites, with a minimum and maximum mean values (±SD) of 35.78±31.38 µM (Stn. 1) and 45.45±36.49 µM (Stn. 3) (Fig. 9).

The surface water temperature showed an increasing trend from December to April. Generally, surface water temperature is influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mix up with ebb and flow from

Table - 1: Proximate composition of copepod, *A. spinicauda* at Station 1 (Sea)[1]

Months		Parameter (%)				
		Moisture*	**Protein**	**Lipid**	**Carbohydrate**	**Ash**
October'02	**I**	84.38±0.27^{b}	73.05±0.05^{c}	12.82±0.34^{a}	6.78±0.22^{a}	4.23±0.33^{ef}
	II	82.81±0.11^{b}	72.33±0.20^{c}	12.42±0.31^{a}	7.1±0.10b^{a}	4.17±0.12^{f}
November	**I**	82.31±0.20^{a}	71.22±0.26^{a}	12.81±0.15^{a}	7.29±0.21^{de}	3.88±0.09^{e}
	II	82.06±0.08^{a}	71.7±0.20^{c}	13.52±0.27^{b}	7.57±0.03^{d}	4.15±0.11^{f}
December	**I**	85.55±0.11^{f}	72.7±0.26^{bc}	13.43±0.27^{b}	7.55±0.10^{e}	4.81±0.12^{g}
	II	85.25±0.11^{fg}	72.46±0.41^{c}	14.56±0.32^{d}	7.13±0.12^{bc}	3.86±0.16^{e}
January'03	**I**	85.06±0.06^{cd}	72.03±0.32^{b}	15.42±0.39^{f}	7.44±0.14^{de}	3.8±0.09^{de}
	II	84.54±0.14^{cd}	71.53±0.30^{b}	16.58±0.32^{f}	7.93±0.07^{e}	3.66±0.12^{cde}
February	**I**	84.43±0.23^{b}	71.46±0.45^{a}	14.85±0.19^{e}	7.46±0.19^{de}	4.58±0.42^{f}
	II	85.41±0.22^{g}	67.33±0.41^{a}	15.77±0.19^{g}	7.53±0.13^{d}	3.84±0.05^{e}
March	**I**	84.07±0.06^{bcd}	73.26±0.35^{d}	15.36±0.19^{ef}	7.16±0.05^{cd}	3.66±0.08^{cde}
	II	84.66±0.11^{cd}	72.46±0.36^{c}	17.22±0.18^{h}	7.28±0.01^{c}	3.86±0.16^{e}
April	**I**	85.42±0.21^{ef}	74.65±0.16^{ef}	14.20±0.20^{d}	7.10±0.11^{bc}	3.50±0.10^{cd}
	II	84.77±0.14^{cd}	72.14±0.22^{c}	15.24±0.08^{f}	7.57±0.16^{d}	3.69±0.12^{cde}
May	**I**	85.21±0.26^{cdef}	73.01±0.11^{c}	15.0±0.16^{e}	7.5±0.23^{bc}	3.21±0.04^{b}
	II	85.46±0.14^{g}	74.20±0.14^{d}	15.0±0.16^{e}	7.98±0.13^{e}	3.41±0.09^{ab}
June	**I**	84.85±0.18^{c}	74.86±0.09^{f}	14.10±0.23^{c}	7.0±0.20^{bc}	3.54±0.20^{cd}
	II	85.21±0.39^{fg}	75.42±0.37^{f}	13.68±0.26^{b}	6.97±0.14^{bc}	3.80±0.16^{de}
July	**I**	85.08±0.29^{cd}	74.89±0.14^{f}	14.19±0.19^{cd}	6.69±0.11^{ab}	3.86±0.12^{e}
	II	85.11±0.28^{ef}	74.85±0.22^{e}	13.69±0.09^{b}	7.56±0.27^{d}	3.47±0.24^{bc}
August	**I**	85.42±0.31^{ef}	74.56±0.18^{ef}	14.0±0.33^{c}	7.21±0.11^{cd}	3.0±0.29^{a}
	II	85.25±0.42^{fg}	74.76±0.17^{e}	14.34±0.17^{d}	6.98±0.20^{a}	3.74±0.08^{de}
September	**I**	85.09±0.40^{cd}	74.40±0.05^{e}	14.29±0.33^{cd}	7.10±0.30^{bc}	3.69±0.13^{cd}
	II	84.88±0.23^{de}	74.48±0.31^{c}	14.0±0.21^{c}	7.54±0.30^{d}	3.26±0.17^{a}

[1] Means of triplicate samples ± standard deviation, Means of triplicate in the same column sharing different superscripts are significantly different ($p<0.05$), *Wet matter basis

adjoining neritic waters. The water temperature during October was low because of strong land sea breeze and precipitation and the recorded high summer value could be attributed to high solar radiation (Govindasamy *et al*., 2000; Santhanam and Perumal, 2003; Ajithkumar *et al*., 2006; Ashok Prabhu *et al*., 2008).

The salinity was found to be high during summer season and low during the monsoon season at all the stations. The recorded higher values could be attributed to the low amount of rainfall, higher rate of evaporation and also due to neritic water dominance, as reported by earlier workers in other areas (Gowda *et al.,* 2001; Rajasegar, 2003; Asha and Diwakar, 2007). During the monsoon season, the rainfall and the freshwater inflow from the land in turn moderately reduced the salinity. The statistical analysis revealed that salinity showed highly significant negative correlation with rainfall.

Hydrogen ion concentration (pH) in surface waters remained alkaline throughout the study period at all the stations with maximum value during the summer season and the minimum during monsoon. Generally, fluctuations in pH values during different seasons of the year is attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, low primary productivity, reduction of salinity and temperature and decomposition of organic matter (Paramasivam and Kannan, 2005; Bragadeeswaran *et al*., 2007). The recorded high pre-monsoon and summer pH might be due to the influence of seawater penetration and high biological activity (Govindasamy *et al*., 2000) and due to the occurrence of high photosynthetic activity (Sridhar *et al*., 2006; Saravanakumar *et al*., 2008).

It is well known that the temperature and salinity affect the dissolution of oxygen (Govindasamy *et al*., 2000). In the present investigation, higher values of dissolved oxygen were recorded during monsoon months at all the stations. The observed high monsoonal values might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing (Rajasegar, 2003). Season-wise observation of dissolved oxygen showed an inverse trend against temperature and salinity. Dissolved oxygen was observed to be low during post-monsoon and summer seasons, which could be due to the gradual saline

Table - 2: Proximate composition of copepod, *A. spinicauda* at Station 2 (Vellar-mouth)[1]

Months		Parameter (%)				
		Moisture*	**Protein**	**Lipid**	**Carbohydrate**	**Ash**
October'02	I	83.28 ± 0.26^{a}	68.5 ± 0.35^{b}	$14.76\pm0..24^{c}$	6.63 ± 0.18^{f}	3.61 ± 0.16^{abc}
	II	82.10 ± 0.03^{a}	68.1 ± 0.10^{a}	14.25 ± 0.10^{c}	5.88 ± 0.37^{e}	4.4 ± 0.32^{f}
November	I	85.43 ± 0.12^{d}	70.78 ± 0.22^{c}	12.65 ± 0.15^{a}	4.66 ± 0.44^{ab}	4.49 ± 0.24^{g}
	II	85.83 ± 0.14^{g}	69.68 ± 0.16^{d}	13.28 ± 0.16^{a}	4.41 ± 0.26^{a}	3.64 ± 0.35^{ab}
December	I	84.43 ± 0.28^{bc}	67.5 ± 0.29^{a}	13.63 ± 0.22^{b}	5.83 ± 0.08^{e}	3.43 ± 0.28^{ab}
	II	84.49 ± 0.24^{d}	68.37 ± 0.14^{b}	13.69 ± 0.18^{b}	6.5 ± 0.28^{f}	3.49 ± 0.46^{a}
January'03	I	83.18 ± 0.08^{b}	72.67 ± 0.10^{g}	16.85 ± 0.26^{f}	5.39 ± 0.48^{d}	3.98 ± 0.19^{de}
	II	83.63 ± 0.08^{fg}	71.45 ± 0.19^{e}	17.02 ± 0.19^{h}	7.34 ± 0.27^{g}	3.8 ± 0.21^{bc}
February	I	84.17 ± 0.14^{b}	70.47 ± 0.13^{c}	14.75 ± 0.22^{c}	6.7 ± 0.14^{f}	3.62 ± 0.14^{abc}
	II	84.38 ± 0.17^{ef}	69.3 ± 0.14^{c}	15.32 ± 0.27^{d}	6.21 ± 0.25^{e}	4.1 ± 0.05^{cde}
March	I	84.20 ± 0.12^{b}	71.02 ± 0.51^{c}	17.81 ± 0.25^{h}	5.23 ± 0.23^{d}	4.22 ± 0.12^{fg}
	II	85.58 ± 0.37^{fg}	72.64 ± 0.15^{g}	17.19 ± 0.12^{hi}	5.76 ± 0.33^{e}	3.61 ± 0.16^{ab}
April	I	84.66 ± 0.10^{c}	72.67 ± 0.23^{g}	17.14 ± 0.21^{ghi}	4.65 ± 0.24^{ab}	3.89 ± 0.17^{cd}
	II	85.33 ± 0.32^{ef}	72.42 ± 0.13^{g}	16.94 ± 0.48^{g}	4.85 ± 0.16^{bc}	3.63 ± 0.17^{ab}
May	I	84.89 ± 0.65^{c}	71.67 ± 0.02^{e}	17.60 ± 0.28^{h}	5.40 ± 0.21^{a}	4.38 ± 0.15^{a}
	II	84.42 ± 0.31^{cd}	72.67 ± 0.15^{g}	17.63 ± 0.35	5.18 ± 0.16^{cd}	3.64 ± 0.09^{ab}
June	I	85.39 ± 0.26^{d}	72.36 ± 0.22^{f}	17.16 ± 0.29^{g}	5.50 ± 0.18^{ab}	3.70 ± 0.15^{bc}
	II	84.53 ± 0.13^{d}	73.27 ± 0.28^{h}	16.84 ± 0.25^{g}	5.28 ± 0.14^{d}	4.21 ± 0.27^{df}
July	I	84.38 ± 0.17^{bc}	73.56 ± 0.32^{h}	16.82 ± 0.32^{f}	4.66 ± 0.16^{ab}	3.80 ± 0.08^{bcd}
	II	85.18 ± 0.16^{e}	74.35 ± 0.13^{i}	16.29 ± 0.05^{f}	4.79 ± 0.12^{b}	4.09 ± 0.08^{cd}
August	I	84.59 ± 0.06^{c}	72.85 ± 0.18^{g}	15.17 ± 0.14^{d}	4.56 ± 0.15^{ab}	4.18 ± 0.13^{ef}
	II	85.30 ± 0.32^{ef}	73.25 ± 0.27^{h}	15.84 ± 0.06^{e}	4.80 ± 0.18^{bc}	4.22 ± 0.06^{def}
September	I	84.69 ± 0.19^{c}	74.0 ± 0.06^{i}	15.65 ± 0.26^{e}	4.78 ± 0.10^{ab}	4.32 ± 0.11^{fg}
	II	84.55 ± 0.22^{cd}	74.62 ± 0.25^{j}	15.41 ± 0.15^{d}	5.10 ± 0.31^{cd}	4.41 ± 0.17^{ef}

[1] Means of triplicate samples ± standard deviation, Means of triplicate in the same column sharing different superscripts are significantly different ($p<0.05$), *Wet matter basis

water incursion and increasing temperature (Govindasamy *et al*., 2000; Saravanakumar *et al*., 2007).

The recorded highest nitrates value in the present study during monsoon season could be mainly due to the organic materials received from the catchment area during ebb tide (Ashok Prabu *et al*., 2005, 2008). Another possible way of nitrates entry is through oxidation of ammonia form of nitrogen to nitrite formation (Rajasegar, 2003). The recorded low values during non-monsoon period may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity and also due to the neritic water dominance, which contained only negligible amount of nitrate (Rajaram *et al*., 2005; Bragadeeswaran *et al*., 2007). Further, significant inverse relationship between rainfall and nutrients indicated that freshwater flow constituted the main source of the nutrients in the estuaries.

The recorded higher nitrite values during monsoon season could be due to the increased phytoplankton excretion, oxidation of ammonia and reduction of nitrate and by recycling of nitrogen and also due to bacterial decomposition of planktonic detritus present in the environment (Govindasamy *et al*., 2000). Further, the denitrification and air-sea interaction exchange of chemicals are also responsible for this increased value (Rajasegar, 2003; Ashok Prabhu *et al*., 2008). The recorded low nitrite value during post-monsoon seasons may be due to less freshwater inflow and high salinity (Saravanakumar *et al*., 2008).

The observed high monsoonal phosphates value might possibly be due to the regeneration and release of total phosphorus from bottom mud into the water column by turbulence and mixing (Saravanakumar *et al*., 2007). Moreover, the weatherings of rocks soluble alkali metal phosphates (in the upstream area) the bulk of which are carried into the estuaries are also responsible for the recorded higher values (Govindasamy *et al*., 2000). The addition of super phosphates applied in the agricultural fields as fertilizers and alkyl phosphates used in households as detergents can be other sources of inorganic phosphates during the season (Bragadeeswaran *et al*., 2007). The post-monsoonal low value could be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton (Rajasegar, 2003). The

Table - 3: Proximate composition of copepod, *A. spinicauda* at Station 3 (Vellar-estuary)[1]

Months		Parameter (%)				
		Moisture*	**Protein**	**Lipid**	**Carbohydrate**	**Ash**
October'02	**I**	84.14±0.13^{a}	70.27±0.17^{b}	15.71±0.25^{c}	4.17±0.12^{a}	3.95±0.12^{gh}
	II	85.69±0.24^{fg}	70.38±0.59^{a}	15.57±0.31^{c}	4.01±0.19^{a}	4.6±0.08^{e}
November	**I**	85.03±0.28^{d}	68.65±0.35^{a}	14.94±0.09^{b}	5.31±0.13^{bc}	3.94±0.15^{gh}
	II	82.93±0.28^{a}	71.64±0.29^{b}	14.55±0.25^{a}	4.7±0.07^{cd}	4.39±0.34^{d}
December	**I**	85.02±0.37^{d}	72.32±0.28^{d}	14.58±0.03^{a}	5.0±0.15^{b}	3.99±0.13^{gh}
	II	84.73±0.48^{cd}	72.67±0.20^{d}	14.7±0.39^{b}	4.44±0.34^{bc}	3.67±0.20^{bc}
January'03	**I**	84.54±0.31^{bc}	74.56±0.06^{h}	15.69±0.05^{c}	4.95±0.06^{b}	4.21±0.31^{h}
	II	84.09±0.48^{b}	73.6±0.34^{e}	16.28±0.28^{d}	5.63±0.27^{f}	4.46±0.34^{de}
February	**I**	83.95±0.28^{ab}	73.93±0.19^{g}	16.52±0.27^{e}	5.65±0.21^{c}	3.52±0.29^{cde}
	II	84.02±0.33^{b}	74.0±0.29^{f}	17.42±0.12^{fg}	4.38±0.24^{b}	3.73±0.24^{c}
March	**I**	84.37±0.26^{ab}	74.61±0.23^{de}	17.75±0.19^{i}	7.43±0.25^{d}	3.42±0.17^{bcd}
	II	85.37±0.27^{ef}	74.93±0.25^{g}	17.64±0.16^{g}	7.9±0.07^{i}	3.81±0.15^{c}
April	**I**	85.41±0.21^{e}	72.43±0.31^{d}	16.94±0.12^{f}	4.26±0.14^{a}	3.70±0.15^{def}
	II	84.76±0.44^{cd}	72.59±0.15^{cd}	17.69±0.14^{g}	4.98±0.23^{d}	3.70±0.26^{c}
May	**I**	84.74±0.07^{cd}	71.94±0.30^{c}	17.17±0.09^{g}	5.75±0.35^{c}	3.38±0.22^{bc}
	II	84.59±0.23^{bc}	72.49±0.29^{cd}	16.58±0.12^{e}	5.42±0.15^{ef}	3.29±0.16^{ab}
June	**I**	84.96±0.26^{d}	73.0±0.18^{e}	16.02±0.10^{d}	7.0±0.12^{d}	3.46±0.32^{bcd}
	II	85.12±0.11^{c}	72.44±0.29^{c}	16.13±0.14^{d}	7.21±0.16^{h}	3.61±0.22^{bc}
July	**I**	85.40±0.21^{e}	73.45±0.38^{f}	17.09±0.16^{g}	5.02±0.16^{b}	3.72±0.12^{def}
	II	84.43±0.23^{bc}	73.29±0.15^{e}	17.42±0.17^{fg}	5.12±0.25^{e}	3.02±0.08^{a}
August	**I**	84.57±0.17^{bc}	73.12±0.15^{ef}	17.41±0.06^{h}	5.0±0.30^{b}	2.89±0.28^{a}
	II	84.20±0.17^{b}	72.84±0.41^{d}	17.38±0.12^{f}	6.0±0.19^{g}	3.23±0.18^{ab}
September	**I**	84.39±0.23^{bc}	72.69±0.24^{de}	15.68±0.08^{c}	7.42±0.15^{d}	3.51±0.33^{cde}
	II	84.54±0.21^{bc}	72.65±0.26^{d}	17.23±0.22^{f}	5.49±0.12^{ef}	3.63±0.14^{bc}

[1] Means of triplicate samples ± standard deviation, Means of triplicate in the same column sharing different superscripts are significantly different ($p<0.05$), *Wet matter basis

Table - 4: Seasonal variations in amino acid composition of *A. spinicauda* collected from Parangipettai coastal waters

Amino acid	***A. spinicauda*** **(Sea)**				***A. spinicauda*** **(Vellar-mouth)**				***A. spinicauda*** **(Vellar-estuary)**			
	M	**POM**	**S**	**PRM**	**M**	**POM**	**S**	**PRM**	**M**	**POM**	**S**	**PRM**
Aspartic acid	8.41	7.02	7.43	6.48	7.41	5.62	8.51	7.63	7.18	8.41	6.61	5.99
Threonine	15.18	16.71	15.80	14.58	16.57	10.91	16.02	16.40	17.51	15.68	13.73	16.55
Serine	8.88	8.67	9.91	7.61	7.69	7.22	9.29	8.85	5.36	6.41	7.06	7.30
Glutamic acid	14.57	13.94	11.41	14.03	12.26	11.89	14.89	12.53	12.42	14.27	18.35	13.27
Glycine	3.73	4.65	5.41	4.17	3.68	3.31	4.16	5.11	5.49	3.39	4.59	3.79
Alanine	8.31	10.18	9.29	7.83	8.53	12.16	8.80	10.03	8.71	9.29	9.65	7.78
Cystine	Trace	Trace	Trace	2.03	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Valine	6.79	7.25	7.89	7.40	7.47	10.18	7.42	7.80	8.17	8.38	7.01	7.61
Methionine	2.79	3.38	3.35	9.47	4.81	3.50	Trace	1.62	11.08	4.62	2.31	10.50
Isoleucine	6.23	3.59	3.30	4.87	2.80	3.25	4.32	4.73	2.49	3.88	2.59	2.64
Leucine	4.65	4.40	5.43	4.54	7.54	6.84	7.04	6.99	6.63	6.83	9.24	6.42
Tyrosine	3.24	4.75	3.81	3.16	4.27	10.40	2.80	3.34	1.20	2.67	7.34	1.95
Phenylalanine	5.00	3.79	6.06	4.07	6.31	5.22	5.09	4.28	4.29	4.59	2.76	4.48
Histidine	2.54	2.81	2.72	2.23	1.95	2.96	2.36	3.52	2.56	2.93	2.56	2.59
Lysine	3.95	3.97	3.51	2.83	3.37	3.29	4.90	3.20	3.84	5.84	2.50	4.51
Arginine	5.67	4.91	4.67	4.63	5.26	3.18	4.34	3.90	3.02	2.74	3.64	4.56

M = Monsoon; POM = Post-monsoon, S = Summer, PRM = Pre-monsoon

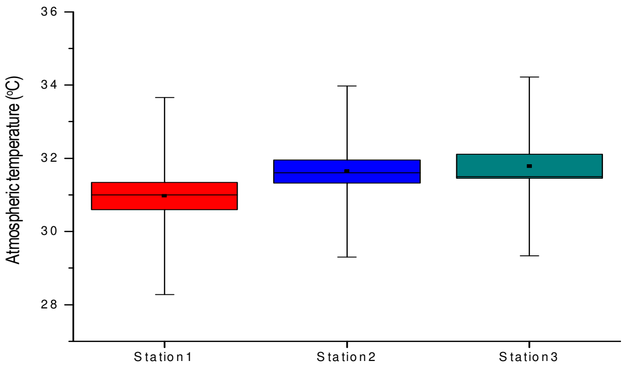

Fig. 1: Variations in atmospheric temperature during 2002 to 2003 at stations 1, 2 and 3

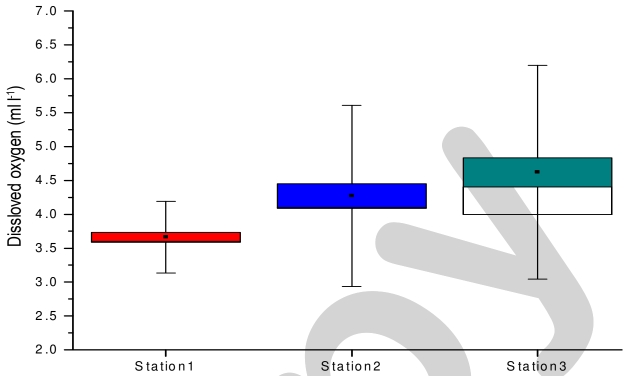

Fig. 5: Variations in dissolved oxygen during 2002 to 2003 at stations 1, 2 and 3

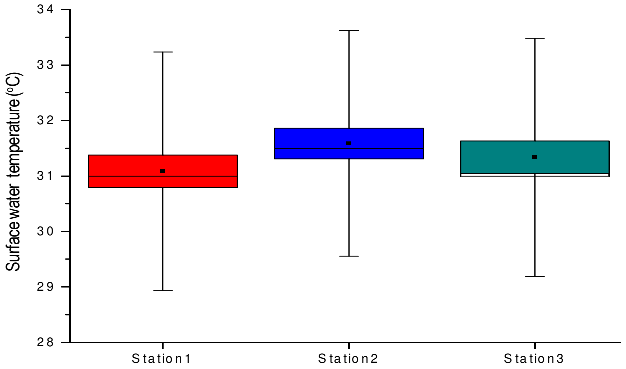

Fig. 2: Variations in surface water temperature during 2002 to 2003 at stations 1, 2 and 3

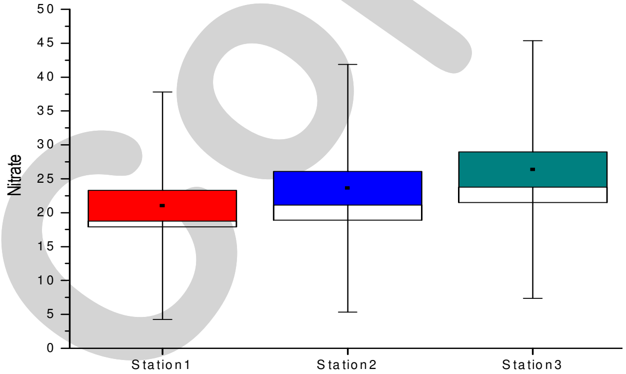

Fig. 6: Variations in nitrate during 2002 to 2003 at stations 1, 2 and 3

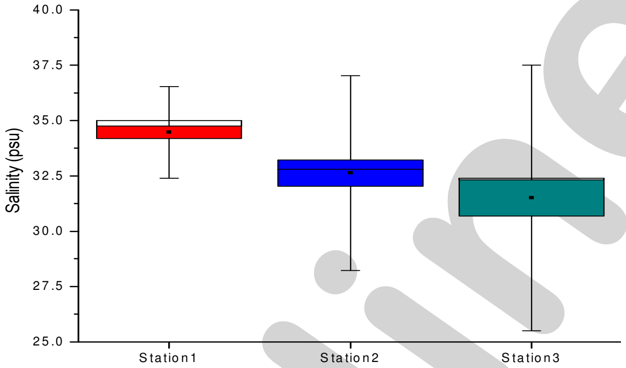

Fig. 3: Variations in salinity during 2002 to 2003 at stations 1, 2 and 3

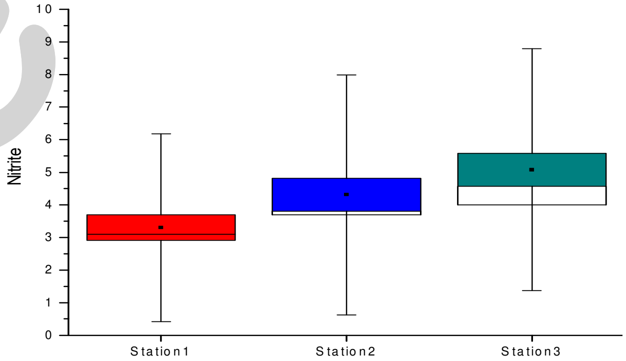

Fig. 7: Variations in nitrite during 2002 to 2003 at stations 1, 2 and 3

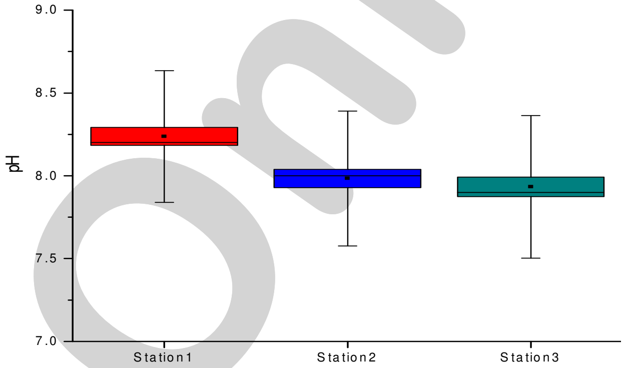

Fig. 4: Variations in pH during 2002 to 2003 at stations 1, 2 and 3

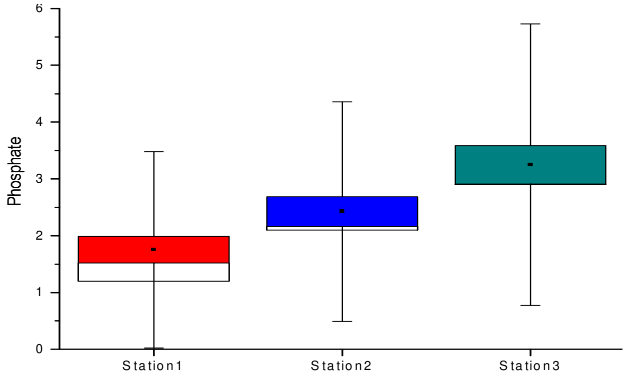

Fig. 8: Variations in phosphate during 2002 to 2003 at stations 1, 2 and 3

Table - 5: Proximate composition of copepod, *O. similis* at Station 1 (Sea)[1]

Months		Parameter (%)				
		Moisture*	Protein	Lipid	Carbohydrate	Ash
October'02	I	82.71 ± 0.21^{f}	62.55 ± 0.43^{c}	13.28 ± 0.30^{e}	3.43 ± 0.26^{a}	3.96 ± 0.12^{d}
	II	82.22 ± 0.31^{f}	59.77 ± 0.66^{b}	14.61 ± 0.47^{e}	3.83 ± 0.10^{d}	3.43 ± 0.17^{a}
November	I	83.72 ± 0.22^{g}	59.9 ± 0.18^{a}	11.6 ± 0.35^{b}	4.79 ± 0.15^{cd}	3.35 ± 0.24^{ab}
	II	83.26 ± 0.16^{g}	60.44 ± 0.47^{c}	12.53 ± 0.33^{c}	3.55 ± 0.26^{a}	3.75 ± 0.12^{d}
December	I	80.13 ± 0.08^{b}	60.73 ± 0.20^{b}	10.76 ± 0.44^{a}	6.28 ± 0.14^{f}	3.93 ± 0.23^{d}
	II	81.46 ± 0.17^{de}	60.51 ± 0.26^{c}	11.62 ± 0.33^{a}	6.09 ± 0.13^{g}	3.58 ± 0.11^{bc}
January'03	I	80.86 ± 0.20^{d}	65.0 ± 0.41^{g}	14.48 ± 0.14^{g}	4.87 ± 0.11^{d}	3.83 ± 0.07^{cd}
	II	80.50 ± 0.32^{ab}	63.91 ± 0.20^{d}	12.06 ± 0.26^{bc}	5.47 ± 0.32^{f}	3.35 ± 0.20^{a}
February	I	81.45 ± 0.18^{e}	63.67 ± 0.41^{e}	12.48 ± 0.42^{c}	6.59 ± 0.34^{g}	3.26 ± 0.19^{a}
	II	80.64 ± 0.14^{b}	59.53 ± 0.29^{a}	12.06 ± 0.44^{bc}	6.02 ± 0.07^{g}	3.71 ± 0.06^{cd}
March	I	81.28 ± 0.24^{e}	60.68 ± 0.09^{b}	13.27 ± 0.20^{de}	3.76 ± 0.20^{ab}	3.83 ± 0.15^{cd}
	II	81.09 ± 0.38^{c}	64.7 ± 0.33^{e}	13.16 ± 0.17^{d}	3.71 ± 0.19^{b}	4.06 ± 0.09^{e}
April	I	80.54 ± 0.13^{cd}	67.58 ± 0.16^{h}	15.45 ± 0.17^{i}	5.34 ± 0.21^{e}	3.42 ± 0.13^{b}
	II	81.45 ± 0.14^{e}	68.21 ± 0.22^{h}	16.98 ± 0.17^{f}	4.26 ± 0.19^{c}	3.71 ± 0.15^{cd}
May	I	80.30 ± 0.12^{b}	66.02 ± 0.11^{h}	17.54 ± 0.11^{j}	4.61 ± 0.21^{cd}	3.26 ± 0.13^{a}
	II	80.41 ± 0.14^{ab}	67.25 ± 0.14^{g}	17.68 ± 0.22^{g}	5.05 ± 0.10^{e}	3.57 ± 0.14^{abc}
June	I	80.23 ± 0.08^{b}	69.48 ± 0.09^{j}	13.88 ± 0.14^{f}	3.68 ± 0.12^{ab}	4.26 ± 0.16^{e}
	II	81.36 ± 0.12^{de}	64.67 ± 0.37^{e}	14.27 ± 0.25^{e}	3.78 ± 0.10^{b}	4.46 ± 0.22^{ab}
July	I	81.27 ± 0.03^{b}	67.60 ± 0.14^{i}	14.36 ± 0.26^{h}	4.57 ± 0.27^{c}	3.73 ± 0.10^{cd}
	II	81.13 ± 0.05^{cd}	69.61 ± 0.22^{i}	14.76 ± 0.39^{e}	4.50 ± 0.31^{d}	3.44 ± 0.18^{ab}
August	I	79.6 ± 0.05^{a}	65.49 ± 0.18^{g}	14.69 ± 0.09^{h}	4.56 ± 0.30^{c}	3.57 ± 0.15^{c}
	II	80.35 ± 0.10^{ab}	64.75 ± 0.17^{e}	14.21 ± 0.15^{e}	4.39 ± 0.28^{c}	4.17 ± 0.13^{ef}
September	I	80.29 ± 0.17^{b}	62.64 ± 0.05^{d}	12.93 ± 0.11^{d}	3.99 ± 0.17^{b}	4.38 ± 0.14^{e}
	II	80.58 ± 0.19^{ab}	65.99 ± 0.31^{e}	13.74 ± 0.13^{d}	4.56 ± 0.25^{d}	4.05 ± 0.10^{e}

[1] Means of triplicate samples ± standard deviation, Means of triplicate in the same column sharing different superscripts are significantly different ($p<0.05$), *Wet matter basis*Wet matter basis

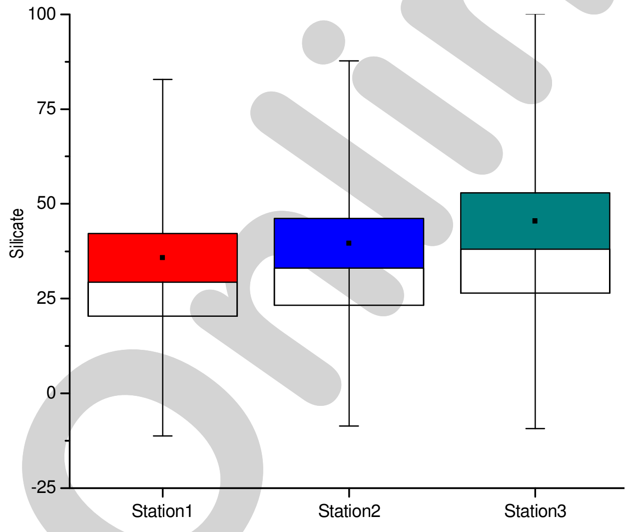

Fig. 9: Variations in silicate during 2002 to 2003 at stations 1, 2 and 3

variation may also be due to the processes like adsorption and desorption of phosphates and buffering action of sediment under varying environmental conditions (Rajasegar, 2003).

The silicate content was higher than that of the other nutrients and the recorded high monsoon values may be due to heavy inflow of monsoonal freshwater derived from land drainage carrying silicate leached out from rocks. Further, due to the turbulent nature of water, the silicate from the bottom sediment might have been exchanged with overlying water (Govindasamy *et al*., 2000; Rajasegar, 2003). The removal of silicates by adsorption and co-precipitation of soluble silicate silicon with humic compounds and iron might also be responsible for the increased value (Rajasegar, 2003). The observed low post-monsoonal values could be attributed to uptake of silicates by phytoplankton for their biological activity (Ashok Prabhu *et al*., 2008).

The surface water temperature, salinity and pH were positively correlated with copepod density. But negative correlation

Table - 6: Proximate composition of copepod, *O. similis* at Station 2 (Vellar-Mouth)[1]

Months		**Parameter (%)**				
		Moisture*	**Protein**	**Lipid**	**Carbohydrate**	**Ash**
October'02	I	81.32 ± 0.12^{c}	64.89 ± 0.31^{e}	11.16 ± 0.51^{b}	4.43 ± 0.25^{b}	3.72 ± 0.13^{b}
	II	80.46 ± 0.23^{b}	64.5 ± 0.32^{d}	10.79 ± 0.23^{a}	4.16 ± 0.12^{b}	3.98 ± 0.15^{a}
November	I	82.43 ± 0.39^{d}	62.39 ± 0.15^{a}	10.26 ± 0.11^{a}	4.03 ± 0.07^{a}	3.77 ± 0.12^{b}
	II	81.57 ± 0.09^{c}	63.89 ± 0.19^{c}	10.69 ± 0.25^{a}	3.78 ± 0.11^{a}	4.4 ± 0.22^{b}
December	I	$82.61 \pm 0.0.31^{d}$	66.64 ± 0.15^{g}	11.72 ± 0.32^{c}	4.46 ± 0.27^{b}	4.28 ± 0.26^{d}
	II	81.85 ± 0.12^{d}	66.58 ± 0.35^{i}	11.44 ± 0.22^{b}	4.82 ± 0.16^{d}	4.19 ± 0.05^{b}
January'03	I	82.58 ± 0.18^{d}	63.69 ± 0.37^{d}	12.61 ± 0.14^{d}	5.82 ± 0.18^{g}	3.7 ± 0.07^{b}
	II	82.91 ± 0.24^{e}	64.48 ± 0.45^{de}	13.11 ± 0.12^{c}	5.14 ± 0.08^{e}	3.6 ± 0.21^{a}
February	I	80.68 ± 0.21^{b}	64.61 ± 0.34^{d}	12.48 ± 0.28^{d}	5.85 ± 0.17^{g}	4.15 ± 0.10^{c}
	II	81.56 ± 0.24^{cd}	65.25 ± 0.24^{gh}	12.81 ± 0.33^{c}	5.53 ± 0.32^{g}	4.14 ± 0.12^{b}
March	I	83.37 ± 0.34^{e}	65.19 ± 0.26^{f}	14.25 ± 0.29^{f}	4.81 ± 0.03^{cd}	4.04 ± 0.11^{c}
	II	83.14 ± 0.10^{e}	64.79 ± 0.22^{ef}	14.06 ± 0.45^{d}	4.82 ± 0.18^{d}	3.79 ± 0.26^{a}
April	I	80.38 ± 0.08^{b}	67.09 ± 0.11^{h}	15.40 ± 0.18^{g}	4.73 ± 0.16^{cd}	3.37 ± 0.21^{a}
	II	81.42 ± 0.11^{c}	66.90 ± 0.02^{j}	15.21 ± 0.26^{g}	4.40 ± 0.19^{a}	3.66 ± 0.16^{a}
May	I	80.59 ± 0.20^{b}	64.39 ± 0.15^{d}	14.96 ± 0.26^{f}	5.51 ± 0.27^{f}	4.33 ± 0.17^{d}
	II	80.14 ± 0.35^{b}	62.65 ± 0.25^{a}	14.67 ± 0.19^{e}	5.16 ± 0.13^{b}	4.19 ± 0.22^{b}
June	I	79.22 ± 0.39^{a}	62.68 ± 0.16^{b}	14.63 ± 0.15^{f}	5.26 ± 0.14^{e}	4.21 ± 0.16^{d}
	II	80.19 ± 0.13^{b}	63.49 ± 0.31^{b}	15.50 ± 0.27^{g}	5.62 ± 0.21^{g}	3.65 ± 0.16^{a}
July	I	80.4 ± 0.04^{b}	65.58 ± 0.14^{f}	15.65 ± 0.20^{h}	4.78 ± 0.13^{cd}	4.00 ± 0.24^{c}
	II	80.41 ± 0.23^{b}	65.12 ± 0.13^{gh}	14.73 ± 0.22^{e}	4.88 ± 0.16^{d}	3.74 ± 0.17^{a}
August	I	80.69 ± 0.19^{b}	64.49 ± 0.22^{d}	15.15 ± 0.13^{g}	4.62 ± 0.21^{bc}	3.52 ± 0.08^{ab}
	II	81.39 ± 0.19^{b}	64.58 ± 0.16^{def}	14.94 ± 0.12^{ef}	4.78 ± 0.12^{d}	3.65 ± 0.24^{a}
September	I	81.27 ± 0.22^{c}	64.42 ± 0.26^{d}	14.63 ± 0.18^{f}	5.58 ± 0.28^{f}	3.80 ± 0.14^{b}
	II	80.68 ± 0.39^{b}	64.24 ± 0.24^{d}	15.17 ± 0.17^{fg}	5.08 ± 0.14^{e}	3.48 ± 0.27^{a}

[1] Means of triplicate samples ± standard deviation, Means of triplicate in the same column sharing different superscripts are significantly different ($p<0.05$), *Wet matter basis*Wet matter basis

was obtained between copepods density and rainfall, dissolved oxygen and nutrients at all the stations.

Proximate composition of *A. spinicauda:* The biomass and abundance of adults of *A. spinicauda* and *O. similis* were 9.80-11.60 ml 100 m^{-3} and 32,000-43,000 no. 100m^{-3} respectively. The protein concentration was the highest and the various chemical constituents by *A. spinicauda* are given in Tables 1 to 3. Moisture values varied from 82.06 to 85.80% for all the three sites, with a minimum and maximum mean values (±SD) of 84.50±0.84% (Stn. 2) and 84.75±0.94% (Stn. 1). Protein values varied from 67.33 to 75.45% for all the three sites, with a minimum and maximum mean values (±SD) of 71.62±2.12% (Stn. 2) and 73.05±1.88% (Stn. 1). Lipid values varied from 12.42 to 17.81% for all the three sites, with a minimum and maximum mean values (±SD) of 14.37±1.14% (Stn. 1) and 16.43±1.01% (Stn. 3). Carbohydrate values ranged between 4.01 and 7.98% for all the three sites, with a minimum and maximum mean values (±SD) of 5.47±0.75% (Stn. 2) and 7.35±0.32% (Stn. 1). Ash concentration ranged between 2.89 to 4.81% for all the three sites, with a minimum and maximum mean values (±SD) of 3.69±0.45% (Stn. 3) and 3.96±0.40% (Stn. 2). Out of 16 amino acids observed, threonine, glutamic acid, alanine, aspartic acid, serine and valine were relatively larger in quantity (Table 4). Serine and leucine showed significantly higher ($P<0.05$) values whereas others are non significant.

Proximate composition of *Oithona similis:* The protein concentration was the highest and the various chemical constituents of *O. similis* are given in Tables 5-7. Moisture values varied from 79.22 to 83.87% for all the three sites, with a minimum and maximum mean values (±SD) of 81.14±1.08% (Stn. 1) and 83.04±0.90% (Stn. 3). Protein values varied from 59.53 to 69.61% for all the three sites, with a minimum and maximum mean values (±SD) of 63.96±2.15% (Stn. 3) and 64.76±1.26% (Stn. 2). Lipid values varied from 9.89 to 17.68% for all the three sites, with a minimum and maximum mean values (±SD) of 13.57±1.83% (Stn. 2) and 13.93±1.81% (Stn. 1). Carbohydrate values ranged between 3.43 and 6.59% for all the three sites, with a minimum and maximum mean values (±SD) of 4.71±0.51% (Stn. 3) and 4.93±0.56% (Stn. 2). Ash concentration ranged between 3.2 to 4.53% for all the

Table - 7: Proximate composition of copepod, *O. similis* at Station 3 (Vellar estuary)[1]

Months		**Parameter (%)**				
		Moisture*	**Protein**	**Lipid**	**Carbohydrate**	**Ash**
October'02	**I**	82.87±0.18^{b}	61.75±0.25^{b}	9.89±0.31^{a}	4.44±0.26^{cd}	3.9±0.09^{c}
	II	83.40±0.21^{d}	62.57±0.37^{c}	11.54±0.45^{b}	4.72±0.22^{d}	4.18±0.15^{f}
November	**I**	83.05±0.16^{b}	60.76±0.42^{a}	12.57±0.21^{b}	4.09±0.15^{b}	3.38±0.20^{ab}
	II	83.46±0.29^{d}	59.57±0.26^{a}	11.57±0.08^{b}	4.37±0.24^{c}	3.67±0.10^{cd}
December	**I**	82.66±0.12^{b}	60.69±0.36^{a}	11.26±0.37^{b}	4.72±0.19^{de}	3.82±0.13^{c}
	II	83.45±0.30^{d}	60.78±0.24^{b}	12.49±0.35^{c}	4.99±0.04^{e}	3.32±0.28^{ab}
January'03	**I**	82.99±0.24^{b}	64.07±0.20^{d}	14.71±0.15^{gh}	5.72±0.22^{i}	3.68±0.21^{bc}
	II	83.46±0.28^{d}	64.56±0.32^{f}	14.73±0.20^{e}	5.46±0.19^{f}	3.68±0.53^{cd}
February	**I**	83.87±0.32^{d}	65.57±0.18^{e}	14.75±0.08^{gh}	4.95±0.13^{fg}	4.34±0.26^{d}
	II	83.08±0.40^{d}	63.95±0.19^{e}	14.4±0.20^{e}	4.6±0.29^{d}	3.99±0.11^{e}
March	**I**	83.47±0.26^{c}	67.6±0.19^{f}	14.0±0.14^{de}	4.74±0.22^{ef}	3.58±0.31^{bc}
	II	83.25±0.18^{d}	67.55±0.29^{h}	13.51±0.24^{d}	4.01±0.10^{a}	3.36±0.17^{bc}
April	**I**	83.3±0.52^{c}	67.52±0.54^{f}	13.67±0.32^{d}	5.0±0.39^{fg}	3.33±0.22^{a}
	II	84.42±0.28^{e}	66.45±0.30^{g}	14.0±0.14^{d}	4.58±0.24^{cd}	3.20±0.05^{a}
May	**I**	81.71±0.22^{a}	65.89±0.17^{e}	14.45±0.13^{fg}	4.61±0.23^{de}	4.24±0.21^{d}
	II	81.61±0.08^{a}	64.59±0.24^{f}	14.0±0.11^{d}	4.29±0.20^{bc}	4.34±0.20^{f}
June	**I**	84.29±0.23^{d}	64.13±0.27^{d}	13.29±0.24^{c}	4.51±0.16^{de}	3.68±0.25^{bc}
	II	84.4±0.08^{e}	64.53±0.33^{f}	15.17±0.15^{f}	4.67±0.17^{d}	4.53±0.23^{f}
July	**I**	82.60±0.13^{b}	62.78±0.26^{c}	14.29±0.17^{ef}	3.71±0.07^{a}	3.82±0.13^{c}
	II	82.31±0.21^{c}	63.31±0.14^{d}	13.62±0.23^{d}	4.06±0.10^{a}	3.56±0.27^{c}
August	**I**	82.71±0.13^{b}	63.72±0.35^{d}	14.95±0.20^{h}	5.25±0.04^{h}	3.44±0.30^{ab}
	II	82.54±0.26^{c}	63.38±0.18^{d}	15.32±0.22^{fg}	5.55±0.15^{f}	3.68±0.07^{cd}
September	**I**	81.64±0.10^{a}	62.94±0.32^{c}	15.23±0.22	5.0±0.09^{fg}	3.50±0.15^{ab}
	II	81.54±0.12^{a}	64.59±0.21^{f}	15.44±0.26^{fg}	4.61±0.17^{d}	3.55±0.09^{c}

[1] Means of triplicate samples ± standard deviation, Means of triplicate in the same column sharing different superscripts are significantly different ($p<0.05$), *Wet matter basis*Wet matter basis

Table - 8: Seasonal variations in amino acid composition of *O. similis* collected from Parangipettai coastal waters

Amino acid	***O. similis* (Sea)**				***O. similis* (Vellar-Mouth)**				***O. similis* (Vellar-Estuary)**			
	M	**POM**	**S**	**PRM**	**M**	**POM**	**S**	**PRM**	**M**	**POM**	**S**	**PRM**
Aspartic acid	7.08	7.07	6.65	6.33	7.61	6.44	8.11	8.40	7.55	7.36	6.73	8.01
Threonine	15.75	13.35	15.32	14.42	15.52	13.15	15.37	14.60	15.13	14.91	17.57	16.48
Serine	9.36	3.86	8.69	8.46	9.72	8.00	9.12	7.63	10.57	9.46	7.57	10.56
Glutamic acid	12.82	19.54	12.99	12.37	15.30	14.39	15.53	16.21	13.25	12.22	15.06	14.24
Glycine	3.89	4.38	3.93	4.21	3.80	4.23	4.20	4.16	4.29	4.21	4.65	4.57
Alanine	7.30	10.70	7.83	12.07	8.58	10.14	8.34	8.20	8.34	7.37	9.82	8.78
Valine	7.83	7.56	7.19	10.36	7.56	7.92	7.18	7.32	6.15	6.49	8.58	7.60
Methionine	6.08	0.94	10.43	Trace	1.02	10.58	0.60	0.53	3.20	11.32	1.65	Trace
Isoleucine	5.85	2.27	4.31	3.24	2.59	2.00	2.29	2.70	2.93	2.66	2.99	2.81
Leucine	1.83	8.46	4.74	9.74	7.92	5.22	8.80	9.06	9.01	5.63	8.77	8.54
Tyrosine	5.09	4.19	2.31	3.05	2.03	2.10	2.27	2.55	2.37	1.85	1.61	2.60
Phenylalanine	7.05	5.26	4.04	4.93	5.37	5.11	5.39	5.54	4.61	4.27	4.44	5.12
Histidine	1.92	2.57	2.72	2.52	2.92	3.03	2.05	2.17	2.75	2.39	2.17	1.94
Lysine	4.09	4.95	4.04	4.36	5.02	3.85	5.00	5.03	4.63	4.17	5.41	4.25
Arginine	4.00	4.84	4.73	3.88	4.97	3.77	5.66	5.82	5.15	5.62	2.91	4.44

M = Monsoon, POM = Post monsoon, S = Summer, PRM = Pre monsoon three sites, with a minimum and maximum mean values (±SD) of 3.74±0.37% (Stn. 3) and 3.85±0.37% (Stn. 2). Out of 15 amino acids observed, threonine, glutamic acid, serine, alanine, aspartic acid, valine and methionine were relatively higher in amount (Table 8). Threonine and tyrosine showed significant values ($p<0.05$). Among them tyrosine showed mostly maximum significant.

Assessment of biochemical composition, such as protein, up to the level of amino acids, lipid and carbohydrate in copepods is important for better understanding of the organic production and cycling of biogeochemical elements in the marine and estuarine biotopes. The present study indicates that protein is the major biochemical component in copepods, *A. spinicauda* and *O. similis* and the values are higher than those of the earlier reports of Nageswara Rao and Krupanidhi (2001) in Andaman Sea. The protein contents of copepods were higher in sea when compared to those from estuaries which indicates that salinity of the water might influence the protein content of the copepods (Nageswara Rao and Krupanidhi, 2001; Ashok Prabu *et al.,* 2005; Rajkumar *et al*., 2008). The presently recorded variations in protein contents are comparable to those reported for mixed zooplankton from higher latitudes (Goswami *et al*., 2000). The dominance of protein in *A. spinicauda* and *O. similis* may be because of the phytoplanktonic food of the wild copepods (Maruthanayagam and Subramanian, 1999; Goswami *et al*., 2000; Ashok Prabu *et al.,* 2005; Rajkumar *et al*., 2008). Protein forms the major fraction, indicating its usefulness as energy reserve. The observed variations in the protein content might be due to the fact that it is utilizated as a metabolic substrate (Nageswara Rao and Krupanidhi, 2001). Maruthanayagam and Subramanian (1999) noticed that the protein content was positively related to salinity of the water.

The lipid content was slightly higher than that of carbohydrate and lower than that of protein. In tropical environments, the rate of primary production far exceeds the rate of consumption of copepods and the continuous supply of phytoplankton food would render lipid reserve unnecessary, which may be the reason for the low lipid content in copepods (Nageswara Rao and Krupanidhi, 2001; Rajkumar *et al*., 2008). The lipid content of tropical zooplankton, when compared to temperate zooplankton is significantly low which may be due to the hydrological conditions and the type of availability of food organisms in environment as shown by the findings of Ashok Prabu *et al*. (2005). Nageswara Rao and Krupanidhi (2001) showed that variations in the lipid content can be attributed to its storage and utilization during periods when it serves as an effective energy reserve. The function of protein as an important energy reserve may be of importance for zooplankton having low lipid content. The low lipid content observed in the present investigation supports the view that these are all surface water copepods and moreover the protein may form a major metabolic reserve substrate in copepods (Maruthanayagam and Subramanian, 1999).

In general, carbohydrate content was very low in the copepods as compared to protein and lipid. Lower values of carbohydrate of wild-copepods have been reported earlier by many workers (Maruthanayagam and Subramanian, 1999; Nageswara Rao and Krupanidhi, 2001; Ashok Prabu *et al*., 2005; Rajkumar *et al*., 2008). The present observation of low carbohydrate content may be attributed to the fact that glycogen is the usual storage carbohydrate in many animals. Besides, the utilization of carbohydrate glucosamine during the chitin synthesis in crustaceans may prone to the decrease of carbohydrate level in copepods (Ashok Prabu *et al*., 2005).

Goswami *et al.* (2000) reported that carbohydrate content of zooplankton community is dependent upon its composition, declining in gelatinous forms than those with calcareous shells and increasing with copepods. The fluctuations in glycogen content of animals generally depend upon their feeding activities (Nageswara Rao and Krupanidhi, 2001). The low carbohydrate content and high levels of protein in zooplankton suggest that protein, in addition to lipid, may function as a food reserve (Ashok Prabu *et al*., 2005). Maruthanayagam and Subramanian (1999) felt that the carbohydrate from the food might be oxidized directly by zooplankton and that fats might be oxidized on need or stored as principal reserve food. In general low carbohydrate content in zooplankton led to contemplations on the functional role of other biochemical fractions in their metabolism. In the present study, the carbohydrate content (7.98 and 6.59%) of *A. spinicauda* and *O. similis* was found to be much higher than those recorded earlier by Indian workers (Maruthanayagam and Subramanian, 1999; Nageswara Rao and Krupanidhi, 2001; Ashok Prabu *et al*., 2005; Rajkumar *et al*., 2008).

During the present analysis, totally 16 and 15 amino acids were observed in wild copepods, *A. spinicauda* and *O. similis* respectively with threonine, glutamic acid, alanine, aspartic acid, serine, valine and methionine as the prominent ones. Only very limited information is available on the amino acid content of copepods. Santhanam and Perumal (2001) have found 10 amino acids in the cultured copepod, *O. rigida* with the predominance of norvaline. Rajkumar and Kumaraguru vasagam (2006) observed 16 amino acids in the cultured copepod, *A. clausi*, with a predominance of lysine, alanine and glutamic acid. Ashok Prabu and Rajkumar (2007) found 10 amino acids from the cultured copepod, *A. spinicauda* with the major component was asparagine. Further studies are needed along this line which is important in understanding their physiological functions, metabolism and nutritive value.

The present study indicates that the two species of copepods are nutritionally equal to any other live-food organisms and they can be exploited successfully for feed purpose and for preparing various by-products similar to fish and prawn by-products for selected animals and may be even used as live feed for aqua farming purpose.

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