

*SALINITY AND DISTRIBUTION OF BRACKISH WARM WATER ZOOPLANKTON IN INDIAN ESTUARIES

T. S. S. RAO

Regional Centre, National Institute of Oceanography, Cochin - 682 018, India

Estuaries form natural transition areas between marine and freshwater zones and exhibit wide ranges in hydrographical conditions. This calls for special ecological adaptations from its inhabitants.

The present review deals with the status of our knowledge on the salinity and distribution of zooplankton in the Indian estuaries, particularly the Godavari and Vellar estuarine systems on the east coast and the Cochin backwaters, Zuari and Mandovi estuaries on the west coast.

In these warm waters the salinity fluctuations are large (0 - 39‰) as compared to temperature (20 - 30°C). The qualitative and quantitative abundance and distribution of zooplankton are closely related to seasonal variations in salinity.

INTRODUCTION

Brackish water fauna comprise of specialised animals adapted to tolerate wide range of environmental fluctuations. The constant seawater-freshwater interaction renders osmoregulation as the primary problem to the inhabitants of this area. Hence brackish water zooplankton form a class by themselves. Especially in the tropical estuaries where temperature fluctuations are minimal, distribution and abundance of zooplankton are closely linked with salinity variations.

Estuarine zooplankton have been classified into truly estuarine, estuarine and marine, euryhaline marine and stenohaline marine organisms (Jeffries, 1967) based on the salinities in which they live. True estuarine and marine species compose the bulk of the zooplankton composition of brackish waters. Euryhaline marine organisms occur at the lower reaches of estuaries but are often limited at the upper regions where salinity values tend to decrease due to freshwater discharges. Stenohaline marine organisms are stragglers and restricted to the immediate vicinity of the mouth. They do not form a dominant component of the brackish water fauna at any time. In addition, stray freshwater zooplankton or species operating in low salinities are often encountered during low salinity periods.

While salinity reflects the hydrographic status of the estuary, the zooplankton content both in quality (species) and quantity (biomass) represents the productivity and also the 'health' of the estuary.

Work on the Indian estuarine organisms dates back to 1882 when Hamilton first gave an account of the estuarine fauna from the Gangetic delta. Subsequently there have been many workers in this field and mention may be made

of Blanford (1867) on molluscan fauna of the Irrawadi and Ganges and Kemp (1917) and Alcock (1911) from the Ganges delta. The Chilka lake drew attention from Annandale and Kemp (1915) and Sewell (1942). Interesting work was carried out on the brackish water fauna of the Madras area by Panikkar and Aiyar (1937) and Panikkar (1951) reviewed the physiological adaptations of animals in an estuary.

More recently the Hooghly river estuary was studied by Dutta *et al.* (1954), Shetty *et al.* (1963) and Gopalakrishnan (1971), and the Godavari estuary by Ganapati (1964).

The Vellar-Coleroon estuarine system has been the subject of study by several workers at the Porto Novo Marine Research Station and mention may be made of the contributions of Seshaiya (1959), Rengarajan (1959), Krishna-murthy and Sundararaj (1973).

The general composition of zooplankton of Cochin backwaters was first studied by George (1958). Some aspects of seasonal changes in zooplankton have been studied by Nair and Tranter (1971), Wellershaus (1974); and biomass by Menon *et al.* (1971). Distribution and ecology of some of the groups of zooplankton have been studied, such as: hydromedusae by Vannucci *et al.* (1970) and Santhakumari and Vannucci (1971); chaetognaths by Nair (1971, 1973) and Srinivasan (1971); copepods by Pillai (1971), Pillai and Pillai (1973), Pillai *et al.* (1973); and species of family Acartiidae by Tranter and Abraham (1971). Species composition and their fluctuations in the estuary is given by Madhupratap and Haridas (1975) and Rao *et al.* (*In press*).

The Zuari and Mandovi estuaries have been studied by Dehadrai and Bhargava (1972), Parulekar *et al.* (1973), Bhargava and Daivedi (1974) and Goswami and Singhal (1974).

SALINITY

The distribution of salinity in relation to tides largely follows the classical pattern in all the estuaries in the Indian area. The range of the tide is normally less than 2 m in South Indian estuaries and depending on the location of the station inside the estuary the salinity bears a direct relation with the tide. Superimposed on the tidal rhythm, the monsoons and the resulting floods in the Indian rivers bring about drastic changes in the salinity distribution.

On the west coast in the Cochin and Mandovi-Zuari (Goa) estuaries, the lowest salinities correspond to SW monsoon during June-September when due to heavy rains, there is almost a complete flooding and flushing of the estuaries. Correspondingly on the east coast estuaries, lowest salinities are recorded during October-November months owing to flood waters of the SW monsoon reaching the estuaries a couple of months later than on the west coast and also due to the NE monsoon (Fig. 1).

In the Hooghly-Matlah estuaries lower salinities are reached during July and December, lowest being in October-November months. Gopalakrishnan (1971) has divided this huge estuary into 5 zones and his observations (Table 1) given below shows the different values of salinity in the estuary.

Salinity and Distribution of Zooplankton

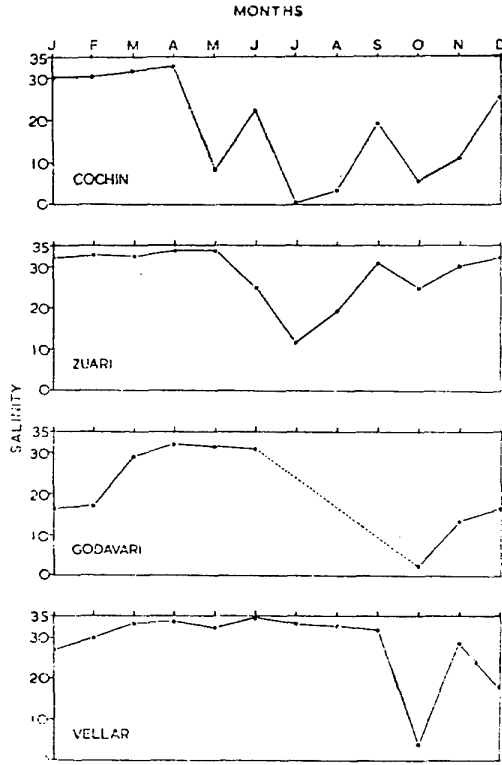


Fig. 1. Shows monthly variation in the surface salinity (‰) of the Cochin backwaters and Zuari estuary, both located on the west coast, and the Godavari and Vellar estuaries situated in the east coast of India

TABLE 1

Zone	Salinity ‰		Temperature °C	
	Min.	Max.	Min.	Max.
Freshwater zone	Nil	Traces	21.80	31.80
Gradient zone	Traces	27.30	19.60	33.46
Marine zone	2.34	33.75	19.44	33.68
Rupnarrian zone	Traces	15.87	17.70	33.00
Matlah zone	8.20	30.65	20.10	31.76

In the Chilka lake (Mohanty, 1975) the waters are fresh during the monsoon months due to the flooding of the Daya and Bhargavi rivers. The

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highest surface salinity recorded was 39.24‰ and lowest 0.61‰. The annual ranges of variation were between 29.24‰ and 36.36‰ in the surface waters and 28.55‰ and 36.18‰ in the case of bottom waters.

Data from the Godavari estuary based on surface waters of the Coringa river (Ramasarma and Ganapati, 1971) indicates that minimum values of salinity *i.e.*, 0 - 23.96‰ are found from June to December and the maximum value of 30.16 is found only during March-May.

Krishnamurthy (1961) and Subbaraju and Krishnamurthy (1972) have reported on hydrography and plankton in the Vellar - Coleroon estuary.

Salinity values at the estuarine station varied between 20 and 30‰ from October to March. The NE monsoon is in full swing during October to December on the east coast, when the estuary is flooded and salinity approaches that of freshwater on some days. From April to September the salinity range is rather limited between 28 and 35‰.

In the Cochin backwaters salinity attains peak values (34.5‰) by the late premonsoon period (March-April) with a gradient from mouth to head. During the monsoon most of the estuary remains freshwater with tidal incursion restricted to the bottom layers at the lower reaches.

In the Zuari and Mandovi estuarine system the salinity varies from 34.0‰ recorded in May to 5.0‰ or less found in June-August period (Dehadrai and Bhargava, 1972).

ZOOPLANKTON IN RELATION TO SALINITY

Recent studies from Cochin backwaters (Madhupratap and Haridas, 1975; Madhupratap *et al.*, 1975 and Rao *et al.*, *In press*) have shown close association between salinity changes in the environment and zooplankton abundance. The system is sparsely populated during the low saline monsoon period when the freshwater discharges are heavy. Wellershaus (1974) has also found the abundance and diversity of microzooplankton to be positively correlated with salinity. Some amount of stability of the environment is achieved only during the post and premonsoonal months when higher salinity conditions prevail. Zooplankton population is rich and diverse during this period.

The salinity incursion into the estuary after the monsoons begins during the postmonsoon months. It is gradual, the lower reaches regain high salinities during the postmonsoon months and middle and upper reaches later. A salinity gradient decreasing towards the head occurs even at the height of saline period.

The various high saline species become abundant at the lower reaches during early periods of salinity regime and penetrate further up along with salinity incursion. Estuarine and marine, euryhaline marine and truly estuarine species preferring high salinities are dominant in high saline areas whereas other estuarine species operating in medium salinity ranges form the bulk of zooplankton population in the middle and upper reaches during the saline period. During the low saline period these are flushed out of the estuary and replaced by low saline species. But their numbers are comparatively very low. Other factors such as high turbidity and strong currents must be limiting their abundant flourishing.

Salinity and Distribution of Zooplankton

Species diversity of zooplankton is high during the salinity regime with higher diversity at the mouth region and a progressive diminution towards head. The diversity trends at various phases of the estuary have been found to be closely linked with salinity. Zooplankton production has also been found to be low during monsoonal period and the figures of the production rates are presented elsewhere in this volume (Madhupratap, *et al.*).

Mechanisms by which intermonsoon waters of estuary get repopulated after monsoonal efflux have been examined by Tranter and Abraham (1971); Santhakumari and Vannucci (1971) and Madhupratap and Haridas (1975). They suggested that apart from recruitment from adjoining coastal waters, resting stages to tide over low saline conditions may occur for zooplankton of the backwaters. Occurrence of resting eggs in copepods have been confirmed since then (Kasahara *et al.*, 1974; Grice and Gibson, 1975). Evidence of occurrence of resting eggs of copepods in the estuary have been found subsequently (Madhupratap *et al.*, unpublished). Unlike temperature which induces formation of resting eggs in waters of higher latitudes, salinity has been found to be the causative factor for this in Cochin backwater.

Estuarine species are able to undergo a wide range of salinity variations. But peak densities of population of a particular species occur at optimum ranges and conditions. While optimum conditions last, the particular species blossom and flourish extracting the maximum benefit from the environment within the available period. Salinity alone need not be the total controlling factor. Grindley and Wooldridge (1974) found that the salinity tolerance of *Pseudodiaptomus* species of Richards Bay, S. Africa ranged from nearly fresh water to 60‰ and peak survival at approximately 35‰ and that these species do not occur in normal seawater. They believe that it is not salinity but competition from marine organisms that prevent fauna from surviving in the sea whereas their adaptation for surviving extreme environmental fluctuations allow them to flourish in the estuary.

Coefficients of correlation for copepod abundance and salinity were highly significant in Cochin backwaters whereas correlation was not exhibited when temperature was considered as a factor (Madhupratap *et al.*, 1975). Principal component analysis also showed the changes in the environment of the estuary to be largely dependent on salinity (Madhupratap, 1976). Studies of Pillai *et al.* (1975) also gave similar results. Pillai (1971) has summarized the situation with regard to copepods in the Indian estuaries (Table 2). He has grouped them under limnetic (less than 0.5‰), mixohaline (0.5 - 30.00‰) and euhaline (30.00 - 40.00‰) categories. Except for some species of Diaptomidae and Acartiidae, which are limnetic the rest of the copepods fall under the other two categories. The summary of distribution of some species of Pseudodiaptomidae and Acartiidae given below are illustrative of the spatial distribution in relation to salinity and other ecological conditions.

Information on the plankton community in the Mandovi and Zuari estuaries in relation to hydrographic condition during the monsoon months of 1972 is reported by Goswami and Singbal (1974). The data pertains to the months of June-September when there is heavy rainfall and inundation in the rivers. The diversity of plankton taxa was very low during the monsoon period.

In the Vellar - Coleroon estuary major zooplanktonic groups flourish during April-September when salinities are high. According to Krishnamurthy (1961)

TABLE 2

Marine & Brackish (Estuarine)	Brackish Estuarine	Brackish and fresh-water	Freshwater (Limnetic)
<i>Acartia southwelli</i>	<i>A. plumosa</i>	<i>A. chilkaensis</i>	<i>Acartiella tortaniformis</i>
<i>A. erythraea</i>	<i>A. cartiella gravelyi</i>	<i>A. minor</i> <i>A. major</i>	<i>P. lobipes</i>
<i>A. centrura</i>			
<i>Pseudodiaptomus serricaudatus</i>	<i>A. keralensis</i>	<i>P. binghami malayalus</i>	
<i>P. mertoni</i>	<i>P. annandalei</i>		
<i>P. aurivilli</i>	<i>P. binghami</i>		
<i>P. jonesi</i>			

and Subbaraju and Krishnamurthy (1972) salinity and rainfall control to a large extent, the occurrence and distribution of Porto Novo plankton.

Godavari estuary: This forms one of the largest estuaries on the east coast. Ganapati (1964) and Chandramohan (1963) have studied the zooplankton of the area.

A gradual migration of the inshore fauna into the estuary with increased salinity has been recorded in this estuary. The migration of plankton is facilitated by the regular sequence of high tides which tend to push these into the estuaries where they became established during the stable period of salinity. Studies on the biology of *Rhophalophthalmus kempi* is a good example of such migration into the estuarine areas.

Freshwater fauna, particularly cyclopoid copepods and daphnids have been noticed in this estuary at the upper reaches where the salinity is tolerable to them. Hooghly-Matlah estuary is perhaps the largest estuarine system in India covering an area of nearly 8000 square km. Shetty *et al.* (1963) have made observations on the plankton of this estuary and more recently Gopalakrishnan (1971) has dealt with the biology of the estuary.

As stated earlier the salinity varies in the different zones of the estuary depending on the flow in the rivers and highest salinity is normally recorded in July, and the lowest in October. The highest values for the various groups of zooplankton are coincident with stable and high salinity values, particularly in June and July. Zooplankton shows two peaks during the year, one in June/August and the other during November/January. According to Shetty *et al.* (1963) the distribution of the various groups of zooplankton and their composition generally follow the salinity pattern.

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DISCUSSION

- TIWARI : Does the term species diversity relate to the diversity in species composition or diversity in the distribution of the same species at different conditions?
- RAO : The term species diversity is related to the number of species in an area or in a sample at different times. For the calculations, number of species and number of individuals present in the samples were taken into account.
- MURTY : What are the parameters involved in species dispersion index and how it is computed?
- RAO : The data required for the calculation of species diversity are the number of species present in an area or sample and the number of individuals in each species in the sample. The diversity index was calculated using the formula of Fisher *et al.* (1943).