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An approach to differentiate high and low tide data in the diurnal hydrobiological studies of estuaries

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Abstract

In the estuarine water bodies, diurnal and tidal cycle studies on physico-chemical and biological parameters give better understanding of the fluctuation in the quality of incoming and outgoing waters with reference to tidal effects. In such studies of true estuaries, high and low tide data are normally differentiated based on the direction of water flow (period of rise and fall for high and low tide phases respectively) which do not always give satisfactory results of their effects on hydrographic and hydrobiological parameters. In the present study, an attempt was made to compare the high and low tide data separated based on the local tidal amplitude with that of the direction of water flow using salinity as the tide dependent parameter. When the local tidal amplitude was taken into account, bihourly data collected during the period with more than 50% of local tidal amplitude were treated for high tidal effect and the data falling below 50% of it were treated for low tidal effect. The data on salinity and primary productivity obtained from Chandragiri and Murad estuaries of north Kerala were examined to study the high and low tidal effects. The results confirmed that the proposed methodology based on 'tide water level' (local tidal amplitude) would give reliable results than the existing method (based on the direction of water flow) in the diurnal studies of estuarine ecosystems. Separation of low and high tide data on primary productivity based on the proposed methodology revealed that low tide water was relatively more productive than high tide water especially during postmonsoon period in these two estuaries along the southwest coast of India.

Keywords: Methodology to differentiate high and low tide data, hydrobiology, estuaries

Introduction

Tides play very important role in determining the water quality and fertility of estuarine ecosystems. To have a better understanding of the influence of tides on the physico-chemical and biological features and productivity of the estuarine water-bodies, time series data on diurnal studies are preferred. Diurnal and tidal cycle studies project light on fluctuations in the quality of incoming and outgoing waters of river-borne estuarine systems with reference to tidal effects. In such studies, the data pertaining to high and low tides are normally separated based on the direction of water flow which do not always give satisfactory results for the tidal effects on hydrographic and hydrobiological parameters. In the present study, an attempt was made to compare the high and low tide data separated based on the local tidal amplitude with that of the direction of water flow (existing method) using the diurnal data on salinity and primary productivity collected from two estuaries of north Kerala along the southwest coast of India.

Materials and methods

The estuaries selected for the diurnal study were Chandragiri and Murad located about 80 km and 50 km north of Cannanore respectively in Kerala. Depth at stations varied between 1 and 2 m, fixed at the head of the estuaries, about one kilometer interior to the mouth where salinity did not show any remarkable vertical stratification during summer (premonsoon) and postmonsoon months. Bi-hourly diurnal data were collected on rise and fall in water level, salinity and gross primary productivity (G.P.P.) from the surface between 0630 and 1830 hours at the fixed stations during December 1991 representing postmonsoon season and March 1992 representing premonsoon (summer) season. In addition, the time of change in the direction of water flow and the lowest and highest tide marks of the day were noted; and the local tidal height (tidal amplitude) and the period of tide rise and fall were determined. While considering the direction of tide water flow (T.F.) to differentiate the high and low tide phases (existing method), data on salinity obtained

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during the period of rise (having surface water flow from sea side to estuary) were treated for high tide and of the fall (having water flow from estuary to the sea side) for low tide. In the present methodology, while the local 'tide water level' (T.W.L.) was considered as the criterion, the salinity data collected during the period with more than 50% of local tidal amplitude were treated for high tidal effect and the data falling below 50% of T.W.L. of that day were treated for low tidal effect (Fig.1 A & B). High and low tide data thus obtained (by these two methods) on G.P.P. were compared using salinity as the tide dependent parameter. G.P.P. was estimated by light and dark bottle oxygen technique using L-D value per 12 light hours of the day (Strickland and Parsons, 1972). The results thus obtained on primary productivity during high and low tidal phases were compared with those of Moplah Bay (Selvaraj and Molly Varghese, 1999) located along the north Kerala coast at Cannanore having more of marine characteristics (considered as the control station).

Results and discussion

Comparison of the bihourly changes in tide water level, surface salinity and G.P.P. of Chandragiri and Murad estuaries during postmonsoon and premonsoon (summer) months are presented in Tables 1 and 2 respectively. Local tidal amplitudes observed were 96 and 90 cm respectively during December and 72 and 60 cm during March in these estuaries. In Chandragiri Estuary, surface salinity ranged from 15 to 30 ppt and it was 23.8 - 33.7 ppt in the Murad Estuary while the ranges in G.P.P. values were 0 - 0.563 and 0.283 - 0.976 $gC/m^3/d$ respectively during December (Table 1); and during March, the ranges in salinity values were 29.2 - 34.4 and 31.7 - 35.8 ppt and G.P.P. 0.121 - 0.528 and 0.126 - 0.608 $gC/m^3/d$ respectively (Table 2). The variations in salinity values between high and low tide phases based on T.F. and T.W.L. for Chandragiri and Murad estuarine systems are given in Tables 3 and 4 respectively and that of average G.P.P. values for the two estuaries are given in Table 5.

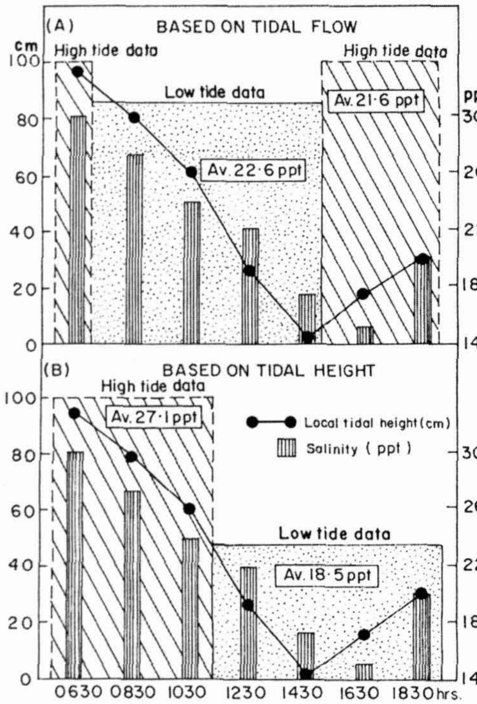

Fig. 1 Illustration showing local tidal amplitude and salinity values: (A) based on 'Tide Flow' (T.F.); (B) based on 'local Tide Water Level' (T.W.L.) in bi-hourly diurnal studies at Chandragiri Estuary (17-12-1991).

While surface water temperature is influenced by solar heat and dissolved oxygen, nutrients and primary productivity are influenced by photosynthesis diurnally, salinity is the only factor showing direct relationship with high and low tides in the estuarine ecosystems. The direct relationship observed between tides and salinity is illustrated in Figure 1. It is also evident from the ranges and mean values of salinity, with higher values recorded during high tidal phase (Tables 3 & 4). Hence, salinity was considered as the standard tide dependent parameter in the present study.

The results indicated that the classification of high and low tide data based on T.W.L. would give reliable results as compared to that of T.F. It is evident from Fig. 1 'A' and 'B' that the proposed methodology would give better results than the existing method. It is very reasonable to accept that the water samples collected soon after the highest tide (when the low tidal flow started) would show more of the high tidal effect in water quality although the 'tidal flow' might indicate low tide; and so also, water samples collected just after the lowest tide (when the high tidal flow started) would indicate more of the low tidal effect in water quality although the 'tidal flow' might indicate high tide as it is evident from the salinity values (Fig. 1). It is also evident from the degree of overlapping of salinity values between low and high tide data and from the difference in the mean salinity values between high and low tide phases based on T.F. and T.W.L. (Tables 3 & 4) that the classification based on 'local tide water level' gives better results than that of the direction of 'tidal flow' to differentiate high and low tide data more effectively in the hourly or bihourly diurnal studies of

Table 1. *Bi-hourly variation in tide water level, salinity (ppt) and gross primary production ($gC/m^3/d$) in Chandragiri and Murad estuaries during December (postmonsoon)*

	Chandragiri Estuary (17-12-1991)					Murad Estuary (19-12-1991)				
Time (hrs)	Tide ht. (cm)	Tide (based on T.F.)	Tide (based on T.W.L.)	Salinity	G.P.P.	Tide ht. (cm)	Tide (based on T.F.)	Tide (based on T.W.L.)	Salinity	G.P.P.
0630	96	H	H	30.0	0.094	90	H	H	33.7	0.283
0830	80	L	H	27.3	0.0	75	L	H	33.7	0.542
1030	60	L	H	23.9	0.0	58	L	H	33.4	0.424
1230	26	L	L	21.9	0.542	30	L	L	30.5	0.948
1430	0	L	L	17.2	0.514	15	L	L	25.8	0.424
1630	16	H	L	15.0	0.563	0	L	L	23.8	0.976
1830	30	H	L	19.9	N.D.	16	H	L	28.0	N.D
			Mean :	22.2	0.286			Mean	29.8	0.600

T.F. = Based on Tidal Flow; T.W.L. = Based on Tide Water Level ;
H = High tide; L = Low tide ; N.D. = No data

Table 2. *Bihourly variation in tide water level, salinity (ppt) and gross primary production ($gC/m^3/d$) in Chandragiri and Murad estuaries during March (premonsoon/summer)*

	Chandragiri Estuary (12-03-1992)					Murad Estuary (17-03-1992)				
Time (hrs)	Tide ht. (cm)	Tide (based on T.F.)	Tide (based on T.W.L.)	Salinity (ppt)	G.P.P.	Tide ht. (cm)	Tide (based on T.F.)	Tide (based on T.W.L.)	Salinity (ppt)	G.P.P.
0630	48	L	H	32.4	0.148	12	H	L	34.5	N.D.
0830	28	L	L	31.0	0.121	34	H	H	35.5	0.435
1030	3	L	L	30.0	0.234	60	H	H	35.8	0.608
1230	0	L	L	29.2	0.528	52	L	H	35.7	0.448
1430	27	H	L	31.7	0.485	29	L	L	33.8	0.126
1630	55	H	H	33.1	0.381	14	L	L	31.7	N.D.
1830	72	H	H	34.4	N.D.	0	L	L	32.3	N.D.
			Mean :	31.7	0.316			Mean	34.2	0.404

Table 3. *Variation in salinity values (ppt) at high (H.T.) and low tide (L.T.) periods based on tidal flow (T.F) and tide water level (T.W.L) in the bihourly diurnal observations at Chandragiri Estuary during postmonsoon and summer months*

Particulars	December 1991 (Post-monsoon)		March 1992 (Summer / Pre-monsoon)	
	Based on T.F.	Based on T.W.L.	Based on T.F	Based on T.W.L.
Ranges in salinity :				
a) at low tide	17.2 – 27.3	15.0 – 21.9	29.2 – 32.4	29.2 – 31.7
b) at high tide	15.0 – 30.0	23.9 – 30.0	31.7 – 34.4	32.4 – 34.4
Overlapping values : (between H.T. & L.T.)	15.0 – 27.3 (12.3)	Nil	31.7 – 32.4 (0.7)	Nil
Mean salinity :				
a) at high tide	21.63	27.09	33.06	33.29
b) at low tide	22.61	18.51	30.64	30.48
Difference in the mean : (between H.T. & L.T.)	-0.98	8.58	2.42	2.81

Table 4. *Variation in salinity values (ppt) at high (H.T.) and low tide (L.T.) periods based on tidal flow (T.F) and tide water level (T.W.L) in the bihourly diurnal observations at Murad Estuary during postmonsoon and summer months*

Particulars	December 1991 (Postmonsoon)		March 1992 (Summer / Premonsoon)	
	Based on T.F.	Based on T.W.L.	Based on T.F	Based on T.W.L.
Ranges in salinity :				
a) at low tide	23.8 – 33.7	23.8 – 30.5	31.7 – 35.7	31.7 – 34.5
b) at high tide	28.0 – 33.7	33.4 – 33.7	34.5 – 35.8	35.5 – 35.8
Overlapping values :	28.0 – 33.7		34.5 – 35.7	
(between H.T. & L.T.)	(5.7)	Nil	(1.2)	Nil
Mean salinity :				
a) at high tide	30.87	33.63	35.27	35.66
b) at low tide	29.45	27.03	33.37	33.08
Difference in the mean :				
(between H.T. & L.T.)	1.42	6.60	1.90	2.58

Table 5. *Gross primary productivity values (G.P.P. in g.C/m³/d) at high and low tide phases based on tidal flow (T.F) and tide water level (T.W.L.) during premonsoon (summer) and postmonsoon months*

Particulars	G.P.P. mean values (Tables 1 & 2)	Based on Tidal flow (T.F)		Based on Tide water level (T.W.L.)	
		High tide average	Low tide Average	High tide average	Low tide average
March : (premonsoon):					
a) Chandragiri	0.316	0.433	0.258	0.265	0.342
b) Murad	0.404	0.522	0.287	0.497	0.126
December (postmonsoon) :	0.286	0.328	0.264	0.031	0.540
a) Chandragiri	0.600	0.283	0.663	0.416	0.783
b) Murad					

river-borne estuarine systems.

Note on primary productivity: In the Chandragiri Estuary, G.P.P. values ranged from 0.121 to 0.528 gC/m³/d during March and 0 to 563 gC/m³/d in December with the mean values recorded as 0.316 and 0.286 g.C/m³/d respectively; and in the Murad Estuary, G.P.P. values ranged from 0.126 - 0.608 and 0.283 - 0.976 gC/m³/d during March and December with the mean values recorded as 0.404 and 0.600 gC/m³/d respectively (Tables 1 & 2). The mean G.P.P. values of these two estuaries during south-west monsoon period were 0.065 and 0.190 gC/m³/d respectively. Since very little information is available in literature on the primary productivity potential and its seasonal variation from these estuaries, the present record of these values should be of interest.

The results revealed that Murad Estuary was relatively more productive during premonsoon, south-west monsoon and postmonsoon months. It is to state here that the Moplah Bay located at Cannanore recorded the mean G.P.P. values of 0.763, 0.536, 0.716 g.C/m³/d for the three seasons respectively during 1991-92 in the surf zone with the mean net primary productivity (N.P.P.) values recorded as 0.610, 0.447 and 0.573 g.C/m³/d respectively (Selvaraj and Molly Varghese, 1999) indicating higher productive potential than these two estuaries during premonsoon, monsoon and postmonsoon months along the north Kerala coast.

In the earlier studies on Moplah Bay and Murad Estuary, the productive potential of dissolved oxygen has been dealt by Selvaraj (1997) adopting light and dark bottle oxygen technique and projecting microbial interference on biochemical utilisation of oxygen in the estuarine systems; and the results indicated relatively low N.P.P. values in these estuarine waters. It is due to the fact that, in those studies, L-I values (with bacterial interference) were considered to determine N.P.P. instead of derivation from G.P.P. values *i.e.,* 0.8 (L-D) per 12 light hours as later described by Selvaraj (2000; 2002) for the determination of N.P.P. in shallow estuarine ecosystems.

Application of proposed methodology on G.P.P. values: It is to state here that adoption of the proposed methodology (based on T.W.L.) might bring out reliable results of high and low tidal effects in the case of other water characteristics also in the estuarine water-bodies with considerable tidal influence as it has been applied and observed in the case of G.P.P. values of Chandragiri and Murad estuaries (Table 5). In the former estuary, while the classification of tides based on T.F. revealed that high tide water was relatively more productive, the present classification based on T.W.L. showed a reverse trend during March and December. The Murad Estuary also indicated a relatively higher productive potential in the low tide water (0.783 $gC/m^3/d$) during December in the present methodology as compared to the classification based on T.F. (Table 5). In the Moplah Bay also, low tide water recorded the highest mean N.P.P. value of 0.646 $gC/m^3/d$ (G.P.P. = 0.775 $gC/m^3/d$) during postmonsoon month (December) than the premonsoon average (N.P.P. = 0.319; G.P.P. = 0.383 $gC/m^3/d$) as reported by Selvaraj and Molly Varghese (1999). To sum up, separation of high and low tide data based on T.W.L. (proposed methodology) revealed that low tide water was relatively more productive especially during postmonsoon period in Chandragiri and Murad estuaries as observed in the Moplah Bay along the southwest coast of India.

Thus, the present study confirms that consideration of T.W.L. upto 50% of local tidal height (tidal amplitude) would give the low tidal effect and water samples collected during the period above 50% of the T.W.L would give the high tidal effect on hydrographic and hydrobiological parameters much closer to reality in the shallow estuarine ecosystems where the diurnal tidal amplitude is more than 50 cm and vertical stratifications of hydrographic parameters are not expected. In the larger and deeper estuaries where vertical stratifications are expected, surface and bottom data may be considered (during high and low tidal phases) adopting the proposed methodology to get reliable results.

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References

Selvaraj, G.S.D. 1997. A methodology to assess the biochemical oxygen utilisation and production in estuarine ecosystems. *In*: R. Santhanam, V. Ramadhas and P. Gopalakrishnan (Eds.) *Proceedings of the National Seminar on Water Quality Issues in Aquaculture Systems*, 18-19 December, 1996, Fisheries College and Research Institute, Tuticorin, p. 139-146.

——, 2000. Validity of net primary productivity estimation by light and dark bottle oxygen technique in tropical inshore waters with a note on primary productivity of the surf zone at Cochin. *Seaweed Res. Utiln.*, 22 (1&2): 81-88).

——, 2002. An approach to differentiate net photosynthetic production and other biochemical production and consumption of oxygen in estuarine water-bodies and aquaculture systems. *Proc. Natl. Sem. Devt. Trans.. Fish. Tech.*, p. 59-65.

—— and Molly Varghese. 1999. Hydrography and plankton productivity of the surf zone of Moplah Bay, north Kerala. *In*: M. Mohan Joseph, N.R. Menon and N. Unnikrishnan Nair (Eds.) *Proc. Indian Fisheries Forum*. Asian Fisheries Society (Indian Branch), p. 1-4.

Strickland, J.D.H. and T.R. Parsons. 1972. A practical handbook of seawater analysis. *Bull. Fish. Res. Bd. Canada*, 167:311pp.

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