E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(2): 80-84

www.fisheriesjournal.com
Received: 12-01-2017
Accepted: 13-02-2017

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Comparison of hydrographic and sediment characteristics of seagrass meadows of Gulf of Mannar and Palk Bay, South West Coast of India

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Abstract
Near shore of Gulf of Mannar and Palk Bay are characterized by seagrass meadows which has potential in coastal protection and as nursery feeding grounds for marine organisms besides use by fishers as medicine. The dynamic ecological disturbances affect the meadows constantly and as it is important to understand the effects, a study on the hydro-chemical and sediment characteristics of major seagrass meadows in these areas was carried out to access the pollution status and factors regulating the seagrass population. The nutrients and heavy metals concentrations were high in Gulf of Mannar than Palk Bay. Dissolved oxygen, nitrate and total nitrogen levels in the surface waters were varied from 5.39 to 8.16 mg/l, 2.73 to 5.18 µmol/l and 15.23 to 126.90 µmol/l respectively. The sediment characteristics showed sandy in nature (72.02- 97.06%) and the total organic carbon in the sediment varied from 0.24-0.58%. Even though, the heavy metals were low in sediments and water compared to reported data, toxic metals such as mercury, arsenic, cadmium and lead were detected in the sediments and their presence may affect the utilization of seagrasses.

Keywords: Gulf of Mannar, Seagrass, Nutrients, Hydrochemical characteristics, Sediment

1. Introduction
Seagrasses play a major role in maintaining the ecology by promoting secondary productivity in the surrounding region through stabilizing the sediments, producing particulate organic matter and transporting it to large varieties of other biological systems [1]. Distributions and growth of seagrasses are controlled by physical factors (temperature, salinity, substratum characteristics, turbidity and sub marine irradiance chemical factors (nutrients availability and pollutants) and biological conditions (presence of epiphytes and other fauna) of the surroundings environments which influences the species diversity and seasonal cycling of seagrass communities [2, 5]. Hydrographical characteristics such as under water irradiance and sediment characteristics play a role in regulating the growth of seagrasses. For the last three decades, the coastal areas are subjected to eutrophication through anthropogenic activities. Seagrasses reduces the sediment erosion as well as the settling of suspended particles in the water column which gives support to large biomasses of organisms living below and above the seagrass meadows [6]. Besides seagrasses enhance the microbial breakdown of dissolved organic nitrogen released from plant roots and decomposition of senescent plant material in sediments [7]. Thus the chemo-dynamics plays an important role in sustaining the biomass in the marine ecosystem.
The growth and reproductive capacity of seagrasses were dependent upon the availability of nutrients in the surroundings of sediments and water column [1, 8-10]. Relatively lower studies were carried out on the hydrographic and sediment characteristics of seagrass meadows of Gulf of Mannar and Palk Bay. There were no reported attempts to analyse the level of toxic metals of mercury, arsenic and cobalt in the waters and sediments of seagrass meadows, especially at Gulf of Mannar and Palk Bay. There are not many systematic studies on the water and sediment characteristics of seagrass meadows and their pollution status. Hence, a study on hydro-chemical and sediment characteristics of seagrass meadows situated at Gulf of Mannar and Palk Bay was carried out to assess the environmental condition and pollution status of these sensitive ecosystems.

2. Materials and Methods

Water and sediments were collected from the two seagrass meadows belonging to Gulf of Mannar (Thonithurai and Chinnappalam) during November2010 and two belonging to Palk Bay (Munaikkadu and Mathacovil) during June 2011 (Fig.1). Surface water samples were collected using a clean plastic bucket and sediment samples using a Van Veen grab (0.045m^2).Water and sediment samples were carried to laboratory in an ice box and kept frozen (-20^{0}C) till analysis and analyses were carried out in triplicates and average values are reported. During south west monsoon, high waves are noticed at Gulf of Mannar while Palk Bay showed high waves during and north east monsoon [11]. Sampling strategy of water and sediment samples were related to availability seagrasses (Table 1). Due to strong waves during north-east monsoon at Palk Bay and during south-west monsoon at Gulf of Mannar, sampling of seagrasses were not possible during the season.

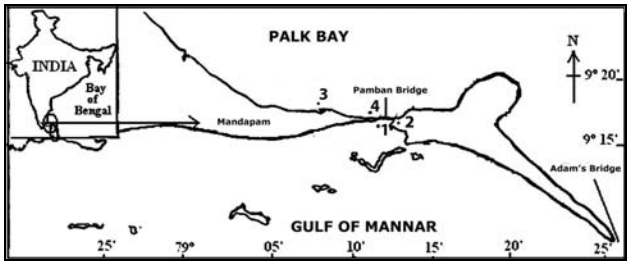

Fig 1: Location of the study area indicating the sampling points (1) Thonithurai, (2) Chinnappalam, (3) Munaikkadu and (4) Mathacovil

Table 1: Population of seagrass species taken for the study

SI. No:	Location	Stations	Seagrass species
1	Gulf of Mannar	Thonithurai	*Cymodocea serrulata* and *Syringodium isoetifolium*
2	Gulf of Mannar	Chinnappalam	*C. serrulate* and *Enhalus acoroides*
3	Palk Bay	Munaikkadu	*C. serrulata* and *Thalassia hemprichii*
4	Palk Bay	Mathacovil	*C. serrulata* and *S. isoetifolium*

The pH of the water samples were measured in situ using portable pH meter (Eutech, pH Tester 10) and temperature was recorded using a sensitive thermometer (sensitivity of 0.10 ˚C). Salinity of the water samples were estimated by Mohr- Knudsen method [12] and dissolved oxygen in the samples were estimated by Modified Winkler [13]. Nutrients (nitrite, nitrate, ammonia, phosphate and silicate) were estimated using a spectrophotometer (Genesys 10UV, Thermo Spectronic) by following the method of Hansen and Koroleff [14]. The total nitrogen and total phosphorous content were measured by alkaline persulphate oxidation method [14]. Trace elements in the surface water were extracted with 1 % APDC followed by chloroform [15] and were estimated using ICP-AES (iCAP 600 Series, Thermo Scientific).

The grain size characteristics of the sediments (sand, silt, and clay) were determined using wet sediment samples [16]. Sediment samples were freeze-dried and finely powdered using agate mortar for further analyses. Total carbon, nitrogen and sulphur were determined using Vario EL III CHNS Analyser. Total organic carbon (TOC) was estimated by TOC analyzer (Vario TOC Select-Elementar) [17]. Heavy metals in the surface sediments were estimated using ICP-OES (iCAP 600 Series, Thermo Scientific) after digestion with 1:5 $HClO_4$:HNO_3 [18]. The certified reference material used for the precision of the metal analysis was BCSS-1 from National Research Council of Canada and spiked samples ranged between 96±2% and 98±2% respectively for cadmium and lead.

3. Results

The general hydro-chemical characteristics of near shore waters of sea grass meadows exhibited alkaline pH of 7.7-8.12, while salinity values were around 15*psu* in Gulf of Mannar waters and 28*psu* in Palk Bay (Table 2). The lower salinity values may be attributed to the intense rainfall during the field survey period. The dissolved oxygen levels varied from 5.39 (Thonithurai) to 8.16mg/l (Chinnappalam) at Gulf of Mannar.The nutrients (nitrate, ammonia, phosphate, silicate, total nitrogen and phosphorous) characteristics were recorded comparatively higher concentration in Gulf of Mannar. The surface sediments were sand and the total organic carbon ranged from 0.24 to 0.58 %, with alkaline pH in Gulf of Mannar whereas slightly acidic pH was noticed in Palk Bay. The general sedimentary parameters were given in Table 3. Heavy metals, Iron (0.20 to 5.30 µg/l), Manganese (0.16 to 0.33µg/l), Copper (nd. to 1.03µg/l), Nickel (0.22 to 0.56µg/l), Chromium (0.27 to 2.04µg/l), Zinc (2.06 to 11.61µg/l), Cadmium (0.01 to 0.07µg/l), Lead (nd. to 0.12µg/l) and Selenium (nd. to 0.20µg/l) were detected in water collected from seagrass bed (Table 4).

Table 2: General Hydrographic parameters in the seagrass meadows in the sampling areas

Parameters	Gulf of Mannar		Palk Bay	
	Thonithurai	Chinnappalam	Munaikkadu	Mathacovil
pH	7.93±0.15	8.12±0.18	8.02±0.16	7.70±0.21
Salinity (*psu*)	15.07±0.45	15.81±0.50	28.36±0.90	25.52±0.80
Temperature (ºC)	26±0.12	26±0.15	35±0.25	32.4±0.18
Dissolved Oxygen(mg/l)	5.39±0.25	8.16±0.20	6.22±0.28	6.06±0.18
Nitrite (µmol/l)	0.15±0.11	0.11±0.15	0.06±0.10	0.018±0.16
Nitrate (µmol/l)	2.73±0.40	5.18±0.65	3.07±0.29	3.27±0.25
Ammonia (mg/l)	21.67±2.25	22.45±2.50	7.49±1.50	10.65±1.80
Phosphate (mg/l)	0.66±0.22	0.76±0.28	0.106±0.14	0.245±0.25
Silicate (mg/l)	22.39±2.24	10.89±2.18	1.72±1.25	1.07±1.50
Total Nitrogen (µmol/l)	109.91±3.50	126.90±4.50	15.23±1.25	22.54±1.50
Total Phosphorous (mg/l)	15.14±3.00	15.92±2.80	3.13±0.85	3.33±0.90

Table 3: General sedimentary parameters in the seagrass meadows in the sampling areas

	Location	Sand (%)	Clay (%)	Silt (%)	TOC (%)	pH	Temp. (º C)
Gulf of Mannar	Thonithurai	93.60±0.29	1.96±0.30	4.44±0.28	0.42±0.18	7.11±0.09	24.4±0.08
	Chinnappalam	72.02±0.38	3.07±0.25	24.91±0.33	0.58±0.16	7.46±0.07	24.1±0.07
Palk Bay	Munaikkadu	96.60±0.23	1.01±0.17	2.39±0.28	0.24±0.26	6.60±0.12	33.2±0.11
	Mathacovil	97.06±0.22	1.11±0.18	1.83±0.24	0.30±0.22	6.46±0.14	31.0±0.14

Dissolved toxic metals (Zinc, Cadmium and Lead) were detected in all the sea grass stations. Gulf of Mannar stations were found to be more polluted than Palk Bay stations in terms of Zinc and Cadmium and the reverse trend was observed for Lead. Heavy metals residual levels in sediments are given in Table 5. which followed the order Iron (965 to 1195 µg/g) > Manganese (42.00 to 64.42µg/g) > Arsenic (3.28 to 8.62µg/g) > Chromium (4.82 to 6.40µg/g) > Zinc (1.34 to 2.72µg/g) > Copper (1.55 to 2.16µg/g) > Nickel (1.22 to 2.02µg/g) > Cobalt (0.81 to 1.24µg/g) > Lead (0.54 to 0.81µg/g) > Cadmium (0.24 to 0.31µg/g) > Mercury (nd. to 0.03µg/g). The results demonstrated that the pH water during the period of sampling was alkaline with a salinity of over 15*psu* and dissolved oxygen level of 5 ppm. Besides, the water and sediments were contaminated with trace and heavy metals indicating possible pollution in the area which ultimately reflected in the contamination of seagrasses.

Table 4: Trace metals in water (µg/l) in the seagrass meadows in the sampling areas

Elements	Gulf of Mannar		Palk Bay	
	Thonithurai	Chinnappalam	Munaikkadu	Mathacovil
Copper	0.117±0.21	ND	0.319±0.19	1.027±0.22
Chromium	0.265±0.22	2.039±0.60	0.606±0.25	0.317±0.18
Manganese	0.163±0.14	0.206±0.18	0.288±0.20	0.330±0.23
Nickel	0.227±0.12	0.561±0.25	0.198±0.14	0.375±0.22
Iron	4.60±0.60	5.30±0.90	0.198±0.25	0.375±0.35
Zinc	4.74±0.80	11.61±0.95	6.38±0.75	2.06±0.65
Selenium	0.200±0.25	0.113±0.18	ND	ND
Copper	ND	ND	ND	ND
Cadmium	0.021±0.25	0.065±0.70	0.009±0.10	0.015±0.20
Lead	0.007±0.10	ND	0.019±0.20	0.121±0.45
Mercury	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND

Table 5: Trace metals in sediment (µg/g) in the seagrass meadows in the sampling areas

Elements	Gulf of Mannar		Palk Bay	
	Thonithurai	Chinnappalam	Munaikkadu	Mathacovil
Copper	2.16±0.30	1.94±0.25	1.68±0.24	1.55±0.22
Chromium	4.86±0.28	6.40±0.35	4.92±0.30	4.82±0.25
Manganese	52.95±0.40	64.42±0.40	42.68±0.50	42±0.50
Nickel	2.02±0.20	1.56±0.15	1.22±0.14	1.41±0.16
Iron	1095±1.00	1195±1.00	1040±0.60	965±0.60
Zinc	2.72±0.25	1.34±0.20	2.24±0.20	2.01±0.22
Selenium	ND	ND	ND	ND
Copper	1.24±0.30	0.81±0.25	0.91±0.20	0.84±0.18
Cadmium	0.237±0.25	0.311±0.30	0.276±0.18	0.238±0.15
Lead	0.679±0.24	0.540±0.21	0.811±0.38	0.618±0.25
Mercury	0.030±0.20	0.011±0.18	0.009±0.15	ND
Arsenic	7.66±0.45	8.62±0.55	ND	3.28±0.35

4. Discussion

Coastal seagrass meadows were subjected to anthropogenic impact during the past three decades. The distribution of hydrographic parameters in Gulf of Mannar and Palk Bay and the nutrient concentration in the present study are comparable with the earlier studies in the region [1, 10]. The low dissolved oxygen with high nitrite indicated that it might be due to the decomposition of algae by microorganisms [2]. The study showed lower nutrient concentrations along the study areas during the period of study. However, higher nutrient enrichment in Gulf of Mannar seagrass meadows than Palk bay has been reported in earlier studies [1, 4, 5, 10]. Comparatively higher concentrations of nutrients in Gulf of Mannar than Palk bay were attributed due to land runoff due to heavy rainfall during the monsoon season [1, 9, 19]. The low phosphate content could be related to greater utilization by phyto benthic communities [9]. It was also reported that nutrients concentration was directly proportional to the algal growth as well as larger phytoplankton population and inversely proportional to the seagrass growth [5].

The lower surface water temperature, salinity and dissolved oxygen during northeast monsoon were reported in earlier studies [4, 20] and relatively lower dissolved oxygen at Thonithurai than Chinnapalam of Gulf of Mannar might be due to water mixing at Pamban (opposing currents) as well as cultivation of seaweeds [2]. Similarly the acidity of the sediments was attributed to the decomposition of seagrasses and seaweeds [21, 22] and also due to the low carbonate contents of in the seagrass sediments [23]. The surface sediments of Gulf of Mannar were reported to be sandy (74-88%) [4, 5, 23, 24] with less in organic carbon content of 0.14-0.91% as reported by previous studies [23] which compares well with the present

findings in Gulf of Mannar. The relatively higher variations in sediment composition at Gulf of Mannar over Palk Bay could be due to the mixing up of silt and clay by wave action, tides, wind agitation and fresh water discharges. Relatively high slit and clay as well as TOC at Chinnappalam and Thonithurai were due to flow of water with high nutrients with organic matter from Palk Bay to Gulf of Mannar through Pamban Pass leading to high TOC [23].

The results show a very low level of dissolved heavy metals in the seagrass meadows than those reported from other meadows worldwide [25-28] as well as the previous studies pertaining to the Gulf of Mannar and Palk Bay [29-31]. Most of metals studied showed variations in their concentrations between stations along Gulf of Mannar and Palk Bay whereas no remarkable differences were noticed in the case of Cadmium [31]. Heavy metals distributions in the water column had strongly influenced by factors such as rainfall, ocean current, winds etc and its effect reflect immediately in the water column [30]. Metal to metal variations at Gulf of Mannar was affected by factors such as anthropogenic activities, northward movement of sediments and currents along with continuous re-suspension of bottom sediments [29].

Chromium, Nickel, Iron, Selenium and Cadmium concentrations were high at Gulf of Mannar than Palk Bay, while Copper, Manganese and Lead were high at Palk Bay compared to Gulf of Mannar. The surface sediments of Gulf of Mannar and Palk Bay were considerable polluted with Arsenic and sediments of Gulf of Mannar were found to be polluted with Mercury. This reflects the increased anthropogenic perturbations in these seagrass meadows. Land run off, fluvial inputs and microbial degradation also would produce an increased metal level during monsoon [32]. Cadmium and Lead concentrations decreased from near shore to offshore at most of the stations and lead content predominated over cadmium. Cadmium and Lead content in sediments and seawaters in the present study are much lower than earlier study [33] at Mandapam, Gulf of Mannar. Near shore sediments were characterized by very fine sand and trace metals in seawater has a tendency to form colloids and increasing their size by adsorbing to planktonic debris and settled down in sediment. Some of these metals were trapped in the lattices of the sand and they were not affected by turbulences, waves, currents etc. This leads to an increase in the concentration of these metals in sediment [33]. This might be the reasons for higher concentrations of toxic metals in sediments and their lower or no content in seawater. And also trace metals which are not in the lattices were affected by physical process in the sea.

A comparatively higher content of lead was noticed in sediment leached with seagrasses than sediment alone (a 20 fold increase) [34]. Apart from anthropogenic activities at Gulf of Mannar arsenic released from degrading beach rocks could also contributed to its level in the sediments [35]. An increase in the concentration of arsenic at Yellow river estuary of China has been reported as a result of human activities, agricultural irrigation, agrochemicals and fertilizers through drainage etc. [36]. Metal minerals present in the sediment have a tendency to absorb trace metals from the water column. At Gulf of Mannar, continual re-suspension of bottom sediments leads to scavenge followed by concentration of metals which are already present in the water column. The southern part of Gulf of Mannar region contained industries while at northern part domestic wastes enters directly to the sea [29]. This might be the reason for station wise variations of trace metals at Gulf of Mannar than Palk Bay.

5. Conclusion

Investigations carried out at Sea grasses meadows from Gulf of Mannar and Palk Bay to assess the environmental conditions prevailing in such systems showed that the dissolved nutrients and heavy metal concentrations were comparable to those reported by the previous studies. Even though the dissolved heavy metal concentrations were low, the sediments were considerably polluted with arsenic and mercury. The nutrients and heavy metals exhibited higher concentrations in Gulf of Mannar than Palk Bay. The Mercury and arsenic may pose detrimental effects to the sea grass and marine biota.

6. Acknowledgements

The authors are thankful to the Director, ICAR-Central Institute of Fisheries Technology, Cochin, the Director, School of Marine Sciences, the Dean, Faculty of Marine Sciences, Head Department of Chemical Oceanography, Cochin University of Science and Technology for their support and facilities provided.

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