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Zooplankton Assemblage in Hambanota Port and Adjacent Coastal Waters of Sri Lanka

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Abstract

Present study was to investigate zooplankton assemblage in Hambantota port and adjacent coastal waters in Sri Lanka. Samples were collected from the port before the commencement of commercial operations in order to have baseline information on zooplankton assemblage that can be used in the future to study any community change. Species composition, abundance, spatial distribution and diversity of zooplankton were investigated over a period of six months from January 2011 to June 2011. Monthly samples were collected from both inner-harbor and outer-harbor. Physico-chemical parameters such as temperature, pH, salinity, density, conductivity, nitrate, orthophosphate, DO, BOD_5 and Ch *a* were also measured. Zooplankton diversity, species richness and evenness were calculated using Shannon-Weiner diversity index (H′), Simpson's index (D) and Pielou's evenness (E). A total of 72 zooplankton types were identified throughout the research project mainly *Calanus* sp., *Paracalanus* sp., *Sapphirina* sp., *Acartia tranteri*, Barnacle nauplii, Crustacean cypris larvae, *Oikopleura* sp., Tunicate larvae, *Brachionus calyciflorus calyciflorus*, *Brachionus forficula*, Fish larvae, *Discorbis* sp., Actinula larvae and *Sagitta* sp.. Copepod nauplii dominated the zooplankton. According to percentage occurrences arthropods (71%), protozoans (10%) and ichthyoplankton (9%) were abundant in the inner harbor. In the outer harbor also arthropods (66%), ichthyoplankton (11%) and protozoans (7%) were recorded in higher numbers. Highest species diversity (H′ =2.685), highest species richness (S=39) and highest evenness (E=0.856) were recorded from outer harbor locations (HFHB1 and HPM). Several species such as *Ceratium furca*, *Chaetoceros* sp., *Thalassiosira* sp., *Rhizosolenia* sp. and *Protoperidinium* sp. known to form harmful algal blooms were also observed in this study.

Key words: Zooplankton assemblage, Hambantota port, Ballast water, Invasive Alien Species (IAS)

Introduction

Introduction of Invasive Alien Species (IAS) via ballast water is one of the four greatest threats to world oceans (Alexandrov and Berlinsky, 2005). These sudden introductions cause major threats to native biodiversity, natural ecosystems and ecosystem services. Apart from habitat degradation, introduction of IAS has become devastating to native ecosystems which harbor much of the worlds threatened biodiversity. It has been estimated that at any time more than 3,000 species ranging from protists to fish are able to survive as blind passengers in ballast water tanks for several weeks during transoceanic cruises and a total of several thousand or even millions of organisms are transported in ballast water holds of a single ship (Locke *et al.*, 1993). The situation becomes worse when ballast water tanks serve as incubators for certain species depending on their characteristics (Gollasch *et al.*, 2000). The invasiveness of most of these alien species causes ecological imbalance and results in severe economic losses to their receiving countries. For example, Zebra mussel (*Dreissena polymorpha*), an invasive mollusk species, carried accidently to North America via ballast water caused billions of dollars of damage to underwater pipes in the Great lakes of USA by fouling (De Poorter, 2009). Since the extent of commercial vessel traffic varies considerably among ports, the risk of IAS introductions in ports can also fluctuate depending on the frequency and volume of ballast water it receives. The viability of introduced species in recipient waters provides important information on potential threats (Senanayake *et al.*, 2010) and indicates the necessity of implementing ballast water management strategies.

The Hambantota Port project is to meet with the high demand and for efficient cargo handling in Sri Lanka. It is planned to be developed as a services and industrial port. It facilitates excellent water depth conditions, arid climatic conditions and sufficient land. The most important feature of the location is that it is only 6-10 nautical miles from the busiest main East-West shipping route. Upon completion, the port will cover 4,000 acres of land and will accommodate 33 vessels at any given time making it the largest port and gradually become a container transshipment hub in South Asia. The new port will help to minimize the pressure in the Colombo port and also will provide services to ships that normally take three and a half day detours from their shipping lanes to receive services including refueling, maintenance, logistics and buying provisions and medical supplies. However, it is inevitable that such large-scale development projects would also pose threat to our coastal ecosystems mainly through risk of ballast water invasions (Ranatunga *et al.*, 2010). Therefore, obtaining baseline information on zooplankton assemblage is imperative at this stage for imparting the impact of shipping on our marine environment.

The primary objective of the present contribution was to collect baseline information on zooplankton assemblage and associate phytoplankton in Hambantota port and adjacent coastal waters before the commencement commercial operations.

Materials and methods

Study area and sampling sites

Samples were collected from four sampling stations of the developing Hambantota Port and three offshore sampling stations from either side of the port mouth (Figure 1).

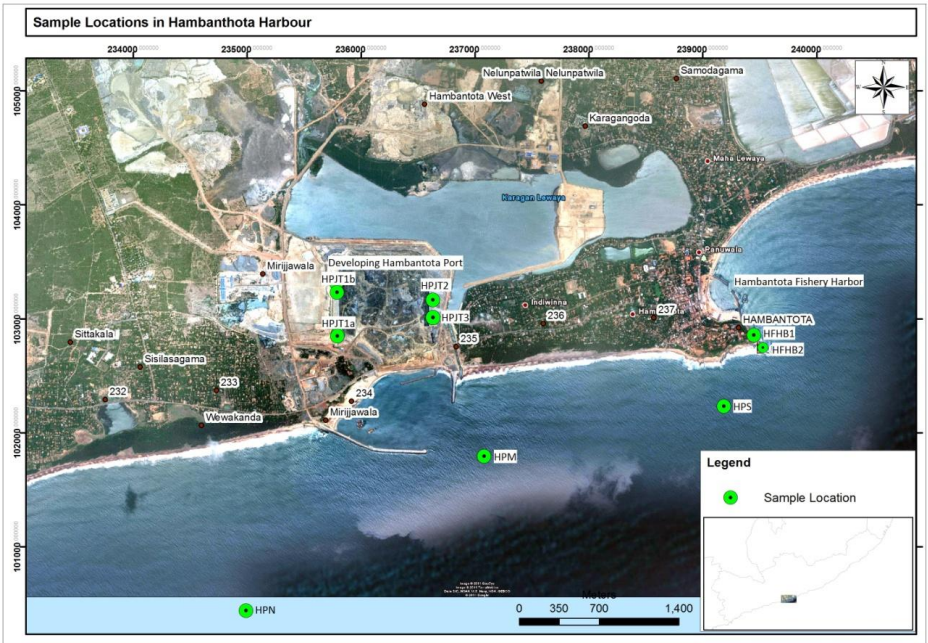

Figure 1. Study area showing sampling locations

HPJT1a -Hambantota Port Jetty 1a, **HPJT1b** - Hambantota Port Jetty 1b, **HPJT2** - Hambantota Port Jetty 2, **HPJT3** - Hambantota Port Jetty 3, **HFHB1** - Hambantota Fishery Harbour – Beach1, **HFHB2** - Hambantota Fishery Harbour – Beach2, **HPS** - Hambantota Port – South, **HPM** - Hambantota Port – Mouth, **HPN** - Hambantota Port - North

Each field visit comprised of two sampling dates. Field sampling was carried out at the dusk of first day and at the dawn of second day. Evening samples were collected only from the inner harbor sites (from the Jetty). Morning samples were collected from all inner harbor sites and outer harbor (offshore) sites.

At each sampling station, water samples were obtained for water quality analysis and for zooplankton analysis. Water samples were collected from the surface as well as from the bottom (from 4.5m depth) from inner harbor sites. Vertical and horizontal samples were collected at each outer harbor sampling site. All the samples included two replicate samples. Several physico-chemical (such as temperature, pH, salinity, density, conductivity, DO, nitrate, orthophosphate) and biological parameters (such as BOD_5 and Chlorophyll *a*) were also determined.

Temperature was measured using a Mercury thermometer and pH was read using a standard digital pH meter (WTW pH 340-A). Salinity and density were determined using a refractor meter (ATAGO S/Mill-E) and conductivity was measured using a digital conductivity meter (WTW Cond 330i). Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were measured using Winkler method (Wetzel and Likens, 2000).

For nutrient analysis water samples were collected from the surface and deep (0.5m) using a Ruttner water sampler. After collecting water samples to clean polyethylene cans, they were covered with Aluminum foil and transported to the laboratory stored in ice. At the laboratory filtered water samples were analyzed for nitrate following Sodium-Salycilate method and for orthophosphate following Ammonium-molybdate method (Wetzel and Likens, 2000). For determination of Ch *a*, water samples were covered with Aluminum foil and transported to the laboratory stored in ice. Filtered water samples were immediately analyzed for Ch *a* at the laboratory following the spectro-photometric method (Wetzel and Likens, 2000).

Zooplankton Sampling

For plankton sampling a zooplankton net with a radius of 4.5cm and 50µm mesh size was used. In inner harbor sites, the net was pulled up from the bottom for a height of 15m water column. After retrieval, samples were collected in to clean 100ml polyethylene bottles (Ebberts and Wing , 1997; Tan *et al.* 2004). Each sample was preserved *in situ* using a 5% buffered formalin solution and at the laboratory, samples were fixed by adding one drop of Lugol's solution to 20ml of the plankton extract before enumerating. For outer harbor samples, horizontal and vertical tows were conducted. Horizontal samples were towed for 2min at a speed of approximately 2knots. Vertical plankton samples were collected by pulling up the net from the bottom for a height of 10m water column from the surface.

Zooplankton enumeration and microscopic identification

Identification was done to the nearest possible taxa by microscopic examination of concentrated samples using plankton identification guides (Conway *et al.*, 2003; Jayasiri, 2009; Kasturirangan, 1963; Perry, 2003; Swadling, *et al.*, 2008; Yamaguchi and Bell, 2007). Zooplankton enumeration was conducted using a Sedge-Wick Rafter counting chamber (Chittapun *et al.*, 2009; Nikwoji *et al.*, 2010). Images were captured with a Microscope Image Projection System (Magnus Live USB 2.0 camera) for further identification.

Data analysis

Densities at each location were calculated after enumerations. Zooplankton diversity at each location was calculated using Shannon Weiner's diversity index (Beals and Harrell, 2000a), Simpson's index (Beals and Harrell, 2000b) and Pielou's evenness test. Phytoplankton count was also obtained at each location to calculate the phytoplankton: zooplankton ratio.

All statistical analysis was carried out using MINITAB 14.0 statistical software. Two-way Analysis Of Variance (ANOVA) was used to identify significant differences between sample collection time and environmental conditions as well as between sample collection methods and the environmental conditions. Zooplankton density, zooplankton diversity, species richness and species evenness were considered there. At the end an attempt was made to link biotic data with environmental factors using the Regression analysis (GLM).

Results and Discussion

Table 1. Taxonomic composition and spatial distribution of zooplankton in the dusk and dawn

Zooplankton species	Stations								
	HPJT1a	HPJT1b	HPJT2	HPJT3	HPS	HPM	HPN	HFHB1	HFHB2
Phylum Protozoa									
1) Unidentified radiolarians (colony)	-	+	+	+	+	+	+	-	-
2) Foraminiferan	-	-	-	-	+	+	+	-	-
3) *Discorbis* sp.	+	-	+	-	+	+	+	+	-
4) TS 01	+	+	-	+	+	+	+	+	+
5) TS 02	-	+	-	+	+	+	+	+	-
6) TS 03	+	-	-	+	+	+	+	+	-
Phylum Cnidaria									
1) Hydroid medusa	-	-	-	-	-	+	-	-	-
2) *Obelia* sp.	-	-	-	-	+	-	-	-	-
3) Actinula larvae	-	-	-	-	-	-	+	+	+
Phylum Chaetognatha									
1) Chaetognath	-	-	-	-	-	+	-	-	-
2) *Sagitta* sp.	-	-	-	-	-	+	+	-	-
Phylum Annelida									
1) PL 01	+	+	+	+	+	-	+	-	-
2) PL 02	+	+	+	+	+	+	+	-	-
3) PL 03	+	+	+	+	+	+	-	+	+
4) PL 04	+	+	-	-	+	+	-	+	-
5) PL 05	-	+	-	-	+	+	-	-	-
6) PL 06	+	+	-	-	+	-	-	+	+
7) PL 07	-	-	-	-	+	-	-	-	-
8) PL 08	-	-	-	-	+	-	-	-	-
9) PL 09	-	+	-	-	+	+	+	-	-
10) PL 10	-	+	-	-	+	-	+	-	-
11) *Tomopteris* sp.	-	-	-	-	-	-	+	-	-
Phylum Mollusca									
1) Mid gastropod veliger larvae	+	+	-	-	+	+	+	+	-
2) Veliger larvae	-	-	-	-	-	+	+	-	-
3) Young *Diacria*	-	-	-	-	-	-	+	+	-
Phylum Arthropoda									
1) Unidentified Cladocera	-	+	-	-	-	-	-	-	-
2) *Calanus* sp.	+	+	+	+	+	+	+	-	-

3)	*Paracalanus* sp.	-	+	-	-	+	+	+	+	-
4)	*Metacalanus* sp.	-	-	-	-	+	-	-	+	-
5)	*Pseudocalanus elongatus*	+	+	+	+	+	+	+	+	+
6)	*Acartia tranteri*	+	+	+	+	+	+	+	-	-
7)	*Oncaea media*	+	+	+	+	+	+	+	+	+
8)	*Isias tropica*	+	-	-	-	-	-	-	-	-
9)	*Euchaeta* sp.	-	+	-	+	+	+	+	+	-
10)	Harpacticoid copepod	+	+	+	+	+	+	+	+	+
11)	*Oithona* sp.	-	+	-	-	+	-	+	-	-
12)	*Sapphirina* sp.	+	-	-	-	-	-	+	-	-
13)	CoS 01	-	-	-	-	-	+	-	-	-
14)	CoS 02	-	-	-	-	-	+	-	-	-
15)	Calanoid copepod nauplii	+	+	+	+	+	+	+	+	+
16)	Harpacticoid copepod nauplii	+	+	+	+	+	+	+	+	+
17)	Cyclopoid copepod egg sac	+	+	-	-	+	+	+	+	-
18)	Free-spawned calanoid copepod egg	-	+	-	-	-	-	-	-	-
19)	Barnacle nauplii	+	+	-	+	+	+	+	+	+
20)	Crustacean nauplii	+	+	+	+	+	+	+	+	+
21)	Crustacean Cypris larvae	+	-	+	-	-	+	+	+	-
22)	*Gammarus* sp.	-	+	-	-	-	+	-	-	-
23)	Ostracod	-	-	-	-	-	-	-	+	-
24)	AS 01	-	-	-	-	-	-	-	+	-
25)	AS 02	-	-	-	-	-	-	-	+	-
26)	AS 03	-	-	-	-	-	-	-	+	-
27)	CS 01	+	+	+	+	+	+	+	+	+
28)	CS 02	+	-	-	-	-	-	+	-	-
29)	CS 03	-	+	-	-	+	-	-	-	-
Phylum Echinodermata										
1)	Echinopluteus larvae	-	+	-	-	+	+	-	-	-
Phylum Chordata										
1)	*Oikopleura* sp.	+	+	-	-	+	+	+	-	-
2)	Tunicate larvae	-	-	-	-	+	-	+	-	-
Phylum Rotifera										
1)	*Brachionus calyciflorus calycyflorus*	+	-	-	-	-	+	+	+	-
2)	*Brachionus forficula*	-	-	-	-	-	-	+	-	-
3)	Unidentified rotifers	+	+	-	-	-	+	-	-	-
Ichthyoplankton										
1)	Early fish embryo	+	+	+	+	+	+	+	+	-
2)	Late fish embryo	+	+	+	+	+	+	+	+	+
3)	Fish larvae	-	+	+	+	+	+	+	-	-
4)	Fish egg	-	+	+	+	-	+	+	-	-
Unidentified species										
1)	US 01	+	+	-	-	+	+	+	+	-

2)	US 02	+	+	-	-	-	-	-	-	-
3)	US 03	-	+	-	-	-	+	-	-	-
4)	US 04	-	-	-	-	-	-	-	+	-
5)	US 05	-	-	-	-	-	-	-	-	+
6)	US 06	-	-	-	-	-	-	-	-	+
7)	US 07	-	+	-	-	-	-	-	-	-
8)	US 08	-	-	-	-	-	-	+	-	+
9)	US 09	-	-	+	-	-	-	-	-	+
10)	US 10	-	-	+	-	-	-	-	+	-
11)	US 11	-	-	+	-	-	-	-	-	+

TS –Tintinnida Species, **PL** –Polychaete Larvae, **CoS** –Copepod Species, **AS** – Arthropod Species, **CS** – Crustacean Species, **US** –Unknown Species

In the inner-harbor and outer-harbor, during both dawn and dusk, the highest species composition was recorded in HPJT1 while the lowest was recorded in HPJT3 (Table 1). As HPJT2 and HPJT3 were under construction for the first two months (March and April) of the study period, field sampling from those locations was only possible from May onwards. This can be the reason for apparent less species composition in HPJT3. HFH B1 and HFH B2 were used as alternative locations in rough-sea conditions where sea going was not possible. Apparent less species composition there can be due to relatively turbulent conditions.

When comparing abundance of species, relatively higher number was recorded from the outer-harbor (71) compared to the inner-harbor (54). Naturally proper mixing of water column facilitates the growth of planktonic organisms (Tseng *et al.,* 2008). According to Acabado *et al.,* (2010), in offshore stations, crustaceans show a drastic increase in abundance in the 50-100m depth strata. This appears to be related to the thermocline where typically higher upper layer primary productivity can support dense communities of zooplankton. Since field sampling in this study was not done up to that depths, the reason for relatively higher species composition in the outer-harbor may be due to well-mixed water there in.

Some of the zooplankton identified in this study such as *Acartia* sp., *Euchaeta* sp., *Oncaea media*, *Isias tropica*, *Pseudocalanus elongatus*, *Calanus* sp., *Paracalanus* sp., *Brachionus* sp., *Discorbis* sp., *Oikopleura* sp. and *Sagitta* sp. have been recorded in previous studies in Colombo harbor and adjacent coastal waters (Chandrasekara and Fernando, 2009; Senanayake *et al.,* 2010; Ranatunga *et al.,* 2010). Since Hambantota port was not polluted by commercial operations at that time it can be assumed that the above mentioned species naturally inhabit Sri Lankan coastal waters.

Changes in physico-chemical and biological parameters

In all inner-harbor and outer-harbor samples relative increase in several physico-chemical parameters such as temperature, pH, salinity, density, conductivity, nitrate, orthophosphate and in Chlorophyll *a* was observed in May and June months.

According to weather data, in April-June months the temperature in Hambantota is relatively higher. The south-west monsoon generally begins around the start of June and fades down by the end of September. Monsoon driven currents are powerful physical forces (Hwang *et al*., 2010). Tseng *et al.* (2008), states that winds play a vital role in

shaping species richness and diversity of plankton in coastal waters. Therefore, these climatic conditions of the region may have affected observed variations (Figure 2, Figure 3 and Figure 4).

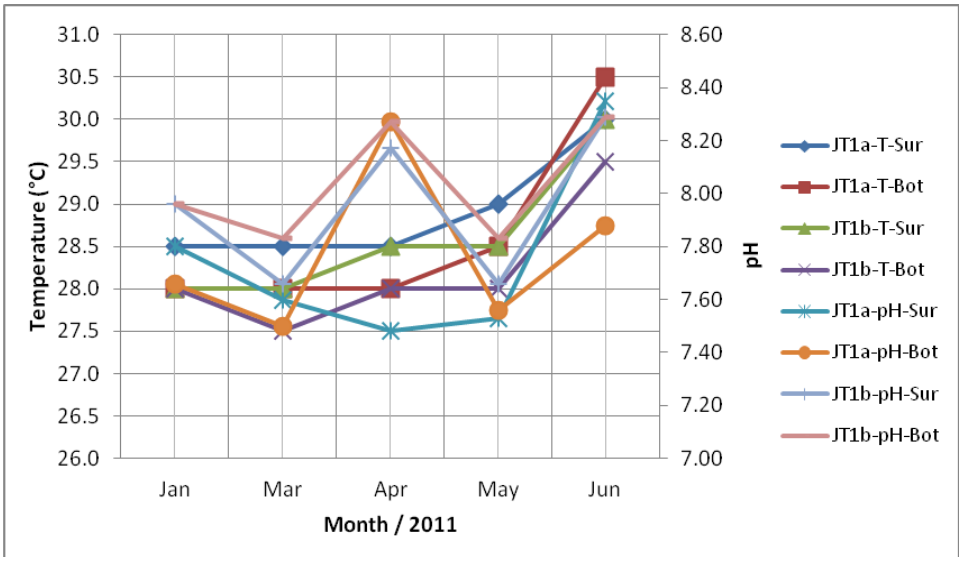

Figure 2. Monthly variations in temperature and pH in the inner harbor in the dusk

T –Temperature, **Sur** –Surface, **Bot** –Bottom

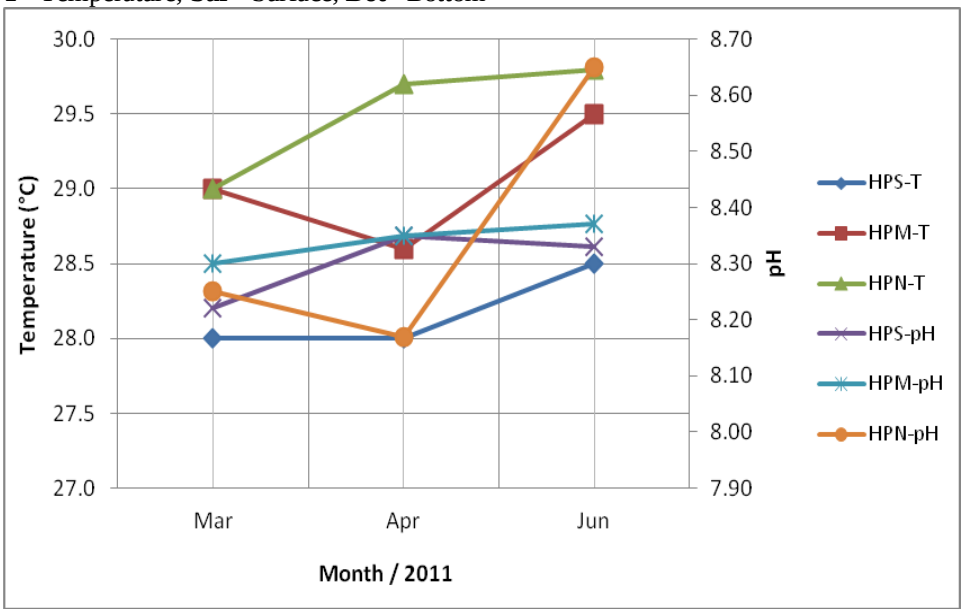

Figure 3. Monthly variations in temperature and pH in the inner harbor in the dawn

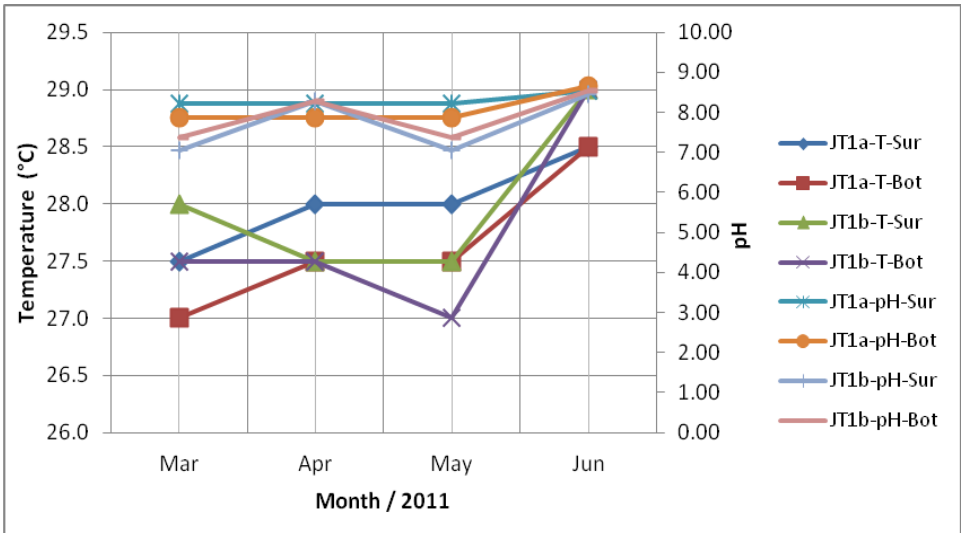

Figure 4. Monthly variations in temperature and pH in the outer harbor

Highest DO was recorded in April and May and relative decrease in BOD_5 was observed in June. The reason for the increase of DO and the decrease of BOD_5 may also be due to the south-west monsoon condition (Figure 5, Figure 6 and Figure 7).

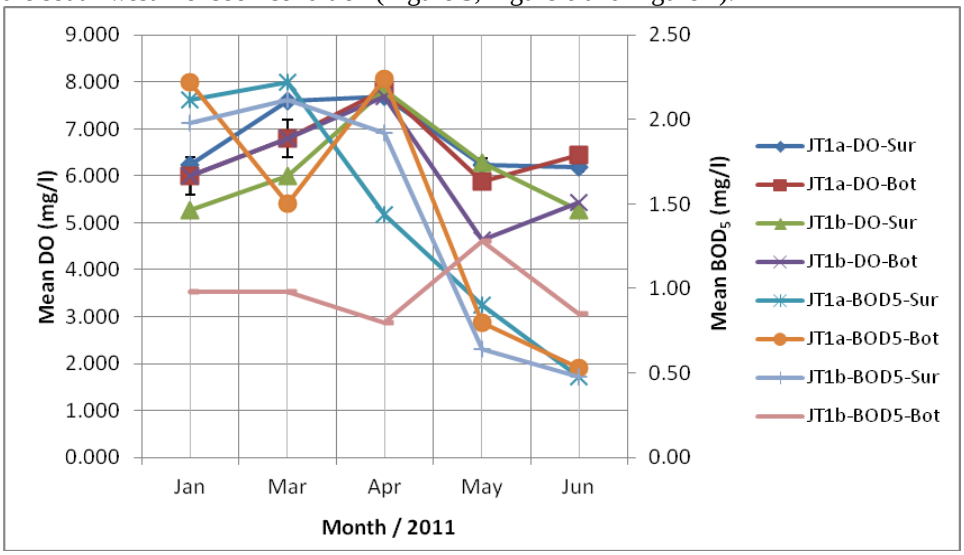

Figure 5. Monthly variations in Dissolved Oxygen (DO) and Biological Oxygen Demand$_5$ BOD_5 in the inner harbor at dusk

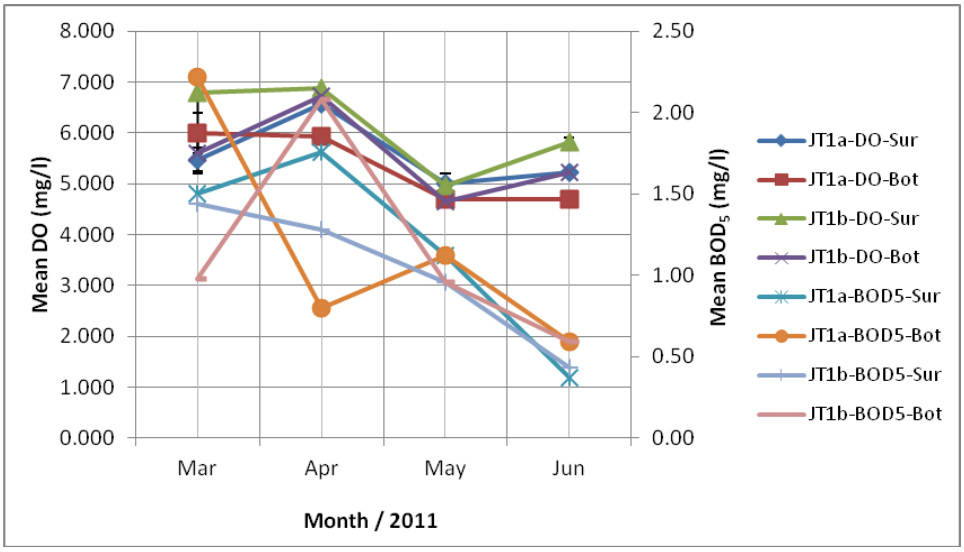

Figure 6. Monthly variations in DO and BOD_5 in the inner harbor in the dawn

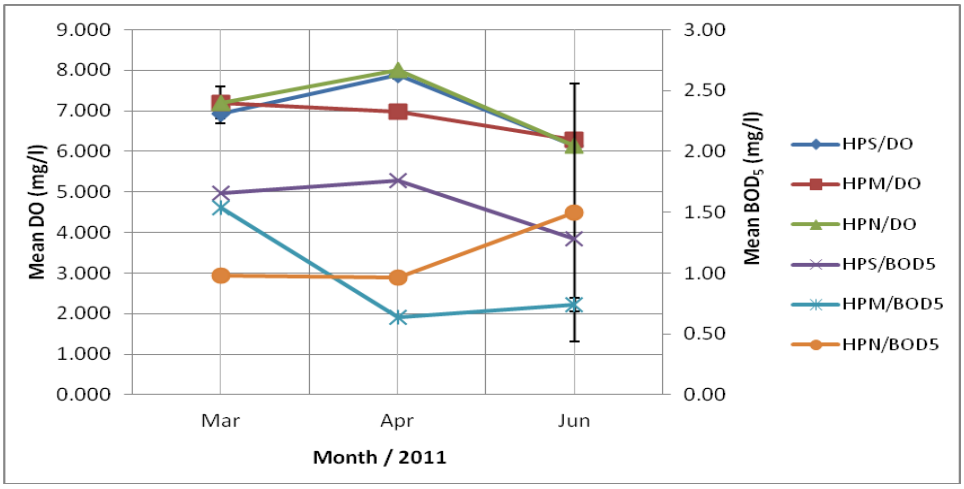

Figure 7. Monthly variations in DO and BOD_5 in the outer harbor

At the same time a sudden decrease of zooplankton density was observed in May and June while the highest phytoplankton: zooplankton ratio was recorded in May. It indicates that in May and June months the phytoplankton abundance has increased. The monsoon mixing of water columns may have favored the growth of phytoplankton and also the highest nitrate, orthophosphate and Chlorophyll *a* readings in June facilitate the situation. According to Jyothibabu and Madhu (n.d.), zooplankton attain their lowest annual value during June-August when the summer monsoon is active and the runoff is high (Figure 8, Figure 9 and Figure10).

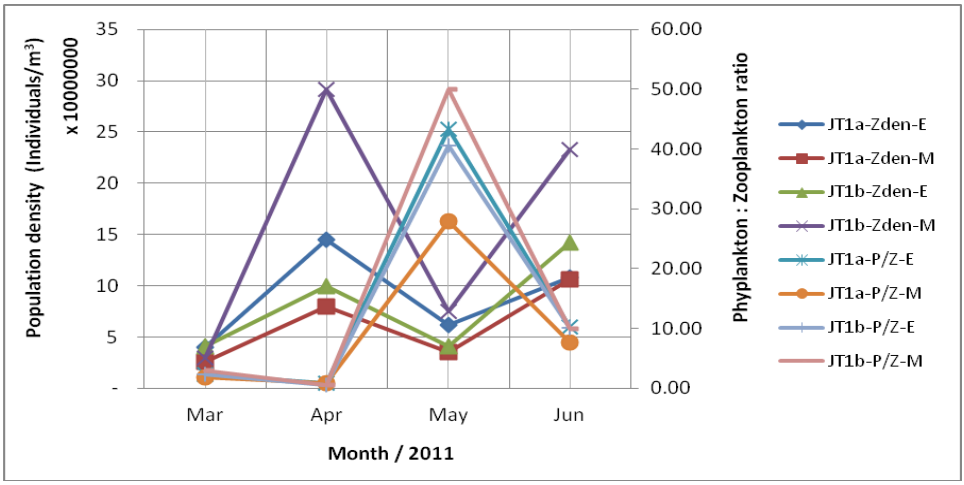

Figure 8. Monthly variations in zooplankton population density and phytoplankton: zooplankton ratio in the inner harbor

Zden –Zooplankton density, **P/Z** –Phytoplankton: zooplankton ratio, **M** –Morning **E** –Evening

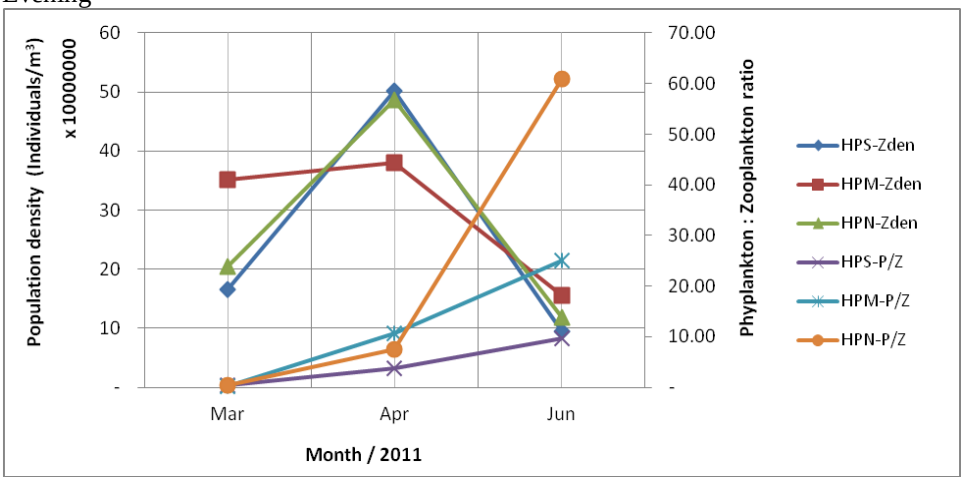

Figure 9. Monthly variations in zooplankton population density and phytoplankton: zooplankton ratio in the outer harbor-vertical tow

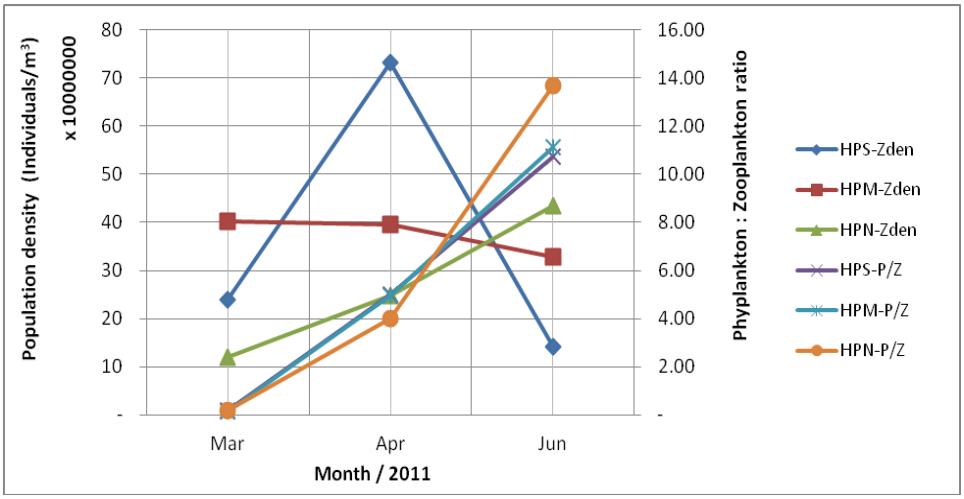

Figure 10. Monthly variations in zooplankton population density and phytoplankton: zooplankton ratio in the outer harbor-horizontal tow

In all inner-harbor and outer-harbor samples, arthropods were recorded the highest percentage while ichthyoplankton and protozoans being the next abundant groups. Out of arthropods, copepod nauplii were the most abundant zooplankton. According to Ekwu and Sikoki (2008), copepods have a preference for higher salinities while rotifers prefer fresh waters. As both inner and outer harbor locations recorded relatively higher salinities, this can be the reason for higher abundance of copepod nauplii while rotifers were recorded in relatively insignificant numbers. Rakhesh *et al.* (2006), also states that changes in zooplankton community structure across water bodies can be associated with differing salinity. According to statistical analysis, for all inner-harbor samples there was no significant difference between sample collection time and location with respect to zooplankton density, species richness and evenness. The reason may be the monsoon mixing of water column. There was a significant difference, however, between locations in the inner-harbor with respect to species diversity. This may be due to apparent less species compositions in HPJT2 and HPJT3.

For all outer-harbor samples there was no significant difference between sample collection method (vertical and horizontal tows) and location with respect to zooplankton density, species richness, species diversity and evenness. The reason may be the monsoon mixing of water columns. According to obtained figures, it indicates higher zooplankton diversity in the outer-harbor.

In this study several toxin-producing algal species were also observed apart from zooplankton identification. Among them were *Ceratium furca* which can cause water discoloration and fish kills, *Chaetoceros* sp. which can cause fish kills, *Pseudo-nitzschia* sp. which can produce domoic acid, *Thalassiosira* sp., *Protoperidinium* sp. and *Rhizosolenia* sp. which can cause water discoloration and fish kills (Horner *et al.*, 1997; Gollasch *et al.*, 2000). This is very alarming that there can be harmful algal bloom formation in coastal waters in Hambantota port area and should be closely monitored throughout.

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