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EVALUATION OF POTENTIAL FACTORS AFFECTING THE DISTRIBUTION OF MYSIDS (Crustacea: Mysidacea) IN PUTTALAM LAGOON, SRI LANKA

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Abstract

Limited information is available on mysids in estuarine systems in Sri Lanka. Present study attempts to find out the distribution of mysids in Puttalam lagoon and also to evaluate the possible factors affecting its distribution. The spatial distributional survey recorded 30 mysid habitats. *Mesopodopsis zeylanica*, *Mesopodopsis orientalis* and a new *Sirella srilankensis* were identified, with *M. orientalis* being the most abundant and widely distributed species. Survey of temporal variation in mysid abundance was also carried out at two sites for a six months period. This collection of *M. orientalis* was the first record in Sri Lanka. Distribution of mysid species is primarily dependent on the salinity. Other than the salinity distribution, and abundance of mysids depend on water level and boundary conditions. The occurrence of mysids exhibited a strong positive correlation ($P \leq 0.01$) with boundary condition of the lagoon, while presence of garbage, water level, and salinity correlated negatively. Furthermore, species distribution were strongly and positively correlated ($P \leq 0.01$) with boundary conditions and negatively correlated with salinity and presence of garbage. The occurrence of *M. zeylanica* depended on low salinity level while *M. orientalis* and *S. srilankensis* depended on high salinity. Lower water levels and boundary vegetation were more favorable for mysids along with sites consisting of mangroves or widespread seagrass beds while soil filled boundary areas and waste disposal sites along the boundary were found to be unsuitable. Reforestation and restoration of mangrove boundary areas can enhance the biodiversity in the lagoon.

Key words: Anthropogenic effects, Mysid distribution, Puttalam lagoon, Sri Lanka

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Introduction

Mysids are hyperbenthic crustaceans which occupy a variety of aquatic habitats and show high abundance in estuarine waters (Fockedey et al., 2006; Suzuki et al., 2009; Punchihewa and Krishnarajah, 2013a, 2019). These minute animals are a dominant component of the estuarine hyperbenthos playing a significant role in the estuarine food web (Vilas et al., 2008; Mantiri et al., 2012). They form important links in estuarine food chains as omnivores, and also serve as a main food source for juvenile and adult fish (Punchihewa and Krishnarajah, 2013b). Additionally, mysids are important animals used in toxicological studies in estuarine ecosystems (Verslycke et al., 2004) as indicator species.

The Puttalam lagoon harbours marine, brackish and freshwater species, and is considered one of the most productive 'basin estuaries' in Sri Lanka (IUCN, 2012). However, large areas of mangroves continue to be cleared for unplanned developmental activities without considering its significant role in providing habitats for a variety of fauna.

Earlier studies have indicated that in general, the distribution and abundance of mysids depends on salinity, temperature, chlorophyll concentration and dissolved oxygen (Biju et al., 2009; Rappé et al., 2011). Moreover, different Mysid taxa are affected differently by these factors. For instance, salinity primarily determines the spatial distribution of mysids along the Westerschelde estuary (Rappé et al., 2011). Baldo et al. (2001) also reported salinity to be primarily responsible for the horizontal distribution of *Rhopalophthalmus mediterraneus* within an estuary. The spatial distribution of *Mesopodopsis slabberi* is determined by temperature and turbidity (Rappé et al., 2011). According to Mees et al. (1995) the spatial distribution of *Neomysis integer* in the upstream reaches was determined by limited oxygen concentrations. The mysids in the Auckland region showed that the salinity ranges for which each three mysid species distributed, (*Tenagomysis chiltoni* 0-18 ppt, *Tenagomysi novaezealandiae*, 26 ppt and *Gastrosacus australis* 1.5-12.6 ppt) were different (Punchihewa and Krishnarajah, 2013a). According to previous studies in Sri Lanka (Punchihewa et al., 2017; Punchihewa and Krishnarajah, 2019), estuarine boundaries with natural vegetation are the most suitable mysid habitats than the boundaries with man-made concrete edges. The present study also assess whether the boundary vegetation depends on the distribution mysid in the Puttalam lagoon.

There is a scarcity in baseline data on mysid distribution and abundance in estuarine environments in Sri Lanka. *Mesopodopsis zeylanica* is only the estuarine species documented in Sri Lanka from Bolgoda Lagoon (Nouvel, 1954; Punchihewa et al., 2017). This species is also found in a tropical estuary, the Cochin backwater in India (Biju and Panampunnayil, 2010). *Mesopodopsis zeylanica* and a new species, *Sirella srilankensis* were recorded from Negombo lagoon (Punchihewa and Krishnarajah, 2019). Thus, it is important to carry out a further survey of mysid species in estuarine areas to gather up to date information on the distribution and abundance of mysids in Sri Lanka. Such studies have not been previously conducted in the Puttalam lagoon.

Therefore, the present study attempts to find out the mysid habitats in Puttalam lagoon and determine the potential factors which influence the distribution of mysids. From the fishery point of view, this lagoon is considered to be one of the most ecologically productive lagoons in Sri Lanka. It provides different habitats for fish and crustaceans. Hence, this study provides the first documented information on mysid distribution in this lagoon.

Materials and Methods

The study was conducted in the Puttalam lagoon from June 2012 to May 2013. The lagoon is situated within the Wet zone on the Western coastal strip of the Puttalam District in the North Western province of Sri Lanka at 7°44'46 - 8°35'60 North and 79° 48'25 - 79°49'17 East. It receives freshwater from main rivers Kala Oya and Mee Oya and a small river, the Moongil Area. It opens to the sea at its northern end and the salinity of water is similar to oceanic salinity (35 ppt). However, water is hyper-saline in the south, as a result of high evaporation (IUCN, 2012). This is one of the largest estuaries in Sri Lanka, extending over 327 km^2 and consists of different ecosystems such as mangroves (including numerous mangrove islands), sea grass beds, reed beds, salt marshes etc.

The present study considered two aspects related with mysid distribution: a spatial distribution survey throughout the lagoon from June 2012 to May 2013 and a temporal distribution survey over a six-month period at two sites, from July 2012 to December 2012. These two sites were selected due to the relatively high numbers of mysids that were recorded during initial reconnaissance surveys. One of this study sites is located in the Eththal area in the western part of the lagoon, that has patchily distributed mangroves and this site is subject to human interferences. The other site is a mangrove island in the eastern part of the lagoon. The spatial distribution survey was conducted at 39 randomly selected sites to cover the considerable area of the lagoon (Fig. 1 and Table 1).

All surveys were carried out during the day time, using a hand held dip net of mouth area 25×20 cm^2 and 500 µm mesh size which was swept along the boundary of the lagoon. Samples were preserved in 70 % ethyl alcohol. At each site, four replicate surveys were undertaken along an eighty meter transect. Each replicate consisted of 10 m length (each with 10 m apart and total area is 10x4). Environmental parameters such as water temperature, salinity, pH and dissolved oxygen (DO) were measured at each sampling event using WTW 400i Multi-Parameter Water Quality Field Meter (Geotech Environmental Equipment, USA). The boundary conditions at each site were also noted. Morphological characteristics were analyzed in the laboratory to identify the mysid species.

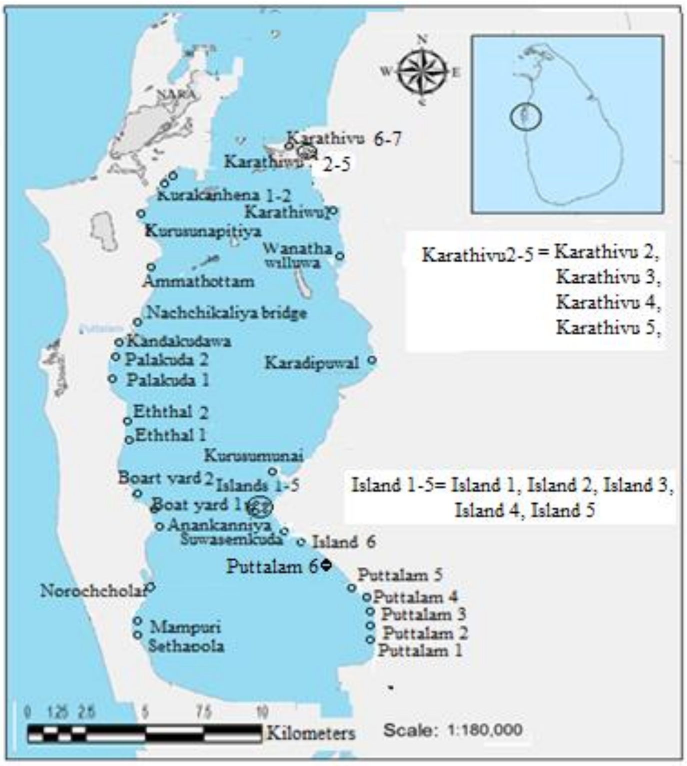

Figure 1: Sampling sites, Puttalam Lagoon

Table 1: Description of sampling sites, Puttlam lagoon

Study site	Vegetation	Study site	Vegetation	Study site	Vegetation/other
Kurusanapitiya	Mangroves	Karadipuwal	Mangroves, seagrasses	Puttalam 2	Mangrove cleared
Kurukkanhena1	Mangroves	Andankannniya	Mangroves, seagrasses	Puttalam 3	Mangrove cleared
Kurukkanhena 2	Mangroves	Wanathawilluwa	Mangroves, seagrasses	Puttalam 4	Mangrove cleared
Kurusamunai	Mangroves	Puttlam 6	Mangroves, seagrasses	Puttalam 5	Mangrove cleared
Eththal 1	Mangroves	Karathiwu 1	Mangroves, seagrasses	Karathiwu 6	Rocky area
Eththal 2	Mangroves	Karathiwu 2	Mangroves, seagrasses	Karathiwu 7	Rocky area
Sethapola,	Mangroves	Karathiwu 3	Mangroves, seagrasses	Island 6,	Mangrove cleared
Ammathottam	Mangroves	Karathiwu 4	Mangroves, seagrasses	Norochcholai	No vegetation
Island 1	Mangroves	Karathiwu 5	Mangroves, seagrasses	Puttalam1	No vegetation, polluted
Island 2	Mangroves	Mampuri	Mangroves		
Island3	Mangroves	Suwasemkuda	Mangroves		
Island 4	Mangroves	Palakuda 1	Mangroves		
Island 5	Mangroves	Palakuda 2	Mangroves		
Boat yard 1	Mangroves	Kandakudawa	Mangroves		
Boat yard 2	Mangroves	Nachchikalliya Bridge	Mangroves		

Statistical analysis

The mean and standard deviation of abundance values (temporal distribution) were calculated. The variations among them were inferred through a series of one-way Analysis of Variance (ANOVA) tests considering the site, month and species separately as factors. Tukey test was performed to assess the significant variation of Mysid abundance in different sites and months. Pearson correlation analysis was performed to assess the factors that affect the distribution of mysid species and their abundance using Minitab version 14.

Results

Spatial distribution survey

Out of 39 sampling sites (Fig. 1 and Table 1), mysids were found at 30 sites (Table 2). Three mysid species, *Mesopodopsis zeylanica* Nouvel, *Mesopodopsis orientalis* Tattersall, and a new *Sirella srilankensis* Punchihewa were identified. This collection of *M. orientalis* was the first record from Sri Lanka. *Mesopodopsis zeylanica*, inhabited two sites, *M. orientalis*, inhabited twenty sites as a single species and *S. srilankensis* inhabited two sites as a single species. Furthermore, *S. srilankensis* was found at nine sites, inhabited sympatrically with *M. orientalis*. Of the three species recorded, *M. orientalis* is the most widely distributed and the dominant species in Puttalam lagoon (Table 2). The sites where mysids were recorded, had widely distributed mangrove forests and in some sites had widespread sea grass beds. Mysids were not found from the sites where there was absence of boundary vegetation, unauthorized garbage disposal sites, recently cleared mangrove areas for recreational purposes and soil filled areas for urban development projects (Table 1, 2).

Table 2: Distribution and occurrence of mysid species in different study sites

Sites, *M. zeylanica* found as single species	Sites, *M. orientalis* found as single Species	Sites, *S. srilankensis* found as single species	Sites, *S. srilankensis* & *M. orientalis* found together	Sites, mysids absent
Kurusanapitiya Kurukkanhena1	Kurukkanhena 2 Kurusamunai Wanathawilluwa Karadipuwal Andankannniya, Suwasemkuda Boat yard 2 Ammathottam, Island 1–Island 5 Karathiwu sites (1,2,3, 4 and 5) Nachchikalliya Bridge	Puttlam 6 Eththal 1	Eththal 2 Sethapola, Mampuri Palakuda 1 Palakuda 2 Kandakudawa Boat yard 1	Island 6, Norochcholai Puttalam1 Puttalam 2 Puttalam 3 Puttalam 4 Puttalam 5 Karathiwu 6 Karathiwu 7

Temporal Distribution

Only *M. orientalis* and *S. srilankensis* were recorded at the main study sites: Eththal and island site. Over the six month period, *M. Orientalis* was the most common mysid species found at the Island site, while *S. srilankensis* was the most common mysid species recorded at Eththal.

In the island site, a total of 822 *M. orientalis* were collected over the survey period and a total of 22 *S. srilankensis* were encountered only in November and December. The number of individuals of *M. orientalis* was high in each month and peaks in abundance occurred during October and December (Fig. 2, Table 3), although a recurring seasonal trend was not apparent. In the Eththal site, a total of 117 *S. srilankensis* were recorded over the survey period, except September and December. In the same site a total of seven *M. orientalis* were found only in September.

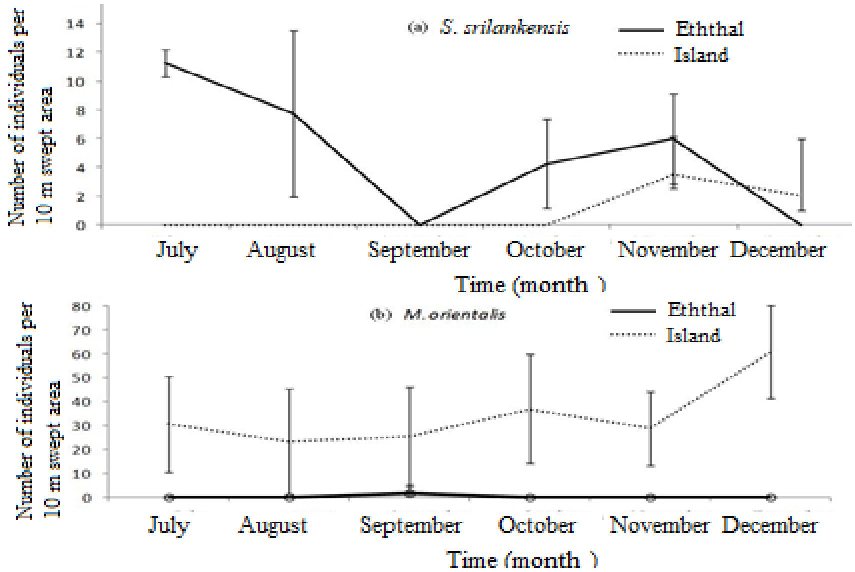

Figure 2: Monthly variation in mean (±SD) (n = 4) abundance of mysids at Eththal and island site in Puttalam lagoon.

Table 3: Variation in the number of individuals of mysids (mean±SE) recorded from two sites.

	M. orientalis		*S. srilankensis*	
	Eththal Mean±SE	Island Mean±SE	Eththal Mean±SE	Island Mean±SE
July	0.00±0.00	30.75± 9.99	11.25±0.48	0.00±0.00
August	0.00±0.00	23.25± 10.96	7.75±2.90	0.00±0.00
September	1.75±1.75	25.25±10.42	0.00±0.00	0.00±0.00
October	0.00± 0.00	36.75±11.40	4.25±1.55	0.00±0.00
November	0.00± 0.00	28.75± 7.71	6.00±1.58	3.50±1.32
December	0.00± 0.00	60.75± 9.51	0.00±0.00	2.00±2.00

SE= standard error

Table 4: Synopsis of significance/non significance in variation of the number of individuals of mysids among months and between sites.

Species	Site	F value	Df	Significance/ non significance
S. srilankensis	Eththal	8.71	05	S
	Island	2.34	05	Ns
M.orientalis	Island	1.88	05	Ns
	Eththal	1.00	05	Ns
All mysids	Island	1.68	05	Ns
	Eththal	6.05	05	S

s = significance at $P \leq 0.05$, ns = not significant, df=degrees of freedom.

One-way ANOVA showed that the mean abundance values of *S. srilankensis* were significantly different among the months at Eththal site while it was not significantly different for *M. orientalis* ($P \leq 0.05$) at both sites. Tukey test showed that the mean abundance values of *S. srilankensis* at the Eththal site were significantly higher in July than September, October and December (Table 3, 4) and this mean abundance for all mysids at the Island site was significantly higher than the Eththal site (Table 4).

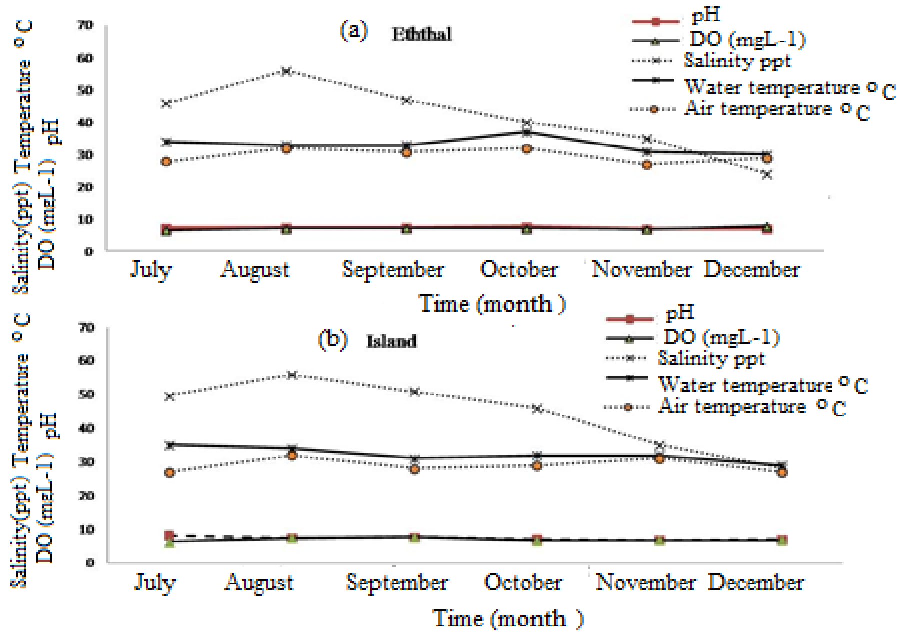

Figure 3: Monthly variation of environmental parameters in study sites (a) Eththal (b) Island

During the monitoring period, the water temperature ranged between 30 °C to 37 °C, dissolved oxygen levels were between 6.1– 8.0 mg L^{-1}, pH values ranged from 6.2 – 8.3 and salinity values were recorded as 24–56 ppt. Both areas recorded higher salinities (above 35 ppt) during July to November, which is ranged 40–56 ppt. It seems that water temperature, dissolved oxygen levels and pH values were not much varied among the months and the sites. Salinity was the most variable factor observed during monitoring period (Fig. 3). *Mesopodopsis zeylanica* inhabited only in two sites (Table 2) where salinities values were 36 and 37 ppt. *Sirella srilankensis* and *M. orientalis* occured mostly in a wide range of salinities, 24–56 ppt and both species preferred higher salinity levels.

Table 5: Pearson correlation coefficients (r) of bivariate analysis of the different parameters on mysid availability and species distribution.

	pH	DO	Salinity	Water temperature	Air temperature	Water level	Boundary condition	Presence of garbage
Presence of mysids	-0.149	0.401	-0.463	0.063	-0.023	-0.354	0.687	-0.506
Significance	Ns	Ns	s**	Ns	Ns	s**	s**	s**
Species distribution	-0.017	0.275	-0.289	0.159	0.088	0.278	0.587	-0.432
Significance	Ns	Ns	s*	Ns	Ns	Ns	s**	s**

*significant at P ≤ 0.05, ** significant at P ≤ 0.01, Ns = not significant, s = significant, DO = dissolved oxygen

In this study good boundary conditions were assessed as the presence of natural boundary vegetation (mainly mangroves).The correlation of potential factors on availability of mysids and species distribution is shown in Table 5. The outcome of this correlation demonstrated that the occurrence of mysids is strongly and positively correlated with the boundary condition ($P \leq 0.01$), while presence of garbage, water level, and salinity correlated negatively ($P \leq 0.01$). Species distribution strongly and positively correlated with boundary condition ($P \leq 0.01$) and negatively correlated with salinity and the presence of garbage ($P \leq 0.01$). These results reflect that lower water levels and boundary vegetation are more favorable for mysids.

Discussion

Mesopodopsis zeylanica is the only estuarine mysid species recorded from Sri Lanka in Bolgoda lagoon (Nouvel, 1954; Punchihewa et al., 2017).The present study recorded the same species with two other species: *Mesopodopsis orientalis* and *S. srilankensis.* Although this study recorded *M. orientalis* for the first time in Sri Lanka, originally this species was recorded from India by Tattersall (1908) and has been reported several times by others as well (Nair, 1939; George, 1958; Pillai, 1968; Bhattacharya and Kewalramani, 1972; Bhattacharya, 1982; Biju and Panampunnayil, 2010, 2011). Distribution of this species extends through South East Asia: Malaysia (Hanamura et al., 2009), and the Gulf of Thailand (Chaitiamwonges and Yoodee, 1982). The presence of mysids in 30 sites out of 39 sites being sampled is a good indication that these sites provide better environmental conditions for their prevalence. This widespread mysid habitats were recorded from the shaded edges of the lagoon where extensive mangrove forests present without any anthropogenic effects. Most of the mangrove areas were subjected to anthropogenic influences, such as destruction of mangroves and as use stream boundary as garbage dumps.

The occurrence of mysids only in some habitats is an issue to consider. Mysids were not recorded from nine sites along the boundary of the lagoon. These sites lack vegetation, have garbage dumps, cleared mangrove areas and newly soil filled boundaries for recreational purposes under urban development projects. This clearly indicates that estuarine waters with marginal vegetation and without any disturbances provide suitable habitats for mysids. Human interference on originally fringed mangrove forests is a serious threat in Sri Lanka. It is alarming that the waste disposal sites and clearing of stable boundary vegetation significantly impacts on the disappearance of mysids due to loss of habitats. Such disturbed sites cannot provide niche requirements, such as food, shelter and aggregation for their social behaviour or reproduction.

The previous studies in the Bolgoda and Negombo lagoons (Punchihewa et al, 2017; Punchihewa, and Krishnarajah, 2019) revealed that mysids were absent from the areas where boundary vegetation consisted of water hyacinth, garbage dumping areas and edges constructed with concrete. Therefore, this study also demanded good condition of the estuarine boundary which is important for mysids occurrence.

In the present study, the number of occurrences of each species was different: *M. orientalis* occurred at 27 sites, *M. zeylanica* at two sites and *S. srilankensis* at nine sites. Each species was able to inhabit in sympatry whereas on some occasions they were recorded as single species. Hence, *M. orientalis* was the most geographically widespread species in the Puttalam lagoon and the dominant species. This could be hypothesized to be due to the hypersaline conditions prevalent in most of the sites within the lagoon during the dry season.

The highest numbers of *M. orientalis* were recorded in the Puttalam island site. At this site the highest salinity values, 50–56 ppt were recorded during the period of July to August. However, number of occurrence was highest within salinity range of 35–49 ppt that indicates the possible preferred range. However, *M. orientalis* was also found within the range of 24−54 ppt. This occurrence in wider range of salinity is in agreement with the studies in India: Versova mangrove ecosystem in India (20.3−37.1 ppt) (Biju and Panampunnayil, 2011), and Bhayander salt pan (1.2−63.6 ppt) (Biju and Panampunnayil, 2010). Salinity tolerance studies on *M. orientalis* under laboratory conditions (Bhattacharya, 1982), has revealed that the species is able to survive under an extremely wide range of salinity conditions. This ability ensures its wide distribution from sea water to near freshwater conditions and even in the saltern. Considering the previous studies, it is agreed that euryhaline species are well adapted to live in an environment with a wide fluctuation in salinity through their capacity to prevent excessive changes in their internal environment by maintaining their blood osmolality as hyper/hypo-osmotic to the medium (McLusky and Heard, 1971). In contrast *M. zeylanica* occurrence is a result of low salinity in the lagoon while *M. orientalis* and *S. srilankensis* occurrence is dependent on high salinity. Previous studies (Punchihewa et al, 2017; Punchihewa and Krishnarajah, 2019) in Sri Lanka also proved the distribution of *M. zeylanica*in low saline waters such as Bolgoda and Negombo lagoons. This indicates that salinity is a prime factor to consider the distribution of mysid species.

The effect of salinity on mysid distributions in other countries are well documented for different species: *Neomysis integer*, *Gastrosaccus spinifer*, *Schistomysis kervillei* and *Schistomysis spiritus* in the Waterschelde estuary in South - West Netherlands (Rappé et al., 2011), *Acanthomysis thailandica* in a tropical estuary in Malaysia (Ramarn et al., 2012) and *Tenagomysis chiltoni*, *Tenagomysis novaezealandiae* and *Gastrosacus australis* in Auckland region, New Zealand (Punchihewa and Krishnarajah, 2013a).

Furthermore, dissolved oxygen and water levels also have an influence on mysids distribution. More favorable dissolved oxygen levels were recorded in each sampling event (between 6 − 8 mg L^{-1}). It was observed that a water level below 1m was suitable for mysid occurrence.

Temporal trend of species abundance was not evidenced over the six month period at both Eththal and island sites. This finding is in agreement with Hanamura et al. (2009) on the abundance of *M. orientalis* within 21 months in the open sandy beaches of Malaysia. However, in India, *M. orientalis* has been known to show temporal variation with respect to species abundance. In the Cochin backwater, their abundance was associated with the monsoon period (Biju et al., 2009), whereas in Hooghly estuary, the periodicity in abundance weekly correlated with the monsoon season (Sarkar and Choudhury, 1986). Hanamura et al. (2009) stated that stable water temperature reduced the seasonality of mysids in tropical shallow-waters.

Conclusion and recommendation

Present study recorded three mysid species: *Mesopodopsis zeylanica*, *Mesopodopsis orientalis* and *Sirella srilankensis*. *Mesopodopsis orientalis* was the most geographically widespread species in the Puttalam lagoon. This collection of *M. orientalis* was the first record in Sri Lanka. Distribution of mysid species is primarily dependent on the salinity. Other than the salinity distribution, and abundance of mysids depend on water level and boundary conditions. Lower water levels and boundary vegetation were more favorable for mysids. The sites consisting of mangroves or widespread seagrass beds were observed as suitable mysid habitats while soil filled boundary areas and waste disposal sites along the boundary were found to be unsuitable. Reforestation and restoration of mangrove boundary areas can enhance the biodiversity in the lagoon.

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