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Factors influencing the distribution of mysids (Crustacea: Mysidacea) in Chilaw lagoon, Sri Lanka

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Abstract
The main objective of this study was to locate the mysid habitats in Chilaw lagoon as a novel study. Surveys were undertaken from July 2012 to May 2013 during daytime, along the boundary of the lagoon. Samples were collected using a dip net of 500 µm mesh size with an opening of 25×20 cm^2 at fifteen randomly selected sites along the lagoon. *Mesopodopsis zeylanica*, *Mesopodopsis orientalis* and new *Sirella srilankensis* were identified. *Mesopodopsis zeylanica* being the most abundant species. Survey of temporal variation in mysid abundance was also conducted at two sites for a six-month period starting from July 2012 to December 2012. Mysid species did not show any temporal variation. The abundance of mysids negatively correlated ($P \leq 0.05$) with temperature and salinity. The spatial distribution of mysids along the lagoon boundary was found from 13 sites and mysids were not recorded from two sites. These areas are vulnerable to effluent discharge from nearby shrimp farms, and this may be the most likely reason behind the absence of mysids in this area.

Keywords: mysids, estuarine, chilaw, lagoon

Introduction

Mysids are one of the most abundant small crustaceans in the benthos, which occur in large numbers in estuarine waters (Fockedey *et al*., 2006; Suzuki *et al*., 2009; Punchihewa and Krishnarajah, 2013a, 2019; Punchihewa, 2020) [8, 28, 18, 21, 23]. They serve as an important food source for fish and crustaceans, therefore their significant role in the food chains is becoming apparent (Vilas *et al*., 2008; Rastorgueff *et al*., 2011; Mantiri *et al*., 2012; Punchihewa and Krishnarajah, 2013b; Punchihewa 2015; Punchihewa and Silva, 2019) [34, 26, 12, 19, 22, 20]. Mysids are sensitive to water quality, therefore, they are widely used for bioassays in aquatic ecosystems. (Verslycke *et al*., 2004; Verslycke *et al*., 2007; Thomas *et al*., 2016; Echols, 2021) [32, 33, 30, 6]. Considering worldwide ecological significance of mysids, it is worthwhile understanding their distribution in different aquatic bodies.

Chilaw lagoon is one of the major lagoons in Sri Lanka. Based on its high productivity and high diversity, the lagoon was declared as a Fishery Management Area, under Section 31 of the Fisheries and Aquatic Resources Act, No. 2 of 1996. The lagoon offers several distinct habitats for fish and crustaceans. Thus, the present study provides the first documented information on mysid distribution in Chilaw lagoon.

Distribution of mysids in different estuarine bodies depends on a variety of natural environmental factors as well as anthropogenic factors. Previous studies have shown that the distribution and abundance of mysids depends on salinity, temperature, chlorophyll concentration and dissolved oxygen (Biju *et al*., 2009; Rappé *et al*., 2011) [13, 25]. Baldo *et al*. (2001) [1] also reported salinity to be primarily responsible for the horizontal distribution of *Rhopalophthalmus mediterraneus* within an estuary. The spatial distribution of mysids was determined by natural environmental factors such as temperature and turbidity for *Mesopodopsis slabberi* (Rappé *et al*., 2011) [25] and limited oxygen concentrations for *Neomysis integer* (Mees *et al*., 1995) [13].

According to recent studies in Sri Lanka (Punchihewa *et al*., 2017; Punchihewa and Krishnarajah, 2019, Punchihewa, 2020) [17, 20, 23], estuarine boundaries with natural vegetation, mainly mangroves, offers the most suitable mysid habitats which provide the shade and accumulated food supply necessary for their population to flourish. Factors that negatively impacted mysid distributions included anthropogenic factors such as boundaries with man-made concrete edges, newly soil filled areas and waste disposal sites (Punchihewa *et al*., 2017; Punchihewa and Krishnarajah, 2019, Punchihewa, 2020) [17, 20, 23].

There is limited research on mysid distribution and abundance in estuarine waters in Sri Lanka. *Mesopodopsis zeylanica* is the first estuarine mysid species documented in Sri Lanka from Bolgoda Lagoon (Nouvel, 1954; Punchihewa *et al*., 2017) [15, 17]. Subsequently, two species from Negombo lagoon, *M. zeylanica* and a new species, *Sirella srilankensis* (Punchihewa and Krishnarajah, 2019) [20] and three species from Puttalam lagoon *M. zeylanica*, *S. srilankensis* and, *Mesopodopsis orientalis* (Punchihewa, 2020) [23] were recorded. Since there was a need to gather up-to-date information on the distribution and abundance of mysids in Sri Lanka, the present study was to find the distribution of mysids in the Chilaw lagoon and assess the factors which affect their distribution as a novel study.

Meterials and Methods

The study was conducted in the Chilaw lagoon, situated on the west coast within the intermediate zone of Sri Lanka (latitude: 7.5328ºN, longitude: 79.8101ºE). It is connected to the ocean through two narrow channels, located at the extreme north and south ends of the lagoon. The southern entrance is mostly closed, due to sand bar formation at the mouth (at Thoduwawa). There are no rivers discharging directly into Chilaw lagoon. However, the lagoon occasionally receives freshwater from the rivers namely, Deduru Oya (northern channel) and Lunu Oya (southern channel).

This study examined two aspects related to mysids: a spatial distribution survey around the lagoon and a temporal distribution survey over a six-month period from July 2012 to December 2012, at two sites, Rathnauyana and Thoduwawa. These two sites were selected following initial reconnaissance surveys, during which relatively high numbers of mysids were recorded. Thoduwawa is one of the study sites close to the mouth (southern entrance) and is subject to human interferences, where mangroves are patchily distributed. Rathnauyana is the second site which is situated in the northern side of the lagoon with an extensive mangrove belt.

The spatial distribution survey was conducted from June 2012 to May 2013 at 15 randomly selected sites, to cover a considerable area of the lagoon (Figure. 1, Table 1). At each site, four replicate samples were taken (10 m length x 4) along an 80 m stretch close to the estuarine boundary of the lagoon.

Mysid surveys were conducted during daytime, using a dip net (mouth area of 25 × 20 cm^2 with 500 µm mesh size) dragged along the boundary of the lagoon. Samples were preserved in 70 % ethyl alcohol. Water parameters: salinity, pH, dissolved oxygen (DO), and water temperature was measured at each sampling event, using WTW 400i Multi-Parameter Water Quality Field Meter, Geotech Environmental Equipment, USA.

Table 1: Qualitative description of sampling sites, Chilaw Lagoon.

Study site	**Location (GPS)**	**Ecological profile of the stream**	Other special features of the site
Rathnauyana	7°5713N,79°7897E	Mangrove belt, seagrasses	
Thoduwawa 1	7°4922N,79°7995E	Patchily distributed mangroves,	
Thoduwawa 2	7°4923N,79°7999E	Patchily distributed mangroves,	
Lansiyawatta	7.5745N,79.7911E	Mangrove belt	
Suduwella	7.5641N,79.7914E	Mangrove belt	
Pambala 1	7.5514N,79.8035E	Mangrove belt	
Pambala 2	7.5516N,79.8035E	Mangrove belt	
Meerawila	7.5477N,79.8044E	Mangrove belt	
Eranawila 1	7.5376N, 79.8010E	Mangrove belt	
Eranawila 2	7.5372N, 79.8010E	Mangrove belt	
Eranawila 3	7.5373N, 79.8009E	Mangrove belt	
Sarakkuwatta 1	7.5248N ,79.8034E	Mangrove belt	
Sarakkuwatta 2	7.52502N,79.8185E	Mangrove belt	
Thoduwawa pahala yaya 1	7.49082N,79.8044E	sparse vegetation	vulnerable to effluent discharge from nearby shrimp farms
Thoduwawa pahala yaya 2	7.49134 79.81503	sparse vegetation	

Statistical analyses

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. The mean separation was done using Tukey's Honestly Significant Difference (HSD). The factors that affect the distribution of mysid species and their abundance were determined using Pearson correlation analysis.

Results

Spatial Distribution Survey

Of the 15 sites surveyed, mysids were found in 13 sites. Three mysid species *Mesopodopsis zeylanica*, Nouvel 1954 [15] *Mesopodopsis orientalis*, Tattersall, 1908 [29] and new *Siriella srilankensis*, Punchihewa 2012 were identified. *Mesopodopsis zeylanica*, inhabited ten sites, *M. orientalis* inhabited 3 sites and *S. srilankensis* inhabited four sites. All three species were found together in both Rathnauyana and Thoduwawa sites. However, *M. zeylanica* was the widely distributed and the dominant species in the Chilaw lagoon (Table 2).

The sites where mysids were recorded had patchily or extensively distributed mangroves as boundary vegetation. Mysids were absent from only two sites sampled at Thoduwawa Pahala yaya where the areas are vulnerable to effluent discharge from the nearby shrimp farms (Table 2).

Table 2: Distribution of mysid species in different study sites

Sites where mysids were present	**Mysid species**			**Sites where mysids were not recorded**
	M. zeylanica,	***M. orientalis***	***S. srilankensis***	
Rathnauyana	P	P	P	Thoduwawa Pahala yaya 1
Thoduwawa 1	P	P	P	Thoduwawa Pahala yaya 2
Thoduwawa 2	P			
Lansiyawatta		P		
Suduwella	P			
Pambala 1 Pambala 2	P P			
Meerawila	P			
Sarakkuwatta 1			P	
Sarakkuwatta 2	P			
Eranawila 1			P	

Eranawila 2	P			
Eranawila 3	P			

P = presence of mysids

Table 3: Number of individuals of *M. zeylanica, M.* o*rientalis* and *S. srilankensis* collected from different study sites (Except temporal distribution survey).

Study site		Number of individuals	
	M. zeylanica	***M. orientalis***	***S. srilankensis***
Thoduwawa 2	81		
Lansiyawatta		17	
Suduwella	13		
Pambala 1	08		
Pambala 2	98		
Meerawila	10		
Sarakkuwatta 1			14
Sarakkuwatta 2	56		
Eranawila 1			14
Eranawila 2	63		
Eranawila 3	117		
Total	446	17	28

Temporal Distribution

All three mysid species *M. orientalis*, *M. zeylanica* and *S. srilankensis* were encountered at both Rathnauyana and Thoduwawa sites. A total of 110 *Mesopodopsis orientalis* were collected over a six month period at Rathnauyana and it was the most common mysid species found at this site. Secondly, 39 individuals of *S. srilankensis* were collected within a five-month period except December. Only seven individuals of *M. zeylanica*, were recorded in August and September (Fig. 3).

Compared to Rathnauyana, at the Thoduwawa site, there were lower numbers of individuals of all three species: 31 *S. srilankensis*, during July to September, 15 *M. orientalis* during September and November and, 48 *M. zeylanica* only in November.

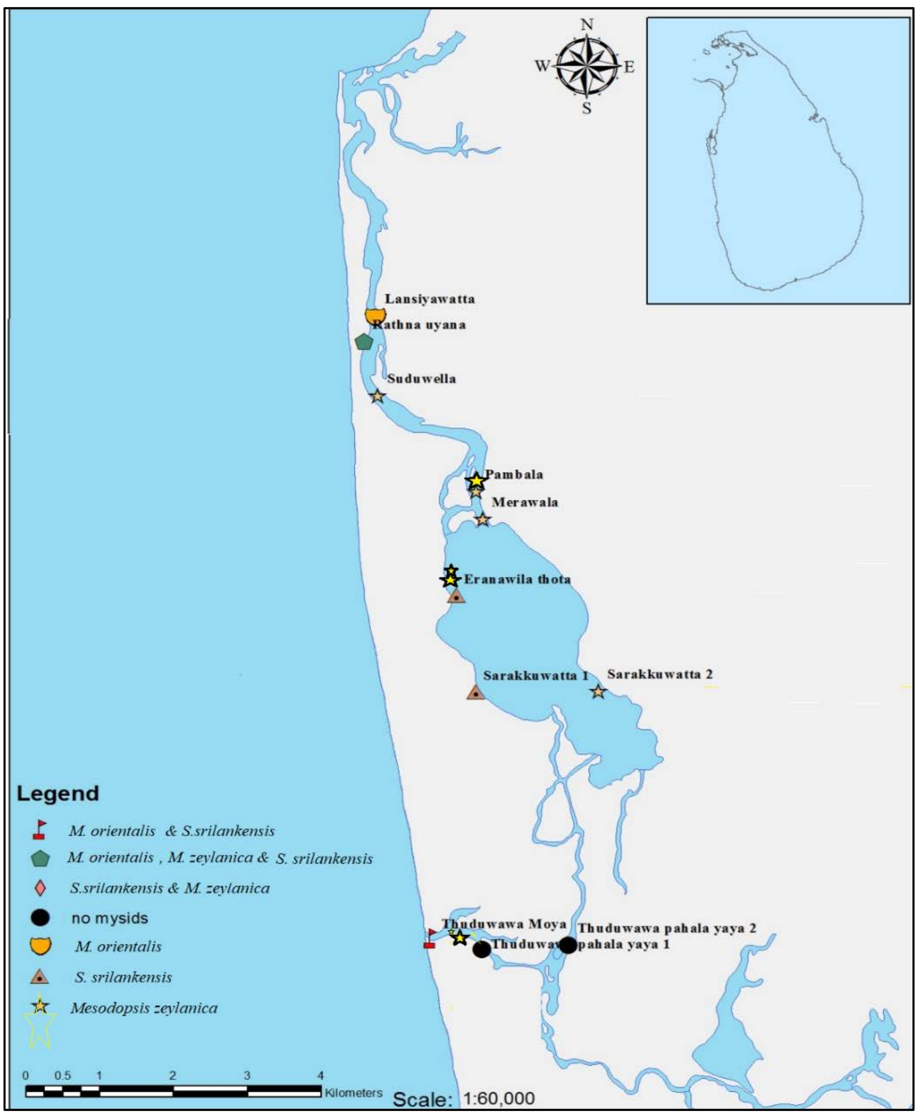

Fig 1: Distribution of mysid habitats, Chilaw Lagoon.

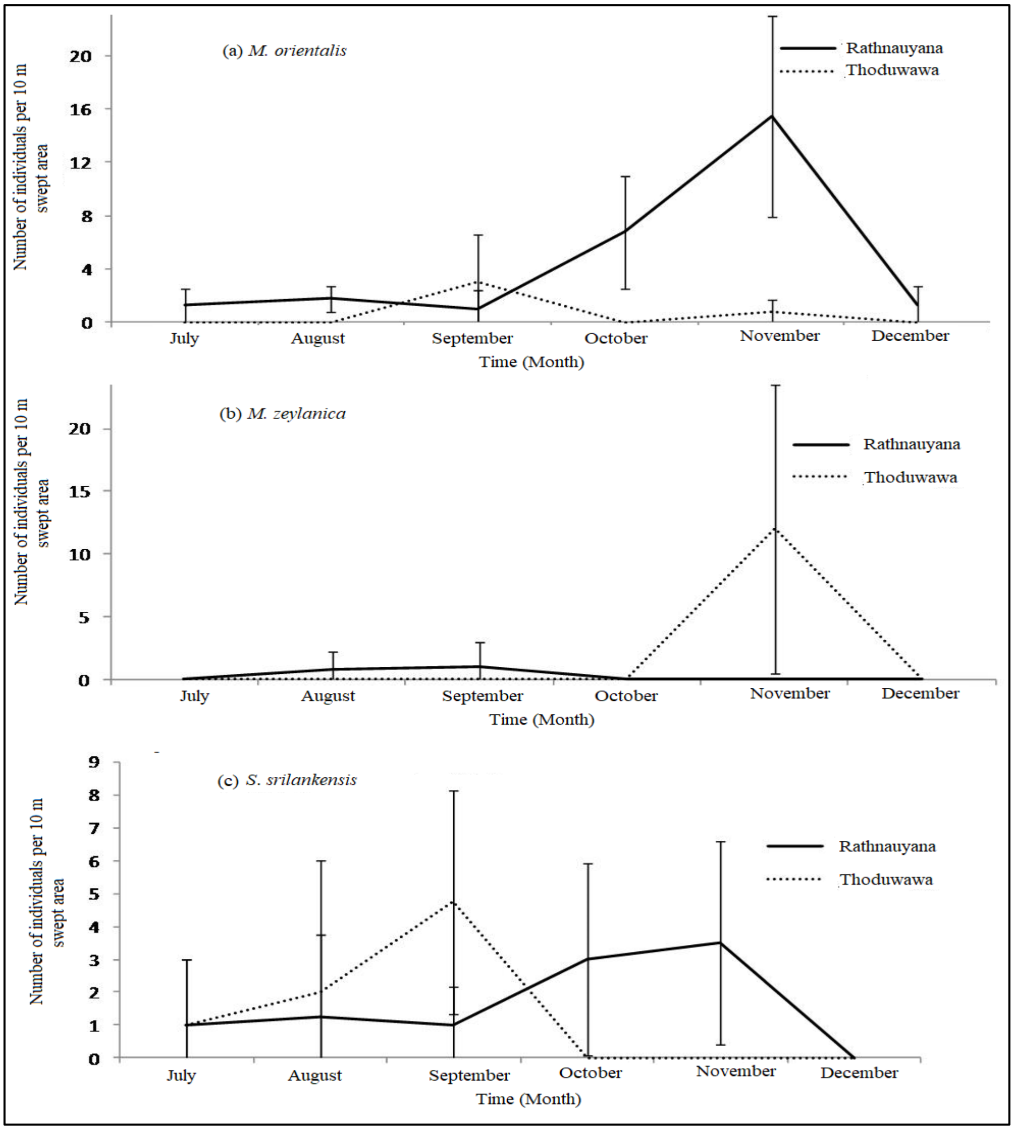

Fig 2: Monthly variation of mean (± SD) abundance (n = 4) of mysid species, (a) *M. orientalis* (b) *M. zeylanica* (c) *S. srilankensis* in Chilaw lagoon.

A major peak in the density of *M. orientalis* and *S. srilankensis* was apparent in November in Rathnauyana. For both species, numbers continued to decline to reach low values during July to September. *M. orientalis* recorded low values again in December, (Fig. 2, Table 4) although no clear recurring temporal trend was apparent in both species. One-way ANOVA showed that the mean abundance of *M. orientalis* among the months were significantly different ($P \leq 0.05$) (Table 4 and 5). Tukey test confirmed that the mean abundance values of *M. orientalis* in November was significantly higher than the period from July to September and December (Table 4).

A major peak in the density of *S. srilankensis* was demonstrated in September and low numbers were recorded in July and August (Fig. 2, Table 4) in Thoduwawa. One-way ANOVA showed that the mean abundance values of *S. srilankensis* were not significantly different ($P \leq 0.05$) among the monitoring period (Table 4 and 5). One-way ANOVA showed that the mean abundance values of all mysids at both sites were not significantly different ($P \leq 0.05$) (Table 5).

Table 4: Variation in the number of individuals of mysids (mean±SE), recorded from different sites during monthly survey.

	M. zeylanica		***S. srilankensis***		***M. orientalis***	
	Rathnauyana	**Thoduwawa**	**Rathnauyana**	**Thoduwawa**	**Rathnauyana**	**Thoduwawa**
	Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**
July	0.00± 0.00	0.00± 0.00	1.00± 1.00	1.00±1.00	1.25±0.63	0.00± 0.00
August	0.75±0.75	0.00±0.00	1.25± 1.25	2.00±2.00	1.75±0.48	0.00± 0.00
September	1.00±1.00	0.00±0.00	1.00±0.58	4.75±1.70	1.00±0.71	3.00± 1.75
October	0.00±0.00	0.00±0.00	3.00±1.47	0.00± 0.00	6.75±2.14	0.00± 0.00
November	0.00±0.00	12.00±5.76	3.50±1.55	0.00± 0.00	15.50±3.77	0.70± 0.48
December	0.00±0.00	0.00±0.00	0.00± 0.00	0.00± 0.00	1.25±0.75	0.00± 0.00

SE = standard error

Table 5: 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
All mysids	Rathnauyana	8.44	05	S
	Thoduwawa	3.77	05	S
	Both sites	1.58	01	Ns
M. zeylanica	Rathnauyana	0.81	05	Ns
	Thoduwawa	4.34	05	S
S. srilankensis	Rathnauyana	1.44	05	Ns
	Thoduwawa	2.67	05	Ns
M. orientalis	Rathnauyana	9.77	05	S
	Thoduwawa	2.55	05	Ns

Ns= not significance, S = significance at $P \leq 0.05$, df =degrees of freedom.

Percentage composition of male and female collected from 13 sites for all three species (Fig. 3) has shown that female composition was always higher than males.

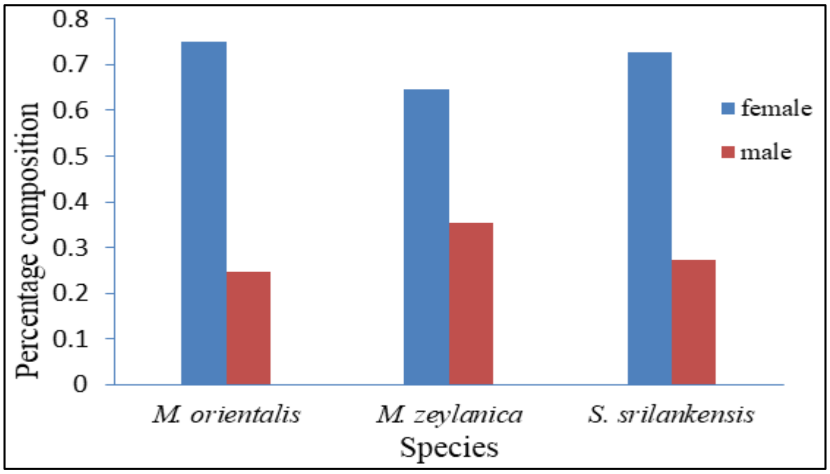

Fig 3: Percentage composition of male and female of *M. orientalis*, *M. zeylanica* and *S. srilankensis* (pooled data).

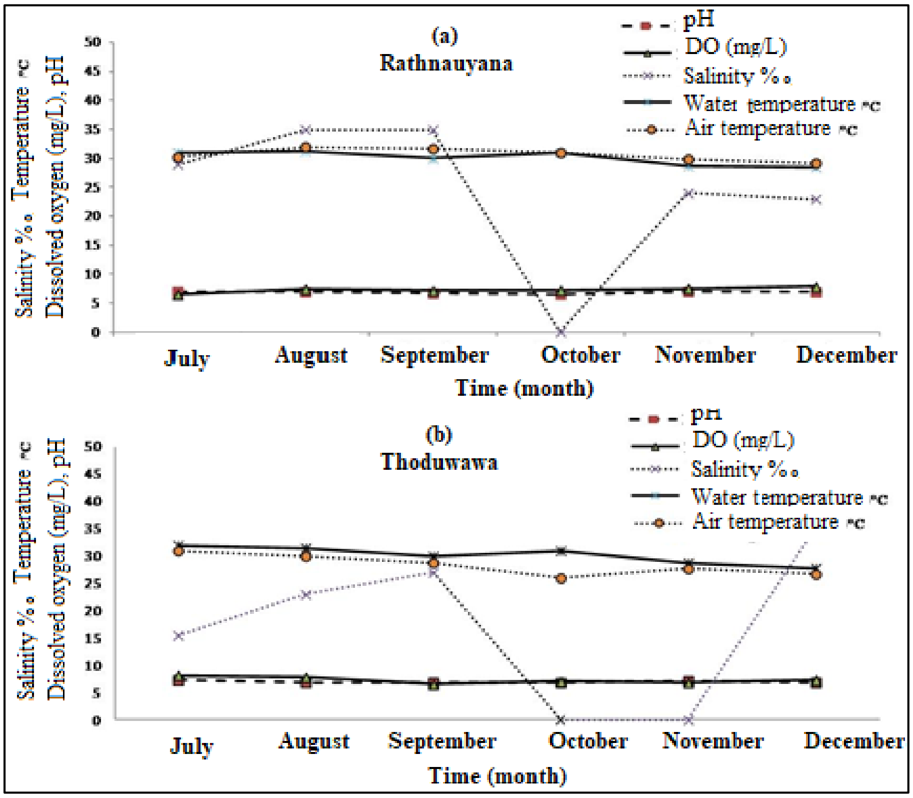

Fig 4: Monthly variation of environmental parameters, Chilaw lagoon sites, (a) Rathnauyana (b) Thoduwawa.

The environmental parameters recorded during the monthly survey is given in Fig. 4. During the monitoring period, water temperature fluctuated between 28°C and 33°C among the sites at the Chilaw lagoon. Typical salinity values fell between 0–35 ‰ and dissolved oxygen (DO) levels were generally above 6.2 mg L^{-1} up to 8.3 mg L^{-1} at all sites. The pH values ranged from 6.5–8.2.

The correlation among the environmental parameters on mysid abundance and species distribution is given in Table 6. The outcome of this correlation demonstrated that the occurrence of mysids is negatively correlated with salinity, water temperature, and air temperature ($P \leq 0.05$).

Table 6: Pearson correlation coefficients (r) among mysid abundance, species distribution and environmental Parameters.

	pH	DO	Salinity	Water temperature	Air temperature
Mysid abundance	0.129	-0.070	-0.483	-0.530	-0.511
Significance	Ns	Ns	s*	s*	s*
Species distribution	-0.147	-0.013	0.046	-0.070	-0.031
Significance	Ns	Ns	Ns	Ns	Ns

*significant at $P \leq 0.05$, ns = not significant, s = significant, DO = dissolved oxygen

Discussion

Three mysid species, *M. zeylanica*, *M. orientalis* and *S. srilankensis* were recorded for the first time in Chilaw lagoon as a novel study. *Mesopodopsis zeylanica* was the most geographically widespread species within the lagoon. Similar to Chilaw lagoon same three species were previously recorded from Puttlam lagoon (Punchihewa, 2020) [23] and two species *M. zeylanica* and *S. srilankensis*, were recorded from Negombo lagoon in Sri Lanka (Punchihewa, 2019) [21]. Initially, before the above studies, *M. zeylanica* was the only estuarine mysid species recorded from Sri Lanka in the Bolgoda lagoon (Nouvel, 1954; Punchihewa *et al*., 2017) [15, 17]. Although, originally, *M. zeylanica* was recorded from Sri Lanka by Nouvel, (1954) [15] it was consequently recognized in India (Biju & Panampunnayil, 2010; Verlecar *et al*., 2012) [5, 31]. *Mesopodopsis orientalis* has been reported several times from India (Tattersall, 1908; Nair, 1939; Pillai, 1968; Bhattacharya and Kewalramani, 1972; Bhattacharya, 1982; Biju and Panampunnayil, 2010) [29, 14, 16, 2, 3, 5], Malaysia (Hanamura *et al*., 2009), and the Gulf of Thailand (Chaitiamwonges and Yoodee, 1982).

Mysid habitats were found from the shaded edges of the lagoon where extensive mangrove forests are present. The presence of mysids in 13 sites out of 15 sites being sampled is a good indication that these sites provide better environmental conditions for their prevalence. However, it was observed that some areas were subject to anthropogenic influences such as waste disposal, deforestation and shrimp farming. The two sites which mysids were not recorded is connected with Karambalan oya and these areas were subject to discharge of effluents from nearby shrimp farms. The shrimp farming industry in the Chilaw lagoon has serious negative impacts on the mangrove ecosystems and the lagoon (Kalansooriya and Wijesinghe, 2012). Many shrimp farms discharge polluted water containing nutrient remains and chemicals via creeks and canals. Therefore, the Chilaw lagoon has been seriously affected by shrimp farming (Silva *et al*., 2013). All mud flats, marshes, patches of mangrove swamps and other marginal lands at both ends of the Chilaw lagoon have been converted into shrimp farm ponds (Katupotha, 2014).

Similar to present findings, the previous studies on mysid distribution in the Bolgoda, Negombo and Puttalam lagoons (Punchihewa *et al*, 2017; Punchihewa, and Krishnarajah, 2019; Punchihewa, 2020) [17, 20] also revealed that mysids were absent from the areas where any anthropogenic influences occurred in the boundary of the lagoons.

No clear, temporal trend was apparent for each species at each site. It is possible that the short duration of the present study and the shallowness of the lagoon has not shown a temporal variation of mysid abundance. This study is consistent with that of Hanamura *et al*. (2009) [9] which showed that stable water temperature reduced the seasonality of mysids in tropical shallow waters.

In the present study it was clear that high temperatures and high salinity had a negative impact on mysid abundance. The effect of salinity on mysid abundance and distribution are well documented for different species in temperate and tropical regions of the world: *Neomysis integer*, *Gastrosaccus spinifer*, *Schistomysis kervillei* and *Schistomysis spiritus* in the Waterschelde estuary in South - West Netherlands (Rappé *et al*., 2011) [25], *Acanthomysis thailandica* in a tropical estuary in Malaysia (Ramarn *et al*., 2012) [24], *Tenagomysis chiltoni*, *Tenagomysis novaezealandiae* and *Gastrosacus australis* in Auckland region, New Zealand (Punchihewa and Krishnarajah, 2013a) [18] and *Rhopalophthalmus mediterraneus* in Guadalquivir Estuary in South - West Spain (Baldo *et al*., 2001) [1]. Present study also reveals that low temperature environments are vital for mysids to thrive. It reflects the necessity of boundary vegetation in providing shelter and shade for mysids to inhabit the area successfully. Therefore, protecting the mangrove boundary vegetation in the Chilaw lagoon is important in conserving the biodiversity of the lagoon.

Conclusion and recommendation

Among the three mysid species recorded, *Mesopodopsis zeylanica*, *Mesopodopsis orientalis* and *Sirella srilankensis*. *Mesopodopsis zeylanica* was the most geographically widespread species within the lagoon. High temperatures and high salinity had a negative impact on mysid abundance. Mysid habitats were found throughout the lagoon where the mangroves available as a continuous boundary vegetation and mysids were not recorded from sites, where the areas are vulnerable to effluent discharge from nearby shrimp farms. Restoration of mangrove along the boundary and refrain from anthropogenic inputs to the lagoon can enhance the biodiversity in the lagoon.

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