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Distribution of estuarine mysids in Sri Lanka

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Abstract
The distribution and abundance of estuarine mysids throughout the South-west to North-west region of Sri Lanka were studied during March 2012 to July 2013. Surveys were conducted along the boundary of the estuaries, during daytime, using a dip net (mesh size 500 µm., opening 25×20 cm^2). Four mysid species were identified, *Mesopodopsis orientalis*, *Mesopodopsis zeylanica*, *Sirella srilankensis* (new) and *Anisomysis srilankensis* (new). *Mesopodopsis orientalis* was the most widespread taxon and most common species in North-west coast and showed abundance in Puttalam, Mannar, Arippuwa, Mundal and Kalpitiya. *Mesopodopsis zeylanica* and *S. srilankensis* were distributed in both West and North-west cost. *Mesopodopsis zeylanica* was the most abundant species in Negombo, Bolgoda, Achchankulam and Chilaw. *Anisomysis srilankensis* were recorded only from Kalpitiya lagoon. *Mesopodopsis zeylanica* was confined to lower salinities and lower temperatures. *Sirella srilankensis* and *M. orientalis* occurred within wider salinities. Salinity, temperature and pH influenced the variation in mysid abundance. Mysids were abundant in shady areas where widely distributed mangroves present as boundary vegetation. They were not found in; sites with pollutants, where no mangroves or newly filled boundaries or concrete boundaries, where *Eichhornia crassipes* available. The condition of the estuarine boundary, especially marginal vegetation, play an important role in the occurrence of mysids.

Keywords: Boundary vegetation, distribution, estuarine, mangroves, mysid species

Introduction

The history of mysids in Sri Lanka initiated in 1906, with the collection of a single specimen of *Siriella paulsoni* Czerniavsky, 1880 (Tattersall, 1906) from the Pearl banks, Cheval Paar. Tattersall, (1922) [33] again collected 13 species from the northern end of the Gulf of Mannar, in which, seven were described as new species. From this collection, five species were attributed to the genus *Siriella*: *Siriella hanseni* Tattersall,1906; *Siriella brevicaudata* Paulson,1875; *Siriella quadrispinosa* Hansen, 1910; *Siriella affinis* Hansen, 1910[11]; *S. paulsoni* and three species were attributed to the genus *Heteromysis*: *Heteromysis proxima* Tattersall, 1906; *Heteromysis zeylanica* Tattersall, 1906; *Heteromysis gymnura* Tattersall, 1906; additional species included *Erythrops minuta* Hansen, 1910[11]; *Mysidopsis kempi* Tattersall, 1906; *Dioptromysis perspicillata* Zimmer, 1915[35]; *Neomysis indica* Tattersall, 1906; *Idiomysis inermis* Tattersall, 1906. However, all these collections were from oceanic waters.

Subsequently, Nouvel (1954) [18] recorded *Mesopodopsis zeylanica* Nouvel, 1954[18] from the Bolgoda lagoon, and it is the only estuarine species recorded in Sri Lanka in large numbers of adult males, ovigerous females and immature individuals. This species was also found in a tropical estuary in India (Cochin backwater) and recorded throughout the year as the most dominant species (Biju and Panampunnayil, 2010) [4]. Sri Lanka being an island in Indian Ocean closer to India, it shares its mysid distribution with western parts of India while same species were recorded in both countries.

After Nouvel (1954) [18], there were no studies on the mysids in Sri Lanka for nearly six decades. There were scarcity in baseline data on mysid distribution and abundance throughout Sri Lankan estuarine environments. The documentation of mysid distribution in estuarine waters, has become an essential issue to improve the understanding of the status of the mysid distribution. This study presents the novel information on distribution of estuarine mysids in Sri Lanka which has not been subjected to an in-depth study.

The sufficient information on estuarine fauna are not currently available to policy and decision makers in conservation of coastal environments, to implement the appropriate management plans of the estuarine environment and its associated species. Further, a number of developmental projects in coastal areas led to loss of natural habitats of estuarine species which demand their conservation, so as to promote the conservation of a valuable aquatic living components of the biodiversity.

Materials and Methods

Mysid habitat surveys were conducted along the coastal region from South-west to North-west of Sri Lanka starting from March 2012 and concluded in July 2013. The reconnaissance surveys were conducted at ten major Lagoon systems and the brackish water bodies from Kalutara to Galle, extending from Mannar lagoon, North-Western part of Sri Lanka, to Mahamodara estuary in the South-Western part of Sri Lanka, along the South-West, West, and North-West coastal region (Fig. 1). Surveys were undertaken in Bolgoda lagoon, Lunawa lagoon, Negombo lagoon, Chilaw lagoon, Mundal lagoon, Puttalam lagoon, Kalpitiya lagoon, Arippuwa estuary, Achchankulam estuary and Mannar lagoon.

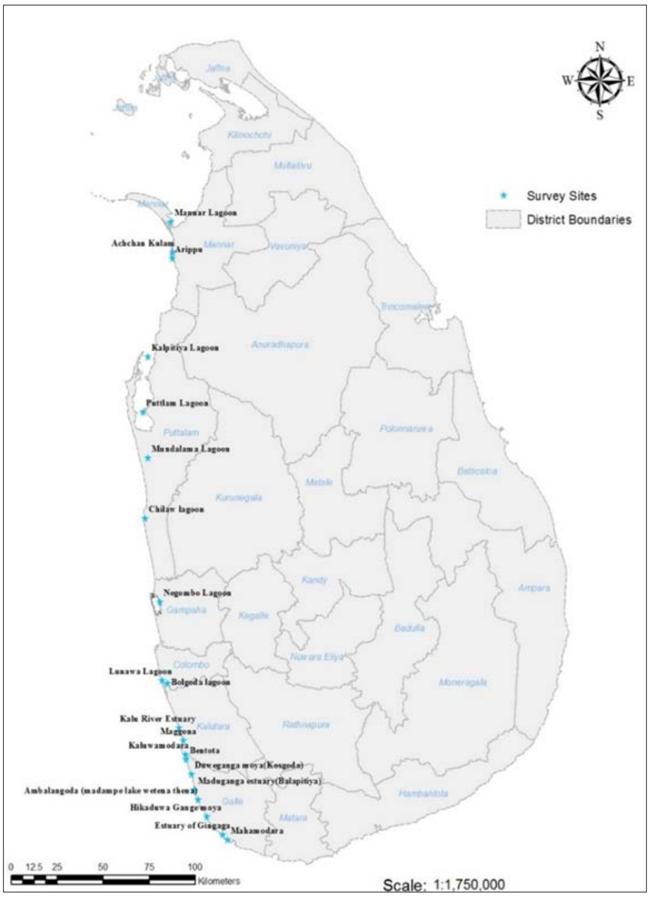

Fig 1: Locations of survey sites: South-west to North-west region of Sri Lanka

Both spatial and temporal distribution surveys were conducted in Negombo (18 sites), Puttalam (39 sites) and Chilaw (15 sites) lagoons (Punchihewa & Krishnarajah, 2019; Punchihewa, 2020; Punchihewa, 2021) [22, 25, 26]. Only the spatial distributon surveys were conducted in Kalpitiya (17 sites), Bolgoda lagoon (13 sites), Achchankulam estuary (11 sites), Mannar lagoon (11 sites), Arippuwa estuary (9 sites) and Mundal lagoon (5 sites).

Mysid surveys were conducted along the boundary of the estuarine waters during the daytime. The samples were obtained using a handheld dip net with a mouth area of 25 × 20 cm^2, and with 500 µm mesh size was gently dragged along the boundary of the waterbody. In each survey, at each site, four replicate samples were taken (10 m length x 4 and 10 m apart) along the 80 m stretch of the boundary. All mysids retained in the net along each transect were immediately collected into separate, appropriately labelled bottles containing 70% ethyl alcohol.

Except Bolgoda and Mundal lagoons, the boundary vegetation of other lagoons consists of large extent of mangrove vegetation. Puttalam and Kalpitiya lagoon system is with a cluster of several islands fringed with rich mangrove communities.

Statistical analyses

The Principal Component Analysis (PCA) was performed on the data collected from the study. The CART is a modern statistical technique ideally suited for both exploratory and modelling such data, but have seldom been used in ecology. Hence, accurate analysis is now often seen as a principal objective of species-environment analysis (Steven et al., 2012) [30].

The CART analysis often produces a "Tree" (dendogram) explaining the variation of a single response variable by one or more explanatory variables. The response variable is usually either categorical or numerical, and explanatory variable can be categorical and/or numeric. The tree is constructed by repeatedly splitting (binary spilt) the heterogeneous data into sub sets (nodes), defined by a simple rule based on a single explanatory variable. At each split the data are partitioned into two mutually exclusive groups, each of which is as homogenous as possible. The splitting procedure is then applied to each group separately. The objective is to partition the response variable into homogenous groups, but also to keep the tree reasonably small. The size of a tree equals the number of final groups. Splitting is continuous until an over-large tree is grown, which is then pruned back to the desired size. Each group is typically characterized by either the distribution or mean value of the response variable, group size, and the values of the explanatory variables that define it. From all possible predictor variables, the CART selected the one that maximized the homogeneity of the two resulting groups and the optimal model was chosen based on the tree yielding the minimum cross-validated error rate.

Thus, CART was used to recognize the best environmental parameters which contributed much to the variation of mysid species abundance, included in the study.

The classification and regression tree (CART) analysis is an exploratory technique which is based on uncovering structure in data. CART analysis has been used to establish the relationships between species and environment (De'ath and Fabricus, 2000) [8].

All the analyses including PCA and CART were performed on SPSS PC Version 20 and Minitab version 15 for ANOVA, Kaplan-Meier survival plot, Wilcoxon test and log rank tests.

Results

Mysids were located mainly at survey sites of Western and North-western estuarine areas: Bolgoda lagoon, Negombo lagoon, Chilaw lagoon, Mundal lagoon, Puttalam lagoon, Kalpitiya lagoon, Mannar lagoon, Arippuwa, and Achchankulam estuarine area (Fig. 2). Mysids were not recorded from Lunawa lagoon and also from the estuarine areas surveyed from Kalutara to Galle on South-west coast.

Four mysid species were recorded: *Mesopodopsis zeylanica* (at eight lagoons), *Mesopodopsis orientalis* (at seven lagoons), *Siriella srilankensis* (at six lagoons) and *Anisomysis srilankensis* (only at Kalpitiya lagoon) (Table 2). Three taxa occurred on West coast and four taxa occurred on North-West coast (Table 2). In the West coast the most common species was *M. zeylanica* while in the North-West coast, it was *M. orientalis*. In both coasts *S. srilankensis* was uniformly distributed.

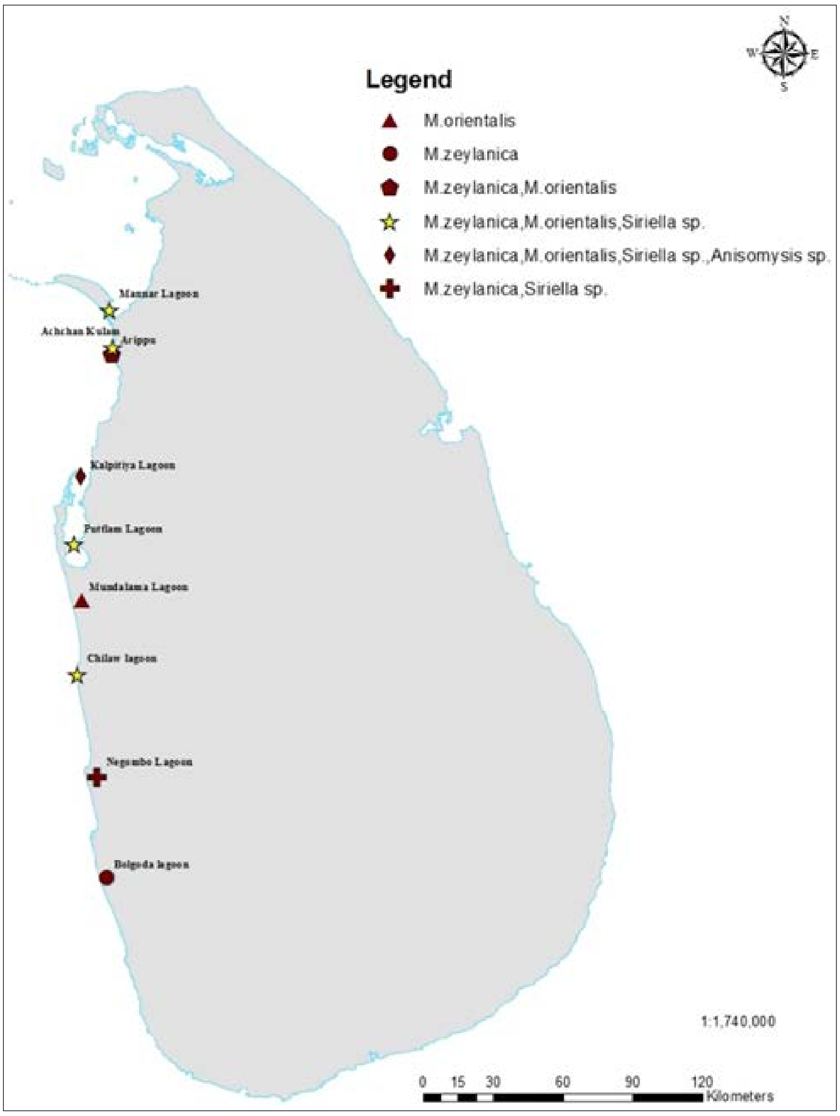

Fig 2: Recognized distribution of mysid taxa throughout, South-West, to North-West region, Sri Lanka.

Table 1: Incidence of mysid taxa throughout the Western and North-western estuarine waters

	Mesopodopsis zeylanica	***Mesopodopsis Orientalis***	***Siriella srilankensis***	***Anisomysis srilankensis***
Bolgoda lagoon	P			
Negombo lagoon	P		P	
Chilaw lagoon	P	P	P	
Mundal lagoon		P		
Puttalam lagoon	P	P	P	
Kalpitiya lagoon	P	P	P	P
Achchankulam estuary	P	P	P	
Arippuwa estuary	P	P		
Mannar lagoon	P	P	P	

p denotes the presence

The number of mysid taxa inhabited in each lagoon was different. Kalpitiya lagoon recorded the highest species number, four: *M. orientalis*, *M. zeylanica*, *S. srilankensis* and *A. srilankensis*. Puttalam, Chilaw, Achchankulam and Mannar, each recorded three species: *M. orientalis*, *M. zeylanica* and *Siriella* sp.. Negombo lagoon recorded two species, *M. zeylanica* and *S. srilankensis* whereas Arippuwa, recorded *M. orientalis* and *M. zeylanica*. Bolgoda lagoon recorded only *M. zeylanica* while Mundal lagoon recorded only *M. orientalis*.

Of nine lagoons from which mysids were collected, three were on the West coast; Bolgoda, Negombo and Chilaw and six on the North-West coast; Mundal, Puttalam, Kalpitiya, Arippuwa, Achchankulam and Mannar (Table 2). Among those estuarine waters, the least mysid habitats were found for Bolgoda (31%) and the highest were found for both Mannar and Achchankulum (91%). Except Mundal (60%) and Negombo (61%), other four lagoons also exhibited widespread mysid habitats (77%–87%).

Table 2: Description of mysids occurrence in respective lagoons in Sri Lanka, and their Relative Percentage Occurrences.

No of sites surveyed	No of sites each species found								No of sites mysids found
	Z single	O single	SSingle	Z & O symp	Z & S Symp	O & S Symp	Z, O & S symp	A Single	
West coast									
Bolgoda-13	4								04
Negombo-18	7		1		3				11
Chilaw-15	8	1	2			1	1		13
RPO	67.7	8.8	23.5						
North-West coast									
Puttalam-39	2	19	2			7			30
Kalpitiya-17	2	5	1	2				3	13
Mannar -11	2	5		2			1		10
Achchankulum-11	7	2			1				10
Arippuwa-9	2	5							07
Mundal-5		3							03
RPO	24.1	58.6	13.8					3.5	
Overall RPO	36.4	44.6	16.5					2.5	
Total sites- 138									Total sites- 101

Z, *M. zeylanica;* O, *M. orientalis;* S, *S. srilankensis*; *A. srilankensis*; symp, sympatric

In view of the number of occurrences of each species, they showed different Relative Percentage Occurrence (RPO) values for both West and North-West coasts. Within the West coast *M. zeylanica* recorded the highest RPO value (67.7) for 23 occurrences and within the North-West coast *M. orientalis* recorded the highest RPO value (58.6) for 51 occurrences. Overall highest RPO value recorded (44.6) for *M. orientalis* and second highest (36.4) for *M. zeylanica* (Table 2). The mysid species *M. orientalis*, *M. zeylanica* and *S. srilankensis* were inhabited in estuarine habitats either as a single species or in sympatry (Table 2).

Mesopodopsis zeylanica was the dominant mysid taxon in Negombo, Chilaw and Achchankulum lagoons whereas *M. orientalis* was the dominant mysid taxon in Puttalam, Kalpitiya, Mannar and Aripppuwa lagoons. Only one species recorded from Bolgoda (*M. zeylanica*) and Mundal (*M. orientalis*) lagoons.

The environmental parameters recorded during distributional surveys are given in Table 3. The highest salinity values were recorded from Puttalam (56 ‰) Mundalama and Kalpitiya lagoons (55 ‰) whereas lower salinity were recorded at Bolgoda and Lunawa lagoons. Extremely high pH values (8.56–8.8) were recorded at Lunawa lagoon. The dissolved oxygen levels were generally above 6.0 mg L^{-1} up to 8.5 mgL^{-1} at all sites. Water temperature fluctuated among sites, the highest recorded in Puttalam lagoon (27–38°C), the lowest recorded in Bolgoda (25–28°C) and other surveys it fluctuated between 27–33°C (Table 3).

Table 3: Environmental parameters recorded in each estuarine survey

Estuarine body	DO mg L^{-1}	pH	Salinity ‰	Water temperature °C	Air temperature °C
Bolgoda	6.3 – 7.0	6.9 – 8.3	0 – 20	25 –28	27 –30
Lunawa	6.0 – 6.7	8.6 – 8.8	0	29 –30	28 –29
Kalpitiya	6.5 – 7.6	5.9 – 7.5	0 –55	27 –32	27 –36
Mundalama	6.3 – 7.0	7.1 – 8.5	10 –55	28 –33	29 –34
Mannar	6.4 – 7.4	7.1 – 8.2	13 –36	28 –33	29 –34
Arippuwa	6.5 – 7.1	7.5 – 7.8	30 –35	30 –31	29 –33
Achchankulum	6.2 – 7.2	7.4 – 7.6	20 –30	29 –32	28 –34
Puttalam	6.1 – 8.5	6.8 – 8.4	24 –56	27 –38	26 –36
Chilaw	6.3 – 8.1	6.0 – 8.1	0 –37	29 –33	27 –36
Negombo	6.4 – 7.8	6.3 – 8.4	0– 28	28 –34	27 –33

DO -dissolved Oxygen

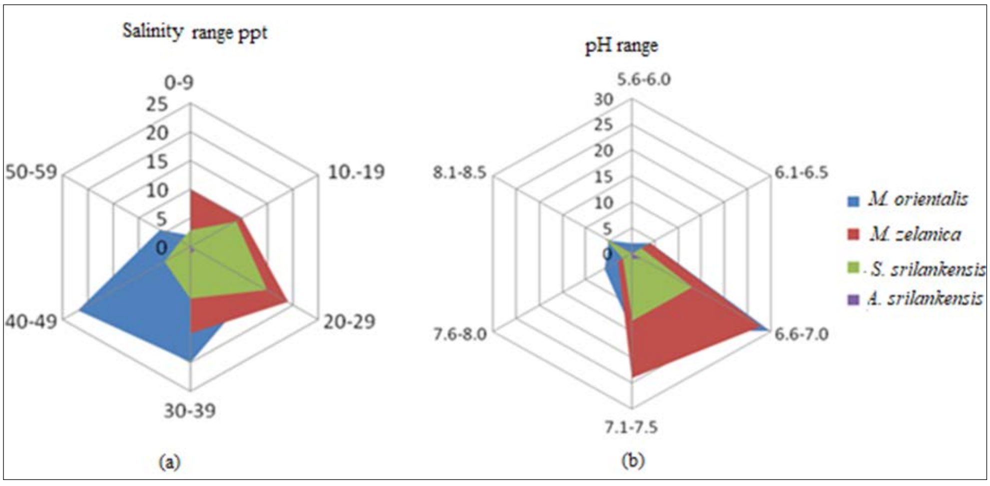

Fig 3: Frequency of occurrences of Sri Lankan mysids in different salinity and pH levels.

Mysid species occurrence in relation with salinity and pH are given in Figs. 3a & 3b respectively. Highest occurrences of each species were noticed in specific salinity levels. Maximum occurrence of *M. orientalis* was within the salinity range of 30–39 ‰, *S. srilankensis* it was within the salinity range of 10–29 ‰, and *M. zeylanica* within the salinity range of 20–29 ‰ (Fig. 3a). However, in all three species higher occurrences were within the pH value of 6.6–7.0 (Fig. 3b).

The results of CART analysis of mysid species within monthly survey sites in relation to environmental parameters is shown in Fig. 4. Salinity and pH contributed much to the variation in the abundance of *M. zeylanica*, *M. orientalis* and *S. srilankensis*. Based on the salinity, root Node of the dendogram is split into two child nodes (Node 1 and 2).

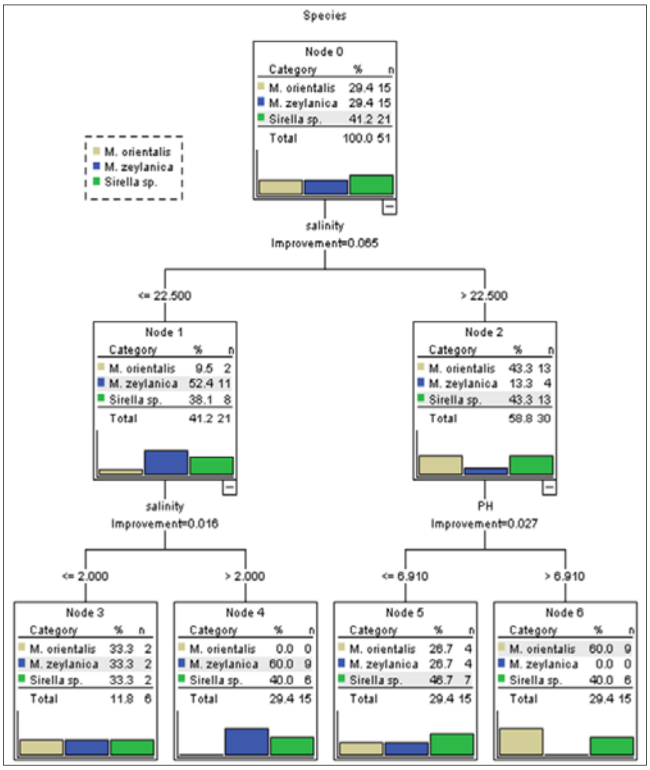

Fig 4: classification and regression tree analysis of the distribution of mysid species within monthly survey sites.

Node 1 includes 52% of *M. zeylanica*, 38% of *S. srilankensis* and 10% of *M. orientalis*. The left branch of the right node of the tree (Node 2) includes similar percentages of *M. zeylanica* and *S. srilankensis* Node 1 further split into two child nodes (Node 3 and 4). The Node 3 included similar percentages of each species. Node 4 includes 60% of *M. zeylanica*, 40% of *S. srilankensis* Based on the pH, Node 2 split into two child nodes, as Node 5 and 6. In Node 5, includes similar percentages (26.7%) of both species, *M. zeylanica* and *M. orientalis* and 46.7% of *S. srilankensis* In node 5, similar percentages of both species *M. zeylanica* and *S. srilankensis* and 29.6% of *M. orientalis* are represented. Node 6 includes 60% *M. orientalis* and 40% of *S. srilankensis*. In general, the findings of the analysis could lead to conclude that salinity and the pH is playing the major role in the distribution of the mysid species.

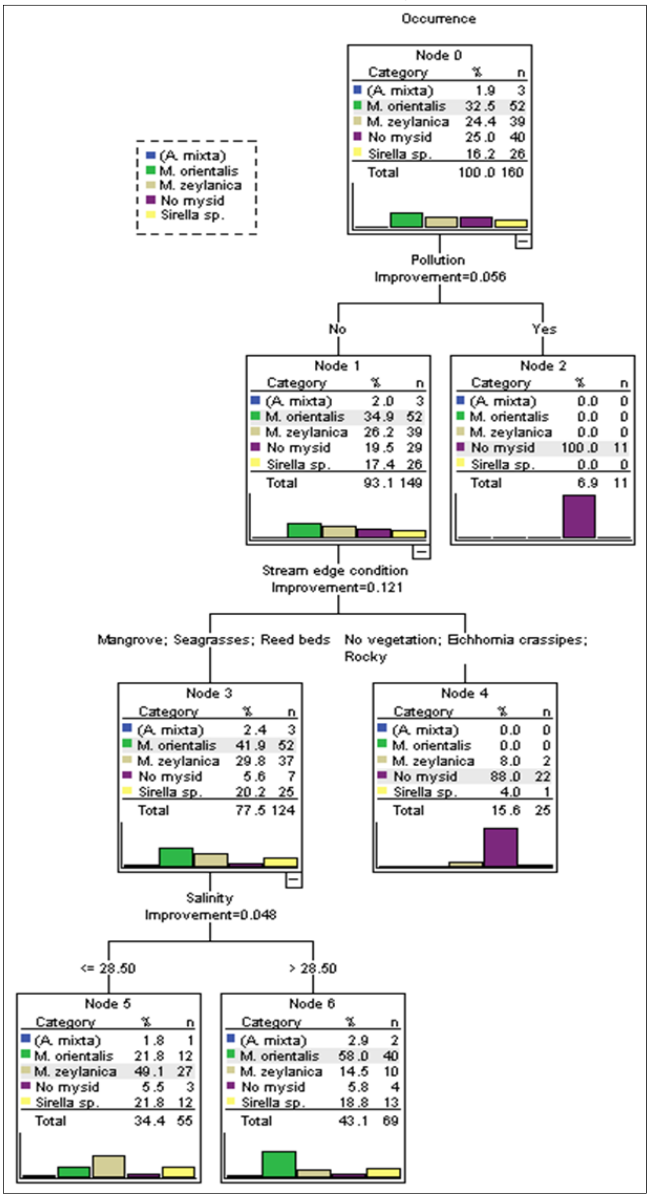

Fig 5: Classification and Regression Tree analysis of the distribution of mysid species in different estuarine waters, Sri Lanka.

The CART analysis of mysid species, in different estuarine bodies is shown in Fig. 5. The boundary condition of estuaries contributed much to the distribution of mysids. Based on the level of pollution, root node of the dendogram is split into two child nodes Nodes 1 and 2. Node 1 includes the mysids living in the unpolluted water. The left branch of the right node of the dendogram (Node 2) includes the polluted area and no mysids (Fig. 5). Node 1, further split into two child nodes (Nodes 3 and 4) on the basis of stream edge condition. The Node 3 (mangroves, seagrasses and reed beds boundaries) included 41.9 % of *M. orientalis* and similar percentages (21.8%) of *S. srilankensis* and *M. zeylanica*. The Node 4 (no vegetation, *Eichornia crassipes*, and rocky boundary) shows 88% of no mysid occurrences. Based on the salinity, node 3 split into two child nodes, as node 5 and 6. The Node 5 includes similar percentages of both species *M. orientalis* and *S. srilankensis* (21.8%) and

49.1% of *M. zeylanica*. The results of the analysis revealed that polluted condition of the estuarine boundary and the associated vegetation type also play a major role in the distribution of the mysid species (Fig. 5).

Table 4: Principal Component Analysis of the distribution of mysid species and the distribution pattern of sites.

Component	1	2	3	4
Eigen Value	4.53	1.90	1.34	1.16
% variance explained	41.15	17.29	12.21	10.58
Cumulative % variance explained	41.15	58.44	70.65	81.23
Biological Parameters Reproductive population	0.986	0.085	0.012	0.007
Total abundance	0.977	-0.013	0.124	-0.024
Gravid female	0.952	0.091	-0.048	0.014
Male	0.939	0.028	0.041	-0.041
Adult female	0.848	0.037	0.164	0.077
Juvenile and sub adults	0.260	-0.205	0.659	-0.102
Environmental Parameters Temperature	0.086	0.924	0.018	0.210
Salinity	0.047	0.912	-0.039	-0.20
Dissolved oxygen	-0.080	0.069	0.767	0.012
pH	-0.098	-0.387	-0.520	-0.42
Monthly rainfall	-0.007	-0.027	-0.038	0.940

The component loading in the Table 4 indicated that the variables related to the biological parameters such as reproductive population, gravid females, adult females, males and are heavily loaded along the first PC (above 90%). However, adult females indicated a loading of 84%. Therefore, the first PCA could be considered as a component which represents the contribution made by biological parameters into the variation in mysid distribution in study sites. Meanwhile, the second PC was loaded heavily with temperature (92.4%) and salinity (91.2%). The third PC was loaded heavily with DO (76.7%), Juveniles (66%) with lower loading for pH (52%). The fourth component represents the contribution of rain fall (94%) into the variation of mysid distribution.

The biplot produced by plotting PCA1, PCA2 and PCA3 and PCA1 with PCA 2 (Fig. 6), indicated a distribution pattern in which species were overlapped considerably. Specially, *M. zeylanica*, *M. orientalis* and *S. srilankensis*, showed a wider distribution in the plot. *M. zeylanica* indicated a trend of separation from the rest and *M. orientalis* and *S. srilankensis* were separated into opposite directions (Figure 6) indicating the sympatric nature of the species.

The site-wise plotting of PCA1 and PCA2 (Fig. 7) showed that the mysids were also area specific in their distribution. However, in Liyanagemulla and Kadolkele sites, *M.*, and *S. srilankensis* were well separated; further in Eththal and Island sites, *M. orientalis* and *S. srilankensis* also separated well. In Rthnauyana and Thoduwawa, the species under consideration were seems to be sympatric. The trends those reflected from the Figure 7, indicated that the sites distributed in the plot of PC1 with PCA 2 were separated, Eththal and Island sites in Puttalam lagoon in one direction and Liyanagemulla and Kadolkele in Negombo lagoon in other direction. This pattern of distribution of species and sites is more or less related to the variation of environmental parameters such as temperature (92.4%), salinity (91.2%), dissolved oxygen (76.7%) and pH (52%).

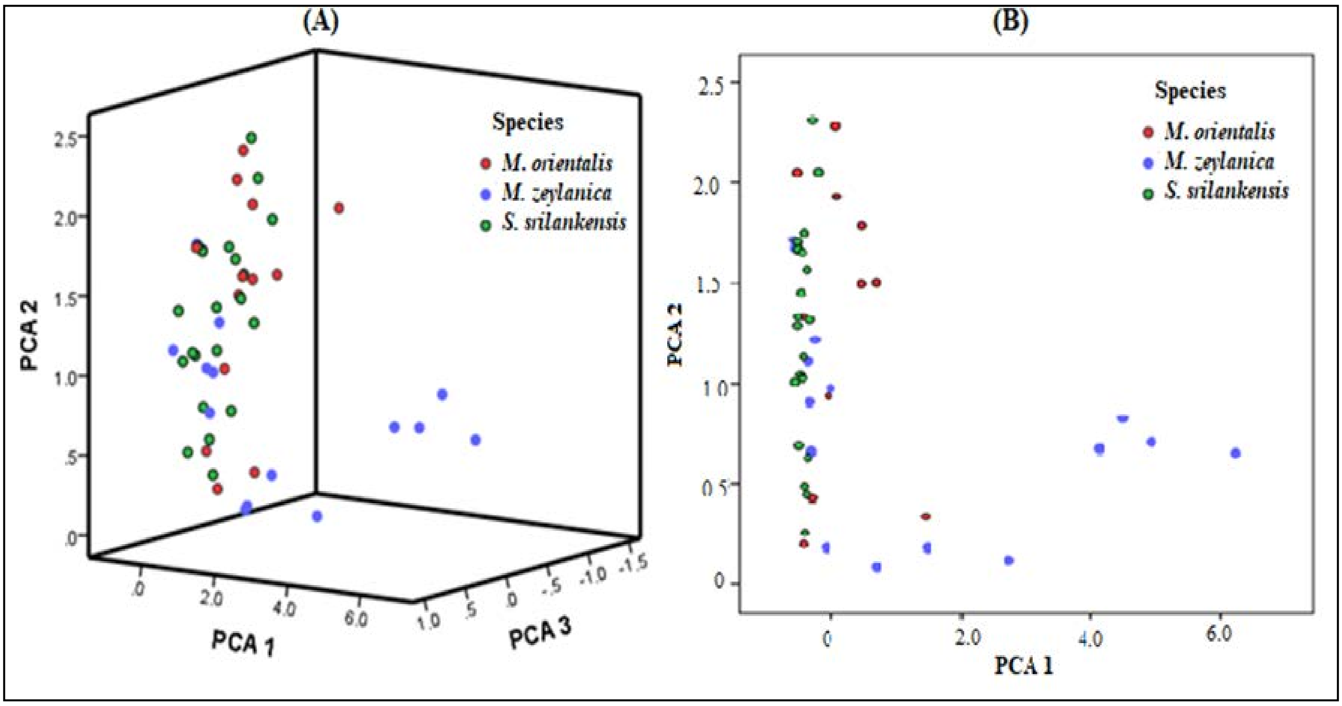

Fig 6: Distribution of mysid species in relation with distribution pattern of sites, produced by Principal component analysis.

a. 3D plot for species using Principal components 1, 2 and 3
b. Biplot for species using Principal components 1 and 2

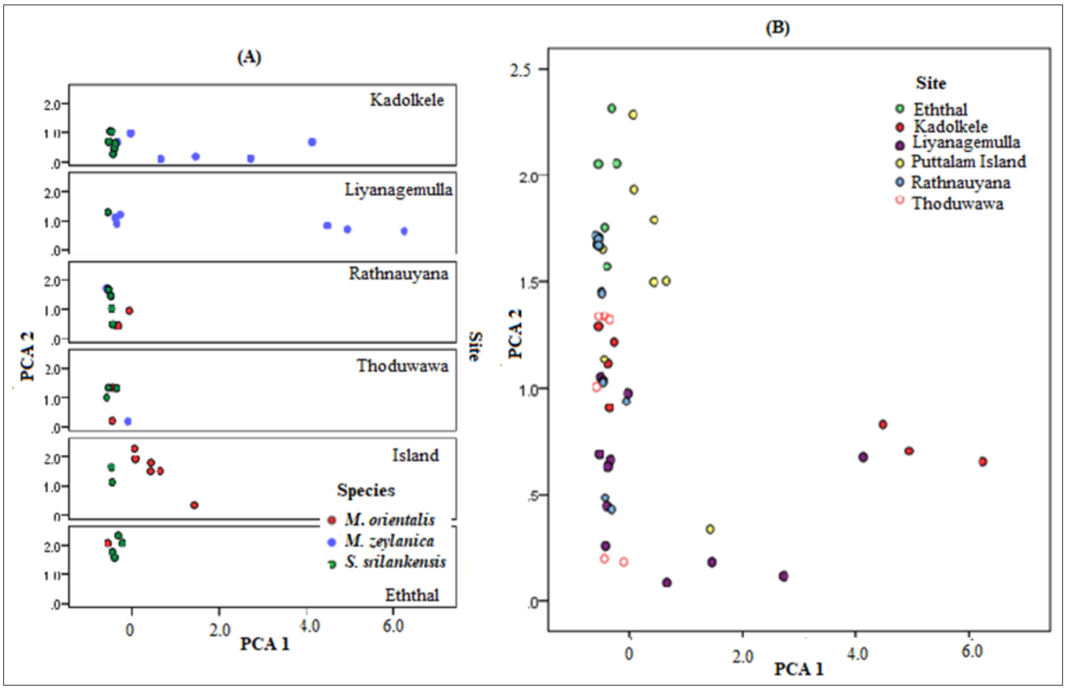

Fig. 7: Distribution pattern of study sites, in relation with mysid species, produced by Principal Component analysis.

a. Biplot for species in relation with sites using PCA 1 and 2.
b. Biplot for distribution pattern of sites using PCA 1 and 2

Discussion

Four species of mysids dominated in Sri Lankan estuarine waters incorporate in to three genera. *Mesopodopsis zeylanica*, *M. orientalis*, *S. srilankensis* and *A. srilankensis* were found within nine lagoons, throughout Western and North-western coastal regions of Sri Lanka. Their occurrences among the lagoons were different; *M. zeylanica* recorded from eight lagoons, *M. orientalis* from seven lagoons, *S. srilankensis* from five lagoons and *A. srilankensis* from one lagoon. Prior to the present study, *M. zeylanica*, was the only estuarine mysid species recorded from Sri Lanka, as a new species from Bolgoda lagoon (Nouvel,1954) [18]. The present study revealed its distribution is widespread, throughout the west coast to North - West coast. Although this species was originally found in Sri Lanka, its distribution extended to India, (Jadhav and Josekutty, 2003; Biju and Panampunnayil, 2010; Verlecar *et al*., 2012) [4, 13, 34]. Hence, *M. zeylanica* has a wide geographic distribution in Sri Lankan estuarine bodies as well as in Indian estuarine waters.

Although *M. orientalis* recorded for the first time in Sri Lanka, its distribution is reported from several countries as well. Originally this species was recorded from India (Tattersall, 1908) [32], and subsequent to that it has been reported several times (Nair, 1939; George, 1958; Pillai, 1968[9, 16, 21]; Bhattacharya and Kewalramani, 1972[1]; Bhattacharya, 1982[2]; Biju and Panampunnayil, 2010[4], 2011). Distribution of this species extended through Southeast Asia: Malaysia (Hanamura *et al*., 2009) [10], prawn ponds of Singapore Island and the fish rearing lagoons of Java (li, 1964), and Gulf of Thailand (Chaitiamwonges and Yoodee, 1982) [6]. They were recorded from estuaries (Biju & Panampunnayil, 2011) [5], salt pans (Biju and Panampunnayil, 2010) [4] and coastal regions (Panampunnayil, 1999; Hanamura *et al*., 2009) [10, 19] as well.

The present study recorded two new species, *A. srilankensis* and *S. srilankensis*. *Anisomysis srilankensis* (Punchihewa, 2025) [27] found only from Kalpitiya lagoon which shows similar characteristics with *Anisomysis mixta*, this species originally recorded from Japan: mainland of Japan, Okinawa and North of Hawai (Nakazawa, 1910; Murano and Fukuoka, 2003[15, 17])

Sirella srilankensis was recorded from six estuarine waters: Negombo, Chilaw, Puttalam, Kalpitiya, Mannar and Achchankulum. However, in Sri Lanka, Tattersall recorded five different *Siriella* species from oceanic waters: *Sirella paulsoni* from pearl banks (Tattersall, 1906) and *S. brevicaudata*, *S. quadripinosa*, *S. affinis*, *S. hanseni*, *S. paulsoni* from Gulf of Manaar (Tattersall, 1922) [33].

The number of species recoded from each lagoon was different: Kalpitiya (four), Chilaw, Puttalam, Achchankulum and Mannar (three from each), Negombo and Arippuwa (two from each) and Bolgoda and Mundal (one). Similar to Kalpitiya lagoon, a tropical estuary, Cochin backwater system of India also recorded four species of mysids (Biju and Panampunnayil, 2010) [4], in which *M. orientalis* and *M. zeylanica* are common to both estuarine waters of two countries.

During the present survey, 101 mysid habitats were recorded and the number of occurrences of each species was different: *M. orientalis* occurred at 54 of them, *M. zeylanica* at 44 of them and *S. srilankensis* at 20 of them. Hence, *M. orientalis* was the most geographically widespread estuarine mysid taxa, followed by *M. zeylanica*. However, *M. zeylanica* and *S. srilankensis* were almost equally distributed in both West and Northwest coast while *M. orientalis* was the most geographically widespread species in Northwest coast. Those surveyed estuarine areas appeared to be dominated by *M. orientalis*, *M. zeylanica* and *S. srilankensis* and they were able to inhabit in sympatry whereas on some occasions they were recorded as a single species. It is evidenced that there are regionally dominated taxa in different sites, *M. zeylanica* dominated in the lagoons of Negombo, Bolgoda, Achchankulam and Chilaw, *M. orientalis* dominated in Puttalam, Mannar, Arippuwa, Mundal and in Kalpitiya lagoons.

Mysids distribution recognised throughout the South-Western, to North-Western coastal regions in Sri Lanka. Mysids were found to be absent from South-Western region whereas they were located along the Western and North-Western coastal regions, from Bolgoda to Mannar lagoon except Lunawa lagoon. Throughout the entire survey within nine lagoons (138 sites) mysids were recorded at nearly ¾ of the (101 sites) sites surveyed. This apparent presence of mysid is a good indication that these sites provide better conditions for their prevalence.

The South-West estuarine areas from Kalutara to Galle (10 sites), where mysids were not recorded are surveyed once only. However, in such sites, mangroves located very rarely as boundary vegetation. Only Maggona, Kaluwamodara, and Madu river estuary, mangroves located as discontinuously patchy distribution and other six areas no mangroves were evidenced.

Among the estuarine areas surveyed, Lunawa lagoon is exceptional due to its highly polluted condition, and it is a cause for concern that mysids were not recorded from this lagoon. During the survey, it was noted that this lagoon was separated from the sea by a sand bar which in turn resulted in the accumulation of most of the pollutants received from the channels. The Mundal lagoon, only five sites were sampled due to the difficulties which came across when survey was conducted. Mysid habitats were found only in three sites, in which mangrove vegetation exist, whereas in the other two sites neither marginal vegetation nor mysids were recorded.

Considering the estuarine bodies where mysids were recorded, the lowest number of mysid habitats found for the Bolgoda lagoon (31%), and this proved that boundary condition and polluted condition are having a great effect on presence of mysids (Punchihewa,*et al*., 2017). However, the other lagoons (Negombo, Chilaw, Puttalam, Kalpitiya, Mannar, Achchankulam and Arippuwa), where originally fringed extensive mangrove forests are present and the widespread mysid habitats were recorded, from the shaded edges of the lagoons. Most of the mangrove areas have been destroyed due to human interference mainly in Puttalam city area. The Puttalam Lagoon it was revealed that sites with boundary vegetation consisting of mangroves or widespread seagrass beds were more favourable for mysids to exist while soil filled boundary areas and waste disposal sites along the boundary were found to be unsuitable (Punchihewa, 2020) [25]. In the Chilaw lagoon, mysid habitats were found from 13 sites surved where mangroves found as boundary vegetation and mysids were not recorded only from two sites where these areas are vulnerable to effluent discharge from the nearby shrimp farms posing a serious hazard to the wellbeing of mysid habitats (Punchihewa, 2021) [26]. This also evidenced that the habitat suitability for mysid existence. During some sampling occasions, it was difficult to confirm the presence of mysids from some sites of Kalpitiya, Arippuwa and Puttalam lagoons due to dominance of shrimp species in these areas.

It is alarming us that the clearing of stable boundary (riparian) vegetation and accumulation of pollutants resulted in the loss of mysid habitats. It was noted that if any habitat does not provide suitable requirements for their survival, they might have the local migration to nearby suitable habitats. This experienced in New Zealand mysid distribution study as well (Punchihewa, 2018) [23]. Now, it is apparent that mysid habitats found mainly from extensive mangrove boundaries or mangrove forest without any anthropogenic effects. Based on the analysis collectively done in all lagoons under survey, mysids were absent from the areas with pollutants, and constructed edges with concrete (Punchihewa *et al*., 2017; Punchihewa, 2019; Punchihewa, 2020; Punchihewa, 2021) [22, 25, 26]. Undoubtedly, it is obvious that the condition of the estuarine boundary is important for mysid occurrence. Marginal vegetation has a vital role of protection of estuarine fauna for providing their niche requirements.

Hence, estuarine waters provide the suitable habitats for mysids, if marginal vegetation present and/or anthropogenic effects should be minimal for that site. Then the absence of mysids in these sites could be a cause for concern. It reflects that these sites are not suitable for their survival due to incapability of providing niche requirements, such as food, shelter and aggregation for their social behaviour or reproduction. The Kadolkele site, in the Negombo lagoon, is an undisturbed mangrove forest and the highest mysid numbers were recorded, indicating, that the habitat suitability for mysids to thrive in this habitat (Punchihewa and Krishnarajah, 2019) [22].

Mysids are one of the gaps in our biodiversity list under crustaceans, and the present new findings met the requirements to fulfil this gap. Therefore, it is worthy of conservation of mysids and there habitats.

This is the first estuarine mysid habitat survey carried out in Sri Lanka after a long lap. Due to the lack of historical data on the distribution of mysid taxa in Sri Lankan estuarine waters except Bolgoda lagoon, it cannot make a decision whether any change in their distributions and population dynamics have occurred. Nouvel (1954) [18] reported only the presence of *M. zeylanica* from Bolgoda lagoon. After 58 years, the present study reported the same species from Bolgoda North Lagoon (Punchihewa *et al*, 2017).

Different species show different salinity tolerance levels and inhabit accordingly. Surveys clearly indicated that *M. zeylanica* was confined to lower salinities and lower temperatures. Although this species was recorded from 0–37 ‰ salinities, highest occurrences within the range 20–29 ‰ (preferable range). *Sirella srilankensis* recorded from wider salinity range 0–56 ‰ and maximum occurrences was within the range 10–29 ‰. *M. orientalis* also occurred within salinity range of 0–56 ‰ and highest occurrences was in 30–39 ‰ salinity range. The occurrence of *M. orientalis* in a wider range of salinity (0−56‰) in Sri Lanka, is in agreement with the studies in India: Versova mangrove ecosystem in India (20.3−37.1‰) (Biju and Panampunnayil, 2011) [5], and Bhayander salt pan (1.2−63.6) (Biju and Panampunnayil, 2010) [4]. According to salinity tolerance studies on *M. orientalis* under laboratory conditions (Bhattacharya, 1982) [2], it revealed that this species could survive under an extremely wide range of salinity conditions. This ability ensures its wide distribution from sea water to near freshwater conditions even in the saltern. Considering all these 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 hyper/ hypo-osmotic to the medium (McLusky and Heard, 1971) [14]. Due to the ability to live in hyper saline conditions *M. orientalis* is found to be the most geographically widespread species in Sri Lanka specially in dry zone.

Salinity effect on mysid distributions in other countries is well documented for other estuarine species; *Acanthomysis thailandica* in a tropical estuary Malaysia (Ramarn *et al*, 2012) [28], *Tenagomysis chiltoni Tenagomysis novaezealandiae*, *Tenagomysis macropsis* and *Gastrosacus australis* from different estuarine environments in Auckland region, New Zealand (Punchihewa, 2018) [23] and *N. integer*, *Gastrosaccus spinifer*, *Schistomysis kervillei* and *S. spiritus* in the Waterschelde estuary in South - West Netherlands (Rappé *et al*., 2011) [29].

Although salinity is mainly affect on the mysid distribution and abundance, it cannot be described only with a single environmental factor. Combination of factors govern the mysid distribution. It is agreed that distribution and abundance of Sri Lankan mysid species, mainly due to several factors. In the present study, salinity, temperature and pH contributed much to the variation in the abundance of mysids. Mysids of different countries also reported similar results. Temperature, and to a lesser extent turbidity control the distribution of *M. slabberi* in the Westerschelde estuary (Rappé *et al*., 2011). Biju *et al*. (2009) [3, 29] reported that the population density of mysids in Cochin estuary (India) was influenced by temperature, chlorophyll concentration, DO, and salinity. The abundance and distribution of two New Zealand mysids had opposite correlation with pH and salinity levels; *T. chiltoni* numbers increase with lower pH and lower salinity levels whereas *T. novaezealandiae* numbers increase with higher pH and higher salinity levels (Punchihewa, 2018) [23].

It showed that the mysids were also area specific in their distribution. This pattern of distribution of species and sites is more or less related to the variation of environmental parameters such as temperature, salinity, dissolved oxygen and pH. The occurrence of *M. zeylanica* depended on low salinity level while *M. orientalis* and *S. srilankensis* depended on high salinity.

Conclusion

From four mysid species recorded, two were new, *Sirella srilankensis*) and *Anisomysis srilankensis*. *Mesopodopsis orientalis* was the most widespread taxon. *Mesopodopsis zeylanica* and *S. srilankensis* were distributed in both West and North-west cost. Salinity, temperature and pH influenced the variation in mysid abundance.The condition of the estuarine boundary, especially marginal vegetation, play an important role in the occurrence of mysids.

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