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DISTRIBUTION AND MIGRATION OF MYSIDS IN THE GULF OF RIGA (NORTHERN BALTIC)

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Abstract. Relationships were sought between temperature, salinity, and the density of mysid species in the Gulf of Riga. Most of the variability in the distribution of *Mysis mixta*, *M. relicta*, and *Neomysis integer* can be explained by the temperature. *M. relicta* is confined to the deeper parts of the gulf where temperature is constantly low. *N. integer* migrates to the coastal areas in late spring. Its production increases with water temperature in summer. In the course of summer, as the depth of the thermocline increases, *Neomysis* invades deeper areas. Similar migration takes place on the other side of the thermocline where *M. mixta* avoids the expanding warm water. The distribution of mysid populations becomes more homogeneous after storms in autumn. The distribution pattern of *Praunus* spp. is positively influenced by the density of benthic vegetation.

Key words: Mysidacea, seasonal migration, Gulf of Riga.

INTRODUCTION

A total of 18 mysid species have been found in the Baltic Sea (Köhn, 1992). Because of their high abundance and wide distribution, mysids are an important component in the Baltic Sea ecosystem. Mysids are omnivorous, feeding on phyto- and zooplankton, seston, and degrading parts of phytobenthos (Kinne, 1955; Arndt & Jansen, 1986). Mysids are preyed by several fish species, among these Baltic herring (*Clupea harengus membras* L.), flounder (*Pleuronectus flesus* L.), and eelpout (*Zoarces viviparus* L.) (e.g., Kostrichkina, 1968; Oyaveer, 1983).

To survey mysid populations, a specific sampling technique is required as traditional methods for studies of zooplankton and zoobenthos are inefficient in describing the quantitative distribution of mysids. This is the reason why the life history of mysids is relatively poorly known.

Only five species of mysids occur in the Gulf of Riga (Yarvekyulg, 1979). These are *Neomysis integer* (Leach), *Mysis mixta* Lilljeborg, *M. relicta* Lovén, *Praunus flexuosus* Müller, and *P. inermis* Rathke. The changes in their abundances and biomasses have been estimated in Pärnu Bay and adjacent sea areas in June–July (Yarvekyulg, 1979).

The purpose of this study was to quantify the distribution of mysids in a much larger area of the Gulf of Riga, describe their horizontal (seasonal) migration, and relate the distribution and migration to hydrological conditions.

MATERIAL AND METHODS

The studied area embraces more than 2/3 of the total area of the Gulf of Riga, including the deepest parts of the gulf (Fig. 1). The bottom relief of the study area

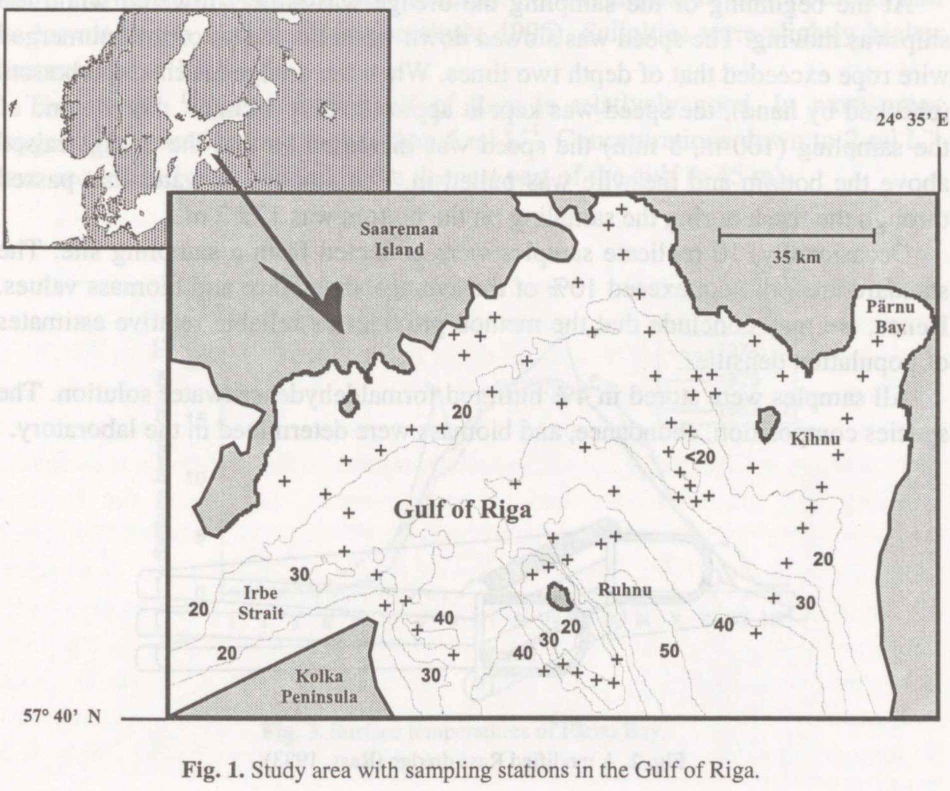

Fig. 1. Study area with sampling stations in the Gulf of Riga.

is relatively flat with gentle slopes towards deeps. The average distance between sampling sites was 6 km on plains and 1 km on deeper slopes.

Samples collected in daytime during the ice-free seasons in 1974–75 (total of 531 samples) were used. Thus, this study represents a situation where the eutrophication level was much lower than nowadays. Hence, physical properties of the sea, e.g. salinity and temperature, influenced the distribution of mysids more than the pollution load. A modified Rass dredge (Rass, 1933; Fig. 2) was used for sampling. The dredge is made of three identical nylon netbags, which are attached to a rectangular metal frame. The mesh size of the nets was 0.4 mm. During the sampling the openings of netbags were located 0–0.2, 0.2–0.5, and 0.5–0.8 m from the sediment surface. The dredge was towed on a rotating metal cylinder (stone, gravel, sand, hard clay bottoms) or sledge (silty hard clay bottoms). This dredge is unsuitable for sampling on silty sediment where the mesh will be clogged up.

Pilot sampling with different types of nets indicated that the daytime distribution of mysids is restricted to less than 1 m above the bottom, making the Rass dredge a suitable tool in this study. Prior to the data analysis all mysids caught in three nets were pooled together.

At the beginning of the sampling the dredge was slowly lowered while the ship was moving. The speed was slowed down when the length of the submerged wire rope exceeded that of depth two times. When the dredge touched the bottom (checked by hand), the speed was kept at approximately 1 km h^{-1}. By the end of the sampling (100 m, 5 min) the speed was increased so that the dredge raised above the bottom and the wire was pulled in. The amount of water that passed through the mesh during the sampling on the bottom was 17 ± 3 m^3.

Occasionally, 10 replicate samples were collected from a sampling site. The standard error did not exceed 10% of the average abundance and biomass values. Hence, we may conclude that the method provides us reliable relative estimates of population densities.

All samples were stored in 4% buffered formaldehyde–seawater solution. The species composition, abundance, and biomass were determined in the laboratory.

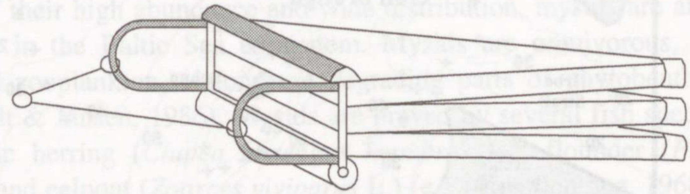

Fig. 2. A modified Rass dredge (Rass, 1933).

The values of salinity, temperature, and oxygen content were recorded during each sampling. The database of the Estonian Hydrometeorological Institute was used to describe the hydrology of the Gulf of Riga during 1974–90.

RESULTS

Hydrology

Until late May no clear thermocline occurs in the Gulf of Riga and the water is cold. Later the surface water temperature rises to about 17–19 °C and a thermocline builds up. The thermocline reaches a depth of 25 m in August and disintegrates in September–October due to intensive wind mixing. Figure 3 shows the monthly temperature dynamics of surface water in the study area. The changes in water temperature were close to the average in 1974 whereas the values were much higher in 1975.

In most parts of the Gulf of Riga the salinity is 5–6.5‰, with lower values close to the mouth of the Pärnu and Daugava rivers and higher values at Irbe Strait. During spring and summer the salinity is the highest in bottom layers and the lowest in the surface layer (Berzinsh, 1995). Salinities were slightly higher than average in 1974–75.

The oxygen regime of the Gulf of Riga is relatively good. In most areas oxygen concentrations are higher than 5 ml L^{-1}. Concentrations down to 2 ml L^{-1} have occasionally been found in the deepest part of the gulf (>45 m).

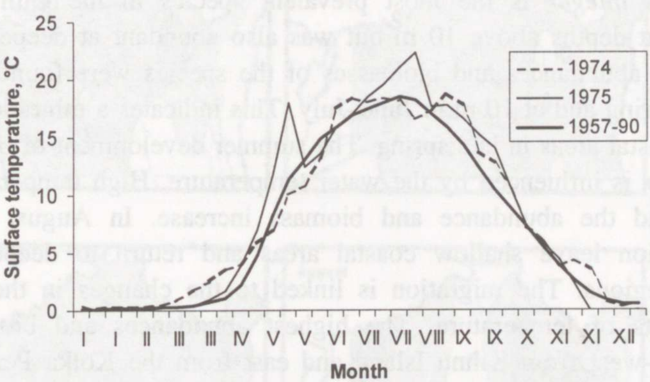

Fig. 3. Surface temperatures of Pärnu Bay.

Distribution ecology

Abundances and biomasses of mysids were correlated to bottom water temperature and to some extent to salinity (Table 1). The latter correlation is probably the result of covariation between temperature and salinity.

Table 1. The values of correlation coefficient between abiotic and biotic variables. Numbers in bold are significant at $p < 0.05$ ($n = 349$)

Variable	Temperature	Salinity
Abundance		
Neomysis integer	**0.32**	**–0.16**
Mysis mixta	**–0.11**	**0.17**
M. relicta	**–0.26**	**0.11**
Praunus flexuosus	0.08	–0.05
P. inermis	**0.13**	–0.06
Biomass		
Neomysis integer	**0.27**	**–0.13**
Mysis mixta	**–0.14**	**0.15**
M. relicta	**–0.25**	0.09
Praunus flexuosus	0.08	–0.04
P. inermis	**0.13**	–0.07

Neomysis integer is the most prevalent species in the Gulf of Riga. It dominated at depths above 10 m but was also abundant at deeper study sites. The highest abundances and biomasses of the species were found at 20–30 m depths in spring and at 10 m in June–July. This indicates a migration from deep water to coastal areas in late spring. The summer development of the population of *N. integer* is influenced by the water temperature. High temperatures favour breeding and the abundance and biomass increase. In August the bulk of the population leave shallow coastal areas and return to deeper, i.e. over-wintering regions. The migration is linked to the changes in the distribution of the fronts of temperature. The highest abundances and biomasses were found south-west from Kihnu Island and east from the Kolka Peninsula. Both areas are characterized by steep slopes and hence, strong gradients in water temperature. Winter mortality was much higher in the Kolka area. As a result, *N. integer* remained abundant only in the vicinity of Kihnu Island (Figs. 4, 5; Table 2).

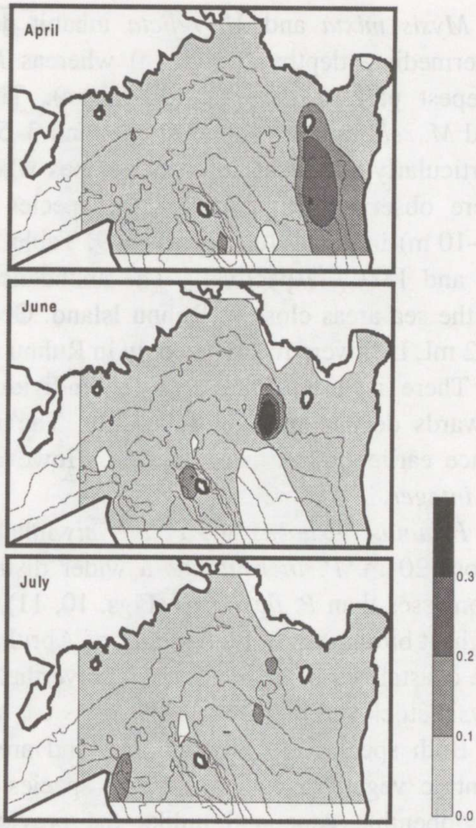

Fig. 4. Biomass distribution of *Neomysis integer* in 1974 (g m^{-3}).

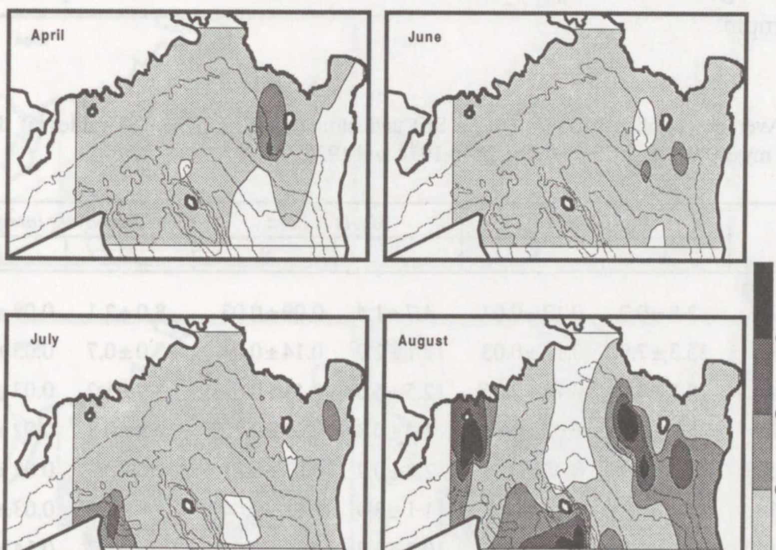

Fig. 5. Biomass distribution of *Neomysis integer* in 1975 (g m^{-3}).

Mysis mixta and *M. relicta* inhabit depths below 5 m. *M. mixta* prefers intermediate depths (10–40 m) whereas *M. relicta* is mostly confined to the deepest part of the gulf (20–55 m). The highest abundances of *M. mixta* and *M. relicta* were found at 6–9 and 3–5 °C, respectively. Both species were particularly abundant at steeper slopes where very strong temperature gradients were observed. Juveniles of the species were often found in shallow areas (5–10 m) in April–June (Figs. 6–9, Table 2), where they can be found at up to 16 and 18 °C, respectively. The abundances of *M. relicta* were relatively low in the sea areas close to Ruhnu Island. Occasionally low oxygen concentrations (<2 mL L^{-1}) were measured only in Ruhnu deep during June–July.

There is a tendency that the individuals of *M. mixta* perform migration towards deeper areas in June–July. The migration is more marked and takes place earlier in warmer summers. However, the process is not so clear as for *N. integer*.

Praunus flexuosus and *P. inermis* inhabit only coastal areas at depths up to about 20 m. *P. inermis* has a wider distribution area, higher abundances and biomasses than *P. flexuosus* (Figs. 10, 11). *P. flexuosus* and *P. inermis* have the highest biomasses in the vicinity of Abruka and Kihnu islands and *P. inermis* in the coastal sea of Ruhnu Island. Nevertheless, the share of *Praunus* in the total mysid stock is fairly low.

Both species are phytophilous and are found in the areas where abundant benthic vegetation occurs. These species spend all their life-cycle within the phytobenthic zone and unlike the previous species never perform extensive seasonal migrations to deeper areas. We never found both *Praunus* species in the same sample.

Table 2. Average abundance (A, ind m^{-3} ± SE) and biomass (B, g m^{-3} ± SE) values of dominant species of mysids during different months in 1974 and 1975

Time	*Mysis mixta*		*Mysis relicta*		*Neomysis integer*	
	A	B	A	B	A	B
April, 1974	2.8 ± 0.7	0.12 ± 0.03	4.7 ± 1.4	0.09 ± 0.03	8.0 ± 2.1	0.08 ± 0.02
June, 1974	35.3 ± 7.9	0.13 ± 0.03	12.1 ± 2.9	0.14 ± 0.04	3.0 ± 0.7	0.05 ± 0.02
July, 1974	18.2 ± 3.6	0.19 ± 0.06	12.5 ± 3.6	0.11 ± 0.03	3.9 ± 1.2	0.03 ± 0.01
April, 1975	2.2 ± 0.5	0.02 ± 0.01	1.2 ± 0.3	0.01 ± 0.003	3.3 ± 0.8	0.02 ± 0.01
June, 1975	11.6 ± 2.9	0.05 ± 0.01	2.8 ± 0.7	0.03 ± 0.01	4.0 ± 0.9	0.02 ± 0.004
July, 1975	12.6 ± 2.7	0.16 ± 0.04	11.1 ± 3.9	0.12 ± 0.04	5.1 ± 1.8	0.03 ± 0.01
August, 1975	5.0 ± 1.5	0.12 ± 0.03	10.2 ± 3.3	0.15 ± 0.05	22.9 ± 4.3	0.14 ± 0.02

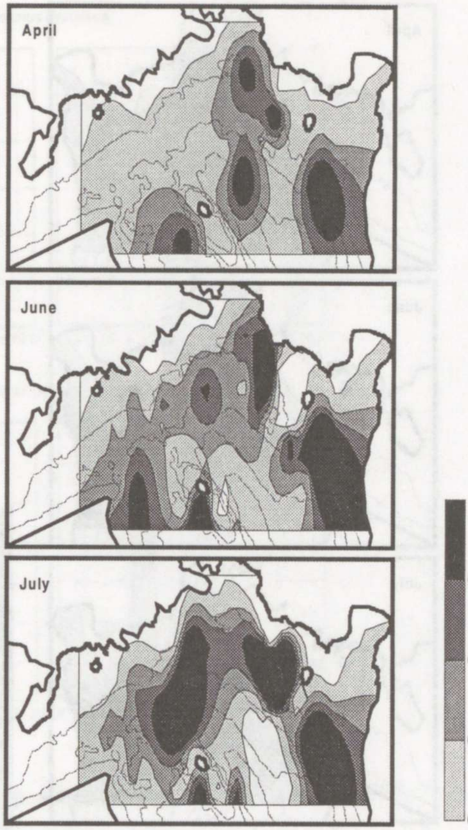

Fig. 6. Biomass distribution of *Mysis mixta* in 1974 (g m^{-3}).

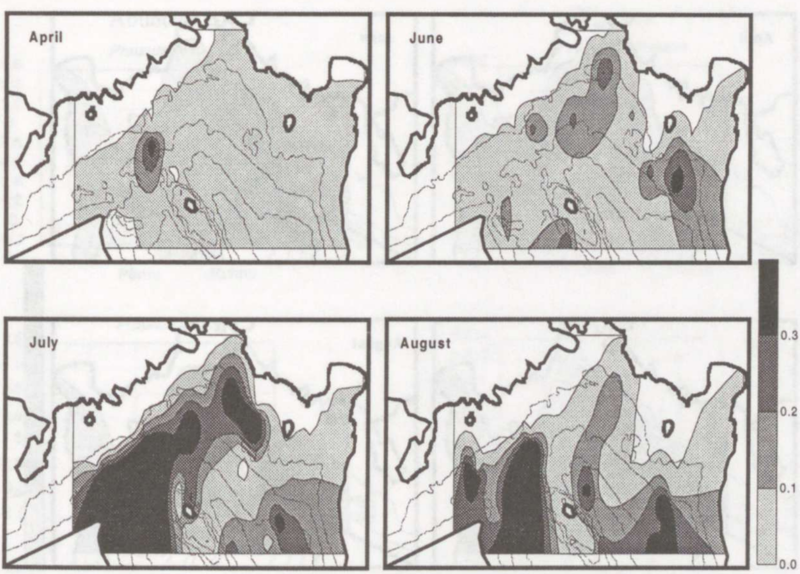

Fig. 7. Biomass distribution of *Mysis mixta* in 1975 (g m^{-3}).

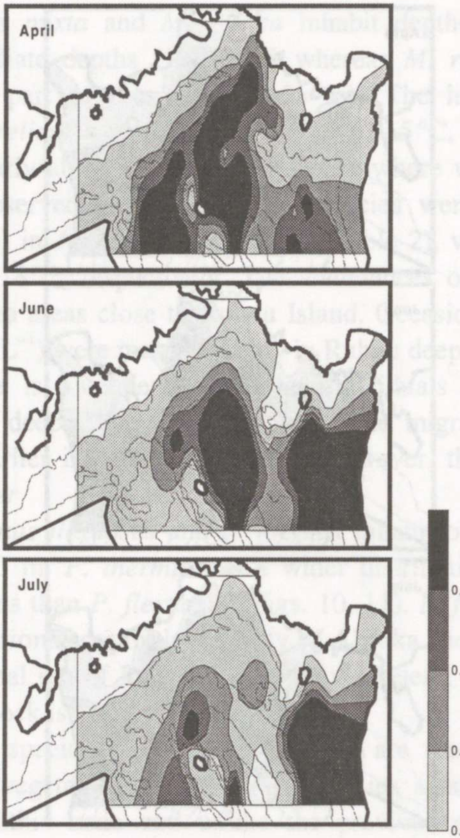

Fig. 8. Biomass distribution of *Mysis relicta* in 1974 (g m^{-3}).

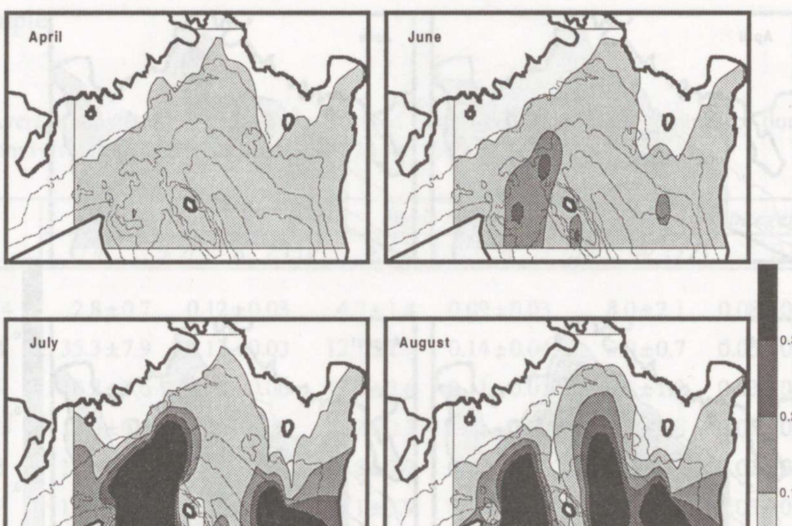

Fig. 9. Biomass distribution of *Mysis relicta* in 1975 (g m^{-3}).

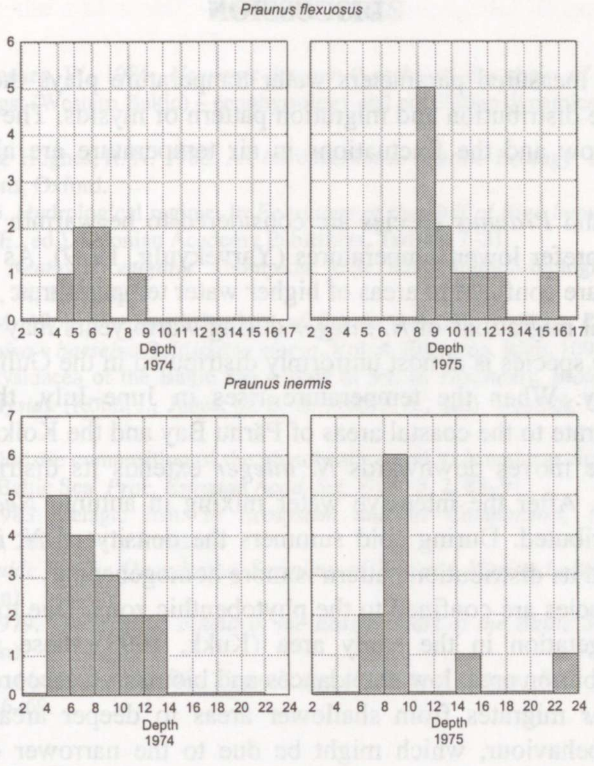

Fig. 10. Distribution of *Praunus* spp. along depth gradient in 1974 and 1975.

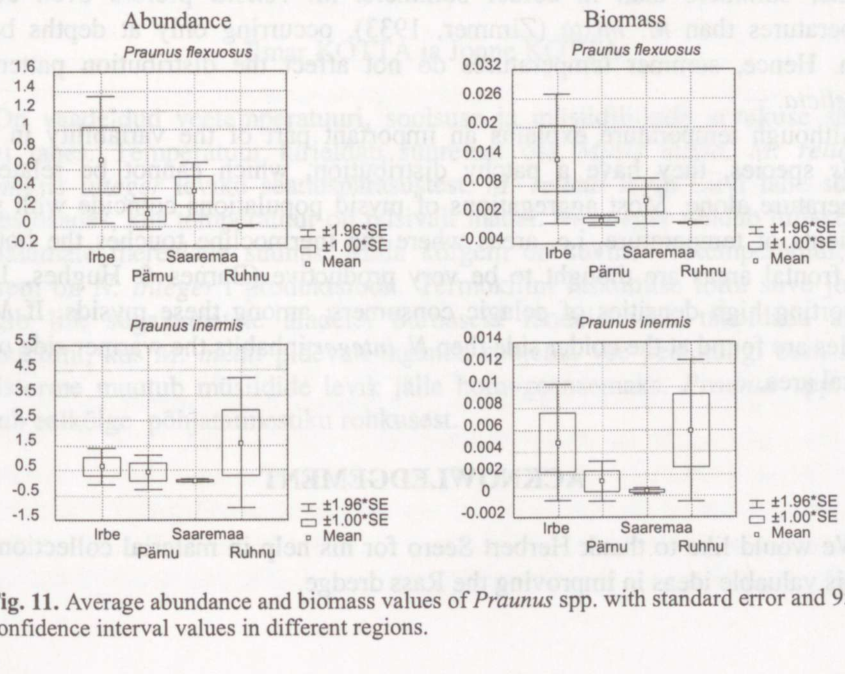

Fig. 11. Average abundance and biomass values of *Praunus* spp. with standard error and 95% confidence interval values in different regions.

DISCUSSION

Among the measured parameters water temperature plays the major role in determining the distribution and migration pattern of mysids. The Gulf of Riga is relatively shallow and the fluctuations in air temperature are also reflected in deep water.

N. integer and *Praunus* species are considered to be warmth loving whereas *Mysis* species prefer lower temperatures (Yarvekyulg, 1979). As a rule, warmth loving species are confined to areas of higher water temperatures.

The seasonal migrations of *N. integer* during warm years may be summarized as follows. The species is almost uniformly distributed in the Gulf of Riga during November–May. When the temperature rises in June–July, the bulk of the population migrate to the coastal areas of Pärnu Bay and the Kolka Peninsula. As the thermocline moves downwards *N. integer* extends its distribution towards deeper regions. After the intensive water mixing in autumn *Neomysis* is again uniformly distributed. During cold summers the density of *N. integer* remains much lower and its distribution pattern is more homogeneous.

Praunus species are confined to the phytobenthic zone. Due to a low biomass of benthic vegetation in the study area (Kukk, 1993) these species have a restricted distribution area, low abundances and biomasses. According to Zimmer (1933) *Praunus* migrates from shallower areas to deeper areas. We did not observe such behaviour, which might be due to the narrower depth limits of phytobenthos distribution in the Gulf of Riga.

M. mixta cannot tolerate high temperatures and inhabits deeper areas in warmer summers than in colder summers. *M. relicta* prefers even colder temperatures than *M. mixta* (Zimmer, 1933), occurring only at depths below 20 m. Hence, summer temperatures do not affect the distribution pattern of *M. relicta*.

Although temperature explains an important part of the variability in both *Mysis* species, they have a patchy distribution, which cannot be related to temperature alone. Most aggregations of mysid populations coincide with steep gradients of temperature, i.e. areas where the thermocline touches the bottom. The frontal areas are thought to be very productive (Barnes & Hughes, 1988) supporting high densities of pelagic consumers, among these mysids. If *Mysis* species are found at the colder side then *N. integer* inhabits the warmer side of the frontal area.

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MÜSIIDIDE LEVIK JA RÄNDED LIIVI LAHES (LÄÄNEMERE PÕHJAOSA)

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On vaadeldud veetemperatuuri, soolsuse ja müsiidiliikide arvukuse seoseid Liivi lahes. Temperatuur kirjeldab suuremat osa *Mysis mixta, M. relicta* ja *Neomysis integer* leviku seaduspärasustest. *M. relicta* levib Liivi lahe sügavamates osades, kus temperatuur on püsivalt madal. *N. integer* rändab hiliskevadel madalamate merealade suunas. Mida kõrgem on suvine veetemperatuur, seda suurem on *N. integer*'i produktsioon. Termokliini laskumise tõttu suve jooksul tungib liik sügavamatele aladele. Sarnaseid rändeid võib täheldada allpool termokliini, kus *M. mixta* pidevalt taganeb soojema vee pealetungi eest. Pärast sügistorme muutub müsiidide levik jälle homogeensemaks. *Praunus* spp. levik sõltub eelkõige põhjataimestiku rohkusest.