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MEIOBENTHIC HARPACTICOIDA (COPEPODA) FROM THE SOUTHERN PART OF THE GULF OF TRIESTE (NORTHERN ADRIATIC) II. ECOLOGY AND SPATIAL DISTRIBUTION

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ABSTRACT

The article presents a review of all ecological investigations of harpacticoid copepods in the southern part of the Gulf of Trieste between 1970 and 2000, with emphasis on the spatial distribution of species, demonstrated with 90 charts. The diversity analysis of this group indicates that the greater part of the area is inhabited by a single community.

Key words: Harpacticoida, Copepoda, Gulf of Trieste, spatial distribution

ARPACTICOIDI (COPEPODA: HARPACTICOIDA) MEIOBENTONICI DELLA PARTE MERIDIONALE DEL GOLFO DI TRIESTE (NORD ADRIATICO) II. ECOLOGIA E DISTRIBUZIONE SPAZIALE

SINTESI

L'articolo presenta i risultati delle ricerche effettuate sulle caratteristiche ecologiche dei copepodi arpacticoidi della parte meridionale del Golfo di Trieste, tra il 1970 ed il 2000. Particolare attenzione e' stata prestata alla distribuzione spaziale delle specie, che viene evidenziata in 90 cartine. Nella gran parte dell'area analizzata la diversità degli arpacticoidi è pressoché uguale, pertanto l'autore parla di un'unica comunità costiera di arpacticoidi dei fondali molli.

Parole chiave: Harpacticoida, Copepoda, Golfo di Trieste, distribuzione spaziale

INTRODUCTION

Like in almost every part of the marine environment, the harpacticoid copepods in the meiofauna of the Gulf of Trieste are ranked second as far as their abundance is concerned, immediately after Nematoda. This is why ecological knowledge of this group is often the key to a wider understanding of the entire meiobenthos.

Of the total six predominantly ecological studies of meiofauna, three have dealt in somewhat greater detail with the biocenological aspects of harpacticoids and spatial distribution of species in the southern part of the Gulf of Trieste: Marcotte & Coull (1974; near Piran), Vrišer (1986; Bays of Koper, Strunjan and Piran) and Vrišer (1992; open waters of the Gulf). The position of sampling sites used during these investigations is shown in figure 1.

The more comprehensive studies of harpacticoid communities from larger areas in the Mediterranean in general are not particularly numerous, but there are certainly none of this particular kind known to us from the wider North Adriatic. In the more important Mediterranean studies, where names like Monard (1935, 1937), Chappuis (1953), Raibaut (1962, 1965, 1967), Soyer

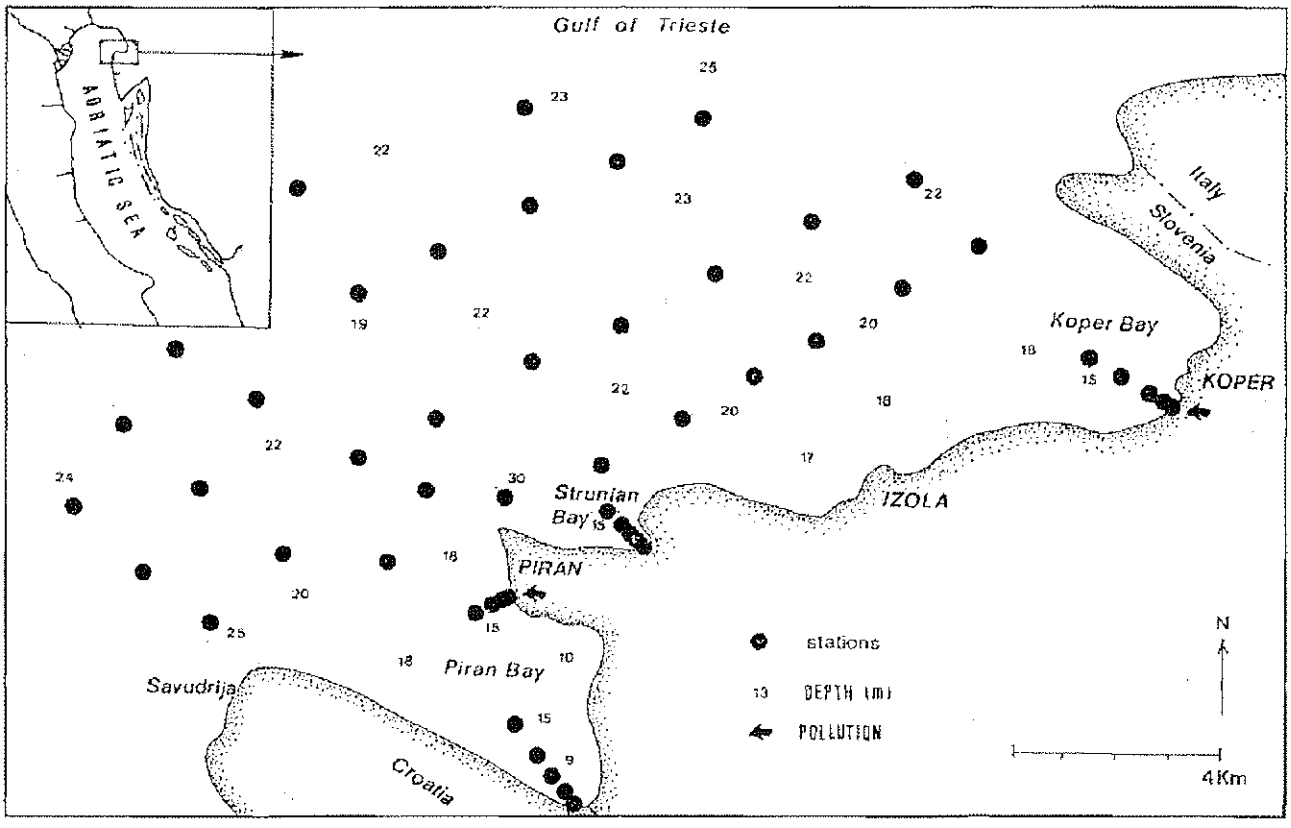


Fig. 1: Investigated area with sampling stations.
Sl. 1: Raziskovano območje z vzorčevalnimi postajami.

(1964a, b, 1969, 1970a, b), Bodin (1964, 1968), Por (1964) and Castel (1985) stand out, systematics and ecology of this group are normally depicted.

In the present article the ecological characteristics of Harpacticoida from the southern part of the Gulf of Trieste are given as a summary of the three already mentioned studies (Marcotte & Coull, 1974; Vrišer 1986, 1992), with a scheme of spatial distributions of all species in the area, while a complete list of species and the group's systematics are presented in a separate article (Vrišer, 2000).

METHODS

All samplings were carried out with the gravity core (Meischner & Rumohr, 1974), with 3 replicates (10 cm^2 sediment surface, 10 cm deep). Meiofauna was extracted with the sieving-decantation technique of Wieser (1960) on 1 mm, 0.125 mm and 0.050 mm sieves, fixed (4% formalin with seawater), stained (rose - bengal), sorted out and counted. Homogeneity of the harpacticoidal communities was examined with the similarity analysis according to Sanders (1960), while the species diversity was established with the Shanon-Wiener index (Pielou, 1969).

ECOLOGICAL CONDITIONS

Depth span of the sampling sites in the study of coastal harpactioids (Marcotte & Coull, 1974; Vrišer, 1986) was between 1 to 15 m, while in the open waters of the Gulf (Vrišer, 1992) it was between 19 and 25 m, exceptionally 30 m.

Samplings in the coastal areas between 1 and 15 m were carried out in winter (February) and summer (August), all the rest in summer (August). Only a few of the shallowest sites (1 - 5 m) in the Bays of Koper and Piran were at the time of sampling under the local influence of sewage pollution (Marcotte & Coull, 1974; Vrišer, 1986), while all the others were not.

The annual thermal conditions of the area's bottom layer vary between 9 and 21°C, salinity between 35 and 37 PSU, while average oxygen saturation reaches 90%, except during hypoxia crisis when it can fall under 40%.

The sediment of the investigated area is represented mostly by clayey silt (10-20% clay), which nearer to the coast and in the interior of the Bays gradually turns into silty clay (25% clay) and towards open waters of the Northern Adriatic into fine sands (Ogorelec *et al.*, 1991).

BIOCENOLOGICAL ANALYSIS OF HARPACTICOIDA

Abundance

Summer harpacticoid abundances of the coastal belt between the coast and the depth of 15 m are on average about 100 ind./10 cm², while in summer they are by half smaller (Marcotte & Coull, 1974; Vrišer, 1986). With the depth the abundance increases, so that out of the coastal bays but parallel to the main coastal line it reaches, at the depth of 20 m, 200-250 ind./10 cm². Towards the centre of the Gulf of Trieste and towards Cape Savudrija the abundance is evenly reduced, at places even below 40 ind./10 cm². In the central part of the investigated area this decrease is less distinct.

There were 25 harpacticoid species on average at separate localities. None of the species surpassed 9% of total relative density, and only 22 occurred with more than 1%, which means that the great majority of the species are represented by only a few individuals (Vrišer, 1992). The most common species in the area, in view of % of their relative abundance, are: *Haloschizopera pontarchis* (8.47%), *Typhlamphiascus confusus* (7.16%), *Bulbamphiascus inermis* (7.10%), *Cletodes pusillus* (6.34%), *Stenhelia adriatica* (4.96%), *etc.*

Diversity and biocenology of coastal harpacticoids

At coastal stations the values of the Hs (Shanon - Wiener) diversity index were in spite of some minor oscillations quite stable (Hs = 1.7-2.2). They drastically fell (Hs = 0.2) only in the direct vicinity of the two sewage outflows in the Bays of Koper and Piran (Marcotte & Coull, 1974; Vrišer, 1986). We believe that here we are dealing with two communities - with due to pollution impoverished community of stressful environment and with the community of the remaining clean, unpolluted coastal belt, where two associations are detected. The first, which is of somewhat higher diversity, coincides with the belt of sea meadows to the depth of 10 m, while the other, deeper association belongs to the bare sediment floor.

Diversity and biocenology of harpacticoids of the outer areas

In further text the data presented are those from the study by Vrišer (1992). The Shannon - Wiener diversity index (Hs) indicated a large diversity range (1.88-3.02) which, however, was in such diverse environment more or less expected. For the fact is that the geological structure of the sea floor changes from slimy clayey silts of the southeastern coastal margin to fine sands of the open sea in the west. Diversity increases in the direction towards the sandy floor and is here the greatest (3.02); it decreases towards the centre of the Gulf of Trieste (2.10) and in the immediate vicinity of Cape Piran.

An estimate of the affinity indices of all available pairs of harpacticoid samples for the assessment of biocenologically similar areas indicated a few nuclei. The most distinct is the area of the seven stations with high faunal affinity (over 70%) on clayey silt of the outer margin of Koper Bay (Fig. 2, area A). Other nuclei were also observed and represent a gradual transition from clayey-sandy silt to sandy floor of the open sea (Fig. 2., areas B, C, D) and in the direction of poorer community (in terms of its species composition and abundance) of the centre of the Gulf and the vicinity of Cape Piran (Fig. 2., areas E and F).

By considering the degree of associability established with the above mentioned similarity analysis, the species diversity and arrangement of the specific species occurring only on certain types of floor, and the prevailing, dominating species, we can divide the investigated area into six ecological units (Fig. 2):

Zone A - province of clayey silty floor. Seven stations of high associability. Average diversity Hs = 2.57. Specific species: *Pontocletodes ponticus, Stenhelia (Delavalia) sp.1, sp.2, Harpacticus sp.5, Laophonte sp.4, Typhlamphiascus sp.1.*; Dominant species (succession of prevalence): *Haloschizopera sp.1, Typhlamphiascus confusus, Cletodes pusillus, Stenhelia (Delavalia) adriatica, Proameira sp.1.*

Zone B - province of sandy-silty floor. Ten stations of medium associability of samples. Average diversity Hs = 2.53. Specific species: *Nitocra fragilis, Ameira sp.1*; Dominant species (succession of prevalence): *Bulbamphiascus inermis, Haloschizopera pontarchis, Haloschizopera sp.1, Cletodes pusillus.*

Zone C - province of sandy floor. Ten stations of medium associability of samples. Average diversity Hs = 2.77. Specific species: *Cletodes limicola, Paradactylopodia brevicornis, Paralaophonte sp.1, Laophonte sp.3, Harpacticus sp3., sp4., Enhydrosomella staufferi, Amphiascopsis sp.1, Ectinosoma sp.2, Pseudobradya sp.1, Harpacticus sp.1, Laophonte longicaudata*; Dominant species: *Haloschizopera pontarchis, Heteropsyllus sp.1, Bulbamphiascus inermis, Heterolaophonte stroemi, Stenhelia (Delavalia) adriatica.*

Zone D - sandy floor of deeper open waters. This probably transitional area is represented by two stations with low associability without a clear affinity for other stations in the area. Average diversity Hs = 2.59. Specific species: *D'Arcythompsonia sp.1, Ameira sp.1; Dominant species: Typhlamphiascus confusus, Haloschizopera pontarchis, Bulbamphiascus inermis, Robertsonia knoxi, Cletodes pusillus.*

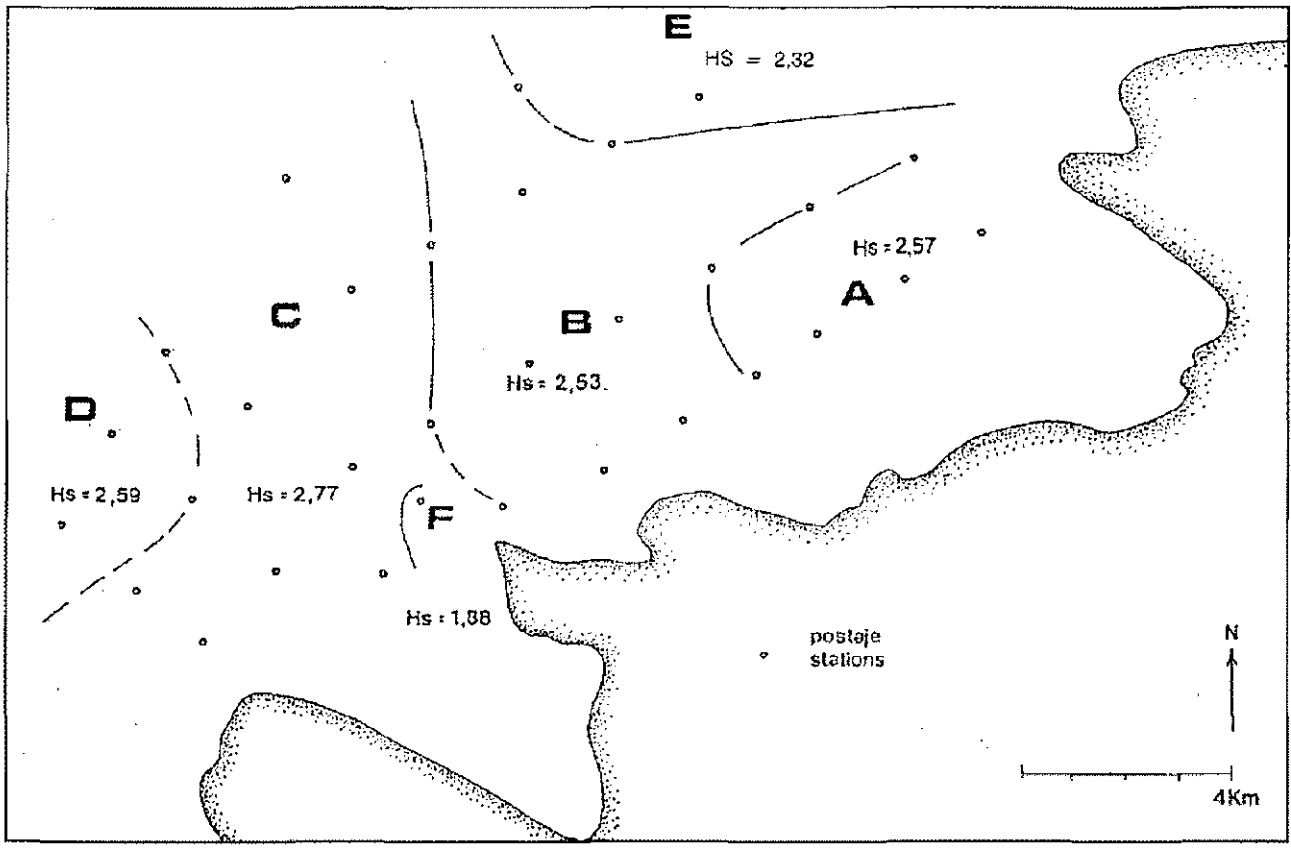


Fig. 2: Biocenological distribution of ecological provinces A, B, C in the coastal community of Harpacticoida with D, E, F transition areas.
Sl. 2: Biocenološka razmejitev ekoloških provinc A, B, C obalne združbe harpaktikoidov in njenih prehodnih področij D, E, F.

Zone E - clayey-sandy silt in the central part of the Gulf. One station only. Hs = 2.32. No specific species. Dominant species: *Enhydrosoma sordidum, Cletodes pusillus, Longipedia coronata.*

Zone F - with only one station off Cape Piran, very low affinities for the stations in zones B and C, and low diversity (Hs = 1.88). No specific species. Dominant species: *Bulbamphiascus inermis, Typhlamphiascus confusus, Cletodes pusillus.*

The presented spatial distribution of harpacticoids is similar to the distribution of the entire meiofauna and its remaining leading groups (Nematoda, Polychaeta; Vrišer, 1989, 1991). However, the reduced abundance of copepods in the direction of the Gulf's centre (known for its frequent hypoxia) and in the direction of the open sea is more distinct than in other meiofauna. A partial reason for this may lie in the smaller resistance of harpacticoids to periodical hypoxic conditions, at least in comparison with nematods, as reported in a number of studies *(e.g.* Josefson & Widbom, 1988; Murell & Fleeger, 1989; Travizi, 1990).

Among the dominant species of the entire investigated area we came across three species *(Haloschizopera pontarchis, Typhlamphiascus confusus, Cletodes pusillus),* which had been as dominant species referred to also by Soyer (1970b) after carrying out a research in Catalonia on a similar floor. All the leading species are estimated as predominantly eurivalent, distributed in places from clayey silt to sand.

Although the total diversity span of the entire area was relatively large (Hs = 1.88-3.02), it was only between 2.40 in 2.60 in the greater part of the investigated area, the only exception being the extreme NW part, where the index was higher than 2.80.

With the exception of Cape Piran (Hs = 1.88) and the centre of the Gulf (Hs = 2.26), the greater part of the area, including the coastal belt, is still more or less similar and it therefore belongs to the same harpacticoid community. The northernmost part of the area belongs to other, in terms of species and abundance truncated harpacticoid community of the central part of the Gulf known for its frequent hypoxia. The low diversity around Piran Cape is perhaps caused by specific hydrodynamics, but is for the time being still unexplainable.

The harpacticoid community of the greater part of the investigated area is not homogeneous but is, according to the associability criterion, composed of three ecological provinces, the most compact of which is the one by the entrance to the silty Koper Bay, while the other two are much less distinct. The harpacticoid investigations have in fact been confirmed by similar assessments (Vrišer, 1989, 1991) about the meiofauna's division into coastal community (although in copepods with more distinct marks of ecologically transitional area than in meiofauna) and hypoxic, poorer meiofaunal community of the Gulf's centre.

Considering that the greater part of the investigated area is in terms of its diversity more or less uniform, we believe that we are dealing with the very same coastal community of soft bottom harpacticoids composed of three subunits, which reflect the floor's transition from clayey silt to fine sand.

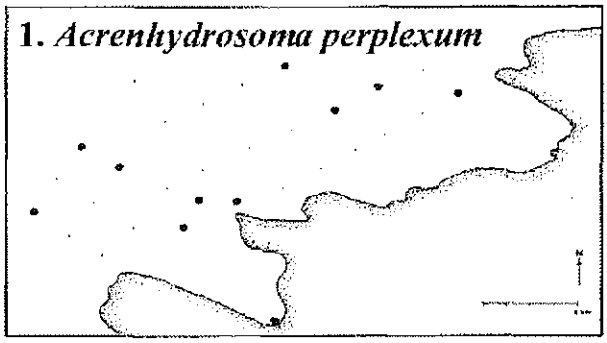
SPATIAL DISTRIBUTION OF SEPARATE SPECIES

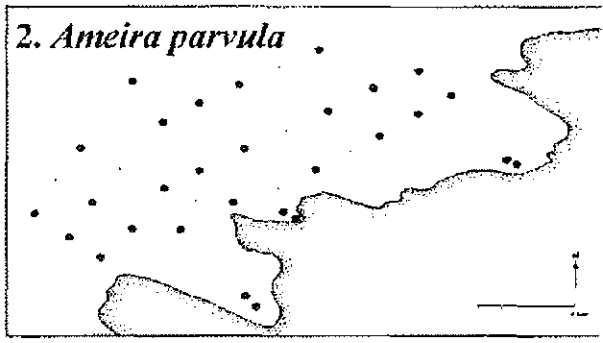
Spatial distribution of all to date registered harpacticoid species of the southern part of the Gulf of Trieste is presented on figures 3-12. The number in front of the name of each species is a successive number from the collective list of species (see Vrišer, 2000).

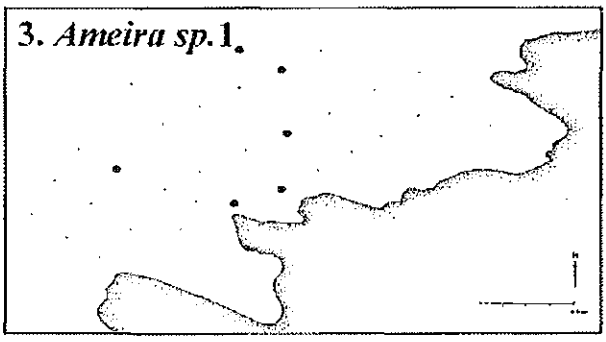
Figs. 3-12: Spatial distribution of harpacticoid species.
Sl. 3-12: Prostorska razporeditev harpaktikoidnih vrst.

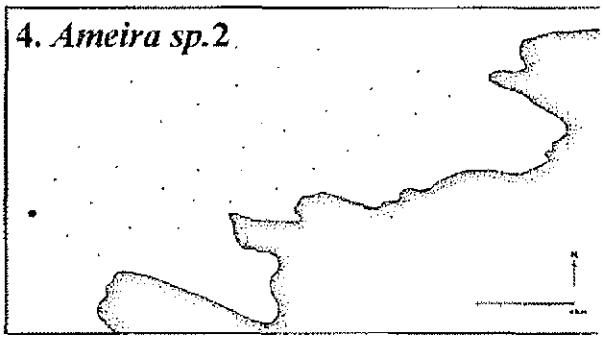
Chart K shows the distribution of the following species:
Karta K prikazuje razporeditev sledečih vrst:

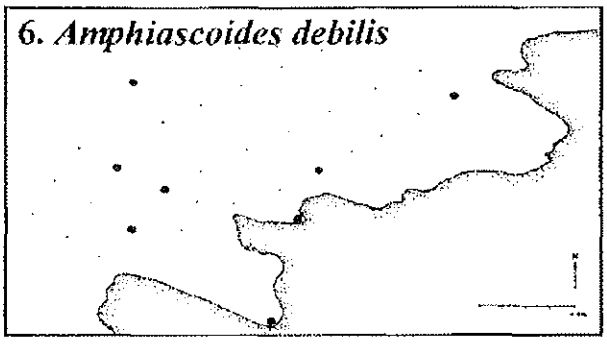
5. *Amonardia similis*, 7. *Amphiascella proxima*, 9. *Amphiascopsis thalestroides*, 10. *Amphiascopsis cinctus*, 14. *Amphiascus caudaespinosus*, 15. *Amphiascus congener*, 16. *Amphiascus minutus*, 23. *Bulbamphiascus minutus*, 25. *Brianola stebleri*, 31. *Cletodes longicaudatus*, 32. *Cletodes tenuipes*, 35. *Dactylopodella flava*, 37. *Danielssenia perezi*, 45. *Ectinosoma melaniceps*, 50. *Enhydrosoma longifurcatum*, 53. *Enhydrosoma tunisensis*, 56. *Eurycletodes (Oligocletodes) latus*, 59. *Halectinosoma angulifrons*, 60. *Harpacticus obscurus*, 61. *Harpacticus tenellus*, 67. *Haloschizopera bulbifera*, 68. *Haloschizopera junodi*, 73. *Heterolaophonte quinquispinosa*, 79. *Itunella muelleri*, 88. *Laophontopsis lamellifera*, 90. *Longipedia pontica*, 92. *Mesopsyllus atargatis*, 94. *Nitocra divaricata*, 98. *Paradanielssenia kunzi*, 100. *Paralaophonte brevirostris*, 111. *Robertgurneya rostrata*, 112. *Robertgurneya ecaudata*, 114. *Robertsonia propinqua*, 118. *Stenhelia (Delavalia) intermedia*, 119. *Stenhelia (Delavalia) reflexa*, 125. *Tisbe gracilis*, 126. *Tisbe clodiens*, 127. *Tisbe reluctans*, 130. *Zosime atlantica*

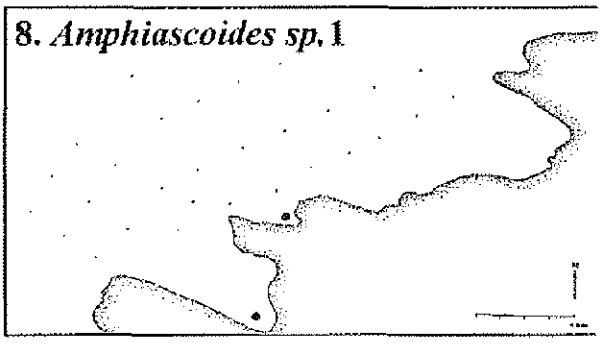

1. Acrenhydrosoma perplexum

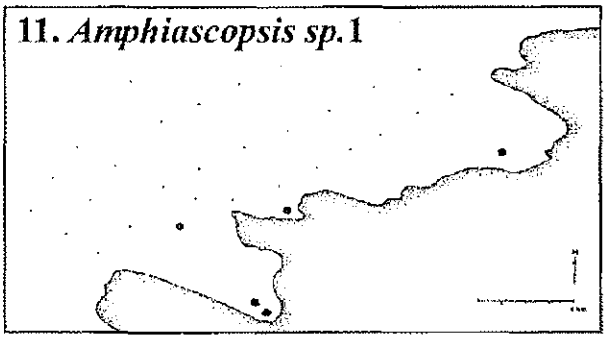

2. Ameira parvula


3. Ameira sp.1


4. Ameira sp.2


6. Amphiascoides debilis


8. Amphiascoides sp.1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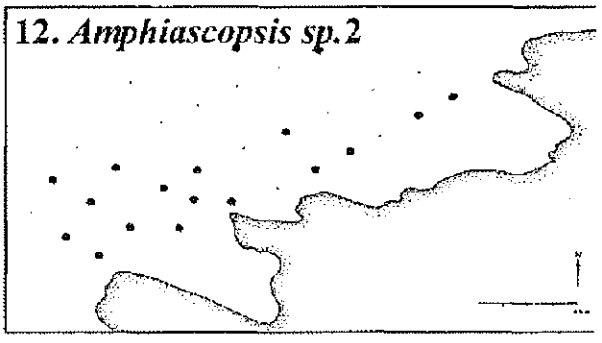
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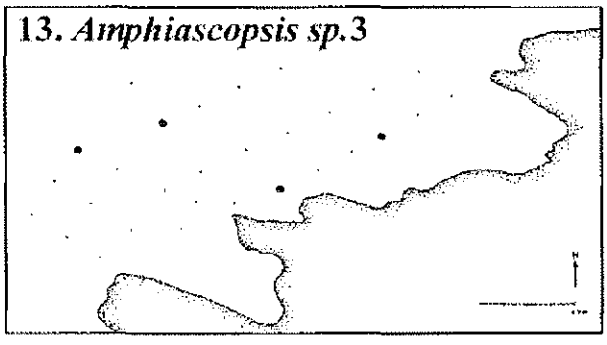
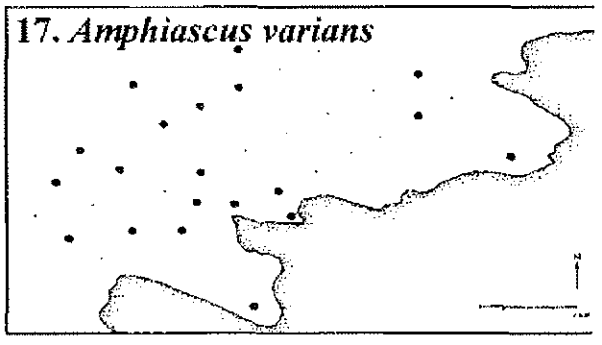
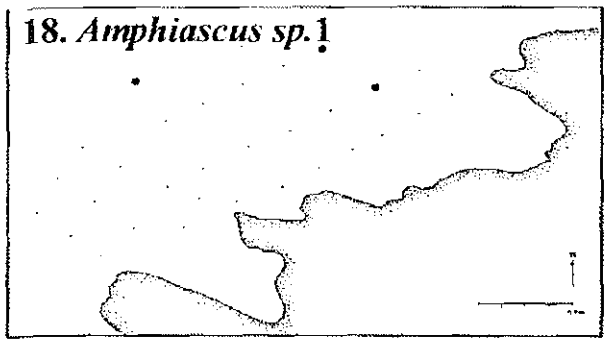
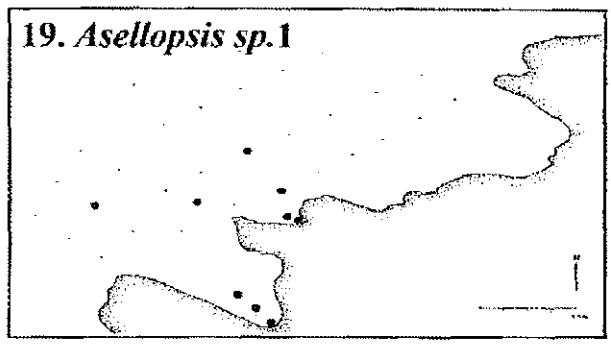
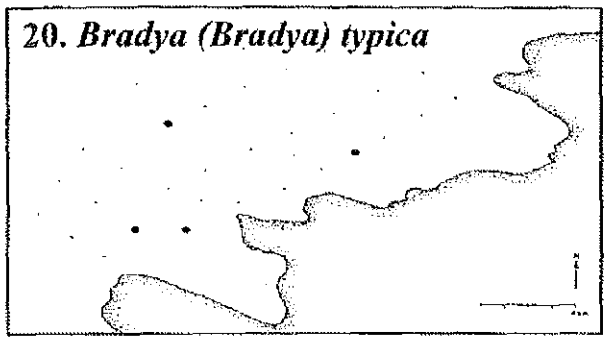
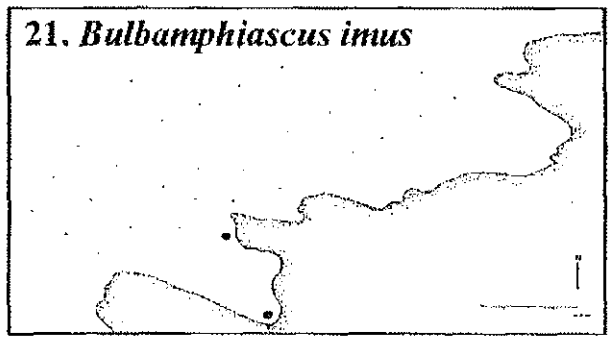

13. Amphiascopsis sp.3

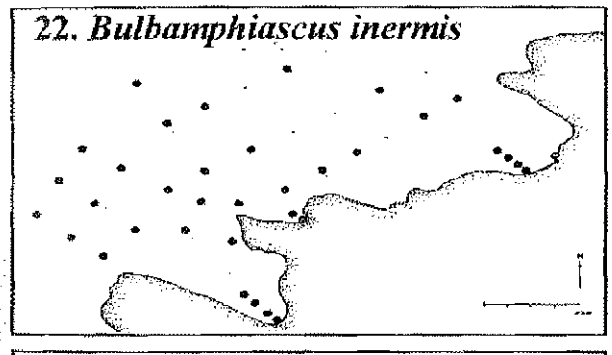

17. Amphiascus varians


18. Amphiascus sp.1


19. Asellopsis sp.1


20. Bradya (Bradya) typica


21. Bulbamphiascus imus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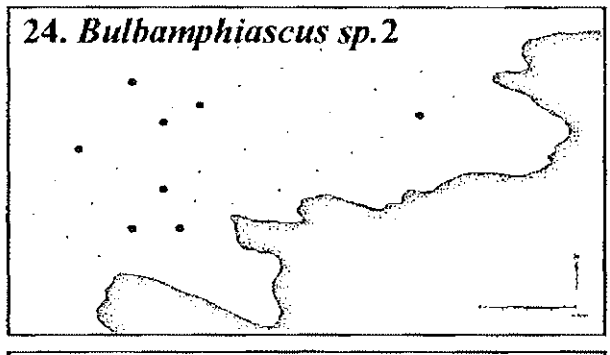
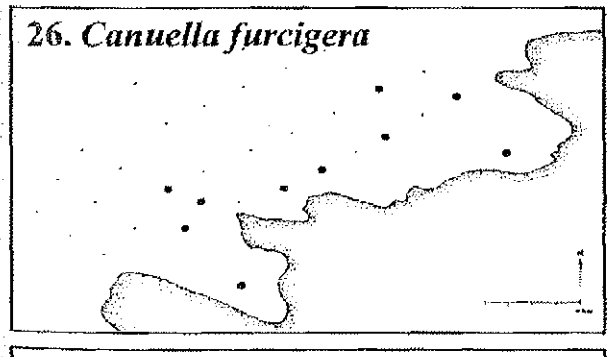
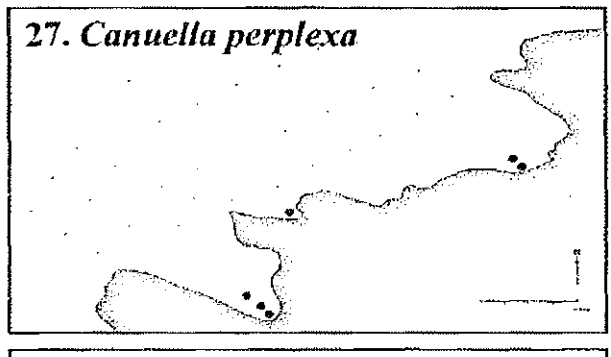
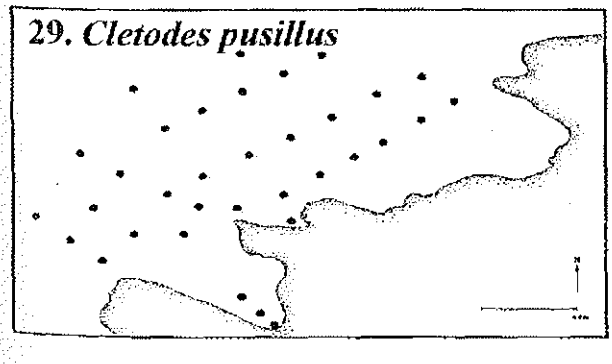
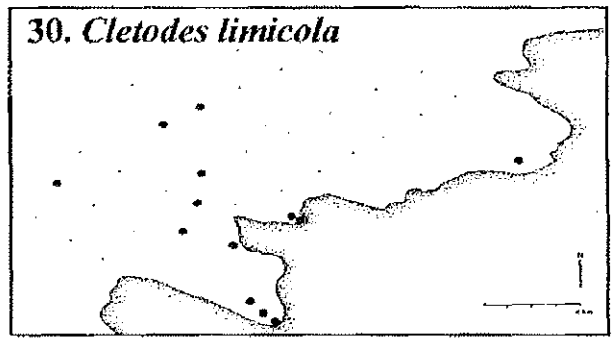
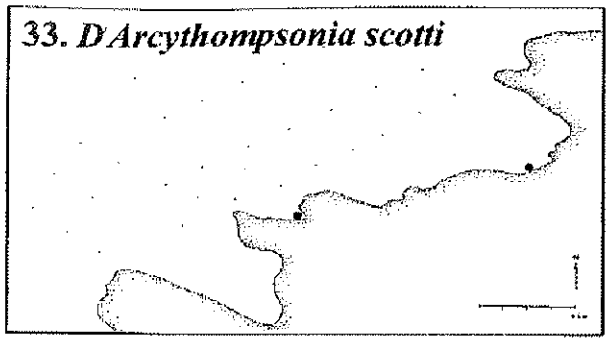

24. Bulbamphiascus sp.2

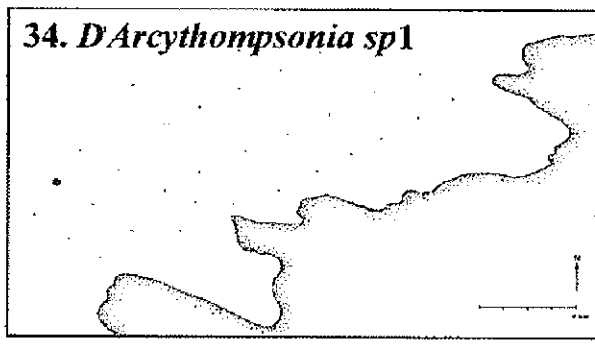

26. Canuella furcigera


27. Canuella perplexa


29. Cletodes pusillus


30. Cletodes limicola


33. D'Arcythompsonia scotti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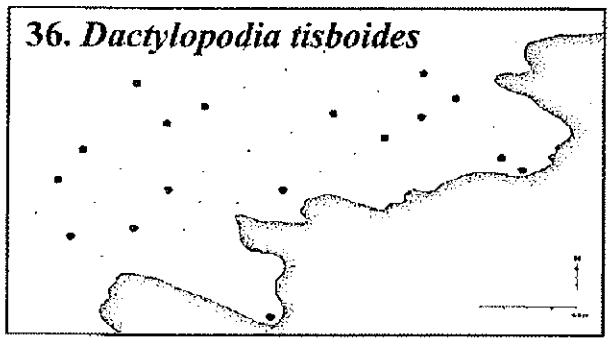
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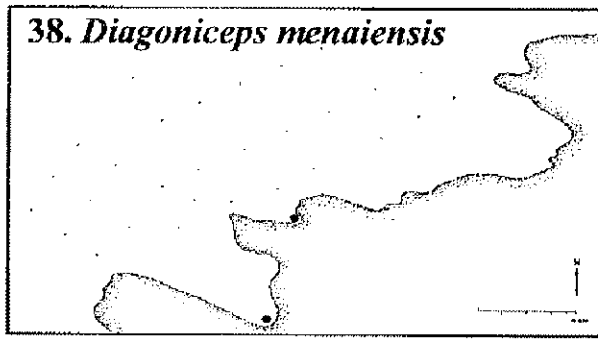
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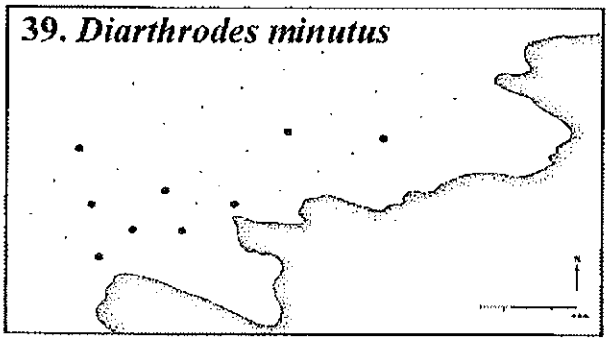
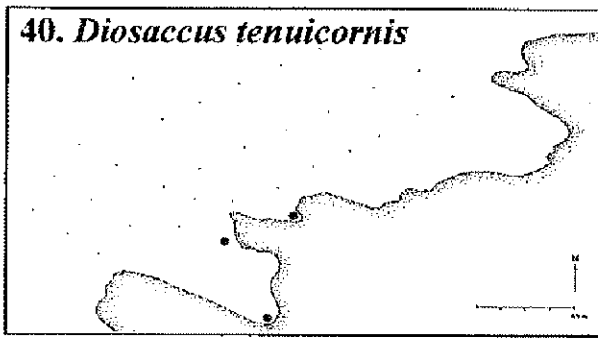
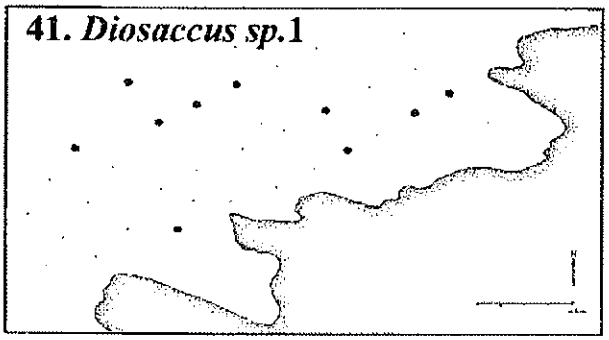
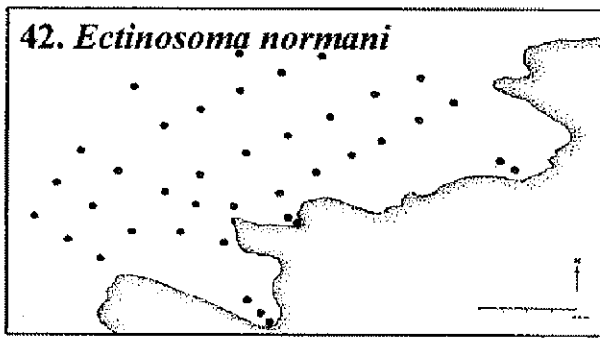
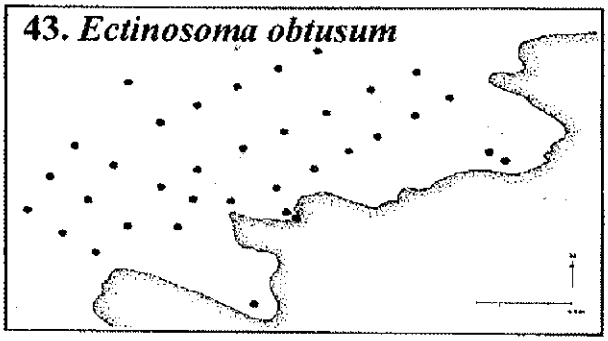
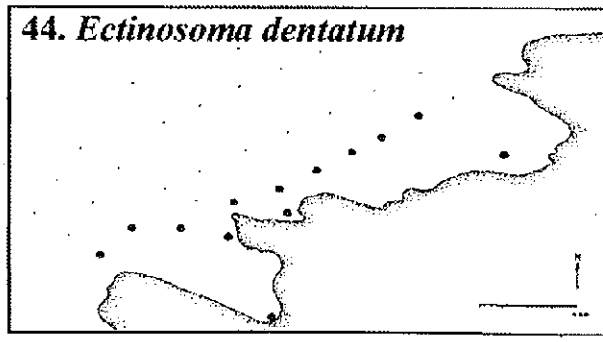

39. Diarthrodes minutus

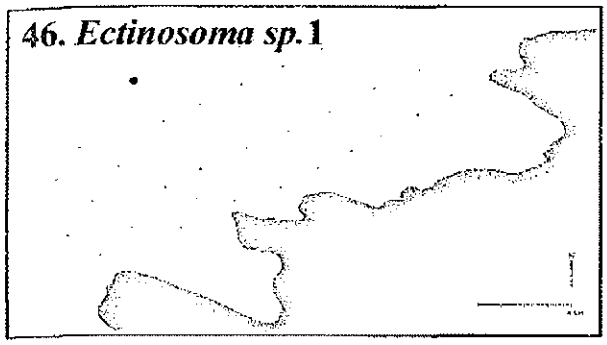

40. Diosaccus tenuicornis

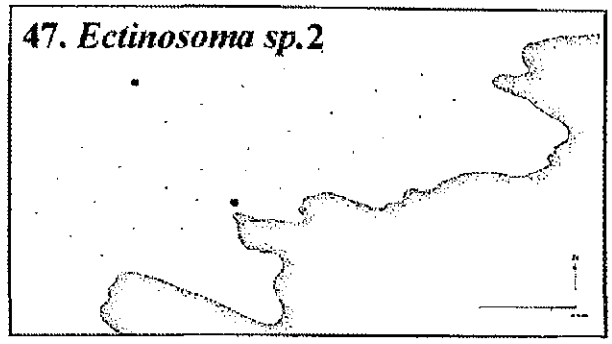

41. Diosaccus sp.1

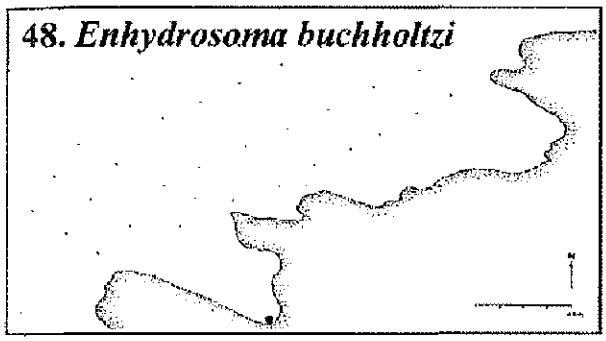

42. Ectinosoma normani

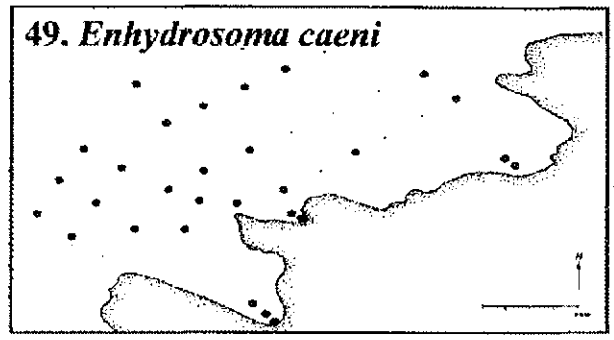

43. Ectinosoma obtusum

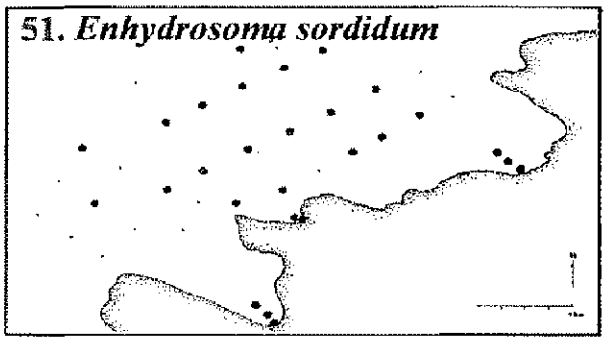

44. Ectinosoma dentatum

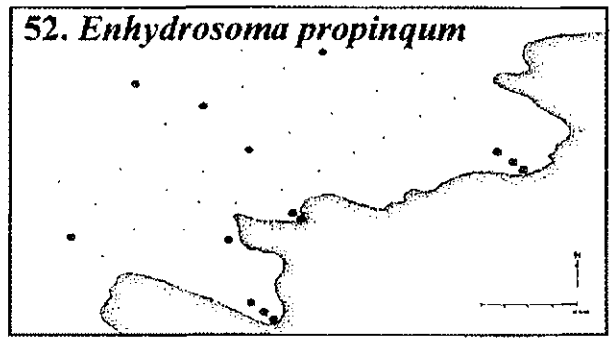

46. Ectinosoma sp.1

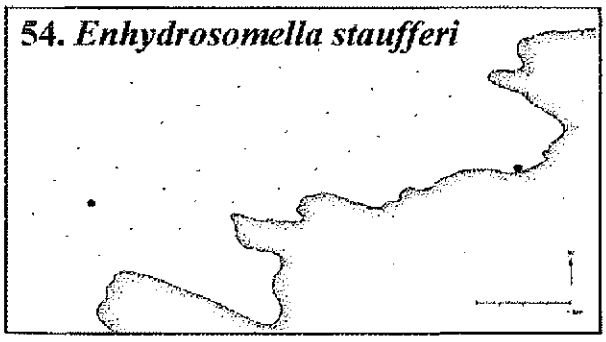

47. Ectinosoma sp.2

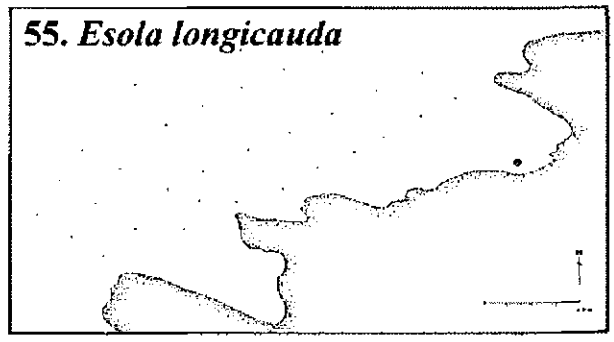

48. Enhydrosoma buchholtzi

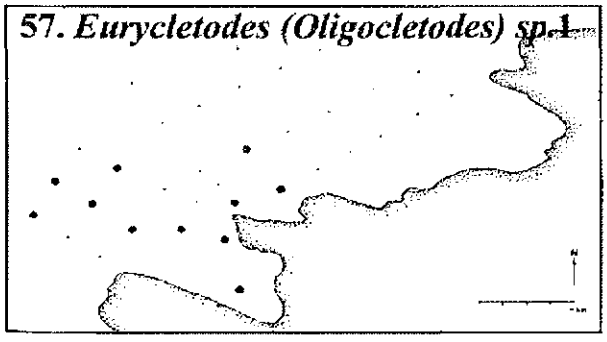

49. Enhydrosoma caeni

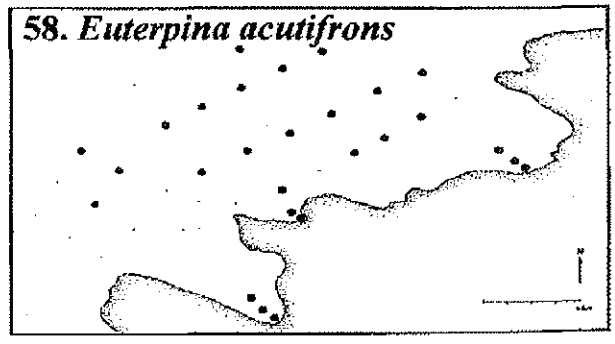

51. Enhydrosoma sordidum

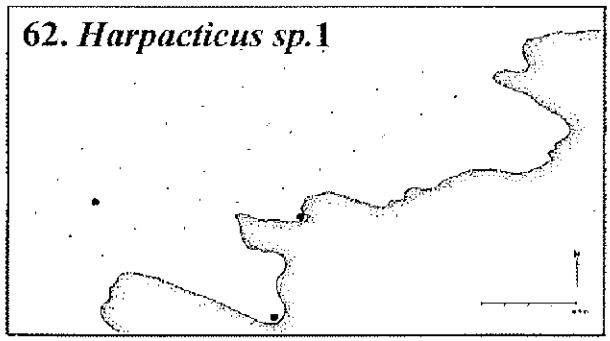

52. Enhydrosoma propinqum

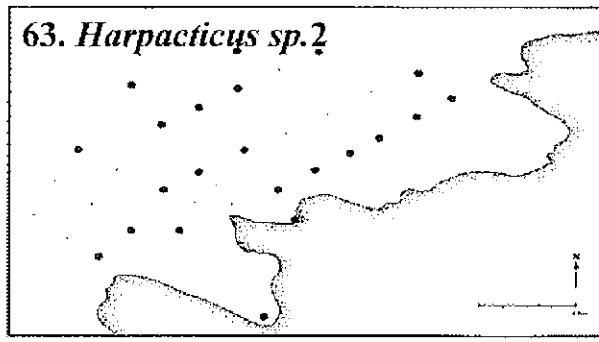

54. Enhydrosomella staufferi

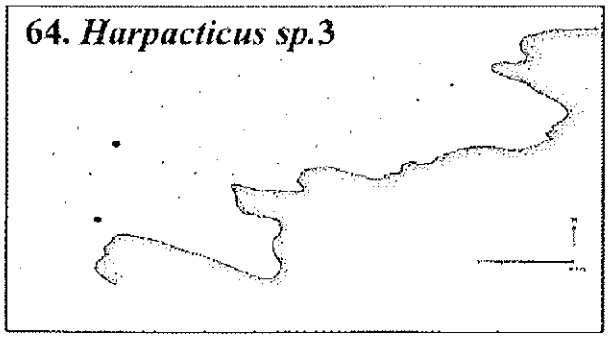

55. Esola longicauda

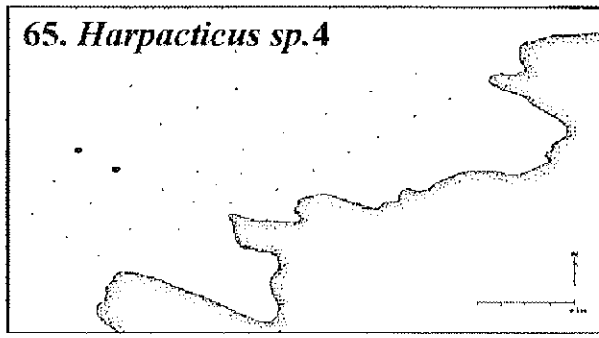

57. Eurycletodes (Oligocletodes) sp.1

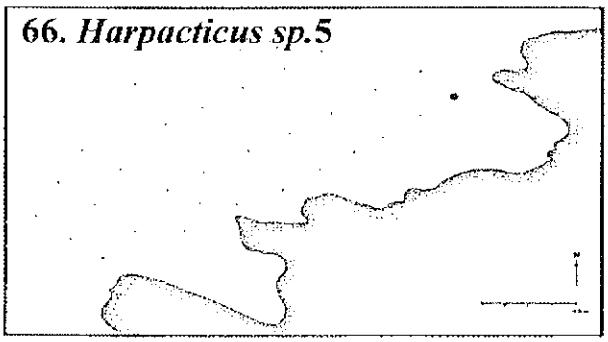

58. Euterpina acutifrons

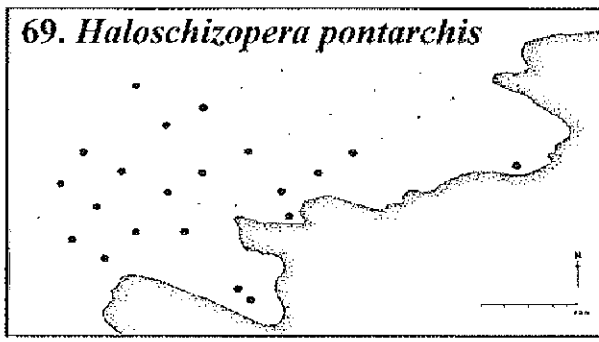

62. Harpacticus sp.1

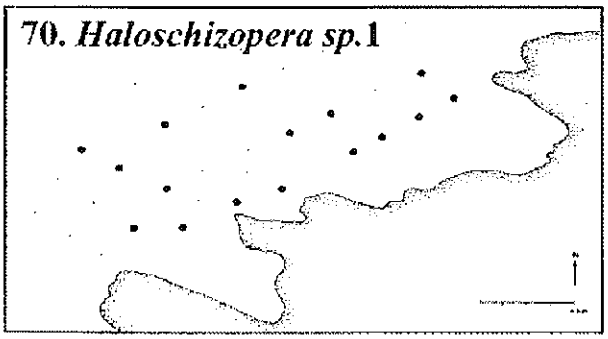

63. Harpacticus sp.2

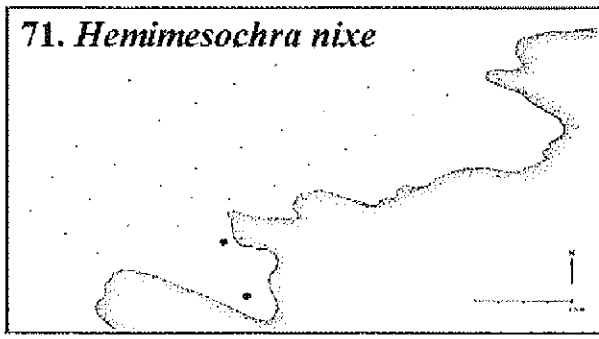

64. Harpacticus sp.3

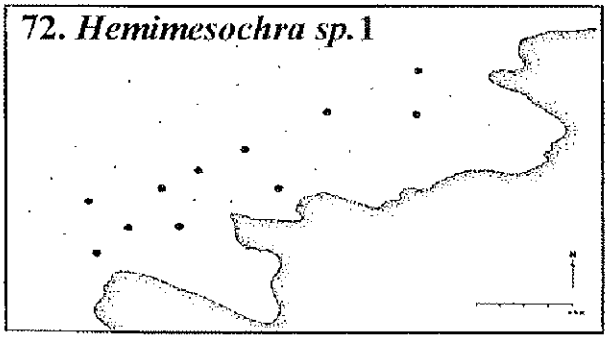

65. Harpacticus sp.4

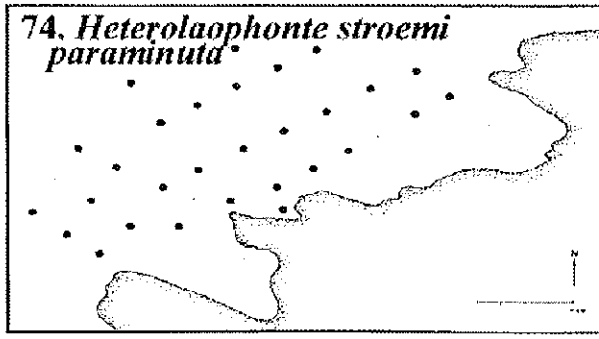

66. Harpacticus sp.5

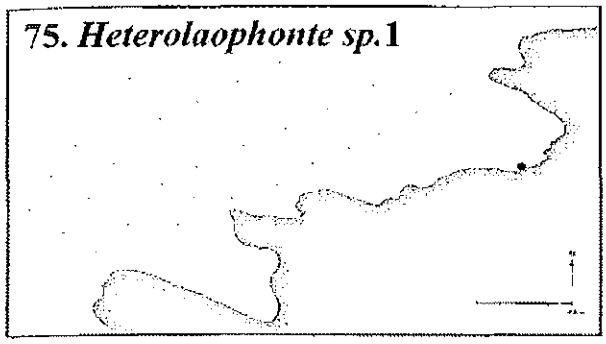

69. Haloschizopera pontarchis

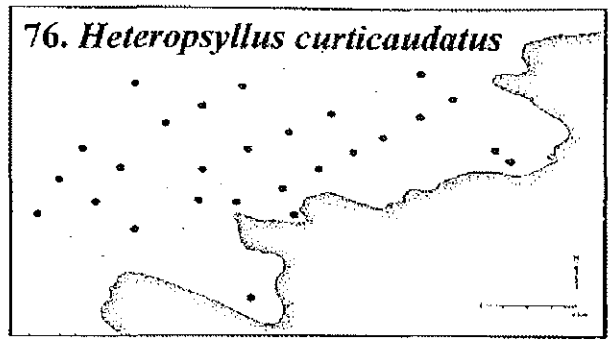

70. Haloschizopera sp.1

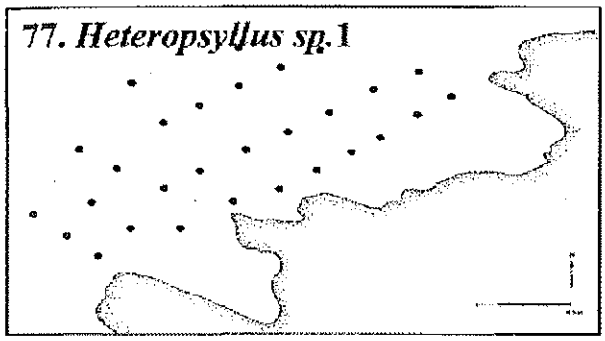

71. Hemimesochra nixe

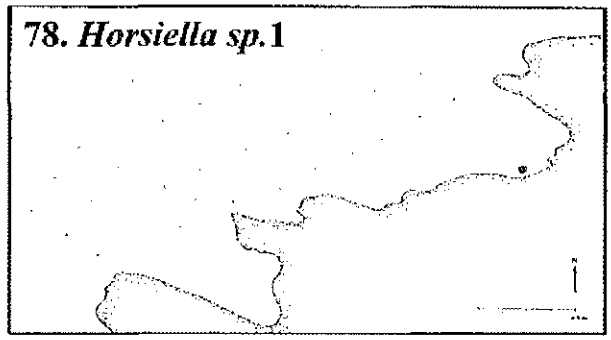

72. Hemimesochra sp.1

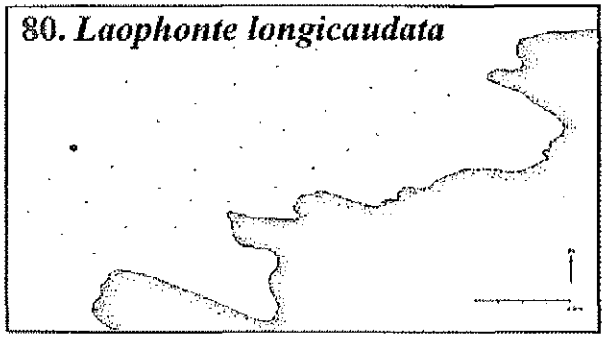

74. Heterolaophonte stroemi paraminuta

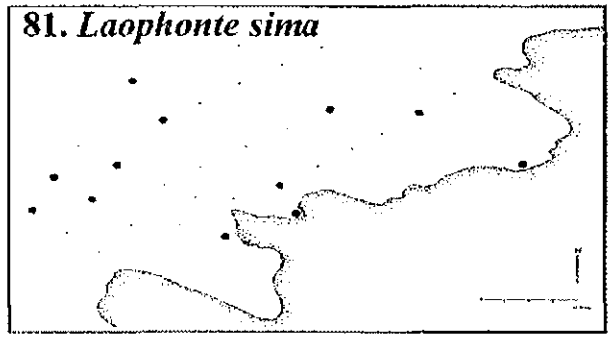

75. Heterolaophonte sp.1

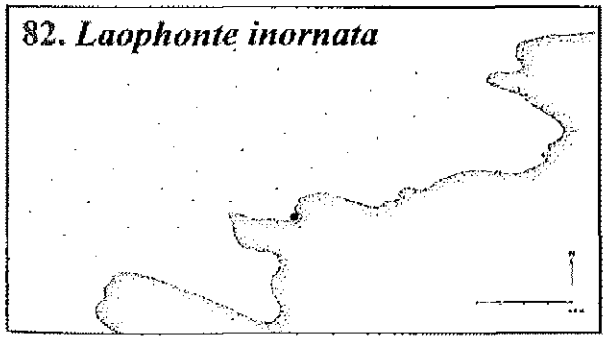

76. Heteropsyllus curticaudatus

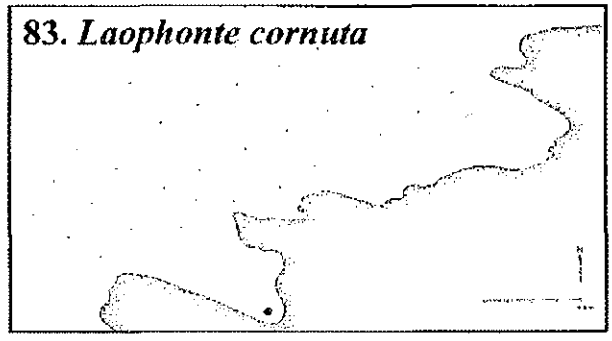

77. Heteropsyllus sp.1

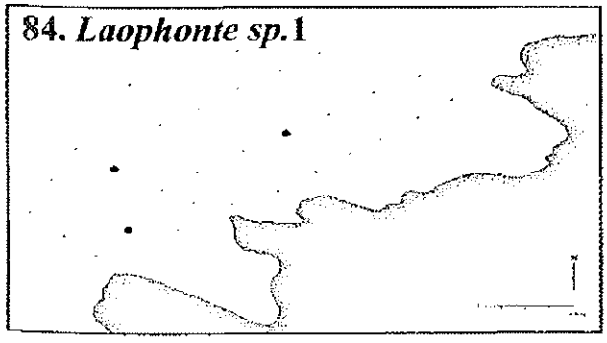

78. Horsiella sp.1

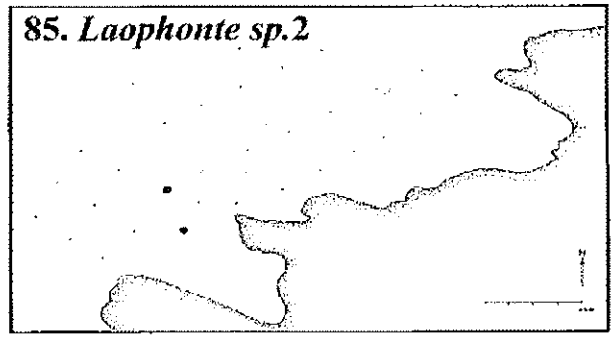

80. Laophonte longicaudata

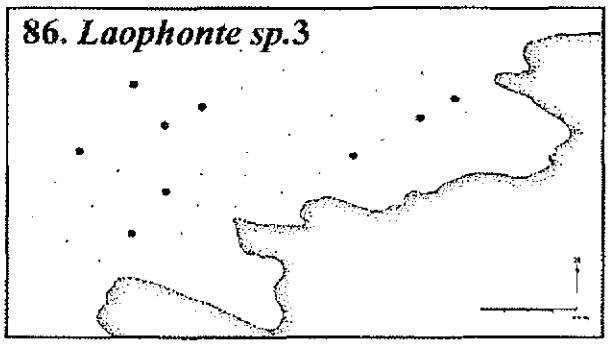

81. Laophonte sima

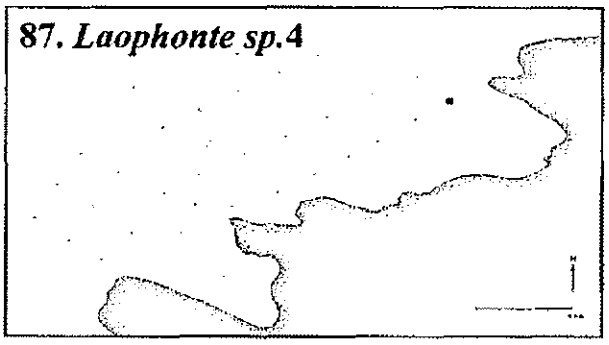

82. Laophonte inornata

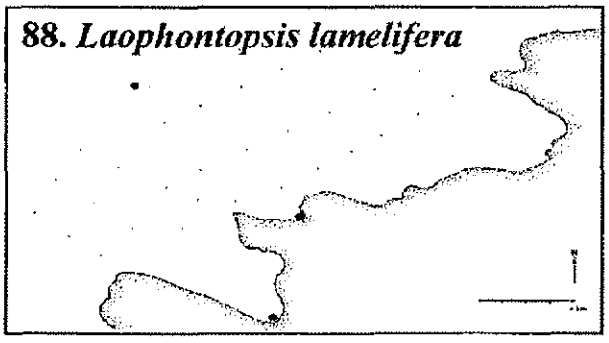

83. Laophonte cornuta

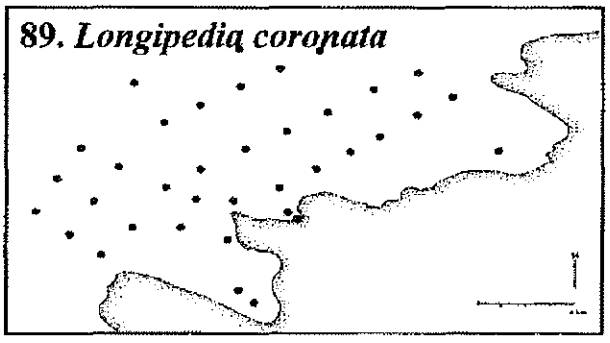

84. Laophonte sp.1

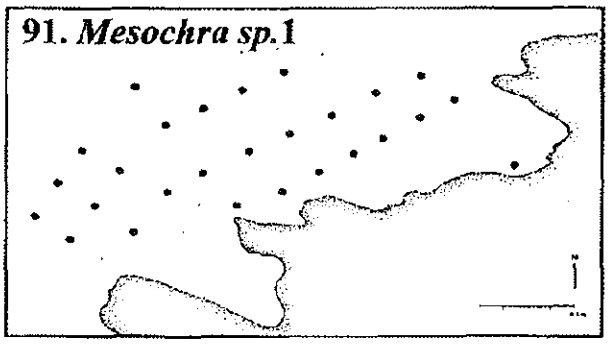

85. Laophonte sp.2

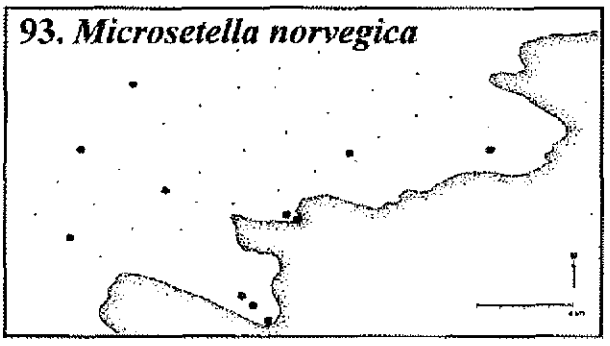

86. Laophonte sp.3

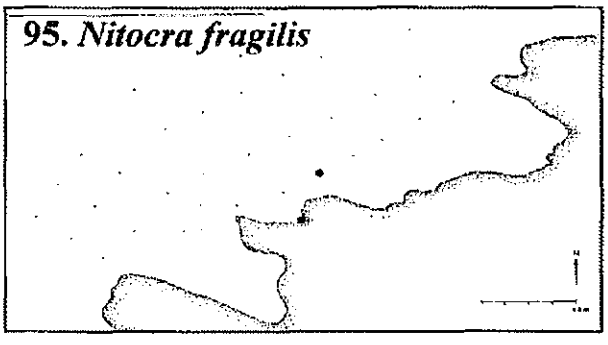

87. Laophonte sp.4

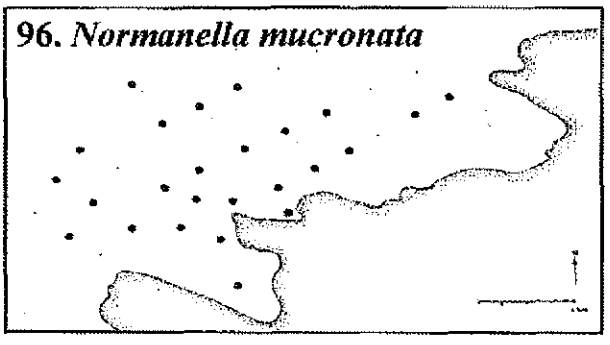

88. Laophontopsis lamelifera

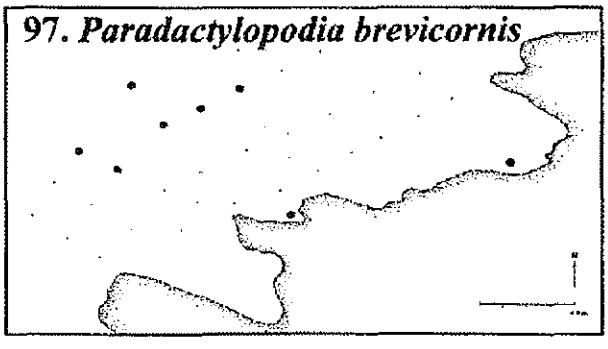

89. Longipedia coronata

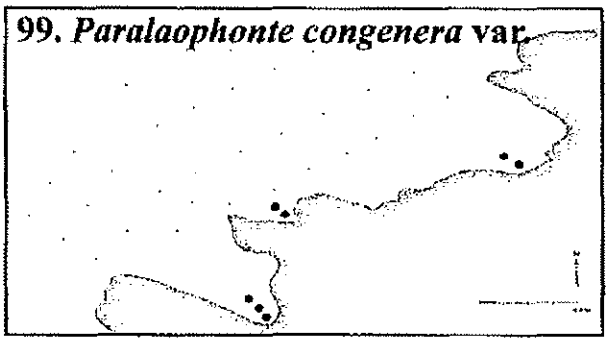

91. Mesochra sp.1

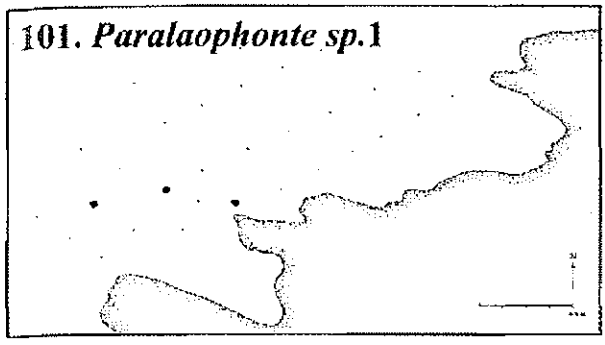

93. Microsetella norvegica

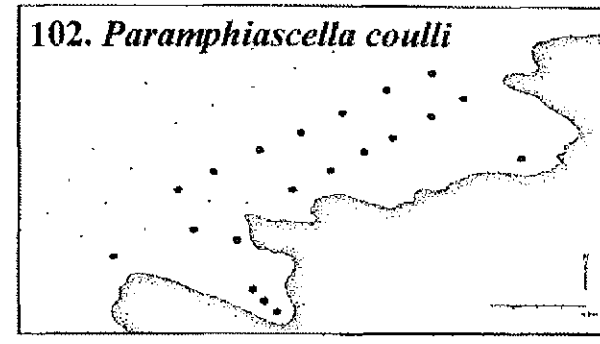

95. Nitocra fragilis

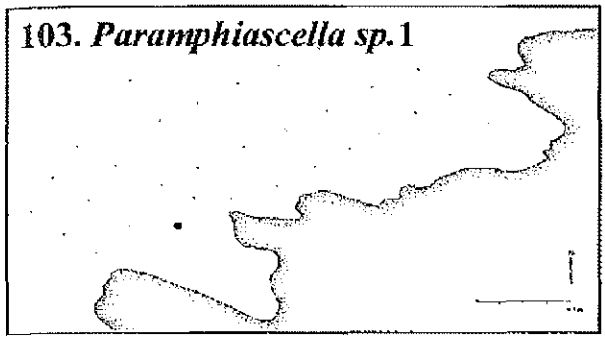

96. Normanella mucronata

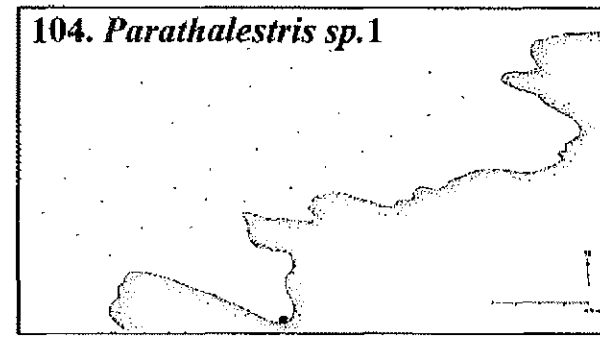

97. Paradactylopodia brevicornis

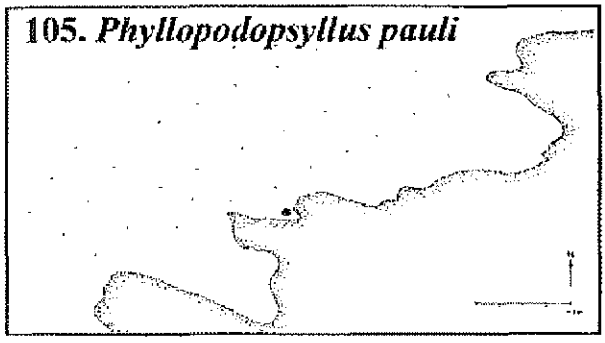

99. Paralaophonte congenera var.

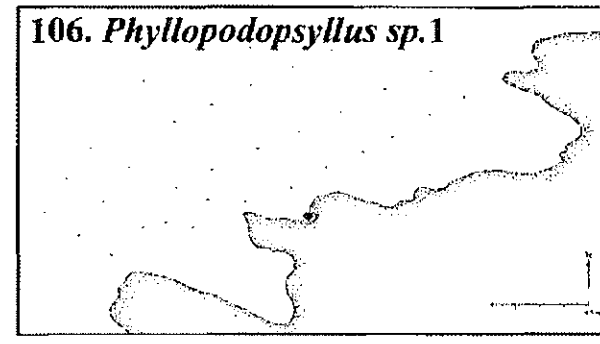

101. Paralaophonte sp.1

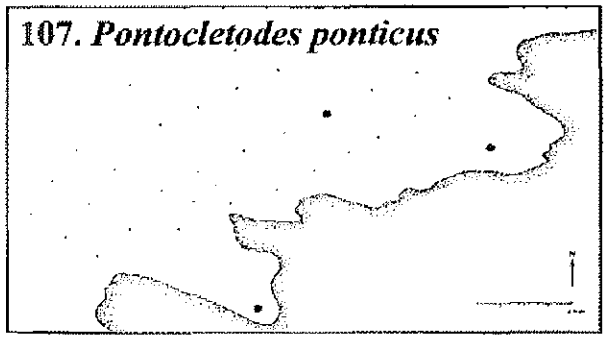

102. Paramphiascella coulli

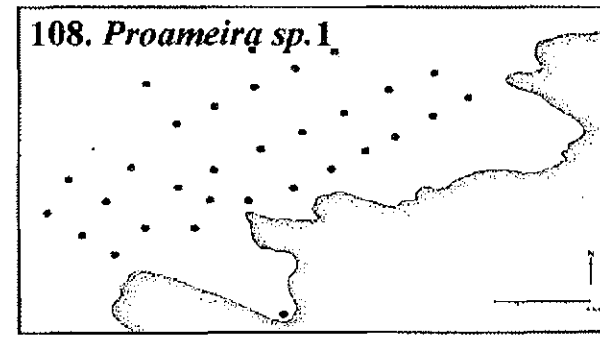

103. Paramphiascella sp.1

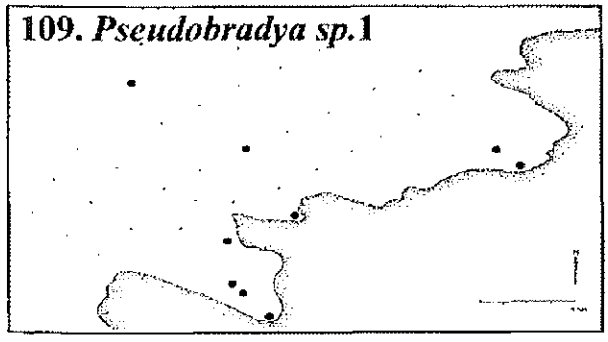

104. Parathalestris sp.1

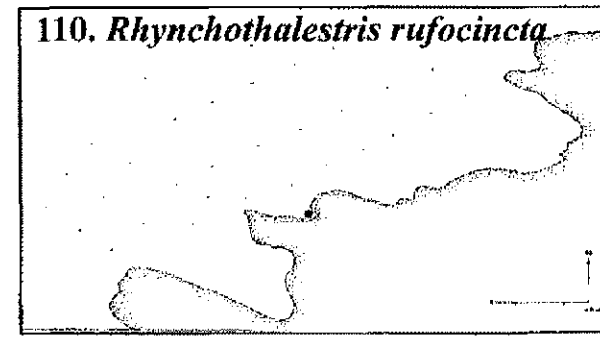

105. Phyllopodopsyllus pauli

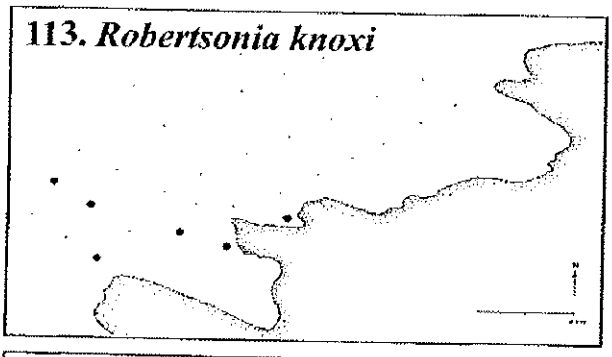

106. Phyllopodopsyllus sp.1

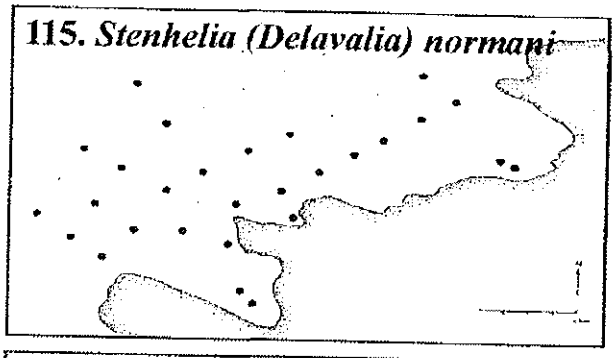

107. Pontocletodes ponticus

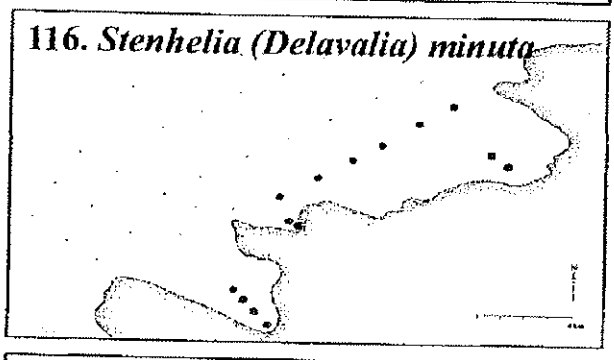

108. Proameira sp.1

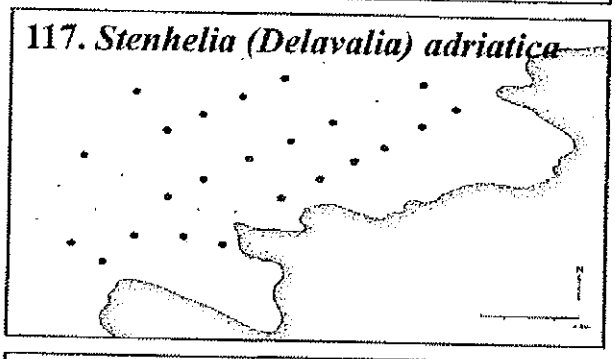

109. Pseudobradya sp.1

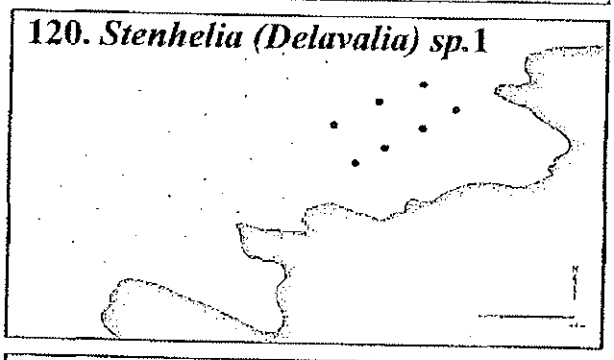

110. Rhynchothalestris rufocincta

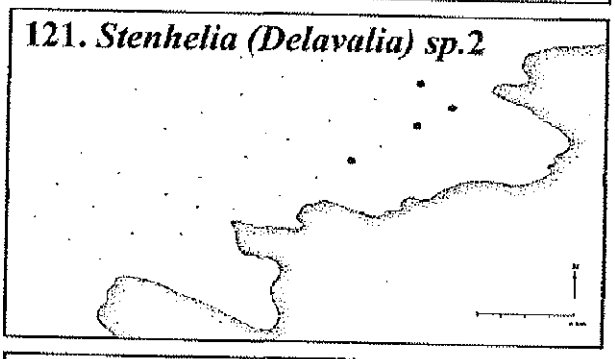

113. Robertsonia knoxi

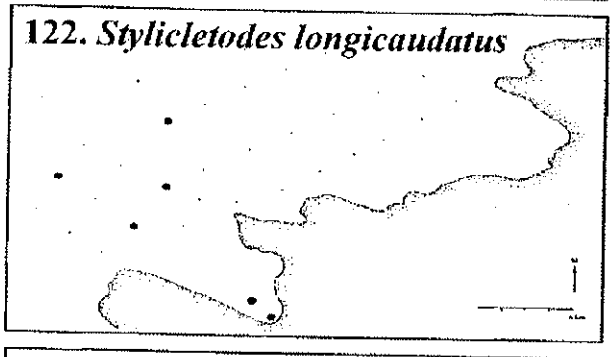

115. Stenhelia (Delavalia) normani

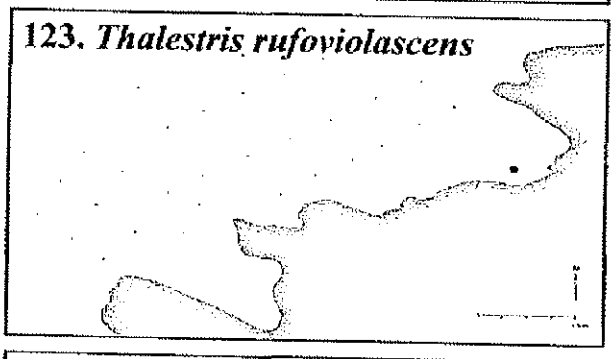

116. Stenhelia (Delavalia) minuta

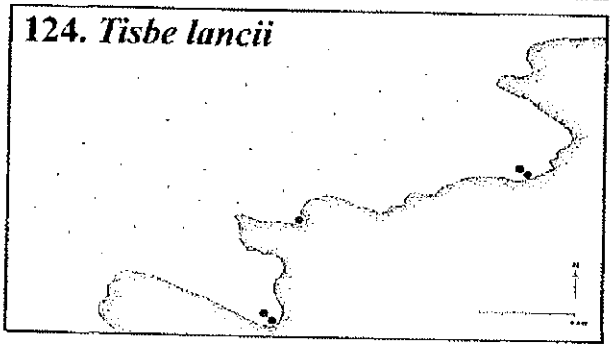

117. Stenhelia (Delavalia) adriatica

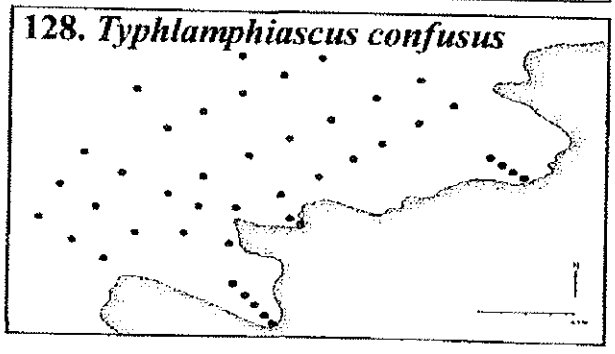

120. Stenhelia (Delavalia) sp.1

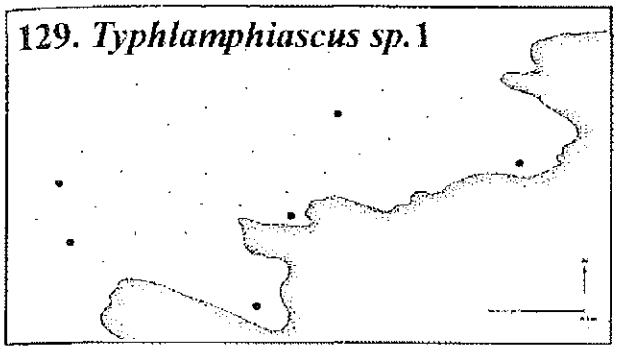

121. Stenhelia (Delavalia) sp.2

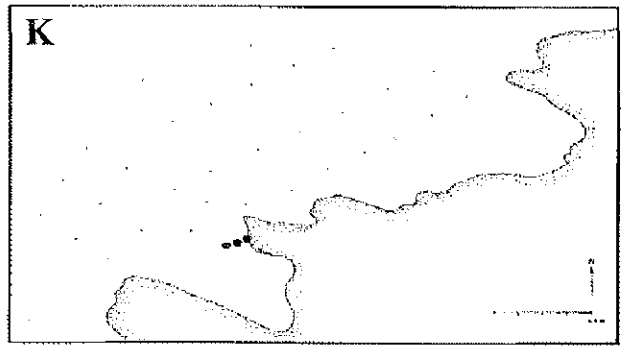

122. Stylicletodes longicaudatus


123. Thalestris rufoviolascens


124. Tisbe lancii


128. Typhlamphiascus confusus





MEIOBENTOŠKI HARPAKTIKOIDI (COPEPODA: HARPACTICOIDA) JUŽNEGA DELA TRŽAŠKEGA ZALIVA. II. EKOLOGIJA IN RAZŠIRJENOST VRST

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POVZETEK

Prispevek podaja pregled dosedanjih raziskav ekoloških značilnosti harpaktikoidov južnega dela Tržaškega zaliva s posebnim poudarkom na prostorski razširjenosti posameznih vrst, ki jih ponazarja 90 kart. Diverziteta harpaktikoidov pretežnega dela raziskovanega področja je dokaj enotna, zato lahko govorimo o eni, skupni obalni združbi harpaktikoidov mehkega dna. To združbo sestavljajo tri izrazitejše ekološke province, ki odsevajo prehod morskega dna od glinastih meljev obalnega pasu do finih peskov odprtega dela zaliva. Dve drugi opaženi združbi harpaktikoidov sta obrobnega pomena. Prva je prostorsko omejena na neposredno okolico dveh kanalizacijskih izlivov, druga, ki leži v centru Tržaškega zaliva, pa je verjetno posledica pogostih lokalnih hipoksij.

Ključne besede: Harpacticoida, Copepoda, Tržaški zaliv, razširjenost vrst

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