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The Introduction of Polychaetes *Hydroides elegans* (Haswell), *Polydora limicola* Annenkova, and *Pseudopotamilla occelata* Moore to the Northwestern Part of the East Sea

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Abstract: The polychaeta fauna of the benthos and fouling of the northwestern part of the East Sea was studied during the period of 1971-1998. Three introduced species of polychaetes: *Hydroides elegans* (Haswell), *Polydora limicola Annenkova*, and *Pseudopotamilla occelata* Moore were found. *H. elegans* was discovered only on the artificial surfaces in Golden Horn Inlet (port Vladivostok), where this species may occur because of hermal pollution due to the discharge of warm waters of the water cooling system of Thermal-Electric Power Station-2 (TEPS-2) in Vladivostok which has been in function since 1971. The abundant population of *H. elegans* exists in the bay throughout the year and is capable of reproduction. The biomass of *H. elegans* may reach several kg/m^2 in August-September. *P. limicola* was found at the same time in the fouling of hydrotechnical structures of Vladivostok, Nakhodka, Holmsk and Uglegorsk ports with a biomass of 1-3 kg/m^2. Slow introduction of *P. limicola* occurs by coastal sail ships at present. The invasion of *P. occelata* into Peter the Great Bay may be an example of introduction and subsequent naturalization, which produced considerable changes in the structure of benthic communities. The three species of polychaetous sessile organisms and their invasion occurred by ocean and coasters sea-going ships (unintentional transport vectors). *H. elegans* and *P. occelata* were most probably transported to the northwestern part of the East Sea from Japan, and *P.*

1. Introduction

The problem of species immigration is one of the most acute ecological problems of the end of the 20th century (Carlton and Geller 1993). For the last 5-6 decades, because of a rapid development of navigation, the cases of species spread to different parts of the World Ocean by means of ships became more frequent. Not only immigration of individual animals but also global changes at the level of whole faunas occur. Most often the ships spread the sedentary forms - the representatives of the sub-order *Balanomorpha*. The number of their species that have been found on the ships comprises 9% of their total number (Zevina 1982). The process of species immigration has reached its greatest scale in the recent years. In 1990s a Japanese algae *Undaria pinnatifida* immigrated to the waters of Australia (Hay 1990), a European bryozoan *Membranipora membranacea* and nudibranchiate mollusc *Tritonia plebeia* immigrated to the northwestern Atlantica (Lambert

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et al. 1992), and Venezuelan mussel *Perna perna* settled in Texas (Hicks and Tunnel 1993), a Japanese crab *Hemigrapsus sanguineus* penetrated into the coastal waters of the state of New Jersey, a spionid polychaetes *Marenzelleria viridis* from America moved to live in Germany (Essink and Kleff, 1993). The process of introduction and naturalization of these polychaetes in the European seas was discussed in a special issue of the international journal quatic Ecology (1997), dedicated to the spionid polychaetes *Marenzelleria* spp. (Bastrop *et al* 1997). A North-Atlantic green crab made transoceanic migrations with a following penetration into the local fauna and has become common at the coast of San Francisco (Cohen *et al.* 1995). A gastropod mollusc *Philine auriformis* from New Zealand also immigrated there (Gosliner 1995). A common for the Black Sea hydromedusa *Maeotias inexpectata* also penetrated into San-Francisco Bay and is a part of the local fauna now (Mills and Sommer 1995). The authors suggested that *Marenzelleria* spp. were carried with the ballast waters of the ships to the North Sea and the Baltic Sea from the North America.

A fact of a recent transcontinental introduction of the far-eastern starfish *Asterias amurensis* to Australia is known (Ward and Andrew 1995). The authors showed allozymic changeability between the Japanese, Russian and immigrant Tasmanian populations of this species. At present, this predator species is a real threat to the Australian benthic and cultivated bivalves. An immigration of the European bivalve mollusc *Dreissena* to the North America was reported (Effler *et al* 1996). These species are dominant in the fouling communities in the inland European seas. An Asian estuary mollusc *Corbicula fluminea* also immigrated to the North America (Phelps 1994).

The process of introduction of the fouling organisms to Tokyo Bay (Honshu Island) was first described in the early 20th century and it continues even now. The immigrant species include the mussel *Mytilus galloprovincialis* that was introduced in 1929 and was first described by Miyazaki (Miyzaki 1938). In 1950, *Balanus improvisus* immigrated to Tokyo Bay (Henry and McLauphlin 1975), *B. improvisus* in the second half of the 1960s, *Molgula manhattensis* - in 1975 (Kajichara 1996). Since the latter half of 1970s, this author has described the immigration to Tokyo Bay of three more bivalve species that were found in the fouling: *Limnoperna fortunei*, *Chloromytilus viridis*, and *Mytilopsis sallei*.

In 1971-1998, during the study of the polychaetes in the fouling and benthos of the northwestern part of the East Sea three immigrant species were found: *Hydroides elegans* (Haswell), *Polydora limicola* Annenkova, and *Pseudopotamilla occelata* Moore.

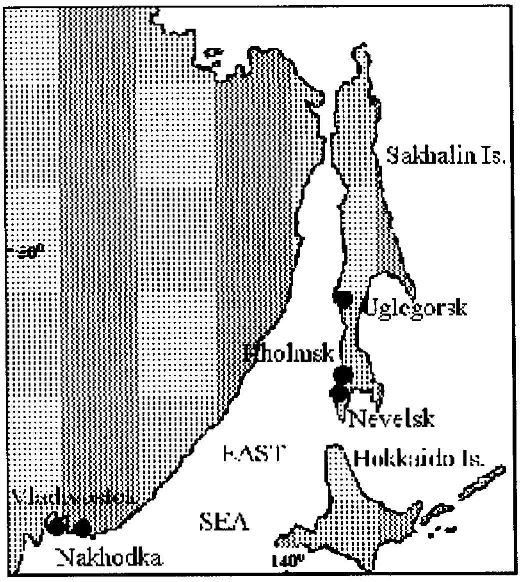

Fig. 1. Map showing the study sites of the fouling of wharf constructions in the northwestern part of the

2. Materials and Method

In 1971, the fouling samples from wharf constructions were collected in the ports of Vladivostok, Nakhodka, Nevelsk, Kholmsk and Uglegorsk (Fig. 1) and in 1981 in the port of Vladivostok and a number of smaller ports of Peter the Great Bay by using SCUBA (Kashin 1982). The fouling of the ships of different exploitation regimes was studied afloat from 1974 to 1980 (Zvyagintsev and Mikhailov 1980). About 100 coasters and port ships as well as laid up ships and ships during long-time mooring between voyages were examined.

For the study of the benthic polychaetes (Fig. 2), the samples of Far-eastern Hydrometeorological Institute and Institute of Marine Biology of FEB RAS collected in 1979-1995 in Peter the Great Bay (Nakhodka, Amursky, Ussuriysky Bays, and Golden Horn Inlet) were used. About 300 samples of the benthos of the upper sublittoral to the depth of 30 m have been examined. For the sample collection, Van-Veen and Petersen bottom grabs with sampling area of 1/10 and 1/40 m^2 were used. As a rule, 2 bottom grabs were used for each station.

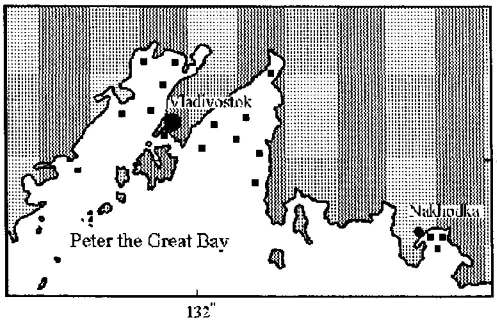

Fig. 2. Map showing the sites of benthic sampling in Peter the Great Bay.

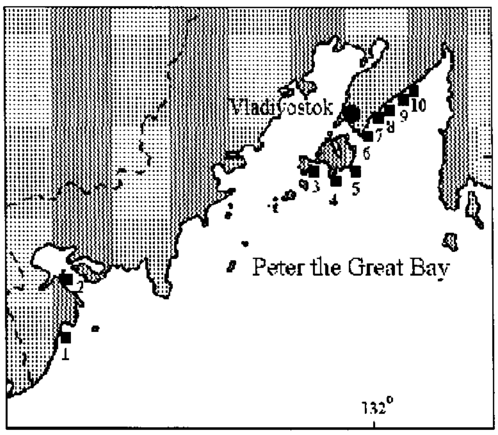

Fig. 3. Map showing the location of *Pseudopotamilla occelata* assemblages in Peter the Great Bay: 1. Ostrovok Falshivy Cape; 2. Nazimova Spit; 3. Popova Island, Prohodnoy Cape; 4. Russky Island, Shkota Cape; 5. Russky Island, south-east coast; 6. Bassargina Peninsula; 7. Tikhaya Inlet; 8. Gornostai Inlet; 9. Lazurnaya Inlet; 10. Emar Inlet, Engelma

The observations of the changes in the state of the benthic settlements of *P. occelata* were made on Engelma Cape in Ussuriysky Bay (Fig. 3). The works were conducted by use of SCUBA. We fixed colonies of *P. occelata* and kept a visual record of the number of colonies per m^2, and outlined areas of settlement of this species, which were determined via aquaplane. In 1993, we made five hydrobiological transects and took 25 quantitative samples, each 100 cm^2 in area at 0.5 m increments. Quantitative parameters and vertical distribution to a depth of 2.5 m of *P. occelata* were determined. The qualitative composition of the community of *P. occelata* was determined and its quantitative parameters were established.

The material was processed under laboratory conditions by a method generally accepted for benthos (Zhadin). The polychaetes and their tubes were weighed. In the article their raw weight is given.

3. Results

Polydora limicola. This species was found on all types of anthropogenous substrates in different parts of the region studied (Fig. 1). However, in mass quantities it was observed in the fouling of the piers and wharves of Vladivostok, Nevelsk, Kholmsk and Uglegorsk as well as on the ships that spent long time docking in these ports. The maximal biomass (3,070 g/m^2) was observed on a fishing seiner, laid up in Golden Horn Inlet. The significant quantities of this species were also found on one of the ships that spent about 8 months in Kholmsk on the territory of a ship repair plant. The whole underwater part of the ship hull was covered by a layer of *P. limicola* tubes. In the bow part of the bottom of the ship in a thick layer of fuel oil, where no more animal or plant species were found, the biomass of *Polydora* reached up to 265 g/m^2. The maximal biomass, that was equal to 2,720 g/m^2, was observed on the propeller blade. In the same port on a concrete breakwater the biomass of *P. limicola* sometimes comprised about 50% of the total biomass of the fouling and reached up to 1,150 g/m^2.

Hydroides elegans. This species was found in the fouling of the laid up ships and operating port ships in Golden Horn Inlet as well as the ships that come to the bay in hydrological summer. On the operating ships the length of the tubes did not exceed 20-30 mm, the tubes stretched along the substrate. On the laid up ships the tubes were situated perpendicularly to the surface of the hull, forming a 100% covering, their length reached up to 60-70 mm. The maximal quantitative parameters were registered for the ships that did not leave the bay. Thus, on the tanker olgograd that spent 4 months laid up, the biomass of this species reached up to 21 kg/m^2. The quantitative parameters of *H. elegans* were directly dependent on the time that the ships spend in Golden Horn Inlet.

On the ships that often come to this bay or work only there, a community of tubular polychaete *H. elegans* has been registered. These ships can be divided into three groups in accordance with the regime of exploitation: 1 - laid up ships; 2 - ships that spend 70% time in Golden Horn Inlet; 3 - ships that spend 20% time in this bay. For group 1 the total biomass of the fouling has been 5,468 g/m^2 with a maximal value of 27,326 g/m^2. Four algae species have been registered, their sum biomass accounts 4.6% of the total biomass, and 34 animal species. *H. elegans*, that has been recorded in 88% samples, accounts for 53% of the total biomass (the highest value is 21,000 g/m^2) (Fig. 4). A typical species of one group is *M. trossulus* (30% of total biomass, to 24,000 g/m^2). Besides *H. elegans*, 7 polychaete species have been observed in the community, of which the most common is *N. pelagica* - to 200g/m^2. Of four barnacle species, *B. improvisus* and *B. amphitrite*, that have been registered in almost all samples, have the highest quantitative values. The role of other groups represented by a number of amphipods, isopods, bryozoans and hydroids is insignificant. The remaining groups are represented by individual specimens.

For group 2 of the ships the fouling biomass was twice as small (2,496 g/m^2 with the highest value 7,100 g/m^2). Only two species of green algae have been registered, which together account for 2.4% of the total biomass. Thirty animal species has been registered, out of which the biomass of *H. elegans* makes up about one half of the total biomass with a frequency of occurrence of 95%. The structure of this variant of community does not differ significantly from the previous one. However, the typical species there include *B. crenatus* (to 7,700 g/m^2, 30,500

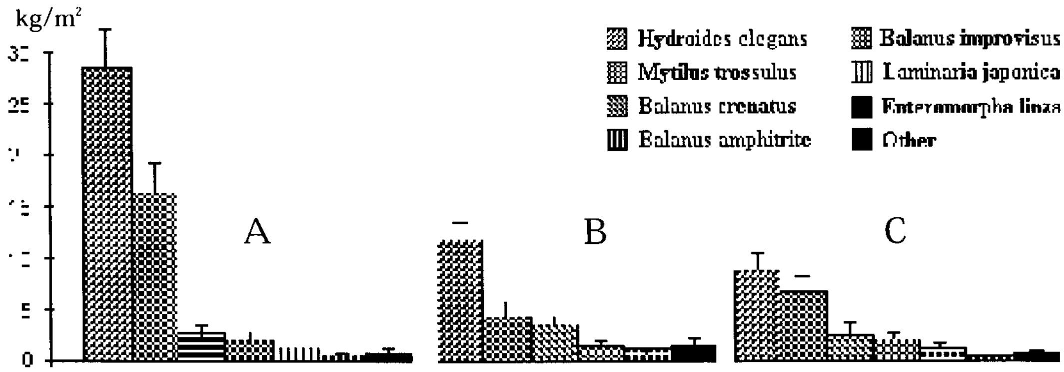

Fig. 4. Structure of the community of *Hydroides elegans* on the coasters from Golden Horn Inlet: A: group 1, B: group 2, C: group 3 of the ships (see commentary in the text). Along the abscissa: background species of the community; along the ordinate: biomass, kg/m^2. Vertical lines are mean errors.

Table 1. Taxonomic composition and distribution over the depth of benthic community *Pseudopotamilla occelata* on Engelma Cape in Ussuryisky Bay(Sea of Japan / East Sea).

Taxon	Depth, m				
	0.5	1.0	1.5	2.0	2.5
1	2	3	4	5	6
ALGAE					
RHODOPHYTA					
1. *Antithamnion sparsum*	-	-	-	-	+
2. *Bossiella cretacea*	+	-	-	+	+
3. *Ceramium kondoi*	-	-	-	+	+
4. *Champia parvula*	-	-	-	-	+
5. [illegible]	-	-	-	-	-
6. *Gymnogongrus flabelliformis*	-	-	-	-	-
7. *Laurencia nipponica*	-	+	-	-	-
8. *Odonthalia corymbifera*	-	-		-	+
PHAEOPHYTA					
9. *Fucus evanescens*	-	+	-	-	-
CHLOROPHYTA					
10. *Bryopsis plumosa*	-	+	-	-	+
11. *Ulva fenestrata*	-	+	-	-	-
ANGIOSPERMAE					
12. *Phyllospadix iwatensis*	-	-	-	-	-
ANIMALIA					
SPONGIA					
13. *Haliclona cinerea*		-	-	-	-
14. *H.* [illegible]		-	-		-
COELENTERATA					
15. *Cnidopus japonicus*	+		-	-	
16. [illegible]	-	-	-	-	-
17. *Sertularella* [illegible]	-	+	+	+	
POLYCHAETA					
18. *Arabella iricolor*	-	+	+	-	
19. *Capitella capitata*	-	+	-	-	-
20. Cirratulidae gen. sp.	-	+	-	-	-
21. *Cirriformia tentaculata*		-	-		-
22. *Eulalia viridis*	-	-	-	+	-
23. *Halosydna brevisetosa*		+	+	+	
24. *Lumbrineris inflata*	-	-	-	+	-
25. *L. longifolia*	-	-	+	-	-
26. *L. japonica*	-	-	-	-	-
27. *Lumbrineris* sp.	-	-	-	-	+
28. *Naineris laevigata*	-	+	-	-	+
29. *N. quadricuspida*	-	-	-	-	-
30. *Neodexiospira alveolata*	-	-	-	-	-
31. *Nereis pelagica*	-	-	-	-	-
32. *N. zonata*	-	+	-	-	+
33. *Nereis* sp.	-	-	-	-	-
34. *Mediomastus californiensis*		-	-	-	-
35. Phyllodocidae gen. sp.	-	+	-	-	-
36. *Pista elongata*	-	-	-	-	-
37. *Platynereis bicanaliculata*	-	-	-	-	-
38. *Pseudopotamilla occelata*		+	-	-	-
39. *Schistomeringos japonica*	-	-	-		-
40. Serpulidae gen. sp.	-	-	-	-	-
41. Spionidae gen. sp.	-	-	-	-	-
42. Spirorbidae gen. sp.	-	+	+	-	-
43. *Terebella ehrenbergi*	-	+	-	-	-
44. *Typosyllis orientalis*		+			-
45. *T.* [illegible]	-	-	-	-	-
PANTOPODA					
46. *Lecythorhynchus hilgendorfi*	-	+	+	-	+
BALANIDAE					
47. *Balanus crenatus*	-	-	+		-
48. *Semibalanus cariosus*	-	-	+	-	+
DECAPODA					
49. *Cancer amphioetus*	+	-	+	-	+
50. *Erimacrus isenbeckii*	-	-	-	-	+
51. *Pachycheles stevensii*	-	+	+		+
52. *Pagurus middendorffii*	+	+	-		
53. *Pugettia quadridens*	-	-	+	-	-
AMPHIPODA					
54. *Amphithoe japonica*	+	-	+	-	-
55. *Amphithoe* sp.	+	-	-	-	-
56. [illegible]	-	-	-	-	+
57. *Caprella* [illegible]	+	+	-	+	
58. *Corophium* [illegible]	+	+		-	-
59. *Jassa marmorata*	+	-	-	-	-
60. *Parallorchestes ochotensis*	-	-	-	-	-
ISOPODA					
61. *Holotelson tuberculatus*	-	-	-	-	+
62. *Paranthura japonica*		-	-	-	
GASTROPODA					
63. [illegible]	-	-	-	+	+
64. *Homalopoma sangarense*	-	-	-	+	-
65. *Mitrella burchardi*	-	-	-	+	-
66. *Nucella heyseana*	-	-	+	-	-
67. [illegible]	-		-	-	-
68. [illegible]	+	-	+	+	+
BIVALVIA					
69. [illegible]		-	-	+	-
70. *Chlamys farreri nipponensis*	-	-	+	+	+
71. *Crenomytilus grayanus*	-	-	-	+	+
72. [illegible]	-	-	-	+	+
73. *Hiatella arctica*	-	-	-	-	
74. *Modiolus kurilensis*	+		+	-	+
75. *Mytilus trossulus*	-		-	-	-
76. *Protothaca euglypta*	-	-	-	-	-
77. *Protothaca* sp.	-		+	-	-
78. *Septifer keenae*	+		+	-	+
BRYOZOA					
79. [illegible]	-	-	+	-	+
80. [illegible]	-	-	-	-	-
ECHINOIDEA					
81. *Strongylocentrotus intermedius*	-	-	-	+	-
ASTEROIDEA					
82. *Asterias amurensis*	-	-	+	-	+
83. *Patiria pectinifera*	-	-	+	-	-
OPHIUROIDEA					
84. [illegible]	-	-	-	+	+
ASCIDIAE					
85. [illegible]	-	-	-	-	+

ind./m²). Moreover, on the ships of this group oysters are often observed, which are lacking in the previous variant.

For the fouling communities of the ships of group 3, which rarely come to Golden Horn Inlet, a decrease in the biomass of *H. elegans* to 907 g/m² (39.5% of the total biomass) is typical. The structure community remains the same in this case.

Pseudopotamilla occelata. In the course of the hydrobiological operations made for some years off the Primorye coast and the South Kurils, we recorded for the first time settlements of this species on rocky surf-washed capes of the upper sublittoral at a depth of 0.5- 2.5 m. The individual colonies of *P. occelata* with a diameter of

15-20 cm were found in Khromova Bay (Shikotan Island), near the port of Preobrazheniye, on the western coast of Ussuriysky Bay in the Inlets of Emar, Lazurnaya, Gornostai and Tikhaya. This species was also found on the eastern coast of Popova and Russky Islands and in Possyet Bay, on Kosa Nazimova Spit and on Mramornyi Cape, on Ostrovok Falshivyi Cape (Fig. 3). No special studies of *P. occelata* community were conducted there.

The state of *P. occelata* settlements on Engelma Cape, Ussuriysky Bay has been observed for 20 years since 1975. For the first few years only single colonies of this species of 1-2 per m^2 were observed. In 1980, the size of the colonies reached 30-40 cm in diameter. By 1987, the substrate was 50-60% covered. By 1993, the colonies of polychaetes had formed continuous settlements covering tens of square meters with a maximum biomass of 100 kg/m^2. The community of *Crenomytilus grayanus* +*Balanus rostratus*, which had existed on this substrate earlier, was buried under the layer of polychaetes, accompanied by a mass decay of mussels and barnacles. The fresh epibiosis that had formed at most depth levels was a clear-cut monodominant community of *P. occelata*. As an example, we give a description of this community in the upper sublittoral off Engelma Cape in Ussuriysky Bay. In 1993, we made five hydrobiological transects and took 25 quantitative samples, each 100 m^2 in area, at 0.5 m increments.

A total of 85 hydrobiont species were recorded in the composition of *P. occelata* community, of which 12 were algae and 1 was a representative of angiosperm (Table 1). Most algae (8) belonged to the division Rhodophyta, followed by the representatives of the divisions Chlorophyta and Phaeophyta (two and one species, respectively). Of the animals, the largest number of species (28) were polychaete worms. The second significant group was bivalve molluscs (10 species), followed by heteropod crabs (7 species), gastropod molluscs (6 species) and decapod crabs (5 species). The species richness of the remaining groups was small.

The total biomass of the community at different depth ranges varied within 178-332 g/m^2. At most depths, it was a typical monodominant community, where *P. occelata* accounted for nearly 100% of the total biomass. The depth of 0.5 m was an exception. Here, nearly half of the biomass belonged to *Phyllospadix iwatensis*. At a depth of 2 m, 13% of the total biomass was *Modiolus kurilensis*. The biomass of the remaining species was negligible compared with the total community biomass and accounted for fractions of a per cent.

4. Discussion

Polydora limicola Annenkova - is a sedentary polychaete from the family Spionidae, which builds silt tubes. It was originally described as a subspecies *P. ciliata limicola* from the littoral of Bering Island (Commander Islands) (Annenkova 1934). Later, O. Hartman (1961) raised it to the range of a species. N.P. Annenkova (1934) mentioned that on the littoral of Bering Island this form occurred rather rarely, while in the upper horizonths of the sublittoral of Avachinskaya Inlet it was a mass species. From *P. ciliata* this species is distinguished by a weakly developed lateral tooth of modified setae of the fifth segment. Besides, these polychaetes build thin straight, almost transparent, tubes that are covered with silt particles, in contrast to *P. ciliata*, that drills lime rocks.

In 1959-60, G.B. Zevina (1961) found *P. limicola* (identification by V.V. Khlebovich) in the fouling of two ships that sailed only in the Barents Sea. On the fishing seiner RS - 5203 the polychaete worms were observed only in the upper side of ship keels, and on RT- 159 they were found also on the ship stern and bottom. Unfortu- nately, the author did not give any quantitative data. Most likely, it was low. Interestingly, that none of the authors, who studied the benthic communities of the Barents Sea, found this species (Averintsev 1977; Petrovskaya 1960; Khlebovich 1964).

In 1962, G.V. Losovskaya and D.A. Nesterova (1964) for the first time found *P. limicola* in Sukhoi Liman estuary of the Black Sea. In 1963, this species reached mass development there. The largest congregations of these polychaete worms were observed in the part of the estuary, where a floating dock was situated. The authors considered that this species was not an aboriginal species of this estuary, and was carried there either by a floating dock, or one of the ships that were docked for repair. In 1963-1974, a gradual penetration of *P. limicola* to the pre-estuary and coastal areas of the northwestern part of the Black Sea and the estuaries of the northwestern Prichernomorye that had different hydrological conditions was observed. G.V. Losovskaya (1977) considered that this species had a high ecological plasticity. The salinity range, within which *P. limicola* was observed, varied from 6 to 17‰. The bottom sites that were inhabited by *Polydora* were polluted with oil products (fuel oil) to a significant degree.

Approximately at the same time Polydora was found in the fouling of the hydrotechnical structures of Kilsky Channel (Schutz 1963, cited from: Hartmann- Schr dr 1971). As it was mentioned above, *P. limicola* was found on all types of anthropogenic substrates. However, more frequently it was observed in the aquatories of the ports of Vladivostok, Nevelsk, Kholmsk and Uglegorsk. It is quite possible that the introduction of *P. limicola* by means of the ships occurred simultaneously in several ports of Primorye and Sakhalin. But none of the authors, who studied benthic polychaetes in the northwestern part of the East Sea, found this species (Ushakov 1955; Buzhinskaya 1967, 1971, 1980, 1985; Bagaveeva 1980; Radashevsky 1993). Only in 1997, several specimens of *P. limicola* were registered in the benthos of Golden Horn Inlet.

N.A. Rudyakova (1967) observed the fouling of the ships with the tubes of *P. limicola* in Avachinskaya Guba, which was connected with the abundance of this species in the coastal biocenoses of this region. In the Barents Sea and

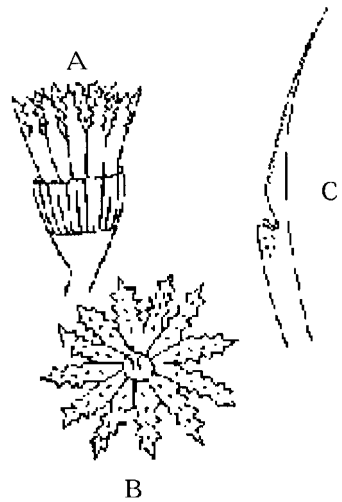

Fig. 5. *Hydroides elegans* (Haswell). A: operculum (lateral view), B: upper crown of operculum dorsal view, C: bayonet-shaped seta of the first setae segment.

Kilsky Channel, this species was registered only in the fouling. In the East Sea, *P. limicola* was found only in the fouling for a long time. Only recently it has been observed in the benthic communities but only in Golden Horn Inlet.

As it is known, for the introduction and naturalization of hydrobionts it is very important whether there are any competitive relationships with local fauna or not (Zevina 1972). Most likely, this fact played a decisive role in the acclimatization of *P. limilcola* in the Black Sea. In the Barents Sea and the East Sea its habitat area is limited mainly by port aquatoria, i.e. the places that are most unsuitable for the life of many hydrobionts. All the above testifies that *P. limicola* in the northwestern part of the East Sea is at one of its first stages of acclimatization (Zenkevich 1940).

Hydroides elegans (Haswell) - is the second species introduced into the northwestern part of the East Sea. This is a sedentary polychaete from the family Serpu- lidae, which builds lime tubes. In 1883, a new polychaete species *Eupomatus elegans* was described using the material collected in Port Jackson (Australia) (cited from Allen 1953). In 1911, it was reduced to a synonym of *Hydroides norvegica* (cited from Zibrowius 1970), that had been recorded in the warm and temperate waters of the northern and southern hemispheres in the Pacific and Atlantic Oceans not only in port areas but also in the open aquatoria. Zibrowius (1970) made a revision of some species of the genus *Hydroides*. On the basis of numerous studies of morphology, anatomy and ecology of the populations from different places of the earth globe, he came to the conclusion that all findings of *H. norvegica* in port biocenoses of temperate and warm seas actually referred to *H. elegans*.

H. elegans differs quite significantly from *H. norvegica*. The main difference is that the basal parts of collar bayonet-shaped setae in *H. norvegica* are smooth, and in *H. elegans* they are covered with numerous teeth. Also, for *H. elegans* an almost regular presence of a tooth in the center of upper crown of operculum is typical. The spines of upper crown of *H. elegans* are shorter and the number of lateral teeth is lesser as compared with *H. norvegica* (Fig. 5).

H. elegans also differs from *H. ezoensis* - affined species living in Peter the Great Bay, both in normal and in thermal waters. *H. ezoensis* has the teeth of the upper crown only from the inside, and lateral teeth is not present. Besides there is not a tooth in the center of upper crown of operculum, and the basal parts of collar bayonet-shaped setae are smooth. Main difference in ecology of *H. elegans* from *H. ezoensis* is that the first species lives only in Golden Horn Inlet, but second - both in Golden Horn Inlet and in Peter the Great Bay.

It is known that only euribiontic species can withstand traveling for long distances with a following acclimatization in a new place. *H. elegans* is among these species. Zibrowius (1970) noted that when new surfaces were being inhabited this species appeared first, endured significant variations of salinity and was found in the lagoons and estuaries of the Mediterranean Sea. Moreover it could withstand very heavy pollution. For example, in port of Taranto (Italy) *H. elegans* lives in the water with a high percentage of chlorine.

N.A. Rudyakova (1958) mentioned *H. norvegica* as one of the dominant forms in the

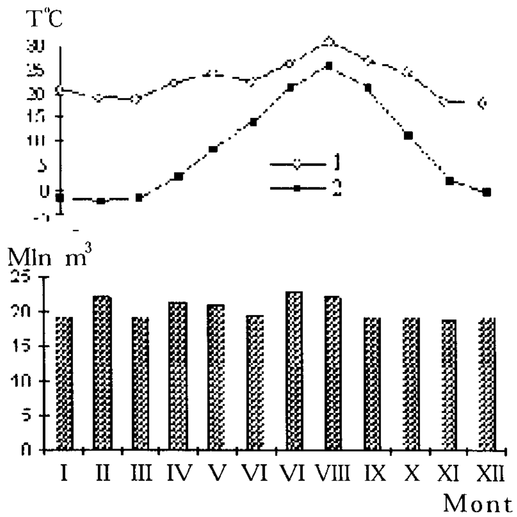

Fig. 6. Changes of water temperature (above) and volume (below) at the water discharging place after passing through the cooling system of TEPS-2 in Vladivostok in 1997: 1. monthly water temperature means at the water discharging place, 2. control temperature of water surface layer in the open part

fouling of the ships that spent a long time in bays or sailed at a speed of 6-8 knots in Peter the Great Bay. Obviously, she spoke about *H. elegans*, but it is impossible to repeat the identification of the polychaete. We have found *H. elegans* on the majority of the ships examined in Peter the Great Bay. The analysis of the routes of the ships has showed that a necessary condition for the presence of this species in the fouling is visiting Golden Horn Inlet and at least short time docking there in August-September. Maximum quantitative characteristics have been registered on a tanker olgograd that spent 4 months in Golden Horn Inlet. The biomass of this species reached 21 kg/m^2, the tubes were to 10 cm in length growing perpendicularly to the surface of the ship hull and covering 100 percent of the surface.

On the basis of data on Golden Horn Inlet it may be assumed that the quantitative parameters of the dominant species of the fouling community on the ships in this bay are dependent on the time that the ships spend in the bay. As it follows from data mentioned above, the ships that have worked in Golden Horn Inlet or often

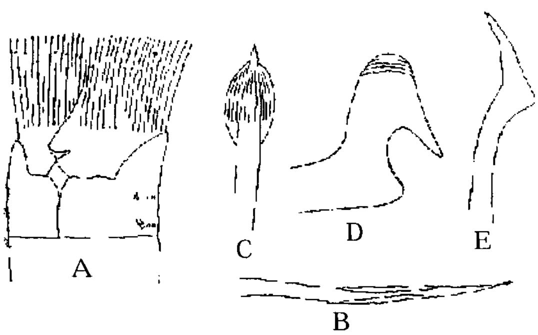

Fig. 7. *Pseudopotamilla occelata* Moore. A: anterior end, dorsal view, B: thoracic limbate notoseta, C: thoracic spatulate notoseta, D: avicular uncinus from torax, E: pennoned thoracic neuroseta.

come there are characterized by a very special composition of the fouling. The dominant species there is *H. elegans*. The community of *H. elegans* reaches its maximal development on the ships that spend long time anchoring in this bay. Often, the biomass of the polychaetes reaches tens of kg/m^2, their tubes lime tubes grow perpendicularly to the surface of the ship hull, reaching 10-12 cm in length and forming a 100 per cent covering. We have not met anything similar in other parts of Peter the Great Bay. When looking for the explanation of this phenomenon, we, first of all, have taken into consideration the temperature regime as the main limiting factor of the process of acclimatization. It has been found that during the last decades this bay has suffered the hermal pollution caused by the discharge of the warm waters of the water cooling system of TEPS-2 of Vladivostok. In 1970, an experimental power-generating unit was put into operation and at the beginning of 1971 four water pumps with a capacity of 6,000 m^3 per hour each were established and started to work for the cooling system of TEPS-2. In 1976 four water pumps with a doubled capacity of 12,000 m^3 per hour were established. The seawater that was used for cooling passed from Ussuriysky Bay (area of Tikhaya Inlet) through the system of the electrical power station and was discharged into the Obyasneniya River that falls into Golden Horn Inlet. It is known that water is significantly heated during its passing through the pipes of the electrical power stations and industrial enterprises: when it is discharged into the environment its temperature is 5-10 ℃, and sometimes 24 ℃ higher than the natural one (Mileykovsky 1977). According to data received from the administration of TEPS-2, the temperature of the water that is discharged from the cooling system of the electrical power station varies within 18.4 - 30.8 ℃, the volume of the discharged water varies within 18,793,000-22,546,000 m^3, correspondingly, per month (Fig. 6). In Golden Horn Inlet, no such big temperature difference is observed as compared with the neighboring aquatoria, which is due to the significant remoteness of TEPS-2 from the discharging point of the heated waters. However, since this electrical power station started to operate, the bay stopped to get frozen in winter. According to our data, in the inner part of the bay (the discharging place of heated waters) the water does not get colder than 0 ℃ during the whole winter.

hermal pollution caused by a discharge of heated waters may result in different ecological consequences for populations of benthos (Mileykovsky 1977) and fouling. In particular, it can facilitate the process of acclimatization of exotic species. In this case, as a result of this phenomenon, Golden Horn Inlet serves as an interface or an intermediate that enhances the spread of warm-water species, first of all *H. elegans*. In this bay, there is an all-year round flourishing population of this species, which is able to reproduce. However, it is found only in the fouling communities of the ships because in Golden Horn Inlet there are almost no natural hard substrates.

Pseudopotamilla occelata is a colonial tubular polychaeta from the family Sabellidae, body length 80-120 mm, width 5-7 mm, dark to pale brown. Thoracic segments, 8; abdominal, 130-160. Gill ray bases are semiround. On the dorsal side, they have a deep recess, dorsal lobes overlap each other (Fig. 7). Connecting membrane is absent. Each gill ray may have four to nine eyespots. Gill rays are plumose with inner rows of elongated-paired pinnules. The first segment has only notopodial setae. There are notopodia on the thorax with two kinds setae: the upper are long, hairlike, fringed on both sides; the lower, spatulate. Neuropodia with spatulate and hoe-shaped setae is forming two coupled rows. Abdominal notopodial setae are also beaked but they are smaller than thoracic beaked setae. The tube is parchmentlike. The specimens that we studied correspond fully to the description of this species in the literature. According to these authors, *P. occelata* inhabits the littoral and upper sublittoral of the coasts of Vancouver Island, Alaska, Oregon, California, and Japan.

Naturalization of this species makes an excellent example of autotransplantation of exotic species with all the consequences up to the global changes at the level of whole faunas (Zvyagintsev and Bagaveeva 1998). For this reason it is worthwhile to have a more detailed look at the introduction of *P. occelata* to Peter the Great Bay.

On the basis of the many-year observations of the community of *Pseudopotamilla occelata* on natural and anthropogenous substrates, a conclusion can be made that this species is an immigrant one. During an examination of the fouling settlement in Nevelsk in 1970, the dominance of an immigrant species *Polydora limicola* in the community of the fouling of hydrotechnical structures was observed (Bagaveeva *et al.* 1975). Ten years later no Polydora specimens were found on the wharf constructions of Nevelsk. The fouling consisted of a monodominant community of *P. occelata*. Because this species had not been recorded in the Russian waters previously, and it was first found in the ports and small ports, it is obvious that *P. occelata* was brought to the northwestern part of the East Sea by means of ships (individual findings of this species are known to us from the fouling of the coasters in the coastal zone of Pri- morye).

On the basis of data on hydrotechnical structures for 1980-1983, a conclusion can be made that the immigrant species *P. occelata* in this region was at the stage of an cological explosion at the time of study, which corresponds to Stage 3 of introduction (Rass and Reznichenko 1977). The mass occurrence of this species in the benthos of Peter the Great Bay testifies of the last 5th stage, i.e. naturalization of the species. The lack or rare occurrence of *P. occelata* in the fouling of the hydrotechnical structures in this bay can be explained by the peculiarities of its ecology. For these polychaetes the optimal conditions of their existence occur on open surf-washed capes. The port constructions, as a rule, are located in the Inlet that is protected from the rough wave motion. However, we have observed a typical community of *P. occelata* with a biomass to 800g/m^2 on a submerged dredge in the tidal part of Lazurnaya Inlet (Ussuriysky Bay). It is possible that the mass development of this species in Ussuriysky Bay is facilitated by the antropogenically-caused eutrophication that has been increasing in the recent years. If this fact is proved experimentally, *P. occelata* will perhaps serve as an indicator of this phenomenon.

The emergence of the immigrant species *P. occelata* followed by its naturalization in Peter the Great Bay has caused significant changes in the benthic composition of the upper sublittoral. Taking into consideration the degree of the naturalization and the changes in the benthos at the level of entire communities, this phenomenon approaches global significance, with corresponding ecological aftermaths. Thus, at most depths, the community of *P. occelata* has a very high biomass that reaches sometimes 39 kg/m^2 or more. Moreover, these values do not greatly exceed the average ones, since the colonies attain areas of tens of m^2 in size with a 100 percent covering of the substrate. Even data known to be underestimated give the total stock of these polychaetes only on Engelma Cape in Ussuriysky Bay (northern part of Emar Inlet) as no less than 40 tons. At present, published data on benthic communities in the upper sublittoral of surf-washed capes of the bay do not reflect the true picture, because these communities are buried under a thick layer of the polychaete *P. occelata*.

Succession of benthic communities is well expressed after large defaunations caused by storms, anthropogenous influence, etc. Certain species facilitate succession by being the first to colonize a surface and preparing the substrate for the species to come. For example, the tubes of polychaetes serve as a substrate for those species for which loose ground is unsuitable (Gallacher *et al.* 1983). In this case, a similar phenomenon is observed at the horizonth of 0,5-1 m in a community of *Phyllospadix iwatensis* on silty-sand bottom. When this community is colonized by an immigrant species *P. occelata*, a substrate is created for the existence of a wide range of new species (Table 1) that have previously been absent.

Polychaetes are a known major foodstuff for most benthophagous fish (Ushakov 1976). According to data obtained from trawling surveys, the biomass of the far-eastern redfins *Tribolodon brandti* (Dybowskii 1872) in Peter the Great Bay increased 2.8 times from 1990 to 1994 (Vdovin and Gavrenkov 1995). No doubt that such mass development of polychaetes that are favorite food for redfins facilitates the increase of their abundance in the bay. Because all the three species have been observed first in the fouling of ships and hydrotechnical structures, we have come to the conclusion that these three species have been introduced to the northwestern part of the East Sea by means of ships and have significantly increased their habitat area due to this. The most probably route of immigration for *H. elegans* and *P. occelata* is from Japan, and for *P. limicola* - from the coast of Kamchatka Peninsula. *P. limicola*, previously known from the coast of Bering Island and Kamchatka Peninsula (Annenkova 1934, 1938), the Kuril Islands (Khlebovich 1961), California (Hartman 1961), is now observed in the Black Sea (Losovskaya 1977) and in the northwestern part of the East Sea. *H. elegans*, known from the Mediterranean Sea and the Red Sea, Persian Bay, the coast of the Netherlands, eastern, western and southern Africa, the Indian Ocean, coast of New Zealand, Australia, the Philippine Islands, Japan, California, Florida, Mexican Bay (Zibrowius 1970), now also inhabits the northwestern part of Japan. However, this species was recorded only in Golden Horn Inlet due to its hermal pollution . According to literature data, *P. occelata* inhabited the littoral and sublittoral zones off Vancouver Island, Alaska, Oregon, California and Japan (Berkeley and Berkeley 1952; Imajima and Hartman 1964; Hartman 1969). When this species was introduced to the northwestern part of the East Sea, it caused significant changes in the composition of the benthic communities as a result of its naturalization.

It is known that during autotransplantation new discontinuous (bipolar) and amphiboreal areas are formed as well as such global processes as the exchange of the faunas as a result of the change of the temperature regime and the transgression of the World Ocean. The anthropogenous transplantation facilitates this process infinitely many-fold. In biogeographical modeling a notice should be taken of the role of auto- and nootransplantation (anthropogenous purposeful transplantation - Rass and Reznichenko 1977) in the formation of modern disjunctive areas (Bagaveeva *et al.* 1984). Our data fully confirm Zevina opinion (1994) that the development of navigation, the increase of the number of ships of different exploitation regime, the connection of the seas by means of the channels inevitably results in the formation of the unified fouling fauna for more and more large sites of the World Ocean.

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