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INTRODUCED SPECIES IN THE BALTIC SEA AND ITS COASTAL ECOSYSTEMS

ERKKI LEPPÄKOSKI
Department of Biology and Husö Biological Station, Åbo Akademi, SF-20500 Åbo, Finland

ABSTRACT

More than 30 species of anthropochorous immigrants have been reported from the Baltic Sea (east of the Arkona Basin, approx. 13°E). About one third of them originate from North America. Introduced species are mainly restricted to the freshened bays and river mouths of the Southern Baltic region. Most of them belong to the littoral or shallow sublittoral subsystems.

Examples of modes of dispersal and some food chains based on introduced species are given. Some relationships between exotic and native species are discussed. There are a few harmful species among these invaders.

Immigration with man's aid is still occurring. This process can be characterized as (a) an undesirable contamination of the Baltic Sea biota by alien elements, (b) an artificial, anthropogenic increase of species diversity, and (c) an ongoing recovery from the heavy reduction in the number of species caused by the last glaciation and the subsequent developmental phases of the Baltic Sea.

INTRODUCTION

Both plant and animal species not native to the Baltic Sea have been introduced, intentionally or unintentionally, into the Baltic during historic time. The Baltic Sea is one of the most thoroughly investigated sea areas in the world. The appearance of a new species might therefore be expected to be observed and reported without delay. In fact, however, biological studies of the Baltic Sea are very unevenly distributed in space and time. It is not always easy to say whether a 'new' species has been overlooked in previous studies or whether it is a real newcomer. Some faunistically and floristically interesting findings remain unpublished, etc.

In spite of these difficulties, this paper intends to give an overview of the recent distribution of introduced species in the Baltic Sea and to evaluate their importance in the Baltic and its coastal ecosystems. The primary aim is to illustrate the influence of man on the distribution of organisms at the single species level. This approach is quite different from that of pollution and eutrophication studies which deal with recent changes in the relative importance of species already existing within a certain community.

The recent history of some foreign introductions, their spread eastward and northward and their success in establishing populations has been described previously by Nikolajev (1951, 1974) and Zhuravel (1969). Järvekülg (1979) has presented distribution maps for a majority of Baltic invertebrates, among them a number of introduced species. Elmgren (1984) has given a list of newcomers, many of which are of freshwater origin (for a review, see Thienemann 1950).

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MATERIAL AND METHODS

This review is based upon literature available at some Finnish and Polish libraries. For purposes of comparison, unpublished benthos data from Husö Biological Station (Åland Islands) have been used. Some qualitative sampling was done by hand-nets and bottom dredge at the Biological Station of the University of Gdańsk in Górki Wschodnie, Poland, in September 1982. Some of these localities in Martwa Wisła (Dead Vistula) have been previously studied by e.g., Arndt (1965), Jaźdźewski (1967), and Turoboyski (1973).

RESULTS AND DISCUSSION

Comments on individual species

A tentative list on anthropochorous immigrants in the Baltic Sea, east of the Arkona Basin, is given below with some comments on the individual species.

Plants

The number of introduced aquatic plant species seems to be very low; I have found information on three species: *Biddulphia sinensis* Grew. (Bacillariophyceae), an Indo-Pacific phytoplankton species, first recorded in Europe in 1903, found at least in Gdańsk Bay and off the Lithuanian coast (Nikolajev 1951). According to Pankow (1976), however, it occurs in all temperate seas. *Chara connivens* Braun (Charales) has been known from ballast sites since the 1850s from the S Baltic to the Öregrund area in the north (Luther 1979), common in the Vistula Firth, for example (Pliński *et al.* 1978). *Elodea canadensis* Michx. (Spermatophyta) (from N. America), found in brackish water from the German coast to N Gulf of Bothnia was already known in the 1890s (Luther 1951, Julin 1967).

Coelenterata

Cordylophora caspia (Pall.) (Ponto-Caspian species). One of those 4 or 5 species of immigrants reliably reported until the beginning of the 20th century (Nikolajev 1974). Very common from S Baltic (Zmudziński 1974) to the N Bothnian Bay (Haahtela 1964). Considered a cosmopolitan species by e.g., Thienemann (1950).

Polychaeta

Polydora redeki Horst (W Europe). Known from Kiel; first recorded in SW Finland in 1963 (Eliason & Haahtela 1969). At present found from the Åland Islands in the west to Porvoo/Borgå in the east (Bonsdorff 1981, Halsinaho 1984). Obviously not reported from areas between the SW Baltic and the Finnish coast.

Mollusca

Dreissena polymorpha (Pall.) (Ponto-Caspian species). Found in S Baltic lagoons since the early 1800s; now up to the Stockholm archipelago (Thienemann 1950) and the Gulf of Riga (Järvekülg 1979), in places very numerous.

Mya arenaria (L.) (N America). 'No other course remains open than to assume that *M. arenaria* has been transferred from America to Europe through the agency of man . . . during the 16th or 17th century', (Hessland 1946), unintentionally by ships or intentionally for use as bait. At present one of the most common bivalves, up to N Bothnian Sea.

Potamopyrgus jenkinsi (Smith) (New Zealand). Found first in the Baltic in 1887. Gotland 1920, Åland Islands 1926. Now in the whole Baltic, in certain habitats very numerous.

Crustacea

Eriocheir sinensis Milne-Edwards (SE Asia). Recorded for the first time in the Baltic Sea in the early 1930s, within less than 20 years spread (as adults only) to the innermost Bothnian Bay. A steady cessation of its invasion has been noted since the initial colonization in the 1930s (Grabda 1973).

Orconectes limosus (Raf.) (N America). This crayfish is found in coastal lagoons and river mouths of the S Baltic, e.g., in Szczecin and Vistula Lagoon, in salinity levels up to 2‰ (Zmudziński 1961; J. Kossakowski, Z. Piesik, pers. comm.).

Rithropanopeus harrisi (Gould) (N America). First recorded in Poland 1951. Since the 1960s common in Dead Vistula (decreased or disappeared in the late

1970s) and Vistula Firth, as well as in Gdańsk Bay. Apparently decreased in numbers after initial colonization (Kujava 1963, Turoboyski 1973).

Acartia tonsa Dana (N America). Found in 1952 in Gdańsk Bay, 1934 in the Gulf of Finland. Appears commonly in plankton, in general not numerous. Occasionally, however, up to 20 % of zooplankton abundance (in Vistula Firth; Adamkiewicz-Chojnacka 1978).

Corophium curvispinum Sars (Ponto-Caspian species). First recorded in S Baltic firths in 1920-30s (Jaźdźewski 1980). In some slightly brackish coastal waters up to the S part of the Gulf of Riga (Järvekülg 1979).

Acclimatization attempts have been made with some crustacean species in some reservoirs in the Baltic region of the USSR as well as in the Kuronskij Firth (*Chaetogammarus warpachowskyi* Sars, *Obesogammarus crassus* (Sars), *Pontogammarus robustoides* (Sars), *Hemimysis anomala* Sars, *Limnomysis benedeni* Czern., and *Mesomysis kowalewskyi* Czern.). I do not, however, have any information whether these introductions were successful or not. *M. kowalewskyi* seems to be the only species which has also been reported from the open sea (Järvekülg 1965, Lukšenas 1967, Zhuravel 1972, Mištautaité & Kublickas 1975).

Bryozoa

Victorella pavida Kent (Cosmopolitan, Wolff (1972); according to Bacescu (1966) a Ponto-Caspian species). At places from Kiel to Kalmar, at German and Polish coasts, Finnish S coast (Forsman 1972).

Varia

There are some invertebrates considered as introduced species by various authors but I have not been able to find additional information to confirm or disprove these statements. The status of the following species is thus still unclear:

Balanus improvisus Darw. (Crustacea, Cirripedia). According to Luther (1950), observed first time in 1844.

Corophium multisetosum Stock (Crustacea, Amphipoda). Found by Jaźdźewski (1976) off the Polish coast. The manner of its dispersal is unknown, possibly anthropochorous (K. Jaźdźewski, pers. comm.).

Orchestia platensis Kröyer (Crustacea, Amphipoda). Considered as anthropochorous by Elmgren (1984). A related species, *Talorchestia deshayesi* (Audouin) was assumed to be bird transported to the Polish coast by Nawodzińska & Drzycimski (1963).

Palaemonetes varians (Leach) (Crustacea, Decapoda) is mentioned among introduced species by Elmgren (1984).

Congeria cochleata (Nyst) (Mollusca, Bivalvia) has been recorded once in ca. 1930 on the E coast of Gdańsk Bay (cf. Thienemann 1950).

Theodoxus fluviatilis (L.) (Mollusca, Gastropoda) is, according to Nikolajev (1974), an early immigrant belonging to the Ponto-Caspian complex.

Pisces

There are only sporadic notes on the occurrence of introduced fish species in the Baltic. Single individuals of the following species can be caught (Koli 1966 and pers. comm., Otterlind 1970, Karpevich 1975, Solovjova 1976, Westman & Tuunainen 1981, Andreasson & Petersson 1982, M. Himberg, pers. comm.): *Acipenser gueldenstaedti* Brandt (Russian sturgeon), *A. baeri* Brandt (Siberian sturgeon), *Salmo gairdneri* Rich. (rainbow trout, native to N America. Commonly reared on fish farms, annual production in brackish water in Finland, for example, 2200 tons in 1981), *Salvelinus namaycush* Walb. (lake trout, N America) *Oncorhynchus gorbuscha* (Walb.) (pink salmon, N Pacific coasts), *O. keta* (Walb.) (chum salmon, N Pacific coasts), *Coregonus peled* (Gmel.) (peled whitefish, Siberian lakes), and *Ictalurus melas* (Rafin.) (black bullhead, N America). Some cyprinid species (e.g., *Cyprinus carpio* L., common carp, originally from Asia) may also be recorded in brackish water. Most of these species do not occur as self-maintained populations, i.e., they are not able to reproduce in the Baltic Sea or in its drainage area.

Aves

Branta canadensis (L.) (Canada goose, N America). Introduced ca. 1930 into Sweden (approx. 30000 individuals in 1981). In Finland since 1964, now 100-150 individuals. Apparently the commonest goose in the Baltic region (Fabricius 1983).

Mammalia

Mustela vison Schreb. (mink, N America). A fugitive from fur farms. In suitable habitats around the Baltic Sea, also in the outermost archipelago areas in the N Baltic area.

Ondatra zibethica L. (muskrat, N America). Introduced into Europe in 1906. Artimo (1960) found a dispersal rate of 4-120 km · a^{-1} in S Finland. Already observed in the late 1950s on the outermost islands in N Quark and on islands isolated by a 15 km wide open-water area from the main Åland Islands (Hildén & Stén 1964). The muskrat now colonizes N Sweden, incl. the coast of the

Bothnian Bay, where the fluctuating water level and the scarcity of the macrophyte vegetation are limiting factors (Danell 1978). Found, e.g. in coastal lagoons, not on the sea shore, along the Polish coast (S. Strawinski, M. Gromadzki, pers. comm.).

Nyctereutes procyonoides (Gray) (raccoon-like dog, E Asia). Sporadically on sea shores along the southern and eastern coasts, eating dead fish and water fowl. A strong expansion along the Polish coasts during the last 15 years (Krzywiński & Włodek, in press).

Distribution

Distribution of introduced benthic species is presented in Fig. 1. Vertically, most introduced species are restricted to the littoral or upper sublittoral zones or to the uppermost pelagial layer (e.g. *Acartia*, larvae of *Rithropanopeus* and *Dreissena*). Some exceptions can be mentioned. *Mya* can be found down to a depth of 20-30 m, at least. On sheltered sedimentation bottoms, *Polydora* has been recorded at 29 m (Halsinaho 1984) and *Potamopyrgus* at 23 m depth (Fig. 2). Most of the species concerned are invaders from the south. Their northward spread is obviously limited by low temperature combined with unfavourable salinity conditions. In the S Baltic both exposed littoral habitats as well as deeper soft bottoms seem to be entirely free from introduced species (e.g. Zmudziński & Ostrowski 1982).

Biogeographical origin, routes of dispersal

Of the 33 species listed above (species mentioned under 'Varia' not included) 6 fish species have been intentionally introduced into the Baltic Sea, 14 species transferred unintentionally (passive dispersal with man's aid) and 13 species intentionally planted in adjacent bodies of fresh water and from there spread to the Baltic coasts. 16 species may be considered transoceanic immigrants (incl. two salmonid species from the N Pacific region); not less than 11 of these originate from N America. The Ponto-Caspian complex, often considered an important source of Baltic Sea immigrants, is represented by 2-3 species only outside river mouths. According to Wolff (1972), there is not a single species in the NW European brackish water fauna certainly originating from the Ponto-Caspian area. The exact manner of dispersal is unknown in most cases. There are examples of ballast species (*Chara, Elodea, Eriocheir, Rithropanopeus, Acartia, Mya(?), Potamopyrgus*), species attached to the bottoms of ships (*Cordylophora, Polydora, Dreissena, Corophium, Victorella*), and of species spread along river systems from adjacent lakes and reservoirs in which they have acclimatized as economically useful species (species of Mysidacea and Gammaridae listed above, *Orconectes, Ictalurus, Cyprinus, Salvelinus, Ondatra*).

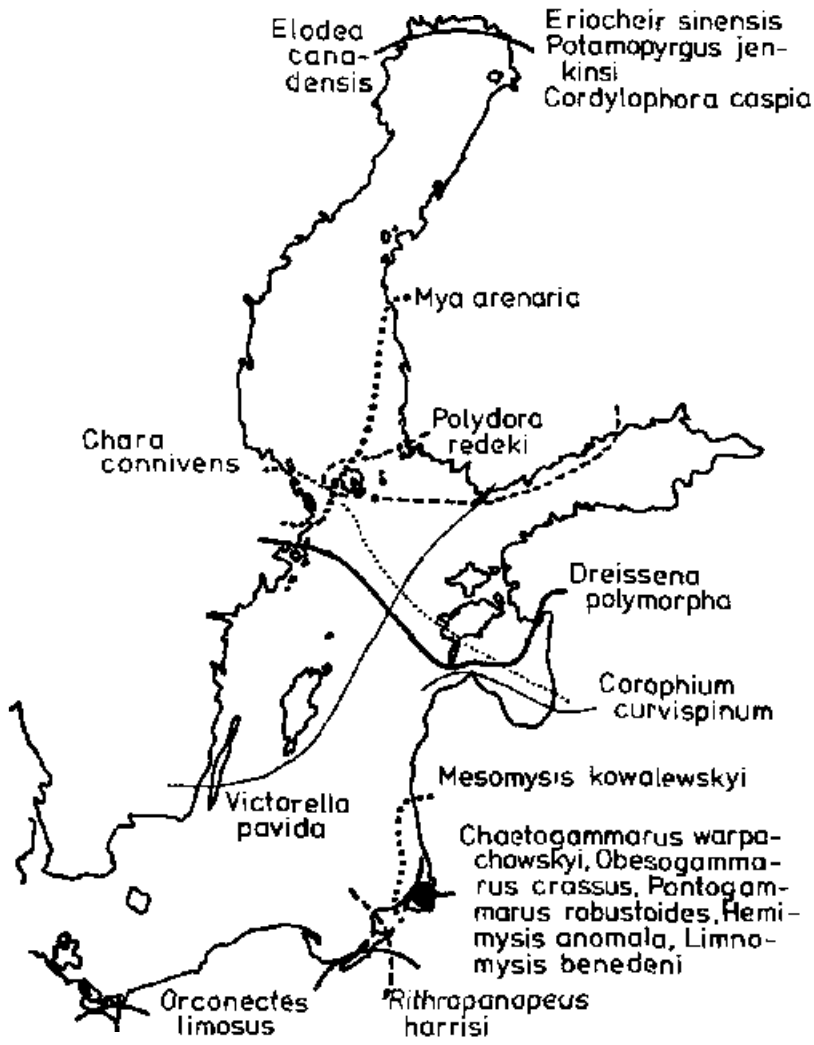

FIG. 1. Distribution of non-pelagic species introduced into the Baltic Sea (east of the Arkona Basin). In part according to Järvekülg (1979).

Man-introduced species in man-made habitats

Anthropochorous immigrants are generally neither common nor numerous. The most marked exceptions are *Dreissena* which predominates in the Szczecin Firth (abundance max. 10^5 ind. · m^{-2}; Wiktor 1969), *Mya*, *Potamopyrgus* and, in some Finnish coastal areas, *Polydora*. An example from the Åland archipelago can be given. At 6 soft-bottom stations (depth 20 m), monitored by Husö Biological Station, a total of 23 taxa was recorded in 1977-1981 (n samples = 263). Among these, two introduced species were found: *Potamopyrgus* (frequency of occurrence 16% of samples taken) and *Mya* (2%).

The abundance of introduced species in some specific habitats, strongly influenced by man, is worth noting. The firths along the S Baltic coast are heavily eutrophicated and here a dense population of filter feeders (*Dreissena*) can be maintained. On extremely soft bottoms, rich in organic material, *Potamopyrgus* made up 57% of the total abundance in samples taken by myself at depths of 1.5-3 m in Dead Vistula, Poland, in September 1982. On secondary hard bottoms (piles) in the same area, studied by Arndt (1965), no less than 5 species out of a total of 15 species were introduced immigrants (*Cordylophora, Dreissena, Potamopyrgus, Rithropanopeus, Victorella*).

On the coasts of Finland some 2-3 immigrants can be found more regularly. E.g., in a *Zostera* community in W part of the Gulf of Finland, only *Potamopyrgus* and *Mya* were recorded among a total of 58 taxa of plants and animals (Lappalainen *et al.* 1977). At slightly polluted soft-bottom localities in SW Finland, the introduced species found were *Potamopyrgus* (rank by frequence 13, among a total of 33 taxa caught at 232 stations in 1965-1973 by Leppäkoski 1975), *Mya* (rank 20) and *Polydora* (21). On hard bottoms, *Cordylophora* is the only immigrant of importance. It also occurs at greater depths: below 8-9 m it has more and more replaced *Mytilus edulis* L. on artificial substrates studied by Kautsky (1982), co-occurring with *Laomedea loveni* (Allm.), *Balanus improvisus* (L.), and *Electra crustulenta* Pallas.

Relations with other species, including man

Food chains

All trophic levels are represented among the introduced organisms. The most successful species are members of detritus food chains (*Dreissena, Potamopyrgus*; Fig. 2). In the open Baltic proper, the introduced element is of no importance (cf., e.g. the Caspian Sea, in which invaders may account for 80-100% of the total biomass of zoobenthos (Kasymov 1982)). In certain coastal waters, food chains and whole benthic communities may, both structurally and functionally, be based upon invaders. In the early 1960s, *Dreissena* made up no less than 88% of the total benthic biomass in the Szczecin Firth (max. 20 kg · m^{-2}; Wiktor 1969). Here the American crayfish *Orconectes* feeds mainly upon the Ponto-Caspian coelenterate *Cordylophora* (Piesik 1974), which uses planktonic larvae of the Ponto-Caspian bivalve *Dreissena* (Wiktor 1969). Young *Dreissena* are of importance as food for certain fish and water fowl (cf. Stańczykowska 1977). In Dead Vistula adult *Rithropanopeus* feed mainly upon *Dreissena* whereas young individuals consume *Cordylophora* (Kujawa 1963, Tutoboyski 1973). *Rithropanopeus* has been a valuable food item for bottom-feeding fish in the Gdańsk Bay (Kujawa 1963). Such instructive examples of food chain relations between two or three introduced species cannot be found in the N Baltic area.

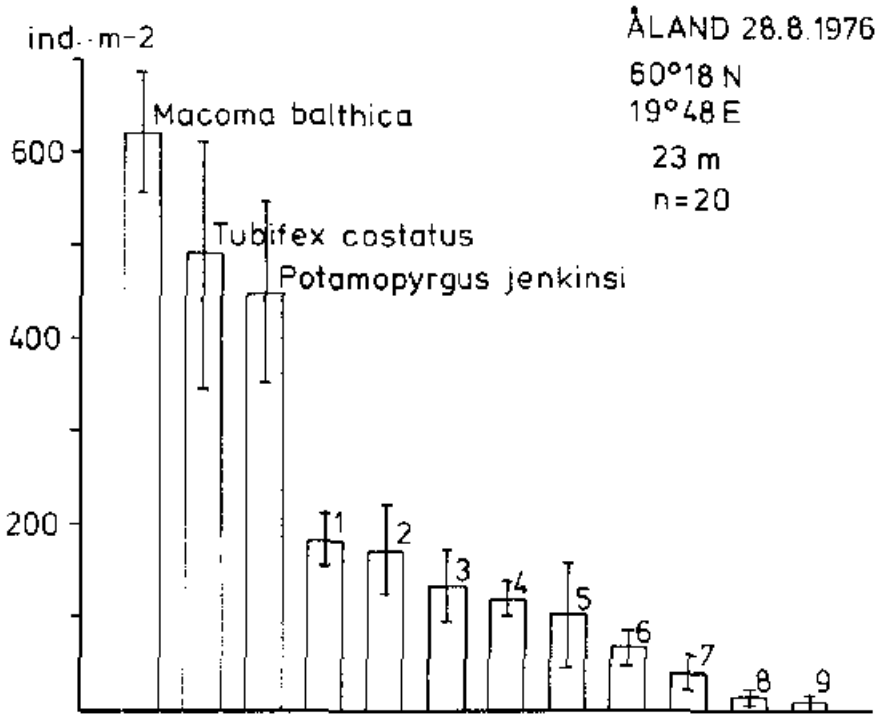

FIG. 2. Macrozoobenthos at a monitoring station in the inner part of the Åland archipelago (Ekman-Birge bottom grab; 0.6 mm mesh sieve). 1, *Chironomus plumosus*-group larvae; 2, *Potamothrix hammoniensis* (Mich.); 3, Tanypodinae spp. larvae; 4, *Pontoporeia affinis* Lindstr.; 5, *Peloscolex heterochaetus* (Mich.); 6, Chironominae sp. I; 7, Chironominae sp. II; 8, *Limnodrilus* sp. juv.; 9, *Mesidotea entomon* (L.).

Habitat changes

Sessile species, such as *Cordylophora* and *Dreissena*, change the physical structure of a habitat. *Dreissena* creates secondary hard bottoms, thus multiplying the surface available for other sessile forms and for *Dreissena* itself. It also acts as a 'sediment trap', turning huge amounts of seston into excreted pseudofaeces which create soft substrates, rich in organic material, for deposit-feeding, infaunal species. Wiktor (1969) found that the biomass of other zoobenthos was twice as high in the vicinity of *Dreissena* beds as in other parts of the Szczecin Firth.

Coexistence with native species

The relatively high number of species introduced by man into NW European brackish waters points to the fact that a number of habitats and niches have been unsaturated (Vaas 1975). In the strongly diluted water of the Baltic coastal lagoons, filter-feeding bivalves did not occur on firm bottoms; the introduction of *Dreissena* filled this gap (cf. Wolff (1969) for Dutch estuaries). In parts of the Szczecin Firth, *Dreissena* and *Mytilus* co-occur but they do not basically over-

lap (L. Szlauer, Z. Piesik, pers. comm.) owing to isolation by the salinity gradient. *Pomatopyrgus* lives as the only gastropod on sublittoral soft bottoms in the N Baltic (Fig. 2), *Eriocheir* as the only decapod crab, *Ondatra* as the only shore-living rodent etc. It is, however, difficult to define a 'free niche'; as pointed out by Li & Moyle (1981), an introduced species may adopt a different realized niche as a response to new ecological conditions. There are only a few well-studied examples of interspecific competition between native and introduced species. On the other hand, we do not have adequate data on pre-introduction conditions for evaluating the impact of an introduction (cf. Hedgpeth 1980). The most interesting pairs of species might be, e.g. *Dreissena – Mytilus*, *Branta-Anser anser* (L.), *Potamopyrgus* – other species of Hydrobiidae (competition in part reduced by spatial segregation, cf. Hylleberg 1978), and *Cordylophora – Laomedea* (among other species of sessile forms, cf. Kautsky 1982).

As far as I know, the exotic species concerned have been free from exotic diseases and parasites when introduced into the Baltic after a stepwise spreading in freshwater systems or along the North Sea coast. Some invaders are known as nuisance organisms: *Eriocheir* and *Cordylophora* may cause damage to fishing gear, *Dreissena* and *Cordylophora* occur as fouling organisms in cooling systems and overgrow underwater constructions. The muskrat may damage shore meadows and constructions; the mink again is known as a predator on water fowl.

Man seems to be unable to intentionally manipulate the species composition of the Baltic Sea (cf. Leppäkoski 1980). The invader element has, generally speaking, occupied only marginal areas and in most cases only marginal niches. Biogeographically, however, this element signifies a great addition to the Baltic fauna and flora, with respect to the naturally low number of species present. For a conservationist, this addition indicates contamination of the biota by foreign elements, the invasion of which has been determined in part by mere chance, in part by man's economic interests and activities (planned acclimatizations, creating a network of canals joining river systems, development of trans-oceanic trade). From an ecologist's point of view, these species have contributed to species diversity and community structure, created new interspecific (e.g. competitive and trophic) relationships, etc.

A biogeographer may have quite a different view. The Baltic Sea is a fairly young body of brackish water. The spontaneous dispersal of species is difficult because of its geographical isolation, by land or by marine water, from estuaries and other brackish water areas. Thus, introduction by human activities helps organisms to cross ecological dispersal barriers. The number of species is still low after the last glaciation and the severe disturbances, e.g. freshwater periods, following it. The present brackish water biota of the Baltic have been formed during the last 7000-8000 years and it is obvious that this process is still going on. The enrichment of the Baltic fauna and flora by introduced species can,

from this point of view, be interpreted as a successive recovery from the last glaciation, anthropochorous dispersal being a spreading mechanism complementary to other manners of dispersal.

My observations confirm the hypothesis presented by Wolff (1974) that non-tidal brackish water ecosystems are more open to introduced species compared with other benthic habitats (marine, tidal brackish, or freshwater). Gradual changes in the Baltic ecosystem are monitored from many aspects within the framework of international cooperation. We have to bear in mind that 'control of the composition of the flora and fauna of the Baltic Sea is a matter worth including in the programs .... concerned with the protection of the waters of the Baltic Sea basin' (Nikolajev 1974).

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