Invasions by plants and animals into coastal, brackish and fresh water of the Netherlands

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SUMMARY

A survey is given of immigrant organisms in marine, brackish and fresh water of The Netherlands. It is concluded that only few species have been successful invaders, and that these are mainly restricted in their occurrence to man-made and heavily disturbed habitats.

INTRODUCTION

In this paper invasions by aquatic plants and animals into The Netherlands are dealt with in a summarized way. For practical reasons the immigrants have been divided into those of the coastal water, the brackish water and the fresh water.

COASTAL WATER

The coastal waters form an important immigration route for aquatic organisms. Much material is transported under the influence of currents and wind. Although the residual current is directed north to north-easternly, transport in the opposite way is possible too. Most material found washed ashore along the Dutch beaches originates from the English Channel. There are many indicator species to prove this southern origin. Material of northern origin has been found also, mainly on the beaches of the Frisian islands (den Hartog, 1959).

Among the species arriving in this way 4 categories can be distinguished.

1. Species which do not settle in the new environment. They form the majority.
2. Species the settlement of which is followed by a permanent establishment;

the invasion has been successful. In the 18th and 19th century, when the seawalls received a stone-cover, an opportunity for settlement was offered to many marine organisms. It can be concluded that the species which succeeded to establish themselves permanently, were not able to live in the Dutch coastal waters due to the lack of a suitable substratum.

3. Species which are able to settle under special climatological conditions but which cannot maintain themselves, because the general conditions do not allow successful reproduction. Such species have to settle again and again, but their presence is always of a temporary nature. The limit of their permanent area of distribution is not far from the southern North Sea. *Patella vulgata* L. and *Littorina neritoides petraea* (Montagu) are good examples.

4. Species which appear very temporarily, without a clear correlation with biotic or abiotic parameters, e.g. the occurrence of the large diatom *Pleurosigma planctonicum* Simonsen in November 1974.

Table I. Immigrants in the marine environment

Polychaeta	
Hydroides elegans (Haswell)	(thermophilous)
Branchiomma bombyx (Dalyell)	(thermophilous)
Polydora hoplura Claparède	
Mollusca	
* *Teredo navalis* L.	(borer)
* *Crepidula fornicata* (L.)	
* *Petricola pholadiformis* Lamarck	(borer)
* *Mya arenaria* L.	
Crassostrea angulata (Lamarck)	(thermophilous)
Crassostrea gigas (Thunberg)	(thermophilous)
Venus mercenaria L.	
Ensis directus (Conrad)	
Crustacea	
* *Elminius modestus* Darwin	
Balanus amphitrite Darwin	(thermophilous)
Callinectus sapidus (Rathbun)	
* *Mytilicola intestinalis* Steuer	
Tunicata	
Molgula manhattensis (De Kay)	
Styela clava Herdman	
Fishes	
Gobius niger L.	
Atherina boyeri Risso	(thermophilous)
Algae	
* *Codium fragile* (Sur.) Hariot	
* *Sargassum muticum* (Yendo) Fensholt	
Dasya baillouviana (Gmel.) Mont.	(thermophilous)

* Naturalized, not dependent on man for survival.

Most spectacular, but also most unpredictable, are the invasions by species of which the actual area of distribution is separated by a wide geographical gap (often in the order of a continent and/or an ocean) from the area to be invaded. In most cases man plays a direct or indirect role by the bridging of the gap. There are, however, a number of cases known where species obviously crossed the Atlantic with driftwood, thus without human aid; however, this did not lead to settlement.

Most immigrants were introduced by man. Most of these do not survive without human care (e.g. *Crassostrea angulata* and *Venus mercenaria*). However, some of them found suitable conditions in the new surroundings, and could indeed transform the potential area into an actual area of distribution, e.g. *Teredo navalis, Mya arenaria, Elminius modestus* and *Codium fragile*. These are fully naturalized, and in no way dependent on man for their survival in the new environment. Some species appear to be bound to the cooling systems of power plants, and waters which receive thermal discharge *(Atherina boyeri, Balanus amphitrite)*.

Table II. Immigrants in brackish water

name	origin
Hydrozoa	
Gonionemus vertens Agassiz	N. Pacific
Polychaeta	
Ficopomatus enigmaticus (Fauvel) (t) (= *Mercierella enigmatica* Fauvel)	worldwide subtropic
Mollusca	
* *Mytilopsis leucophaete* (Conrad) (= *Congeria cochleata* (Kickx))	N. America
* *Potamopyrgus jenkinsi* (Smith)	New Zealand
Crustacea	
* *Eriocheir sinensis* Milne Edwards	E. Asia
Rhithropanopeus harrisi (Gould)	N. America
* *Gammarus tigrinus* Sexton	N. America
Orchestia platensis Kröyer	Cosmopolite

Species with a very wide area of distribution:

Hydrozoa
Cordylophora caspia (Pallas)
Garveia franciscana (Torrey)

Ectoprocta
Bowerbankia div. sp.
Victorella pavida Kent

Crustacea
Balanus improvisus Darwin

* Naturalized, independent of man for survival.
t = thermophilous species.

A list of immigrants in the marine environment (no doubt incomplete) in The Netherlands is given in Table I. In all cases recorded man played a role as an agent and/or as a creator of the suitable circumstances for the immigrant.

BRACKISH WATER

The brackish environment is characterized by large fluctuations in environmental parameters, such as salinity and temperature, and naturally has a restricted number of species. In spite of the fact that the brackish waters are not mutually connected and are situated as a narrow barrier between the marine and the fresh water environment, they contain a relatively large number of immigrants, as well as a number of species with very large areas of distribution. In Table II these are listed.

Table III. Immigrant invertebrates in fresh water

	origin	rivers	thermophilous	brackish	other waters
Hydrozoa					
Craspedacusta sowerbyi Lankester	E. Asia	+	+	–	+
Turbellaria					
* *Dugesia tigrina* (Girard)	N. America	+	+	–	+[s]
Oligochaeta					
* *Branchyura sowerbyi* Beddard	Cosmop.	+	+	–	+[m]
Mollusca					
* *Dreissena polymorpha* (Pallas)	Ponto-Casp.	+	–	–	+[s]
Musculium transversum (Say)	N. America	–	–	–	+[m]
* *Potamopyrgus jenkinsi* (Smith)	New Zealand	+	–	+	+
Physa acuta (Draparnaud)	N. America	+	+	–	+[s]
Lithoglyphus naticoides (Pfeiffer)	Ponto-Casp.	+	–	–	+[m]
Crustacea					
Athyaephyra desmaresti (Millet)	Mediterranean	+	+	+	+
Palaemon longirostris Milne Edwards	Europe	+	–	+	–
* *Eriocheir sinensis* Milne Edwards	E. Asia	+	–	+	+
* *Orconectus limosus* (Rafinesque)	N. America	+	–	–	+[s]
Astacus leptodactylus Eschcholz	N. America	–	–	–	+[s]
* *Gammarus tigrinus* Sexton	N. America	+	–	+	+[s]
Crangonyx pseudogracilis Bousfield	N. America	–	–	–	+[s]
Odonata					
Sympetrum pedemontanum (Allioni)	Mediterranean	–	+	–	+

* Naturalized, not dependent on man for survival.
s = solid substratum
m = muddy substratum

FRESH WATER

Fresh water is a collective name of all waters with a very low content of dissolved salts; consequently a large number of water types can be distinguished. In spite of this it is obvious that most immigrants utilize the rivers and the canals as migration routes. Consequently the hydrotechnical works, such as the enclosure of the Zuyder Sea and the flushing of formerly brackish waters in the northern provinces with "fresh" water of the river Rhine, have caused also small-scale invasions, e.g. of the fluviatilous *Trocheta bykowski* Gedroyć, *Orchestia cavimana* Heller and *Ancylus fluviatilis* (O.F. Müller) into the Frisian broads. All immigrant animals have been found in rivers or the larger broads (Table III). They all seem to occur in habitats, made by man, or strongly influenced by man. *Dreissena polymorpha* found an excellent substratum on the stony banks of the canals, rivers and lakes, a new and empty niche in The Netherlands. Most species seem to be well-adapted to moderately and heavily eutrophicated waters and water under influence of thermal discharge. The nowadays widely spread occurrence in fresh water of *Palaemon longirostris*, a prawn normally found in brackish water, is no doubt a result of the raised salinity of the rivers.

It is conspicuous that immigrants have not or hardly been found in stable fresh water communities, such as those dominated by nymphaeid water plants and *Stratiotes aloides* L. A further noticeable fact is that adventive aquatic insects are virtually absent, although these must be able, due to the ability to fly, to take adequate advantage of all kinds of environmental changes. The

Table IV. Introduced fish in the fresh water

	origin	reproduction
Salmo gairdneri Richardson	N. America	–
Thymallus thymallus (L.)	Europe	–
* *Umbra pygmaea* (De Kay)	N. America	+
* *Cyprinus carpio* L.	E. Asia	+
Ctenopharyngodon idella (Valenciennes)	E. Asia	–
Hypophthalmichthys molitrix (Valenciennes)	E. Asia	–
Leuciscus idus (L.)	Europe	+
Carassius auratus (L.)	E. Asia	+
* *Ictalurus nebulosus* (Le Sueur)	N. America	+
* *Ictalurus melas* (Rafinesque)	N. America	+
t *Lebistes reticulatus* (Peters)	S. America	+
t* *Lepomis gibbosis* (L.)	N. America	+
* *Stizostedion lucioperca* (L.)	Europe	+

* Naturalized, not dependent on man for survival.
t = thermophilous species.

dragonfly *Sympetrum pedemontanum* reaches our waters during warm summers, but does not reproduce here. With relation to fish De Groot (1985) has recorded 27 species, which have been introduced or have escaped from nurseries. Table IV lists the fish species which have become naturalized, those which have been released repeatedly for sport fisheries and water plant control, and some escapes which have been observed frequently.

The number of aquatic fresh water plants that have managed to become established is small (Table V). In fact there are only 3 species, *Elodea canadensis, E. nuttallii* and *Azolla filiculoides*, which were able to build up an extensive area of distribution. Their dispersal was, at least in The Netherlands, favoured by the system of canals and ditches, and by the way aquatic plants are controlled. *E. nuttallii* has been discovered in 1941 for the first time, and is at present the most common aquatic plant. *Vallisneria spiralis* has profited from the fact that in the 18th and 19th century the European rivers have been interconnected, and has reached Maastricht, but does not show further northward extension. Although it is one of the most common aquarium plants, it has not been found as a permanent escape elsewhere. Probably the northward extension has been accomplished by special clones.

CONCLUSIONS

It can be concluded that some of the immigrations refer to the extension of European species, due to removal of barriers that obstructed their extension *(Athyaephyra desmaresti, Vallisneria spiralis)*, or the creation of new habitats which enabled their settlement and consecutive establishment (many algae on the seawalls). These species reached the new areas without man as an agent of transport.

Species from abroad which arrived with intended or unintended help of man as a transporting agent, were generally successful in new man-made habitats, in heavily disturbed habitats, such as the rivers (stony slopes, eutrophication, discharges of poisonous substances, raised salinity, thermal stress), cooling water circuits of power plants, various types of canals and ditches (eutrophication, mechanical cleaning), but did not or scarcely penetrate into well-established, stable, aquatic communities.

A further conclusion may be, that the number of successful immigrants in the aquatic environment is in fact surprisingly small. In only a few cases the appearance of the immigrants has led to a considerable decrease in numbers and range of native species, due to habitat sharing. However, we do not know of any extinctions of native species that can be ascribed to the introduction of alien species.

Table V. Immigrant plants in fresh water

	origin	thermophilous	eutrophication
Waterferns			
* *Azolla filiculoides* Lamk.	N. America	–	+
Azolla caroliniana Willd.	N. America	+	–
Salvinia natans (L.) All.	Europe	+	–
Angiospermae			
* *Elodea canadensis* Michx	N. America	–	–
* *Elodea nuttallii* (Planch.) St. John	N. America	–	+
Egeria densa Planch.	S. America	+	–
Vallisneria spiralis L.	Europe	+	+
Pistia stratiotes L.	Tropics	+	–
Potamogeton coloratus Hornemann	Europe	–	–
Various aquarium-adventives			

*Naturalized

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POSTSCRIPTUM

We intend to elaborate our data into more detail, including a number of case studies and some theoretical reflections, for publishing in an international journal. For that reason we would be most grateful for additional data to our tables and possible other comments.

REFERENCES

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