# 6 Exotic species in the Oosterschelde

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## *6.1 Introduced species in the Oosterschelde*

One of the most pervasive and ecologically damaging effects of human activities in the marine environment is the widespread movement of species beyond their natural range (Ricciardi & Rasmassen, 1998). In most countries, $10^2$-$10^4$ non-indigenous species have been documented (Lodge, 1993), and these numbers will increase as expanding global trade increases. Besides natural dispersal processes, there are several physical means (introduction vectors) by which species are transported from one geographic region to another. These introduction vectors can be grouped into a number of categories:

- Ships, moveable structures and other craft.
  - Ballast water (since the 1870s), solid ballasts and ballast sediments.
  - Hull fouling.
- Aquaculture activities.
  - Intentional release and stock movements and spread of associated species.
  - Accidental release, incl. the associated species.
  - Gear movements.
  - Discharge of feeds.
- Fisheries.
  - Intentional release of species (e.g. the red king-crab, American lobster, pink salmon).
  - Gear movements (e.g. *Caulerpa taxifolia* within the Mediterranean).
  - Release of packing material for living crustaceans and molluscs.
  - Discharge of frozen foods (e.g. white-spot syndrome virus in prawns).
- Aquarium industry and public aquaria.
  - Intentional releases of traded species (e.g. *Limulus polyphemus*).
- Marine leisure tourism.
  - Transport of bait worms for anglers.
  - Movements through fishing and diving gear.
- Research and education.
  - Releases of study objects (e.g. *Mastocarpus stellatus*).
  - Transplantation experiments between different areas.
- Others.
  - Opening of new waterways.
  - Floating objects in the sea.

Once an exotic non-indigenous species has reached a recipient area, secondary vectors or natural dispersal processes might cause a further expansion towards other areas. In general ship movements (hull fouling and ballast water) are the most important primary vectors for the introduction of exotic non-indigenous species. As a secondary vector of transport to the Dutch waters, natural expansion and shellfish transport become more important (Wolff, 2005).

In this study, a distinction is made between exotic non-indigenous and NE Atlantic non-indigenous species. The area of origin of exotic species is located outside the NE Atlantic shelf and for these species a distinction between the possible vectors is made. For most species indigenous for the NE Atlantic, that recently entered the Oosterschelde estuary, the distinction between the possible vectors is more difficult. An extension of the natural range of a species, caused by climatic changes, can be facilitated by anthropogenic influences, like stock movements.

The Oosterschelde estuary is a tidal inlet of the North Sea with unique characteristics, which enable introduced species to establish themselves. Through the construction of the Delta works in 1986, an environment was created with decreased current velocities, high temperatures during summer and a constant salinity. The former estuary provides different types of habitats. The bottom of the tide-ways are sandy and towards the eastern part of the estuary the texture of the sediment is finer and the mud content increases. Especially in the eastern part peat banks protrude through the sediments. Most of the tide-ways are protected with hard substrata of different nature. Limestone and various kinds of non-erosive blocks form 'a natural rocky coast'. The estuary is connected through sluices with brackish waters. Through this diversity in habitats it is relatively easy for an introduced species to establish itself.

## 6.2 Results

In Table 11, the exotic non-indigenous species in the Oosterschelde and adjacent waters are listed. Although it is not always possible to identify the primary vector, it was recorded for the exotic non-indigenous species. If known, also the secondary transport vector for the introduction in the Dutch coastal waters is given. For each of the species the area of origin is listed as well as the location where it was first found in Europe. In Appendix B.1 a more detailed overview is given for these species.

Table 11 Exotic non-indigenous species in the Oosterschelde and adjacent waters, primary and secondary transport vector (AQ = aquaculture, SH = Ships Hull, B = ballast water and dry ballast, H = Host, D = deliberate, T = trade, N= Natural transport ? = unknown) and year of introduction in NL. For a more detailed description of the species: see Appendix B.1

| Taxon | Species | Prim vector | Sec Vector | Year NL |
|---|---|---|---|---|
| Algae | *Acrochaetium densum* | ? | ? | 1967 |
| | *Agardhiella subulata* | AQ | ? | 1998 |
| | *Alexandrium leei* | ? | ? | 1991 |
| | *Anotrichium furcellatum* | AQ | ? | 1950 |
| | *Antithamnionella spirographidis* | SH | AQ | 1974 |
| | *Antithamnionella ternifolia* | SH | AQ | 1951 |
| | *Botrytella sp* | ? | ? | 1919 |
| | *Codium fragile ssp tomentosoides* | SH | AQ | 1904 |
| | *Colaconema dasyae* | AQ | H | ca. 1960s |
| | *Colpomenia peregrina* | AQ | ? | 1986 |
| | *Dasya baillouviana* | AQ | ? | 1950 |
| | *Dasysiphonia sp* | AQ | ? | 1994 |
| | *Elachista sp* | ? | H | 1993 |
| | *Grateloupia turuturu* | AQ | ? | 1993 |
| | *Leathesia verruculiformis* | ? | H | 1994 |
| | *Lomentaria hakodatensis* | AQ | ? | 2004 |
| | *Myriactula sp* | ? | H | 1983 |
| | *Odontella sinensis* | B | ? | 1905 |
| | *Polysiphonia harveyi* | ? | ? | 1960 |
| | *Polysiphonia senticulosa* | ? | ? | 1993 |
| | *Sargassum muticum* | AQ | N | 1980 |
| | *Ulva pertusa* | ? | ? | 1993 |
| | *Undaria pinnatifida* | AQ | D | 1999 |
| Protista | *Bonamia ostreae* | AQ | AQ | 1980 |
| | *Haplosporidium armoricanum* | AQ | AQ | 1974 |
| | *Marteilia refringens* | AQ | AQ | 1974 |
| Porifera | *Acervochalina loosanoffi* | AQ | ? | 1880s |
| | *Celtodoryx girardae* | AQ | ? | 2002 |
| | *Haliclona xena* | AQ | ? | 1982 |
| | *Mycale micracanthoxea* | ? | ? | 19th c. |
| | *Scypha scaldiense* | ? | ? | 1951 |
| Cnidaria | *Garveia franciscana* | ? | ? | 1920 |
| | *Gonionemus vertens* | ? | ? | 1960 |
| | *Haliplanella lineata* | SH | AQ | 1912 |
| | *Nemopsis bachei* | SH | ? | 1990s |
| | *Thieliana navis* | ? | ? | 1964 |
| Platyhelminthes | *Stylochus flevensis* | ? | ? | 1921 |
| Annelida | *Ficopomatus enigmaticus* | SH | ? | 1968 |

| Taxon | Species | Prim vector | Sec Vector | Year NL |
|---|---|---|---|---|
| | *Janua brasiliensis* | SH | H | 1985 |
| | *Marenzelleria wireni* | B | ? | 1983 |
| | *Nereis virens* | ? | ? | 1915 |
| | *Proceraea cornuta* | SH | AQ | 1941 |
| Nematoda | *Anguillicola crassus* | AQ | ? | 1985 |
| Crustacea | *Balanus eburneus* | SH | ? | 1890s |
| | *Callinectes sapidus* | B | ? | 1932 |
| | *Caprella mutica* | ? | ? | 1993 |
| | *Elminius modestus* | SH | ? | 1946 |
| | *Eriocheir sinensis* | B | ? | 1929 |
| | *Eurytemora americana* | ? | ? | 1963 |
| | *Hemigrapsus penicillatus* | SH | ? | 2000 |
| | *Hemigrapsus sanguineus* | B | ? | 1999 |
| | *Monocorophium sextonae*[1] | SH | ? | 1952 |
| | *Mytilicola intestinalis* | AQ | ? | 1949 |
| | *Mytilicola orientalis* | AQ | AQ | unknown |
| | *Mytilicola ostreae* | AQ | AQ | 1992 |
| | *Palaemon macrodactylus* | ? | ? | 1999 |
| | *Rhithropanopeus harrisii* | ? | ? | 1874 |
| Mollusca | *Crassostrea gigas* | AQ | AQ | 1964 |
| | *Crepidula fornicata* | AQ | ? | 1929 |
| | *Ensis directus* | B | N | 1981 |
| | *Mercenaria mercenaria* | AQ | AQ | 1950s |
| | *Mya arenaria* | SH | N | 1765 |
| | *Petricola pholadiformis* | AQ | ? | 1905 |
| Bryozoa | *Smittoidea prolifica* | AQ | ? | 1999 |
| | *Tricellaria inopinata* | SH | ? | 2000 |
| Urochordata | *Botrylloides violaceus* | SH | ? | 2000 |
| | *Pterophora japonica* | ? | ? | 2004 |
| | *Styela clava* | SH | AQ | 1974 |
| Vertebrata | *Oncorhynchus mykiss* | T | ? | 1960s |

In order to identify recent non-indigenous species in the Oosterschelde estuary, the inventory of 1979 is used as a base-line (Elgershuizen *et al.*, 1979). In 2000, Stegenga (2002) reported the changes in the algal composition and more recently, Wolff (2005) published a comprehensive article concerning the non-indigenous species in the marine and estuarine environment. In Table 12, a chronological overview is given of the introduction of NE Atlantic non-indigenous species in the Oosterschelde. A more detailed description of NE Atlantic non-indigenous species is presented in Appendix B.2 of this report. It should be noted that NE Atlantic species, as defined in this report could also be introduced into the Oosterschelde by natural transport processes. This definition is wider than the definition of Wolff (2005) where NE Atlantic species could only be introduced by means of human activities.

Table 12 NE Atlantic non-indigenous species that recently entered the Oosterschelde

| Species | Year | Vector | Where |
|---|---|---|---|
| *Palinurus elephas* | 1769 | SH | eastern part |
| *Leptochiton cancellatus* | 1897 | AQ | eastern part |
| *Elysia viridis* | 1899 | N | |
| *Sabellaria spinulosa* | 1938 | AQ | eastern part |
| *Calyptraea chinensis* | 1940 | AQ | eastern part |
| *Polydora hoplura* | 1940 | AQ | eastern part |
| *Syllis gracilis* | 1940 | AQ | eastern part |
| *Syllidia armata* | 1943 | AQ | eastern part |
| *Goniodoris castanea* | 1949 | ? | |
| *Hymeniacidon perlevis* | 1951 | AQ | eastern part |
| *Tritonia plebeia* | 1952 | ? | |
| *Palaemon adspersus* | 1953 | ? | Ouwerkerk |
| *Goniodoris nodosa* | 1956 | ? | |
| *Prorocentrum triestinum* | 1961 | ? | |
| *Microphtalmus similis* | 1962 | ? | |
| *Gobius niger* | 1964 | ? | Veerse Meer |

[1] The crustacean *Monocorophium sextonae* is often indicated as an exotic species. However this species is actually a cryptogenic species (Wolff, 2005)

| Species | Year | Vector | Where |
|---|---|---|---|
| *Branchiomma bombyx* | 1973 | ? | Kanaal |
| *Calliostoma zizyphinum* | 1976 | AQ | eastern part |
| *Haliclona rosea* | 1976 | AQ | eastern part |
| *Aplidium glabrum* | 1977 | ? | eastern part |
| *Dendronotus frondosus* | 1977 | N | |
| *Diplosoma listerianum* | 1977 | N | western part |
| *Gibbula cineraria* | 1980 | ? | eastern part |
| *Idmidronea atlantica* | 1985 | N | central part |
| *Thecacera pennigera* | 1985 | ? | |
| *Bugula stolonifera* | 1986 | SH | |
| *Alexandrium tamarense* | 1989 | ? | |
| *Gymnodinium mikimotoi* | 1989 | ? | |
| *Hermaea bifida* | 1989 | ? | central part |
| *Inachus phalangium* | 1989 | ? | western part |
| *Leuckartiara octona* | 1989 | ? | western part |
| *Lomentaria clavellosa* | 1989 | ? | eastern part |
| *Plocamium cartilagineum* | 1989 | ? | western part |
| *Schizomavella linearis* | 1989 | ? | western part |
| *Balanus balanus* | 1990 | AQ | eastern part |
| *Phycodrys rubens* | 1991 | ? | eastern part |
| *Facelina auriculata* | 1992 | ? | |
| *Placida dendritica* | 1992 | ? | central part |
| *Athanas nitiscens* | 1994 | N | |
| *Suberites massa* | 1994 | ? | western part |
| *Limacia clavigera* | 1995 | N | western part |
| *Bowerbankia citrina* | 1997 | ? | |
| *Polycera quadrilineata* | 1997 | ? | western part |
| *Janolus hyalinus* | 1998 | N | central part |
| *Jorunna tomentosa* | 1998 | N | |
| *Parablennius gattorugine* | 1998 | N | western part |
| *Acanthocardia echinata* | 1999 | ? | central part |
| *Chilionema foecundum* | 1999 | ? | western part |
| *Flabellina pedata* | 1999 | ? | |
| *Geitodoris planata* | 1999 | N | |
| *Molgula complanata* | 1999 | ? | western part |
| *Myriotrichia clavaoformis* | 1999 | ? | Grevelingen |
| *Onoba semicostata* | 1999 | ? | western part |
| *Porphyrostromium boryanum* | 1999 | ? | western part |
| *Ulva tenera* | 1999 | ? | western part |
| *Bugula simplex* | 2000 | SH | eastern part |
| *Janiropsis breviremis* | 2000 | ? | western part |
| *Amphiporus lactifloreus* | 2001 | ? | eastern part |
| *Bimeria vestita* | 2001 | ? | central part |
| *Carcinonemertes carcinophila* | 2001 | ? | western part |
| *Emplectonema gracile* | 2001 | ? | western part |
| *Flabellina lineata* | 2001 | ? | |
| *Lineus sanguineus* | 2001 | ? | western part |
| *Nemertopsis flavida* | 2001 | ? | western part |
| *Nephasoma minuta* | 2001 | ? | eastern part |
| *Nolella pusilla* | 2001 | ? | eastern part |
| *Tetrastemma ambiguum* | 2001 | ? | western part |
| *Tetrastemma coronatum* | 2001 | ? | eastern part |
| *Tetrastemma robertianae* | 2001 | AQ | eastern part |
| *Trivia arctica* | 2001 | ? | |
| *Fenestrulina malussii* | 2002 | N | eastern part |
| *Petalonia filiformis* | 2002 | ? | western part |
| *Polysiphonia brodiaei* | 2002 | ? | western part |
| *Prosorhochmus claparedii* | 2002 | ? | western part |
| *Trinchesia rubescens* | 2002 | ? | |
| *Eubranchus farrani* | 2003 | ? | central part |
| *Gobius paganellus* | 2003 | N | |
| *Griffithsia corallinoides* | 2003 | ? | eastern part |
| *Halecium lankesteri* | 2003 | ? | western part |
| *Liocarcinus pusillus* | 2003 | ? | central part |
| *Sertularella ellisii* | 2003 | ? | western part |
| *Balistes carolinensis* | 2004 | N | central part |
| *Cutleria multifida* | 2004 | ? | western part |
| *Gobiusculus flavescens* | 2004 | N | eastern part |

| Species | Year | Vector | Where |
|---|---|---|---|
| *Amphiura brachiata* | 2005 | ? | |
| *Corymorpha nutans* | 2005 | ? | western part |
| *Haliclona cinerea* | 2005 | AQ | construction pit |
| *Halisarca dujardini* | 2005 | ? | western part |
| *Oscarella lobularis* | 2006 | ? | western part |

## 6.3 Discussion

In total 158 non-indigenous species have been found in the SW Delta area: 69 with an exotic origin and 89 with a NE Atlantic distribution. 32% of the exotic species were introduced primarily by shipping and 36% by aquaculture. The remaining 32% were brought into the area by trade or its vectors are unknown. The total of 69 exotic species is less than the 80 estimated species for the whole North Sea in 1998 (Reise *et al.*, 1999).

Table 13 Area of origin and vectors for the exotic species in the Oosterschelde estuary.

| Vector/origin | Pac. | NW Atl. | Ind.Oc./trop | Med/Ponto | Unkn. | total |
|---|---|---|---|---|---|---|
| Ships | 12.5 | 7 | 1.5 | 0 | 1 | 22 |
| Aquaculture | 12 | 7.5 | 0 | 2.5 | 3 | 25 |
| Trade | 1 | 0 | 0 | 0 | 0 | 1 |
| Unknown | 11.5 | 3.5 | 1 | 1 | 4 | 21 |
| total | 37 | 18 | 2.5 | 3.5 | 8 | 69 |

The number of introductions from the Pacific is larger than the number from the NW Atlantic and most species were brought into the NE Atlantic by aquaculture (Table 13). The vectors favored different taxonomic groups. Shipping was most successful for crustaceans (32% of the introductions), followed by polychaetes (18%), and algae (14%). Sponges were not introduced by this vector. Aquaculture favored algae (40%), followed by sponges and crustaceans (each 12%). Polychaetes were not introduced by this vector.

The number of NE Atlantic species entering the Oosterschelde estuary is slightly larger than the number of exotic species. 50% of the exotic species were brought into the area since 1971, while the introduction of NE Atlantic species in the Oosterschelde estuary happened more recently. 50% of the species entered the estuary after 1996 (Figure 19). This might partly be a temporary effect related to the mild winters. It might be suspected that many of these species will disappear again in case of a severe winter.

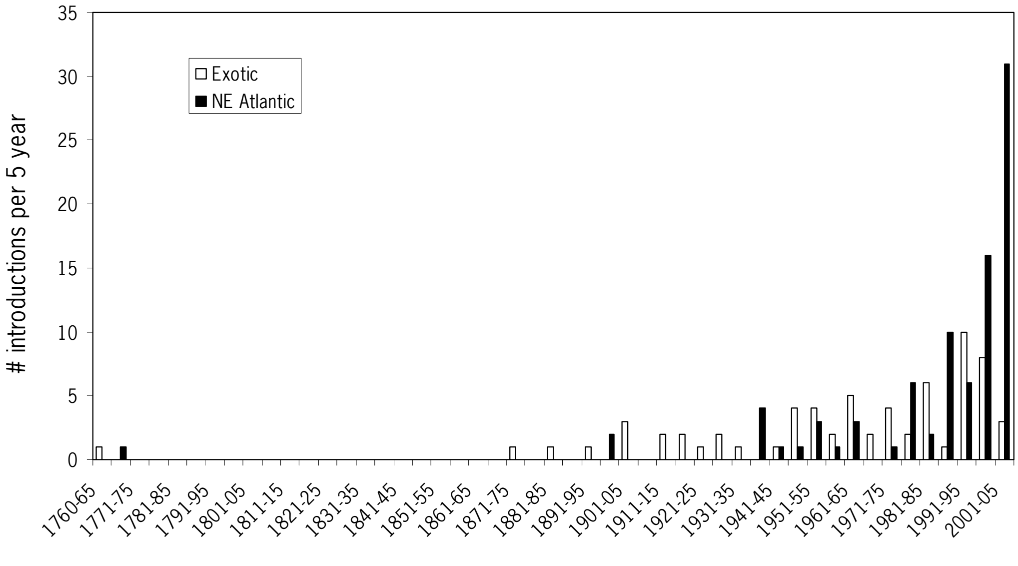

Figure 19: Number of introductions (first observations) of exotic and NE Atlantic non-indigenous species in the Oosterschelde and adjacent waters per 5 years.

There might be several reasons for the increased introductions of NE Atlantic species after 1996.

- Climatic changes, the winters of 1995/96 and 1996/97 were the last severe ones. As the temperature in the Oosterschelde estuary is lower during winter than in the North Sea, mild winters favor NE Atlantic species to establish themselves.
- An increase in the number of underwater observations and the accessibility of the results. The number of observations strongly increased with the popularity of diving in combination with photography and the results can be accessed through the internet, for example through 'Stichting Anemoon'.
- Increased introductions due to increased transport related to human activities.

But it is most likely that all three factors are involved:

- 21% of the species belongs to the nudibranchs, a group of species that is known to be sensitive for changes in temperature. This might partly be a temporary effect. It might be suspected that many of these species will disappear again in case of a severe winter.
- 12% of the species belonged to nemertins, a group of species that might have been overlooked in the past.
- 10% of the species belonged to algae, 9% to sponges and 8% to crustaceans, a contribution that is more similar with the introduction of exotic species through aquaculture than shipping.

Once an introduction is successful, the introduced species might influence the biodiversity of the communities in the recipient area. In most cases, a successful introduction of an exotic species will result in an increase in biodiversity and the impact on the other organisms is negligible or low. However in some exceptional cases an introduction can have a significant effect on the functioning of the ecosystem. An example for this is the introduction of *Crassostrea gigas* in the Oosterschelde. During a monitoring program of sublittoral communities in the Oosterschelde a significant decrease in biodiversity (Figure 20 ) was found by an increasing percentage cover of the introduced exotic *Crassostrea gigas* (Kluijver & Dubbeldam, in prep).

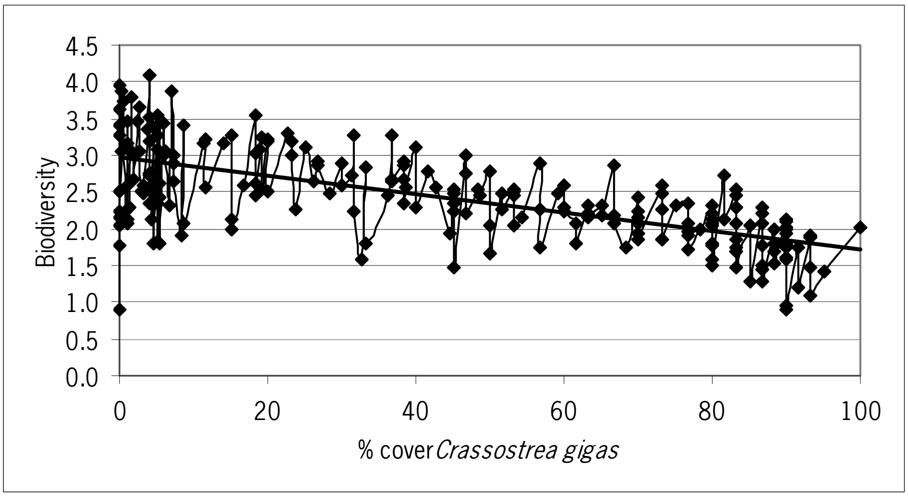


Figure 20: Relation between the percentage cover of *Crassostrea gigas* and the biodiversity of the original communities in the Oosterschelde estuary (n=230, P<5%) (Kluijver & Dubbeldam, in prep).

A similar effect was found for the introduced tunicate *Didemnum lahillei*. Although its area of origin is uncertain at this moment, it might be possible that it is a NE Atlantic species. Its distribution pattern in the Oosterschelde suggest that it has been introduced with oyster imports.