Risk analysis of mussel transports within the Wadden Sea

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Introduction

This risk analysis focuses on the probability that the transport of mussels within the Wadden Sea raises the risk that non-native species have a significant impact on the ecosystem. To do this the risk assessment protocol for shellfish transports of the Dutch government is used. Hereby the probability is assessed that:

[1] non-native species are introduced with shellfish transports into an area where they didn't occur yet,

[2] non-native species are able to settle within an area where they didn't occur yet because of shellfish transports,

3] non-native species are able to expand their populations within the Wadden Sea because of shellfish transports, and finally

[4] non-native species have a significant impact on the ecosystem because of shellfish transports.

To study these aspects we focused on the natural distribution capacities of non-native species within the Wadden Sea, and the habitats where most non-native species are found, i.e. the non-native species hotspots in the Wadden Sea. In addition the importance of a species specific risk assessment is described for species that are present areas where from mussels are transported, but are not present areas in the Wadden Sea where they are imported.

Natural distribution capacities of non-natives within the Wadden Sea

Most marine species have a pelagic life-stage during which they distribute themselves with the sea currents. Depending on the strength of the currents and the duration of this pelagic life-stage they can distribute themselves over large distances. They can also use the sea-currents for their distribution by hitchhiking on drifting algal assemblages, wood or other floating objects. The thongweed *Himanthalia elongata* for example commonly washes ashore in the Wadden Sea. As this species does not occur in The Netherlands and Belgium, these individuals most likely origin from the French and British coasts and have drifted along the south-north current up to the Wadden Sea. This is also confirmed by the large variety of organisms, which are often still alive, that are found on these thongweeds. Among these species there are other algal species but also animals like barnacles, crabs, snails and hydroids that are known to occur in France and Britain. For most of these species the Wadden Sea waters are probably too cold. They therefore don't settle there and do not pose a threat.

In fact, by using the general south-north current along the western European coast (Turrell et al., 1992), most species that are present in the Dutch Wadden Sea will be able to distribute themselves by natural means via the Niedersachsen and Schleswig-Holstein Wadden Sea to the Danish Wadden Sea, assuming that the local habitat there is suitable for their settlement. This may happen directly by larvae drifting along in the sea-currents for 2 to 4 weeks, or indirectly by settling on hard substrates like embankments, buoys and structures in harbours that can function as stepping stones on their way north. An example of such a species is the Japanese oyster *Crassostrea gigas*, which was able to distribute itself throughout the Wadden Sea up north along the Danish coast into various Norwegian and Swedish fjords. This has most likely happened by drifting along with the sea-currents (Wrange et al., 2010) as in most of

the Norwegian and Swedish fjords where the Japanese oyster is found, there is little to no boat traffic and no shellfish aquaculture activities. Also the population genetics of the oyster populations within the Wadden Sea supports this.

Although most non-native species live on hard substrates and have an extended pelagic stage during which they can distribute themselves over the whole Wadden Sea, some non-native species do not. Those species usually do not have a significant impact on the ecosystems however and are therefore not considered "invasive" species because of their relatively weak distribution capacities. For such non-species that cannot easily distribute themselves over the Wadden Sea with the sea-currents, shellfish transports may significantly increase the chance that they are introduced into areas where they did not occur yet.

Non-native species in shellfish production areas

From four species inventories focusing on non-native species in the Wadden Sea between 2009 and 2013 (Gittenberger et al. 2010, 2012, 2013), it was concluded that by far most non-native species (> 95 %), can be found in harbours and then especially on the floating docks (Gittenberger et al., 2010). In comparison, within areas with shellfish, only about 45% of the non-native species were found, and most of those species are only found on oyster reefs. Of the species that do occur in between mussels in mussel production areas most only occur in between and on mussels that are at least two to three years old, while only a selection of those species is found to occur in between or on mussel seed and one year old mussels, i.e. about half the number of species that is found on older mussels (Gittenberger et al., 2011). Mussels that are transported within the Wadden Sea usually concern the younger age classes.

Although the diversity of non-native species on mussels that are being transported may be relatively low, there still exists a risk that they are introduced into new areas by these transports. One therefore needs to monitor which species are present in between mussels, for example with a Shellfish Associated Species Inventory. This methodology, used throughout northwestern Europe, was specifically designed to get an accurate overview of the species that are present among the shellfish within a shellfish production area (Gittenberger, 2010). The list of species that is found to occur among the mussels in the export area has to be compared with the list of species known for the import area to assess whether or not a risk exists that non-native species may be introduced with the transports.

To get an accurate and complete view of the non-native species that are already present, it is best to do an assessment of the species in the harbours in the import area as previous studies show that most non-native species will have settled there. If no harbour is close by, a species inventory on an oyster reefs would probably provide the best overview of non-native species settled in the area.

For a good and reliable risk assessment of the transport of mussels throughout the Wadden Sea it is essential to have accurate lists of species that are present in de various regions of the Wadden Sea. Until recently such species lists were apparently not available. Therefore some parties mistakenly concluded that various non-native species in the Wadden Sea were only locally distributed and that one could manage their spread by stopping all mussel transports. Most of the non-native species turned out to be widely distributed in the Wadden Sea however. They were probably missed in previous years because the ongoing monitoring programs did not focus on finding non-native species. As a result of four species inventories in the Wadden Sea since 2009 that did specifically focus on finding non-native species, more than 20 non-native species

new to the Dutch Wadden Sea were discovered and more than 30 species new to the Schleswig-Holstein Wadden Sea were recorded of which about 14 species appear to be new to Germany. Most of these species have probably been overlooked in the past because the habitats in which they settled were never or rarely monitored and/or the taxonomical expertise available was insufficient, e.g. for the algal species.

Conclusions

The high number of species that was found to be new to the Wadden Sea during the recent non-native species inventories can for the most part be explained by the fact that the ongoing monitoring programs in the region did not focus on species that are found on hard substrates like rocks and floating docks. In addition, some taxa, like the macro-algae, appear to be understudied in the region. To effectively assess and manage the risk of non-native species being transported within the Wadden Sea, one should know which native and non-native species are already there. Many non-native species that were only known from the Dutch part of the Wadden Sea for example, were also found to occur the German Wadden Sea during the recent non-native species inventories. As most marine species have a pelagic life stage, it is to be expected that species that occur in the Dutch part of the Wadden Sea also occur in German part. They have probably spread with the general south to north sea-current along the western European coast as is also confirmed by the distribution patterns of these species, which indicate that they can freely distribute themselves within and between the Dutch and German parts of the Wadden Sea. The most important stepping stones in their distribution are probably the harbours, which were found to be main hotspots of non-native species in the Wadden Sea. In comparison the diversity of non-native species found on mussel beds is relatively low. More in general during the recent non-native species inventories, no indications were found that the transport of mussels within the Wadden Sea will significantly raise the risk that non-native species will increase their distributional range within the Wadden Sea and have a significant impact on the ecosystem.

Schlussfolgerungen

Die hohe Anzahl der als neu fürs Wattenmeer ermittelten Arten, dürfte damit zusammenhängen, dass im Rahmen der vorhergehenden Geländearbeit die festen Substrate vernachlässigt worden sind. Dazu kommt, dass die Arten von einigen Gruppen, wie die Macro-Algen, bis jetzt nur sehr unvollständig aufgesammelt und identifiziert worden sind. Ohne Kenntnis der bereits im Wattenmeer vorhandenen Arten, lässt sich der Einfluss von Invasivarten nicht ermitteln. So ergibt sich zum Beispiel, dass viele nicht-heimischen Arten die bis jetzt nur aus den Niederlanden bekannt waren, auch im deutschen Wattenmeer vorkomen. Das ist an sich auch ganz logisch in Anbetracht der Meeresströmungen. Mit der Süd-Nord Strömung, können die meisten Arten sich im larvalen Stadium durch das ganze Wattenmeer ausbreiten. Im Rahmen der Bestandtaufnahmen wurden keinerlei Anzeichen für das Vorkommen irgendwelcher Barrieren für die natürliche Verbreitung von Arten zwischen den Teilgebieten des Wattenmeeres festgestellt. Die Häfen erwiesen sich im ganzen Wattenmeer als ‚Hotspots' für das Vorkommen von nicht-heimischen Arten, wohingegen die Gebiete mit Muscheln relativ arm an nicht-heimischen Arten waren. Im Rahmen der Bestandaufnahmen im niederländischen und im deutschen Teil des Wattenmeeres wurden keinerlei Anzeigen dafür gefunden, dass die Muscheltransporte innerhalb des Wattenmeeres einen wesentlichen Einfluss auf die Verbreitung der nicht-heimischen Arten hatten.

Planned species inventories

As explained above, it is unlikely that mussel transports in and from the Niedersachsen area throughout the Wadden Sea will have a significant negative impact on the ecosystem because of non-native species that were aided in their distribution by these transports. Taking into account the precautionary principle however, the risk of transporting mussels will be assessed in the coming years by monitoring the mussel production areas from which the transports may take place, and by assessing for each non-native species found the risk of it being transported together with the mussels. More specific the research plans for the coming years include:

1. Species inventories focusing on all non-native species that are present on and in between the mussels in the mussel production areas in the Niedersachsen Wadden Sea. These inventories will be done following a species inventory methodology, i.e. the Shellfish Associated Species Inventory (SASI), which is also used since 2010 for mussel transports to and within the Netherlands to assess the risk of non-native species.

2. For each of the species recorded, it will be assessed whether it is likely that they will settle, expand their population and impact the ecosystem in the potential import region because of shellfish transports within the Wadden Sea.

3. To effectively assess the risk of non-native species being imported in certain regions within the Wadden Sea, one should know which non-native species are already there. Therefore the non-native species diversity will also be assessed in potential import areas both in and just outside of the mussel production areas, with a focus on known non-native species hotspots like harbours and oyster reefs.

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