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Non-indigenous species presence and distribution in intertidal hard substrate environments of the Western Scheldt

Results of Transect Monitoring inventory of 2016

by

Sander Wijnhoven



Study conducted by Ecoauthor commissioned by the Netherlands Food and Consumer Product Safety Authority (NVWA) of the Netherlands Ministry of Economic Affairs (EZ)

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Photos cover from left to lower right: a) Transect at Bath (Right line outside marina in June 2016) view from the lower intertidal; b) Hemigrapsus takanoi, a non-indigenous species, as present in the transect near Bath; c) A quadrant in Fucus vesiculosus dominated habitat in the low intertidal zone near Bath as inventoried on July the 27th, 2016.

Unless indicated differently, all used photos are taken by Sander Wijnhoven.

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Abstract

The current report presents the results of a transect monitoring inventory of intertidal hard substrate benthic communities in the Western Scheldt with the focus on non-indigenous species (NIS) as performed in the summer of 2016. Six transects at Breskens, Vlissingen, Terneuzen, Hoedekenskerke, Hansweert and Bath on regular spatial intervals in the estuarine gradient of the Western Scheldt ware inventoried distinguishing two separate transect lines perpendicular on the water line through the different dominant habitat types and three intertidal strata (i.e. high -, middle - and low intertidal zone). A total of nine NIS and three cryptogenic species are found for which the spatial distribution and relative abundances related to the estuarine gradient and environmental characeristics are presented. Results are compared with the situation as observed in 2015 during transect monitoring within the frame of SEFINS amongst others in the same area, and are discussed in relation to the distribution and relative abundance of potential competing and/or impacted native species.

Important findings are the confirmation of the almost entire replacement of the native amphipod *Melita palmata* by the non-indigenous *M. nitida* over the entire estuarine gradient of the Western Scheldt including the polyhaline zone where *M. nitida* was recorded for the first time in 2015. Also the for the first time in 2015 recorded presence of the non-indigenous anemone *Diadumene lineata* upstream from Baarland (i.e. at Hansweert) is confirmed in 2016, and the species is besides abundantly present in between also present near the mouth of the estuary at Breskens. The Japanese shore crab *Hemigrapsus sanguineus* is abundantly present in the Western Scheldt and observed in the entire estuarine transect from Breskens up to Bath. Its distribution in the Western Scheldt was so far largely unclear and the findings are surprising as the species was not common during the 2015 inventories. The dominant shore crab as recorded in 2015, the non-indigeous *H. takanoi*, is still abundantly present in the entire estuarine gradient, but in 2016 only the most abundant non-indigenous shore crab species in the eastern half of the estuary, and at Bath less abundant than the native shore crab *Carcinus maenas*. The Japanese oyster *Crassostrea gigas* is abundantly present at all research sites, including just in front of the fresh water inlet at Bath (which might be surprising). A new non-indigenous species for the Western Scheldt might be the presence of the acute bladder snail *Physella acuta* at Bath. It is unclear whether it is just a temporal presence of accidently introduced specimen(s) or if there is an established population in the Western Scheldt (as wel). The recording of the non-indigenous red algae species *Caulacanthus ustulatus*, common present at Vlissingen, is a confirmation of earlier findings of the species in the vicinity and indicates the potential of further distribution of the species in the Western Scheldt the coing years. The other non-indigenous species observed are the broad distribution and dominance of the barnacle communities by *Austrominius modestus* from the mouth of the estuary up to somewhere between Hansweert and Bath, and the known presence of *Mnemiopsis leidyi* in the estuary.

1. Introduction

In 2015 a pilot inventory of non-indigenous species (NIS) in a selection of estuaries (i.e. Scheldt, Wash and Canche) was performed within the frame of the INTEREG IV A 2 Seas project SEFINS as commissioned by the NVWA, using the transect monitoring methodlogy. The study was focused on the Scheldt estuary where 10 transects were inventoried (6 in the Netherlands, 4 in Belgium) and a first comparison was made with the two other estuaries where in each 2 transects were inventoried (Wijnhoven et al., 2015). As the 2015 inventory provided amongst others valuable information on the spatial distribution, relative abundances, habitat preferences and potential impacts of several NIS in the intertidal hard substrate habitats of the Western Scheldt, the NVWA asked Ecoauthor to continue the monitoring in the Western Scheldt in 2016 and 2017. Transects were in 2015 located in couples of transects inside - and outside marinas, which resulted in inventories at three research sites in the Western Scheldt. As the NIS encountered inside marinas were generally also found in the transects outside the marinas, moreover as the number of observed NIS seemed to be positively related to total species richness that was often higher outside marinas, it was decided to solely inventory transects outside marinas in 2016 and 2017, however to double the number of research sites. Herewith a more complete coverage of the entire estuarine gradient present in the Western Scheldt is achieved, which gives better insight in the spatial distribution, population developments and potential impacts of NIS in the Western Scheldt and might enlarge the chance of encountering additional NIS the coming years. As in 2015 the complementary monitoring using SETL-plates is executed by GiMaRIS specifically inside the marinas in the vicinity of the inventoried transects, so that the combination of the two methodologies provides a representative view on the status of the occurrence and relative abundance of hard substrate related NIS in the Western Scheldt.

The current report describes the transect monitoring as conducted in 2016 (i.e. specifics of methodology as performed in 2016, characterization of research sites and transects) and presents the results of the inventories of the benthic communities and the presence of NIS in these in particular. A first comparison of the spatial distribution and relative abundances of NIS in the Western Scheldt compared with the fndings in 2015 will be presented and discussed. Relative abundances and distributions of some potentially competing and/or impacted species and the findings for cryptogenic species will be provided and discussed. Additionally the efficiency of the methodology to monitor intertidal hard substrate related NIS will be discussed.

2. Material and methods

2.1 Transect monitoring inventory

Although the monitoring in the summer of 2016 as described in this report is restricted to the Western Scheldt, the study is a continuation of the pilot project as conducted within the frame of SEFINS in 2015 (Wijnhoven et al., 2015). Comparability of results of different years is of importance. Therefore the inventories according to the Transect monitoring methodology do in general not deviate from the methodology described in Wijnhoven et al. (2015). Deviations are only found in the way inventories have been conducted in practice in the field (with no implications for the results), the timing of the inventories and the research sites selected. All deviations are described below in detail:

- Where in 2015 all transects were inventoried by at least two persons, in 2016 all transects have been inventoried by the author, working alone. Where in 2015 the two lines of a transect were always inventoried on the same day, in 2016 the lines were often inventoried on different days as inventories took more time and the tidal frame became limited. This however generally allowed identification of collected material (and algal material in need of a closer look in particular) in fresh condition on the same day before preservation. As a consequence of working alone, the search for supplementary specis in each of the investigated strata per line was done for approximately 10 minutes (instead of 5 minutes wih 2 persons) or slightly more if it was expected that specific habitats were not covered by quadrant inventories but might harbor additional species.
- In 2016 all collected fauna and algae material was preserved in 96% ethanol (instead of formaldehyde), which might have consequences for the stored material on the long term (e.g. color) but not for the identifications done directly or a couple of days after collection.
- The timing of the inventories with transect monitoring in July between the 4th and 25th in 2016 deviates from the transect monitoring in 2015 between the 6th of May and the 5th of June in the Western Scheldt (21st and 22nd of June in the Belgian part of the Scheldt estuary, 10th and 11th of June in the Canche and 15th and 16th of June in the Wash). On the one hand this is a compromise between keeping inventories comparable to those of 2015 and to the SETL plate inventories in 2016, conducted at about the same sites as the transect monitoring, however done in September. As SETL plate inventories largely focus on benthic larvae from the water column that can potentially settle on hard substrate, it is important to do the inventories in late summer (plates are in place all summer long). As transect monitoring focusses on the available communities of species that maintain on permanently present hard substrate, differences in species composition are expected to be not that large between early - and late summer. Moreover as monitoring is semi-quantitative only distinguishing distribution classes. It has to be kept in mind, however, that particularly the presence of juveniles of certain species, the coverage of certain algal species, and the presence of certain specific species might differ with and depend on the time of the year. It will be indicated if it is expected that possible differences in species composition in 2016 compared to 2015 are due to seasonality in community composition development.
- Where one of the focal comparisons in 2015 was to investigate potential differences in the presence of non-indigenous species (NIS) between inside - and outside marina environments it was decided to cover the estuarine gradient present in the Western Scheldt, better in 2016 than in 2015. This to clarify distribution patterns of observed NIS and to possibly enlarge the chance of finding additional NIS in the Western Scheldt. Keeping the relative monitoring efforts in the Western Scheldt similar, only transects outside marinas were inventoried in 2016, however extending the number of research sites from 3 to 6 (see 2.2 Research sites). In 2015 it was found that if differences in number of observed NIS per transect were found, these were generally positively related to the total species richness, and that species richness in transects was often higher outside - than inside marinas (Wijnhoven et al., 2015). Additionally, observed NIS in transects inside – and outside marinas were largely the same.

Below a basal description of the Transect monitoring methodology (further details and a protocol can be found in Wijnhoven et al. (2015)):
Transects always consist of 2 lines (perpendicular on the shore and/or waterline) preferably through two different types of habitat (preferably the dominant hard substrate habitats) situated in each other's vicinity (indicative 50 to 100 meters from each other). Habitats are often determined by different types of hard substrate and/or whether or not (different) macro-algae grow there (see Figure 1 as an example). Additionally habitats differentiate with the height in the intertidal zone (e.g. exposure time).

For each transect 3 intertidal strata are distinguished; further called the high -, middle – and low intertidal zone. The 3 different strata are distinguished by visual observation, dividing the hard substrate gradient in 3 zones by the 2 most distinguishing imaginary horizontal lines (and bounded at the lowest low water level and the highest high water level) (see Figure 1 as an example).

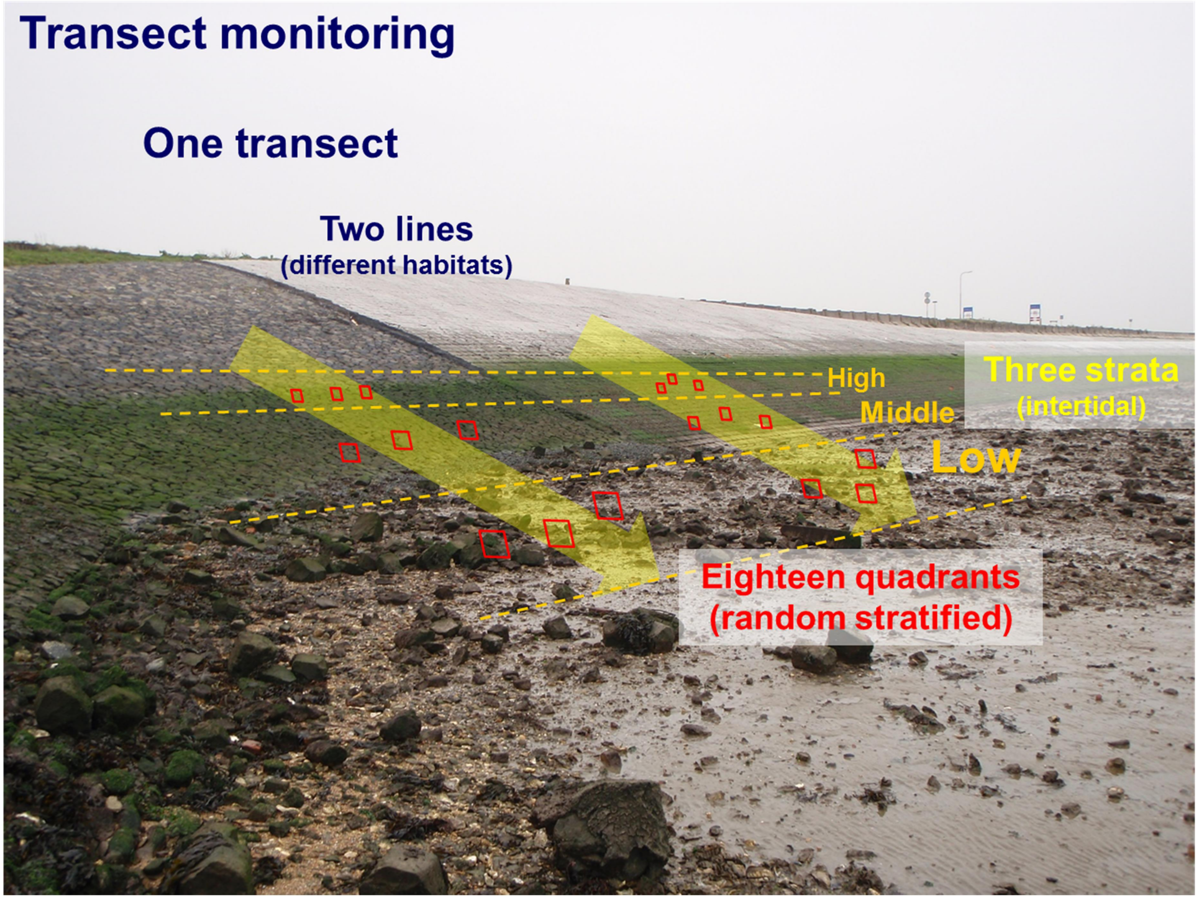


Figure 1. An example of a transect showing the ideal positioning of lines and strata and the random positioning of 18 quadrants.

The actual standardized NIS inventory in done in 0,5 by 0,5 meter quadrants (Figure 2 is an example of such a quadrant random positioned in the field). Quadrants are random placed equally distributed over the 2 lines and 3 strata which lead to 3 inventoried quadrants for each line x stratum combination to achieve a randomly stratified methodology. Although it is called random positioning, quadrants are placed as such that they give a representative view of the hard substrate habitat; i.e. if a habitat consist of reasonable areas with algae and areas without, it is made sure that both are included in the set of 3 random samples in that habitat (therefore 'random' between quotation marks).
At first a photo of the quadrant like shown in Figure 2 is taken. Then the inventory of the quadrant consists of an estimation of the total and the separate coverage (in %) of the total 3D surface by flora and fauna. Additionally dominant species (i.e. those covering more than 20 % of the total surface are noted as a habitat descriptor. This can include several species of macro-algae and sessile fauna with a total percentage coverage of even more than 100 % as they can cover each other.
In each quadrant all species (macrofauna and macro-algae, clearly visible to the naked eye) are noted with an indication of their abundance or coverage for which we only use 3 categories to speed up the inventory proces:

- Abundant: More than 10 % cover or more than 10 specimens present (indicated with A).
- Common: More than 2 % cover or more than 2 specimens present (indicated with C).
- Rare: Less than 2 % cover and only 1 or 2 specimens present (indicated with R).

Additional to the inventory of 3 quadrants per stratum, the entire stratum is investigated for approximately 10 minutes on supplementary species.

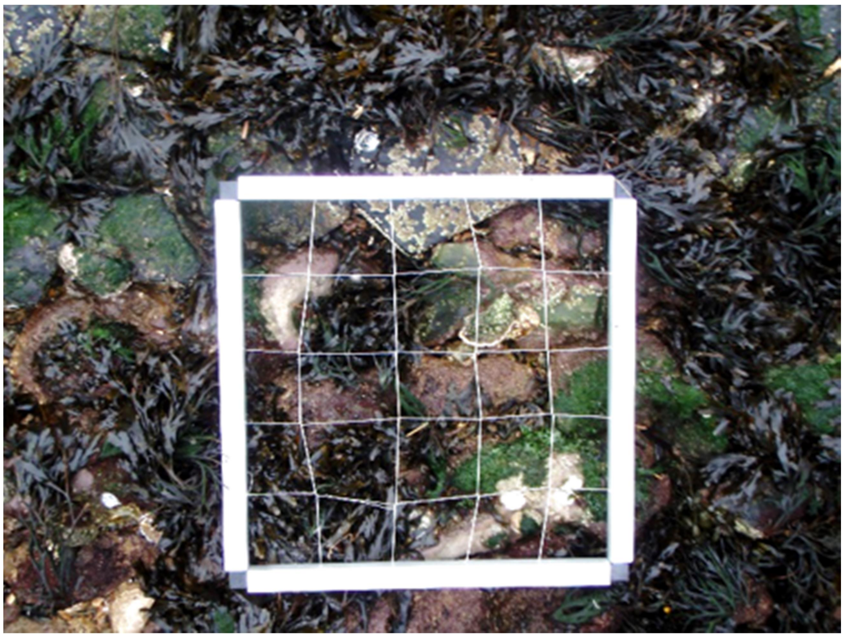


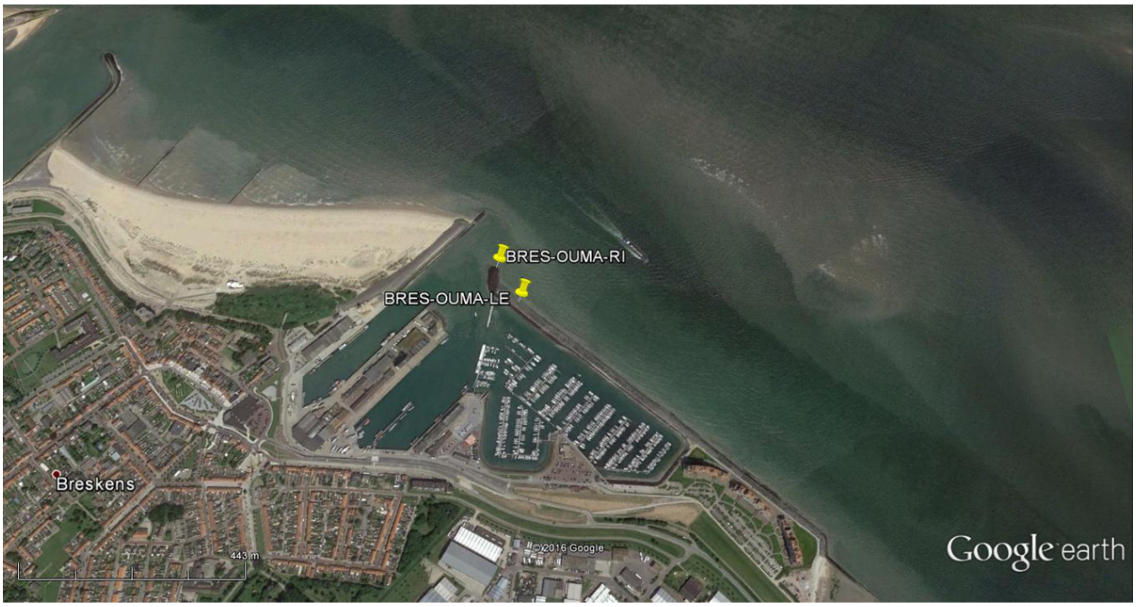
Figure 2. An example of a photo of a 'random' placed quadrant ready to be inventoried.

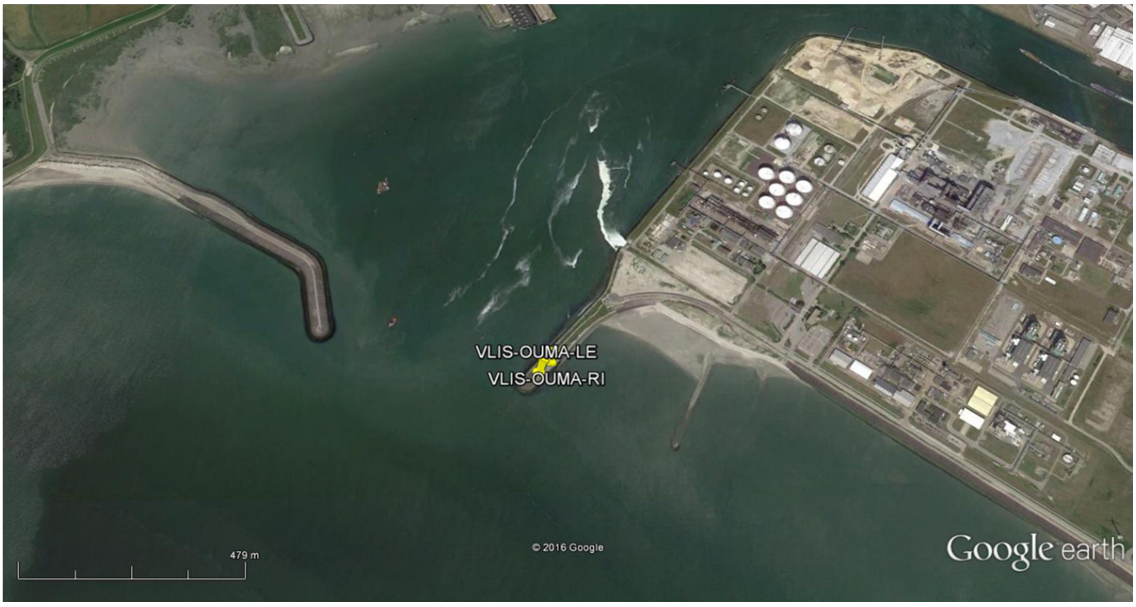
2.2 Monitoring sites

In 2016 transect monitoring is restricted to the Dutch part of the Scheldt estuary, i.e. the Western Scheldt. Aim of the inventories is to cover the estuarine gradient in the Western Scheldt as much as possible and allow comparison with the intertidal hard substrate communities and the NIS distributions in particular, in 2015. Therefore the three monitoring sites also inventoried in 2015 (Breskens, Terneuzen and Hansweert) have been inventoried again. Three additional sites (Vlissingen, Hoedekenskerke and Bath) have been selected as this optimizes the spatial coverage of the estuarine gradient. Those sites are additionally of interest as they are situated near a large harbor (Vlissingen), marina (Hoedekenskerke) and freshwater inlet (Bath).

Figure 3. Map of the Western Scheldt with indication of the monitoring sites from west to east: Breskens (BRES), Vlissingen (VLIS) Terneuzen (TERN), Hoedekenskerke (HOED), Hansweert (HANS) and Bath (BATH). At each site a transect (situated outside the marina if present: OUMA) consisting of two transect lines was inventoried (i.e. a left (LE) and a right (RI) line).

The Western Scheldt is the gate to the world port of Antwerp, but is also the entrance for large harbors like Gent and Vlissingen, and is therefore a very crowded shipping route. Until recently the system was dealing with poor water quality due to the deliverance of untreated waste water, which led to increased pollutant concentrations (e.g. heavy metals), high nutrient loads and poor oxygen conditions particularly upstream. This despite the fact that the system had and still has an important nature function, especially for waders and waterfowl. The last decennia significant improvements in water quality have been made, which have their effect on biodiversity (e.g. fish, birds, marine mammal assemblages) as well, and large parts of the system are now designated as Natura2000 area. However other risks for the system, like effects of deepening of the system for shipping with impacts on amongst others hydrodynamics and turbidity, and the increasing number and dominance of NIS in the system, are very timely. For an extensive overview of the developments of the system and the near current state, see Depreiter et al. (2014). Although soft sediment habitats like sand – and mud flats are characteristic for the system, the amount and diversity of artificial hard substrate in the system has increased during the last centuries.






TERN-OUMA-RI
TERN-OUMA-LE
445 m
© 2016 Google
Google earth


Hoedekenskerke
HOED-OUMA-RI
HOED-OUMA-LE
468 m
© 2016 Google
Google earth


Hansweert
Kruiningen
HANS-OUMA-RI
HANS-OUMA-LE
481 m
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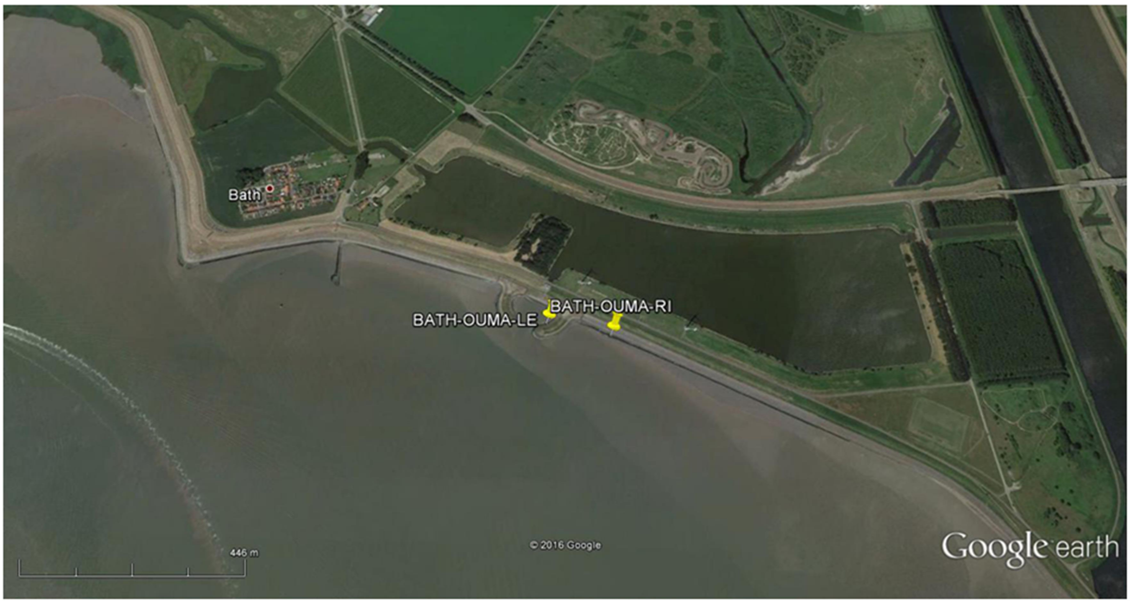


Figure 4. Detail maps of the monitoring sites at a) Breskens (BRES); b) Vlissingen (VLIS); c) Terneuzen (TERN); d) Hoedekenskerke (HOED); e) Hansweert (HANS); and f) Bath (BATH), with indication of the positioning of the left (LE) and right (RI) transect line through different habitat.

The monitoring site of **Breskens** is situated near the mouth of the estuary (Fig. 3). In 2015 transects in- and outside the marina were inventoried here. In 2016 the transect outside the marina was inventoried again (Fig. 4a) on July the 6th and 7th. Salinity on a yearly basis fluctuates between 21,7 and 32,6 depending on the tide, river run-off and wind direction, with an average salinity of 28,7. The average tidal range on a daily basis is 4,8 meters as measured near the fairway in the Western Scheldt (Rijkswaterstaat, 2009) and will approximately be the same at the transect location.
Outside the marina, the hard substrate constructions are rather new (an information sign indicates amongst others that reconstructions have taken place between 2009 and 2014). The left line is situated on a dam covered with large basalt blocks at the estuary side. The high intertidal zone (5 meters in width as measured in 2016) is partially covered with filamentous green-algae (predominantly *Ulothrix flacca* in 2016), transitioning to a 6 meters middle intertidal zone where basalt blocks are overgrown especially with *Fucus spiralis*. The vast low intertidal zone (approximately 40 meters) consists of rubble, partly overgrown with a variety of green algae and the abundant presence of barnacles, especially *Austrominius modestus*, on soft sediment (muddy fine sand) substratum. The right line is situated on the more exposed extending dam at the entrance of the marina. The high intertidal zone (2 meters) consists of green filamentous algae (*Blidingia marginata* and *U. flacca* in 2016) on asphalt transitioning to a 4 meters middle intertidal zone with predominantly *Fucus spiralis* and *Ulva cf lactuca* (also on asphalt). In the 35 meters wide lower intertidal zone, basalt blocks are often overgrown with leafy green algae (*Ulva cf lactuca*) and some brown algae and are characterized by the abundant presence of barnacles, especially *A. modestus*. The blocks are placed on a substratum of steel slags. Interesting aspect is that the habitat, especially due to the presence and constitution of the dominant algal communities, is quite different compared to the situation during the monitoring in 2015.

On the northern shore of the Western Scheldt, the site called **Vlissingen** is selected on the eastern jetty at the entrance of the harbor area Vlissingen-Borsele (Figs. 3 & 4b). After an initial visit to select suitable lines through the dominant habitat types on June the 23rd, the two lines of the transect (outside the harbor area: i.e. indicated by OUMA in the transect code) were respectively inventoried on July the 21st and 22nd. Approximate tidal range is 4,7 meters (Watersport almanak, 2016) and salinity fluctuates between 26,1 and 31,5 with an average of about 28,8 (Rijkswaterstaat, 2009). Average salinity is therefore about the same as at Breskens, however with less fluctuation.
The high zone of the intertidal range of the left line at Vlissingen (6 meters in width) has a toplayer of concrete which is partly overgrown with filamentous green algae (*U. flacca* and *Blidingia sp.*; dependent of the exact location *B. minima* or *B. marginata*). The talud continues in an approximately 15 metres *Fucus* zone on basalt (in order of elevation in the mid-intertidal zone: juvenile *Fucus sp.*, *F. spiralis* and the combined presence of *F. vesiculosus* and *F. serratus*). The low intertidal zone (10

meters of width) consists of basalt blocks containing either *Fucus sp*. (*F. serratus* and *F. vesiculosus*) or *U. cf lactuca*. Halfway the mid-intertidal zone downwards, the presence of barnacles (*A. modestus* and/or *Semibalanus balanoides*) determines the habitat as well. From the lower mid-intertidal to the lowest low-waterline oysters (*Crassostrea gigas*) are important habitat elements. In the right transectline the concrete largely lacks and is only present inbetween the basalt blocks forming the talud in the high and middle intertidal zone (respectively 3 and 7 meters wide). The hard substrate in the high intertidal zone containes much less filamentous green algae than at the left line, and basically consists of *B. marginata*. The middle intertidal zone is dominated by *Fucus sp*. (either *F. spiralis* or *F. vesiculosus*) with some patches of *U. flacca*. The low intertidal zone (extending over about 23 meters) is a horizontal oyster reef (*C. gigas* containing *U. cf lactuca* overgrowth), of which a part (middle part) consists of dumped (partly dead) oysters. From halfway the middle intertidal zone downwards again barnacles (*A. modestus* and *S. balanoides*) are present covering substantial percentages of the area, in the low intertidal zone however more patchy distributed. At Vlissingen in both transect lines numerous small tidal pools are present in the low intertidal zone that form a habitat on their own (subtidal) as they probably permanently contain water.

A salinity of around 20,7 fluctuating between 15,5 and 23,8 is recorded the last years near **Terneuzen** (Rijkswaterstaat, 2009), with a tidal difference of about 5,1 meters (Watersport almanak, 2016). This monitoring site (Figs. 3 and 4c) was inventoried on July the 4th and 5th in 2016, and has been inventoried in 2015 as well (Wijnhoven et al., 2015).
Outside the marina the left line was positioned through a narrow (2 meters) high intertidal zone dominated by mat-forming green-algae (*U. flacca* and *B. marginata*) on a substrate of hydroblocks. The high intertidal zone transitions into a 3 meters wide zone dominated by brown algae with *F. spiralis* in the upper part and *F. vesiculosus* in the lower mid-intertidal zone. The broader low intertidal zone (19 meters) consists of rubble and debris and continues into a vast soft sediment (muddy fine sand) tidal flat. The right transect line (not a perfect continues transect but an aggregation of a dike talud (high intertidal zone) and a groyne extending in predominantly soft sediment environment (middle and low intertidal zones)) is paved with gravel tiles and continues with largely bare basalt in the high intertidal zone with a width of 8,5 meters. The middle intertidal zone (top of the groyne with a width of 2,5 meters) consists of cobblestone overgrown with *Ascophyllum nodosum*. The low intertidal zone (7 meters) basically consists of rubble with oysters (*C. gigas)* and continues in a vast soft sediment (muddy fine sand) tidal flat.

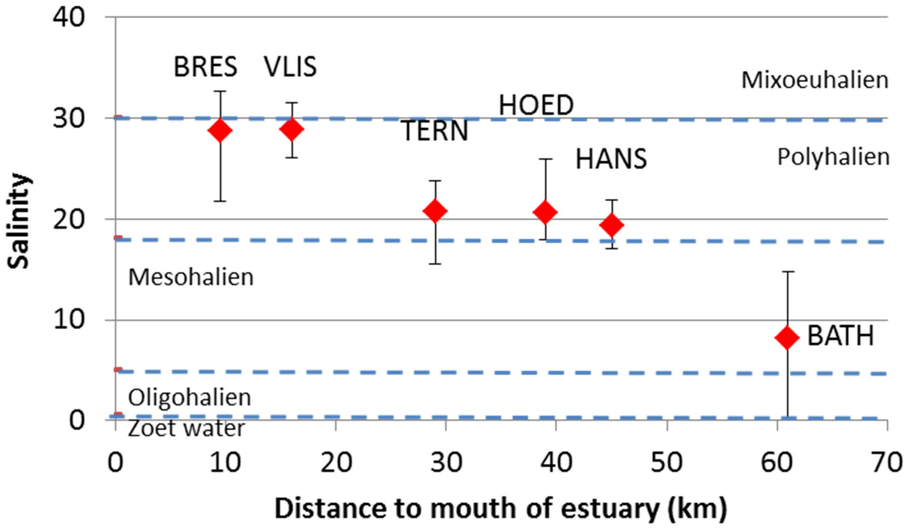
The new transect monitoring site of **Hoedekenskerke** was visited on June the 22nd, 2016, in order to select two transect lines. The inventories were done one month later on July the 19th and the 20th. The tidal range at this site on the east (estuary -) side of a marina jetty (Figs. 3 and 4d) is approximately 5,2 meters, and the salinity fluctuates between 17,9 and 25,9 on a yearly basis, with an average of 20,6 (Rijkswaterstaat, 2009).
The left transectline consists in het highest part of bare asphalted basalt, continuing with slightly asphalted basalt overgrown with filamentous green algae (predominantly *B. minima*) extending over 6 meters. The middle intertidal zone (4,5 meters of width) continues with predominantly *F. vesiculosus* on the same substrate, with however also high coverage of oysters (*C. gigas*) and barnacles (*A. modestus*). The low intertidal zone is formed by an oysterreef (*C. gigas* with abundant presence of *A. modestus* barnacles as well) and after a horizontal strech of soft substrate there are large basalt blocks overgrown with *F. vesiculosus* and *C. gigas*. Hard substrate in the low intertidal zone extents over 5,5 meters. The right transectline is in the high intertidal zone a narrow strip of 1,5 meters partly bare slightly asphalted basalt and partly overgrown with filamentous green algae (*B. marginata* and *U. flacca*). Below, a 10 meters wide *Fucus* zone (from high to low: *F. spiralis*, *F. vesiculosus*, and combined *F. vesiculosus* and *F. serratus*) is present with now and than patches of *U. cf lactuca*, on basalt. The low intertidal zone (13 meters) is characterized by the presence of oysters (*C. gigas*) with algae like *F. vesiculosus*, continuing in a bare and muddy horizontal oysterreef in the lowest part.

Near **Hansweert**, also part of the monitoring in 2015, the salinity is not much lower than near Hoedekenskerke and Terneuzen (where it is about the same): i.e. on average 19,3, fluctuating between 17 and 21,9 (Rijkswaterstaat, 2009). This is largely due to the entrance of the canal ‘Kanaal door Zuid-Beveland’ making the connection with the semi-enclosed saltwater tidal system of the Eastern Scheldt. Salt water coming from the Eastern Scheldt can enter the Western Scheldt through the sluices of Hansweert (and *vice versa*). The tidal difference is approximately 5,3 meters (Watersport almanak, 2016).

The left line of the outside marina (OUMA) transect is inventoried in 2016 on July the 18th and is situated on the extension of the dike/dam into the Western Scheldt. The high intertidal zone (3,5 meters) consists of asphalted rubble, in the highest part bare, and transitions to a coverage of mat-forming green-algae (predominantly *B. minima*) towards the middle intertidal zone. In the middle intertidal zone (3 meters) most of the asphalted rubble is covered by *B. minima* and *F. vesiculosus* with patches of barnacles (*A. modestus*) present. The lower intertidal zone (13 meters) consists of large rubble in the lowest part covered with oysters (*C. gigas*). The right line was already inventoried on July the 8th and consists of bare asphalted basalt-blocks gradually transitioning to overgrow with mat-forming green-algae (*B. minima*) in the 3,5 meters wide intertidal zone. The middle intertidal zone (4,5 meters) consists of basalt-blocks (without asphalt) covered with *F. vesiculosus*. Especially around the transition from the middle to the low intertidal zone, there are several small pools formed in the crevices and in the asphalt. The 14 meters lower intertidal zone starts with a narrow strip of horizontal asphalted rubble, transitioning to a zone with large rubble in the lowest parts covered with oysters (*C. gigas*) and some algae (e.g. *F. vesiculosus*).

A new transect monitoring site was installed near **Bath** at a freshwater inlet indirectly connected with the Schelde-Rijnverbinding (Scheldt-Rhine canal) (Figs. 3 & 4f) for which the site was visited on June the 21st, 2016. Salinity is expected to be around 8,2 here and fluctuating between 0,2 and 14,8 (Depreiter et al., 2014; Kuijper et al., 2014), with the highest fluctuations in the left transect line (situated directly at the sluices). However, salinity depends on the distance to the sluices, frequency of fresh water release and elevation in the transect line as the fresh water layer will float over the more saline layer and gradually mix the further away from the entrance point. The tidal range is about 5,9 meters here (Watersport almanak, 2016). Both transectlines were inventoried on July the 25th.
The left transectline consists of bare slightly asphalted gravel blocks in the highest part of the intertidal zone with the remainder of the high intertidal zone overgrown with filamentous green algae (especially *B. marginata*, but also *B. minima*). The zone has a total width of 2 meters. The mid-intertidal zone (4 meters) with a substratum of basalt is covered with *F. vesiculosus*. In the low intertidal zone (6 meters wide) where large basalt blocks are present in a horizontal flat, these are largely bare and muddy, however covered with *C. gigas* oysters in the lowest part that forms a talud. The right transectline contains asphalt in the highest zone and continues with Hydroblocks gradually overgrown with filamentous green algae (*B. minima* and, *B. marginata*) in the lower part of the high intertidal zone. The elevation gradient continues with a *Fucus* zone (*F. spiralis* combined with *B. minima* in the highest part and *F. vesiculosus* in the lower part). High and middle intertidal zone have a width of 3 and 2 meters respectively. In the low intertidal zone a relative narrow strip (5 meters) with small basalt blocks covered with *F. vesiculosus* is present in front of a vast area of muddy fine sand.

2.3 Sites relative to the estuarine gradient



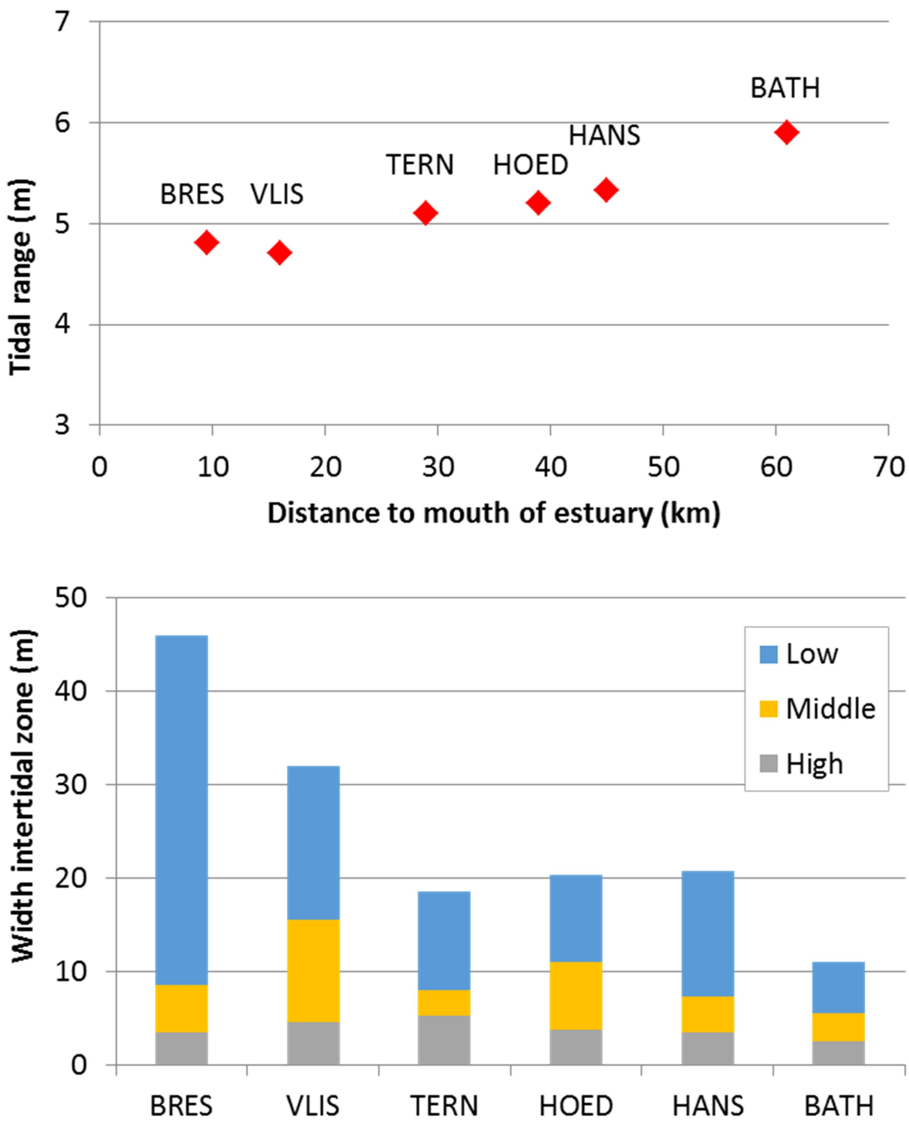


Figure 5. Positioning of the monitoring sites relative to the estuarine gradient. a) Average salinity and salinity range (yearly fluctuations without extremes) related to the distance to the mouth (at the height of Westkapelle) of the estuary as measured through the centre of the estuary. Salinity ranges according to the thalassic system are indicted with dashed blue lines. b) Yearly tidal range (without extremes) in meters related to the distance to the mouth of the estuary. Average intertidal zone width (subdivided into the low, middle and high intertial zone) in meters at the height of the two transect lines at each of the monitoring sites.

As indicated, research sites were selected to cover the estuarine gradient as present in the Western Scheldt, and on a positioning in the vicinity of a marina (or harbor and/or connection with other water bodies) in the vicinity. As most parameters do not display a linear relation with the distance to the mouth of the estuary, it is of importance to keep local environmental conditions in mind when evaluating species distributions. Moreover, environmental conditions as presented (e.g. salinity and tidal range) are extracted from literature and not recorded on theexact research sites. Local conditions might slightly deviate from the values recorded here. Moreover, as conditions like salinity will even fluctuate with elevation in the intertidal range and/or rainwater influence, there is some uncertainty in the local environmental conditions.
As indicated by the salinity measurements as extracted from literature (Rijkswaterstaat, 2009; Depreiter et al., 2014; Kuijper et al., 2014), most of the monitoring sites (except Bath) are situated in the polyhalien reach, with mixoeuhaline conditions occurring at Breskens and Vlissingen, and occasional mesohaline conditions at Terneuzen, Hoedekenskerke and Hansweert (Fig. 5a). It might

be more straightforward to talk about three 'groups' of research sites based on the salinity conditions. Salinity fluctuations are largest at Bath, and might even deviate from time to time as those depend on the drain regime of the sluices present on the site.
The tidal range is smallest at Vlissingen, although almost the same as at Breskens, and increases going east in the Western Scheldt (Fig. 5b). The width of the intertidal zone, largely also indicating the average steepness of the transect, decreases going from west to east in the Western Scheldt. It might partially reflect the available space present for the estuary, but also has to do with the type of waves and high waters the embankments have to widthstand. Besides, there are differences in the width of the intertidal zones as identified. For instance Vlissingen and Hoedekenskerke are characterized by a wide middle intertidal zone, and harbor an extensive *Fucus* zone. One of the aspects that influences the presence of a large low intertidal zone is not only the vastness of the zone, but also whether or not there is hard substrate present in the zone (sand- and mudflats are not part of the transect when no hard substrate is present). A larger transect might indicate that more different niches are potentially present for species as well. Moreover, it means that a larger area is inventoried for additional species.

2.4 Data analyses and statistics

Abundances of species are only recorded in terms of Rare (R), Common (C) and Abundant (A), distinguishing the categories at the transition from 2 to 3 specimens or percentage coverage (where only entire percentages are recorded) per quadrant, and at the transition from 10 to 11 specimens or percentage coverage. For statistical analyses to get average relative abundance indications these categories can be transformed into scores of 1, 2 and 3, so that a score of 3 for the relative abundance of a species at a certain site means that the species is abundant in all quadrants at that site (a score below 1 means that the species was only present in a subset of the quadrants; usually also rare in such quadrants).

All results were recorded in field data sheets made in Excel 2013. To combine results with environmental information and site characteristics, a database was made in Access 2013. Straight-forward statistical testing (e.g. calculation of average values and standard errors, and F- and t-testing) and graph creation was done in Excel. Calculations of the expected number of NIS in a number of random quadrants were performed by calculation of the logarithmic regression according to $Y=a(\ln X)+b$ (i.e. rarefaction curves) in Excel 2013. In the current report, considered an interim report for the 2016-2017 transect monitoring contract, no extensive data analyses on species – environment and NIS – benthic community relations are performed. These will be analysed in more detail on the complete dataset when available in 2017. First patterns in distributions of NIS over the estuarine gradient as present in the Western Scheldt are presented here, and a comparison of the research sites or transects inventoried in 2016 as well as in 2015 is made.

Recordings of additional species present in lines x strata were used as measures of the total number of species present in a line x stratum combination. This assumes that with an additional search all focal macrofauna and macro-algae species locally present (i.e. in the vicinity of the quadrants) are detected. Although there will always be a certain chance of missing species, it is expected that generally all focal species were detected; for which we adjusted the initial methodology (protocol) of searching a standardized period of time to searching till no additional species were expected anymore.

3. Results & discussion

3.1 Observed non-indigenous species

A total of 9 non-indigenous species are observed during the transect inventories in the Western Scheldt in 2016 (Table 1). These include all non-indigenous species found at the monitoring sites of the Western Scheldt during the the transect monitoring of 2015 (Wijnhoven et al., 2015). Two species (the Pacific oyster *Crassostrea gigas* and the brush-clawed shore crab *Hemigrapsus takanoi*) are found in all inventoried transects in 2016 as in 2015, even now that a larger estuarine gradient in the Western Scheldt is covered with the inclusion of the monitoring site at Bath. Both species were however in 2015 also observed more upstream at the monitoring site of Doel (Wijnhoven et al., 2015), so the presence near Bath is no surprise. However in 2016 also the Japanese shore crab *Hemigrapsus sanguineus* was present in all inventoried transects, whereas in 2015 the species was only observed in a transect at the monitoring site of Terneuzen. The New-Zealand barnacle *Austrominius modestus*, in 2015 present in all transects in the Western Scheldt, is in 2015 present in the transects also inventoried in 2015 and at the new intervening (regarding the estuarine gradient) monitoring sites of Vlissingen and Hoedekenskerke. The species is however not observed at the most upstream monitoring site near Bath. Another NIS potentially covering the inventoried estuarine gradient as observed in 2015 (Wijnhoven et al., 2015) is the amphipod *Melita nitida*. This species was however in 2016 not found in the transect inventoried at Breskens. This is however in line with the findings in 2015 as in 2015 the species was lacking in the same transect and only present in the transect inside the marina (not inventoried in 2016). The orange striped green anemone *Diadumene lineata*, in 2015 only found near Hansweert, is in 2016 also observed at the monitoring site of Breskens, and at the new site of Hoedekenskerke (Table 1).

Table 1. Overview of the presence of non-indigenous species and cryptogenic species in transects during the inventories of 2016 and 2015* in the Western Scheldt.

Site	Transect	Year	Non-indigenous species									Cryptogenic species	
			Austrominius modestus	*Caulacanthus ustulatus*	*Crassostrea gigas*	*Diadumene lineata*	*Hemigrapsus sanguineus*	*Hemigrapsus takanoi*	*Melita nitida*	*Mnemiopsis leidyi*	*Physella acuta*	*Amphibalanus improvisus*	*Ulva cf lactuca*
BATH	OUMA	2016			x		x	x	x		x	x	
HANS	OUMA	2016	x		x	x	x	x	x				x
HOED	OUMA	2016	x		x	x	x	x	x			x	x
TERN	OUMA	2016	x		x		x	x	x				
VLIS	OUMA	2016	x	x	x		x	x	x			x	x
BRES	OUMA	2016	x		x	x	x	x		x			x
HANS	OUMA	2015	x		x	x		x	x				x
TERN	OUMA	2015	x		x		x	x	x				x
BRES	OUMA	2015	x		x			x					x
HANS	INMA	2015	x		x			x	x				
TERN	INMA	2015	x		x			x	x				x
BRES	INMA	2015	x		x			x	x				x

Sites: BATH = Bath, HANS = Hansweert, HOED = Hoedekenskerke, VLIS = Vlissingen, BRES = Breskens;
Transects: OUMA = Outside marina, INMA = Inside marina
* As reported in Wijnhoven et al. (2015)

Three NIS are new compared to the inventories of 2015. These concern the acute bladder snail *Physella acuta*, te red algal species *Caulacanthus ustulatus* and the warty comb jelly *Mnemiopsis leidyi*, each only observed at one monitoring site, i.e. respectively Bath, Vlissingen and Breskens. It has to be noticed that the warty comb jelly is a pelagic species that will only be present in the intertidal

zone during low water alive if accidently stuck in a small pool or dying on an exposed site. Also during the inventories of 2015 the species was observed amongst others in the marina of Breskens, however in the subtidal zone not in the vecinty of one of the transect lines, and therefore not recorded (author's own observations).
Table 1 also indicates that two cryptogenic species or groups are observed in 2016 that might be or include NIS. The bay barnacle *Amphibalanus improvisus*, in 2015 only recorded at Belgian sites (Wijnhoven et al., 2015) is in 2016 found at three of the Western Scheldt sites (Table 1); exactly those not visited in 2015. Specimens indicated as *Ulva cf lactuca* (sea lettuce) here, very likely include or predominantly belong to *U. australis* (until recently called *U. pertusa* in the Netherlands) (Stegenga & Mol, 2002; Guiry, 2015b), see details below. Sea lettuce is in 2016 present in the transects from Hansweert up to and including Breskens, however not at Terneuzen where it was recorded in 2015. Due to too much uncertainty about the two algae complexes (*P. fucoides* and *U. cf lactuca*) about which types might be non-indigenous, and which types are encountered during the 2016 transect monitoring, we do not consider them non-indigenous here and describe the distribution of possible types as one group (i.e. *P. fucoides* or *U. cf lactuca*). For clarification of the status in the Western Scheldt, focused research for each of the groups is essential.

3.1.1. Austrominius modestus (New-Zealand barnacle)

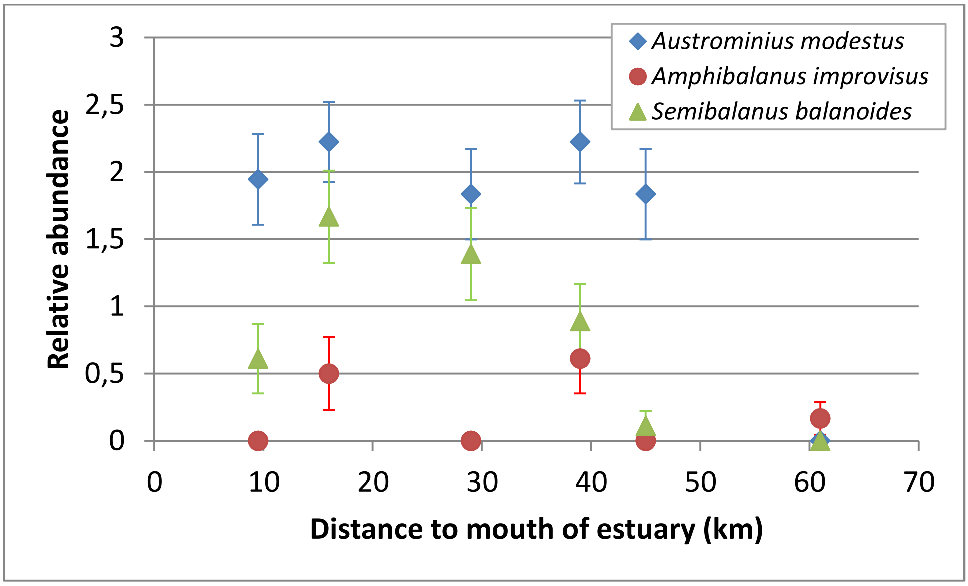
Figure 6a. *Austrominius modestus* collected in 2016 from the transect at Hansweert.

Figure 6b. *Austrominius modestus* as present on hard substrate at the monitoring site of Breskens in 2016.

Like in 2015 (Wijnhoven et al., 2015), three barnacle species are found in the transects of the Western Scheldt, of which the non-indigenous New-Zealand barnacle is the most abundant and dominant species. *A. modestus* is abundantly present at all monitoring sites except for Bath, where it is not found at all (Fig. 8a). This is in line with the findings in 2015, where *A. modestus* appeared to be absent in the transects in Belgium as well. Harms (1999) indicates that at least the larvae of *A. modestus* need mesohaline conditions to develop (Harms, 1999). The monitoring site of Bath is positioned in the mesohaline reach of the Scheldt estuary, however with depending on the exact location oligohaline conditions frequently occurring (Figure 5). The relative abundance (of around a value of 2) of *A. modestus* in the transects from Breskens up to Hansweert is abount the same, no significant differences are found, and this also accounts for the comparisons of the years 2015 and 2016 for transects that were inventoried in both years (Fig. 8b). Only, like in 2015, a significant difference ($p<0,01$) in the relative abundance of *A. modestus* with the relative abundance observed inside the marina of Hansweert (which was much lower), is found.

Figure 7. *Amphibalanus improvisus* collected in 2016 from the transect at Bath.

The cryptogenic bay barnacle *Amphibalanus improvisus* (Kerckhof et al. 2007) is in 2016 observed in three transects where it is found together with *A. modestus* that is the dominant species. A. *improvisus* is however frequently abundantly present as well: e.g. in quadrants at Vlissingen and Hoedekenskerke. Besides the mentioned transects, *A. improvisus* is also found in two quadrants at Bath, where it is the only barnacle species present. In 2015 the species was only found in transects in Belgium (Wijnhoven et al., 2015). In 2015, the native species *Semibalanus balanoides* (northern rock barnacle) was only found in the transects of Terneuzen and Breskens (always outside the marinas), where in a few quadrants it appeared to be abundant. In 2016 the species is much more common during the inventories (present in a larger percentage of the inventoried quadrants). Besides its presence at Breskens and Terneuzen, the species appears to be abundantly present at Vlissingen, present in several quadrants at Hoedekenskerke, and is common in one of the inventoried quadrants at Hansweert. The native species is in 2016 always found in quadrants together with *A. modestus* where densities are usually lower than for the NIS, although the species appears to be frequently abundant in quadrants.



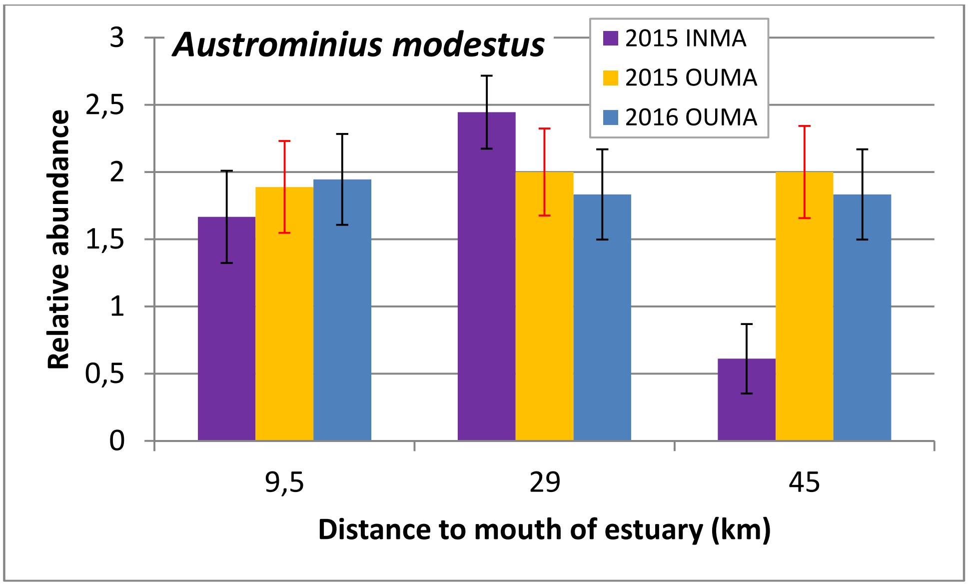


Figure 8. Average (± standard error) relative abundance of barnacles related to the distance of the monitoring sites to the mouth of the estuary. a) Comparison of barnacle species over the estuarine gradient. b) Comparison of presence of Austrominius modestus in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

3.1.2. Caulacanthus ustulatus

(No vernacular name in English or Dutch)

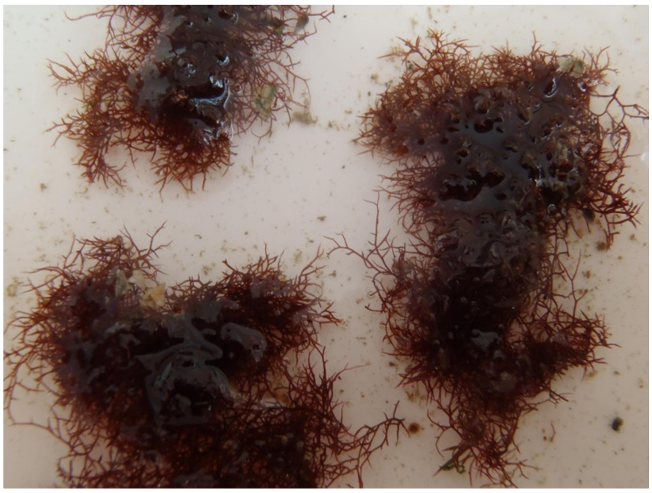


Figure 9. *Caulacanthus ustulatus* as collected in the transect of Vlissingen in 2016.

In the left transectline at Vlissingen a non-indigenous red algae species appeared to be common in the middle intertidal zone (where it was also recorded as common in one of the quadrants). Although the species was first not recognized by the author as being different from the other red algae species present in the transect (particularly in the low intertidal zone). The presence in the middle intertidal zone was however striking, and specimens had a much more compact habitus than for instance the native *Polysiphonia* species. Kind identification by Herre Stegenga revealed that the species belongs to the genus *Caulacanthus* and is non-indigenous. Where Stegenga & Karremans (2014) describe the specimens present in the Netherlands (including those now recorded at Vlissingen) as being *C. okamurae*, this is considered a synonym of *C. ustulatus* in WoRMS and AlgaeBase (Guiry, 2015c). *Caulacanthus ustulatus* in considered indigenous in Western Europe, however not further north than Southern Spain. *Caulacanthus okamurae* which might be another subspecies (but for which there are no indications yet that it might be a separate species) origins from the Asian Pacific region (e.g. Japan). The species was first observed in the Netherlands in 2005 at Neeltje Jans. Stegenga & Karremans (2014) indicate that the species can be found in tidal marine waters, i.e. the Eastern Scheldt, the Canal through Zuid-Beveland, Westkapelle and Ritthem. The entrance of the Canal through Zuid-Beveland in the Western Scheldt and Ritthem are both in the vicity of the transect location at Vlissingen. The current observation confirms the earlier observations on the settlement of the species n the Western Scheldt in the vicinity of Vlissingen. Its presence at the Dutch North Sea coast (Stegenga & Karremans, 2014), at the Belgium coast, and its abundant presence at the French Atlantic coast, also at sheltered places and in brackish environments (VLIZ Alien Species Consortium, 2013; Stegenga & Karremans, 2014), indicates that it is likely that the species will distribute to other sites at least in the mouth of Western Scheldt estuary and potentially further to the east into the Western Scheldt. Stegenga & Karremans (2014) indicate that the distribution pattern points in the direction of an introduction of the species with oysters first in France (where it was first found in 1986; VLIZ Alien Species Consortium, 2013) and secondarily in the Netherlands, and that it is likely that it is the subspecies from Asia that is present in the Netherlands. Distribution in Western Europe can nowadays also occur (naturally) via floating algae and/or algae that remain hanging on projections of vessels or equipment.

3.1.3. Crassostrea gigas (Pacific oyster)

Figure 10a. *Crassostrea gigas* reefs form a habitat for a variety of species, like observed at Hoedekenskerke.

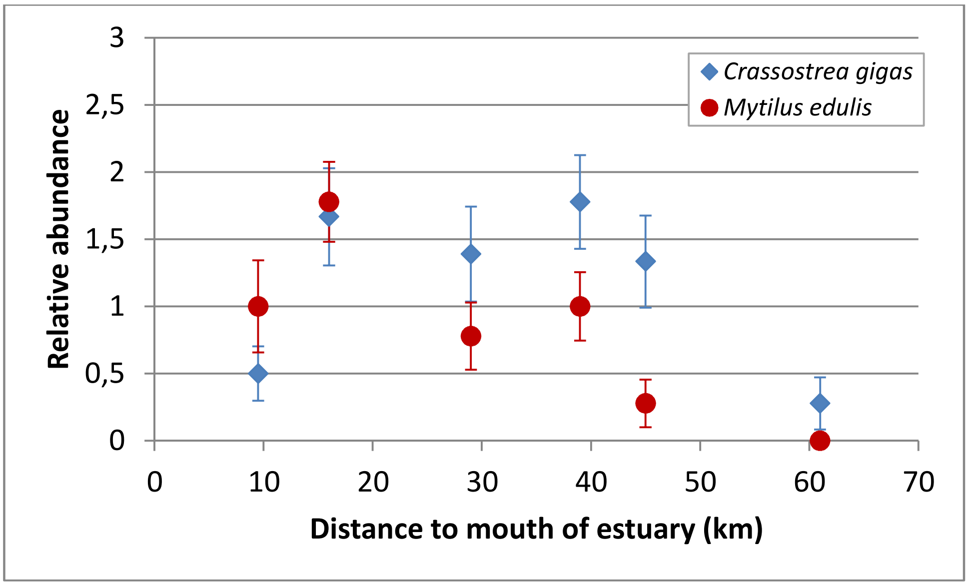
Figure 10b. Typical *Crassostrea gigas* reef as present at the monitoring site of Vlissingen.

In 2015 *Crassostrea gigas* was found in high densities at each of the three monitoring sites in the Western Scheldt and appeared to be locally present at Doel (Belgium) as well, at an average salinity of around 9 (Wijnhoven et al., 2015). Within the light that it seemed that the species succeeds to reproduce in the eastern part of the Western Scheldt at permanent salinities below 18, it is interesting that also a Pacific oyster reef is present at Bath in the low intertidal zone just in front of a fresh water inlet, as observed in 2016. Salinity there is frequently in the oligohaline reach (Fig. 5). However, with *C. gigas* solely present in the low intertidal zone where the more saline waters might prevail, salinity might predominantly be in the mesohaline reach Although about half of the *C. gigas* shells appears to be empty (are dead), still large quantities of living specimens are present. Although size distributions and reproductive state are not specifically investigated, several specimens of at least 12 cm in length are present, which indicates that specimens are at least 3 to 4 years old (Cardoso et al., 2007; Walles et al., 2015). This means that *C. gigas* can very well cope with frequent oligohaline conditions occuring. There is no reason to think that the the Pacific oyster does not reproduce here as also the watertemperature frequently transgresses the 22 °C (Depreiter et al., 2014), expected to be the threshold for reproduction (Cardoso et al., 2007).

Figure 11. Massive settlement of blue mussels around the lowest low water line as present at Breskens.

There are extensive reefs present at Vlissingen, Terneuzen, Hoedekenskerke and Hansweert (Fig. 12a). Where in 2015 *C. gigas* was present in the transect outside the marina of Breskens only in low numbers (only in the left transect line, 2 quadrants where the species was recorded to be common), the distribution and numbers seem to have increased in 2016, although on average for the entire transect differences are not significant (Fig. 12b). At least, the species is present in the right transect line now as well, where it is also recorded in several quadrants and being abundant present in one of the quadrants. It is however interesting to see that *C. gigas* is not the dominant reef building bivalve at Breskens, with the blue mussel *Mytilus edulis* abundantly present in several quadrants of both transect lines. The native *M. edulis* is present in high densities especially, but not solely, around the lowest low water line. Besides in the low intertidal zone also two quadrants in the middle intertidal zone of the right line contained many mussels (i.e mussels recorded abundant). With a size of around 1 cm (not measured in detail) the mussels are predominantly new settlement of 2016. However, also 1+ year old mussels are found. As indicated by Wijnhoven et al. (2015) the hard substrate structures at Breskens are rather new (a few years old). We are witnessing the colonization of bare hard substrate here with succession of early communities (also visible in algae species presence and coverage). It wil be interesting to see the developments in the future. The question is whether blue mussels are at an advantage at present conditions near the mouth of the Western Scheldt especially on relative new hard substrate, or whether 2016 was a good year for *M. edulis* reproduction and a year with little *C. gigas* reproduction.

Mytilus edulis was also common to abundant present in the transects at Terneuzen and Hoedekenskerke, but especially Vlissingen where the average relative abundance for the entire transect is similar to that recorded for *C. gigas*. Further *M. edulis* is also found at Hansweert, but not under the mesohaline conditions with irregular low salinity conditions occurring, as found at Bath. Pacific oyster densities in the transects of Terneuzen and Hansweert in 2016 are comparable to those recorded in 2015.



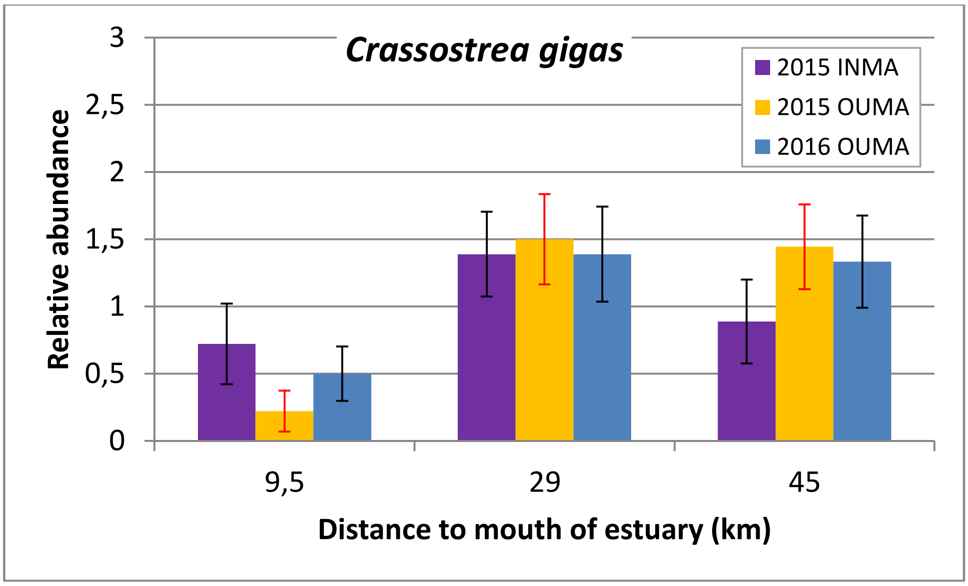


Figure 12. Average (± standard error) relative abundance of potential reef forming bivalves related to the distance of the monitoring sites to the mouth of the estuary. a) Comparison of *Crassostrea gigas* and *Mytilus edulis* over the estuarine gradient. b) Comparison of presence of *C. gigas* in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

3.1.4. *Diadumene lineata (orange-striped green anemone)*

The NIS *D. lineata* was in 2015 only found in the transect outside the marina (canal entrance) at Hansweert (Wijnhoven et al., 2015), which was however an interesting finding, as the species was so far not expected and observed this far to the east in the Western Scheldt (Faasse, 1997; Wolff, 2005). As the distribution range of this species in the Scheldt estuary might be limited more by the mud content of the water column than by salinity, it is interesting to know whether the species is still present at the site in 2016. This is indeed the case, in about the same relative abundance (Fig. 14b); moreover, *D. lineata* is in 2016 also observed at the new monitoring site of Hoedekenskerke (Fig. 14a). In the last case, the transect is probably close to the site of observation as recorded in 2005 by M.A. Faasse in Wolff (2005) as Baarland. At both transects the NIS is common (in specific quadrants recorded as abundant), present in both transect lines in the low intertidal and middle intertidal zone. *D. lineata* was also found rather common near the lowest low waterline at Breskens (where the species was however not found in the inventoried quadrants). Although the species has not been recorded from Breskens before, its presence is not that surprising as *D. lineata* was shown from several localities at the opposite side of the Western Scheldt near the marina of Vlissingen before (Faasse, 1997). Besides its presence in small pools and crevices where it can stay submerged for most of the time, the species was also observed beneath a layer of *Fucus* algae cover (in a permanent moist habitat). There were however also several observations from specimens present in holes in a layer of soft sediment (fine sand and muddy fine sand) near the lowest low water level, in crevices on oyster reefs (Fig. 13) and among young mussels (at Breskens). The inventory of 2016 has taught us that *D. lineata* can be expected at all (semi-)hard substrate locations in the low and middle intertidal zone, when above described habitats are present from the mouth of the estuary to far into the mesohaline. Although the distribution of the species in the Western Scheldt has been largely uncertain so far, it is now clear that the species is widespread in the estuary. It might however be that the species is lately also profiting from changing conditions in the water column of the Western Scheldt (i.e. less muddy conditions).

In both transects where *D. lineata* is found, also the orange anemone *D. cincta* is present. Sometimes together in the same quadrant, sometimes populations are more separated from each other. The last species that is considered native, although sometimes indicated otherwise (Ates, 2006), seems to be slightly more common in the transects than *D. lineata* (Fig. 14a). *D. cincta* is also found in the transects of Breskens and Vlissingen, but relative abundances at Hoedekenskerke and Hansweert are not significantly different from those observed for *D. lineata*. A third anemone species, not found in the Western Scheldt during the inventories of 2015 is observed at Breskens: the mud sagartia *Sagartia troglodytes*, only present in one quadrant together with the earlier mentioned *D. cincta*.

Figure 12a. *Diadumene lineata* in its typical habitat, a permanently submerged crevice, at Hansweert.

Figure 13b. *Diadumene lineata* also present in a sediment rich environment at Hoedekenskerke.

Figure 13c. *Diadumene lineata* making use of the habitat created by Pacific oysters, at Hansweert.

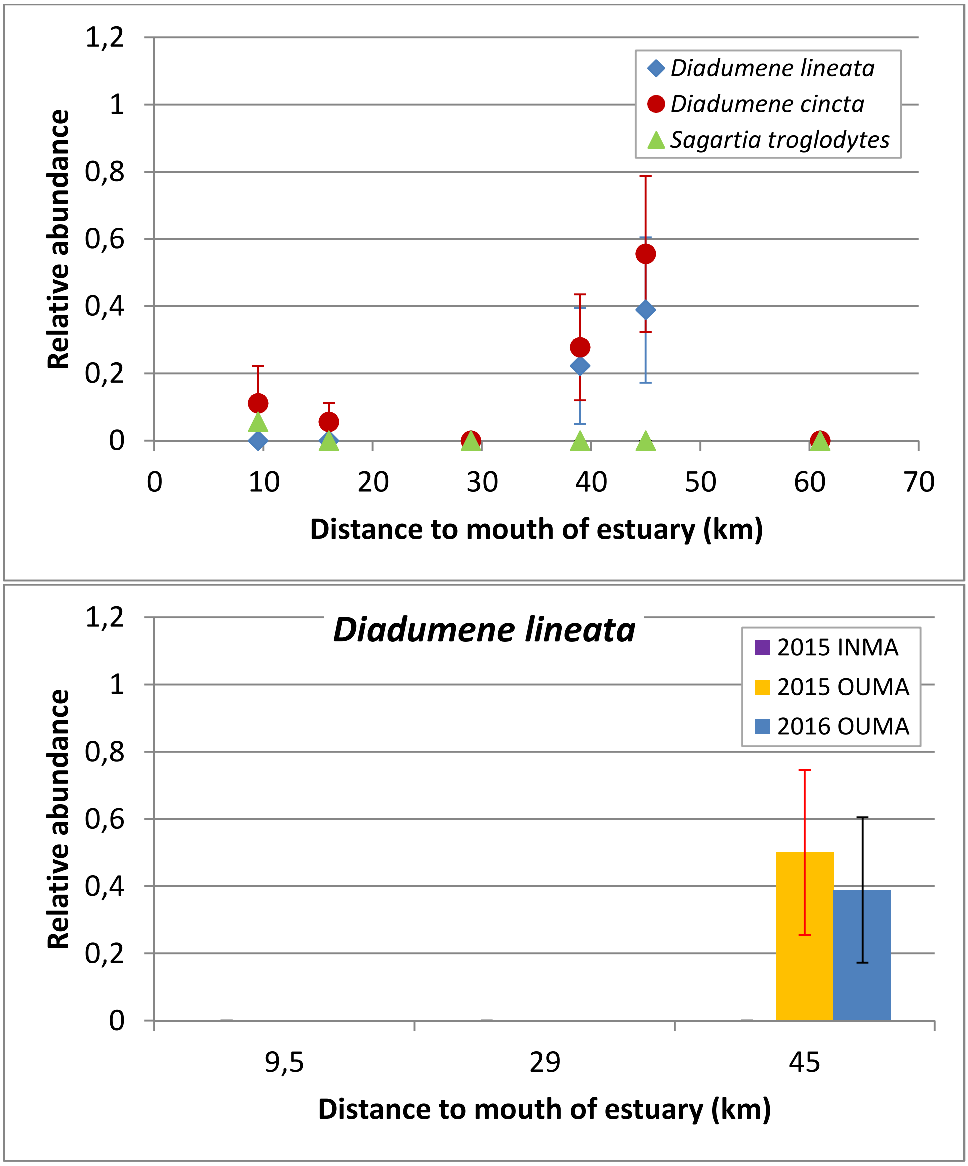


Figure 14. Average (± standard error) relative abundance of anemones related to the distance of the monitoring sites to the mouth of the estuary. a) Comparison of anemone species over the estuarine gradient. b) Comparison of presence of *Diadumene lineata* in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

3.1.5. *Hemigrapsus sanguineus* (Japanese shore crab)

The Japanese shore crab was in 2015 during the inventories a rather unusual appearance compared to the other non-indigenous shore crab species *H. takanoi*, which was abundantly present in all transects in the Western Scheldt. Only two specimens of *H. sanguineus* were found in 2015, one in each transect line at Terneuzen (Wijnhoven et al., 2015). This year the NIS appears to be present at all six monitoring sites. Moreover *H. sanguineus* appears to be the most common brachyuran species in the transects of Breskens, Vlissingen and Terneuzen (Fig. 16a) where it is frequently recorded common in several quadrants and even abundant in one of the quadrants at Breskens. A few specimens are found at Hansweert, and at Hoedekenskerke and Bath the species is observed as an additional species outside the quadrants. This means that the species is found to be significantly more abundant in 2016 at Breskens (p<0.01), and at Terneuzen (p<0.05) than in 2015 in the transects outside the marina (Fig. 16b). It is expected that *H. sanguineus* is especially more abundant at the exposed sites compared to *H. takanoi*. The largest chance of finding the species to be common is

therefore outside the marinas, compared to the inside marina environments (so the focus on outside marine transects increased the chance of finding *H. sanguineus*). Additionally *H. sanguineus* is therefore especially expected in the western part of the estuary (Van den Brink et al., 2012), which was also found. Why such a difference in relative abundance and distribution of the species is observed between the years is unclear. It is not expected that the timing of the inventories (i.e. in spring in 2015 versus in summer in 2016) has a large impact on the observed numbers, as most observed specimens were adults (1+ year) and the *Hemigrapsus* species are not expected to move seasonally from the intertidal to subtidal areas and *vice versa*. Not many juvenile brachyuran specimens were collected in 2015 (which can be an effect of monitoring early in the year), but it seems that *H. sanguineus* had a fruitful reproduction with succesful settlement in the Westen Scheldt in 2015 of which the results were observed.
In 2016 in most transects brachyuran juveniles (that could not be determined to species level) are commonly found, especially at Breskens, Hansweert and Hoedkenskerke where they are especially present in the algal vegetation. These can potentially include *H. sanguineus*, or *H. takanoi* and *Carcinus maenas*. Results for other crab species and the comparison of relative abundances between species are described in chapter 3.1.5.

Figure 15. *Hemigrapsus sanguineus* as observed near Hoedekenskerke.

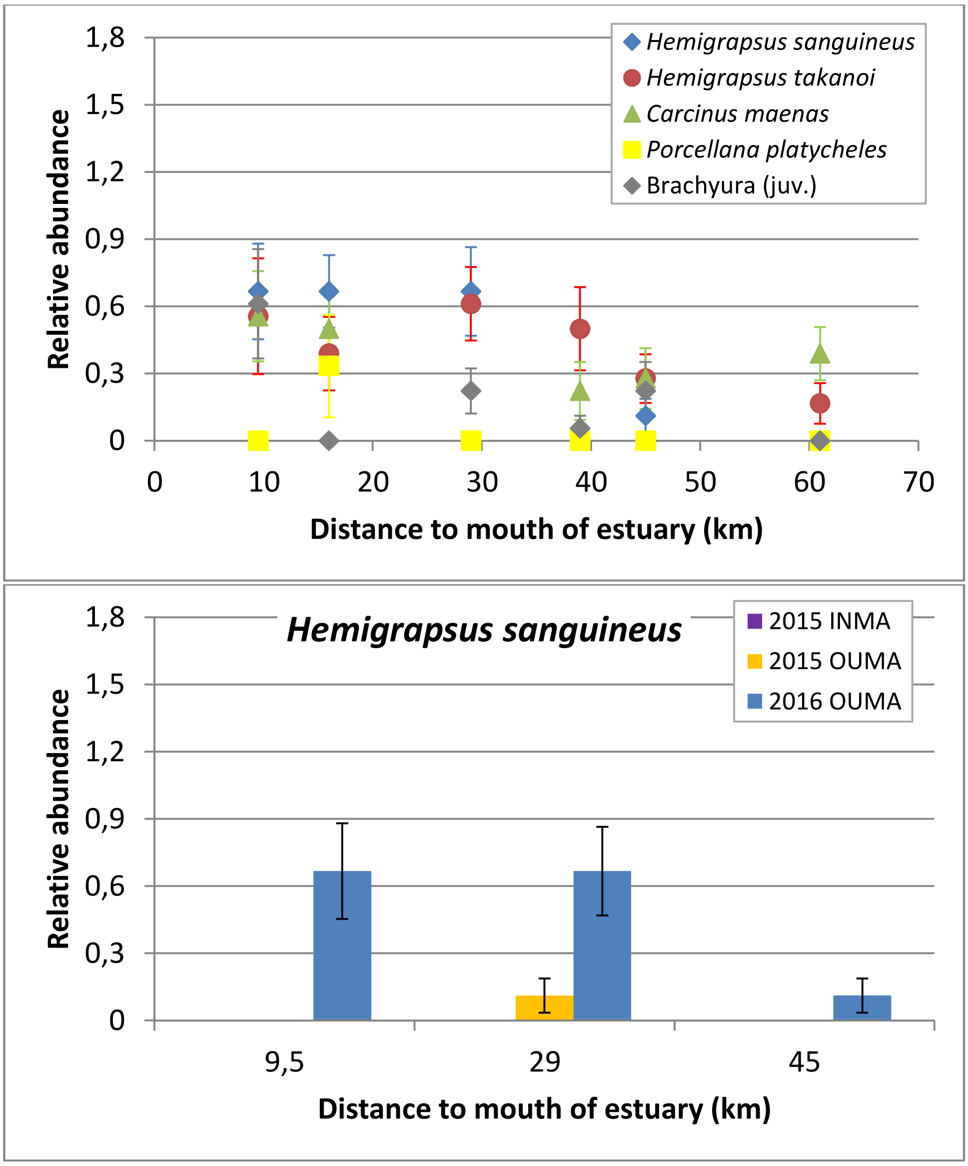


Figure 16. Average (± standard error) relative abundance of brachyurans (crab species) related to the distance of the monitoring sites to the mouth of the estuary. a) Comparison of brachyurans over the estuarine gradient. b) Comparison of presence of *Hemigrapsus sanguineus* in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

3.1.6. Hemigrapsus takanoi (brush-clawed shore crab)

The non-indigenous brush-clawed shore crab is in 2016 a common species in each of the six inventoried transects. This is in line with the observations in 2015, when the species was found from Breskens up to Doel in the Western Scheldt. There seems to be a pattern in the distribution with at most 2 specimens per quadrant at Bath and Hansweert (where however several quadrants contain *H. takanoi*), with *H. takanoi* also being common in several quadrants at Hoedekenskerke, Terneuzen and Vlissingen, and finding H. takanoi being abundantly present in two of the quadrants at Breskens. At Terneuzen, Vlissingen and Breskens, *H. takanoi* and *H. sanguineus* are frequently found together in the same quadrants. Although there are no significant differences, there is a tendency to *H. sanguineus* being more abundant in the three most western transects than *H. takanoi*, whereas the opposite is the case in the three more eastern transects (Fig. 16a). At Hoedekenskerke the relative abundance of *H. takanoi* is significantly higher ($p<0.05$) than that of *H. sanguineus*. But in 2015 *H.*

takanoi dominated the crab communities of all inventoried transects in the Western Scheldt. The difference with 2016 seems to be both that *H. takanoi* relative abundances seem to have decreased (Fig. 17a), whereas those of *H. sanguineus* have increased (Fig 16b). The decrease in relative abundance in a transect outside the marina is significant at Hansweert. Whether the observed pattern is also a direct effect: i.e. *H. sanguineus* profiting from decreasing *H. takanoi* numbers, or decreasing *H. takanoi* numbers due to increased competition with *H. sanguineus*, or a direct effect of changing environmental conditions in the Western Scheldt, is unclear when comparing just 2 years.

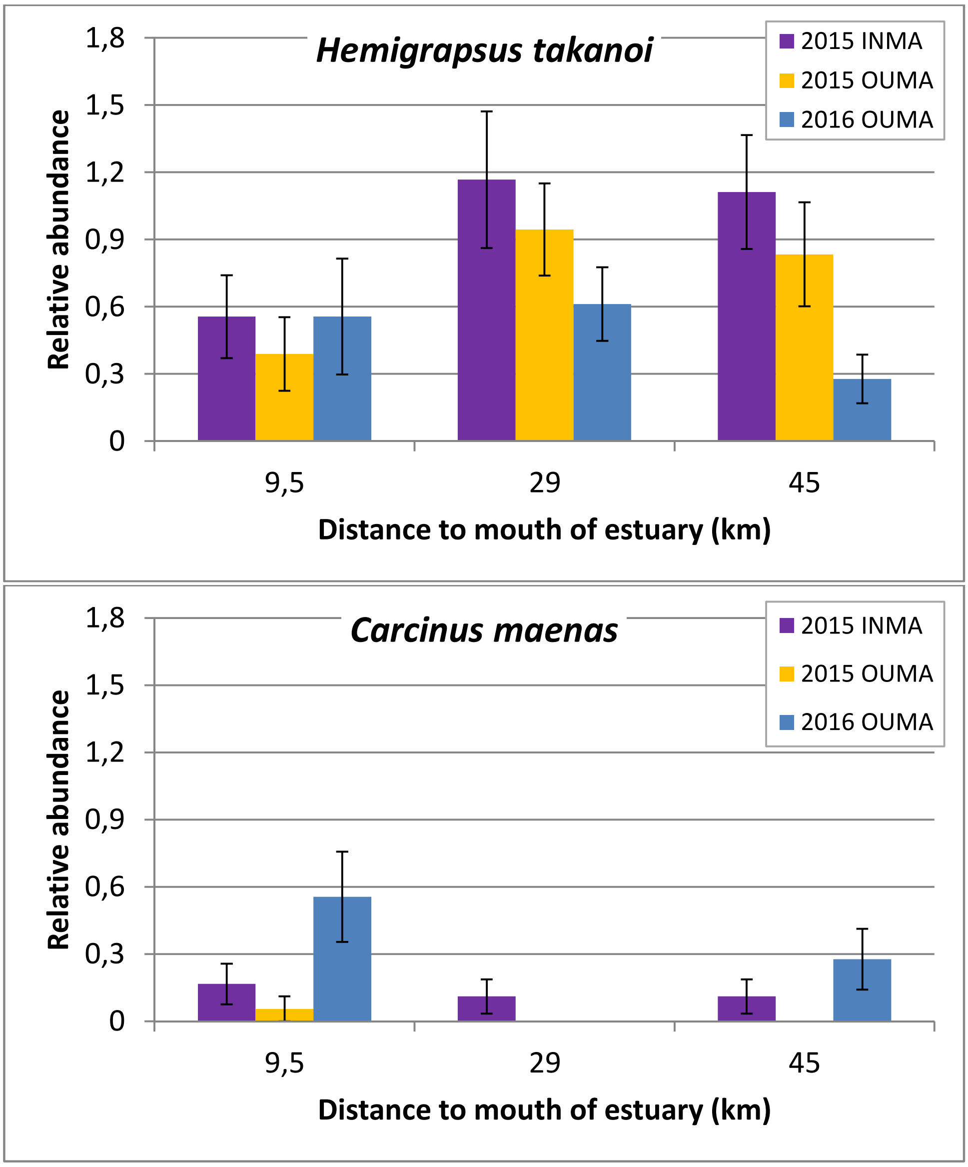


Figure 17. Average (± standard error) relative abundance of brachyurans (crab species) related to the distance of the monitoring sites to the mouth of the estuary. Comparison of presence of *Hemigrapsus takanoi* (a) and *Carcinus maenas* (b) in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

If species are profiting from decreasing *H. takanoi* populations or changing conditions, it might be the native common shore crab *Carcinus maenas* as well. *Carcinus maenas* was not found at Terneuzen (outside the marina also not in 2015), at Hansweert there might be a tendency towards a small increase, but at Breskens there is a significant increase ($p<0.05$) in the relative abundance of the species (Fig. 17b) to levels similar as for both *Hemigrapus* species (Fig. 16a). At Bath, where *H. takanoi* relative abundance is lowest, *C. maenas* is the most frequently observed shore crab species.

It has however to be noticed that the (common) presence of *H. takanoi* near Bath where oligohaline conditions might occur, is remarkable as Mingkid et al. (2006) record that *H. takanoi* cannot go through successful metamorphosis at salinities of 20 or lower, and, Duen,as (2013) records a salinity tolerance in the range of 7-35 for adults. Salinity near Bath is around 8,2, so about the tolerance limit of the species. *H. takanoi* was however solely found in the low intertidal zone where the more saline water prevails. *H. takanoi* seems to survive irregular short periods of low salinity or succeeds to migrate to higher salinity layers if necessary. At Vlissingen a 4th crab species is found to be abundantly present in some quadrants positioned in the low intertidal zone. It is unclear to what extent the native broad-clawed porcelain crab *Porcellana platycheles* might be in competition with the shore crab species, but it looks like it harbors a specific niche predominantly being under flat and relative large stones where spaces are narrow (possibly potentially only accessible for juvenile shore crabs). *Porcellana platycheles* is however found in quadrants where both *Hemigrapsus* species or only *H. sanguineus* are present in low numbers (recorded as rare).

Figure 18a. *Hemigrapsus sanguineus* (left) and *H. takanoi* (right) as collected at Breskens.

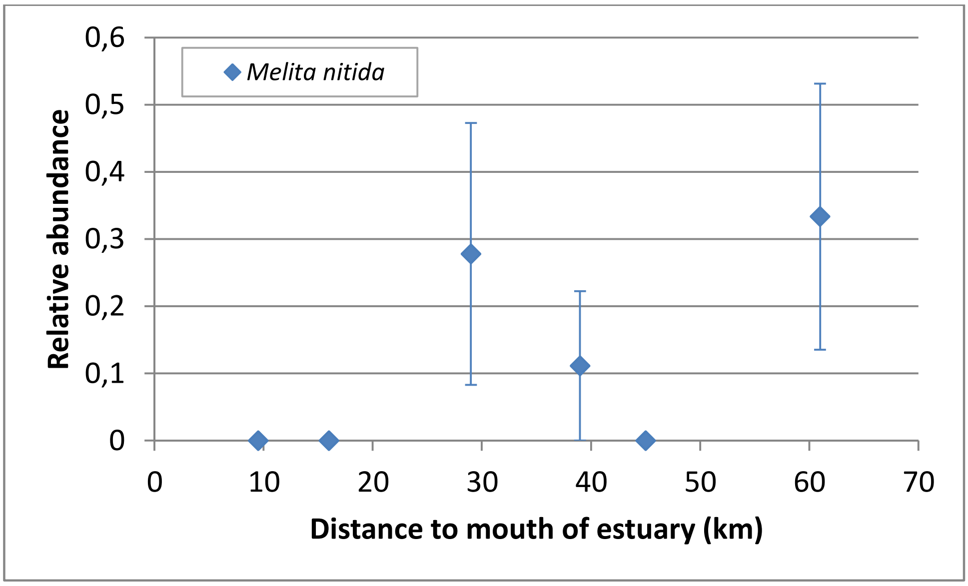
Figure 18b. *H. takanoi* observed in the transect near Bath.

3.1.7. Melita nitida

(No vernacular name in English: ‘elegante honingvlokreeft’ in Dutch)

During transect monitoring in 2015 interesting observations on the distribution of *Melita nitida* in the Western Scheldt were done, as unexpected the species was found besides in the mesohaline – also in the polyhaline zone up to Breskens (Wijnhoven et al., 2015). It had to be noticed that the only recorded observations were from just a few years after the introduction of the species (Faasse & Van Moorsel, 2003) but the results of 2015 clearly showed a drastic range extension in the Western Scheldt. Additionally, the former abundantly present native *Melita* species; *M. palmata*, clearly suffered from competition as it was not found in the transects of the Western Scheldt anymore; only in Belgium at Doel (Wijnhoven et al., 2015). The results of 2016 confirm thefindings of 2015. *Melita nitida* is again found in a large estuarine range from Bath up to Vlissingen. The NIS is locally abundantly present at Bath (where the first observation of the species in Europe also origins from: i.e. Faasse & Van Moorsel (2003)), and Terneuzen, and found to be common at Hoedekenskerke (Fig. 20a). Although not directly found in the quadrants, the species could (due to its specific habitat preference; i.e. under rubble or *Crassostrea* shells on a muddy to muddy fine sand substrate, generally in the low intertidal zone) easily be found at Hansweert as well (i.e. a common additional species). Also at Vlissingen, although found to be rare, *M. melita* is found as an additional species. Only at Breskens the species is not found during this year inventory. The species was however found in 2015 inside the marina, in the transect not inventoried in 2016 (Fig. 20b). Again *M. palmata* is largely lacking at all monitoring sites, except for Bath, where it is found as an additional species (recorded to be rare) in the same transect as where *M. nitida* is abundantly present. So, the replacement of *M. palmata* by *M. nitida* in the Western Scheldt as observed in 2015 is confirmed in 2016.
Even though *M. nitida* is not always found in quadrants of transects, no significant differences with 2015 in the relative abundances of the species are found at Terneuzen and Hansweert (Fig 20b). This because the species, if present, is generally only present in a limited number of quadrants (where it, however, can be abundantly present).

Figure 19. *Melita nitida* collected at Hansweert during transect monitoring.



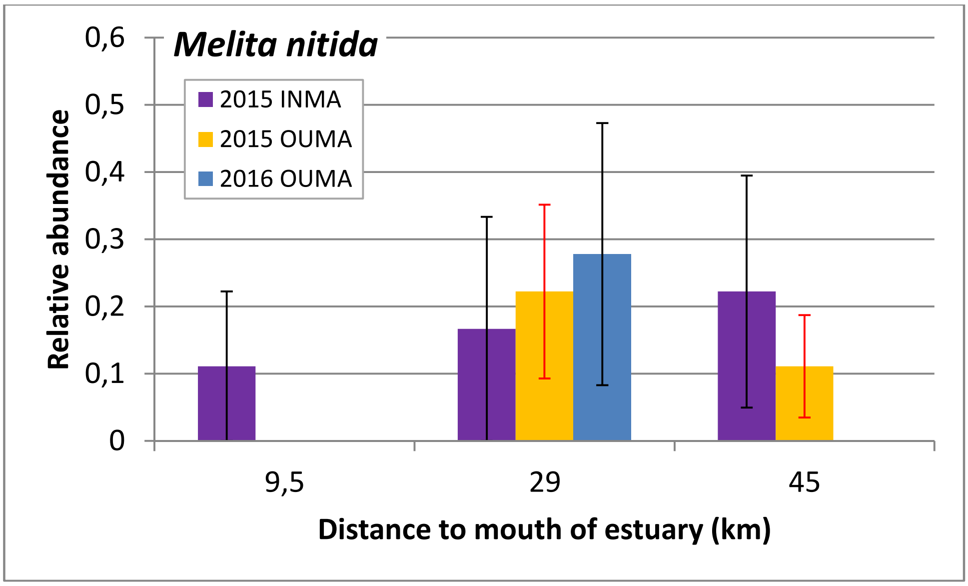


Figure 20. Average (± standard error) relative abundance of *Melita nitida* related to the distance of the monitoring sites to the mouth of the estuary. a) Results from 2016 over the estuarine gradient. b) Comparison of presence of *Melita nitida* in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

3.1.8. *Mnemiopsis leidyi* (warty comb jelly)

A 'new' observation of a NIS present in one of the transects compared to the inventories in 2015 is that of the warty comb jelly *Mnemiopsis leidyi*. Transect monitoring is actually not a suitable methodology to monitor the presence of pelagic species like *M. leidyi*. The species is generally not found in the intertidal zone during low water, except for specific conditions like offshore wind. That appeared to be the case during the monitoring of the left transectline at Breskens on July the 6th, 2016. Therefore coincidently one specimen of the warty comb jelly was present in a quadrant in the low intertidal zone stuck between rocks and oysters. In the vicinity several specimens were stranded, as were specimens of the native compass jellyfish *Chrysaora hysoscella*. It is however known that warty comb jellies are seasonally present in the entire Western Scheldt. And although not recorded in transects in 2015, the species was also several times observed in marinas during the inventories in 2015.

Figure 20. *Mnemiopis leidyi* (a) and *Chrysaora hysoscella* (b) as found during transect monitoring at Breskens.

Mnemiopsis leidyi is a NIS originging from the Atlantic North and South American coast. In 1982 it was introduced in the Black Sea where it started to dominate the entire system, with large ecological consequences for the foodweb overthere. During the 80s and 90s the populations expanded to other seas in the region including the eastern Mediterranean and the Caspian Sea. The species was recognized for the Netherlands for the first time in 2005, but might have been present there already in 2002 (Faasse & Bayha, 2006). At that time, i.e. in 2005 and 2006, the species was also present in France, Germany, Denmark, Norway and Sweden. It is likely that the species was introduced via ballast water transport, possibly introduced in one of the large harbours Antwerp or Rotterdam although natural oceanic transport by the North Atlantic Current under influence of increased water temperature is also suggested (Didžiulis, 2013; Van der Molen et al., 2015). First large bloom was observed in Lake Grevelingen in 2005, but in 2006 the species already appeared to be abundantly present in the North Sea, Eastern Scheldt, Wadden Sea and Western Scheldt. In the Western Scheldt it was collected in 2006 at Borssele (Faasse & Bayha, 2006). It is expected that *M. leidyi* does not reproduce in the eastern part of the Western Scheldt; at salinities below 15, and is in need of temperatures above 12 °C to reproduce. Although *M. leidyi* might survive during winter in marinas or other parts of the system, estuaries, including the Scheldt estuary, are expected to be sinks for the *M. leidyi* populations, that are recruited from the North Sea every spring again (Van Walraven et al., 2013). A large ecological impact of the species in the Netherlands, and in the Scheldt estuary in particular, has not been shown so far. Van Walraven et al. (2013) indicates that peaks in biomass of *M. leidyi* are after the peaks in zooplankton and larvae of benthic species and fish. However, at least in certain systems, like Lake Grevelingen and Lake Veere, a certain impact on the foodweb by the recorded *M. leidyi* densities might be expected (Van Avesaath et al., 2009; De Kluijver et al., 2011).

3.1.9. *Physella acuta* (acute bladder snail)

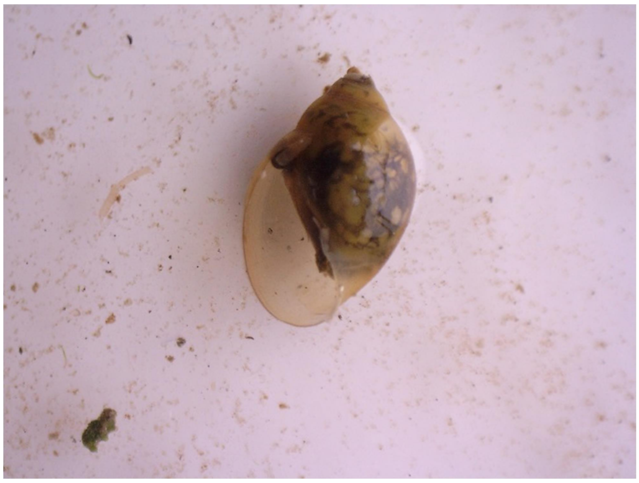


Figure 22. *Physella acuta* collected during transect monitoring at Bath.

In the right transect line at Bath in the high intertidal zone one specimen of *Physella acuta* is found. The acute bladder snail is a NIS originating from North America already known for the Netherlands since 1870. It was probably introduced with water plants in ponds in botanical gardens in Leiden and Amsterdam. It is uncertain whether the species has already been recorded for the Western Scheldt. Although it is a fresh water species, however highly tolerant towards pollutants and eutrofication and slightly brackish environments like salt marshes as well (Gittenberger et al., 1998; Anderson, 2016), its occurrence at Bath near a fresh water inlet is not a complete surprise. The species is known from the fresh waters nearby (e.g. canal Rhine-Scheldt) (ANEMOON, 2016) and additionally is present in the tidal freshwater part of the Scheldt estuary in Belgium (Piesschaert, 2016). Although the species is considered invasive in the Netherlands, competing with native (freshwater) snails, an invasion into the Western Scheldt is not expected due to the salinity conditions. At most the species might locally persist. It seems that *P. acuta* succeeds to survive in the partially rainwater-fed crevices at the transition from the high intertidal to the supratidal zone, but it is doubtful whether a real population is present, or just one or a few specimens.

3.1.10. *Amphibalanus improvisus* (bay barnacle)

Results on the distribution and relative abundance of the cryptogenic species *A. improvisus* in the transects of the Western Scheldt and compared to other barnacle species, are presented in chapter 3.1.1.

3.1.11. *Ulva cf lactuca* (sea lettuce)

During the transect inventories, all *Ulva* with a habitus similar to *Ulva lactuca* is recorded as *U. cf lactuca*. Although this might include several of the species *U. lactuca*, *U. rigida*, *U. curvata*, *U. pseudocurvata*, and *U. australis*, it is decided not to distinguish these as this is largely impossible in the field (Stegenga & Mol, 1983). Additionally identifying the distribution of these species (taking samples for identification in the laboratory) can be a study on itself. Additionally the origin of above mentioned species is uncertain as well, and species have been mixed up frequently as well at which certain types, now the same species were considered non-indigenous and *vice versa* (Guiry, 2004). At least *U. australis*, before in the Netherlands generally identified as *U. pertusa*, but now aggregated under the name *U. australis*, is a NIS in the Netherlands probably origining from the northern Pacific (Guiry, 2004; Couceiro et al., 2011). The species, likely introduced with oyster transports, was first recorded in 1995, but dating back herbarium material, it appeared that the species is present in the Netherlands since 1993. As the species is probably one of the most common species of *Ulva* in the Delta (Stegenga & Mol, 2002; Wolff, 2005), the distribution and relative abundance of *Ulva* with a lettuce-like habitus (i.e. called *U. cf lactuca* here) is presented.

Figure 23a. *Ulva cf lactuca* as collected at Hoedekenskerke.

Figure 23b. High Algal coverage of predominantly *Ulva cf lactuca*, *Fucus serratus* and *F. vesiculosus* in the low intertidal zone at Vlissingen.

Sea lettuce, when present, can reach a high coverage on hard substrate. Especially during low water, the leafs literally cover the hard substrate communities, keep them moisty for a while, but in the higher intertidal zone or on sun exposed sites the leafs desiccate which creates an entirely different environment then at the locations where the algae stay moisty. During inundation the algal leafs provide tertiairy structures in the water column; a habitat for several species (including solely subtidal dwelling fauna). Therefore Ulva, like other potential dominant algal species can be considered ecosystem engineers, significantly changing the habitat for other species. Additionally, especially during late summer, en masse decaying *Ulva* can also cause serious problems for fauna, as it can result in hypoxic conditions. Knowing that a substantial share of the *Ulva* is of non-indigenous origin, it can be concluded that this non-indigenous *Ulva* is invasive.
Ulva cf lactuca is abundantly present at Breskens and Vlissingen in each of the intertidal zones. Whereas almost no *Ulva* is present at Terneuzen (only *U. cf lactuca* recorded as a rare additional species), at Hoedekenskerke and Hansweert *U. cf lactuca* is locally abundantly present (i.e. in some quadrants) especially in the low and middle intertidal zones (Fig. 24a). At Bath no *U. cf lactuca* is observed at all. At the four research sites with *U. cf lactuca*, also *U. intestinalis* is found, however in much lower relative abundances. At Hansweert and Hoedekenskerke *U. intestinalis* is only present in one of the quadrants in the low intertidal zone, where it is however abundantly present. At the two most western research sites *U. intestinalis* is frequently found together with *U. cf lactuca* in the same quadrants. *U. intestinalis* is also present at Bath and Hoedekenskerke, however only outsite the quadrants (i.e. as additional species), at Bath even recorded as common there. At Breskens also *U. prolifera i*s present in one quadrant. At Breskens *U. cf lactuca* is significantly much more abundant present in 2016 than in 2015. Although it has to be kept in mind that for *Ulva* there might be a seasonality effect (more biomass in July than in May), there is no significant increase observed at Hansweert (only a tendency towards a higher relative abundance). It looks like the proliferation of *Ulva cf lactuca* is also part of succession as observed on the relative new bare substrate structures at Breskens. A similar pattern is found for *Fucus spiralis* and *F. vesiculosus* that is usually present all year round with about the same biomass.

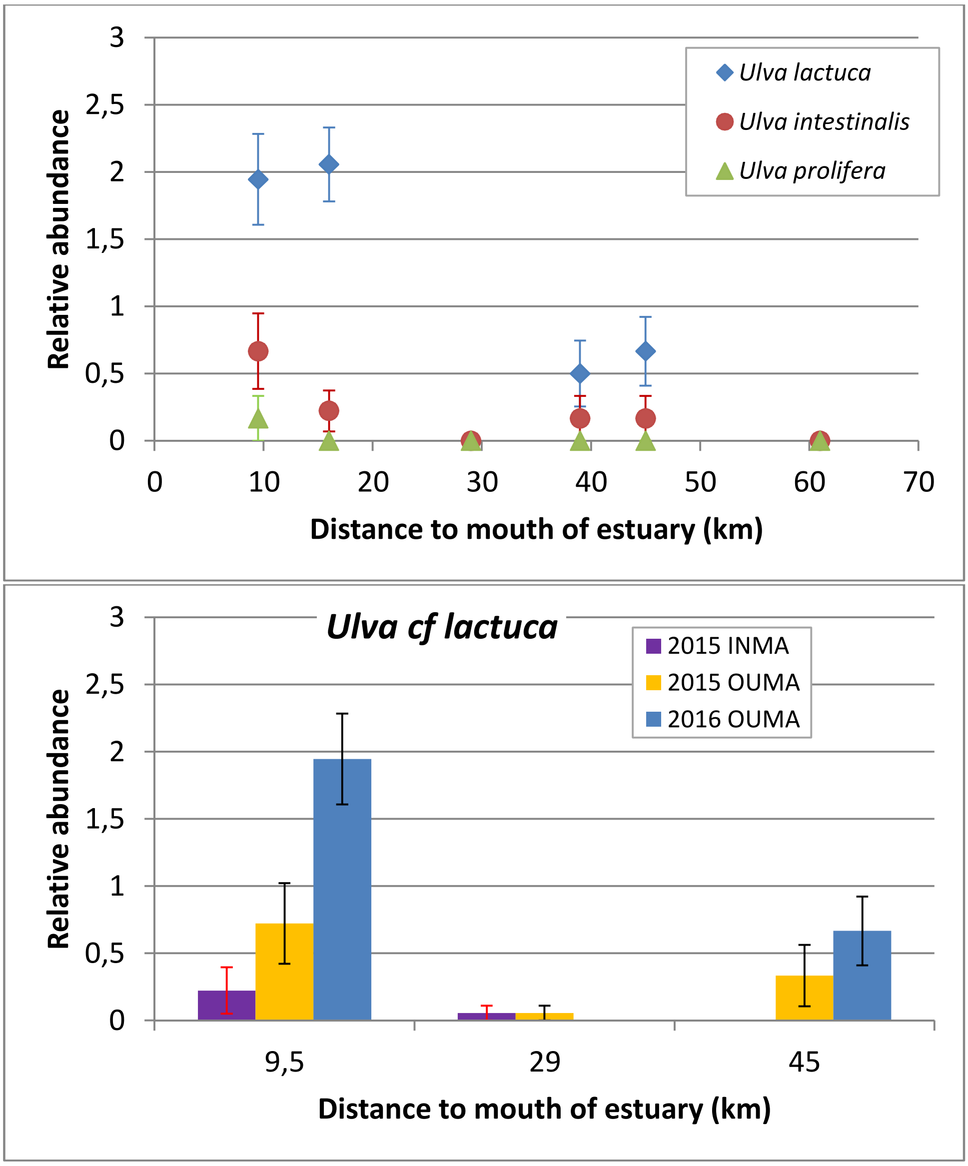


Figure 24. Average (± standard error) relative abundance of *Ulva* species related to the distance of the monitoring sites to the mouth of the estuary. a) Comparison of *Ulva* species over the estuarine gradient. b) Comparison of presence of *Ulva cf lactuca* in the transects at the sites that are inventoried in 2015 and 2016. INMA = transect inside marina; OUMA = transect outside marina. The relative abundance scale goes from absence (0) to rare (i.e. 1: only 1 or 2 specimens per quadrant) to common (2: between 3 and 10 specimens per quadrant) to abundant (3: more than 10 specimens per quadrant).

3.2 Patterns in total NIS numbers

In 2016, Vlissingen appears to be the most species rich site when the total number of species per transect is compared. A total number of 48 species (or taxa identified at another taxonomic level) is found. Also at Hoedekenskerke more than 40 species: i.e. 43 species, are found. At the other research sites, in order of total species richness Breskens, Terneuzen, Bath and Hansweert, respectively 37, 33, 31 and 30 species are found. There does not seem to be a relation between the total number of species and the estuarine –, tidal range – and/or salinity gradient. There might however be a relation between the width of the middle intertidal zone and the total number of species observed, indicating that the zone can harbor very specific species, and is potentially more rich in niches with related species when less steep. The transects with most species are also exactly the sites with an extensive *Fucus* zone containing the different subzones distinguished by different *Fucus* species. It is however unclear whether the observed pattern is based on a real relation as the number of transects is too low and the number of variables too high to acieve significant results.

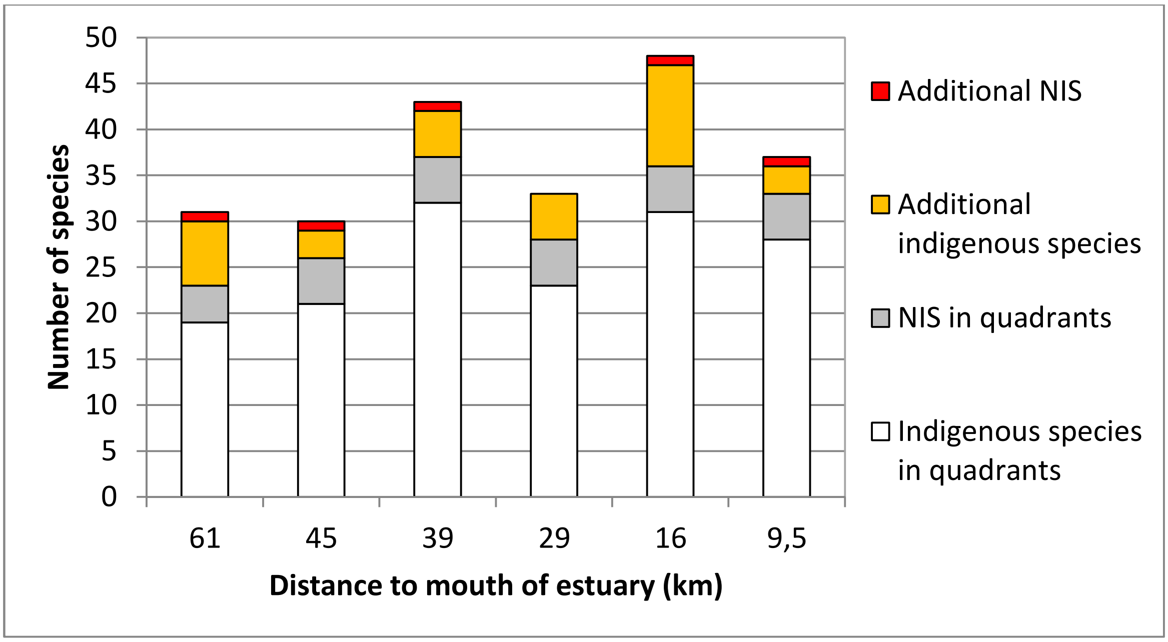


Figure 25. Total number of species observed in 2016 in each of the transects relative to the distance of the mouth of the estuary. The total number of species is subdivided in species observed in the inventoried quadrants and additional species recorded for the transects. Further the share of NIS in the total number of species is indicated.

In each transect always in total 5 or 6 NIS are found; six in the transects at Breskens, Vlissingen, Hoedekenskerke and Hansweert, and five in the other two transects (Fig. 25). Comparing transect on basis of observations from individual quadrants increases the sample size per transect to 18. On basis of individual quadrants again the largest average species richness is found at Vlissingen, followed by Hoedekenskerke (Fig. 25). Variability among the quadrants per transect might however be high, which results in a significant difference in species richness between Vlissingen and the transect of Breskens, Hanweert and Bath. Other significant differences are only found between the site with on average the lowest species richness, Bath, and all the other research sites, except Terneuzen.
A hypothesis might be that NIS are not different from other species, in such a way that sites with high biodiversity will also harbor the most NIS, as numbers might reflect potential habitat suitability and niche diversity. An assumption is then however that the chance that NIS are released and can potentially reach the sites that are compared is about the same. This does not mean that there cannot be locations that are hotspots for the arrival and/or settlement of NIS; it only suggests that the distribution to other parts in estuary from these potential hotspots is relative quick, and that the connectivity is high. The only significant differences in the share of NIS in the total species numbers found in 2016, are te low share of NIS in the quadrants at Bath compared to Terneuzen and Vlissingen. Where the average share of NIS in the transect of Bath is about 11 % and the share at Terneuzen almost 25 %, at the other transects average values only deviate between 15,8 and 19,6 %. An interesting observation is however that the total species richness for the inventoried quadrants in 2016 seems to be much higher than in 2015, whereas the share of NIS in the species numbers is lower. For the transects where we can test these findings (as those were inventoried in 2015 and 2016), significant differences in 2 of the 3 transects (i.e. at Terneuzen and at Breskens) are found in the total species richness. No significant differences in the share of NIS in the species numbers are found. This indicates that it is especially the number of native species that is higher in 2016 in average quadrants, and not that the number of NIS has decreased. Continuation of the monitoring (e.g. in 2017) should shed a light on whether the observations are only temporary or a developmental pattern indicative for changes in the Western Scheldt. We have to be aware that there has been a difference in the timing of the monitoring, and that the difference might partly be due to seasonal changes in community structure (although this is not expected). Analyses identifying potential differences between taxonomic groups might clarify whether the observed pattern could be due to seasonality, when more data (e.g. also the data from 2017) are available.

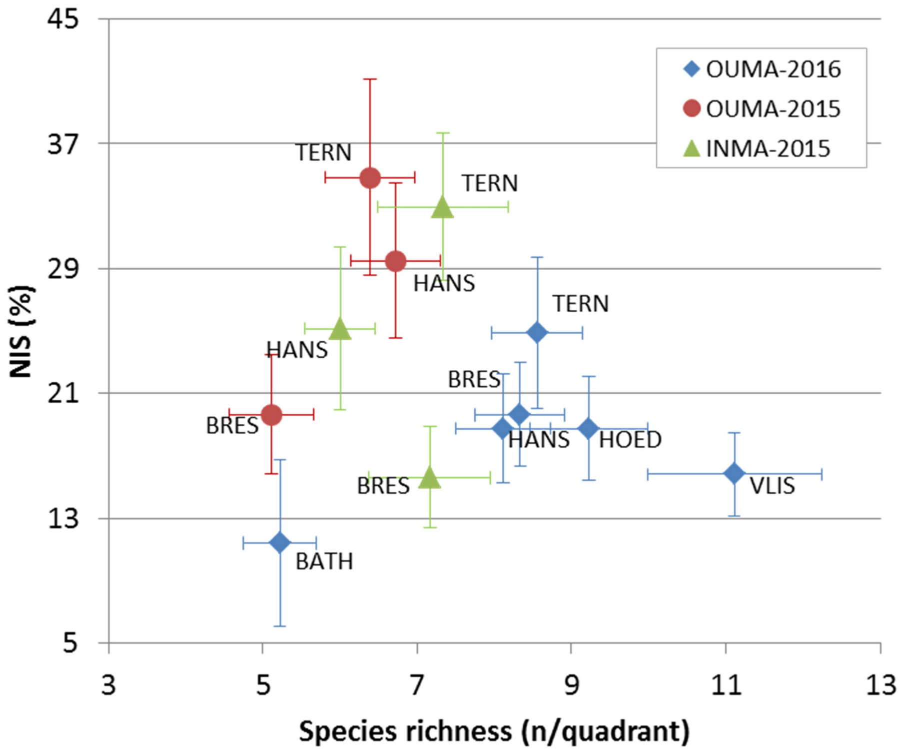


Figure 26. Comparison of transects (inventoried either in 2016 or 2015, and positioned outside (OUMA) or inside (INMA) a marina), on basis of average total species richness and the share of non-indigenous species (NIS %) in the quadrants. Average values ± standard error are shown for the transects at Bath (BATH), Hansweert (HANS), Hoedekenskerke (HOED), Terneuzen (TERN), Vlissingen (VLIS) and Breskens (BRES).

3.3 Efficiency of the methodology

Figure 27 shows the rarefaction curves for the six transects inventoried in 2016. A rarefaction curve is a logarithmic regression (as it is expected that there might always be a chance that a species is missed when not the entire surface is examined) through the datapoints indicating the percentage of the total species number present in the transect, that is found with examining an additional quadrant. An assumption that has been made in the calculations is that with the search for additional species actually all species present in the transect are collected (so that we know the total number of species present). There is always a chance of missing species in the search for additional ones. It is however expected that completely missing a species that is present in the transect is not that large, as if it is by chance missed in a stratum x line combination, there is also a chance of finding the species is an other stratum or line. The largest chance of missing a species, is not recognizing the species (either in the field, or in the collected material identified afterwards).

The data analyses show that with three quadrants for a stratum x line combination always at least 60 % of the species present are encountered (Fig. 27). On average the encountered percentage of species will be between about 75 % at Hoedekenskerke and about 94 % at Breskens. Missing a native species (that is then likely also not very important in the present communities) is not that problematic as the focus of the study is on NIS. Figure 24 shows that by only inventorying quadrants between about 25 (Bath and Vlissingen) and 10 % (Breskens) of the species was missed. With about 5 or 6 NIS present, the chance is indeed realistic that one is missed per transect. This is also what we find: i.e in each transect (except for Terneuzen) a NIS is found among the additional species. But this is exactly why a search for additional species is part of the procedure. It has to be noticed that additional species are often found in specific habitats, not that abundantly present that they become part of the quadrant inventories, but relative easy to find and check (like small pools, the lowest low waterline or uncommon hard elements and/or debris that is present). Additionally experience learns where to search for certain species, when it is expected that a certain species might be present (or has been found there or in the vicinity before).

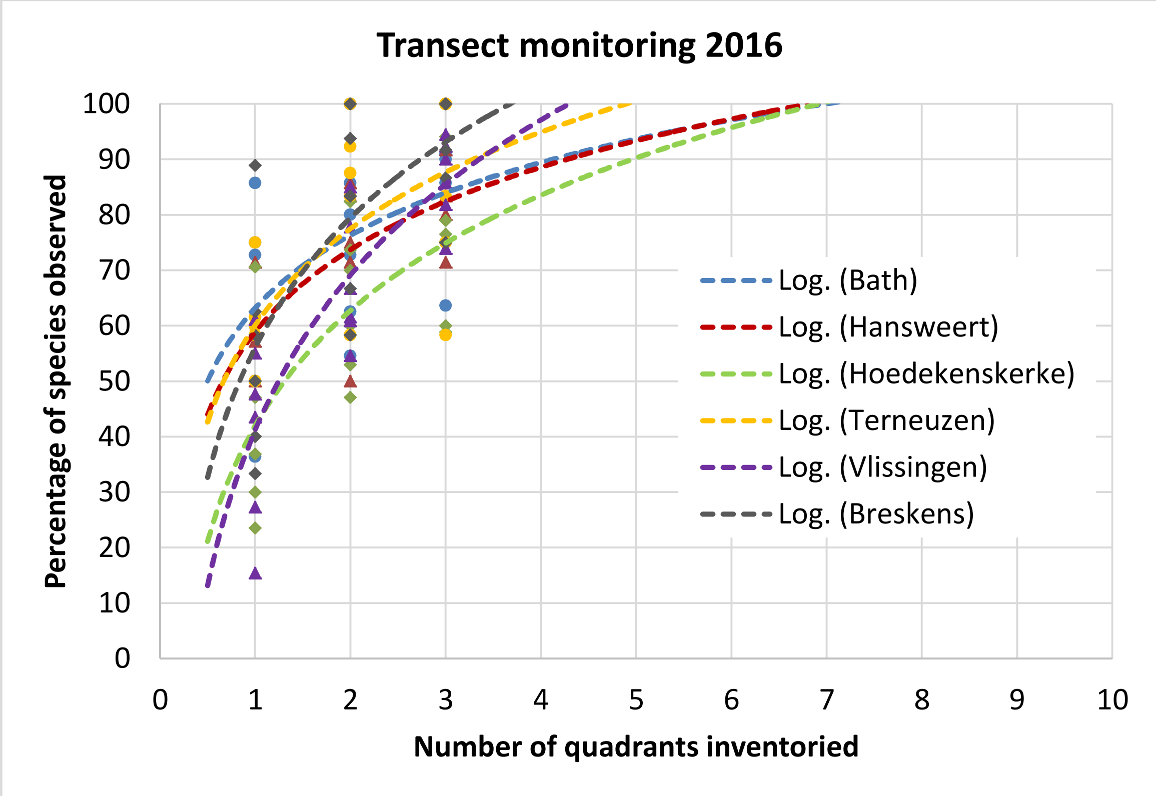


Figure 27. Trends in total number of species observed per habitat (line x stratum combination) with the inventory of an additional quadrant.

4. Conclusions

- The transect monitoring in 2016 focussing on the distribution of NIS over the estuarine gradient of the Western Scheldt and the inventory of six research sites at about regular spatial intervals confirms the common to abundant presence of the six NIS also found in the Western Scheldt in 2015. For two of these species, *Diadumene lineata* and *Hemigrapsus sanguineus*, this common presence was not so certain yet, as few recent inventories have been performed and recent recordings are largely lacking. Additionally, also in 2015 the two species were only present in one transect each.

- For *D. lineata* it is now confirmed that it is potentially present in the entire transect from at least Hansweert up to the mouth of the estuary. The species is now abundantly present at the formerly unknown location of Hansweert (further east than expected) for the second year in a row, is for the first time observed at Breskens (range extension to the west) and abundantly found at a site in between.

- *H. sanguineus* is in 2016 found throughout the Western Scheldt, where its distribution was so far largely unclear, with only two observations in 2015 and an expected presence in the mouth of the estuary as the species is expected to be more abundant at exposed sites. A presence up to Bath has not been recorded before and is therefore a surprise.

- That *Melita nitida* has largely replaced *M. palmata* in the Western Scheldt as already expected from the results in 2015 is now confirmed, with the NIS present in almost the entire estuarine transect (up to Vlissingen), and the native *M. palmata* only present at one site (Bath) and recorded to be rare there. The current presence at Vlissingen confirms the unknown range extension from the mesohaline into the polyhaline zone as observed in 2015.

- *Crassostrea gigas* and *Hemigrapsus takanoi* are found to be abundantly present in the entire estuarine transect of the Western Scheldt. This was largely also expected, but that *C. gigas* seems to do well in front of a fresh water inlet is interesting. It is also interesting to see that in the mouth of the estuary at present the native blue mussel *Mytilus edulis* is more abundant than *C. gigas*. Monitoring in 2017 has to make clear whether this is a lasting situation.

- *Austrominius modestus* indeed reaches its salinity tolerance limits before the Belgian border; at Bath the cryptogenic species *Amphibalanus improvisus* has taken over as expected. *A. improvisus*, although expected to be predominantly a brackish water species is however also present far into the polyhaline zone as indicated by its presence at Vlissingen.

- *Physella acuta* might be a new species for the Western Scheldt, although its presence near a fresh water entry is not that surprising. Future monitoring should clarify whether a permanent population is present in the Western Scheldt, or whether this is only a temporal introduction. It is however not expected that *P. acuta* can become invasive at the salinities present in the Western Scheldt.

- The presence of *Caulacanthus ustulatus* in the vicinity of the entrance of the Canal through Zuid-Beveland (as known from literature) is now confirmed by the common presence at Vlissingen. A further range extention of this red algal NIS in the Western Scheldt is expected in the coming years.

- The presence of *Mnemiopsis leidyi* in the Western Scheldt as observed during the 2016 inventory is well known. Transect monitoring is not considered appropriate to monitor popupulation development of this NIS.

- It is expected that valuable information has been collected on the habitat preferences and relatedness to certain communities of the observed NIS that will be analysed in more detail on a complete dataset covering the period 2015-2017 in 2017. This also accounts for the more fundamental information related to patterns in NIS presence and relative abundance related to species richness and the role of habitat forming species in supporting native and/or non-indigenous species.

5. Literature

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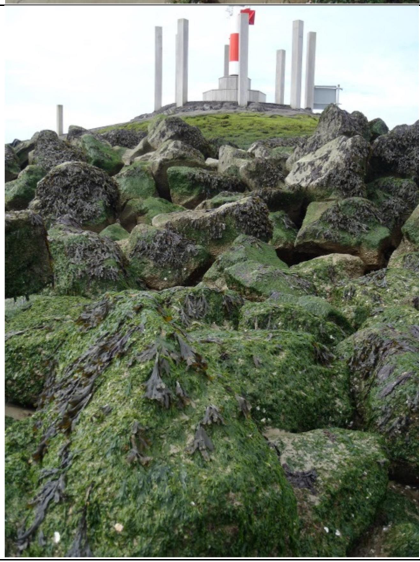
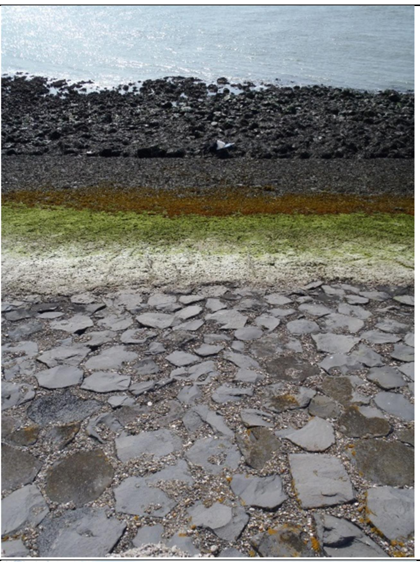
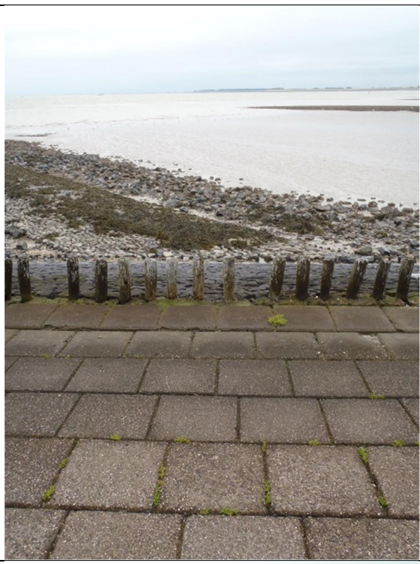
6. Annexes

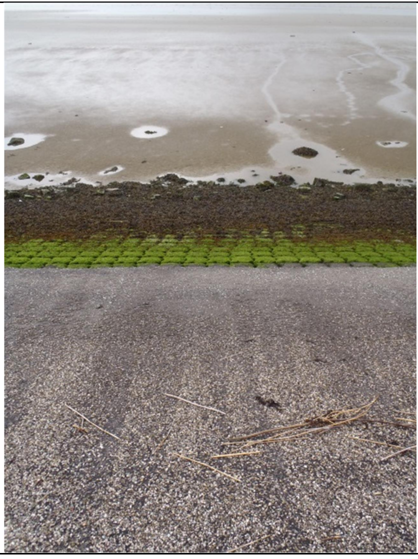
Annex 1. Overview of the in 2016 inventoried lines (left and right line through different habitats) forming a transect, with a view from the high to the low intertidal zone and vice versa.

Transect line (half of a transect)	**View from high to low intertidal.**	**View from low to high intertidal.**
Breskens - Outside marina – Left line (BRES-OUMA-LE)		
Breskens - Outside marina – Right line (BRES-OUMA-RI)		

Vlissingen - Outside harbor – Left line (VLIS-OUMA-LE)		
Vlissingen - Outside harbor – Right line (VLIS-OUMA-RI)		
Terneuzen - Outside marina – Left line (TERN-OUMA-LE)		

Terneuzen - Outside marina – Right line (TERN-OUMA-RI)		
Hoedekenskerke - Outside marina – Left line (HOED-OUMA-LE)		
Hoedekenskerke - Outside marina – Right line (HOED-OUMA-RI)		

Hansweert - Outside working harbor – Left line (HANS-OUMA-LE)		
Hansweert - Outside working harbor – Right line (HANS-OUMA-RI)		
Bath – No marina in vicinity – Left line (BATH-OUMA-LE)		

Bath – No marina in vicinity – Right line (BATH-OUMA-RI)		

Annex 2. Species list

Nr	Taxon	Scientific name	Kingdom	Phylum	Class	Order	Family	Genus	Name analyses	NIS	Cryptogenic
1	Alitta succinea	Alitta succinea	Animalia	Annelida	Polychaeta	Phyllodocida	Nereididae	Alitta	Alitta succinea		
2	Amphibalanus improvisus	Amphibalanus improvisus	Animalia	Arthropoda	INFRACLASS-Cirripedia	Sessilia	Balanidae	Amphibalanus	Amphibalanus improvisus	1	
3	Apohyale prevostii	Apohyale prevostii	Animalia	Arthropoda	Malacostraca	Amphipoda	Hyalidae	Apohyale	Apohyale prevostii		
4	Ascophyllum nodosum	Ascophyllum nodosum	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	Ascophyllum	Ascophyllum nodosum		
5	Assiminea grayana	Assiminea grayana	Animalia	Mollusca	Gastropoda	Littorinimorpha	Assimineidae	Assiminea	Assiminea grayana		
6	Aster tripolium	Aster tripolium	Plantae	Tracheophyta	PH-Tracheophyta	Asterales	Asteraceae	Aster	Aster tripolium		
7	Asterias rubens	Asterias rubens	Animalia	Echinoderma ta	Asteroidea	Forcipulatida	Asteriidae	Asterias	Asterias rubens		
8	Austrominius modestus	Austrominius modestus	Animalia	Arthropoda	INFRACLASS-Cirripedia	Sessilia	Austrobalanidae	Austrominius	Austrominius modestus	1	
9	Bembidion sp.	Bembidion	Animalia	Arthropoda	Insecta	Coleoptera	Carabidae	Bembidion	GEN-Bembidion		
10	Blidingia marginata	Blidingia marginata	Plantae	Chlorophyta	Ulvophyceae	Ulvales	Kornmanniaceae	Blidingia	Blidingia marginata		
11	Blidingia minima	Blidingia minima	Plantae	Chlorophyta	Ulvophyceae	Ulvales	Kornmanniaceae	Blidingia	Blidingia minima		
12	Brachyura (juv)	Brachyura	Animalia	Arthropoda	Malacostraca	Decapoda	INFRAORDO-Brachyura	INFRAORDO-Brachyura	INFRAORDO-Brachyura		
13	Bryopsis plumosa	Bryopsis plumosa	Plantae	Chlorophyta	Ulvophyceae	Bryopsidales	Bryopsidaceae	Bryopsis	Bryopsis plumosa		
14	Caloplaca marina	Caloplaca marina	Fungi	Ascomycota	Lecanoromycetes	Lecanorales	Teloschistaceae	Caloplaca	Caloplaca marina		
15	Carcinus maenas	Carcinus maenas	Animalia	Arthropoda	Malacostraca	Decapoda	Portunidae	Carcinus	Carcinus maenas		
16	Caulacanthus ustulatus	Caulacanthus ustulatus	Plantae	Rhodophyta	Florideophyceae	Gigartinales	Caulacanthaceae	Caulacanthus	Caulacanthus ustulatus	1	
17	Ceramium virgatum	Ceramium virgatum	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Ceramiaceae	Ceramium	Ceramium virgatum		

18	Chaetogammarus marinus	Chaetogammarus marinus	Animalia	Arthropoda	Malacostraca	Amphipoda	Gammaridae	Chaetogamma-rus	Gammarus marinus		
19	Chironomidae	Chironomidae	Animalia	Arthropoda	Insecta	Diptera	Chironomidae	FAM-Chironomidae	FAM-Chironomidae		
20	Chironomidae (Orthocladiinae)	Orthocladiinae	Animalia	Arthropoda	Insecta	Diptera	Chironomidae	SUBFAM-Orthocladiinae	SUBFAM-Orthocladiinae		
21	Chondracanthus acicularis	Chondracanthus acicularis	Plantae	Rhodophyta	Florideophyceae	Gigartinales	Gigartinaceae	Chondracan-thus	Chondracanthus acicularis		
22	Chondrus crispus	Chondrus crispus	Plantae	Rhodophyta	Florideophyceae	Gigartinales	Gigartinaceae	Chondrus	Chondrus crispus		
23	Chrysaora hysoscella	Chrysaora hysoscella	Animalia	Cnidaria	Scyphozoa	Semaeostomeae	Pelagiidae	Chrysaora	Chrysaora hysoscella		
24	Chrysomelidae spec. 1	Chrysomelidae	Animalia	Arthropoda	Insecta	Coleoptera	Chrysomelidae	FAM-Chrysomelidae	Chrysomelidae spec. 1		
25	Chrysomelidae spec. 2	Chrysomelidae	Animalia	Arthropoda	Insecta	Coleoptera	Chrysomelidae	FAM-Chrysomelidae	Chrysomelidae spec. 2		
26	Cladophora rupestris	Cladophora rupestris	Plantae	Chlorophyta	Ulvophyceae	Cladophorales	Cladophoraceae	Cladophora	Cladophora rupestris		
27	Conopeum reticulum	Conopeum reticulum	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Electridae	Conopeum	Conopeum reticulum		
28	Corophium volutator	Corophium volutator	Animalia	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Corophium	Corophium volutator		
29	Crassostrea gigas	Crassostrea gigas	Animalia	Mollusca	Bivalvia	Ostreoida	Ostreidae	Crassostrea	Crassostrea gigas	1	
30	Diadumene cincta	Diadumene cincta	Animalia	Cnidaria	Anthozoa	Actiniaria	Diadumenidae	Diadumene	Diadumene cincta		
31	Diadumene lineata	Diadumene lineata	Animalia	Cnidaria	Anthozoa	Actiniaria	Diadumenidae	Diadumene	Diadumene lineata	1	
32	Ecrobia ventrosa	Ecrobia ventrosa	Animalia	Mollusca	Gastropoda	Littorinimorpha	Hydrobiidae	Ecrobia	Ecrobia ventrosa		
33	Einhornia crustulenta	Einhornia crustulenta	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Electridae	Einhornia	Einhornia crustulenta		
34	Electra pilosa	Electra pilosa	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Electridae	Electra	Electra pilosa		
35	Elymus repens	Elymus repens	Plantae	Tracheophyta	Spermatopsida	Poales	Poaceae	Elymus	Elymus repens		
36	EMPTY		EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY		
37	Fucus serratus	Fucus serratus	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	Fucus	Fucus serratus		
38	Fucus sp. (juv)	Fucus	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	Fucus	GEN-Fucus		
39	Fucus spiralis	Fucus spiralis	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	Fucus	Fucus spiralis		

40	Fucus spiralis (juv)	Fucus spiralis	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	Fucus	Fucus spiralis		
41	Fucus vesiculosus	Fucus vesiculosus	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	Fucus	Fucus vesiculosus		
42	Hemigrapsus sanguineus	Hemigrapsus sanguineus	Animalia	Arthropoda	Malacostraca	Decapoda	Varunidae	Hemigrapsus	Hemigrapsus sanguineus	1	
43	Hemigrapsus takanoi	Hemigrapsus takanoi	Animalia	Arthropoda	Malacostraca	Decapoda	Varunidae	Hemigrapsus	Hemigrapsus takanoi	1	
44	Hydrallmania falcata	Hydrallmania falcata	Animalia	Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	Hydrallmania	Hydrallmania falcata		
45	Idotea granulosa	Idotea granulosa	Animalia	Arthropoda	Malacostraca	Isopoda	Idoteidae	Idotea	Idotea granulosa		
46	Jaera (Jaera) albifrons	Jaera (Jaera) albifrons	Animalia	Arthropoda	Malacostraca	Isopoda	Janiridae	Jaera	Jaera (Jaera) albifrons		
47	Jaera (Jaera) nordmanni	Jaera (Jaera) nordmanni	Animalia	Arthropoda	Malacostraca	Isopoda	Janiridae	Jaera	Jaera (Jaera) nordmanni		
48	Lekanesphaera rugicauda	Lekanesphaera rugicauda	Animalia	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae	Lekanesphaera	Lekanesphaera rugicauda		
49	Leptoplana tremellaris	Leptoplana tremellaris	Animalia	Platyhelmin-thes	Rhabditophora	Polycladida	Leptoplanidae	Leptoplana	Leptoplana tremellaris		
50	Ligia oceanica	Ligia oceanica	Animalia	Arthropoda	Malacostraca	Isopoda	Ligiidae	Ligia	Ligia oceanica		
51	Ligia oceanica (juv)	Ligia oceanica	Animalia	Arthropoda	Malacostraca	Isopoda	Ligiidae	Ligia	Ligia oceanica		
52	Lineus longissimus	Lineus longissimus	Animalia	Nemertea	Anopla	Heteronemertea	Lineidae	Lineus	Lineus longissimus		
53	Lipura maritima	Lipura maritima	Animalia	Arthropoda	Collembola	CLAS-Collembola	Neanuridae	Lipura	Lipura maritima		
54	Littorina fabalis	Littorina fabalis	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	Littorina	Littorina fabalis		
55	Littorina littorea	Littorina littorea	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	Littorina	Littorina littorea		
56	Littorina obtusata	Littorina obtusata	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	Littorina	Littorina obtusata		
57	Littorina saxatilis	Littorina saxatilis	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	Littorina	Littorina saxatilis		
58	Melita nitida	Melita nitida	Animalia	Arthropoda	Malacostraca	Amphipoda	Melitidae	Melita	Melita nitida	1	
59	Melita palmata	Melita palmata	Animalia	Arthropoda	Malacostraca	Amphipoda	Melitidae	Melita	Melita palmata		
60	Mnemiopsis leidyi	Mnemiopsis leidyi	Animalia	Ctenophora	Tentaculata	Lobata	Bolinopsidae	Mnemiopsis	Mnemiopsis leidyi	1	
61	Myosotella denticulata	Myosotella denticulata	Animalia	Mollusca	Gastropoda	[unassigned] Pulmonata	Ellobiidae	Myosotella	Myosotella denticulata		
62	Myosotella myosotis	Myosotella myosotis	Animalia	Mollusca	Gastropoda	[unassigned] Pulmonata	Ellobiidae	Myosotella	Myosotella myosotis		

63	Mytilus edulis	Mytilus edulis	Animalia	Mollusca	Bivalvia	Mytiloida	Mytilidae	Mytilus	Mytilus edulis		
64	Neomolgus littoralis	Neomolgus littoralis	Animalia	Arthropoda	Arachnida	Trombidiformes	Bdellidae	Neomolgus	Neomolgus littoralis		
65	Nereis pelagica	Nereis pelagica	Animalia	Annelida	Polychaeta	Phyllodocida	Nereididae	Nereis	Nereis pelagica		
66	Oligochaeta	Oligochaeta	Animalia	Annelida	Clitellata	SUBCLAS-Oligochaeta	SUBCLAS-Oligochaeta	SUBCLAS-Oligochaeta	SUBCLAS-Oligochaeta		
67	Orchestia mediterranea	Orchestia mediterranea	Animalia	Arthropoda	Malacostraca	Amphipoda	Talitridae	Orchestia	Orchestia mediterranea		
68	Patella vulgata	Patella vulgata	Animalia	Mollusca	Gastropoda	SUBCLAS-Patellogastro-poda	Patellidae	Patella	Patella vulgata		
69	Peringia ulvae	Peringia ulvae	Animalia	Mollusca	Gastropoda	Littorinimorpha	Hydrobiidae	Peringia	Peringia ulvae		
70	Physella acuta	Physella acuta	Animalia	Mollusca	Gastropoda	Hygrophila	Physidae	Physella	Physella acuta	1	
71	Polydora sp.	Polydora sp.	Animalia	Annelida	Polychaeta	Spionida	Spionidae	Polydora	GEN-Polydora		
72	Polysiphonia elongata	Polysiphonia elongata	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae	Polysiphonia	Polysiphonia elongata		
73	Polysiphonia fucoides	Polysiphonia fucoides	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae	Polysiphonia	Polysiphonia fucoides		
74	Polysiphonia stricta	Polysiphonia stricta	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae	Polysiphonia	Polysiphonia stricta		
75	Porcellana platycheles	Porcellana platycheles	Animalia	Arthropoda	Malacostraca	Decapoda	Porcellanidae	Porcellana	Porcellana platycheles		
76	Pseudendo-clonium submarinum	Pseudendo-clonium submarinum	Plantae	Chlorophyta	Ulvophyceae	Ulvales	Kornmanniaceae	Pseudendo-clonium	Pseudendocloniu m submarinum		
77	Pterothamnion plumula	Pterothamnion plumula	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Ceramiaceae	Pterothamnion	Pterothamnion plumula		
78	Pygospio elegans	Pygospio elegans	Animalia	Annelida	Polychaeta	Spionida	Spionidae	Pygospio	Pygospio elegans		
79	Ralfsia verrucosa	Ralfsia verrucosa	Chromista	Ochrophyta	Phaeophyceae	Ralfsiales	Ralfsiaceae	Ralfsia	Ralfsia verrucosa		
80	Sagartia troglodytes	Sagartia troglodytes	Animalia	Cnidaria	Anthozoa	Actiniaria	Sagartiidae	Sagartia	Sagartia troglodytes		
81	Sagina maritima	Sagina maritima	Plantae	Tracheophyta	Spermatopsida	Caryophyllales	Caryophyllaceae	Sagina	Sagina maritima		
82	Salicornia europaea	Salicornia europaea	Plantae	Tracheophyta	PH-Tracheophyta	Caryophyllales	Amaranthaceae	Salicornia	Salicornia europaea		

83	Semibalanus balanoides	Semibalanus balanoides	Animalia	Arthropoda	INFRACLASS-Cirripedia	Sessilia	Archaeobalani-dae	Semibalanus	Semibalanus balanoides		
84	Staphylinidae (Aleochara sp.)	Aleochara sp.	Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae	Aleochara	GEN-Aleochara		
85	Tephromela atra var. atra	Tephromela atra var. atra	Fungi	Ascomycota	Lecanoromy-cetes	Lecanorales	Tephromelata-ceae	Tephromela	Tephromela atra		
86	Tipulidae	Tipulidae	Animalia	Arthropoda	Insecta	Diptera	Tipulidae	FAM-Tipulidae	Tipulidae		
87	Tipulidae (larvae: Tipula paludosa)	Tipula paludosa	Animalia	Arthropoda	Insecta	Diptera	Tipulidae	Tipula	Tipula paludosa		
88	Ulothrix flacca	Ulothrix flacca	Plantae	Chlorophyta	Ulvophyceae	Ulotrichales	Ulotrichaceae	Ulothrix	Ulothrix flacca		
89	Ulva cf lactuca	Ulva lactuca	Plantae	Chlorophyta	Ulvophyceae	Ulvales	Ulvaceae	Ulva	Ulva lactuca		1
90	Ulva intestinalis	Ulva intestinalis	Plantae	Chlorophyta	Ulvophyceae	Ulvales	Ulvaceae	Ulva	Ulva intestinalis		
91	Ulva prolifera	Ulva prolifera	Plantae	Chlorophyta	Ulvophyceae	Ulvales	Ulvaceae	Ulva	Ulva prolifera		

Annex 3. Results per Transect

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-BRES-OUMA-6-7-2016											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Ascophyllum nodosum								R				R
Blidingia marginata	A	A	A		A		A					
Blidingia minima					A				A		A	
Ulva intestinalis		A					R		A	A	C	
Fucus sp. (juv)		A										
Fucus spiralis					A	A	A		R	A	A	
Fucus vesiculosus						R	R				A	
Polysiphonia fucoides												
Pseudendoclonium submarin	A											
Ralfsia verrucosa	R											
Ulothrix flacca	A	A	A		A	A					A	
Ulva cf lactuca		A				A			A	A	C	
Ulva prolifera										A		
Apohyale prevostii					A	A	A					
Asterias rubens												
Austrominius modestus				R	C	A	A		A	A	A	
Bembidion sp.					R							
Brachyura (juv)							A					
Hydrallmania falcata								R				R
Carcinus maenas							R		C			
Chrysaora hysoscella												R
Crassostrea gigas							R		C			
Diadumene cincta												
Diadumene lineata												
Electra pilosa												
Hemigrapsus sanguineus	R	R	C				R					
Hemigrapsus takanoi			C									
Ligia oceanica		C	A									
Lipura maritima		C	R			C						
Littorina saxatilis												
Mnemiopsis leidyi										R		
Mytilus edulis									A	A		
Neomolgus littoralis				R								
Orchestia mediterranea			C									
Sagartia troglodytes												
Semibalanus balanoides						R	C					
Tipulidae		R										

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-BRES-OUMA-6-7-2016											
Line (LE/RI)	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Ascophyllum nodosum									R			
Blidingia marginata	A	A	A				A					
Blidingia minima		C	A		A				A	A		
Ulva intestinalis												
Fucus sp. (juv)												
Fucus spiralis	A		A		A	A	A			A		
Fucus vesiculosus						C				A		
Polysiphonia fucoides									C			
Pseudendoclonium submarinum												
Ralfsia verrucosa												
Ulothrix flacca	A	A										
Ulva cf lactuca	A		A		A	A	A		A	A		
Ulva prolifera												
Apohyale prevostii					A	A	R			A		
Asterias rubens									R			
Austrominius modestus					A	A	A		A	A	A	
Bembidion sp.	R											
Brachyura (juv)					C	C	C			C		
Hydrallmania falcata												
Carcinus maenas					C	C	C		R			
Chrysaora hysoscella												
Crassostrea gigas					R				R	R	A	
Diadumene cincta									C			
Diadumene lineata												C
Electra pilosa									R			
Hemigrapsus sanguineus							C		R	R	A	
Hemigrapsus takanoi							C			A	A	
Ligia oceanica	R	R										
Lipura maritima					C	C	A				A	
Littorina saxatilis	R					C	A					
Mnemiopsis leidyi												
Mytilus edulis						A	A		A		A	
Neomolgus littoralis												
Orchestia mediterranea	A	A	C									
Sagartia troglodytes									R			
Semibalanus balanoides							A			A	C	
Tipulidae												

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-VLIS-OUMA-21-7-2016											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia marginata		A			C							
Blidingia minima			A		C	A	A		A	A		
Bryopsis plumosa												
Caloplaca marina	C											
Caulacanthus ustulatus							C					
Ceramium virgatum									C			
Chondracanthus acicularis												
Chondrus crispus												
Cladophora rupestris												
Fucus serratus						A	A		A	A	A	
Fucus spiralis			A		A							
Fucus vesiculosus						A	A			C	A	
Polysiphonia elongata												
Polysiphonia fucoides												
Pterothamnion plumula												
Ulothrix flacca		A	A									
Ulva cf lactuca		R	A		C	A	C		A	A	A	
Ulva intestinalis							C					
Amphibalanus improvisus									A			
Apohyale prevostii					C	C	C		R			
Austrominius modestus					C	A	A		A	A	A	
Hydrallmania falcata								R				
Carcinus maenas					R	R	R			R		
Chaetogammarus marinus								R				
Chironomidae (Orthocladiinae)				R								
Conopeum reticulum												R
Crassostrea gigas						A	A		A	A	A	
Diadumene cincta									R			
Hemigrapsus sanguineus						R	C		R	R	R	
Hemigrapsus takanoi							R				R	
Idotea granulosa								R				
Leptoplana tremellaris												
Ligia oceanica												
Lipura maritima							C			R		
Littorina fabalis					R	R					R	
Littorina littorea					R	C				R	C	
Littorina obtusata							R					
Littorina saxatilis			R		R	A	A			C	C	
Melita nitida												R
Myosotella myosotis				R								
Mytilus edulis					C	A	A		A	C	C	
Neomolgus littoralis	C									A		
Orchestia mediterranea	R		C									
Patella vulgata						R	C		R	C	R	
Polydora sp.												R
Porcellana platycheles									A			
Semibalanus balanoides						A	A		A	A	A	

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-VLIS-OUMA-21-7-2016											
Line (LE/RI)	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia marginata		C	A			A	C					
Blidingia minima			C						A		C	
Bryopsis plumosa									A			
Caloplaca marina				R								
Caulacanthus ustulatus												
Ceramium virgatum										R		
Chondracanthus acicularis							C					
Chondrus crispus									C			
Cladophora rupestris									A			
Fucus serratus							R					R
Fucus spiralis			A		A	A						
Fucus vesiculosus						C	A				C	
Polysiphonia elongata												R
Polysiphonia fucoides												C
Pterothamnion plumula												R
Ulothrix flacca		C			A	A						
Ulva cf lactuca		R	C		C		A		A	A	A	
Ulva intestinalis											C	
Amphibalanus improvisus									A	A		
Apohyale prevostii			C		A	A						
Austrominius modestus		C	A		A	A	A		A	A	A	
Hydrallmania falcata												
Carcinus maenas					C	R	R			R		
Chaetogammarus marinus												
Chironomidae (Orthocladiinae)												
Conopeum reticulum												
Crassostrea gigas						A	A		A	A	A	
Diadumene cincta												
Hemigrapsus sanguineus						R	R		R	R	C	
Hemigrapsus takanoi									R	C	C	
Idotea granulosa								R				
Leptoplana tremellaris												R
Ligia oceanica		R										
Lipura maritima					A	A				R	C	
Littorina fabalis						R	R					
Littorina littorea		C	C		C	A	C				C	
Littorina obtusata					R							
Littorina saxatilis		A	A		A	A	A			C	A	
Melita nitida												
Myosotella myosotis												
Mytilus edulis	R				C	A	A		A	C	A	
Neomolgus littoralis			R									
Orchestia mediterranea	C	C	R									
Patella vulgata							C		R		R	
Polydora sp.												
Porcellana platycheles									A			
Semibalanus balanoides					R	C	A		A	A	A	

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-TERN-OUMA-4-7-2016											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Ascophyllum nodosum						R	A		A		A	
Blidingia marginata	A	A	A		A							
Blidingia minima		A			A							
Chondrus crispus												R
Fucus spiralis				R	A	A	A					
Fucus spiralis (juv)		A	R									
Fucus vesiculosus						R	A					
Ulothrix flacca	C	A	A									
Alitta succinea												R
Apohyale prevostii		C	C		C	A	A					
Austrominius modestus						C			A	A	A	
Brachyura (juv)						R				R		
Chaetogammarus marinus						C			C			
Chironomidae		R	R									
Crassostrea gigas									A	A		
Ecrobia ventrosa												R
Hemigrapsus sanguineus						C			R	C		
Hemigrapsus takanoi								R	C	R	R	
Ligia oceanica (juv)												
Lineus longissimus											R	
Lipura maritima	R	A	A		C		C		A	C		
Littorina fabalis							R					
Littorina littorea	R				A	A	A		A	A	A	
Littorina obtusata												
Littorina saxatilis					R							
Melita nitida									A			
Mytilus edulis											R	
Oligochaeta	R		C									
Orchestia mediterranea	A	A	A		C		A					
Peringia ulvae									R			
Semibalanus balanoides									A	A	A	
Sagina maritima												
Salicornia europaea												

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-TERN-OUMA-4-7-2016											
Line (LE/RI)	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Ascophyllum nodosum				R	A	A	A			A		
Blidingia marginata												
Blidingia minima												
Chondrus crispus												
Fucus spiralis								R				
Fucus spiralis (juv)	R											
Fucus vesiculosus								C				
Ulothrix flacca	A	C										
Alitta succinea												
Apohyale prevostii						A				C		
Austrominius modestus		R	A		A	A	A		A	A	A	
Brachyura (juv)					R	R						
Chaetogammarus marinus					C	A	C			C		
Chironomidae	R											
Crassostrea gigas			R		A	A	A		A	A	A	
Ecrobia ventrosa												
Hemigrapsus sanguineus			R		R	R			C	C		
Hemigrapsus takanoi				R	R	R	R		R	R	C	
Ligia oceanica (juv)				C								
Lineus longissimus												
Lipura maritima	C	R	R		C	R	C		C	C	C	
Littorina fabalis					R	R						
Littorina littorea	R	A	A		A	A	A		A	A	A	
Littorina obtusata					R	A						
Littorina saxatilis											C	
Melita nitida										C		
Mytilus edulis				R	C	C	C		C	C	A	
Oligochaeta												
Orchestia mediterranea	R	C										
Peringia ulvae												
Semibalanus balanoides				C	A	A	C		C	A	A	
Sagina maritima				R								
Salicornia europaea	R											

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-HOED-OUMA-19-7-2016											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia marginata		A	C		A	A	A					
Blidingia minima	A	A	A									R
Fucus serratus								C		R		
Fucus spiralis		C	A									
Fucus vesiculosus			R		A	A	A			A	A	
Polysiphonia urceolata						C						
Ulothrix flacca	A	A										
Ulva cf lactuca									C			
Ulva intestinalis				R						A		
Alitta succinea									R	C		
Amphibalanus improvisus									C			
Apohyale prevostii				R	A					C		
Austrominius modestus		A	R		A	A	A		A	A	A	
Bembidion sp.				R								
Brachyura (juv)							R					R
Hydrallmania falcata								R		R		
Carcinus maenas				R	C							
Chaetogammarus marinus					C	A	R					R
Chrysomelidae spec 1	R											
Chrysomelidae spec 2	R											
Conopeum reticulum									R			
Corophium volutator							R					
Crassostrea gigas					A	A	A		A	A	A	
Diadumene cincta							C					
Diadumene lineata							R					R
Electra pilosa												C
Hemigrapsus sanguineus												
Hemigrapsus takanoi								R	C	C	R	
Ligia oceanica	R											
Lipura maritima	R		C		A	A	A			C	C	
Littorina fabalis								R			R	
Littorina littorea		C			C	R	R					
Littorina obtusata					R		R					
Littorina saxatilis		C	R							R		
Melita nitida									C			
Mytilus edulis							C		C	C	C	
Neomolgus littoralis				R								
Orchestia mediterranea			R									
Peringia ulvae									R			
Polydora sp.												
Semibalanus balanoides								R	C	A		
Staphilinidae (Aleochara sp.)				R								
Sagina maritima				C								

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-HOED-OUMA-19-7-2016											
Line (LE/RI)	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia marginata	C	A	A									
Blidingia minima				R	A	C	A					R
Fucus serratus					R		A			R		
Fucus spiralis		A	A		A							
Fucus vesiculosus					A	A	A			A		
Polysiphonia urceolata												
Ulothrix flacca	C	A	A									
Ulva cf lactuca						A			A	R		
Ulva intestinalis												
Alitta succinea									C			
Amphibalanus improvisus					C				A	A	R	
Apohyale prevostii					A	A	C			R		
Austrominius modestus					A	A	A		A	A	A	
Bembidion sp.				R								
Brachyura (juv)												
Hydrallmania falcata												C
Carcinus maenas					R	R						R
Chaetogammarus marinus							A			A		
Chrysomelidae spec 1												
Chrysomelidae spec 2												
Conopeum reticulum									R			
Corophium volutator												C
Crassostrea gigas						C	A		A	A	A	
Diadumene cincta										C	R	
Diadumene lineata											A	
Electra pilosa												
Hemigrapsus sanguineus								R				R
Hemigrapsus takanoi								R	C	R	R	
Ligia oceanica		C	R									
Lipura maritima	C	C	C		C	A	A				C	
Littorina fabalis							R			R		
Littorina littorea				R	R							R
Littorina obtusata								R		R		
Littorina saxatilis					C	R	R					
Melita nitida												C
Mytilus edulis						C	C		A	C	R	
Neomolgus littoralis				R								
Orchestia mediterranea	A	A	A		C							
Peringia ulvae												
Polydora sp.										R	R	
Semibalanus balanoides					A	C	C		C	C		
Staphilinidae (Aleochara sp.)												
Sagina maritima												

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-HANS-OUMA-8-7-2016											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia minima	A	A	A		A	A	A		A	C		
Fucus sp. (juv)	A	A	A						C			
Fucus spiralis					A	R						
Fucus vesiculosus					C	A	A					
Ulothrix flacca	A	A				A			A	A		
Ulva cf lactuca							C		C		A	
Ulva intestinalis										A		
Apohyale prevostii					R	C	C					
Austrominius modestus			A		A	A	A		A	A	A	
Bembidion sp.												R
Brachyura (juv)								R				
Carcinus maenas								R				
Chaetogammarus marinus					R							
Crassostrea gigas					C	A	A		A	A	A	
Diadumene cincta											C	
Diadumene lineata											C	
Hemigrapsus sanguineus								R				C
Hemigrapsus takanoi									R	R		
Jaera (Jaera) albifrons												
Lekanesphaera rugicauda												
Ligia oceanica				R								
Lipura maritima					R	A	C		A	A		
Littorina littorea	C		A		C	A	C				C	
Littorina saxatilis		A	A				A			R	C	
Melita nitida												
Mytilus edulis										R	A	
Neomolgus littoralis									R		R	
Orchestia mediterranea	R	C	A		A	C						
Pygospio elegans												
Semibalanus balanoides						C						

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-HANS-OUMA-8-7-2016											
Line (LE/RI)	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia minima		R	A		A		C		A	A		
Fucus sp. (juv)			C									
Fucus spiralis					A							
Fucus vesiculosus					A	A	A		A	C	A	
Ulothrix flacca												
Ulva cf lactuca		R					A				R	
Ulva intestinalis												
Apohyale prevostii					A	A			A			
Austrominius modestus					C	A	R		A		A	
Bembidion sp.												
Brachyura (juv)					R				R	C		
Carcinus maenas					R	C			R	R		
Chaetogammarus marinus					A	A	A		A			
Crassostrea gigas							R		A		A	
Diadumene cincta	C				A	C	R					
Diadumene lineata						C					A	
Hemigrapsus sanguineus									R	R		
Hemigrapsus takanoi						R				R	R	
Jaera (Jaera) albifrons												C
Lekanesphaera rugicauda	R											
Ligia oceanica												
Lipura maritima	R		R		R		C		A	A		
Littorina littorea	A		A		A	C	R		A	R	A	
Littorina saxatilis									R			
Melita nitida												C
Mytilus edulis											R	
Neomolgus littoralis			R									
Orchestia mediterranea	A		A									
Pygospio elegans		R					R		C			
Semibalanus balanoides												R

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-BATH-OUMA-25-7-2016											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia marginata	A	A	A									
Blidingia minima	R		A			C	A					
Caloplaca marina	C											
Fucus spiralis			A		C	A						
Fucus vesiculosus					A	A	A					
Tephromela atra var. atra	R											
Ulothrix flacca					C							
Ulva intestinalis												
Alitta succinea												R
Amphibalanus improvisus							R		C			
Assiminea grayana	A	A	A									
Carcinus maenas						R			R			
Chaetogammarus marinus					A	A	A				R	
Corophium volutator									C			
Crassostrea gigas									A	C		
Einhornia crustulenta									R			
Hemigrapsus sanguineus								R				
Hemigrapsus takanoi									R		R	
Jaera (Jaera) nordmanni										R		
Lekaenesphaera rugicauda												
Ligia oceanica			C		A							
Melita nitida									C	A	R	
Melita palmata												R
Myosotella denticulata				R								
Neomolgus littoralis	R	R										
Nereis pelagica								R				
Orchestia mediterranea	R	R	C		R							
Physella acuta												
Tipulidae (larvae: Tipula paludosa)												
Aster tripolium												
Elymus repens	C											

Field data sheet	*To list species and their relative abundance*											
CODE	NL-SCHE-BATH-OUMA-25-7-2016											
Line (LE/RI)	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI	RI
Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	LI
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)											
Blidingia marginata	A	A				A	C			A	A	
Blidingia minima	A	A			C	A	A		A	C	A	
Caloplaca marina												
Fucus spiralis	A	A			R	A	A				R	
Fucus vesiculosus	A	A			A	A	A		A	A	A	
Tephromela atra var. atra												
Ulothrix flacca												
Ulva intestinalis												C
Alitta succinea												R
Amphibalanus improvisus												
Assiminea grayana										R	C	
Carcinus maenas					R	R	R		R		R	
Chaetogammarus marinus					A	C	A		A	C	A	
Corophium volutator												A
Crassostrea gigas												
Einhornia crustulenta					R							
Hemigrapsus sanguineus												R
Hemigrapsus takanoi											R	
Jaera (Jaera) nordmanni												
Lekaenesphaera rugicauda	C	C							R			
Ligia oceanica												
Melita nitida												
Melita palmata												
Myosotella denticulata												
Neomolgus littoralis	R											
Nereis pelagica												
Orchestia mediterranea	A	C				R						
Physella acuta		R										
Tipulidae (larvae: Tipula paludosa)												C
Aster tripolium				R								
Elymus repens												