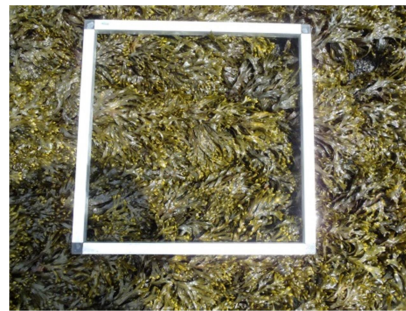


# Non-indigenous species presence and distribution in intertidal hard substrate environments of the Western Scheldt

Results of Transect Monitoring inventory of 2017 compared to 2015-2016.

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 Terneuzen (Left line outside marina in July 2017) view from the lower intertidal; b) Dasya sessilis, a non-indigenous species, as collected near Vlissingen; c) A quadrant in Fucus vesiculosus dominated habitat in the middle intertidal zone near Bath as inventoried on July the 14<sup>th</sup>, 2017.*

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 2017. Six transects on regular spatial intervals in the estuarine gradient of the Western Scheldt (at Breskens, Vlissingen, Terneuzen, Hoedekenskerke, Hansweert and Bath) are 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 site specific -, environmental characteristics and indigenous communities are presented. Results are compared with the situation as observed during former inventories with the same methodology in 2015 and 2016, with in 2016 inventories at exactly the same sites and in 2015 the focus on in- versus outside marina differences at three of the sites.

Compared to 2016 (and 2015) four 'new' non-indigenous and cryptogenic species were observed, all four at the monitoring site of Vlissingen, whereas three NIS observed in 2016 were not found in 2017. Two of the new species, the rhodophyte *Dasya sessilis* and the ascidian *Diplosoma listerianum* are new for the Western Scheldt. The other two 'new' recordings might indicate range extensions into the estuary for the bryozoan *Tricellaria inopinata*, only observed before inside the marinas and harbors of Breskens and Vlissingen, and the Japanese skeleton shrimp *Caprella mutica*, only observed before at the cooling water inlet at Borssele and inside the harbors of Vlissingen. With all NIS + cryptogenic species (except for the orange-striped green anemone *Diadumene lineata*) present at Vlissingen, this rather sheltered site near the harbors with additional important habitats in the form of permanent tidal pools seems to be a hotspot for arriving and expanding NIS in the Western Scheldt.

As already indicated by the inventories in 2015 and 2016, there is a strong relation between the number of NIS (+ cryptogenic species) and the number of indigenous species at the monitoring sites. This indicates that highest chance of finding NIS is in species rich communities, i.e. at good local environmental conditions. Highest numbers of NIS were on average observed in habitats characterized by the presence of sessile habitat-structuring fauna like oysters and barnacles (which themselves are often non-indigenous as well).

Concerning the common to abundantly present NIS in the estuary, it is confirmed that the amphipod *Melita nitida* has largely replaced the indigenous *M. palmata*. Where *D. lineata* and the indigenous *D. cincta* are often present in mixed communities, *D. cincta* seems to do better in the sub-optimal habitats in the mouth of the estuary where *D. lineata* is rare. The distribution of the indigenous (*Carcinus maenas*) and non-indigenous (*Hemigrapsus sanguineus* and *H. takanoi*) shore crab species, considered habitat generalists in the intertidal zone, is largely the result of mutual competition. At present the indigenous blue mussel *Mytilus edulis* clearly benefits from the comprehensive offer of habitat by the Japanese oyster *Crassostrea gigas* in the Western Scheldt.

Transect monitoring is an efficient methodology to detect population and range extensions with their effects for successful NIS that are potentially invasive. For early detection of new NIS in a system, searching for additional species in less common habitats is essential.



## 1. Introduction

In 2017, the transect monitoring inventories in the intertidal zone of the Western Scheldt, with the focus on non-indigenous species as executed in 2016 (Wijnhoven, 2016) were repeated at the same locations. The results of the inventories of 2017, besides non-indigenous and cryptogenic species relative abundance recordings in a representative number of quadrants for a series of transects in a standardized way, also relations with indigenous species presence and environmental and habitat characteristics, are presented in the current report. By inventorying the dominant intertidal hard substrate habitats at six locations along the estuarine gradient of the Western Scheldt outside -but generally in the vicinity of- marinas and harbors, it is expected that a representative view of the current presence and distribution of common and potentially successful non-indigenous and cryptogenic species in this specific zone is achieved. The transect inventories in 2016 and 2017 are a continuation of the pilot inventories of 2015, performed within the frame of the INTEREG IV A 2 Seas project SEFINS, and include the three monitoring locations of 2015 situated outside marinas (Wijnhoven et al., 2015a), expanded with three additional sites to cover the entire gradient. The results of 2015 provided indications that the expected number of non-indigenous species is larger in species rich communities, that the species richness is generally higher outside than inside marinas, and that non-indigenous species observed in transects inside marinas are generally also observed in the vicinity outside these marinas. The results from 2016 provided (additional) insights in the distribution of six non-indigenous species and one cryptogenic species that were also found in 2015, and three additional NIS and one additional cryptogenic species were observed in the transects (Wijnhoven, 2016).

Besides that potentially 'new' NIS can be found in the transects in 2017, the observations of two consecutive years and the series of three years for three of the monitoring sites will provide information on developments of NIS populations in the estuary and developments in relative abundances and spatial distribution in particular. Results will shed a light on the consistency of observed patterns and possible interactions with indigenous species populations. The resulting relative large dataset will allow detailed niche identification. Additionally the detection efficiency of transect monitoring for NIS will be investigated.

## 2. Material and methods

### 2.1 Transect monitoring inventory

As indicated in Wijnhoven (2016), it is of importance for the continuity and comparability of the data that the methodology, as applied during different years, is as much standardized as possible. Although there were some slight adaptations to the methodology from 2015 to 2016, where the pilot methodology was put in practice at more sites in the Western Scheldt, the methodology in 2017 was exactly the same as in 2016. This means that again the monitoring consisted of the inventory of 12 transect lines, two lines through dominant habitat types at each of the six monitoring sites, where positions from last year were repeated. As in 2016, compared to 2015, the timing of the inventories is shifted from late spring to the summer with all the transects inventoried between the 11<sup>th</sup> of July and the 11<sup>th</sup> of August (in 2016 all transects were inventoried in July).

Below the basal description of the transect monitoring methodology is given. Details are provided by Wijnhoven et al. (2015a)), and a few adaptations that were done in 2016 and repeated in 2017, that except for the timing are not expected have an impact on the results when it concern the same site, are described in Wijnhoven (2016).

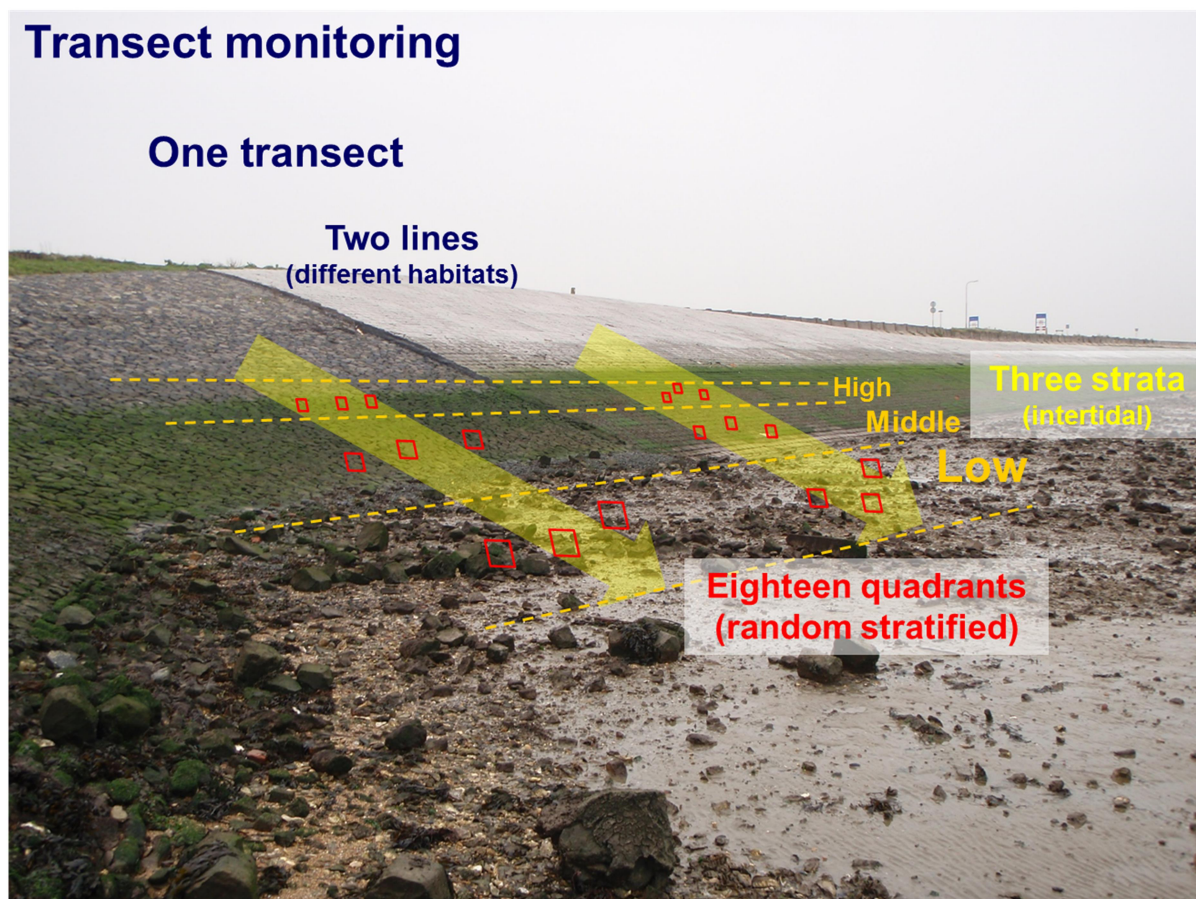


Figure 1. An example of a transect showing the ideal positioning of lines and strata and the random positioning of 18 quadrants.

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).

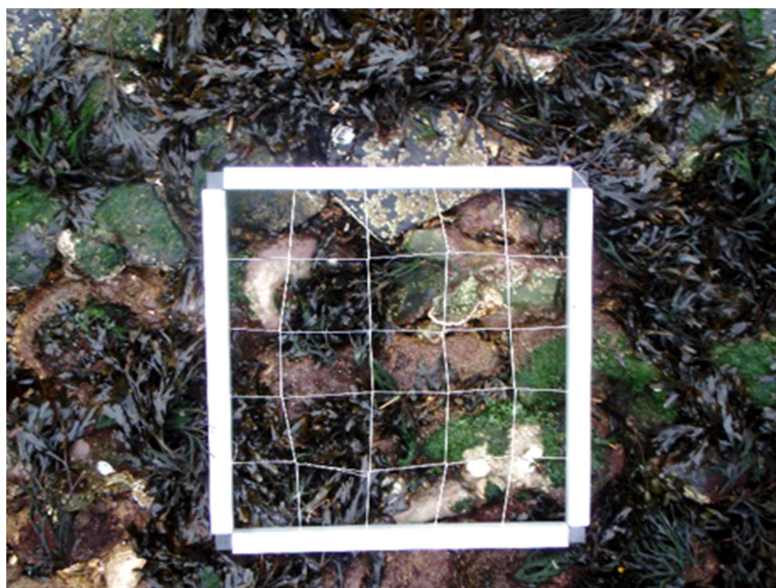


Figure 2. An example of a photo of a 'random' placed quadrat ready to be inventoried.

The actual standardized NIS inventory is 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 quadrat like shown in Figure 2 is taken. Then the inventory of the quadrat 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 quadrat 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 process:

- 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.

## 2.2 Monitoring sites

In 2017 the same transect lines, covering the estuarine gradient in the Western Scheldt at locations outside marinas (or a freshwater inlet), have been inventoried as in 2016. The habitat constitution of the transect lines at Breskens, Vlissingen, Terneuzen, Hoedekenskerke, Hansweert and Bath (see positioning in Western Scheldt in Fig. 3) is described below. Deviations from the situation in 2016 are generally small, and more in the percentages of coverage by algae and/or sessile fauna than characterization of habitats by other species. Detailed aerial photos of the positioning of transect lines are given in Wijnhoven (2016).

The transect lines of **Breskens** were inventoried in 2017 on July the 11<sup>th</sup> and the 12<sup>th</sup>. The left line is situated on a dam covered with large basalt blocks at the estuary side. The high intertidal zone (7 meters in width as measured in 2017) is partially covered with filamentous green-algae (predominantly *Ulothrix flacca* and *Blidingia marginata*), transitioning to a 7 meters middle intertidal zone where basalt blocks are overgrown especially with *Fucus spiralis* (*F. vesiculosus* in the lower part). The low intertidal zone (approximately 15 meters) consists of rubble, partly overgrown with the two mentioned *Fucus* species, on soft sediment (muddy fine sand) substratum, with the presence of a mussel reef at the low water line. The high intertidal zone (3 meters) of the right transect line consists of green filamentous algae on asphalt transitioning to a 6,5 meters middle intertidal zone with predominantly *Fucus spiralis* and the abundant presence of *Austrominius modestus* (also on asphalt). In the 15



meters wide lower intertidal zone, basalt blocks are often overgrown with filamentous green algae, *Ulva cf lactuca* and *F. vesiculosus* and are characterized by the abundant presence of barnacles, especially *A. modestus*. The blocks are placed on a substratum of steel slags in a muddy environment. Also here a mussel reef is present around the low water line with mussels that are generally 2 years old. Where algal communities in 2016 were quite different from those present in 2015, the difference between 2016 and 2017 was not that large. It appears that reconstruction works and fore bank reinforcements at Breskens have at least also taken place in 2014 (RWS, 2013).

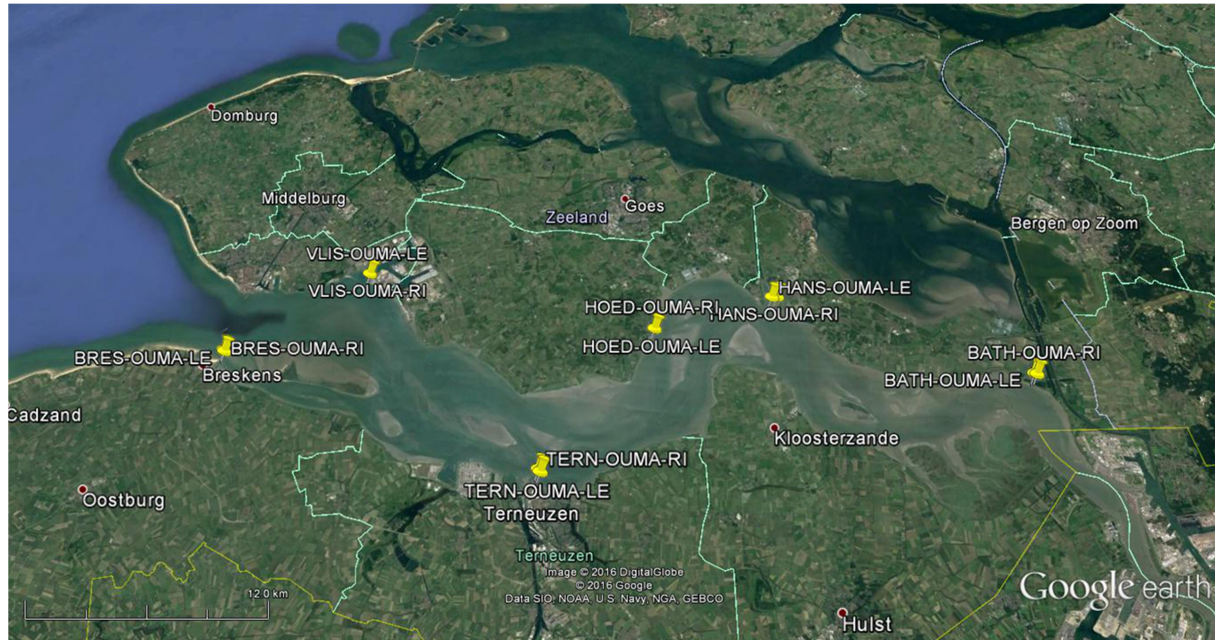


Figure 3. Map of the Western Scheldt with indication of the monitoring sites from west to east: Breskens (BRES), Vlissingen (VLIS) Terneuzen (TERN), Hoedekenskerke (HOED), Hansweert (HANS) and Bath (BATH). At each site a transect (situated outside the marina if present: OUMA) consisting of two transect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

The high zone of the intertidal range of the left transect line at **Vlissingen** (8 meters in width) consists of partly with concrete covered basalt that covers the crevices. The lower part, completely covered with concrete, is partly overgrown with filamentous green algae (*U. flacca* and *Blidingia spp.*). The slope continues in an approximately 11 meters *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*), where the crevices are filled with shell pieces. The low intertidal zone (12 meters of width) consists of basalt blocks on rubble and oyster shells containing either *Fucus serratus* or *U. cf lactuca*. A few pools are present and in the lowest part an oyster reef is present. In the right transect line the high intertidal zone (8 meters) consists of with concrete covered basalt with almost no crevices. The upper part is bare hard substrate, the lower part contains some *Blidingia* growth. The middle intertidal zone (9 meters) is dominated by *Fucus* spp. (either *F. spiralis* or *F. vesiculosus*) on basalt blocks with crevices in between, and oysters in the lower part. The low intertidal zone (extending over about 23 meters) is a horizontal oyster reef (*Crassostrea gigas*), of which a part (middle part) consists of dumped (partly dead) oysters. The lowest part is an oyster reef. The horizontal area contains several quite large pools that permanently contain water.

The site of **Terneuzen** was inventoried on July the 17<sup>th</sup> and 26<sup>th</sup> in 2017. The left transect line was positioned through a 3 meters high intertidal zone of bare hydroblocks gradually continuing with some cover of *U. flacca* and lower *B. marginata*. The high intertidal zone transitions into a 4 meters wide zone dominated by brown algae with *F. spiralis* in the upper part and *F. vesiculosus* in the lower mid-intertidal zone, with some *Ascophyllum nodosum* in the lowest part. The broader low intertidal zone (12 meters) consists of rubble, debris and some basalt blocks partly covered with *Semibalanus balanoides*, and continues into a vast soft sediment (muddy fine sand) tidal flat. The right transect line (an aggregation of a dike slope -high intertidal zone- and a breakwater extending in predominantly soft sediment environment -middle and low intertidal zones-) is paved with gravel tiles and continues with largely bare basalt with large spaces in between in the high intertidal zone with a width of 9 meters.

The middle intertidal zone (top of the breakwater with a width of 6 meters) consists of cobblestone overgrown with *Ascophyllum nodosum*. The low intertidal zone (6 meters) basically consists of rubble, basalt blocks and oyster shells (*C. gigas*) with some *Ascophyllum nodosum*, and continues in a vast soft sediment (muddy fine sand) tidal flat.

The transect lines at **Hoedekenskerke** were inventoried in 2017 on August the 10<sup>th</sup> and the 11<sup>th</sup>. The left transect line consists in the highest part of bare tiles, continuing with a steep slope of basalt with deep crevices -sometimes containing water- between the blocks and in the lower part *Blidingia* spp. growth. The middle intertidal zone consists of a narrow part with *F. spiralis* and the remainder with *F. vesiculosus* growing on basalt and in lower part cobblestones with deep crevices in between. In the lower part more *C. gigas* is present. The low intertidal zone is formed by a horizontal stretch of soft substrate (muddy) with large basalt blocks with *C. gigas* and an oyster reef near the low water line. The high intertidal zone of the right transect line consists of bare slightly asphalted basalt in the highest part and a part overgrown with *Blidingia* spp. (with fauna in crevices under asphalt). The middle intertidal zone continues as an extensive *Fucus* zone (predominantly *F. vesiculosus* with *Ulva intestinalis*). The lower middle intertidal consists of cobble stones with deep crevices and *C. gigas* growth. The low intertidal zone consists of a narrow *C. gigas* band on slope continuing in a mudflat with basalt islands with oyster growth and an oyster reef in the lowest part.

At **Hansweert** the transect lines are inventoried on July the 27<sup>th</sup> and the 28<sup>th</sup>, 2017. The left transect line on an extension of the dike/dam into the Western Scheldt has a high intertidal zone of 6 meters consisting of asphalted rubble/basalt blocks, in the highest part bare, and transitioning to a coverage with *B. minima*. In the middle intertidal zone (4 meters) most of the asphalted rubble is covered by *B. minima* and *F. vesiculosus*. The lower intertidal zone (15 meters) consists of large rubble and basalt blocks partly covered with *B. minima*, and in the lower part more oysters (*C. gigas*) to an oyster reef in the lowest part. The right transect line consists of bare hydroblocks continuing in asphalted basalt-blocks gradually transitioning to overgrowth with mat-forming green-algae (*B. minima*) in the 6 meters wide high intertidal zone. The middle intertidal zone (10 meters) consists of basalt-blocks (without asphalt) covered with *F. vesiculosus*. There are several small pools formed in the crevices and in the asphalt and the zone extends in a narrow strip of horizontal asphalted rubble. The low intertidal zone consists of large rubble and basalt blocks covered with oysters (*C. gigas*) and some algae (e.g. *F. vesiculosus*) extending in a vast zone of muddy fine sand substrate.

The transect lines at **Bath** were inventoried on July the 13<sup>th</sup> and 14<sup>th</sup> in 2017. The left transect line 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 (*B. marginata*). The zone has a total width of 12 meters. The mid-intertidal zone (3 meters) with a substratum of basalt is covered with *Fucus* (*F. spiralis* transgressing to *F. vesiculosus*). In the low intertidal zone (5 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, forming a reef there. The right transect line contains bare 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 *Blidingia* spp. in the highest part and *F. vesiculosus* in the lower part). High and middle intertidal zone have a width of 5,5 and 3,5 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 fine sand.

Visualizations by photos from the transects during the inventories either taken from high to low or from low to high in the intertidal zone are presented in Appendix 1.

## 2.3 Sites relative to the estuarine gradient

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. Figure 4 indicates the distance of the monitoring sites to the mouth of the estuary and shows average salinity and yearly fluctuations as indicated by error bars. The general environmental conditions at each of the sites are described in Wijnhoven (2016); the same data are used in 2017. An exception with values slightly deviating from those as measured in 2016 is the width of the intertidal strata (zone width) as recorded for each of the transect lines (Fig. 6). Although in 2017 inventoried transect lines are situated approximately on the same spots as in 2016, a few meters

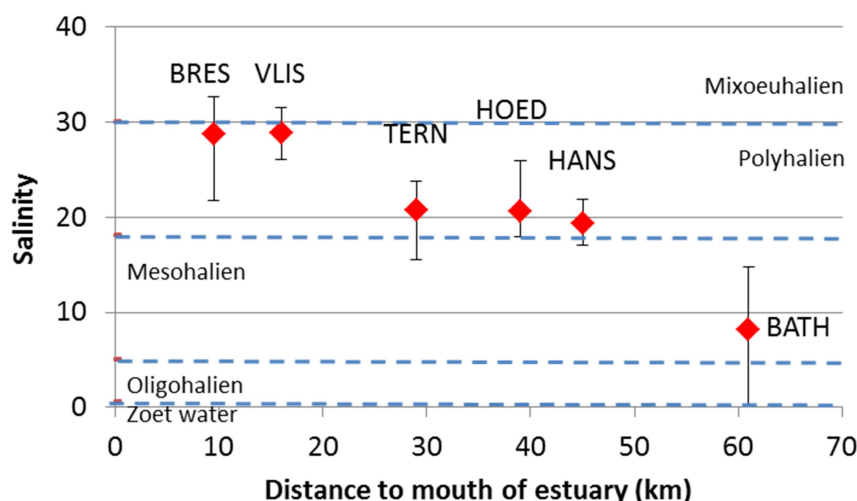


Figure 5. Positioning of the monitoring sites relative to the estuarine gradient as indicated by the average salinity, salinity range (yearly fluctuations without extremes) and the distance to the mouth (at the height of Westkapelle) of the estuary as measured through the center of the estuary.

tidal differences during inventories related to the moon phase and expected presence of hard substrate. The zone width 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 withstand. Especially Vlissingen, but also Hoedekenskerke and Hansweert are characterized by a wide middle intertidal zone, and harbor an extensive *Fucus* zone. A larger transect might indicate that more different niches are potentially present for species as well. Moreover, it also means that a larger area is inventoried for additional species.

Of course, detailed information describing the local habitat like coverage by algae and/or sessile fauna

and the dominant habitat-determining species is subject to changes in time. These characteristics are part of the inventories and results are presented with species abundances in Appendix 3.

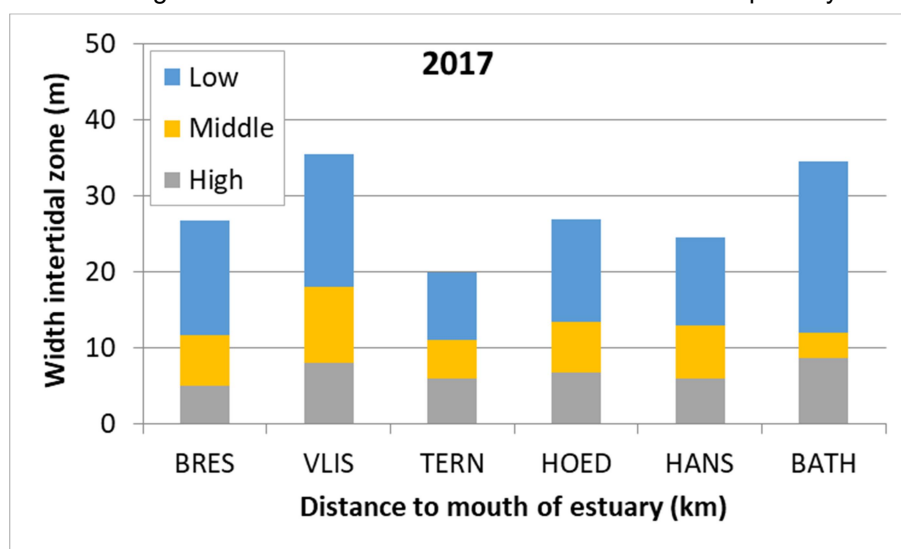


Figure 6. Total width (in meters) and subdivision into three strata of the intertidal zone at the monitoring sites. Presented values are the average of two transect lines.

## 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).

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.

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. Species – environment (location – habitat -, and/or community characteristics) relations are identified with multi-variate statistics using Canoco for Windows 4,5. Initially Detrended Correspondence Analyses were performed on the species data to detect the gradient length. As in all cases presented here, the gradient length appeared to be larger than '3', the gradient length was considered large. This means that dependent of whether an indirect (or unconstrained) gradient analysis or a direct (or constrained) gradient analysis was preferred, respectively a Correspondence Analysis (CA) or a Canonical Correspondence Analysis (CCA) was used. In the first case an optimal distribution of samples is solely based on species data, in which environmental information is plotted afterwards: i.e. analysis focusing on differences between species. In the later an optimal distribution of samples based on species and environmental data is used: i.e. taking known environmental gradients into account (e.g. Leps & Smilauer, 2003).

### 3. Results & discussion

#### 3.1 Observed non-indigenous species

In 2017 a total of 9 non-indigenous species are observed during the transect inventories in the Western Scheldt (Table 1). Of these nine non-indigenous species, three have not been observed during transect monitoring in 2016 and 2015. The new species are all three observed at the monitoring site of Vlissingen. One of these new species, the red algae *Dasya sessilis*, seems to be the first observation of this species in the Western Scheldt. *Dasya sessilis* was only observed outside quadrants as an additional species. The two other new NIS for transect monitoring are also solely observed at Vlissingen, and are the amphipod *Caprella mutica* (only found as an additional species) and the bryozoan *Tricellaria inopinata*, found to be common in one of the quadrants. Both species are known from the Western Scheldt but these observations outside marinas in the vicinity of Vlissingen might indicate range extensions. Additionally also three cryptogenic species were observed during 2017, of which one, the ascidian *Diplosoma listerianum* has not been observed during transect monitoring before. Moreover, although present in the vicinity already decades ago, the species does not seem to be recorded for the Western Scheldt before. Also *D. listerianum* was found in the transect of Vlissingen, in this case in one of the quadrants.

Table 1. Overview of the presence of non-indigenous species and cryptogenic species in transects during the inventories of 2017, 2016 and 2015 in the Western Scheldt.

Year	2017						2016						2015					
Site	BATH	HANS	HOED	TERN	VLIS	BRES	BATH	HANS	HOED	TERN	VLIS	BRES	HANS	TERN	BRES	HANS	TERN	BRES
Transect	OUMA												INMA					
Non-indigenous species																		
<i>Austrominius modestus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Caprella mutica</i>					x													
<i>Caulacanthus ustulatus</i>											x							
<i>Crassostrea gigas</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Dasya sessilis</i>					x													
<i>Diadumene lineata</i>		x	x			x		x				x	x					
<i>Hemigrapsus sanguineus</i>	x	x	x	x	x	x	x	x	x	x	x	x		x				
<i>Hemigrapsus takanoi</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Melita nitida</i>	x		x	x	x		x	x	x	x	x		x	x		x	x	x
<i>Mnemiopsis leidyi</i>												x						
<i>Physella acuta</i>							x											
<i>Tricellaria inopinata</i>					x													
Cryptogenic species																		
<i>Amphibalanus improvisus</i>	x	x	x	x	x		x		x									
<i>Diplosoma listerianum</i>					x													
<i>Ulva cf lactuca</i>	x	x	x		x	x		x	x		x	x	x		x		x	x

Sites: BATH = Bath, HANS = Hansweert, HOED = Hoedekenskerke, TERN = Terneuzen, VLIS = Vlissingen, BRES = Breskens; Transects: OUMA = Outside marina, INMA = Inside marina

Three of the non-indigenous species found in 2016 were not observed in the transects in 2017. Of these, the ctenophore *Mnemiopsis leidyi* is not a typical species to be present in the intertidal zone during low water (only if it gets stuck there). It is therefore not surprising that this species that is definitely still around in Western Scheldt was not observed during transect monitoring. Of *Physella acuta* only one specimen was found in 2016 near Bath. It might be that it was an occasional

observation of a specimen that had floated in but that the species did not succeed to establish at Bath yet, or that a small but not expanding population is present in the vicinity of the transects. The third

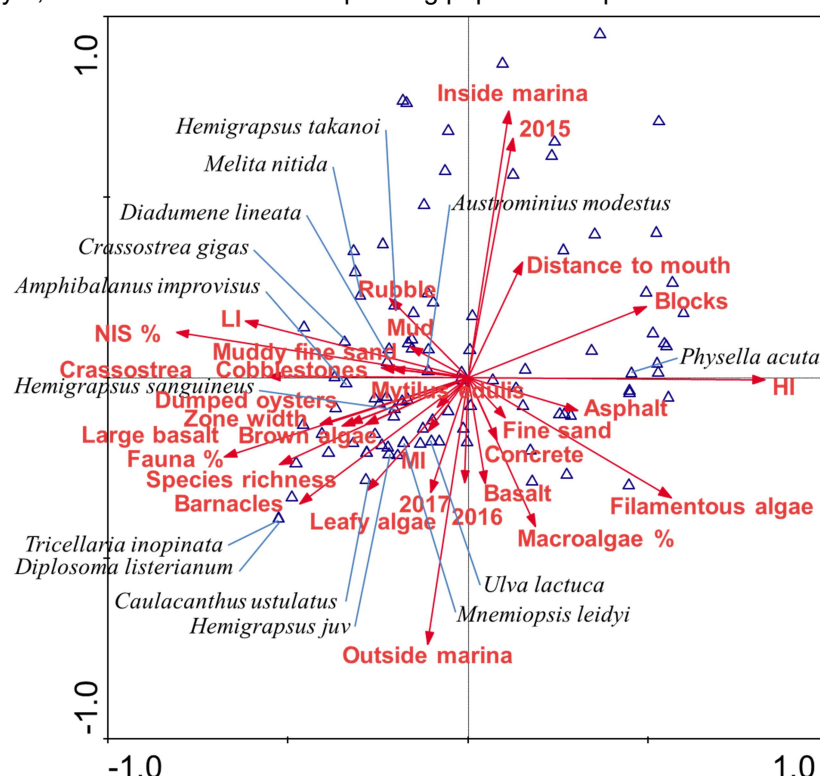


Figure 7. Canonical Correspondence Analysis (CCA) of species relative abundances related to environmental characteristics (i.e. Total coverage of sessile groups in percentage (Fauna %; Macroalgae %), dominant (>10% coverage) habitat-forming species presence (*Crassostrea gigas*; *Mytilus edulis*; Filamentous (green) algae; Leafy (green) algae; Brown algae), hard substrate type (Dumped oysters; Large basalt (boulders); Cobblestones; Blocks (e.g. hydroblocks and concrete blocks revetment); Basalt (block revetment); Asphalt; Concrete; Rubble), sediment typology in vicinity (Mud; Muddy fine sand; Fine sand), positioning relative to marinas (Inside marina; Outside marina), in tidal zones (HI - high intertidal; MI – middle intertidal; LI – low intertidal), and as Distance to the mouth (of the estuary), monitoring year (2015; 2016; 2017), total number of species (Species richness) and percentage of non-indigenous species including cryptogenic species (NIS %) per quadrant. Positioning of non-indigenous species and cryptogenic species to the ordination axes are specifically indicated in the graph.

sites from Bath up to Vlissingen, where in 2016 it was not observed at Hansweert and Terneuzen.

Figure 7 shows the results from a Canonical Correspondence Analysis (CCA) of species relative abundance data and environmental parameters from all transect monitoring campaigns available for the Western Scheldt (i.e. data from quadrants inventoried during 2015-2017). The positioning of all observed non-indigenous and cryptogenic species among the environmental gradients and site characteristics are specifically indicated. An important observation is that most NIS (including cryptogenic species) are typically related to the middle and especially the low intertidal zones. The low intertidal zone is also where on average the largest share of NIS (NIS %) among the total of species is observed. The CCA results also show that as concluded before (Wijnhoven et al., 2015a; Wijnhoven, 2016), a large share of NIS is typically found in quadrants with a large total number of species (Species richness). These are habitats with a relative high coverage by sessile fauna species (Fauna %) as is for instance the case in habitats where *Crassostrea gigas* or barnacle species are of importance. These habitat-structuring species themselves are of course often also non-indigenous or cryptogenic (e.g. *C. gigas*, *Austrominius modestus*, and to a lesser extent *A. improvisus*). Habitats

species, the red algae *Caulacanthus ustulatus* was present in the middle and low intertidal zone at Vlissingen in 2016 with several specimens. That the species was not found in 2017 might indicate that the species at least did not succeed to expand its population there. It is however possible that the species is still present in the vicinity in low numbers but might have been overlooked in 2017. It is very well possible that specimens have been identified as the indigenous *Chondracanthus acicularis*, which is common at Vlissingen as well, in the field. At least other red algae species, especially indigenous species but also the non-indigenous *D. sessilis*, appear to be more abundant especially in the permanent pools in 2017.

Observations for the NIS and cryptogenic species that were observed during both years 2017 and 2016, are in 2017 more or less in line with the earlier observations (Table 1). Slight differences are that the amphipod *Melita nitida* is in 2017 not found at Hansweert, where it was present in 2016 and 2015, and that the balanid species *Amphibalanus improvisus* is present at all monitoring

where filamentous green algae are of importance generally harbor not much NIS, and are generally also not that species rich and often situated in the high intertidal zone.

### 3.1.1. *Austrominius modestus* (New-Zealand barnacle)

Like in 2015 and 2016 (Wijnhoven et al., 2015a; Wijnhoven, 2016), the non-indigenous New-Zealand barnacle *A. modestus*

is the most abundant barnacle species present in the intertidal zone of the Western Scheldt. The species is only absent at the lower salinity site of Bath with oligohaline to mesohaline conditions (Fig. 8). At Bath, Sessilidae are less abundant in general, with only

*Amphibalanus improvisus* (bay barnacle) locally abundantly present (i.e. in just one of the quadrants). *A. improvisus* is however

not an indigenous species as well, but is considered cryptogenic (Kerckhof et al., 2007). The only indigenous barnacle species that is abundantly present in the Western Scheldt as well is *Semibalanus balanoides* (northern rock barnacle). Like *A. modestus* the species is present in the entire salinity range, except for the lower salinity

part and therefore lacking at Bath. Numbers of *S. balanoides* are generally lower than for *A. modestus*, although the species are frequently found as combined communities at the same sites (e.g. Fig. 9). Only at Hansweert the indigenous species is at least as abundantly present as *A. modestus*. Distribution and abundance patterns in 2017 are very similar to those observed in 2016, especially those of *A. modestus* (Fig. 8). A difference is however the presence of *A. improvisus* at Terneuzen and Hansweert where it was not found in the transects in 2016. For the first time, compared to the inventories of 2015-2016, a fourth barnacle species was found in the transects of the Western Scheldt: the indigenous acorn barnacle *Balanus crenatus*. *B. crenatus* is present at Breskens and Hoedekenskerke. The question is whether the non-indigenous and cryptogenic species are real competitors of the indigenous species? In case of the barnacle species discussed here, and the Western Scheldt in particular, this is definitely the case, where the non-indigenous species is dominating the intertidal hard substrate communities which, at least a century ago, used to be inhabited by predominantly the other three mentioned

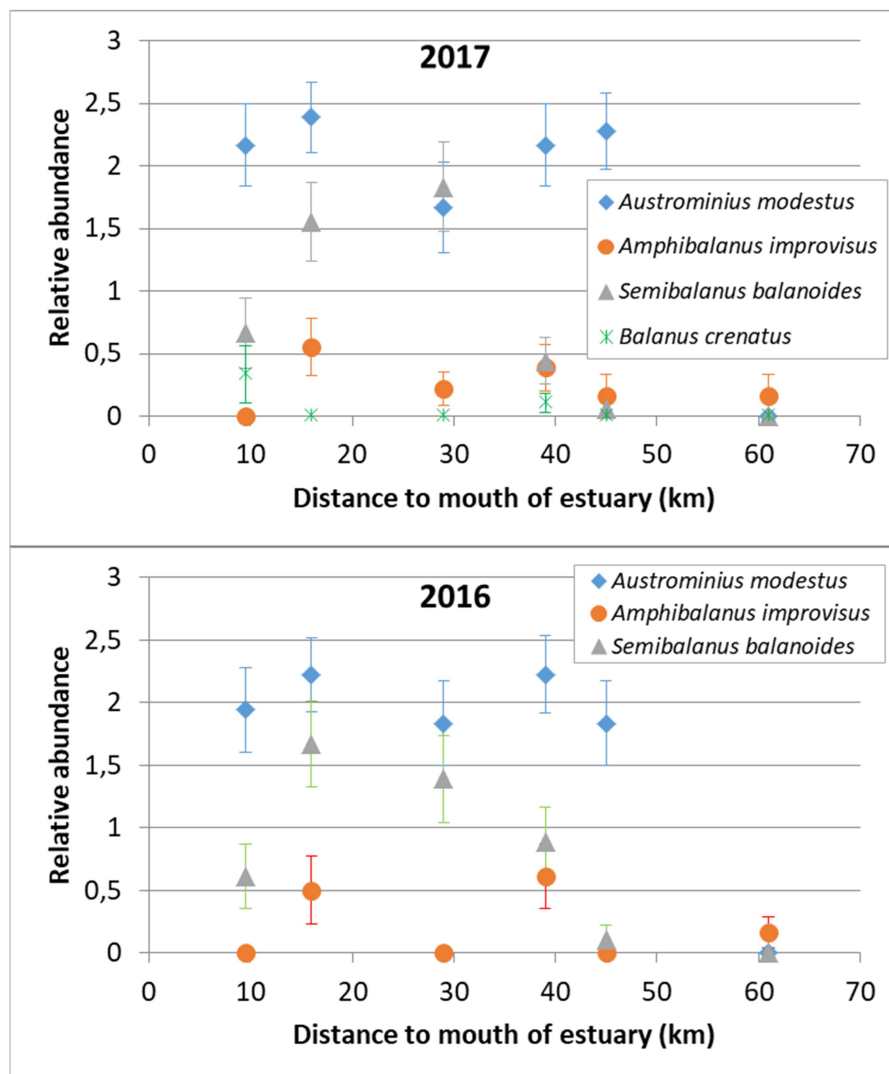


Figure 8. Average ( $\pm$  standard error) relative abundance of barnacles related to the distance of the monitoring sites to the mouth of the estuary. Comparison of barnacle species over the estuarine gradient in 2017 (a) and 2016 (b). The relative abundance scale goes from absence (0) to rare (i.e. 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).



species, and possibly a few other more rare indigenous species (Kerckhof, 2002). It seems that in particularly *B. crenatus* must have been much more abundant in the estuary before the introduction of *A. modestus*. Figure 10 indicates that *B. crenatus* is now only observed in a particular niche (part of the Western Scheldt intertidal zone), typically related to habitats in which *Mytilus edulis* is an important structuring species. This might suggest that the barnacle species can possibly profit in the future from expanding *Mytilus* populations forming reefs as currently observed (see below in this report; Wijnhoven & Kromkamp, 2013). It has however to be noticed that due to the, at present, very low densities of *B. crenatus*, it is uncertain whether *Mytilus* dominated habitats might be a stronghold for the species.



Figure 9. *Amphibalanus improvisus* among *Austrominius modestus* as observed at Hansweert in 2017.

Figure 10 also indicates that both the indigenous *S. balanoides* and non-indigenous *A. modestus* are not very habitat specific, inhabiting the entire intertidal zone. The species might compete for the same spaces but the one is not outcompeted by the other as indicated by the frequent co-existence. *S. balanoides* reaches on average the highest densities at exactly the same sites where *A. modestus* is abundantly present, except for the site nearest to the North Sea (i.e. Breskens) where *S. balanoides* reaches on average the highest densities in habitats where *A. modestus* is found to be rare (Fig. 11). In a few quadrants *S. balanoides* is found to be the only barnacle, but the species is than always present in just a few quadrants.

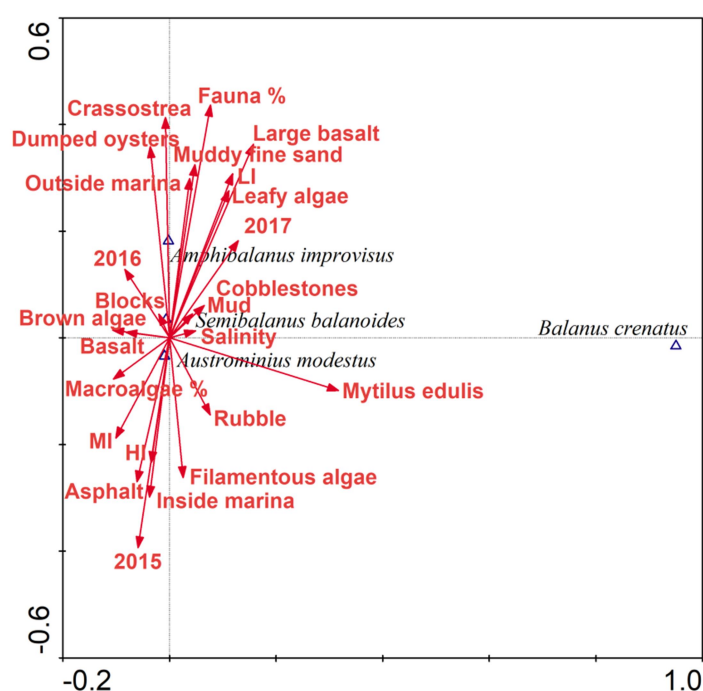
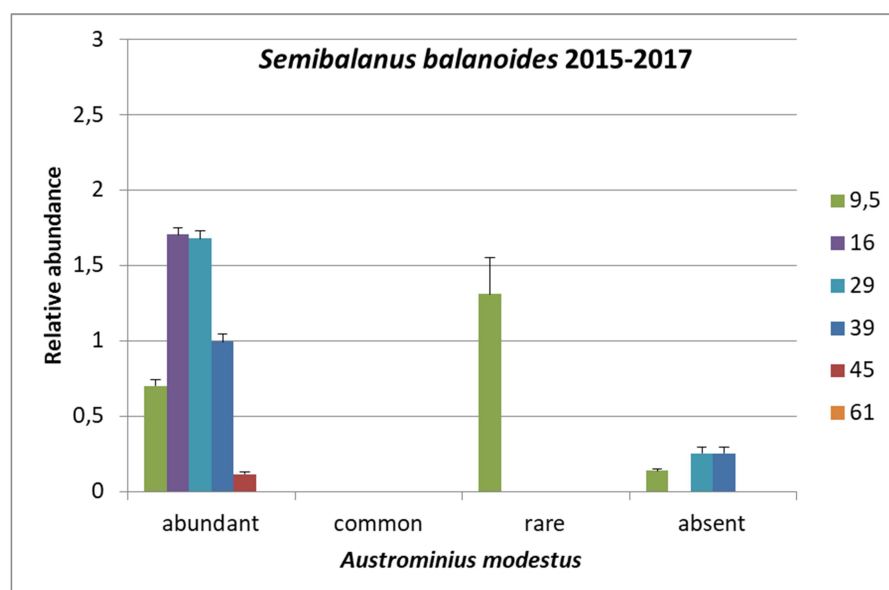


Figure 10. Correspondence Analysis (CA) of Sessilidae relative abundances related to environmental characteristics (i.e. Total coverage of sessile groups in percentage (Fauna %; Macroalgae %), dominant (>10% coverage) habitat-forming species presence (*Crassostrea gigas*; *Mytilus edulis*; Filamentous (green) algae; Leafy (green) algae; Brown algae), hard substrate type (Dumped oysters; Large basalt (boulders); Cobblestones; Blocks (e.g. hydroblocks and concrete blocks revetment); Basalt (block revetment); Asphalt; Rubble), sediment typology in vicinity (Mud; Muddy fine sand), positioning relative to marinas (Inside marina; Outside marina), positioning in tidal zone (HI - high intertidal; MI - middle intertidal; LI - low intertidal), monitoring year (2015; 2016; 2017).

The cryptogenic *A. improvisus* is typically more abundant in habitats dominated by *Crassostrea gigas* (either or not dumped there as a substratum). In such habitats per definition the faunal coverage is relatively high. The communities with *A. improvisus* are more often found when the substratum

consists of large basalt boulders in the low intertidal zone. Additionally, actually related to *C gigas* related habitats, these habitats are generally muddy fine sand habitats where leafy green algae (e.g. *Ulva cf lactuca*) are common. *A. improvisus* therefore typically seems to be present in a habitat structured by non-indigenous species (both oysters and green algae).

Figure 11. Relative abundance of *S. balanoides* in habitats with different *A. modestus* abundances on different distances (in km) from the mouth of the Western Scheldt estuary. 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. *Caprella mutica* (Japanese skeleton shrimp)



Figure 12. *Caprella mutica* (female) as collected in the transect at Vlissingen in 2017.

Searching for additional species in the left transect line at Vlissingen a specimen of *Caprella mutica* was encountered in the middle intertidal zone among the *Fucus* vegetation. The species seems to be present in the Netherlands since 1993, for the first time observed at the entrance of the Eastern Scheldt (Wolff, 2005). In the Western Scheldt the species is at least present since 1997, when it was found at the cooling water discharge at Borssele (Wijnhoven et al., 2017). The species is nowadays found in the Netherlands in several marine waters (e.g. North Sea, Wadden Sea, South-western delta waters) and can be observed in large numbers (Gittenberger et al., 2009; Wijnhoven et al., 2015b). In the Western Scheldt the species is known to be present in the harbor area of Vlissingen as recently found on several sites on SETL-plates and in scrape samples (Wijnhoven et al., 2017). As *C. mutica* is generally found subtidal, the species was not observed during transect monitoring before, and only one specimen was found in 2017. It is however

also unclear if the species is present in the Western Scheldt outside the Vlissingen-Borsele region. It might be that this is not the case yet, or at least not common, as the species is not observed during the various monitoring projects considered in Wijnhoven et al. (2017). It might be very well possible that the non-indigenous species is extending its range in the Western Scheldt from the harbor area of Vlissingen-Borsele to other parts of the estuary.

### 3.1.3. *Crassostrea gigas* (Pacific oyster)

The distribution pattern of *Crassostrea gigas* in 2017 is very similar to that observed in 2016, although the average relative abundance seems to have slightly increased at half of the monitoring sites (i.e. Breskens, Vlissingen and Hansweert) (Fig. 13). Especially the sites of Vlissingen (partly developing on



top of dumped oyster shells; Fig. 14b), Hoedekenskerke and Hansweert harbor extensive oyster reefs that are not solely restricted to the low intertidal zone, but with oysters also abundantly present above this zone. Differences in the average relative abundance of *Mytilus edulis* are only significant at Hoedekenskerke where an increase is observed, and a slight increase might be present at the two most western sites. Comparing the two species this means that *C. gigas* is as abundant at Breskens now as *M. edulis*, but that *M. edulis* is closing the gap at Hoedekenskerke. The increase of the oyster populations at Breskens is a continuation of the pattern observed from 2015 to 2016 and can be seen as an expansion into largely empty niches as arisen after fore bank reinforcement works executed there up to and including the year 2014. Mussel spat fall has not been as massive and successful in 2017 as in 2016, but 0+ *M. edulis* was observed at most sites (except for Bath where salinity might be too low on a regular basis).

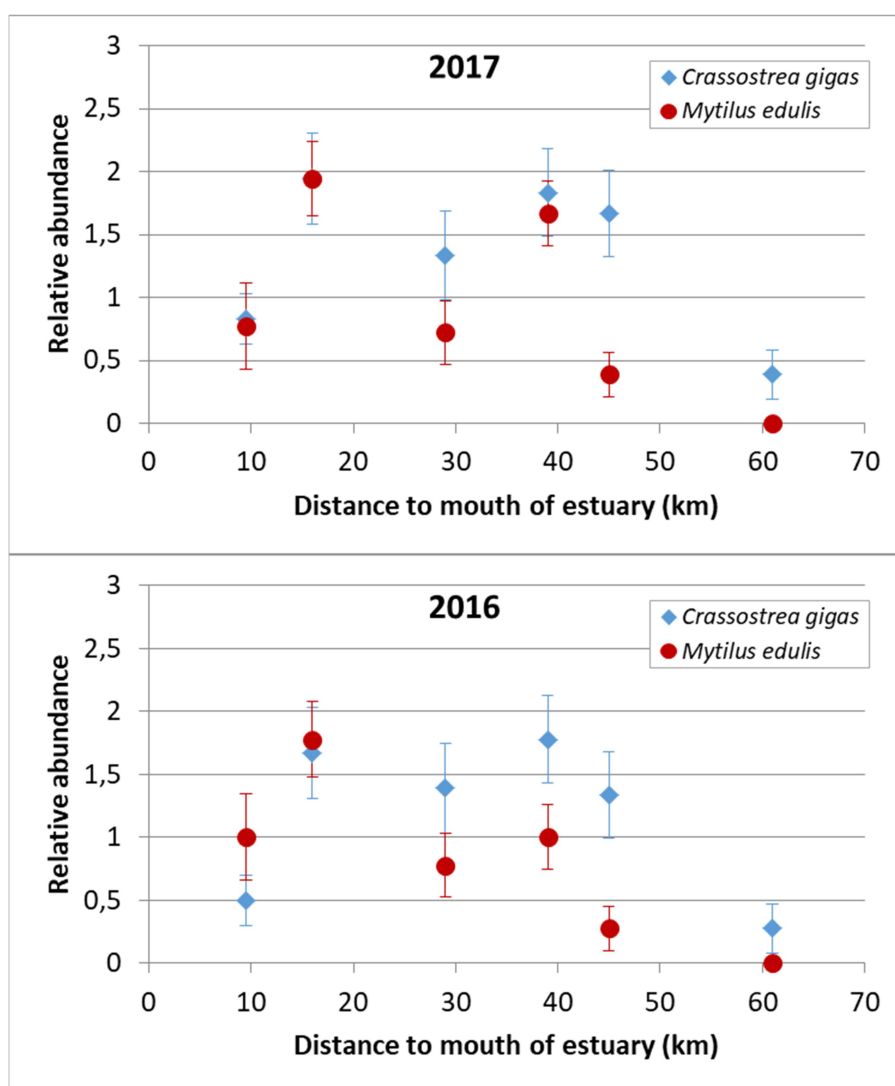


Figure 13. Average ( $\pm$  standard error) relative abundance of *C. gigas* and *M. edulis* related to the distance of the monitoring sites to the mouth of the estuary. Comparison of the two habitat forming bivalve species over the estuarine gradient in 2017 (a) and 2016 (b). The relative abundance 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).

The question is if the non-indigenous *C. gigas* and the indigenous *M. edulis* are competing for resources; predominantly space and food? At the system level it is not expected that food is limited in the Western Scheldt for suspension feeders, but locally around reefs of reef building bivalves it can be the case. It is most likely that the local environmental conditions of the water column are most important in determining whether the environment is suitable for bivalves in which quantities. In the Western Scheldt especially water turbidity and the sediment content of the water column might play a role in combination with water retention at the sites with reef building bivalves (Wijnhoven & Kromkamp, 2013). The bivalves themselves and *C. gigas* in particular can play an important role in the local deterioration of an environment due to massive production of phaeces and pseudofaeces and the increased sedimentation of mud in presence of oyster reefs due to the impact on the local water velocity. Especially in sheltered spots like inside marinas this seems to be an important phenomenon (Wijnhoven et al., 2015a). However, at more exposed sites, reef-building bivalves, like other hard



Figure 14a. *Crassostrea gigas* reef as present in the low intertidal zone at Hansweert.



Figure 14b. *Crassostrea gigas* reef developing on top of a substratum of dumped oyster shells as present at the monitoring site of Vlissingen.

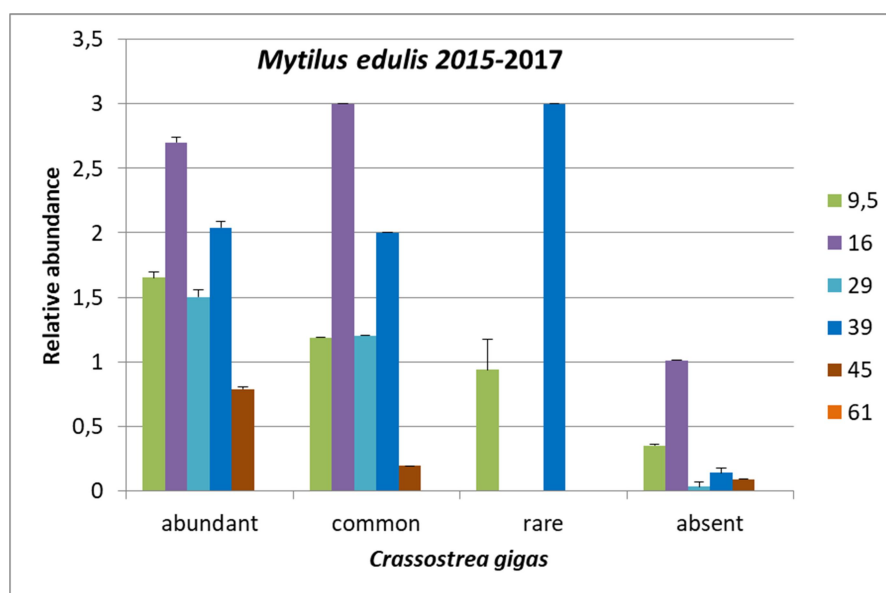
substrate species, can potentially profit from available tertiary structures provided by reef-building species. During the introduction of *C. gigas* in the Western Scheldt in the late 80s and especially the 90s of the 20<sup>th</sup> century, blue mussel reefs were largely absent. Therefore competition for space between the two species was generally not of importance. *C. gigas* could profit from plenty of space (i.e. open niches) available. At present it seems that especially *M. edulis* is growing among Pacific oysters and is using *C. gigas* as substratum. The situation at Breskens in the lowest part of the lower intertidal zone shows that in case of the provision of new substrate on exposed sites, in years of successful mussel spat fall, it is *M. edulis* that is the most successful settler (like in 2016) compared to *C. gigas* (see Fig. 15). Figure 16 shows that in general *M. edulis* abundances are highest in the abundant presence of *C. gigas* and decreases with decreasing numbers of oysters at each of the sites. Exceptions might be the high blue mussel abundances in a few cases at Vlissingen and Hoedekenskerke where oyster are less abundant or even lacking. It has to be noticed that these results are partially due to the low number of cases in which *C. gigas* is common to rare (*C. gigas* is generally abundant present or absent in a quadrant). These cases are generally found in the upper middle and high intertidal zone that can be suitable for mussels but seem to be unsuitable for oysters. Blue mussels are often observed in crevices and under algae there. The results show that there is potential competition between the non-indigenous and the indigenous bivalve species, but that at present *M. edulis* largely benefits from the habitat provided by *C. gigas*.



Figure 15. Blue mussel reefs are still present around the lowest low water line at Breskens, where most specimens have an age of 1+ year now.



Figure 16. Relative abundance of *M. edulis* in habitats with different *C. gigas* abundances on different distances (in km) from the mouth of the Western Scheldt estuary. 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. *Dasya sessilis*

(No vernacular name in English: 'gedrongen zeehoornblad' in Dutch)

The monitoring site of Vlissingen, and the permanent pools and ponds in the low intertidal zone in particular, are like in 2016 the source for new observations of non-indigenous species during the inventories. Like last year a new Rhodophyta species is observed. Several red algae species particularly thrive well in the pools whereas red algae (except for a few species also present at



Figure 17. *Dasya sessilis* as collected from a permanent tidal pool in the transect at Vlissingen in 2017: a) habitus; b) detail.

Vlissingen) are generally scarce in other habitats in the intertidal zone. In 2017, *Dasya sessilis* (kindly identified by Herre Stengenga) was collected from one of the pools, where several rooted plants were present. The species is originally from East Asia and initially introduced probably with oysters in Europe in the Mediterranean, first observed in 1984, but probably already present since the 1970s. The species has spread throughout the western Mediterranean and extended its range into the Atlantic along the Portuguese and Spanish coast up to southern France (Bassin d'Arcachon) (ICES, 2006; Stengenga & Karremans, 2014; Guiry, 2017). The species was first observed in the Netherlands in 2003 in the Eastern Scheldt where it was in 2014 abundantly present in the eastern part and still expanding (Stengenga & Karremans, 2014). In 2015 the species is also recorded for oyster plots in Lake Grevelingen (Gittenberger et al., 2015b). The current recording seems to be the first observation of *D. sessilis* in the Western Scheldt. Although the introduction in the Netherlands is likely oyster transport related, the current observation near Vlissingen might indicate a ship related introduction into the Western Scheldt or passive transport via one of the channels connecting to the Eastern Scheldt. Characterizations of *D. baillouviana*, with which the species has been swapped in the Mediterranean

and the Netherlands before, suggest that the species is thermophilous and needs sheltered places with limited wave action (Wolff, 2005). The current observation of *D. sessilis* present in a permanent pool in a sheltered corner of the Western Scheldt is in line with this and might suggest that massive expansion of the populations in the Western Scheldt is not expected. It is however likely that the species will appear at more sites and can be successful locally.

### 3.1.5. *Diadumene lineata* (orange-striped green anemone)

*Diadumene lineata* remains common to abundantly present at the sites of Hoedekenskerke and Hansweert like in 2016. Moreover relative abundances have increased significantly, especially at

Hoedekenskerke (Fig. 18). This contrary to the relative abundance of the indigenous *D. cincta* whose relative abundance is about the same in 2017 and 2016 at all sites where the species was observed, except for Vlissingen. At Vlissingen where *D. lineata* has not been observed so far, the relative abundance of *D. cincta* has slightly increased. As last year, *D. lineata* was not present in the quadrants inventoried at Breskens, but the species was observed, in low numbers, outside the quadrants, among the much more abundant *D. cincta* populations in the low intertidal zone. A third Actiniaria species, the indigenous *Sagartia troglodytes*, which was recorded inside quadrants at Breskens in 2016, was still present there in relative low densities, and therefore solely outside quadrants. The non-indigenous and the indigenous *Diadumene* species clearly harbor the same niche, often present side-by-side in the same quadrants. At the two sites where *D. lineata* is abundantly present in the quadrants, at least *D. cincta* is also present. Interestingly, in the quadrants where *D. lineata* is common (at Hansweert), the average relative abundance of *D. cincta* is slightly higher than in the quadrants where *D. lineata* is abundant (Figure 20). However, in the quadrants where *D. lineata* is rare (at Hoedekenskerke), the

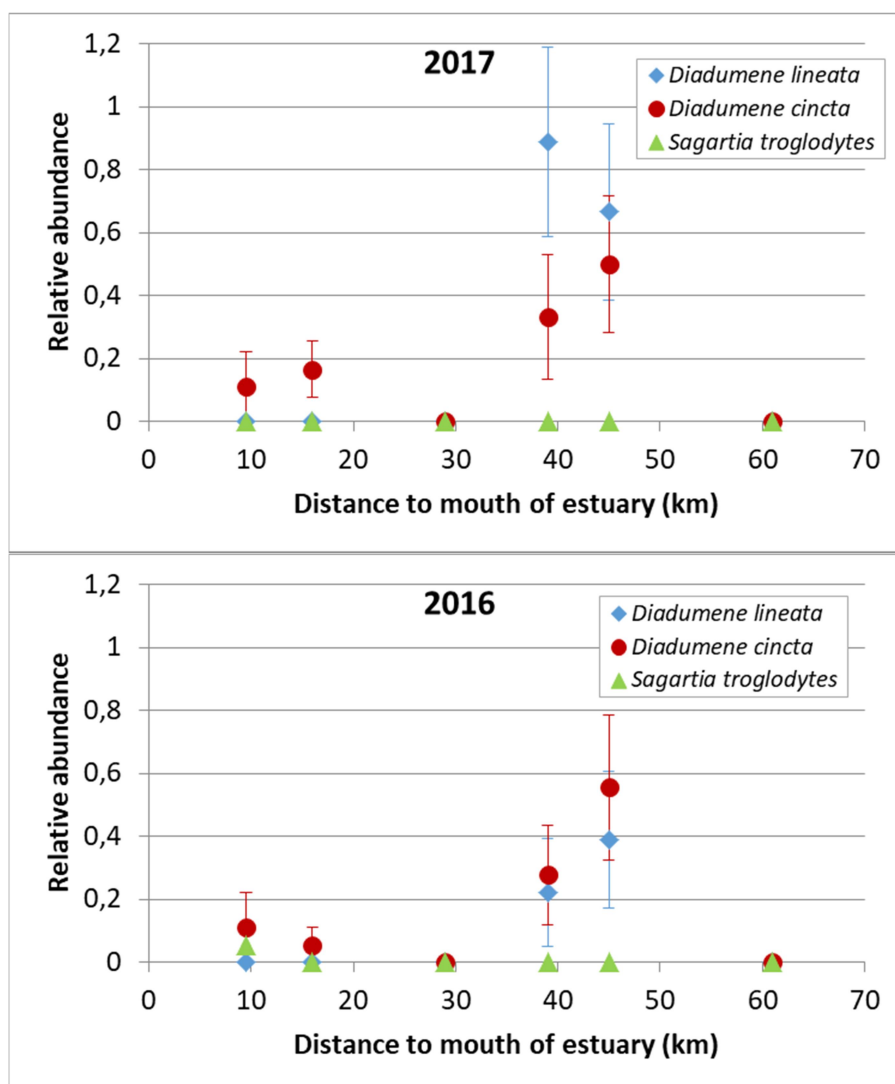


Figure 18. Average ( $\pm$  standard error) relative abundance of *D. lineata* and *D. cincta* related to the distance of the monitoring sites to the mouth of the estuary. Comparison of the anemone species over the estuarine gradient in 2017 (a) and 2016 (b). The relative abundance scale goes from absence (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).



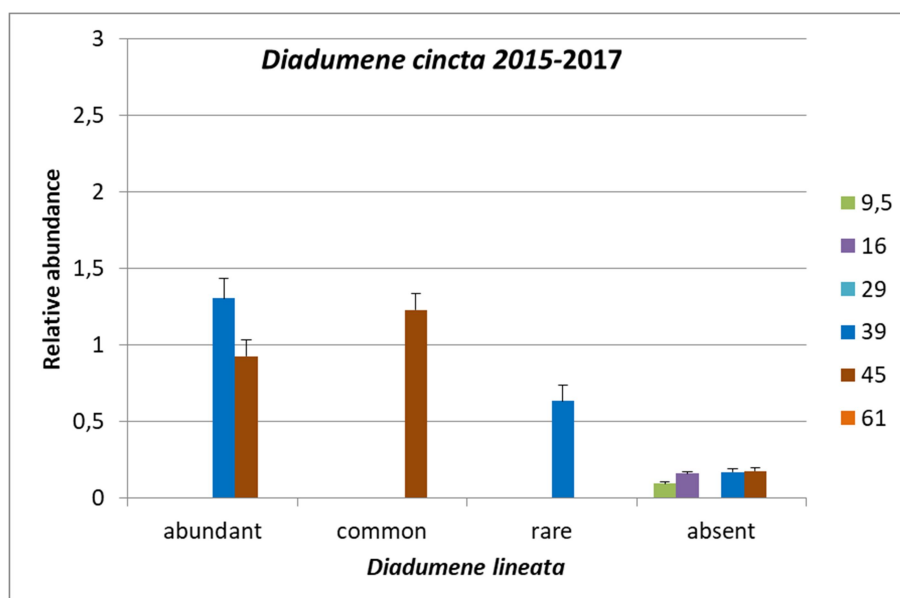
Figure 19a. *Diadumene lineata* in its typical habitat, a permanently submerged crevice, at Hansweert in 2016



Figure 19b. *Diadumene lineata* also present in a sediment rich environment at Hoedekenskerke in 2016.

average relative abundance of *D. cincta* is lower than in the quadrants where *D. lineata* is abundant. This, together with the difference in patterns between 2016 and 2017 that the two species are competing for the same niche and that *D. cincta* density can be higher when *D. lineata* densities are lower. In case *D. lineata* is rare, this likely means that the habitat is suboptimal. *D. cincta* is present there as well, but is generally also less common than at optimal sites. The question is whether the sites of Vlissingen and Breskens where *D. cincta* is locally present abundantly, are at the border of the ecological niche of *D. lineata* (e.g. due to high salinity, water turbidity and/or sedimentation or exposure) or if an increase and/or expansion of *D. lineata* populations can be expected there in the near future. As *D. lineata* is present at Breskens and has been present near Vlissingen (Faasse, 1997), it seems however unlikely that the sites are currently of similar quality as for instance Hansweert and Hoedekenskerke for *D. lineata*, but could not be colonized so far.

Figure 20. Relative abundance of *D. cincta* in habitats with different *D. lineata* abundances on different distances (in km) from the mouth of the Western Scheldt estuary. 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 sanguineus* (Japanese shore crab)

Like in 2016, the Japanese shore crab was present at all inventoried sites in 2017, and was found to be rare at Bath where in both years the species was only observed outside quadrants. Where this was also the case at Hoedekenskerke in 2016, this year *H. sanguineus* was found to be common in one of the quadrants as well. Where the species was at least as abundant this year as last year in the three eastern most transects, its relative abundance appeared to be lower at the three western most sites, which was significant at Breskens and Terneuzen (Fig. 21).



In 2016 *H. sanguineus* was the most abundant Brachyura species at those sites, but in 2017 especially the indigenous *Carcinus maenas* appeared to be much more abundant than *H. sanguineus* at all inventoried sites, except for Terneuzen. Also *H. takanoi* that used to be more abundant than *H. sanguineus* at the three eastern most sites was slightly more abundant than *H. sanguineus* at the three western most sites as well in 2017. However also in 2017 *H. sanguineus* was on average more abundant on the three western most sites than on the three eastern most sites. It has to be noticed that like in 2016 especially at Breskens and Terneuzen a lot of early post-metamorphic juvenile brachyurans (that could not be identified to species level) were present among which there might be *H. sanguineus* specimens as well.

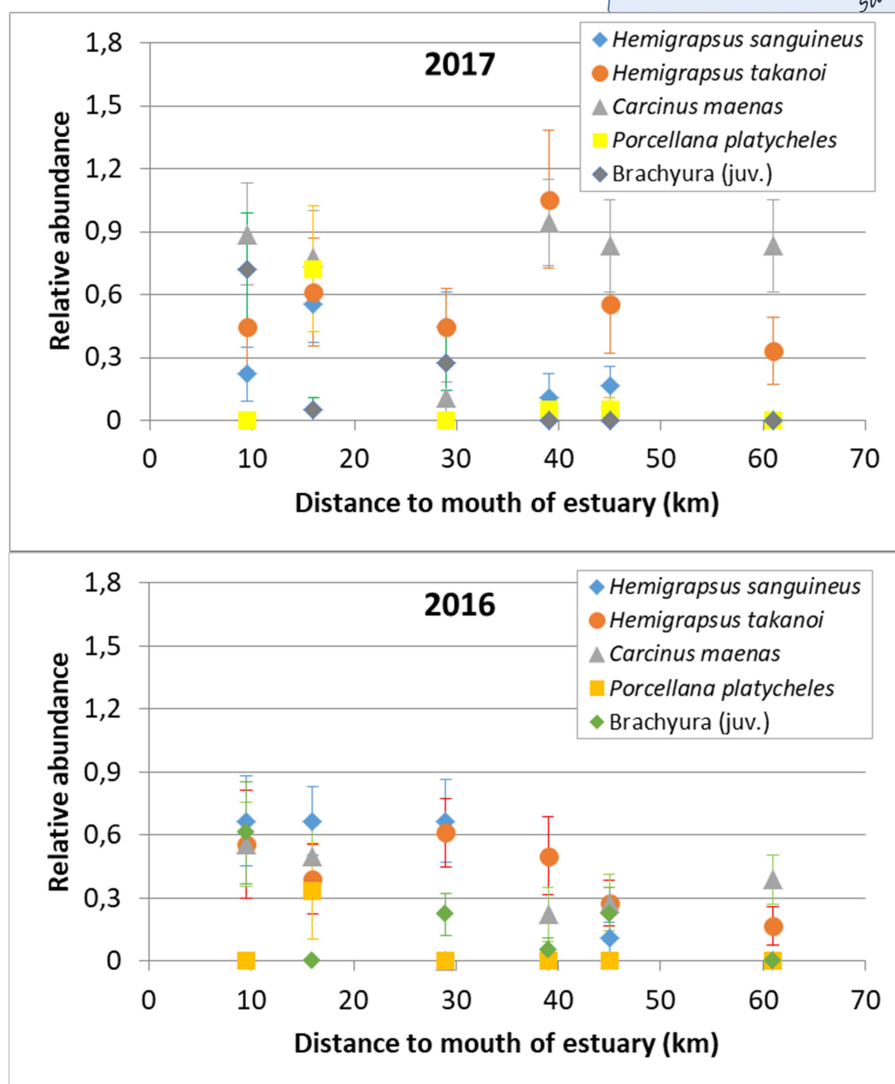


Figure 21. Average ( $\pm$  standard error) relative abundance of Brachyura related to the distance of the monitoring sites to the mouth of the estuary. Comparison of Brachyura species over the estuarine gradient in 2017 (a) and 2016 (b). The relative abundance scale goes from absence (0) to rare (i.e. 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).

Compared to the other common and investigated brachyuran species (the non-indigenous *H. takanoi* and the indigenous *C. maenas* and *Porcellana platycheles*) the ecological niche of *H. sanguineus* is not very specific. This might be the result of not having measured the distinguishing (environmental) parameters, but seems to be more the result of *H. sanguineus* being a habitat generalist when it concerns the intertidal zone (Fig. 22). The species might have a slight preference for habitats with high macroalgal coverage (especially brown algae and filamentous green algae) in the middle intertidal zone, and less the Pacific oyster reefs as predominantly found in the low intertidal zone. The slight preference for the high salinity sites especially outside marinas (Fig. 22) in combination with the observation of a higher relative abundance at the western most sites (Fig. 21) is in line with observations that the species compared to *H. takanoi* is especially present at more exposed sites (Van den Brink et al., 2012).



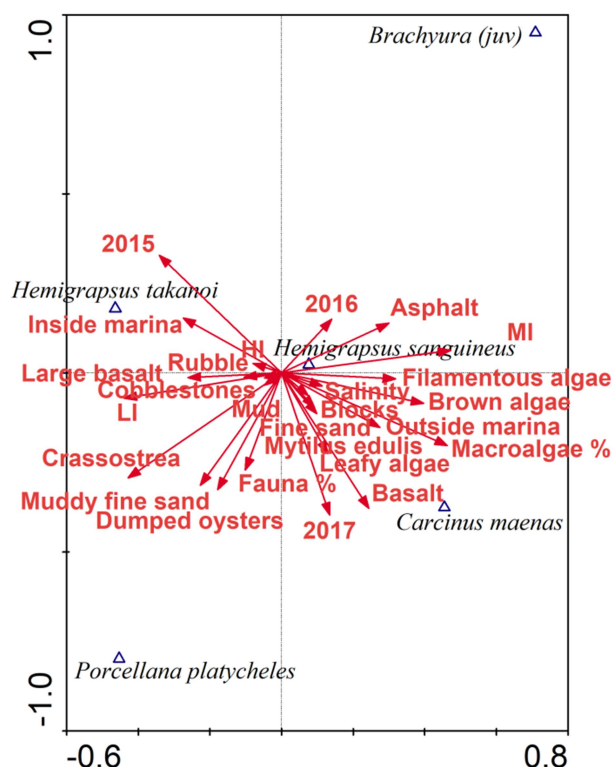


Figure 22. Correspondence Analysis (CA) of *Brachyura* relative abundances related to environmental characteristics (i.e. Total coverage of sessile groups in percentage (Fauna %; Macroalgae %), dominant (>10% coverage) habitat-forming species presence (*Crassostrea gigas*; *Mytilus edulis*; Filamentous (green) algae; Leafy (green) algae; Brown algae), hard substrate type (Dumped oysters; Large basalt (boulders); Cobblestones; Blocks (e.g. hydroblocks and concrete blocks revetment); Basalt (block revetment); Asphalt; Rubble), sediment typology in vicinity (Mud; Muddy fine sand; Fine sand), average salinity, positioning relative to marinas (Inside marina; Outside marina), positioning in tidal zone (HI - high intertidal; MI – middle intertidal; LI – low intertidal), monitoring year (2015; 2016; 2017).

Although the two non-indigenous *Hemigrapsus* species are found together on a regular basis, there might be some competition between the two species as well. At Breskens the two species largely seem to prefer the same habitat, with *H. sanguineus* most abundant in quadrants where *H. takanoi* is abundantly present as well (Fig. 24a). However, at all other sites *H. sanguineus* is never found in those quadrants where *H. takanoi* was abundantly present. Relative abundances of *H. sanguineus* were however often high in quadrants where *H. takanoi* was found to be common to rare: i.e. which might be the sub-optimal habitats for the last species. The different pattern for Breskens might have to do with the absence of a full developed Pacific oyster reef there, which might lead to *H. takanoi* moving more into suboptimal habitat whereas *H. sanguineus* is more frequently observed in the low intertidal zone.



Figure 23. *Hemigrapsus sanguineus* as observed near Hoedekenskerke in 2016 (a) and a reproducing female with eggs as collected in 2017 (b).

Also interactions with indigenous species, and *C. maenas* in particular, might be expected. As indicated by Figure 22, there is at least some overlap in the habitat preference of *H. sanguineus* and

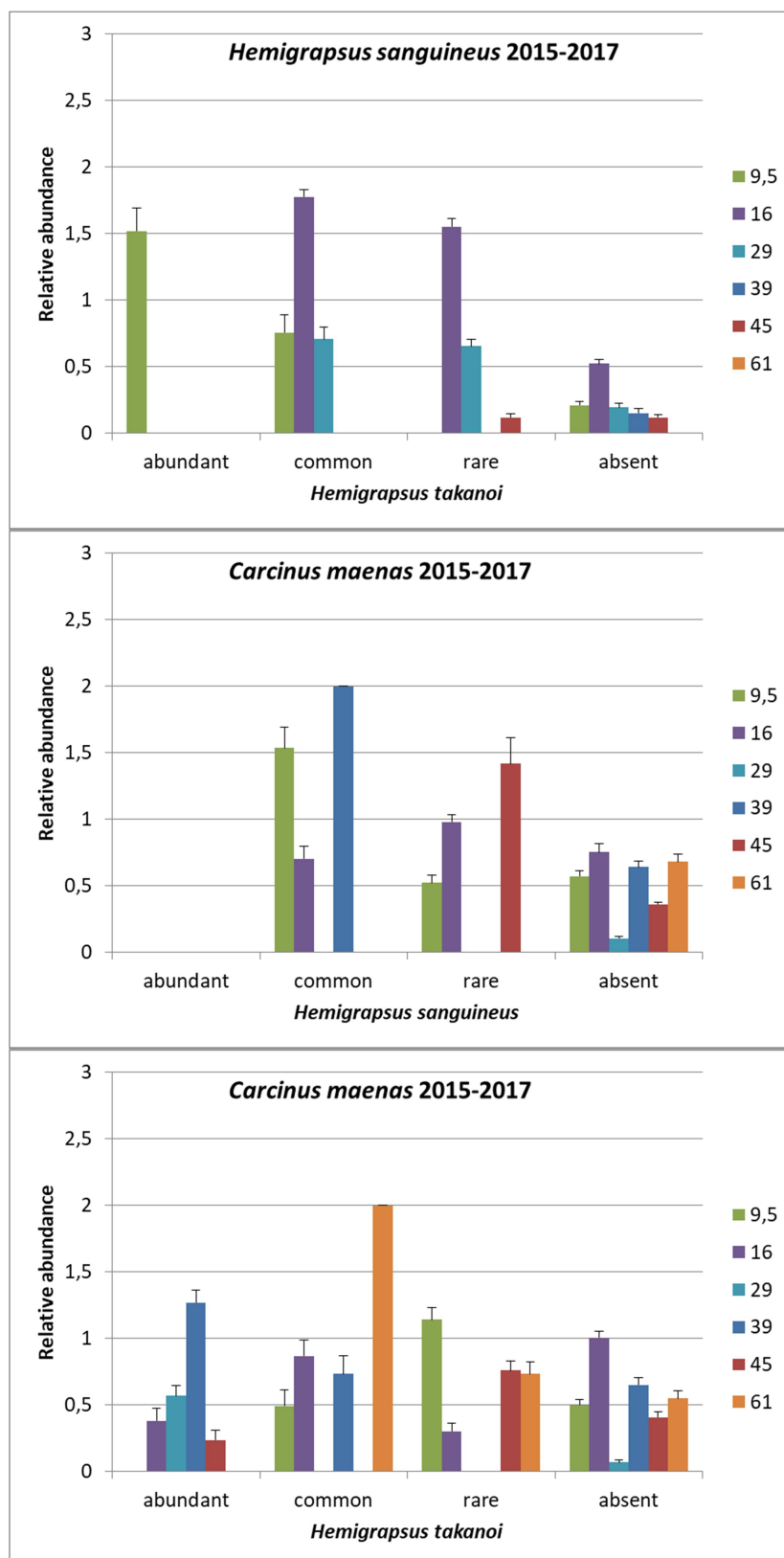


Figure 24. Relative abundance of *H. sanguineus* in habitats with different *H. takanoi* abundances (a), and of *C. maenas* in habitats with different *H. sanguineus* (b) or *H. takanoi* (c) abundances on different distances (in km) from the mouth of the Western Scheldt estuary. The relative abundance 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).

*C. maenas*, as *C. maenas* is strongly related to habitats with high macroalgal coverage, i.e. those with substantial coverage by amongst other brown algae and filamentous green algae in the middle intertidal zone. Figure 24b shows that despite of at least a partial overlap in habitat preferences, *C. maenas* is never abundantly present when *H. sanguineus* is abundant. Moreover, taking into account that among the quadrants where *H. sanguineus* is absent, there will be a large number of quadrants unsuitable for brachyurans in general; the relative abundance of *C. maenas* is generally at least

comparable in suitable quadrants without *H. sanguineus* as in quadrants where *H. sanguineus* is common or rare. This suggests a possible preference for suitable quadrants without *H. sanguineus*.

Figure 22 indicates a clear niche for early post-metamorphic juvenile brachyurans compared to unidentifiable juvenile and adult specimens of the most common species. It is unclear what the share of *H. sanguineus*, or any of the other species, is among these juveniles, but it is expected that they include both *Hemigrapsus* species and *Carcinus maenas*. As the juveniles are related to a specific niche, i.e. the middle intertidal zone, substantially more often found on slopes covered with asphalt, largely absent in *Crassostrea* dominated habitats and the lower intertidal zone, it is expected that there is no large differentiation in the niche of post-settlement juveniles of the separate species. For each of the species the predation risk (including cannibalism by larger juveniles and adults) will be similar. It is therefore expected that habitat selection of post-larvae largely driven by predation (Moksnes et al., 1998) is similar for all shore crab species. Moreover the here identified habitat is in line with findings for *C. maenas* for which the lowest mortality of post-larvae was found among filamentous green algae (Moksnes et al., 1998).

### 3.1.7. *Hemigrapsus takanoi* (brush-clawed shore crab)

In 2017, *Hemigrapsus takanoi* was the most abundant non-indigenous brachyuran species at each of the monitoring sites being significantly more abundant present than *H. sanguineus* at each of the sites except for Vlissingen (Fig. 21). In 2016 *H. sanguineus* was at least as abundant at the three western most monitoring sites and significantly more abundant at Vlissingen. The patterns are the result of both a tendency towards lower *H. sanguineus* abundances at several sites and higher *H. takanoi* relative abundances. Significant increases in *H. takanoi* relative abundances were however observed at the three eastern most sites (where *H. sanguineus* is less abundant or lacking in general).



Figure 25a. *Hemigrapsus sanguineus* (left) and *H. takanoi* (right) as collected at Breskens in 2016.



Figure 25b. *H. takanoi* observed in the transect near Bath in 2016.

This is a similar pattern for *H. takanoi* as observed for the indigenous *C. maenas*, which is the most abundant brachyuran species at 4 of the 6 transect sites now (only the case at Bath in 2016). Although population development patterns of *H. takanoi* and *C. maenas* during 2016-2017 are quite similar, in relation to changes in *H. sanguineus* relative abundances in particular, as it is shown in Figure 24, that there are differences in the relative abundances for two species. This separation is however largely due to the observations for 2015, a year in which *C. maenas* (and *H. sanguineus* as well) were only observed in low numbers at the monitoring sites in the Western Scheldt. Although at least *H. takanoi* was particularly abundant inside marinas, it is less clear whether *C. maenas* is always less abundant there or whether this was due to low numbers for the indigenous species in general during that year. Figure 22 however shows that there are additional differences in habitat preferences, with *H. takanoi* especially abundant in *Crassostrea* dominated habitats with a higher mud content (muddy fine sand habitats) consisting of large basalt blocks in the low intertidal zone, whereas *C. maenas* is more abundant in the middle intertidal zone on slopes with basalt block revetment, dominated by algal growth of any kind. This partial niche segregation between the non-indigenous and indigenous species is also visible from Figure 24, where for instance at Breskens (9,5 km from mouth of estuary) *C. maenas* is completely lacking where *H. takanoi* is abundantly present, and found to be most abundant

where *H. takanoi* is rare. A similar pattern was found at Hansweert and Bath, but at Terneuzen and Hoedekenskerke, the two species appeared to be most abundant at in the same quadrants. As indicated by Van den Brink et al. (2012) and Van den Brink & Hutting (2017) there is at least competition between *H. takanoi* and smaller size classes of *C. maenas* that might lead to increased predation of the later and partly result in the observed niche segregation.

A second indigenous species, *Porcellana platycheles* is present at several sites, and particularly abundant at Vlissingen. The species harbors a typical niche generally present on *Crassostrea* reefs, under dumped oysters and basalt blocks in the low intertidal zone. Some competition with *H. takanoi* might be expected where it is *P. platycheles* that is much smaller, that suffers from the competition. However due to its size and habitus, *P. platycheles* is also present in much smaller crevices typically under hard substrate elements around the lowest low water line. The observation that *P. platycheles* in the Western Scheldt is generally present around the lowest low water line might be the result of competition with *H. takanoi*, as the expected habitat of the species is expected to include the entire middle and low intertidal zone in relative muddy environments (Ages, 2008). Moreover, *P. platycheles* might nowadays potentially profit from the habitat provided by *Crassostrea* reefs in the Netherlands, but therewith faces an additional competitor (typically related to that environment) in the form of *H. takanoi*, as well.

### 3.1.8. *Melita nitida*

(No vernacular name in English: 'elegante honingvlokreelt' in Dutch)

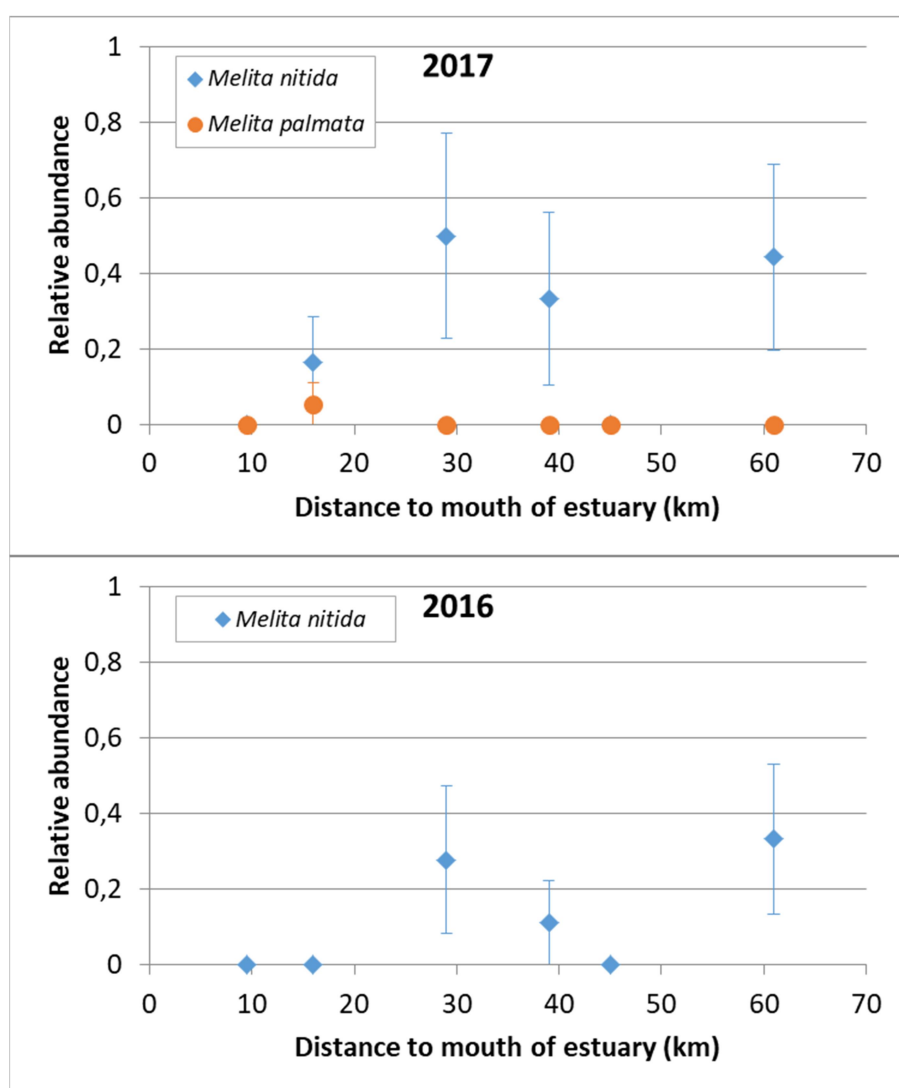


Figure 26. Average ( $\pm$  standard error) relative abundance of *Melita* species related to the distance of the monitoring sites to the mouth of the estuary. Comparison of *Melita nitida* and *Melita palmata* over the estuarine gradient in 2017 (a) and 2016 (b). The relative abundance scale goes from 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).



*Melita nitida* was found to be the most abundant *Melita* species in the intertidal zone of the Western Scheldt in 2015 and 2016 and was found in the polyhaline zone, not observed before (Wijnhoven, 2016). In 2017 this pattern continues with a tendency to higher relative abundances at each of the sites where the species was found in 2016 (Fig. 26). Where *M. nitida* was only found as an additional species at Vlissingen, the species was this year present in quadrants as well. The indigenous *M. palmata*, last year only observed as an additional species at Bath (Wijnhoven, 2016), was in 2017 only found at Vlissingen. A specimen of *M. palmata* was present in one of the quadrants where also *M. nitida* was present and found to be common. This year's results confirm the largely replacement of the native *M. palmata* by *M. nitida* in the entire intertidal zone of the Western Scheldt, although different from 2016 and 2015 actually both species were not found at Hansweert in 2017.



Figure 27. *Melita nitida* collected at Hansweert during transect monitoring in 2016.

### 3.1.9. *Tricellaria inopinata*

(No vernacular name in English: 'onverwacht mosdierkje' in Dutch)

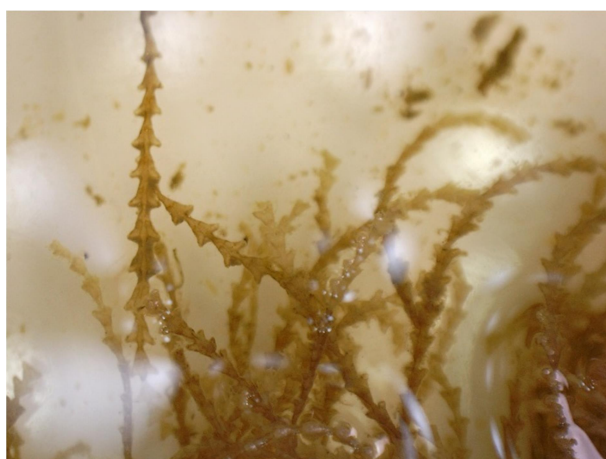


Figure 28a. *Tricellaria inopinata* as collected at Vlissingen in 2017.



Figure 28b. The quadrant in the low intertidal zone at Vlissingen where *T. inopinata* appeared to be common.

One of the new non-indigenous species observed during transect monitoring this year is the bryozoan *Tricellaria inopinata*. It was found in one of the quadrants in the low intertidal zone at Vlissingen where it appeared to be common. De Blauwe already indicates in 2009, that the species is strongly expanding its range and can be expected along the entire Dutch and Belgian coast. The species was at the time of first discovery in the Netherlands in lake Goesse Meer in 2000 also already the most common bryozoan species in the marina of Breskens. Although clearly related to marinas, De Blauwe indicates that the species can be expected in the intertidal zone at several places (De Blauwe, 2009). The species is probably originating from the eastern part of the Pacific and can easily be transferred with all kind of materials that have been or are in the water, including the species on ship hulls. Wijnhoven et al. (2017) incorrectly records the first observation of the growth of the species in the Western Scheldt in 2016 (as already indicated, the species was recorded to be common in the marina of Breskens for the first time by De Blauwe & Faasse (2001)). However, although indicated as potentially present along the entire coast, 2016 is the first documented observation of the species outside the marina of Breskens in the Western Scheldt after the first observations. In 2016, the bryozoan was found on SETL plates on several locations inside the harbor of Vlissingen. The current observation in

the transect at Vlissingen is in the vicinity of the recordings of 2016, as the transect is situated just outside the harbor. De Blauwe & Faasse (2001) indicate that the species is almost exclusively present at very sheltered locations. The transect monitoring site at Vlissingen is a relatively sheltered location as well. It seems that if not overlooked, the species remained restricted in the Western Scheldt to the marina of Breskens for a while due to the rather exposed conditions in a large part of the mouth of the estuary. After some delay, the species is extending its range in the Western Scheldt now as well and could very well appear at the more sheltered sites inside the estuary (e.g. marinas) in the near future, although there is some uncertainty about the salinity tolerance of the species and at what is the low salinity tolerance level of the species.

### 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. *Diplosoma listerianum*

(No vernacular name in English: 'grijze korstzakpijp' or 'geleikorstzakpijp' in Dutch)

*Diplosoma listerianum*, although cosmopolitan is expected to origin from the North-east Atlantic and is therefore considered a cryptogenic species in the Netherlands (Wolff, 2005; Gittenberger et al., 2010). It is unclear whether the species has been present before, but *D. listerianum* was recorded in 1977 from the Eastern Scheldt and was restricted to a part of the system for about a decade. In 1990 the species was present in the Canal through Walcheren near Vlissingen. However, although widely distributed in the Eastern Scheldt, lake Grevelingen, and having been in the vicinity of the Western Scheldt already more than 2,5 decades ago, the species is so far not recorded for the Western Scheldt. The species is present at least since 2009 in the Wadden Sea as well. Although the species might potentially spread to other sites within the Western Scheldt, the chance that the species will have a significant impact on the ecosystem is small, as its distribution is limited to sheltered habitats with relative clear waters (Gittenberger et al., 2015a). This is confirmed by long time it took before the species is observed in the Western Scheldt after that it has been present in the vicinity.



Figure 29. *Diplosoma listerianum* as observed on/inside an empty oyster shell in the transect at Vlissingen in 2017.

The current observation was just one colony, which was however present in one of the inventoried quadrants, but no other colonies could be found in the vicinity. The colony was attached to the inner side of a loose empty oyster shell, and could have arrived from elsewhere. It is however more likely that larvae, either transported and discharged with ballast water in front of the Vlissingen harbor or supplied by sources in the vicinity (e.g. the Canal through Walcheren or sources along the North Sea coast), have settled successfully in the shelter of the harbor jetty.



### 3.1.12. *Ulva cf lactuca* (sea lettuce)

Wijnhoven et al. (2016) already indicated that it is difficult to distinguish non-indigenous from indigenous *Ulva* species in the field, with an additional uncertainty about which species are indigenous or non-indigenous. Like last year, all *Ulva* spp. with a lettuce-like appearance are aggregated here under *Ulva cf lactuca*, for which we presume that the majority is indeed non-indigenous (called cryptogenic here as the origin is uncertain).

Like in 2016, *U. cf lactuca* was abundantly present at Vlissingen and Breskens, and locally common to abundantly present in some of the quadrants at Hansweert and Hoedekenskerke (Fig. 30). Differences in relative abundance between the two years are not significant at each of the sites. Where in 2016, *U. cf lactuca* was found to be rare only outside the quadrants at Terneuzen, the

species was not observed this year. The other way around, in 2017 the species was found although rare in one of the transects of Bath as an additional species. It is unclear whether the presence of *U. cf lactuca* has an impact on the presence of the indigenous *U. intestinalis*. Fluctuations between years for *U. intestinalis* appear to be much larger than for *U. cf lactuca*, with a significantly lower relative abundance than in 2016 at Breskens and a significantly higher relative abundance at Vlissingen and Hoedekenskerke. The indigenous *U. prolifera* was not observed in the transects this year.

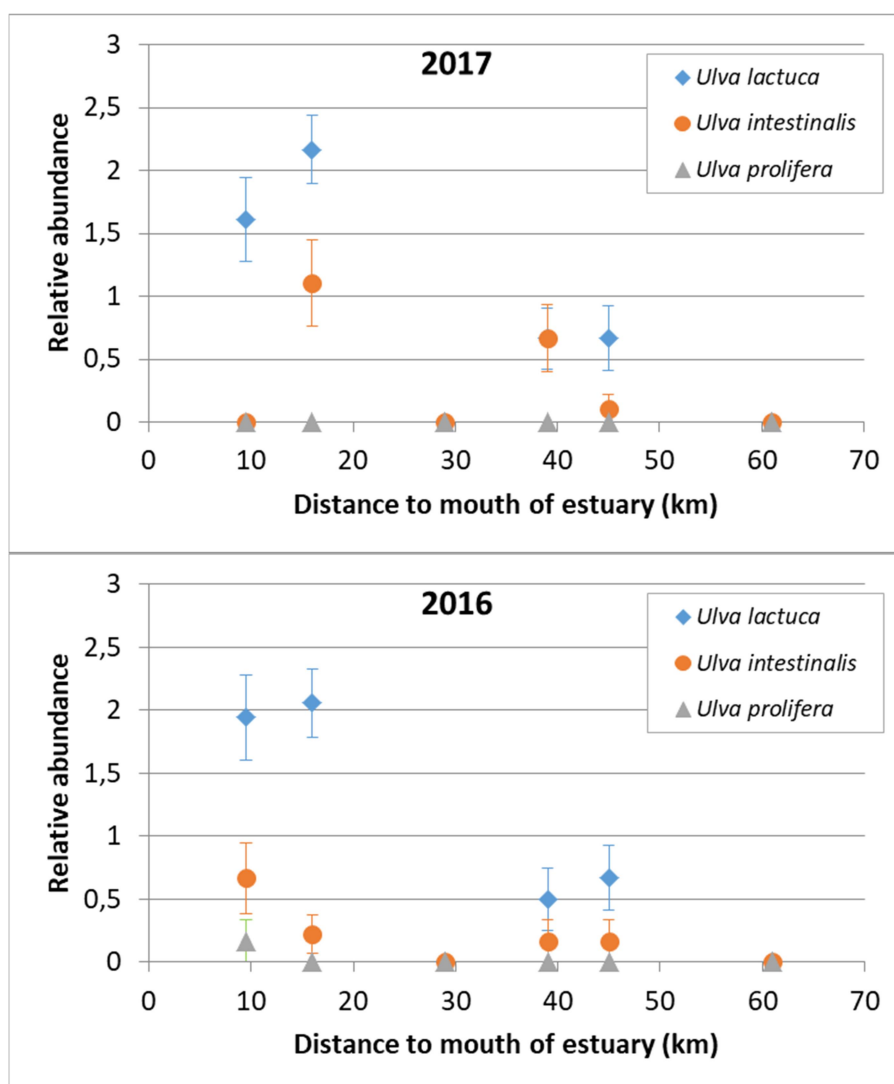


Figure 30. Average ( $\pm$  standard error) relative abundance of three *Ulva* species related to the distance of the monitoring sites to the mouth of the estuary. Comparison of *Ulva lactuca*, *Ulva intestinalis* and *Ulva prolifera* over the estuarine gradient in 2017 (a) and 2016 (b). The relative 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).



Figure 31a. *Ulva cf lactuca* as collected at Hoedekenskerke in 2016.



Figure 31b. Relatively high algal coverage of predominantly *Ulva cf lactuca* and *Fucus serratus* in the low intertidal zone at Vlissingen as observed in 2017.

### 3.2 Patterns in total NIS numbers

As indicated by table 1, the total number of NIS as observed in the transects of the Western Scheldt in 2016 and 2017 is about the same, with only an increase of one species when also the cryptogenic species are taken into account. It is expected that the series of transects is representative for the majority of intertidal hard substratum surface available in the Western Scheldt. It is therefore not expected that there is a dramatic increase in the total number of NIS in the intertidal zone of the Western Scheldt particularly in 2017. It has however to be noticed that although it is expected that the transect monitoring covers the entire estuarine gradient and focusses on dominant habitats in the vicinity of potential hotspots for the arrival of species (e.g. near marinas, harbors and water connections; Wijnhoven et al., 2017), the inventoried surface (compared to the total available in the Western Scheldt) is not large enough to likely detect all available NIS in the intertidal zone. At first, although Wijnhoven et al (2015a) shows that more NIS seem to be present outside than inside marinas, in accordance with patterns in species richness as also shown by the current inventory (e.g. Fig. 7), there will certainly be NIS that find a specific habitat specifically in marinas and harbor. Especially as man-made structures and floating devices and equipment that provide surface in the intertidal zone can exactly be suitable or NIS at least to settle in the first stage of introduction (Hummel & Wijnhoven, 2014). Moreover, it is likely that NIS can exactly find a suitable niche in less common habitat types, as these might better approach conditions in the area of origin (e.g. elevated temperatures in permanent pools or a-typical hard substrate types that might to a certain extent match natural substrates not available naturally in the Western Scheldt), and competition particularly with indigenous species might be reduced there. It is however expected that especially potentially successful NIS and those that might become invasive will soon after arrival, appear in the common habitat types as well, with an increasing chance of being detected during transect monitoring. Moreover, transect monitoring is especially of value towards the identification of potential impacts for indigenous communities and to detect range extension of NIS, potentially in an early phase.

Figure 32 shows that at three of the six monitoring sites the number of observed species has increased from 2016 to 2017. Only at Bath and Breskens the total number of observed species has decreased, and at Hoedekenskerke the number is about the same. The number of observed NIS (+ cryptogenic species) is the same at 4 of the 6 sites but has increased from 5 to 7 at Terneuzen and from 8 to 11 at Vlissingen. Herewith the share of NIS in the total number of species has significantly increased at Bath, Vlissingen and Breskens.

Comparing the results per quadrant, the number of observed NIS (+cryptogenic species) relative to the observed number of indigenous species in 2017 is very much in line with the observations of 2016 (Fig. 33). Calculating a regression line for the two on basis of the combined 2016-2017 data gives a strong relation (with 75 % of the variation in the data explained by a linear model:  $R^2=0,75$ ).

The relation indicates that with every additional indigenous species that can be observed in the Western Scheldt, 0,62 additional NIS species will be found as well (or an additional NIS can be found when 1,61 additional indigenous species are collected). The relation also indicates that when at least 4 species are present at a site, it is likely that at least one of them is a NIS. Surprisingly the observations from 2015 are less in line with the relation found for the years 2016-2017. It seems that local NIS to indigenous species ratios might show some seasonality that possibly can be explained by especially some indigenous species being substantially less abundant at least during spring than in summer. A deviating pattern is however not observed in 2015 insight the marinas which might indicate that in such (more

sheltered) systems the indigenous species show less seasonality in their abundances, like most of the NIS. Focusing on the data per site taking the strong relation into account it can be concluded that in 2017 less NIS are found at Terneuzen and Breskens than would be expected on basis of the number of indigenous species observed, whereas at Hansweert and especially Vlissingen the opposite is true. Whether this is a coincidental or temporary observation or a developmental pattern that will proceed the coming years is uncertain. However, one can expect that NIS to indigenous species ratios deviate with habitat type. It might be that the inclusion of predominantly subtidal species as present in small pools in crevices as present in quadrants at Vlissingen and Hansweert leads to deviating ratios. It is however also possible that ratios deviate with the succession status, which might be especially the case at Breskens where fore bank reinforcements have been taken place till 2014, leaving bare substratum available to be colonized. Also differences in ratios might be expected with differences in environmental quality status that might differ between sites or in time. To clarify such patterns a longer data series is essential.

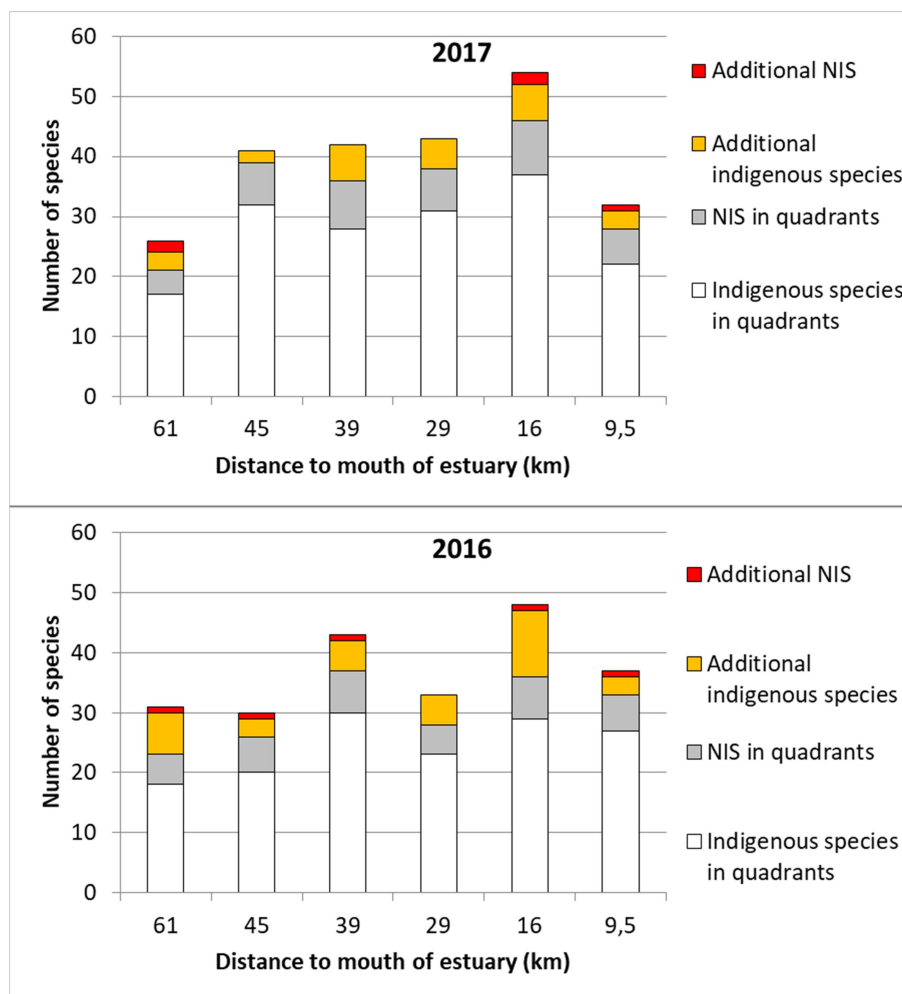


Figure 32. Total number of species observed in 2017 (a) and 2016 (b) in each of the transects relative to the distance to the mouth of the estuary. The total number of species is subdivided in species observed in the inventoried quadrants and additional species recorded for the transects. Further the share of non-indigenous species including cryptogenic species (indicated as NIS) in the total number of species is indicated.



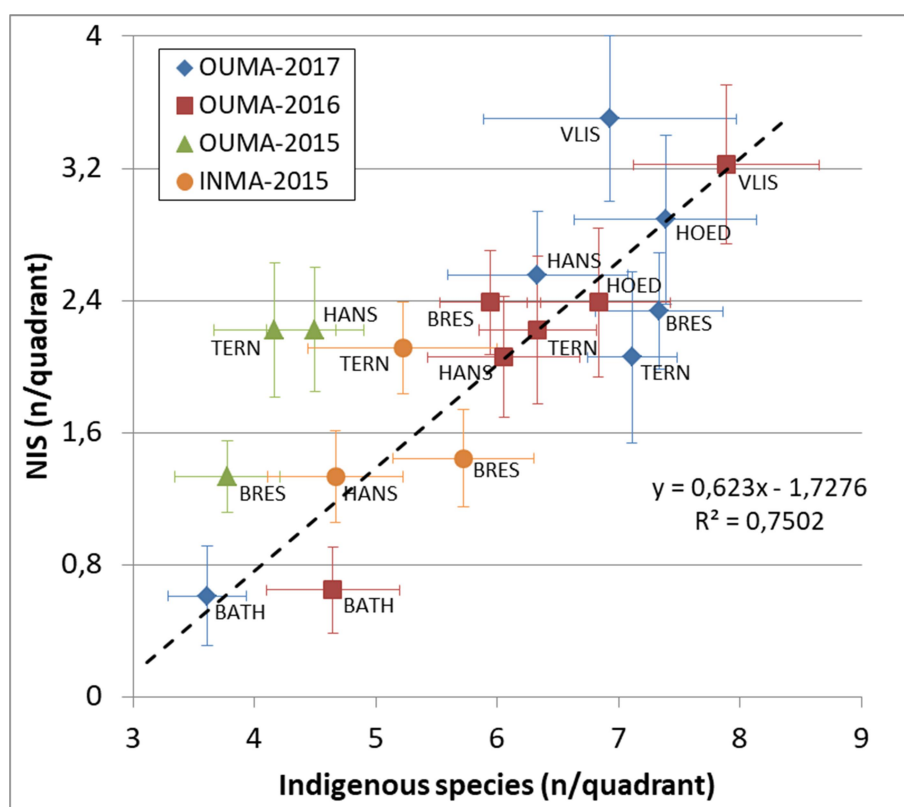


Figure 33. Comparison of transects (inventoried from 2015 to 2017, and positioned outside (OUMA) or inside (INMA) marina), on basis of the average number of non-indigenous species including cryptogenic species (indicated as NIS) related to the average number of indigenous species observed per quadrant. Average values  $\pm$  standard error are shown for the transects at Bath (BATH), Hansweert (HANS), Hoedekenskerke (HOED), Terneuzen (TERN), Vlissingen (VLIS) and Breskens (BRES). The linear regression line (according to  $y = 0,623x - 1,728$ ) based on the 2016-2017 data is indicated in the graph.

### 3.3 Efficiency of the methodology

Figure 32 already indicates that about 5 to 20 % of the species present in the transects is not observed in the inventoried quadrants but found as additional species. At Hansweert almost all species were found in the quadrants, whereas at Bath a substantial part was initially missed. On average more than 87 % of the species present at the monitoring sites is observed insight the quadrants in 2017 and this is a few percent higher than achieved in 2016. However by missing several species with the quadrants this also means that now and then a non-indigenous species is missed if only the quadrants are inventoried. In 2017, two non-indigenous species were only found outside the quadrants at Bath and at Vlissingen whereas at Breskens only one NIS was recorded as additional species.

Figure 34 shows the rarefaction curves as calculated per monitoring site combining the data from two transect lines (through different habitat types), separating the three intertidal zones in different series as those have different species assemblages. The data from the years 2016 and 2017 are however combined as it is shown in for instance figure 33, that differences in species assemblages (as well as habitat constitution) are not that different between the years. Therefore per series; 12 quadrants were available to do the calculations. Rarefaction curves indicate how many samples are necessary to detect all available species, suggesting that with the additional searches indeed all available species in the transects are detected. This last assumption seems to be rather realistic, although an occasional species can always be overlooked. Detection of 100 % of the species would be the ultimate aim; however reaching the point where the logarithmic trend really starts to flatten and therefore the increase in percentage of species that can be observed with additional samples is minimal would be a good sample size as well. As indicated before, there will always be very specific niches that represent often less than 1 % of the total transect surface. The chance that such niches are part of one of the quadrants is always low unless the number of quadrants becomes unrealistic high. It is therefore recommended that two strategies in inventories are combined like already done with transect monitoring so far:

1. Standardized quadrant inventories to achieve the data for analyses of changes in abundances and spatial distributions in time and to clarify relations and/or interactions with (indigenous) species communities and habitat characteristics (niche identifications). Such data are of special importance as those will particularly identify the successful and potential invasive NIS and identify their impacts and allows to identify specific habitats and/or communities that are at risk of invasion. Eventually such data are useful for extrapolations to the system level as well.
2. Trying to detect as much NIS as possible by checking all available niches at a monitoring site (with special efforts on specific (known) habitats that are of little importance concerning the surface area). Such species lists enlarge the chance of detecting new arriving NIS at an early stage that might give options for measures to eradicate or isolate potential invasive species. Such inventories on itself do not provide much information on the status or risk of the NIS itself or the status of the system, for which additional research is than essential.

The rarefaction curves of figure 34 show that for the sites of Breskens and to a lesser extent Terneuzen a 100 % of the available species per stratum can be detected with a limited number of quadrants inventoried. This shows that habitat variability is not that large, and that with inventorying the dominant habitats (as present in two transect lines) almost all available niches are indeed covered. In case of Breskens (15 samples per stratum is expected to lead to observation of all available species) this is expected to be due to the relative early succession stage in which the monitoring site is at present; three years after renewal of the reinforcements.

The results for Terneuzen suggest that also at Terneuzen the hard substrate has been renewed, maybe not that recent as in Breskens, but such that effects are still visible. It might be that dike reinforcements have taken place in 2011 at the transect monitoring site of Terneuzen (Omroep Zeeland, 2011). Ultimately the successional stage cannot explain all habitat variability. It is also the type of embankments, the possible use of various materials and different exposure in the different zones that determines habitat variability and whether the largest share of species is likely to be monitored with two transect lines through the dominant habitat types. The rarefaction curves for the other monitoring sites indicate that 5 to 10 % of the species will not be discovered by solely inventorying quadrants in two transect lines through the dominant habitat types as at these sites very specific niches harboring additional species are present covering only small surface areas.

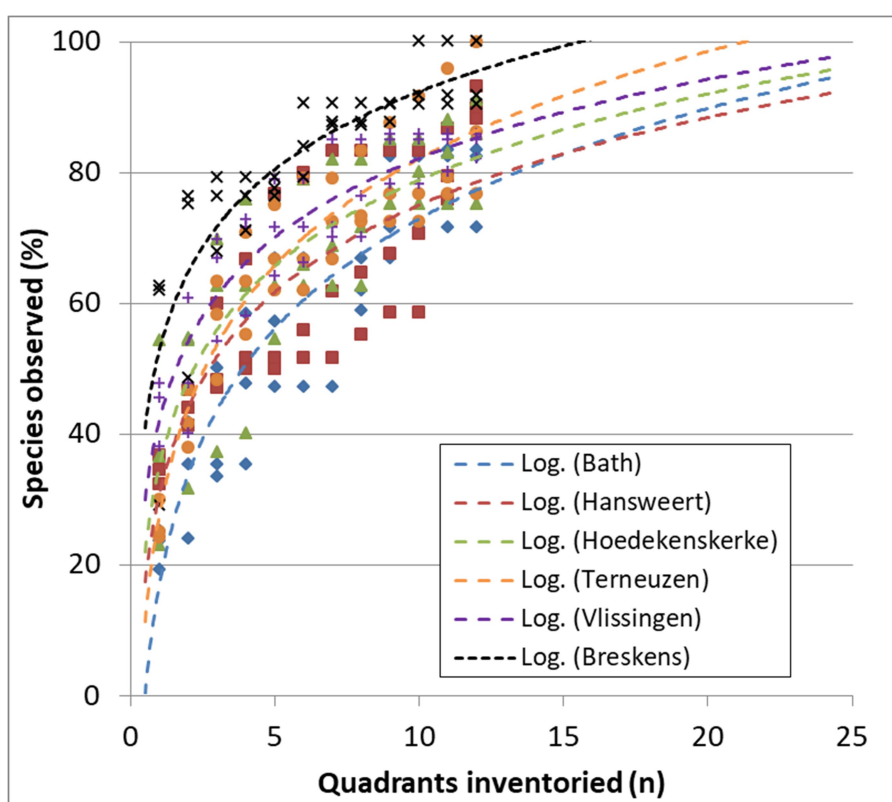


Figure 34. Trends in total number of species observed relative to the total number of species observed (including additional species as found outside the quadrants per stratum) with every additional quadrant inventoried (rarefaction curves) for each of the monitoring sites, combining transect lines and the data of 2016 and 2017.

## 4. Conclusions

- Transect monitoring at six sites covering the dominant intertidal hard substrate habitats in the estuary of the Western Scheldt in 2017 with inventories of 108 0,25 m<sup>2</sup> quadrants and searching for additional species in the vicinity resulted in observations on presence and distribution patterns for 9 non-indigenous and 3 cryptogenic species.
- The observations of the non-indigenous rhodophyte species *Dasya sessilis* and the cryptogenic ascidian *Diplosoma listerianum* seem to be the first recordings of these species in the Western Scheldt. Together with the possible first observation of the non-indigenous bryozoan *Tricellaria inopinata* outside the marina and harbor areas of Breskens and Vlissingen, the transect site at Vlissingen just outside the harbor area seems to be a hotspot for arriving and expanding NIS in the Western Scheldt, due to the rather sheltered conditions and the presence of permanent pools in the intertidal zone. Also the non-indigenous amphipod *Caprella mutica* is found here; before only observed at the cooling water inlet of Borssele and inside the harbor of Vlissingen.
- The largest share of NIS (+ cryptogenic species) in the total number of species per quadrant is found when species richness is high, indicating that on average NIS are also doing best under good environmental quality conditions. Findings are in line with earlier observations in 2015 and 2016 (Wijnhoven et al., 2015; Wijnhoven, 2016). High species richness is typically found in habitats with high coverage by sessile fauna like those habitats where barnacles (indigenous or non-indigenous) and or *Crassostrea* oysters are important habitat-structuring organisms. NIS and indigenous species numbers at the level of entire monitoring sites show a strong positive correlation.
- There are no indications that at present the blue mussel *Mytilus edulis* is suffering from competition with the Pacific oyster *C. gigas*. Moreover, at present *M. edulis* clearly benefits from the habitat provided by *C. gigas*.
- Where the indigenous *Diadumene cincta* and the non-indigenous *D. lineata* largely occupy the same niche (and are often present in mixed communities) and both reach highest densities inside the estuary at Hoedekenskerke and Hansweert, it seems that *D. cincta* is doing better in the mouth of the estuary where *D. lineata* remains relatively rare.
- The fact that the regularly co-occurring two non-indigenous and the indigenous shore crab species partly occupy different niches is largely the result of competition. *Hemigrapsus takanoi* is most abundant in the low intertidal zone especially in oyster reefs but also inhabits other habitats especially inside the estuary where *H. sanguineus* is less abundant and is the dominant species in the (sheltered) marinas. *H. sanguineus* is most abundant at the higher salinity and more exposed sites especially present in habitat with high brown and/or filamentous green algae coverage in the middle intertidal zone, but inhabiting the low intertidal zone as well when oyster reefs largely lack. The indigenous habitat generalist *Carcinus maenas* due to competition is now most abundant in the middle intertidal zone on basalt block revetment with abundant algal growth especially where *H. sanguineus* is less common.
- The pattern as found in 2015 and 2016 that the NIS *Melita nitida* has largely replaced the indigenous *M. palmata* in the entire intertidal zone of the Western Scheldt is confirmed in 2017.
- Transect monitoring is an efficient methodology to gather information on the relative abundances and range extensions of successful NIS that are potentially invasive. Results of the inventories are important for niche identification and identification of species interactions (including competition).
- Searching for (additional) species in specific less common habitats is however essential for the early detection of NIS, as especially a-typical habitats might be most suitable for new arriving NIS. A large share of those NIS only present in a-typical habitats will however not become invasive.



## 5. Literature

Ager, O.E.D. (2008). *Porcellana platycheles* Broad-clawed porcelain crab. In Tyler-Walters, H. and Hiscock, K. (eds.), Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: [www.marlin.ac.uk/species](http://www.marlin.ac.uk/species).

De Blauwe, H., Faasse, M. (2001). Extension of the range of the Bryozoans *Tricellaria inopinata* and *Bugula simplex* in the North-east Atlantic Ocean (Bryozoa: Cheilostomatida). *Nederlandse Faunistische Mededelingen* 14, 103-112.

De Blauwe, H. (2009). Mosdiertjes van de Zuidelijke Bocht van de Noordzee. Determinatiewerk voor België en Nederland. Uitgave Vlaams Instituut voor de Zee (VLIZ), Oostende, 464 pp. (in Dutch).

Gittenberger, A., Rensing, M., Stegenga, H., Hoeksema, B.W. (2009). Inventarisatie van de aan hard substraat gerelateerde macroflora en macrofauna in de Nederlandse Waddenzee. GiMaRIS rapport 2009.11 (in Dutch).

Gittenberger, A., Rensing, M., Dekker, R., Niemantsverdriet, P., Schrieken, N., Stegenga, H. (2015a). Native and non-native species of the Dutch Wadden Sea in 2014. GiMaRIS rapport 2015.08.

Gittenberger, A., Rensing, M., Niemantsverdriet, P., Schrieken, N., D'Hont, A., Stegenga, H. (2015b). Soorteninventarisatie oesterputten en oesterpercelen, 2015. GiMaRIS rapport 2015.19 (in Dutch).

Gittenberger, A., Sanamyan, K., Monniot, C. (2010). *Diplosoma listerianum*. In: Shenkar, N., Gittenberger, A., Lambert, G., Rius, M., Moreira Da Rocha, R., Swalla, B.J., Turon, X. (2017). Ascidiacea World Database. Accessed through: World Register of Marine Species at <http://www.marinespecies.org/aphia.php?p=taxdetails&id=103579> on 2017-10-09.

Guiry, M.D. (2017). *Dasya sessilis* Yamada. In Guiry, M.D. & Guiry, G.M. (2017). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>; accessed on 05 October 2017.

Hummel, H., Wijnhoven, S. (2014). Long-term patterns in the establishment, expansion and decline of invading macrozoobenthic species in the brackish and marine waters of Southwest Netherlands. *Marine Ecology* 35(suppl. 1), 50-55.

ICES (2006). Working Group on Introductions and Transfers of Marine Organisms (WGITMO), 16–17 March 2006, Oostende, Belgium. ICES CM 2006/ACME:05. 334 pp.

Kerckhof, F. (2002). Barnacles(cirripedia, Balanomorpha) in Belgian waters, an overview of the species and recent evolutions, with emphasis on exotic species. *Bulletin van het Koninklijk Belgisch Instituut voor Natuurwetenschappen, Biologie*, 72-Suppl., 93-104.

Kerckhof, F., Haelters, J., Gollasch, S. (2007). Alien species in the marine and brackish ecosystem: the situation in Belgian waters. *Aquatic Invasions* 2, 243-257.

Leps, J., Smilauer, P. (2003). Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press, 283 pp.

Moksnes, P.-O., Pihl, L., Van Montfrans, J. (1998). Predation on postlarvae and juveniles of the shore crab *Carcinus maenas*: importance of shelter, size and cannibalism. *Marine Ecology Progress Series* 166, 211-225.

Omroep Zeeland (2011). Dijkverhoging Oostzeedijk Terneuzen gestart. Nieuws item van woensdag 18 mei 2011. Available from: <http://www.omroepzeeland.nl/nieuws/577/Dijkverhoging-Oostzeedijk-Terneuzen-gestart> (in Dutch).

RWS (2013). Vooroeververdediging Oosterschelde en Westerschelde. Factsheet  
vooroeververdediging fase 2.2. Rijkswaterstaat, document RWS-2254 FS.

Van den Brink, A.M., Wijnhoven, S., McLay, C.L. (2012). Competition and niche segregation following the arrival of *Hemigrapsus takanoi* in the formerly *Carcinus maenas* dominated Dutch delta. *Journal of Sea Research* 73, 126-136.

Van den Brink, A., Hutting, S. (2017). Clash of the crabs: Interspecific, inter-cohort competition between the native European green crab, *Carcinus maenas* and the exotic brush clawed crab *Hemigrapsus takanoi* on artificial oyster reefs. *Journal of Sea Research* 128, 41–51.

Wijnhoven, S., Kromkamp, J. (2013). Ecologisch functioneren. Hoofdstuk 10 in: Depreiter, D., Cleveringa, J., van der Laan, T., Maris, T., Ysebaert, T., Wijnhoven, S. (eds.). T2009 rapportage Schelde estuarium. IMDC, ARCADIS, Universiteit van Antwerpen, IMARES, NIOZ, p. 458-485 + Bijlagen (in Dutch).

Wijnhoven, S., Engelberts, A., Dekker, A., et al. (2015a). Non-indigenous species inventory of estuarine intertidal areas; a comparison of estuaries and habitats using a hard substrate transect methodology. Pilot study within the frame of the INTERREG IV A 2 Seas project SEFINS commissioned by the NVWA. Monitor Taskforce Publication Series 2015 – 07, NIOZ-Yerseke, the Netherlands.

Wijnhoven, S., Verbrugge, L., Kabuta, S., Lavaleye, M., Faasse, M., Gittenberger, A., van Moorsel, G., Smolders, S., de Hullu, E. (2015b). Soortselectie en beoordeling mariene soorten ten behoeve van de EU Exotenverordening. Resultaten en verslaglegging expertpanelbeoordeling van de soortengroep 'mariene soorten'. Initieel product als onderdeel van de expertpanel beoordeling van het totaal aan potentieel invasieve exoten in Nederland. Monitor Taskforce Publication Series 2015-05, NIOZ-Yerseke, the Netherlands (in Dutch).





Wijnhoven, S. (2016). Non-indigenous species presence and distribution in intertidal hard substrate environments of the Western Scheldt: Results of Transect Monitoring inventory of 2016. Ecoauthor Report Series 2016 - 01, Heinkenszand, the Netherlands.

Wijnhoven, S., Gittenberger, A., Faasse, M., Schellekens, T. (2017). Overview alien species monitoring in the Western Scheldt: Current status of monitoring efforts and presence of alien species among macrofauna and algae. Ecoauthor Report Series 2017 - 01, Heinkenszand, the Netherlands.

Wolff, W.J., 2005. Non-indigenous marine and estuarine species in The Netherlands. *Zoologische Mededelingen Leiden* 79, 1-116.

## 6. Annexes

***Annex 1. Overview of the in 2017 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.***

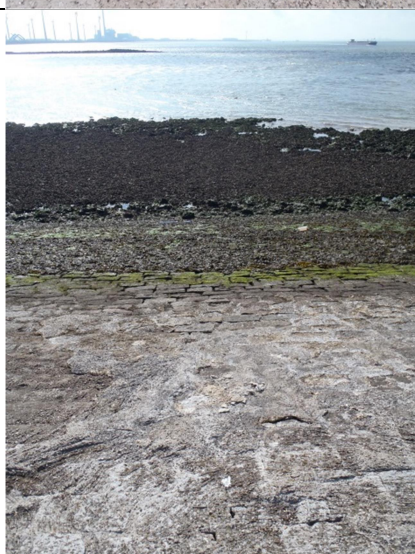
Transect line (half of a transect)	View from high to low intertidal.	View from low to high intertidal.
Breskens - Outside marina – Left line (BRES-OUMA-LE)		
Breskens - Outside marina – Right line (BRES-OUMA-RI)		



Vlissingen - Outside  
harbor – Left line (VLIS-  
OUMA-LE)



Vlissingen - Outside  
harbor – Right line  
(VLIS-OUMA-RI)



Terneuzen - Outside  
marina – Left line  
(TERN-OUMA-LE)





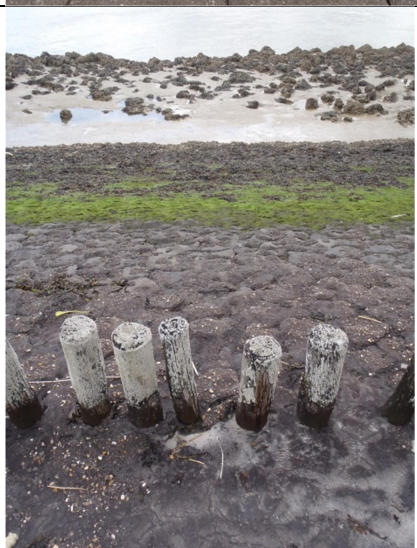
Terneuzen - Outside  
marina – Right line  
(TERN-OUMA-RI)



Hoedekenskerke -  
Outside marina – Left  
line (HOED-OUMA-LE)



Hoedekenskerke -  
Outside marina – Right  
line (HOED-OUMA-RI)





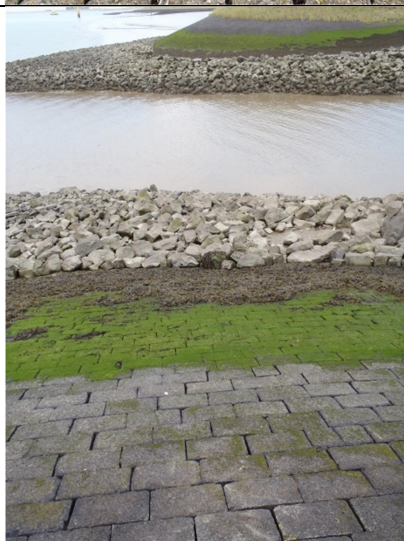
Hansweert - Outside  
working harbor – Left  
line (HANS-OUMA-LE)



Hansweert - Outside  
working harbor – Right  
line (HANS-OUMA-RI)

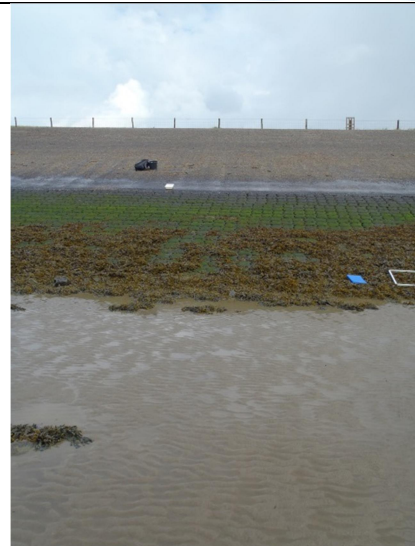


Bath – No marina in  
vicinity – Left line  
(BATH-OUMA-LE)





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



## Annex 2. Species list 2017

Nr	Taxon	Scientific Name	Kingdom	Phylum	Class	Order	Family	Genus	Name analyses	MS	Cryptogenic
1	<i>Abra alba</i>	<i>Abra alba</i>	Animalia	Mollusca	Bivalvia	Cardiida	Semelidae	<i>Abra</i>	<i>Abra alba</i>		
2	<i>Aglaothamnion roseum</i>	<i>Aglaothamnion roseum</i>	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Callithamniaceae	<i>Aglaothamnion</i>	<i>Aglaothamnion roseum</i>		
3	<i>Alitta succinea</i>	<i>Alitta succinea</i>	Animalia	Annelida	Polychaeta	Phyllodocida	Nereididae	<i>Alitta</i>	<i>Alitta succinea</i>		
4	<i>Amphibalanus improvisus</i>	<i>Amphibalanus improvisus</i>	Animalia	Arthropoda	INFRAClass-Cirripedia	Sessilia	Balanidae	<i>Amphibalanus</i>	<i>Amphibalanus improvisus</i>	1	
5	<i>Apohyale prevostii</i>	<i>Apohyale prevostii</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Hyalidae	<i>Apohyale</i>	<i>Apohyale prevostii</i>		
6	<i>Asciidiella aspersa</i>	<i>Asciidiella aspersa</i>	Animalia	Chordata	Asciidiacea	Phlebobranchia	Asciidiidae	<i>Asciidiella</i>	<i>Asciidiella aspersa</i>		
7	<i>Ascophyllum nodosum</i>	<i>Ascophyllum nodosum</i>	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	<i>Ascophyllum</i>	<i>Ascophyllum nodosum</i>		
8	<i>Assiminea grayana</i>	<i>Assiminea grayana</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Assimineidae	<i>Assiminea</i>	<i>Assiminea grayana</i>		
9	<i>Austrominius modestus</i>	<i>Austrominius modestus</i>	Animalia	Arthropoda	INFRAClass-Cirripedia	Sessilia	Austrobalanidae	<i>Austrominius</i>	<i>Austrominius modestus</i>	1	
10	<i>Balanus crenatus</i>	<i>Balanus crenatus</i>	Animalia	Arthropoda	INFRAClass-Cirripedia	Sessilia	Balanidae	<i>Balanus</i>	<i>Balanus crenatus</i>		
11	<i>Balanus crenatus</i>	<i>Balanus crenatus</i>	Animalia	Arthropoda	INFRAClass-Cirripedia	Sessilia	Balanidae	<i>Balanus</i>	<i>Balanus crenatus</i>		
12	<i>Bembidion</i> sp.	<i>Bembidion</i>	Animalia	Arthropoda	Insecta	Coleoptera	Carabidae	<i>Bembidion</i>	GEN-Bembidion		
13	<i>Biflustra tenuis</i>	<i>Biflustra tenuis</i>	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Membraniporidae	<i>Biflustra</i>	<i>Biflustra tenuis</i>		
14	<i>Blidingia marginata</i>	<i>Blidingia marginata</i>	Plantae	Chlorophyta	Ulvophyceae	Ulvaes	Kornmanniaceae	<i>Blidingia</i>	<i>Blidingia marginata</i>		
15	<i>Blidingia minima</i>	<i>Blidingia minima</i>	Plantae	Chlorophyta	Ulvophyceae	Ulvaes	Kornmanniaceae	<i>Blidingia</i>	<i>Blidingia minima</i>		
16	Brachyura (juv)	Brachyura	Animalia	Arthropoda	Malacostraca	Decapoda	INFRAORDO-	INFRAORDO-	INFRAORDO-		

							Brachyura	Brachyura	Brachyura		
17	<i>Caloplaca marina</i>	<i>Caloplaca marina</i>	Fungi	Ascomycota	Lecanoromycetes	Lecanorales	Teloschistaceae	<i>Caloplaca</i>	<i>Caloplaca marina</i>		
18	<i>Caprella mutica</i>	<i>Caprella mutica</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Caprellidae	<i>Caprella</i>	<i>Caprella mutica</i>	1	
19	<i>Carcinus maenas</i>	<i>Carcinus maenas</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Portunidae	<i>Carcinus</i>	<i>Carcinus maenas</i>		
20	<i>Ceramium deslongchampsii</i>	<i>Ceramium deslongchampsii</i>	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Ceramiaceae	<i>Ceramium</i>	<i>Ceramium deslongchampsii</i>		
21	<i>Ceramium virgatum</i>	<i>Ceramium virgatum</i>	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Ceramiaceae	<i>Ceramium</i>	<i>Ceramium virgatum</i>		
22	<i>Chaetogammarus marinus</i>	<i>Chaetogammarus marinus</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Gammaridae	<i>Chaetogammarus</i>	<i>Gammarus marinus</i>		
23	<i>Chondracanthus acicularis</i>	<i>Chondracanthus acicularis</i>	Plantae	Rhodophyta	Florideophyceae	Gigartinales	Gigartinaceae	<i>Chondracanthus</i>	<i>Chondracanthus acicularis</i>		
24	<i>Chondrus crispus</i>	<i>Chondrus crispus</i>	Plantae	Rhodophyta	Florideophyceae	Gigartinales	Gigartinaceae	<i>Chondrus</i>	<i>Chondrus crispus</i>		
25	<i>Conopeum reticulum</i>	<i>Conopeum reticulum</i>	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Electridae	<i>Conopeum</i>	<i>Conopeum reticulum</i>		
26	<i>Corophium volutator</i>	<i>Corophium volutator</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Corophiidae	<i>Corophium</i>	<i>Corophium volutator</i>		
27	<i>Crangon crangon</i>	<i>Crangon crangon</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Crangonidae	<i>Crangon</i>	<i>Crangon crangon</i>		
28	<i>Crangon crangon</i>	<i>Crangon crangon</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Crangonidae	<i>Crangon</i>	<i>Crangon crangon</i>		
29	<i>Crassostrea gigas</i>	<i>Crassostrea gigas</i>	Animalia	Mollusca	Bivalvia	Ostreoida	Ostreidae	<i>Crassostrea</i>	<i>Crassostrea gigas</i>	1	
30	<i>Dasya sessilis</i>	<i>Dasya sessilis</i>	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Dasyaceae	<i>Dasya</i>	<i>Dasya sessilis</i>	1	
31	<i>Dendrocoelum lacteum</i>	<i>Dendrocoelum lacteum</i>	Animalia	Platyhelminthes	Rhabditophora	Tricladida	Dendrocoelidae	<i>Dendrocoelum</i>	<i>Dendrocoelum lacteum</i>		
32	<i>Diadumene cincta</i>	<i>Diadumene cincta</i>	Animalia	Cnidaria	Anthozoa	Actiniaria	Diadumenidae	<i>Diadumene</i>	<i>Diadumene cincta</i>		
33	<i>Diadumene lineata</i>	<i>Diadumene lineata</i>	Animalia	Cnidaria	Anthozoa	Actiniaria	Diadumenidae	<i>Diadumene</i>	<i>Diadumene lineata</i>	1	
34	<i>Diplosoma listerianum</i>	<i>Diplosoma listerianum</i>	Animalia	Chordata	Ascidacea	Aplousobranchia	Didemnidae	<i>Diplosoma</i>	<i>Diplosoma listerianum</i>		1
35	<i>Diptera</i>	<i>Diptera</i>	Animalia	Arthropoda	Insecta	Diptera	ORDO-Diptera	<i>ORDO-Diptera</i>	<i>ORDO-Diptera</i>		
36	<i>Diptera</i>	<i>Diptera</i>	Animalia	Arthropoda	Insecta	Diptera	ORDO-Diptera	<i>ORDO-Diptera</i>	<i>ORDO-Diptera</i>		



37	<i>Ecrobia ventrosa</i>	<i>Ecrobia ventrosa</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Hydrobiidae	<i>Ecrobia</i>	<i>Ecrobia ventrosa</i>		
38	<i>Einhornia crustulenta</i>	<i>Einhornia crustulenta</i>	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Electridae	<i>Einhornia</i>	<i>Einhornia crustulenta</i>		
39	<i>Elymus repens</i>	<i>Elymus repens</i>	Plantae	Tracheophyta	Spermatopsida	Poales	Poaceae	<i>Elymus</i>	<i>Elymus repens</i>		
40	<i>Fucus serratus</i>	<i>Fucus serratus</i>	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	<i>Fucus</i>	<i>Fucus serratus</i>		
41	<i>Fucus spiralis</i>	<i>Fucus spiralis</i>	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	<i>Fucus</i>	<i>Fucus spiralis</i>		
42	<i>Fucus vesiculosus</i>	<i>Fucus vesiculosus</i>	Chromista	Ochrophyta	Phaeophyceae	Fucales	Fucaceae	<i>Fucus</i>	<i>Fucus vesiculosus</i>		
43	<i>Gelidium spinosum</i>	<i>Gelidium spinosum</i>	Plantae	Rhodophyta	Florideophyceae	Gelidiales	Gelidiaceae	<i>Gelidium</i>	<i>Gelidium spinosum</i>		
44	Geophilomorpha	Geophilomorpha	Animalia	Arthropoda	Chilopoda	Geophilomorpha	ORDO-Geophilomorpha	ORDO-Geophilomorpha	ORDO-Geophilomorpha		
45	<i>Hemigrapsus sanguineus</i>	<i>Hemigrapsus sanguineus</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Varunidae	<i>Hemigrapsus</i>	<i>Hemigrapsus sanguineus</i>	1	
46	<i>Hemigrapsus</i> sp. (juv)	<i>Hemigrapsus</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Varunidae	<i>Hemigrapsus</i>	GEN- <i>Hemigrapsus</i>	1	
47	<i>Hemigrapsus takanoi</i>	<i>Hemigrapsus takanoi</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Varunidae	<i>Hemigrapsus</i>	<i>Hemigrapsus takanoi</i>	1	
48	<i>Hydrallmania falcata</i>	<i>Hydrallmania falcata</i>	Animalia	Cnidaria	Hydrozoa	Leptothecata	Sertulariidae	<i>Hydrallmania</i>	<i>Hydrallmania falcata</i>		
49	<i>Jaera (Jaera) albifrons</i>	<i>Jaera (Jaera) albifrons</i>	Animalia	Arthropoda	Malacostraca	Isopoda	Janiridae	<i>Jaera</i>	<i>Jaera (Jaera) albifrons</i>		
50	<i>Jaera (Jaera) ischiosetosa</i>	<i>Jaera (Jaera) ischiosetosa</i>	Animalia	Arthropoda	Malacostraca	Isopoda	Janiridae	<i>Jaera</i>	<i>Jaera (Jaera) ischiosetosa</i>		
51	<i>Janira maculosa</i>	<i>Janira maculosa</i>	Animalia	Arthropoda	Malacostraca	Isopoda	Janiridae	<i>Janira</i>	<i>Janira maculosa</i>		
52	<i>Juncus maritimus</i>	<i>Juncus maritimus</i>	Plantae	Tracheophyta	Magnoliopsida	Poales	Juncaceae	<i>Juncus</i>	<i>Juncus maritimus</i>		
53	<i>Lekanesphaera rugicauda</i>	<i>Lekanesphaera rugicauda</i>	Animalia	Arthropoda	Malacostraca	Isopoda	Sphaeromatidae	<i>Lekanesphaera</i>	<i>Lekanesphaera rugicauda</i>		
54	<i>Ligia oceanica</i>	<i>Ligia oceanica</i>	Animalia	Arthropoda	Malacostraca	Isopoda	Ligiidae	<i>Ligia</i>	<i>Ligia oceanica</i>		
55	<i>Lineus longissimus</i>	<i>Lineus longissimus</i>	Animalia	Nemertea	Anopla	Heteronemertea	Lineidae	<i>Lineus</i>	<i>Lineus longissimus</i>		
56	<i>Lipura maritima</i>	<i>Lipura maritima</i>	Animalia	Arthropoda	Collembola	CLAS-Collembola	Neanuridae	<i>Lipura</i>	<i>Lipura maritima</i>		
57	<i>Littorina fabalis</i>	<i>Littorina fabalis</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littorina</i>	<i>Littorina fabalis</i>		

58	<i>Littorina littorea</i>	<i>Littorina littorea</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littorina</i>	<i>Littorina littorea</i>		
59	<i>Littorina obtusata</i>	<i>Littorina obtusata</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littorina</i>	<i>Littorina obtusata</i>		
60	<i>Littorina saxatilis</i>	<i>Littorina saxatilis</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Littorinidae	<i>Littorina</i>	<i>Littorina saxatilis</i>		
61	<i>Melita nitida</i>	<i>Melita nitida</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Melitidae	<i>Melita</i>	<i>Melita nitida</i>	1	
62	<i>Melita palmata</i>	<i>Melita palmata</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Melitidae	<i>Melita</i>	<i>Melita palmata</i>		
63	<i>Myosotella denticulata</i>	<i>Myosotella denticulata</i>	Animalia	Mollusca	Gastropoda	[unassigned] Pulmonata	Ellobiidae	<i>Myosotella</i>	<i>Myosotella denticulata</i>		
64	<i>Myosotella myosotis</i>	<i>Myosotella myosotis</i>	Animalia	Mollusca	Gastropoda	[unassigned] Pulmonata	Ellobiidae	<i>Myosotella</i>	<i>Myosotella myosotis</i>		
65	<i>Mytilus edulis</i>	<i>Mytilus edulis</i>	Animalia	Mollusca	Bivalvia	Mytiloida	Mytilidae	<i>Mytilus</i>	<i>Mytilus edulis</i>		
66	<i>Neomolgus littoralis</i>	<i>Neomolgus littoralis</i>	Animalia	Arthropoda	Arachnida	Trombidiformes	Bdellidae	<i>Neomolgus</i>	<i>Neomolgus littoralis</i>		
67	<i>Oligochaeta</i>	<i>Oligochaeta</i>	Animalia	Annelida	Clitellata	SUBCLAS- Oligochaeta	SUBCLAS- Oligochaeta	SUBCLAS- Oligochaeta	SUBCLAS- Oligochaeta		
68	<i>Orchestia mediterranea</i>	<i>Orchestia mediterranea</i>	Animalia	Arthropoda	Malacostraca	Amphipoda	Talitridae	<i>Orchestia</i>	<i>Orchestia mediterranea</i>		
69	<i>Patella vulgata</i>	<i>Patella vulgata</i>	Animalia	Mollusca	Gastropoda	SUBCLAS- Patellogastropoda	Patellidae	<i>Patella</i>	<i>Patella vulgata</i>		
70	<i>Peringia ulvae</i>	<i>Peringia ulvae</i>	Animalia	Mollusca	Gastropoda	Littorinimorpha	Hydrobiidae	<i>Peringia</i>	<i>Peringia ulvae</i>		
71	<i>Polydora sp.</i>	<i>Polydora sp.</i>	Animalia	Annelida	Polychaeta	Spionida	Spionidae	<i>Polydora</i>	GEN-Polydora		
72	<i>Polysiphonia elongata</i>	<i>Polysiphonia elongata</i>	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae	<i>Polysiphonia</i>	<i>Polysiphonia elongata</i>		
73	<i>Polysiphonia fucoides</i>	<i>Polysiphonia fucoides</i>	Plantae	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae	<i>Polysiphonia</i>	<i>Polysiphonia fucoides</i>		
74	<i>Porcellana platycheles</i>	<i>Porcellana platycheles</i>	Animalia	Arthropoda	Malacostraca	Decapoda	Porcellanidae	<i>Porcellana</i>	<i>Porcellana platycheles</i>		
75	<i>Pygospio elegans</i>	<i>Pygospio elegans</i>	Animalia	Annelida	Polychaeta	Spionida	Spionidae	<i>Pygospio</i>	<i>Pygospio elegans</i>		
76	<i>Ralfsia verrucosa</i>	<i>Ralfsia verrucosa</i>	Chromista	Ochrophyta	Phaeophyceae	Ralfsiales	Ralfsiaceae	<i>Ralfsia</i>	<i>Ralfsia verrucosa</i>		
77	<i>Sagartia troglodytes</i>	<i>Sagartia troglodytes</i>	Animalia	Cnidaria	Anthozoa	Actiniaria	Sagartiidae	<i>Sagartia</i>	<i>Sagartia troglodytes</i>		
78	<i>Sagina maritima</i>	<i>Sagina maritima</i>	Plantae	Tracheophyta	Spermatopsida	Caryophyllales	Caryophyllaceae	<i>Sagina</i>	<i>Sagina maritima</i>		
79	<i>Salicornia</i>	<i>Salicornia</i>	Plantae	Tracheophyta	PH-Tracheophyta	Caryophyllales	Amaranthaceae	<i>Salicornia</i>	<i>Salicornia</i>		

	<i>europaea</i>	<i>europaea</i>							<i>europaea</i>		
80	<i>Semibalanus balanoides</i>	<i>Semibalanus balanoides</i>	Animalia	Arthropoda	INFRAClass-Cirripedia	Sessilia	Archaeobalanidae	<i>Semibalanus</i>	<i>Semibalanus balanoides</i>		
81	<i>Tephromela atra</i> var. <i>atra</i>	<i>Tephromela atra</i> var. <i>atra</i>	Fungi	Ascomycota	Lecanoromycetes	Lecanorales	Tephromelataceae	<i>Tephromela</i>	<i>Tephromela atra</i>		
82	Tipulidae	Tipulidae	Animalia	Arthropoda	Insecta	Diptera	Tipulidae	FAM-Tipulidae	Tipulidae		
83	<i>Tricellaria inopinata</i>	<i>Tricellaria inopinata</i>	Animalia	Bryozoa	Gymnolaemata	Cheilostomatida	Candidae	<i>Tricellaria</i>	<i>Tricellaria inopinata</i>	1	
84	<i>Ulothrix flacca</i>	<i>Ulothrix flacca</i>	Plantae	Chlorophyta	Ulvophyceae	Ulotrichales	Ulotrichaceae	<i>Ulothrix</i>	<i>Ulothrix flacca</i>		
85	<i>Ulva cf lactuca</i>	<i>Ulva lactuca</i>	Plantae	Chlorophyta	Ulvophyceae	Ulvaes	Ulvaceae	<i>Ulva</i>	<i>Ulva lactuca</i>	1	
86	<i>Ulva intestinalis</i>	<i>Ulva intestinalis</i>	Plantae	Chlorophyta	Ulvophyceae	Ulvaes	Ulvaceae	<i>Ulva</i>	<i>Ulva intestinalis</i>		



### ***Annex 3. Results per Transect***

Non-indigenous species on hard substrate in the Western Scheldt -  
Wijnhoven (2017)



Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
NL-SCHE-BRES-OUMA-11-7-2017													NL-SCHE-BRES-OUMA-11-7-2017												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	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	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	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species	(A/C/R)												Species	(A/C/R)											
Ascophyllum nodosum						C							Ascophyllum nodosum												
Blidingia marginata	A	A	C				A						Blidingia marginata	A	A	A				A		A	A		
Blidingia minima										A	A		Blidingia minima	A	A	A				A		A	A		
Fucus spiralis	A	A				A	A			A	A	C	Fucus spiralis		A	A			A	A	A		C	A	
Fucus vesiculosus						A				C		R	Fucus vesiculosus						A			C	A		
Ralfsia verrucosa					R								Ralfsia verrucosa												
Ullothrix flacca	A	A	A			A				A			Ullothrix flacca	A											
Ulva cf lactuca	C	A						R		A	A	A	Ulva cf lactuca	C	A	A			A	A	A		A		
Alitta succinea													Alitta succinea							R		R			
Apothya prevostii		C	C			A	A	A		R			Apothya prevostii			R			A	A	A				
Austrominius modestus			A			A	A	A		A	A	A	Austrominius modestus	A	A	A			A	A	A		A	A	
Balanus crenatus											C		Balanus crenatus												
Brachyura (juv)													Brachyura (juv)						C				R	C	
Carcinus maenas						R				C	A	A	Carcinus maenas			R			C	C	C		A	C	
Crassostrea gigas								C	C			C	Crassostrea gigas					C	R	C		A	A	C	
Diadumene cincta											R		Diadumene cincta									C			
Diadumene lineata													Diadumene lineata												R
Hemigrapsus sp. (juv)										C			Hemigrapsus sp. (juv)									A		A	
Hemigrapsus sanguineus					C								Hemigrapsus sanguineus			R			C					R	
Hemigrapsus takanoi			C					C					Hemigrapsus takanoi						R			R	R	A	
Hydrallmania falcata													Hydrallmania falcata									C			
Ligia oceanica			A										Ligia oceanica	C		R									
Lipura maritima						R							Lipura maritima		R				A	A			R	R	
Littorina fabalis													Littorina fabalis							R					
Littorina saxatilis									R				Littorina saxatilis			C				C				C	
Mytilus edulis								R			A	C	Mytilus edulis					C	C	A		A	C	C	
Neomolgus littoralis													Neomolgus littoralis			R									
Orchestia mediterranea													Orchestia mediterranea	C	C	C									
Patella vulgata						R							Patella vulgata												
Sagartia troglodytes													Sagartia troglodytes												R
Semibalanus balanoides						A	A			A			Semibalanus balanoides			C				R					C
Tipulidae	R												Tipulidae												

Non-indigenous species on hard substrate in the Western Scheldt -  
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Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
NL-SCHE-VLIS-OUMA-8-8-2017													NL-SCHE-VLIS-OUMA-8-8-2017												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	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	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	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species													Species												
Dasya sessilis													Dasya sessilis												R
Blidingia marginata		A	A										Blidingia marginata		A	A			A						
Blidingia minima			A		A	C	C						Blidingia minima			A		C	A						
Aglaothamnion roseum													Aglaothamnion roseum												R
Caloplaca marina	C												Caloplaca marina	A											
Ceramium virgatum										C	C		Ceramium virgatum												R
Ceramium deslongchampsii													Ceramium deslongchampsii												R
Chondracanthus acicularis						R							Chondracanthus acicularis					R	C		R				
Chondrus crispus									A				Chondrus crispus							R			R		
Fucus serratus						C			R	A	R		Fucus serratus							R			R		
Fucus spiralis			C		A	A					C		Fucus spiralis			A		A	A	A					
Fucus vesiculosus						A	A				A		Fucus vesiculosus				R		A				A		
Gelidium spinosum													Gelidium spinosum												R
Polysiphonia elongata									A				Polysiphonia elongata												R
Polysiphonia fucooides													Polysiphonia fucooides												R
Ulothrix flacca		A	A		A								Ulothrix flacca		A	A		C	A						
Ulva cf lactuca		C	R		A	C	A		A	A	A		Ulva cf lactuca		C	C		A	A	A		A		A	
Ulva intestinalis					A	A	A		A	A	A		Ulva intestinalis											C	
Abra alba							R						Abra alba												
Alitta succinea													Alitta succinea											R	
Amphibalanus improvisus						R			C	A			Amphibalanus improvisus					C						C	
Apohyale prevostii					C	C							Apohyale prevostii			C		C	A	R			A		
Austrominius modestus			R		A	A	A		A	A	A		Austrominius modestus		A	A		A	A	A		A	A	A	
Biflustra tenuis													Biflustra tenuis											R	
Brachyura (juv)											R		Brachyura (juv)												
Caprella mutica							R						Caprella mutica												
Carcinus maenas				R	C	C			C	C	C		Carcinus maenas					C		R			R		
Chaetogammarus marinus										A			Chaetogammarus marinus												
Crassostrea gigas						C	A		A	A	A		Crassostrea gigas			A		A	A	A		A	A	A	
Diadumene cincta										R			Diadumene cincta					R	R						
Diplosoma listerianum									R				Diplosoma listerianum												
Diptera													Diptera										R		
Geophilomorpha	R												Geophilomorpha												
Hemigrapsus sanguineus							C		R	C	R		Hemigrapsus sanguineus					R	R			C			
Hemigrapsus takanoi							R			C			Hemigrapsus takanoi									C	A	A	
Hydrallmania falcata													Hydrallmania falcata											R	



Continued

Field data sheet	To list species and their relative abundance												Field data sheet	To list species and their relative abundance											
CODE	NL-SCHE-VLIS-OUMA-8-8-2017												CODE	NL-SCHE-VLIS-OUMA-8-8-2017											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	Line (LE/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	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	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species													Species												
Ligia oceanica				R									Ligia oceanica												
Lineus longissimus									R				Lineus longissimus												
Lipura maritima			R		C	C	C						Lipura maritima			C		A	C						
Littorina fabalis							R				C		Littorina fabalis			R		R							
Littorina littorea			R					R			A		Littorina littorea			R		C	A	A			A	A	
Littorina obtusata											R		Littorina obtusata					R							
Littorina saxatilis			A		A	C	C				C		Littorina saxatilis			A		C	R	A			R	A	
Melita nitida										C			Melita nitida											R	
Melita palmata										R			Melita palmata												
Myosotella myosotis													Myosotella myosotis				R								
Mytilus edulis				A	A	A		A	C	A			Mytilus edulis			R		A	A	A		C	A	A	
Orchestia mediterranea			R										Orchestia mediterranea				R								
Patella vulgata					R		R				R		Patella vulgata							C					C
Polydora sp.											R		Polydora sp.									C			
Porcellana platycheles									A	A			Porcellana platycheles									A	A	R	
Pygospio elegans					C	C							Pygospio elegans												
Semibalanus balanoides					C	A	A			C	A		Semibalanus balanoides				A	C	A			A	C	C	
Tricellaria inopinata									C				Tricellaria inopinata												

Non-indigenous species on hard substrate in the Western Scheldt -  
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Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
NL-SCHE-TERN-OUMA-17-7-2017													NL-SCHE-TERN-OUMA-17-7-2017												
CODE													CODE												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	Line (LE/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	Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	
Species													Species												
Ascophyllum nodosum						C	A		A				Ascophyllum nodosum				R	A	A	A		A			
Blidingia marginata	A	A	A		A								Blidingia marginata		C										
Blidingia minima		R											Blidingia minima												
Caloplaca marina													Caloplaca marina		A										
Fucus spiralis		C	C		A	R					R		Fucus spiralis												
Fucus vesiculosus						A	C						Fucus vesiculosus				R								
Tephromela atra var. atra													Tephromela atra var. atra		A										
Ulothrix flacca	A	A											Ulothrix flacca		A	C									
Alitta succinea									R	R			Alitta succinea											R	
Amphibalanus improvisus											C		Amphibalanus improvisus					R						R	
Apohyale prevostii						A	A						Apohyale prevostii						C	C		R			
Austrominius modestus						A			A	A			Austrominius modestus			A		A	A	A		A	A	A	
Bembidion sp.			R										Bembidion sp.												
Brachyura (juv)							R				R		Brachyura (juv)												
Carcinus maenas					R	R						R	Carcinus maenas												
Chaetogammarus marinus													Chaetogammarus marinus				R	R							
Crassostrea gigas								R	A	A			Crassostrea gigas				C	A	A	A		A	A	A	
Crangon crangon												C	Crangon crangon												
Dendrocoelum lacteum													Dendrocoelum lacteum											R	
Ecrobia ventrosa												R	Ecrobia ventrosa												
Einhornia crustulenta									C				Einhornia crustulenta												
Geophilomorpha		R											Geophilomorpha												
Hemigrapsus sp. (juv)									C		R		Hemigrapsus sp. (juv)												
Hemigrapsus sanguineus									C	R			Hemigrapsus sanguineus					R	R			R		C	
Hemigrapsus takanoi									C	R			Hemigrapsus takanoi					R					C	C	
Janira maculosa													Janira maculosa											C	
Jaera (Jaera) ischiosetosa									C	C	A		Jaera (Jaera) ischiosetosa												
Ligia oceanica													Ligia oceanica	R	C										
Lineus longissimus												R	Lineus longissimus												
Lipura maritima	A	A	A		C	A	C		A		C		Lipura maritima		C	A		R	C				C	C	
Littorina fabalis													Littorina fabalis					R	C					R	
Littorina littorea			R			R					R		Littorina littorea		C	A		A	A	A		A	A	A	
Littorina obtusata													Littorina obtusata								R				
Littorina saxatilis					C	C	A		A	A	A		Littorina saxatilis		A	A			R			R	A	R	
Melita nitida									A	A	A		Melita nitida											R	
Mytilus edulis								R	R	C			Mytilus edulis					A	C			C	C	R	

Continued

Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
CODE													CODE												
NL-SCHE-TERN-OUMA-17-7-2017													NL-SCHE-TERN-OUMA-17-7-2017												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	Line (LE/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	Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	
Species													Species												
Neomolgus littoralis	R	R	C										Neomolgus littoralis					C	C		C	C	C		
Oligochaeta		C											Oligochaeta	A											
Orchestia mediterranea	C	A	A		A								Orchestia mediterranea	C	C	R									
Peringia ulvae									C	A	A		Peringia ulvae												
Semibalanus balanoides						A			A	A	A		Semibalanus balanoides			A		A	A		A	A	A		
Sagina maritima				R									Sagina maritima	C											
Salicornia europaea				R									Salicornia europaea	C											

Non-indigenous species on hard substrate in the Western Scheldt -  
Wijnhoven (2017)



Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
NL-SCHE-HOED-OUMA-10-8-2017													NL-SCHE-HOED-OUMA-10-8-2017												
CODE													CODE												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	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	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	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species													Species												
Ascophyllum nodosum								R					Ascophyllum nodosum												
Blidingia marginata		A	A		A	A	A						Blidingia marginata		A	A		A	A	A					
Blidingia minima			A			A							Blidingia minima			A		C		C					
Caloplaca marina	A												Caloplaca marina	A											
Fucus serratus							C					R	Fucus serratus					R	A	C			C		
Fucus spiralis			A		C								Fucus spiralis			A		C							
Fucus vesiculosus			R		A	A	A			A			Fucus vesiculosus					A	A	A			A	R	
Tephromela atra var. atra	A												Tephromela atra var. atra	A											
Ulothrix flacca		A	A		A	A	A						Ulothrix flacca		C	A		C							
Ulva cf lactuca			C				R		C	C			Ulva cf lactuca								A	C			
Ulva intestinalis		C			C								Ulva intestinalis			C		A		A					
Alitta succinea										R			Alitta succinea												
Amphibalanus improvisus							R		C		C		Amphibalanus improvisus						R		C				
Apohyale prevostii					C	C							Apohyale prevostii					R		C					
Asciidiella aspersa													Asciidiella aspersa								R				
Austrominius modestus		A	A		A	A	A		A	A	A		Austrominius modestus			A			A			A	A	A	
Balanus crenatus									R				Balanus crenatus								R				
Carcinus maenas					R	R	C		R	C	C		Carcinus maenas					C	C	R		C	R		
Chaetogammarus marinus					R	C	R			R			Chaetogammarus marinus					A	A	A					
Conopeum reticulum									R		R		Conopeum reticulum									R			
Corophium volutator									R				Corophium volutator												
Crassostrea gigas					C	A	A		A	A	A		Crassostrea gigas					R	A	A		A	A	A	
Diadumene cincta							R			A			Diadumene cincta										C		
Diadumene lineata			R		R					A	A		Diadumene lineata									A	C	A	
Hemigrapsus sanguineus													Hemigrapsus sanguineus					C							
Hemigrapsus takanoi									A	A	C		Hemigrapsus takanoi						A		C	A	A		
Hydrallmania falcata												A	Hydrallmania falcata											R	
Ligia oceanica	C												Ligia oceanica			R									
Lipura maritima	A	C	C		C	C							Lipura maritima		A	C		C	R						
Littorina fabalis								R					Littorina fabalis								R		R		
Littorina littorea		R	R										Littorina littorea												
Littorina obtusata													Littorina obtusata								R				
Littorina saxatilis		A	A		A	R			R				Littorina saxatilis		R	C		A	A	C				R	
Melita nitida												R	Melita nitida									A	A		
Mytilus edulis			R		C	C	C		A	A	A		Mytilus edulis					A		C		A	A	A	
Neomolgus littoralis													Neomolgus littoralis						R						
Orchestia mediterranea	C		A										Orchestia mediterranea		R	A									



*Continued*

Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
CODE	NL-SCHE-HOED-OUMA-10-8-2017												CODE	NL-SCHE-HOED-OUMA-10-8-2017											
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	Line (LE/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	Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	
Species													Species												
Porcellana platycheles										R			Porcellana platycheles												
Semibalanus balanoides					R					C	C		Semibalanus balanoides					R				C			
Tipulidae													Tipulidae								R				
Sagina maritima	A												Sagina maritima					R							
Elymus repens													Elymus repens					C							

Non-indigenous species on hard substrate in the Western Scheldt -  
Wijnhoven (2017)



Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
NL-SCHE-HANS-OUMA-27-7-2017													NL-SCHE-HANS-OUMA-27-7-2017												
CODE													CODE												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	Line (LE/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	Stratum (HI/MI/LI)	HI	HI	HI	HI	MI	MI	MI	MI	LI	LI	LI	
Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	
Species													Species												
Blidingia minima	C	A	A		A	A					A		Blidingia minima			A			C			A			
Blidingia marginata							C						Blidingia marginata												
Caloplaca marina													Caloplaca marina	A											
Fucus spiralis		A	A		C	R							Fucus spiralis			C		A		R					
Fucus vesiculosus					A	A	A						Fucus vesiculosus					A	A	A			A		
Tephromela atra var. atra													Tephromela atra var. atra	A											
Ulothrix flacca	C	C	C		A		A					A	Ulothrix flacca			A			C	A		A	C		
Ulva cf lactuca			R			R			A	C			Ulva cf lactuca									A		C	
Ulva intestinalis													Ulva intestinalis										C		
Alitta succinea													Alitta succinea									R			
Amphibalanus improvisus								R					Amphibalanus improvisus						A						
Apothyale prevostii			C		A	R	R						Apothyale prevostii				R	C	A						
Assimineea grayana													Assimineea grayana	C											
Austrominius modestus		A	A		A	A	A		A	A	A		Austrominius modestus					A	A	A		C	A	A	
Bembidion sp.						R							Bembidion sp.												
Carcinus maenas					C	C			R		C		Carcinus maenas					R	C	C		C	R		
Chaetogammarus marinus					C	A	A						Chaetogammarus marinus					R	A	A		A			
Conopeum reticulum													Conopeum reticulum					R							
Crassostrea gigas			C		C	A	A		A	A	A		Crassostrea gigas							A		C	A	A	
Diadumene cincta										C			Diadumene cincta			R		R	C					A	
Diadumene lineata						R							Diadumene lineata			C			A			A	A		
Hemigrapsus sanguineus											R		Hemigrapsus sanguineus									R	R		
Hemigrapsus takanoi					R		R		A	A	R		Hemigrapsus takanoi							R				C	
Hydrallmania falcata													Hydrallmania falcata											C	
Jaera (Jaera) albifrons													Jaera (Jaera) albifrons							C					
Lekanesphaera rugicauda													Lekanesphaera rugicauda									R			
Ligia oceanica	R												Ligia oceanica												
Lipura maritima	C	A	A		A	A	A				A		Lipura maritima		C	C		R		A		C			
Littorina littorea				R	R	R	R				R		Littorina littorea			R			R	A				C	
Littorina saxatilis			C		C	C				A	C		Littorina saxatilis				R			A				C	
Myosotella denticulata													Myosotella denticulata	R											
Myosotella myosotis													Myosotella myosotis	A											
Mytilus edulis				R	R		R		A	A	C		Mytilus edulis												
Neomolgus littoralis													Neomolgus littoralis							C					
Oligochaeta											R		Oligochaeta						R						
Orchestia mediterranea	R		R										Orchestia mediterranea	C											

Non-indigenous species on hard substrate in the Western Scheldt -  
Wijnhoven (2017)

Continued

Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
CODE													CODE												
NL-SCHE-HANS-OUMA-27-7-2017													NL-SCHE-HANS-OUMA-27-7-2017												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	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	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	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species													Species												
Peringia ulvae													Peringia ulvae									R			
Porcellana platycheles									R				Porcellana platycheles												
Pygospio elegans					R	C							Pygospio elegans								C	C			
Semibalanus balanoides						R							Semibalanus balanoides												R
Sagina maritima													Sagina maritima				R								

Field data sheet													Field data sheet												
To list species and their relative abundance													To list species and their relative abundance												
NL-SCHE-BATH-OUMA-25-7-2016													NL-SCHE-BATH-OUMA-25-7-2016												
CODE													CODE												
Line (LE/RI)	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	LE	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	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	Replicate (R1/R2/R3)	R1	R2	R3	ADD	R1	R2	R3	ADD	R1	R2	R3	ADD
Species													Species												
Blidingia marginata		A	A		A					A	A		Blidingia marginata	A	A	A			A						
Blidingia minima		C	A										Blidingia minima	A	A	A		C	A	C		R		R	
Caloplaca marina	A												Caloplaca marina												
Fucus spiralis			C		A	A							Fucus spiralis		C	A		A	A	A					
Fucus vesiculosus						A	A						Fucus vesiculosus					C	A	A		A	A	A	
Tephromela atra var. atra	A												Tephromela atra var. atra												
Ulva intestinalis													Ulva intestinalis												R
Ulva cf lactuca													Ulva cf lactuca												R
Amphibalanus improvisus									A				Amphibalanus improvisus												
Assiminea grayana	A		R										Assiminea grayana												R
Carcinus maenas		R			C		C		C	C			Carcinus maenas	R				C		C		R			
Chaetogammarus marinus					A	A	A					R	Chaetogammarus marinus					A		C					
Corophium volutator									C				Corophium volutator												
Crassostrea gigas									A	A	R		Crassostrea gigas												
Einhornia crustulenta										C			Einhornia crustulenta												
Hemigrapsus sanguineus												R	Hemigrapsus sanguineus												
Hemigrapsus takanoi									C	C	R		Hemigrapsus takanoi									R			
Lekaenesphaera rugicauda			R				A						Lekaenesphaera rugicauda	C	R	R		R							
Ligia oceanica	R	C											Ligia oceanica												
Melita nitida									A	A	C		Melita nitida												R
Myosotella denticulata	A												Myosotella denticulata												
Neomolgus littoralis		A								C			Neomolgus littoralis												
Orchestia mediterranea				R		R							Orchestia mediterranea	C	C	R									
Elymus repens	R												Elymus repens												
Sagina maritima				R									Sagina maritima				R								
Juncus maritimus													Juncus maritimus				R								