Marine Alien Species Detection Network of the Netherlands: 2024 results

Issued by the Office for Risk Assessment and Research,
the Netherlands Food and Consumer Product Safety Authority of
the Ministry of Agriculture, Nature and Food Quality

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GiMaRIS

GiMaRIS report 2025_04

Date:
April 2025

Report number:
GiMaRIS_2025_04

Cover photo:
Cooling water outlet in Terneuzen

Title:
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Issued by:
Office for Risk Assessment and Research, the Netherlands Food and Consumer Product Safety Authority of the Ministry of Agriculture, Nature and Food Quality

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Cite as:
Gittenberger, A., Rensing, M. & H. Keeler-Perez, 2025. Marine alien species detection network of the Netherlands: 2024 results. Issued by the Office for Risk Assessment and Research, the Netherlands Food and Consumer Product Safety Authority of the Ministry of Agriculture, Nature and Food Quality. GiMaRIS report 2025_04: 58 pp.

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1.1 Samenvatting

De voornaamste vectoren bij de introductie en verspreiding van mariene uitheemse soorten zijn gerelateerd aan de scheepvaart, visserij en aquacultuur, maar ook met alternatieve vectoren dient rekening gehouden te worden. Om de belangrijkste vectoren van introductie, de hotspots van vestiging en potentiële stepping-stones te onderzoeken, werd in 2021 een detectie netwerk voor mariene uitheemse soorten opgezet (Gittenberger et al., 2023). Dit detectie netwerk werd gebaseerd op reeds lopende monitoring programma's en ad-hoc onderzoekprogramma's die sinds 2006 zijn uitgevoerd. Binnen het netwerk zijn plekken langs de Nederlandse kust bekeken, waar het voorkomen, of nieuwe introducties van uitheemse soorten verwacht kunnen worden. Er werd gebruik gemaakt van "SETL" plaatjes, onderwater video beelden, schraapnetten, korren, bodemhappers, en planktonnetten. Dit rapport beschrijft de resultaten uit 2024.

In 2024 zijn binnen dit onderzoek 25 locaties geselecteerd. Deze locaties waren niet alleen vector gerelateerd, zoals havens, maar ook potentiële "stepping stones" zoals de boeien langs de Noordzee kust, werden onderzocht. Hiernaast is in 2024 extra aandacht besteed aan locaties waar koelwater wordt geloosd. Dit is gedaan om te bekijken in hoeverre uitheemse soorten, die zich normaal gesproken alleen in warmere streken vestigen, zich ook lokaal in thermisch vervuilde locaties in Nederland kunnen handhaven. De bemonsteringsmethoden die werden ingezet waren bedoeld om een zo breed mogelijk spectrum aan soorten te kunnen detecteren. Hierbij heeft elke methode zijn eigen additieve waarde en specifieke soorten die daarmee het best kunnen worden vastgesteld. Zo werden met de meeste methoden die in 2024 werden ingezet, tenminst één of meer soorten gevonden die met de andere methodes niet werden vastgesteld. In totaal werden in 2024 binnen het netwerk 712 monsters geanalyseerd of plekken visueel doorzocht om zoveel mogelijk soorten te vinden. Uiteindelijk werd het voorkomen van 232 soorten vastgesteld, waarvan er vermoedelijk 89 uitheems zijn. De determinatie van de organismen gebeurde primair op basis van hun morfologie, maar bij twijfel en bij mogelijk 'nieuwe' soorten voor Nederland, werden aanvullend ook moleculaire analyses gebruikt.

Bij de waargenomen uitheemse soorten ging het in zeven gevallen om soorten die vóór 2024 nog niet in Nederland waren waargenomen:

[1] het groenwier *Ulva meridionalis*
[2] het roodwier *Aglaothamnion halliae*
[3] het roodwier *Antithamnion sparsum*
[4] het roodwier *Pyropia suborbiculata*
[5] het kalkkorstwier *Phymatolithon squamulosum*
[6] het mosdiertje *Amathia tertia*
[7] het mosdiertje *Schizoporella* cf. *japonica*

Drie van deze soorten werden alleen vastgesteld nabij koelwaterinstallaties. Dit betrof het uit Noorwegen afkomstige kalkkorstwier *Phymatolithon squamulosum*, en twee soorten algen die voorheen alleen bekend waren uit aanzienlijk warmere streken dan Nederland: het groenwier *Ulva meridionalis* en het roodwier *Pyropia suborbiculata*. De hypothese dat dergelijke warmwater soorten zich ook in Nederland lokaal kunnen vestigen wordt ondersteund door deze twee "nieuwe" exoten en ook door het mosdiertje *Biflustra grandicella*, een tropische exoot die zich al meerdere jaren lokaal in de Westerschelde heeft gevestigd. Deze warmwater soorten zijn tot op heden alleen nabij koelwaterafwateringen gevonden, wat aangeeft dat ze zich vermoedelijk daarbuiten niet goed kunnen vestigen. Van de zeven soorten die als nieuw voor Nederland werden ontdekt, zijn alleen van het groenwier *U. meridionalis* uit

de literatuur concrete voorbeelden bekend dat deze exoot een significante impact kan hebben op de natuur. Deze soort was nog niet eerder waargenomen in Europa. Het is een wereldwijd bekende invasieve soort waarvan de individuen binnen een dag tijd vier keer zo groot kunnen worden. Daarnaast bestaan er gedocumenteerde voorbeelden dat deze soort oestersterftes heeft veroorzaakt op plekken waar hij is geïntroduceerd, met een 30% afname van de oesterpopulatie tot gevolg. Aangezien de soort warme wateren prefereert, zou verondersteld kunnen worden dat het effect op de natuur in Nederland beperkt is. Vanwege zijn groeisnelheid is het niet uitgesloten dat *U. meridionalis* in de warmere maanden wel een impact heeft. Verder is het mogelijk dat deze soort zijn vestigingslocatie in Nederland gebruikt als "stepping-stone" in de verspreiding naar bijvoorbeeld de Middellandse Zee. Daar is deze exoot nog niet vastgesteld en lijkt het klimaat ideaal voor zijn vestiging en verdere verspreiding.

De overige vier exoten die in 2024 als nieuw voor Nederland werden ontdekt, werden allen gevonden op drijvende steigers in havens. De twee mosdiertjes *Amathia tertia* en *Schizoporella* cf. *japonica* en het roodwier *Antithamnion sparsum* werden elk in slechts één haven vastgesteld. Individuen van het roodwier *Aglaothamnion halliae* werden daarentegen verzameld in zowel de haven van Rotterdam als in de haven van IJmuiden en in de haven van Den Helder. Dit lijkt aan te geven dat deze soort zich recentelijk erg snel kan vestigen en verspreiden binnen Nederland. Op de "SETL"-platen die op deze locaties aan de steigers hingen, werden deze vier nieuwe exoten niet vastgesteld. Dit zou mogelijk kunnen beteken dat deze soorten een voorkeur hebben om zich te vestigen op de sterker begroeide steigers. Als dat klopt, dan zou dit betekenen dat met het beter schoon houden van steigers, de kans kan worden verlaagd dat dergelijke nieuwe exoten zich in Nederland vestigen en verder verspreiden.

1.2 Summary

The main vectors regarding marine alien species introduction and spread, are shipping or aquaculture related, but other vectors should be considered as well. To study these pathways of introduction, hotspots of first establishment, and potential stepping stones used by marine alien species, a marine alien species detection network was started along the Dutch coastline in 2021 (Gittenberger et al., 2023) based on ongoing monitoring programs and ad-hoc surveys focused on alien species since 2006. By using settlement plates, underwater video cameras, scrape nets, dredges, bottom grabs, and gelatinous zooplankton nets, besides visual inspections, most marine habitats where alien species were expected to be present along the Dutch coastline, were included. The present report describes the results from 2024.

The 25 locations that were selected to be searched for alien species in 2024 include mainly vector related sites like ports and marina's, but also sites that may function as stepping stones, like buoys along the North Sea coast. Sites with cooling water outlets were specifically focused on in 2024. The goal was to find out to what degree non-native species, originating from warmer climates, can establish themselves locally in the Netherlands. Sampling methods were selected with the aim of detecting a broad range of species. Each method had its own added value and was best suited for detecting particular species. Consequently, most of the sampling methods resulted in the detection of species that were not detected by the other methods. This shows that every survey method contributed to the final result. In total 712 samples were analysed or habitats were visually searched for species.

A total of 232 marine species were recorded in 2024, 89 of which were non-native. These species were identified based on the morphology of organisms, supplemented by molecular analysis for uncertain identifications or potential new species in the Netherlands.
Of the 89 non-native species detected, seven concerned species, which were not known to the Netherlands yet:

[1] the green alga *Ulva meridionalis*
[2] the red alga *Aglaothamnion halliae*
[3] the red alga *Antithamnion sparsum*
[4] the red alga *Pyropia suborbiculata*
[5] the coralline alga *Phymatolithon squamulosum*
[6] the bryozoan *Amathia tertia*
[7] the bryozoan *Schizoporella* cf. *japonica*

Three of these species were only recorded in the surveys that focused on sites with cooling water outlets close-by. This includes the Norwegian coralline alga *Phymatolithon squamulosum*, in addition to two species that are only known from distinctly warmer climates than the temperate climate in the Netherlands, i.e., the green alga *Ulva meridionalis* and the red alga *Pyropia suborbiculata*. The hypothesis that non-native species preferring warmer climates can locally establish themselves in the Netherlands, is supported by these two species, and the tropical bryozoan *Biflustra grandicella*, a species that has established itself about 10 years already, locally in the Westerschelde. In the Netherlands, these three species have only been found near cooling water outlets, indicating that they cannot easily establish themselves elsewhere. Of the seven alien species that were recorded as new to the Netherlands, especially the green alga *Ulva meridionalis*, here reported for the first time in Europe, appears to pose a risk. Although the impact that this species can have on ecosystems is well documented, such evidence from literature was not found for the other six newly recorded species. As a globally recognised invasive species, *U. meridionalis* can quadruple in size daily and has been found to cause up to 30% oyster mortality in areas it has invaded. Because it prefers warmer waters, its ecological impact in the Netherlands may remain limited. However, one may consider a potential impact in summer time, and the fact that the Netherlands could function as a stepping stone for this species en route to the Mediterranean, where the environment seems optimal for its establishment and rapid spread.

The remaining four species that were recorded as new to the Netherlands, were all found in fouling communities on floating docks in ports and harbours. Although the two bryozoans and the red alga *Antithamnion sparsum* were found only locally, *Aglaothamnion halliae* was discovered in the ports of Rotterdam, IJmuiden, and Den Helder, suggesting a rapid spread. Finding these species only on floating docks emphasises the potential importance of these docks for marine non-native species' establishment and distribution in the Netherlands. Settlement plates deployed from the same docks did not have these species on them, implying a preference for the more heavily fouled docks. Should this prove accurate, managing fouling on docks could decrease the establishment and spread chances of such non-native marine species.

2. Introduction

Shipping and aquaculture are generally assumed to be the primary vectors for the introduction and spread of invasive marine species. Despite this, it is critical to acknowledge the possibility of other vectors being involved as well. The main focus, when dealing with alien species in the marine environment, should be on minimizing the number of introductions through all available vectors. Possible courses of action include abiding by the IMO ballast water convention and adopting measures like the regulations on transporting live shellfish as are set in the Netherlands. Given that complete prevention of introductions through vectors like hull fouling is not possible, it becomes increasingly important to prioritise efforts in preventing the establishment and subsequent spread of these species.

In order to gain a deeper understanding of the primary vectors and pathways of introduction and the areas where initial establishment is most prevalent, a marine alien species detection network was established along the Dutch coastline in 2021 (Gittenberger et al., 2024). The detection network was based on already ongoing alien species focused monitoring programs and ad-hoc surveys that are conducted since 2006 along the Dutch coast. In order to evaluate and develop measures for hotspot, pathway, and vector management, the locations that are monitored annually within the network encompass not only vector-related sites such as ports and shellfish production areas, but also sites that may serve as stepping stones, such as buoys along the North Sea coast. In order to cover a wide range of habitats where alien species could potentially be found, the sampling approach includes various methods such as settlement plates, dredges, bottom grabs, and gelatinous zooplankton nets. To ensure maximum efficiency and expedite species detection, the monitoring process involves a qualitative approach, where organism morphology serves as the primary basis for identifications, with molecular analyses offering supplementary evidence. Saving voucher material is hereby done by capturing photos of diagnostic characters and/or preserving specimens.

Besides the annual surveys of coastal sites that are assumed to be hotspots for introduction, establishment and/or spread of marine non-native species, each monitoring year also includes more intense surveys (including most habitats) in less-visited sites that may also harbour alien species. In 2024, these surveys focused on six sites with cooling water outlets nearby. We investigated the possibility that non-native species intolerant of the Dutch temperate climate, could establish there, using these cooling water sites as stepping stones in their further spread, for example to the Mediterranean.

The main focus of the present report is to describe the outcomes of the marine alien species detection network of the Netherlands for the year 2024. These monitoring results can be used in subsequent studies to identify, for example, the main vectors and pathways of marine alien species.

3. Methods

3.1. General methods

The methods that were employed have the aim of documenting a wide range of marine species, both native and non-native, that can be found in alien species hotspots and in areas along the Dutch coastline that serve as potential stepping stones (Figs.1-2; Table 1). The marine alien species detection network of the Netherlands was not designed to detect endo-parasites and/or micro-organisms. Its development was focused on the detection of non-native marine macro-floral and -faunal species. To accomplish this, the following methods were implemented (see also Fig. 1):

[1] SETL-project monitoring using settlement plates (see paragraph 3.2). Since 2006, this project has been consistently conducted in marinas and ports along the Dutch coast. With its deployment of clean plates every three months, the SETL-project is specifically designed to effectively detect species in their early stages of establishment. This method was used to detect non-native species that may have been introduced by fouling on the hulls and/or in the submerged niche areas of commercial ships and pleasure crafts.

[2] Visual inspections of docks and jetties (see paragraph 3.3) in the field, and based on underwater video. This sampling method is especially suitable for recording species of which the individuals start to dominate and/or become better detectible in the later succession stages. By incorporating visual searches for non-native species, the search area can be expanded beyond what is possible with scrape sampling alone, thereby improving the chances of detecting easily visible non-native organisms. The purpose of using this sampling method was to target non-native species that could have been brought in through fouling on the hulls or in the submerged niche areas of both commercial ships and pleasure crafts.

[3] Scrape-samples from docks and jetties (see paragraph 3.3). When it comes to recording species that could easily be overlooked during visual inspections of docks and jetties, this sampling method proves to be especially suitable. It was included in the network to detect non-native species that may have been introduced by fouling on the hulls and/or in the submerged niche areas of commercial ships or pleasure crafts.

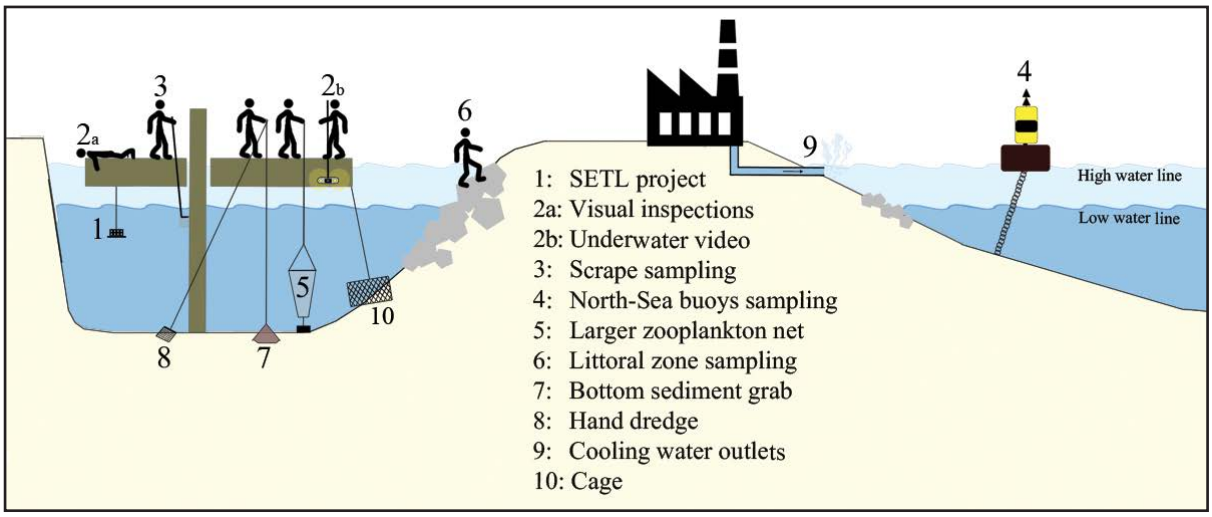

Fig. 1. Sampling and inspection methods used in different habitats.

[4] Scrape-samples from North Sea buoys (See paragraph 3.4). This sampling method is especially suitable to detect non-native fouling species, which may use the buoys in the North Sea as stepping stones in their spread.

[5] Gelatinous Zooplankton sampling (see paragraph 3.5). This sampling method is especially suitable for the detection of gelatinous zooplankton species, among which non-native jellyfish and ctenophores. This method was incorporated with the intention of detecting pelagic non-native species that might be spread through ballast water.

[6] Visual inspections of the littoral zones of dikes in marinas and ports (see paragraph 3.6). This sampling method is especially suitable for the detection of non-native species, which establish themselves in the littoral zone of a dike, i.e. above the low water line. This method was included to detect non-native species that may have been introduced in ballast water tanks, or by fouling on commercial ships or pleasure crafts.

[7] Bottom sediment sampling with a Petite Ponar in marinas and ports (see paragraph 3.7). This sampling method is especially suitable for the detection of non-native species, which establish themselves in the sediment of the bottom. The method was included especially to detect non-native species that may have been introduced in ballast water tanks.

[8] Bottom flora and fauna sampling with a hand dredge in marinas and ports (see paragraph 3.7). In situations where hard substrata, such as oysters and rocks, create obstacles for collecting bottom sediment samples with a Petite Ponar bottom grab, the use of a hand dredge can prove useful for detecting non-native species that inhabit the bottom. The purpose of including this method is to identify non-native species that may have been introduced through ballast water tanks or hull fouling communities.

[9] Cooling water outlet monitoring (see paragraph 3.8). These species assessments in relatively high-temperature waters were not done with a single method, but usually a combination of several methods, taking into account the habitats present. This “method” was used to specifically assess the diversity of non-native species that thrive better in warmer waters rather than the Dutch temperate environment.

[10] Cages for catching fish and crabs. This method was only deployed at one location near to a cooling water outlet off Velsen. This is the only method that specifically focuses on catching bottom dwelling fish and crabs.

Where the weather and sampling methods allowed it, most organisms were identified in the field, photographing their diagnostic characters. The remaining organisms were preserved in the field or in the lab on ethanol 96% (animals and algae) and/or formaldehyde 4% (algae), depending on the taxa concerned with the aim of enabling both molecular analyses and identifications based on morphology. Specimens of certain taxa, such as flatworms and nudibranchs, were photographed while alive in seawater before being preserved to help identify them by their colour patterns and shapes, which could be lost after preservation. Collected organisms were identified in the laboratory with a binocular and/or a microscope with integrated HD-camera based on their morphology and/or subsequent molecular analyses. In some cases the characters (morphological and/or molecular) of an organism closely resembled the characters of a specific species, but did not allow for an identification with certainty. In those cases the abbreviation cf. (confer in Latin) was used to indicate for a species name, that the identification is likely but is not certain. All scientific names were checked and where necessary revised to align with the accepted names in the World Register of Marine Species (www.marinespecies.org).

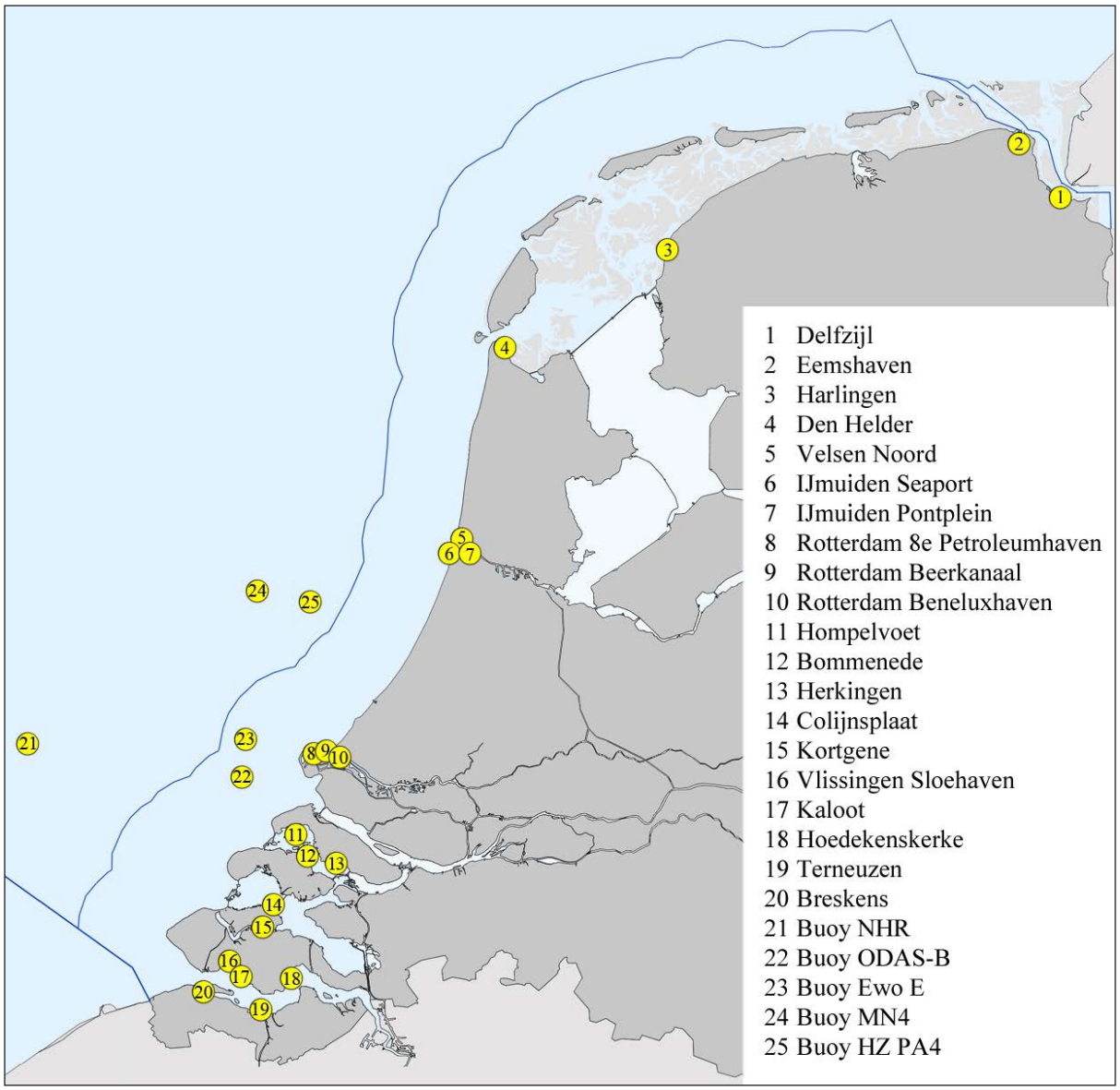

Fig. 2. Locations sampled in 2024. Details can be found in table 1 and Appendix I.

Table. 1. Habitats sampled / methods used at the different locations (Figs. 1-2) in 2024.

Sampling methods (nrs in Fig. 1)	**1**	**2-3**	**4**	**5**	**6**	**7-8**	**9**
Locations (nrs in Fig. 2)	**SETL monitoring**	**Floating docks & jetties**	**Buoy North Sea**	**Gelatineous zoo-plankton monitoring**	**Littoral zone**	**Bottom monitoring**	**Cooling water outlets**
1. Delfzijl							1
2. Eemshaven	1	1		1	1	1	
3. Harlingen							1
4. Den Helder	1	1		1	1	1	
5. Velsen Noord							1
6. IJmuiden Seaport	1	1		1	1	1	
7. IJmuiden Pontplein	1	1		1		1	
8. Rotterdam 8e Petroleumhaven	1	1		1	1	1	
9. Rotterdam Beerkanaal							1
10. Rotterdam Beneluxhaven	1	1		1	1	1	
11. Hompelvoet	1						
12. Bommenede	1	1		1		1	
13. Herkingen	1						
14. Colijnsplaat	1	1		1	1	1	
15. Kortgene	1	1		1		1	
16. Vlissingen Sloehaven	1	1		1		1	
17. Kaloot					1		1
18. Hoedekenskerke	1					1	
19. Terneuzen							1
20. Breskens	1	1		1	1	1	
21. Buoy NHR			1				
22. Buoy ODAS-B			1				
23. Buoy Ewo E			1				
24. Buoy MN4			1				
25. Buoy HZ PA4			1				
	14	**11**	**5**	**11**	**8**	**12**	**6**

3.2 SETL-project

In 2024 at 14 locations (Fig. 2; Fig. 3; Table 1) 14 x 14 cm, grey PVC plates, i.e. SETL plates, were checked for fouling species. These SETL plates were horizontally attached to a brick on a rope that was tied to either floating or fixed structures (Fig. 4). Plates hanging from floating docks were one meter below the water surface, while those deployed off piers in tidal waters, hung one meter below the lowest low water level (Lindeyer & Gittenberger, 2011; Gittenberger *et al.*, 2017). The minimum distance between the plates was one meter. The objects were suspended in the open water, ensuring that they did not come into contact with the bottom or any other structures. In order to create the best possible conditions for organisms to settle, the plates were carefully sanded. Every three months, i.e. in March, June, September and December the plates were retrieved from the water and photographed. Hereby the underside of a PVC plate was photographed in a container with just enough sea water to submerge the plate and the fouling organisms on it. The plates were swiftly retrieved and submerged in a container filled with water, making certain that they were not exposed to air for over 10 seconds. Care was taken during this procedure not to damage organisms attached to the plate. An overview photograph and multiple close-up (macro) photographs were taken from each plate with a digital camera (Lindeyer & Gittenberger, 2011; Gittenberger *et al.*, 2017). At every location, three SETL plates, which were in the water for three months (deployed in the previous monitoring-period) were analysed for pioneer species. Following that, three new SETL plates were used as replacements for the previous ones. Apart from the 3-month old plates, the remaining plates, with some dating as far back as 2009, were used to evaluate the composition of fouling species communities during later stages of succession. Throughout each of the four monitoring seasons, our team documented all species that could be detected per plate, considering both the overview and macro photographs. Organisms were identified from the photos and/or in the laboratory directly after collecting them. During the four fieldwork periods in 2024, in total 269 unique plates were analysed 560 times. The specific details regarding the number of plates checked per location within each of the seasons can be found in Appendix I.

Fig. 3. SETL-plate locations monitored in 2024.

Fig. 4. SETL-plates in Breskens (loc. 20 in Fig. 2) placed in buckets of seawater ready to be photographed in September 2024.

3.3 Floating docks and jetties: scrape sampling and visual inspections

In June and September 2024, the floating docks and jetties in 11 marinas and ports along the Dutch coast were searched for non-native fouling species (Fig. 2; Figs 5-6, Table 1, Appendix I) based on visual inspections and scrape samples. The 13 visual inspections were done by searching for species in the field, e.g. by researchers laying down on docks (Fig. 1) and looking into the water and/or based on video's shot with a GoPro in an underwater- housing on an extendable pole with underwater lights (Fig. 6). Additionally, a total of 22 scrape samples were taken from different floating docks and jetties in the sublittoral, 11 in June 2024 and 11 in September 2024. These samples were taken with a scrape net attached to a 2.5 m aluminium long pole with a scraping blade (Fig. 6). The area scraped for each sample was estimated to be approximately 20 dm^2. Samples were first placed in plastic trays and photographed. Where possible organisms were identified in the field, photographing their diagnostic characters. The remaining organisms were preserved on either ethanol 96% (animals and algae) and/or formaldehyde 4% (algae), depending on the taxa concerned with the aim of enabling both molecular analyses and identifications based on morphology. They were identified at a later stage in the laboratory with a binocular and/or a microscope with integrated HD-camera based on their morphology and/or subsequent molecular analyses.

Fig. 5. Locations where floating docks and jetties were monitored in 2024.

Fig. 6. An aluminium scrape net used for sampling floating docks and jetties in 11 locations in 2024.

3.4 North-Sea buoys: scrape sampling

In July and December 2024, scrape samples were collected from 5 buoys along the Dutch coast (Fig. 2; Figs 7-8; Table 1; Appendix I). This was done by the crew of the "Betonningsschepen" from the Dutch Rijksrederij, during the annual maintenance of navigational buoys along the coastline. Following a prescribed protocol by Gittenberger (2021), samples were taken. A re-usable, sturdy, water-tight sampling bag was used to collect approximately 3 kg of fouling organisms. The purpose of this collection was to include all organisms found on the buoy that appeared different in form and/or colour to the crew member who took the sample. GPS-coordinates and buoy name were noted on the attached water-tide labels, with predefined sampling codes. Samples were kept at a cool place until arrival in the port, where GiMaRIS collected them as soon as possible after arrival. In the lab, the samples were sorted, and photographed in detail, while identifying the organisms alive where feasible. The remaining organisms were preserved on either ethanol 96% (animals and algae) and/or formaldehyde 4% (algae), depending on the taxa concerned to enable both molecular analyses and identifications based on morphology. They were identified at a later stage in the laboratory with a binocular and/ or a microscope with integrated HD-camera based on their morphology and/or subsequent molecular analyses.

Fig. 7. Locations of the buoys that were monitored in 2024.

Fig. 8. Navigational buoys on the emplacement of the Dutch Rijksrederij in Rozenburg.

3.5 Larger zooplankton including gelatinous species sampling

In September 2024, 33 “larger” zooplankton samples, including gelatinous species, were collected at 11 locations along the Dutch coastline (Fig. 2, Figs 9-10; Table 1, Appendix I), with a standard 500 µm mesh drop net, 500 mm wide and 2 m deep. Tow rate was adjusted to approximately 1 m/s, and the net was stopped 1 m before the bottom following the HELCOM OSPAR (2013) port survey protocol. In relatively shallow waters, the net was pulled through the water horizontally over a distance of about 15 meters. Larger zooplankton species, including gelatinous species, were examined immediately after collection in a large shallow tray filled with sea water. Where feasible, organisms were identified and photographed in detail in this tray. In order to facilitate both molecular analyses and identifications based on morphology, organisms that were difficult to identify in the field were either kept alive in containers with water or preserved on ethanol 96%, depending on the specific taxa involved. They were identified in the laboratory with a binocular and/ or a microscope with integrated HD-camera based on their morphology and/or subsequent molecular analyses.

Fig. 9. Locations where “larger” zooplankton / gelatinous species net samples were taken in 2024.

Fig. 10. A “larger” zooplankton drop net with a 500 µm mesh. It is 500 mm wide and 2 m deep.

3.6 Littoral zone sampling

In September 2024, at 8 locations (Fig. 2, Figs 11-12; Table 1, Appendix I), the littoral zones of the dikes were searched during low tide. Each clearly distinguishable littoral zone on the dike was included. At each location, a section of about 50 meters of a dike was selected, including as many habitats as possible (e.g. tidal pools, different dike construction substrata, etc.). The search was continued until less than one new species was expected to be found in double the search time. This was usually the case after a search of about 30 minutes with two persons. In general, most species were recorded (and/ or collected) within the first 5 minutes, after which some additional species were found in the following 10 minutes, whereas no further species were found in the remaining search time. Where possible organisms were identified in the field, photographing their diagnostic characters. The remaining organisms were preserved on either ethanol 96% (animals and algae) and/or formaldehyde 4% (algae), depending on the taxa concerned to enable both molecular analyses and identifications based on morphology. They were identified at a later stage in the laboratory with a binocular and/ or a microscope with integrated HD-camera on the basis of their morphology and/or subsequent molecular analyses.

Fig. 11. Locations where the littoral zone was monitored in 2024.

Fig. 12. Dike in the Eemshaven (loc. 3 in Fig. 2) in September 2024.

3.7 Bottom monitoring: Petite Ponar and hand dredge sampling

In September 2024, an assessment was conducted focused on species living on or in the bottom in 12 marinas and ports (Fig. 2, Fig. 13; Table 1, Appendix I). This was done on the basis of 33 Petite Ponar bottom grab samples and 11 hand dredge samples. The petite ponar is a benthic grab which is suitable for taking samples both in soft sediments and in bottoms with pebbles and shells. As the petite ponar is relatively heavy, it was attached to an iron cable, with handholds every half meter. With these handholds the petite ponar can easily be lifted out of the water by hand by one person without having to be very strong. (Fig. 14a). The hand dregde that was used was a professional 'Naturalists' hand dredge. This dredge, weighing 5 kg, with a 450 x 185 mm frame and a net bag with a 1 mm mesh size, was used to scrape over the bottom over a distance of about 15 meters (Fig. 14b). The sediment samples from the bottom were collected and then sieved using a sieve that had a mesh size of 1 mm. Samples were first placed in plastic trays and photographed. Where possible organisms were then identified in the field, photographing their diagnostic characters. The remaining organisms were preserved on either ethanol 96% (animals and algae) and/or formaldehyde 4% (algae), depending on the taxa concerned with the aim of enabling both molecular analyses and identifications based on morphology. They were identified at a later stage in the laboratory with a binocular and/ or a microscope with integrated HD-camera based on their morphology and/or subsequent molecular analyses.

Fig. 13. Locations where bottom samples were taken in 2024.

Fig. 14. [A] The Petite Ponar bottom grab and [B] the 'Naturalists' hand dredge, used for bottom sampling in September 2024.

3.8 Cooling water outlets

Between June and December 2024, six sites with cooling water outlets were surveyed for various species using a combination of methods depending on the habitat present (Figs. 1-2, Tables 1-2). At most locations (Fig. 6; Table 2) this included searching the intertidal zone of a dike directly next to the cooling water outlet, as described in paragraph 3.6. Where possible, samples were taken from floating docks or jetties as described in paragraph 3.3, and bottom samples were taken as explained in paragraph 3.7. Only at the location in Velsen Noord, three Chinese crab traps were deployed (Fig. 1, Table 2).

Locations (nrs in Fig. 2)	**Used methods (nrs in Fig. 1)**
1. Delfzijl	2b, 6
3. Harlingen	2a, 2b, 6, 7
5. Velsen Noord	2a, 6, 10
9. Rotterdam Beerkanaal	3, 6, 8
17. Kaloot	6
19. Terneuzen	6

Table 2. The survey methods used at each of the six locations with cooling water outlets, following the method numbering of figure 1: [2a] visual inspections, [2b] underwater video, [3] scrape sampling, [6] littoral zone sampling, [7] bottom sediment grab, [8] hand dredge, [10] cages (Fig. 1).

The traps measured 63 cm x 42 cm x 20 cm, with 1.3 cm mesh netting. Traps were baited with frozen fish (cod) and were weighted by attaching a brick to the frame. After 48 hours the traps were retrieved and the catch was identified in the field and/or placed in zipper storage bags for identification at a later time in the lab.

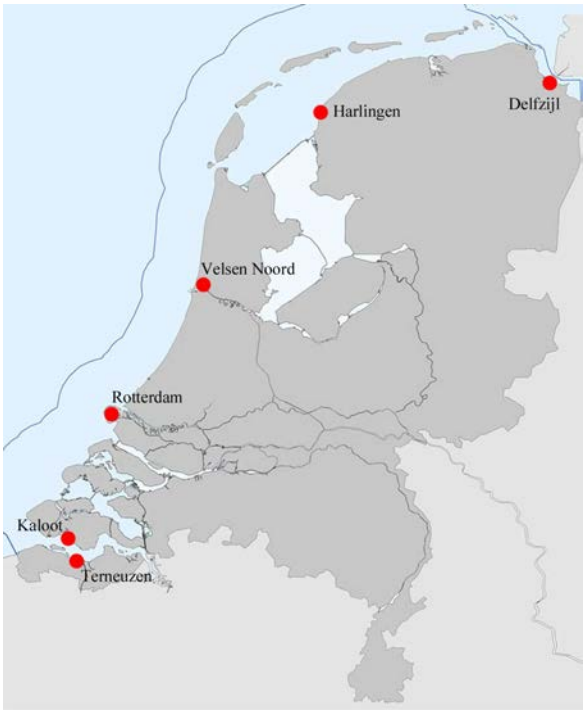

Fig. 6. Locations of the plant with cooling water outlets where monitoring took place in 2024.

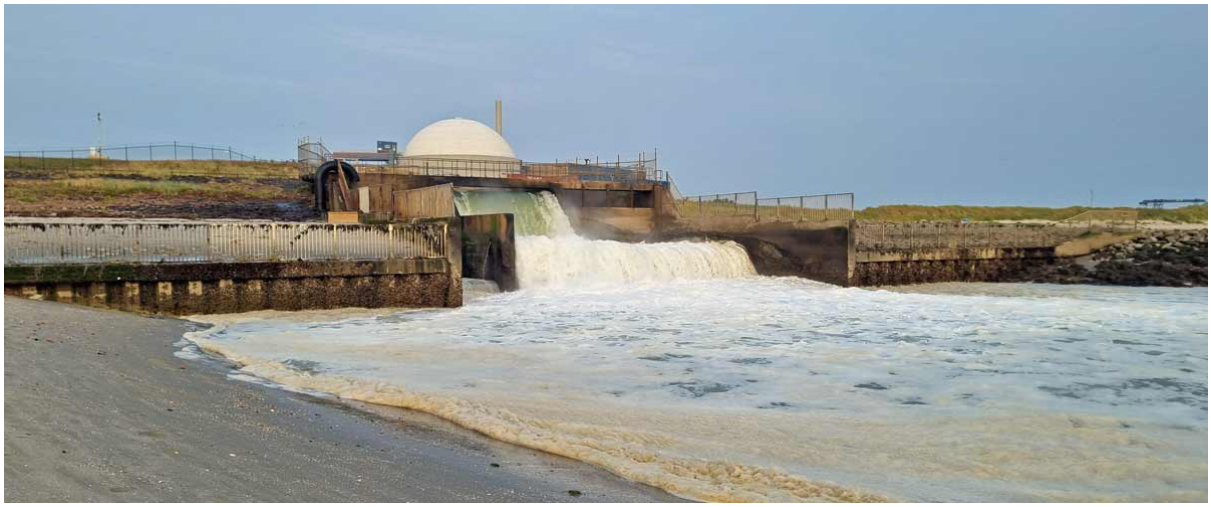

Fig. 16. Cooling water outlet in the Westerschelde of a nuclear plant.

4. Results

4.1. General results and conclusions

In table 3, you can find a concise summary of the key findings from the marine alien species detection network of the Netherlands for the year 2024. In total, 712 samples were taken or sites were visually searched for species (Appendix I). The researchers documented 232 species, with 89 of them likely being non-native to the Netherlands (see Table 4). This includes the five species in table 4 that are denoted by *, indicating that they have an unknown native range. Despite the lack of certainty regarding their origin, the records that are currently available indicate that these cryptogenic species are not native to the Netherlands. Seven of the detected non-native species were unknown to the Netherlands prior to 2024:

[1] the green alga *Ulva meridionalis*
[2] the red alga *Aglaothamnion halliae*
[3] the red alga *Antithamnion sparsum*
[4] the red alga *Pyropia suborbiculata*
[5] the coralline alga *Phymatolithon squamulosum*
[6] the bryozoan *Amathia tertia*
[7] the bryozoan *Schizoporella* cf. *japonica*

The green alga *Ulva meridionalis* was first recorded in the littoral zone just outside the cooling water outlet of the nuclear plant in Borssele in the Westerschelde. This concerns the first record of this (sub)tropical species in Europe, which is an invasive species, known to be spreading globally. It can pose a significant threat to ecosystems into which it is introduced. A fourfold daily growth rate, made it the fastest-growing multicellular autotrophic plant ever recorded (Hiraoka *et al*., 2020). Partly because of this rapid growth, this *Ulva* species was noted to be a significant threat to oyster farms along Taiwan's west coast, resulting in mortality rates as high as 30% (Su *et al*., 2024). As it prefers warmer waters, it seems likely that the ecological impact of this species will remain limited in the Netherlands. However, acknowledging its rapid growth speed, one cannot rule out that it may have an impact in summer time. In addition it should be considered that the Netherlands could function as a stepping stone for this species en route to the Mediterranean, where the environment seems optimal for its establishment and rapid spread.

The rapid spread of the red alga *Aglaothamnion halliae* is noteworthy, as it was discovered in three separate North Sea port locations within the first year that it was recorded in the Netherlands.

Table. 3. General results of surveys done in 2024 within the marine alien species detection network.

	Totaal	**SETL monitoring**	**Floating docks & jetties Scrape sample**	**Buoy North Sea, Scape samples**	**Gelatineous zoo-plankton monitoring**	**Littoral zone**	**Bottom monitoring Petite Ponar / Hand dredge**	**Cooling water outlet monitoring**
# Locations (Fig. 2; Appendix I)	**25**	14	11	5	11	8	12	6
# Samples taken (Appendix I)	**712**	560	35	5	33	8	44	27
# Species recorded (Appendix II)	**232**	105	156	29	20	36	64	65
# Non-native species (Table 4)	**89**	41	70	4	6	11	29	32
# Non-native species uniquely found with one method only (Fig. 1; Table 4)	**36**	4	16	1	1	0	3	11
# Species uniquely found with one method only (Fig. 1; Appendix I-II)	**100**	20	34	14	6	1	6	17

In the ports of Den Helder and IJmuiden it was collected from the floating docks on 2 September 2024. On 3 September it was additionally found on the docks in the port of Rotterdam. Newly discovered species in the Netherlands do not usually have such a wide distribution in their first year, indicating that *A. halliae* is spreading relatively fast and may be found at more locations in the coming years.

The red alga *Antithamnion sparsum* was first recorded on floating docks in Bommenede (Grevelingen) on 11 September 2024. This discovery may indicate the recent introduction of a new non-native in the NE Atlantic. The NW Pacific red seaweed *A. sparsum* was first spotted in the NW Atlantic (on Nova Scotia's rocky shores) only three years prior, in 2021 (https://invasions.si.edu/nemesis/species_summary/12923). Recorded as "new" three years apart on opposite coasts of the Atlantic, seems to suggest a rapidly spreading species.

On June 20 2024, *Pyropia suborbiculata*, a red alga, was first seen on a jetty and in the intertidal zone of a dike near a cooling water outlet in the port of Rotterdam's Beerkanaal. This *Pyropia* species from Asia was previously only found in the eastern Atlantic off the coasts of Portugal and Spain (Verges et al., 2013). *Pyropia* and *Neopyropia* seaweeds are commonly used to produce nori for making sushi in Asia. The discovery of now six of these non-native "nori" species in the Netherlands since 2021 is noteworthy (Gittenberger *et al*., 2022, 2023; Knoop *et al*., 2024), as none were recorded along the Dutch coast before then.

The coralline alga *Phymatolithon squamulosum* was first recorded on Pacific oysters (*Maggalana gigas*) growing in the intertidal of a dike near Terneuzen, directly next to a cooling water outlet. The known native distribution of the species only includes the Norwegian coast. The species' native range may be larger, however, as it closely resembles several native coralline alga species and can easily be mis-identified.

The bryozoan *Amathia tertia*, a species originally described from the American Atlantic coast, was first recorded on floating docks in the Port of Rotterdam on 3 September 2024. As it closely resembles several native *Amathia* species, it is easily misidentified and may have been missed in previous years.

The bryozoan *Schizoporella* cf. *japonica* was first recorded on floating docks in the Sloehaven, port of Vlissingen, on 24 September 2024. Our sequence of the bryozoan colony from Vlissingen, here identified as *S.* cf. *japonica*, matches a sequence of *S. japonica* for 100% on Genbank. We are not certain of the identification, however, because of the potential misidentifications of several similar-looking, recently discovered non-native *Schizoporella* species in NW European waters. Based on our DNA-analyses we can conclude with certainty that the *S.* cf. *japonica* species we recorded in 2024, concerns a different species than the *Schizoporella* species that was recorded in previous years in the Wadden Sea and Oosterschelde within the alien species detection network. That species, which was first identified as *S.* cf. *japonica*, then as *S.* cf. *errata* and most recently as *S.* cf. *variabilis*, significantly differs in its DNA from the *Schizoporella* species that was recorded in 2024 in Vlissingen.

The upcoming paragraphs provide an overview of the 2024 results obtained from the marine alien species detection network. The outcomes of each sampling and monitoring method are discussed separately.

Table. 4. 89 non-native species recorded in 2024 within the marine alien species detection network of the Netherlands. * Cryptogenic species, i.e. the origin of the species is unknown. As known records seem to indicate that the species may not be native for the Netherlands, the species is included in this table. The seven species that are new to the Netherlands, are highlighted. ** Based on DNA-analyses it is concluded that this *Schizoporella* cf. *japonica* species concerns a different species than the *Schizoporella* species that was recorded in previous years in the Wadden Sea and Oosterschelde within the alien species detection network. That species occasionally was also identified as *Schizoporella* cf *japonica*, but is at present known as *S.* cf *variabilis*.

Species	SETL monitoring	Floating docks & jetties	Buoys North Sea	Gelatineous zoo-plankton monitoring	Littoral zone monitoring	Bottom monitoring Petite Ponar	Cooling water outlet monitoring
Species found (232)	105	156	29	20	36	64	65
Non-native species found (89)	42	70	4	6	11	29	32
ALGAE							
Agardhiella subulata	1	1				1	
Aglaothamnion halliae		1					
Antithamnion sparsum		1					
Antithamnionella spirographidis		1				1	
Bonnemaisonia hamifera		1					
Caulacanthus okamurae		1			1	1	1
Ceramium sungminbooi	1	1		1		1	1
Ceramium tenuicorne	1	1				1	
Codium fragile *		1					
Dasysiphonia japonica	1	1				1	1
Gelidium vagum	1	1					
Gracilaria vermiculophylla							1
Grateloupia turuturu		1					
Melanothamnus harveyi		1				1	
Phymatolithon squamulosum							1
Pyropia collinsii		1					
Pyropia elongata		1					
Pyropia suborbiculata							1
Sargassum muticum	1	1					
Ulva australis		1		1	1	1	1
Ulva californica							1
Ulva meridionalis							1
Ulva cf. *shanxiensis*		1					
Undaria pinnatifida	1	1					
ANNELIDA							
Bispira polyomma	1	1					
Ficopomatus cf. enigmaticus	1	1			1	1	1
Hydroides ezoensis	1	1				1	1
Neodexiospira brasiliensis	1	1			1	1	1

Species	SETL monitoring	Floating docks & jetties	Buoys North Sea	Gelatineous zoo-plankton monitoring	Littoral zone monitoring	Bottom monitoring Petite Ponar	Cooling water outlet monitoring
ASCIDIACEA							
Aplidium glabrum *	1	1					
Botrylloides diegensis	1	1					
Botrylloides violaceus	1	1				1	
Didemnum vexillum	1	1					
Diplosoma listerianum *	1	1					
Molgula manhattensis	1	1					1
Perophora japonica	1	1					
Styela clava	1	1					
BRYOZOA							
Amathia tertia		1					
Biflustra grandicella							1
Bugula neritina	1	1					
Bugulina simplex		1					
Bugulina stolonifera	1	1					
Conopeum chesapeakensis	1	1					
Pacificincola perforata	1	1					
Schizoporella cf. *japonica* **		1					
Smittoidea prolifica	1						
Tricellaria inopinata	1	1				1	
CHELICERATA							
Ammothea hilgendorfi	1	1				1	
CNIDARIA							
Aurelia coerulea	1	1		1			
Cordylophora caspia	1						
Diadumene cincta *	1	1					1
Diadumene lineata	1	1			1		1
CRUSTACEA							
Amphibalanus improvisus	1	1				1	1
Ampithoe valida		1				1	1
Austrominius modestus	1	1	1		1	1	1
Caprella mutica	1	1				1	
Caprella scaura							1
Ericthonius didymus		1					1
Eriocheir sinensis							1
Gammarus tigrinus		1					
Hemigrapsus sanguineus	1	1			1		1
Hemigrapsus takanoi	1	1			1	1	1
Jassa marmorata		1	1				
Melita nitida		1		1	1		

Species	SETL monitoring	Floating docks & jetties	Buoys North Sea	Gelatineous zoo-plankton monitoring	Littoral zone monitoring	Bottom monitoring Petite Ponar	Cooling water outlet monitoring
CRUSTACEA							
Palaemon macrodactylus							1
Perforatus perforatus			1				
Ptilohyale littoralis		1					
Rhithropanopeus harrisii		1				1	1
CTENOPHORA							
Mnemiopsis leidyi				1			
MOLLUSCA							
Arcuatula senhousia						1	
Crepidula fornicata		1					
Ensis directus							1
Haloa japonica		1				1	
Heleobia charruana		1		1			
Ischadium recurvum		1				1	1
Magallana gigas	1	1			1	1	1
Mulinia lateralis							1
Mytilopsis leucophaeata	1	1				1	1
Potamocorbula amurensis						1	
Ruditapes philippinarum		1					
Yoldia limatula						1	
NEMERTEA							
Cephalothrix simula		1					
PLATYHELMINTHES							
cf. *Discocelis tigrina*	1	1					
Notocomplana koreana		1	1		1		
Prosthiostomum wagurensis		1					1
PORIFERA							
Celtodoryx ciocalyptoides		1				1	
*Haliclona xena**	1	1					
Hymeniacidon perlevis		1				1	
Suberites massa	1	1					
Sycon scaldiense	1						

4.2 SETL-project

In 2024, SETL-plates were deployed at 14 locations in March, June, September and December. At every location, three new plates were deployed in each season. Three months after deployment, these plates were photographed and returned to the lab for further analysis. Besides these 3-month old plates, many locations still have plates that were deployed much longer ago (up to 2009). They are also photographed in buckets of water in the field and then redeployed. They are used to monitor fouling communities over longer time periods. In total, there were 560 instances that plates were analysed in 2024. This concerned 269 unique plates. Specific information about these plates and the timing and locations of each instance that they were analysed, can be found in Appendix I.

In 2024, 105 species were recorded on the SETL plates, of which 41 concerned non-native species to the Netherlands. These non-native species (Tables 4-5) concern the algal species *Agardhiella subulata, Ceramium sungminbooi, Ceramium tenuicorne, Dasysiphonia japonica, Gelidium vagum, Sargassum muticum* and *Undaria pinnatifida,* the worms *Bispira polyomma, Ficopomatus enigmaticus, Hydroides ezoensis* and *Neodexiospira brasiliensis*, the tunicates *Aplidium glabrum, Botrylloides diegensis, Botrylloides violaceus, Didemnum vexillum, Diplosoma listerianum, Molgula manhattensis, Perophora japonica* and *Styela clava,* the bryozoans *Bugula neritina, Bugulina stolonifera, Conopeum chesapeakensis, Pacificincola perforata, Smittoidea prolifica* and *Tricellaria inopinata*, the sea-spider *Ammothea hilgendorfi*, the cnidarians *Aurelia coerulea, Cordylophora caspia, Diadumene cincta* and *Diadumene lineata,* the crustaceans *Amphibalanus improvisus, Austrominius modestus, Caprella mutica, Hemigrapsus sanguineus, Hemigrapsus takanoi*, the bivalves *Magallana gigas* and *Mytilopsis leucophaeata,* the flatworm cf. *Discocelis tigrina* and the sponges *Haliclona xena, Suberites massa* and *Sycon scaldiense*.

During the 2024 monitoring within the Marine Alien Species Detection Network, the researchers scored 22 species, including 3 non-native species that were only found on SETL-plates (* in Table 5). This shows the added value of the SETL-project within the network. The 3 non-native species that were only found on SETL-plates concern the bryozoan *Smittoidea prolifica*, the cnidarian *Cordylophora caspia* and the sponge *Sycon scaldiense*.

Table 5. Species recorded within the SETL-project. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). * The 22 species exclusively found within the SETL-project.

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam, Beneluxhaven	Hompelvoet	Bommenede	Herkingen	Collijnsplaat	Kortgene	Vlissingen, Sloehaven	Hoedekenskerke	Breskens
Location # in Fig. 2:	*2*	*4*	*6*	*7*	*8*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*18*	*20*
Species found (108)	**38**	**37**	**21**	**9**	**23**	**24**	**41**	**45**	**43**	**51**	**30**	**37**	**16**	**43**
Non-native species found (43)	**15**	**14**	**11**	**6**	**10**	**9**	**18**	**20**	**16**	**22**	**12**	**17**	**9**	**16**
ALGAE														
Agardhiella subulata											1			
Aglaothamnion pseudobyssoides *					1	1								
Bryopsis plumosa		1				1	1	1	1	1			1	
Ceramium secundatum									1					
Ceramium sungminbooi						1								
Ceramium tenuicorne			1						1					
Ceramium virgatum										1				
Chaetomorpha aerea										1				
Chaetomorpha linum							1		1					
Cladophora albida								1						
Cladophora glomerata				1										
Cladophora vagabunda			1											
Dasysiphonia japonica	1		1		1		1	1	1	1			1	
Ectocarpus siliculosus *											1			
Gelidium vagum							1							
Griffithsia corallinoides *										1				
Polysiphonia stricta											1			
Pterothamnion plumula										1				
Sargassum muticum							1							
Undaria pinnatifida										1				
Vertebrata fucoides													1	
ANNELIDA														
Bispira polyomma								1		1				1
Ficopomatus enigmaticus		1	1	1	1	1			1		1	1	1	
Hydroides ezoensis			1		1	1	1	1	1	1		1		1
Neodexiospira brasiliensis	1		1		1	1	1	1	1	1	1	1	1	1
Sabella pavonina								1		1	1			
Serpula vermicularis *												1		1
Spirobranchus lamarcki								1				1		1
Spirobranchus triqueter		1			1	1	1	1	1	1	1	1		1
Spirorbis cf. *spirorbis* *														1
ASCIDIACEA														
Aplidium glabrum							1	1	1	1	1	1		1
Ascidiella aspersa	1	1				1	1	1	1	1	1	1		1

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam, Beneluxhaven	Hompelvoet	Bommenede	Herkingen	Collijnsplaat	Kortgene	Vlissingen, Sloehaven	Hoedekenskerke	Breskens
Botrylloides diegensis	1	1					1	1		1		1		1
Botrylloides violaceus	1	1	1		1	1	1	1	1	1	1	1		1
Botryllus schlosseri	1	1	1		1	1	1		1	1	1	1		1
Ciona intestinalis *	1						1	1		1		1		1
Didemnum vexillum	1	1					1	1		1	1	1		
Diplosoma listerianum	1	1					1	1		1	1	1		1
Molgula manhattensis	1	1	1		1	1			1	1	1	1	1	1
Perophora japonica							1							1
Styela clava	1	1						1	1	1	1	1		1
BRYOZOA														
Alcyonidioides mytili	1	1			1	1		1				1		
Amathia cf. *gracilis*	1	1	1							1		1		1
Anguinella palmata *										1				
Bugula neritina								1	1	1	1			
Bugulina stolonifera		1							1	1		1		
Conopeum chesapeakensis	1	1		1						1				
Conopeum reticulum	1	1			1	1		1	1	1		1	1	1
Conopeum seurati			1	1		1			1		1			1
Crisularia plumosa	1						1	1	1	1				1
Cryptosula pallasiana	1						1	1	1	1	1	1		1
Electra pilosa	1	1							1			1		
Pacificincola perforata								1						
Scrupocellaria scruposa	1				1			1	1	1	1	1		1
Smittoidea prolifica *		1											1	
Tricellaria inopinata	1	1			1	1	1	1	1	1	1	1		1
CHELICERATA														
Ammothea hilgendorfi							1	1		1		1		
CNIDARIA														
Aurelia cf. *aurita*	1	1	1			1	1	1	1	1	1			1
Aurelia coerulea														1
Clytia hemisphaerica *													1	1
Cordylophora caspia *				1										
Cylista elegans *		1												
Diadumene cincta	1	1												
Diadumene lineata									1					
Eudendrium cf. *rameum* *				1			1							
Hartlaubella gelatinosa *							1	1						
Kirchenpaueria pinnata *										1				
Metridium senile	1	1							1		1			1

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam, Beneluxhaven	Hompelvoet	Bommenede	Herkingen	Collijnsplaat	Kortgene	Vlissingen, Sloehaven	Hoedekenskerke	Breskens
ASCIDIACEA														
Obelia dichotoma *	1	1			1	1	1	1	1					
Obelia geniculata	1	1	1		1	1	1	1	1	1	1	1	1	1
Obelia longissima	1	1	1		1	1	1	1	1	1	1	1		
Tubularia indivisa		1												
CRUSTACEA														
Amphibalanus improvisus	1	1	1	1	1	1	1	1	1	1		1	1	1
Austrominius modestus	1	1	1		1		1	1	1	1		1	1	1
Balanus crenatus	1	1	1		1	1	1	1	1	1	1	1	1	1
Caprella mutica	1						1	1			1	1		
Carcinus maenas														1
Gammarus locusta									1					
Hemigrapsus sanguineus										1				
Hemigrapsus takanoi			1						1				1	1
Idotea balthica									1					
Idotea chelipes									1					
Macropodia rostrata *										1				
Melita palmata									1					
Porcellana platycheles										1				
Semibalanus balanoides			1							1				1
ECHINODERMATA														
Amphipholis squamata							1	1						
Asterias rubens	1	1												
MOLLUSCA														
Geitodoris planata *		1												
Magallana gigas	1		1		1			1		1		1	1	1
Mytilopsis leucophaeata				1										
Mytilus edulis	1	1			1	1	1	1	1	1	1	1		1
Ostrea edulis *	1	1					1	1				1	1	1
PISCES														
Gobius niger									1					
Pholis gunnellus		1												
Taurulus bubalis *							1							
PLATYHELMINTHES														
cf. *Discocelis tigrina*				1										
PORIFERA														
Halichondria bowerbanki	1	1			1	1	1	1	1	1	1	1		1
Halichondria panicea	1	1	1		1		1	1	1	1	1	1		1
Haliclona oculata	1													1
Haliclona xena							1	1						
Leucosolenia variabilis	1						1	1		1	1			1
Suberites massa							1							
Sycon ciliatum							1	1		1				1
Sycon scaldiense *								1		1				

4.3 Floating docks and jetties: scrape sampling and visual inspections

The assessment of fouling species communities occurring on floating docks and jetties took place in both June and September 2024, covering 11 marinas and ports along the Dutch coast. Exact details on when and where the docks and jetties were surveyed, can be found in Appendix I.

The visual inspections in the field and from underwater video, in combination with the laboratory analyses of the scrape samples from the docks and jetties (Figs. 1, 6; Table 1; Appendix I), resulted in the detection of 156 species, of which 70 were non-native to the Netherlands (Tables 3 and 5). These species concern the algal species *Agardhiella subulata, Aglaothamnion halliae, Antithamnion sparsum, Antithamnionella spirographidis, Bonnemaisonia hamifera, Caulacanthus okamurae, Ceramium sungminbooi, Ceramium tenuicorne, Codium fragile, Dasysiphonia japonica, Gelidium vagum, Grateloupia turuturu, Melanothamnus harveyi, Pyropia collinsii, Pyropia elongata, Sargassum muticum, Ulva australis, Ulva* cf. *shanxiensis* and *Undaria pinnatifida,* the worms *Bispira polyomma, Ficopomatus* cf. *enigmaticus, Hydroides ezoensis* and *Neodexiospira brasiliensis,* the tunicates *Aplidium glabrum, Botrylloides diegensis, Botrylloides violaceus, Didemnum vexillum, Diplosoma listerianum, Molgula manhattensis, Perophora japonica* and *Styela clava,* the bryozoans *Amathia tertia, Bugula neritina, Bugulina simplex, Bugulina stolonifera, Conopeum chesapeakensis, Pacificincola perforata, Schizoporella* cf. *japonica* and *Tricellaria inopinata,* the sea-spider *Ammothea hilgendorfi,* the cnidarians *Aurelia coerulea, Diadumene cincta* and *Diadumene lineata,* the crustaceans *Amphibalanus improvisus, Ampithoe valida, Austrominius modestus, Caprella mutica, Ericthonius didymus, Gammarus tigrinus, Hemigrapsus sanguineus, Hemigrapsus takanoi, Jassa marmorata, Melita nitida, Ptilohyale littoralis* and *Rhithropanopeus harrisii,* the molluscs *Crepidula fornicata, Haloa japonica, Heleobia charruana, Ischadium recurvum, Magallana gigas, Mytilopsis leucophaeata* and *Ruditapes philippinarum,* the nemertean *Cephalothrix simula,* the flatworms cf. *Discocelis tigrina, Notocomplana koreana* and *Prosthiostomum wagurensis,* and the sponges *Celtodoryx ciocalyptoides, Haliclona xena, Hymeniacidon perlevis* and *Suberites massa.*

Of the species recorded in the Marine Alien Species Detection Network in 2024, 34 were only recorded from floating docks and jetties through visual inspections and scrape sample analyses (* in Table 5). Among these species, 16 were non-native, i.e., the algal species *A. sparsum, A. halliae, B. hamifera, C. fragile, G. turuturu, P. collinsii, P. elongata,* and *U.* cf. *shanxiensis,* the bryozoans *A. tertia, B. simplex* and *S.* cf. *japonica,* the crustaceans *G. tigrinus* and *P. littoralis,* the molluscs *C. fornicata* and *R. philippinarum,* and the nemertean *C. simula.*

Four of these non-native species were sighted in the Netherlands for the first time, i.e. the two bryozoans *A. tertia* (in the Port of Rotterdam) and *S.* cf. *japonica* (in the Sloehaven, port of Vlissingen), and the two red algal species *A. halliae* (in the ports of Den Helder, IJmuiden and Rotterdam) and *A. sparsum* (in the harbour of Bommenede, Grevelingen).

These findings show the added value of monitoring floating docks and jetties within the Marine Alien Species Detection Network.

Table 6. List of the 156 species recorded in scrape samples from floating docks and jetties. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). * The 34 species exclusively found in scrape samples from floating docks and jetties.

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Breskens
Location # in Fig. 2:	*2*	*4*	*6*	*7*	*8*	*10*	*12*	*14*	*15*	*16*	*20*
Species found (156)	**50**	**37**	**43**	**15**	**34**	**34**	**54**	**54**	**53**	**57**	**51**
Non-native species found (70)	**19**	**13**	**17**	**11**	**16**	**12**	**27**	**21**	**28**	**24**	**22**
ALGAE											
Agardhiella subulata							1		1		
Aglaothamnion halliae *		1	1		1						
Antithamnion sparsum *							1				
Antithamnionella spirographidis								1			
Ascophyllum nodosum	1									1	1
Blidingia marginata										1	
Bonnemaisonia hamifera *											1
Bryopsis plumosa	1	1	1		1	1	1	1	1	1	1
Callithamnion corymbosum	1		1			1		1			
Carradoriella denudata *								1			
Carradoriella elongata *								1			
Caulacanthus okamurae					1						
Ceramium cimbricum *	1						1				
Ceramium secundatum						1					
Ceramium sungminbooi	1	1				1	1	1	1	1	1
Ceramium tenuicorne	1	1	1			1		1			
Ceramium virgatum										1	
Chaetomorpha linum									1		
Chondrus crispus					1						1
Cladophora albida							1				1
Cladophora glomerata				1			1				
Cladophora laetevirens	1										
Cladophora vagabunda			1			1					1
Codium fragile *									1		
Dasysiphonia japonica			1		1		1		1	1	1
Fucus vesiculosus	1		1		1	1		1		1	1
Gaillona rosea		1						1			
Gelidium vagum							1				
Grateloupia turuturu *					1						
Leptosiphonia brodiei *			1					1			
Melanothamnus harveyi								1		1	
Polysiphonia stricta											1
Porphyra purpurea *						1					

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Breskens
ALGAE											
Pterothamnion plumula								1		1	1
Pyropia collinsii *								1			
Pyropia elongata *								1			
Sargassum muticum						1	1		1		
Ulva australis			1		1	1	1		1		1
Ulva compressa					1	1		1		1	
Ulva intestinalis *								1			
Ulva lactuca	1							1		1	1
Ulva linza	1			1	1					1	
Ulva prolifera *		1									1
Ulva cf. *shanxiensis* *							1				
Undaria pinnatifida								1	1		1
Vertebrata fucoides								1		1	1
ANNELIDA											
Alitta succinea	1	1	1	1	1	1					
Amphitrite figulus							1			1	
Bispira polyomma							1		1		
Eulalia viridis *	1										
Ficopomatus cf. *enigmaticus*		1	1	1	1			1	1	1	
Harmothoe imbricata	1	1					1	1	1		
Hediste diversicolor *			1			1					
Hydroides ezoensis					1	1	1		1	1	
Lepidonotus squamatus	1	1					1				
Neodexiospira brasiliensis			1		1	1	1	1	1	1	1
Platynereis dumerilii *								1		1	
Sabella pavonina							1		1		
Spirobranchus lamarcki			1								
Spirobranchus triqueter		1					1	1		1	
ASCIDIACEA											
Aplidium glabrum	1						1	1	1		1
Ascidiella aspersa			1				1	1	1	1	1
Botrylloides diegensis	1	1					1	1	1	1	1
Botrylloides violaceus	1	1	1			1	1	1	1	1	1
Botryllus schlosseri	1	1	1		1	1		1	1	1	1
Didemnum vexillum	1									1	
Diplosoma listerianum	1						1		1		1
Molgula manhattensis	1	1	1		1	1		1	1	1	
Perophora japonica											1
Styela clava	1						1		1	1	1

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Breskens
BRYOZOA											
Alcyonidioides mytili	1	1				1		1	1	1	
Amathia tertia *						1					
Bugula neritina							1		1		
Bugulina simplex *											1
Bugulina stolonifera										1	1
Conopeum chesapeakensis				1							
Conopeum reticulum	1	1	1		1	1		1		1	
Conopeum seurati				1							
Crisularia plumosa								1			1
Cryptosula pallasiana					1	1		1	1	1	1
Einhornia crustulenta *	1										
Electra pilosa										1	1
Pacificincola perforata							1				
Schizoporella cf. *japonica* *										1	
Scrupocellaria scruposa							1			1	
Tricellaria inopinata						1	1	1	1	1	1
CHELICERATA											
Ammothea hilgendorfi							1	1	1	1	
CNIDARIA											
Aurelia cf. *aurita*							1		1		
Aurelia coerulea											1
Diadumene cincta	1										
Diadumene lineata	1								1		1
Metridium senile	1	1	1						1		1
Obelia geniculata	1	1	1		1		1	1		1	
Obelia longissima	1	1	1		1	1	1	1			
Urticina felina	1										
CRUSTACEA											
Amphibalanus improvisus		1	1	1	1				1		
Ampithoe valida			1		1	1				1	
Aora gracilis							1				
Austrominius modestus	1	1	1		1			1		1	1
Balanus crenatus	1	1	1		1	1	1	1	1	1	1
Cancer pagurus *						1					
Caprella mutica	1						1		1	1	
Carcinus maenas	1	1	1		1	1		1	1	1	
Corophium volutator	1										
Ericthonius didymus							1			1	

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Breskens
CRUSTACEA											
Gammarus locusta							1	1	1		1
Gammarus salinus *		1									
Gammarus tigrinus *			1	1							
Hemigrapsus sanguineus	1	1	1		1		1				
Hemigrapsus takanoi	1	1	1	1	1			1			
Idotea balthica							1		1		
Idotea chelipes									1		
Idotea pelagica									1		
Jassa marmorata										1	
Marinogammarus marinus					1	1					
Melita nitida	1	1	1	1				1			
Melita palmata	1					1			1		1
Microdeutopus gryllotalpa		1	1			1		1	1		1
Monocorophium acherusicum	1		1				1		1	1	
Monocorophium insidiosum *		1							1	1	
Palaemon elegans *								1		1	
Palaemon serratus								1			1
Porcellana platycheles										1	
Praunus flexuosus								1			1
Ptilohyale littoralis *					1					1	
Rhithropanopeus harrisii				1							
ECHINODERMATA											
Amphipholis squamata							1				
Asterias rubens	1	1	1								
MOLLUSCA											
Crepidula fornicata *								1			
Haloa japonica									1		
Heleobia charruana				1							
Ischadium recurvum				1							
Magallana gigas	1	1	1		1	1	1	1	1	1	1
Mimachlamys varia *							1				
Mytilopsis leucophaeata				1							
Mytilus edulis	1	1	1		1	1	1	1	1	1	1
Onchidoris bilamellata *		1	1								
Patella vulgata											1
Ruditapes philippinarum *									1		

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Breskens
NEMERTEA											
Cephalothrix simula *									1		1
Emplectonema gracile		1									
Lineus longissimus *			1		1	1					
PISCES											
Gobius niger							1				
Pholis gunnellus		1	1							1	
PLATYHELMINTHES											
cf. *Discocelis tigrina*				1							
Notocomplana koreana										1	
Prosthiostomum wagurensis	1										
PORIFERA											
Celtodoryx ciocalyptoides							1				
Halichondria bowerbanki							1		1		
Halichondria panicea	1	1	1		1		1	1		1	1
Haliclona oculata	1		1				1		1	1	1
Haliclona xena							1				1
Hymeniacidon perlevis	1						1	1	1	1	1
Leucosolenia variabilis	1				1		1	1	1	1	1
Suberites massa			1								
Sycon ciliatum	1		1						1	1	1

4.4 North-Sea buoys: scrape sampling

The analysis conducted in 2024 focused on samples that were scraped from 5 buoys in the North sea (Fig. 2, Table 1, Appendix I). Exact details on when and where the scrape samples of the buoys were taken, can be found in Appendix I. The laboratory analyses of the samples resulted in the detection of 29 species, of which 4 were non-native to the Netherlands (Table 4 and 7). These species concern the crustaceans *Austrominius modestus, Jassa marmorata* and *Perforatus perforatus* ant the flatworm *Notocomplana koreana*

During the 2024 monitoring within the Marine Alien Species Detection Network, 14 species were solely recorded in scrape samples from North Sea buoys. One of these species has a non-native origin, i.e., barnacle *Perforatus perforatus*. These findings show the added value of including scrape samples from North-Sea buoys within the Marine Alien Species Detection Network.

Table 7. List of the 29 species recorded in scrape samples taken from the buoys in the North Sea. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). * The 14 species exclusively found in scrape samples taken from the buoys in the North Sea.

Species	Buoy NHR	Buoy ODAS-B	Buoy Ewo E	Buoy MN4	Buoy HZ PA4
Location # in Fig. 2:	*21*	*22*	*23*	*24*	*25*
Species found (29)	**10**	**6**	**11**	**16**	**11**
Non-native species found (4)	**2**	**1**	**1**	**3**	**2**
ANNELIDA					
Eunereis longissima *		1			
Harmothoe extenuata *				1	
Lepidonotus squamatus					1
Phyllodoce laminosa *				1	
Spirobranchus triqueter	1		1	1	
BRYOZOA					
Alcyonidioides mytili			1	1	
Conopeum reticulum			1		
Electra pilosa	1			1	1
CNIDARIA					
Ectopleura larynx				1	1
Metridium senile	1	1	1	1	1
Obelia longissima	1				
Sagartia undata *		1		1	
Tubularia indivisa			1		
Urticina felina	1				
CRUSTACEA					
Austrominius modestus					1
Idotea pelagica				1	
Jassa falcata *			1		
Jassa herdmani *		1			1
Jassa marmorata	1	1	1	1	1
Leucothoe cf. spinicarpa *					1
Perforatus perforatus *				1	
Pilumnus hirtellus *				1	
Pisidia longicornis *			1		
ECHINODERMATA					
Asterias rubens	1			1	1
Psammechinus miliaris *			1	1	1
MOLLUSCA					
Brachystomia scalaris *			1		
Heteranomia squamula *	1				
Mytilus edulis	1	1	1	1	1
PLATYHELMINTHES					
Notocomplana koreana	1			1	

4.5 Larger zooplankton including gelatinous species

In September 2024, 33 larger zooplankton net samples were taken at 11 locations (Fig. 2, Table 1, Appendix I). Exact details on when and where they were taken can be found in Appendix I. In total, 20 species were recorded of which 6 species are non-native to the Netherlands (Tables 3 and 8). These species concern the algae *Ceramium sungminbooi* and *Ulva australis,* the Pacific cryptic jellyfish *Aurelia coerulea,* the crustacean *Melita* cf. *nitida,* the comb jelly *Mnemiopsis leidyi* and the snail *Heleobia charruana.*

During the 2024 monitoring within the Marine Alien Species Detection Network, 6 species were solely recorded in the larger zooplankton samples taken. One of these species has a non-native origin, i.e., *Mnemiopsis leidyi*. This shows the added value of taking larger zooplankton net samples within the network.

Table 8. List of the 20 species recorded in gelatineous zooplankton samples in 2024. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). * The 6 species exclusively found in gelatineous zooplankton samples.

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Breskens
Location # in Fig. 2:	*2*	*4*	*6*	*7*	*8*	*10*	*12*	*14*	*15*	*16*	*20*
Species found (20)	**3**	**2**	**1**	**1**	**5**	**8**	**3**	**1**	**6**	**2**	**0**
Non-native species found (6)	**2**	**1**	**0**	**1**	**1**	**3**	**2**	**1**	**2**	**1**	**0**
ALGAE											
Ceramium sungminbooi	1						1				
Chaetomorpha linum							1				
Cladophora laetevirens	1										
Ulva australis						1					
CNIDARIA											
Aurelia coerulea							1		1		
Eucheilota maculata *										1	
Obelia longissima					1	1					
CRUSTACEA											
Ampithoe rubricata *						1					
Carcinus maenas						1					
Idotea pelagica									1		
Ligia oceanica *			1								
Melita cf. *nitida*						1					
Melita palmata						1			1		
Microdeutopus gryllotalpa									1		
Monocorophium acherusicum					1	1			1		
Praunus flexuosus		1									
CTENOPHORA											
Beroe cucumis *					1						
Mnemiopsis leidyi *	1	1			1	1		1	1	1	
Pleurobrachia cf. *pileus* *					1						
MOLLUSCA											
Heleobia charruana				1							

4.6 Littoral zone sampling

In September 2024, the littoral zones of dikes were surveyed at 8 locations in the Netherlands (Fig. 2, Table 1, Appendix I). Exact details on when and where the littoral zones of dikes were inspected can be found in Appendix I. These surveys resulted in the detection of 36 species (Tables 3 and 9) of which 11 concern non-natives. These non-native species are the algal species *Caulacanthus okamurae* and *Ulva australis*, the worms *Ficopomatus* cf. *enigmaticus* and *Neodexiospira brasiliensis*, the anemone *Diadumene lineata*, the crustaceans *Austrominius modestus*, *Hemigrapsus sanguineus*, *Hemigrapsus takanoi* and *Melita nitida*, the Pacific oyster *Magallana gigas* and the flatworm *Notocomplana koreana*.

During the 2024 monitoring within the Marine Alien Species Detection Network one species solely recorded during the littoral zone sampling, i.e., the algal species *Fucus spiralis*. This shows the added value of sampling the littoral zone within the detection network. Additionally, it should be noted that the alga species *Ulva meridionalis*, which was recorded near the cooling water outlet of Borssele in 2024, was also recorded in the littoral zone. This concerns a new alien species to Europe. The record is described in more detail in paragraph "4.8. Cooling water outlets".

Table 9. List of the 36 species recorded in the littoral zones of dikes. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). * Species exclusively found in the littoral zones of dikes.

Species	Eemshaven	Den Helder	IJmuiden Seaport	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Collijnsplaat	Kaloot	Breskens
Location # in Fig. 2:	*2*	*4*	*6*	*8*	*10*	*14*	*17*	*20*
Species found (36)	**15**	**12**	**12**	**9**	**7**	**14**	**21**	**8**
Non-native species found (11)	**5**	**3**	**4**	**3**	**2**	**6**	**8**	**4**
ALGAE								
Ascophyllum nodosum	1			1		1		1
Blidingia marginata				1	1			
Caulacanthus okamurae				1	1	1	1	
Chondrus crispus						1		
Fucus spiralis *			1					
Fucus vesiculosus		1	1	1	1	1	1	
Gaillona rosea		1						
Porphyra umbilicalis							1	
Ulva australis				1				1
Ulva compressa		1	1			1	1	
Ulva lactuca		1				1	1	
Ulva linza	1							

Species	Eemshaven	Den Helder	IJmuiden Seaport	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Collijnsplaat	Kaloot	Breskens
ANNELIDA								
Alitta succinea	1							
Ficopomatus cf. enigmaticus			1					
Neodexiospira brasiliensis		1	1			1		
Spirobranchus triqueter	1							
BRYOZOA								
Amathia cf. gracilis	1							
Conopeum reticulum							1	
CNIDARIA								
Actinia equina							1	
Diadumene lineata							1	
CRUSTACEA								
Austrominius modestus	1	1	1			1	1	1
Balanus crenatus	1	1	1	1			1	
Carcinus maenas	1		1				1	
Gammarus locusta					1			
Hemigrapsus sanguineus	1						1	
Hemigrapsus takanoi	1					1	1	1
Marinogammarus marinus			1					
Melita nitida	1					1	1	
Semibalanus balanoides	1	1		1	1	1		1
MOLLUSCA								
Cerastoderma edule							1	
Littorina littorea	1	1	1			1	1	1
Littorina saxatilis							1	
Magallana gigas	1	1	1	1	1	1	1	1
Mytilus edulis	1	1	1	1	1	1	1	
Patella vulgata		1					1	1
PLATYHELMINTHES								
Notocomplana koreana							1	

4.7 Bottom monitoring: Petite Ponar and hand-dredge sampling

In September 2024, in total 44 bottom samples (33 Petite ponar samples and 11 hand dredge samples) were taken at 12 locations in the Netherlands (Fig. 2, Table 1, Appendix I). Exact details on when and where samples were taken can be found in Appendix I. The analyses of the samples resulted in the detection of 64 species, of which 29 species were non-native to the Netherlands (Tables 3 & 10). These concern the algal species *Agardhiella subulata, Antithamnionella spirographidis, Caulacanthus okamurae, Ceramium sungminbooi, Ceramium tenuicorne, Dasysiphonia japonica, Melanothamnus harveyi* and *Ulva australis,* the worms *Ficopomatus* cf. *enigmaticus, Hydroides ezoensis* and *Neodexiospira brasiliensis,* the tunicate *Botrylloides violaceus,* the bryozoan *Tricellaria inopinata,* the sea spider *Ammothea hilgendorfi,* the crustaceans *Amphibalanus improvisus, Ampithoe valida, Austrominius modestus, Caprella mutica, Hemigrapsus takanoi* and *Rhithropanopeus harrisii,* the mollusks *Arcuatula senhousia, Haloa japonica, Ischadium recurvum, Magallana gigas, Mytilopsis leucophaeata, Potamocorbula amurensis* and *Yoldia limatula,* and the sponges *Celtodoryx ciocalyptoides* and *Hymeniacidon perlevis.*

During the 2024 monitoring within the Marine Alien Species Detection Network, 6 species were solely recorded in the samples taken from the bottom. Three of these species were of a non-native origin, i.e. the mollusks *Arcuatula senhousia, Potamocorbula amurensis* and *Yoldia limatula.* This shows the added value of bottom sampling within the network.

Table 10. List of species recorded in samples taken from the bottom with a Petite ponar or a hand dredge. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). * The 6 species exclusively found within samples taken from the bottom.

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Hoedekenskerke	Breskens
Location # in Fig. 2:	*2*	*4*	*6*	*7*	*8*	*10*	*12*	*14*	*15*	*16*	*18*	*20*
Species found (64)	**5**	**6**	**10**	**8**	**10**	**7**	**13**	**8**	**21**	**11**	**6**	**0**
Non-native species found (29)	**1**	**1**	**6**	**5**	**6**	**4**	**6**	**4**	**10**	**4**	**2**	**0**
ALGAE												
Agardhiella subulata									1			
Antithamnionella spirographidis								1				
Blidingia minima			1									
Bryopsis plumosa										1		
Callithamnion corymbosum		1										
Caulacanthus okamurae									1			
Ceramium sungminbooi						1		1		1		
Ceramium tenuicorne		1										
Chaetomorpha aerea									1			
Dasysiphonia japonica			1				1					
Gracilariopsis longissima *									1			
Melanothamnus harveyi								1				
Ulva australis									1			
Ulva lactuca		1						1				
Ulva linza				1						1		
Vertebrata fucoides										1		
ANNELIDA												
Alitta succinea				1								
Ficopomatus cf. *enigmaticus*			1	1	1			1	1			
Harmothoe imbricata							1					
Hydroides ezoensis					1	1						
Neodexiospira brasiliensis			1		1	1			1			
Spirobranchus triqueter							1					
ASCIDIACEA												
Ascidiella aspersa							1					
Botrylloides violaceus									1			
Botryllus schlosseri					1							
BRYOZOA												
Conopeum reticulum						1		1	1	1		
Conopeum seurati				1								
Cryptosula pallasiana						1			1			
Scrupocellaria scruposa									1			
Tricellaria inopinata							1			1		

Species	Eemshaven	Den Helder	IJmuiden Seaport	IJmuiden Pontplein	Rotterdam, 8e petroleumhaven	Rotterdam Beneluxhaven	Bommenede	Collijnsplaat	Kortegene	Vlissingen	Hoedekenskerke	Breskens
CHELICERATA												
Ammothea hilgendorfi							1			1		
CNIDARIA												
Metridium senile		1							1			
CRUSTACEA												
Amphibalanus improvisus				1	1							
Ampithoe valida											1	
Austrominius modestus	1		1		1					1		
Balanus crenatus			1		1				1	1		
Caprella mutica									1			
Carcinus maenas	1	1								1		
Corophium volutator											1	
Crangon crangon	1		1									
Gammarus locusta								1	1			
Hemigrapsus takanoi									1			
Microdeutopus gryllotalpa									1			
Monocorophium acherusicum									1			
Palaemon serratus					1							
Rhithropanopeus harrisii				1								
ECHINODERMATA												
Amphipholis squamata							1					
Asterias rubens	1											
MOLLUSCA												
Arcuatula senhousia *			1									
Cerastoderma edule											1	
Haloa japonica									1			
Ischadium recurvum				1								
Macoma balthica *											1	
Magallana gigas					1	1	1		1			
Mytilopsis leucophaeata				1								
Mytilus edulis	1	1	1		1	1	1		1	1		
Peringia ulvae *											1	
Potamocorbula amurensis *											1	
Yoldia limatula *			1									
PISCES												
Gobius niger								1				
PORIFERA												
Celtodoryx ciocalyptoides							1					
Halichondria panicea							1					
Hymeniacidon perlevis							1					
Leucosolenia variabilis							1					

4.8. Cooling water outlets

Between June and December 2024, six locations with cooling water outlets were visited and searched for species with a combination of methods, depending mostly on the habitats present (Fig. 2, Tables 1-2). Included were primarily visual searches in the littoral zones of dikes, as well as occasional bottom sampling using a petite ponar or hand dredge, and placing traps for fishes and crabs. Exact details on when, where and with which methods samples were taken, or species searches were conducted, can be found in Appendix I.

In total of 65 species were found, of which 32 species were non-native to the Netherlands (Tables 3 & 11). The non-natives concern the algal species *Caulacanthus okamurae*, *Ceramium sungminbooi*, *Dasysiphonia japonica*, *Gracilaria vermiculophylla*, *Phymatolithon squamulosum*, *Pyropia suborbiculata*, *Ulva australis*, *Ulva californica* and *Ulva meridionalis*, the tubeworms *Ficopomatus* cf. *enigmaticus*, *Hydroides ezoensis* and *Neodexiospira brasiliensis*, the tunicate *Molgula manhattensis*, the bryozoan *Biflustra grandicella*, the sea anemones *Diadumene cincta* and *Diadumene lineata*, the crustaceans *Amphibalanus improvisus*, *Ampithoe valida*, *Austrominius modestus*, *Caprella scaura*, *Ericthonius didymus*, *Eriocheir sinensis*, *Hemigrapsus sanguineus*, *Hemigrapsus takanoi, Palaemon macrodactylus* and *Rhithropanopeus harrisii*, the mollusks *Ensis directus*, *Ischadium recurvum*, *Magallana gigas*, *Mulinia lateralis* and *Mytilopsis leucophaeata* and the flatworm *Prosthiostomum wagurensis*.

Of the species recorded in the Marine Alien Species Detection Network in 2024, 17 were only recorded in the surveys focused on cooling water outlets (* in Table 10). Among these species, 11 were non-native, i.e., the algal species *G. vermiculophylla, P. squamulosum, P. suborbiculata, U. californica* and *U. meridionalis*, the bryozoan *B. grandicella*, the crustaceans *C. scaura*, *E. sinensis* and *P. macrodactylus*, and the molluscs *E. directus* and *M. lateralis*. Three of these non-native species were sighted in the Netherlands for the first time, i.e., the seaweeds *P. squamulosum, P. suborbiculata* and *U. meridionalis*. The latter concerns a species, which is also new to Europe. These findings show the added value of specifically searching areas with cooling water outlets.

Among these 17 species, three are exclusively known from subtropical and tropical climates , i.e., the green alga *Ulva meridionalis*, the red alga *Pyropia suborbiculata*, and the bryozoan *Biflustra grandicella*. Within the surveys, these three species were only found in close proximity to cooling water outlets and nowhere else, suggesting a limited impact in the Netherlands' temperate waters. While specimens that have settled away from cooling outlets may not survive winter, the alga of the species *U. meridionalis*, which can quadruple in size daily (Hiraoka et al., 2020), could still have an impact in the summer, however. The species has already been shown to kill up to 30% of the oysters in other places it has invaded (Su et al., 2024). Moreover, the Netherlands could act as a stepping stone for the species' expansion into the Mediterranean, where it is not known yet and the climate seems ideal for its settlement. The invasive tropical bryozoan *B. grandicella* has a similar risk. This species also has not been found in the Mediterranean yet. The species' impact on the ecosystems it has invaded, has been significant, forming basketball-sized calcareous colonies that cover the ocean floor (Gittenberger & Rensing, 2017). The probability of this species impacting ecosystems in the Netherlands during summer seems lower than that of *U. meridionalis*, as it has a considerably slower growth rate. With respect to the red alga *Pyropia suborbiculata*, the possibility of the Netherlands serving as a stepping stone to the Mediterranean is negligible, given that the species is already there (Vergés et al., 2013). Though this species may exhibit temporary population growth in the Netherlands during the summer months, published research does not indicate that it can have any substantial impact on the ecosystems it invaded. To conclude, primarily *U. meridionalis* and *B. grandicella* form a risk.

Table 11. List of species recorded in samples nearby cooling water outlets. Non-native and cryptogenic species are highlighted. Locations are ordered from north to south in the Netherlands (see figure 2). The numbers in the columns refer to the numbered survey methods shown in figure 1, i.e., [2a] visual inspections, [2b] underwater video, [3] scrape sampling, [6] littoral zone sampling, [7] bottom sediment grab (petite ponar), [8] hand dredge, [10] cage. * The 17 species exclusively found within samples taken near cooling water outlets.

Species	Delfzijl	Harlingen	Velsen Noord	Rotterdam Beerkanaal	Kaloot	Terneuzen
Location # in Fig. 2:	*1*	*3*	*5*	*9*	*17*	*19*
Species found (65)	**15**	**22**	**5**	**13**	**29**	**20**
Non-native species found (32)	**5**	**9**	**4**	**4**	**17**	**11**
ALGAE						
Ascophyllum nodosum	6	6				
Blidingia minima		2a, 2b, 6		3, 6		6
Bryopsis plumosa				3, 8	6	6
Caulacanthus okamurae				3, 8	6	
Ceramium sungminbooi					6	
Cladophora vagabunda				3		
Dasysiphonia japonica						6
Fucus vesiculosus	2b, 6	2a, 2b		3, 6		6
Gracilaria vermiculophylla *						6
Phymatolithon squamulosum *						6
Porphyra dioica *					6	
Porphyra umbilicalis					6	
Pyropia suborbiculata *				3, 6		
Ulva australis					6	
Ulva californica						6
Ulva compressa	6			3	6	
Ulva lactuca				3, 6	6	
Ulva linza		2b, 6, 7				
Ulva meridionalis *					6	
ANNELIDA						
Alitta succinea		6, 7				
Amphitrite figulus					6	
Arenicola marina *						6
Ficopomatus cf. *enigmaticus*	6	2b, 6, 7	2a, 6, 10			6
Heteromastus filiformis *	6					
Hydroides ezoensis				8	6	
Neodexiospira brasiliensis						6
ASCIDIACEA						
Ascidiella aspersa		2b				
Molgula manhattensis		2b, 7			6	
BRYOZOA						
Biflustra grandicella *					6	
Conopeum reticulum	6					

Species	Delfzijl	Harlingen	Velsen Noord	Rotterdam Beerkanaal	Kaloot	Terneuzen
CNIDARIA						
Actinia equina					6	
Diadumene cincta		2b				
Diadumene lineata					6	
Metridium senile		2b, 7				
CRUSTACEA						
Amphibalanus improvisus	6	2b, 6, 7			6	6
Ampithoe valida						6
Aora gracilis		6				
Austrominius modestus	6	2b		6	6	6
Caprella scaura *					6	
Carcinus maenas		6	10	6	6	
Crangon crangon	6	7				
Ericthonius didymus					6	
Eriocheir sinensis *					6	
Hemigrapsus sanguineus					6	6
Hemigrapsus takanoi		6			6	
Melita palmata	6					
Monocorophium acherusicum	6					
Palaemon macrodactylus *	6					
Rhithropanopeus harrisii			6, 10			
Semibalanus balanoides		2a, 2b, 6		6		6
ECHINODERMATA						
Asterias rubens					6	
MOLLUSCA						
Ensis directus *					6	
Ischadium recurvum			6, 10			
Littorina littorea	6				6	6
Littorina saxatilis						6
Magallana gigas	6	2b, 6, 7			6	6
Mulinia lateralis *		7				
Mytilopsis leucophaeata			2a, 6, 10			
Mytilus edulis	6	2b, 6, 7			6	6
Patella vulgata						6
Spisula subtruncata *		7				
Venerupis corrugata *					6	
NEMERTEA						
Emplectonema gracile				3		
PLATYHELMINTHES						
Prosthiostomum wagurensis		7				

5. Literature

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Appendix I

List of locations (Fig. 2) where samples were taken or visual inspections were done in 2024, and the methods that were used. * Per SETL location there are multiple SETL plates deployed (normally ~2-4 m apart).

Sample	Habitat	Method	Date	GPS
DELFZIJL (loc 1; Fig. 2)				
1	Littoral zone dike	Scrape sample	18-9-2024	N 53 18.858, E 06 59.307
2	Littoral zone dike	Underwater video	18-9-2024	N 53 18.862, E 06 59.308
3	Littoral zone dike	Visual inspection	18-9-2024	N 53 18.854, E 06 59.302
4	Littoral zone dike	Visual inspection	18-9-2024	N 53 18.858, E 06 59.307
EEMSHAVEN (loc 1; Fig. 2)				
5-14	Floating Dock	SETL	8-3-2024	N 53 26.682, E 06 49.531*
15-24	Floating Dock	SETL	13-6-2024	N 53 26.682, E 06 49.531*
25-33	Floating Dock	SETL	18-9-2024	N 53 26.682, E 06 49.531*
34-45	Floating Dock	SETL	12-12-2024	N 53 26.682, E 06 49.531*
46	Floating Dock	Visual inspection	18-9-2024	N 53 26.686, E 06 49.479
47	Floating Dock	Visual inspection	18-9-2024	N 53 26.688, E 06 49.470
48	Floating Dock	Scrape sample	13-6-2024	N 53 26.682, E 06 49.531
49	Floating Dock	Scrape sample	18-9-2024	N 53 26.686, E 06 49.479
50	Water collumn	GZP net	18-9-2024	N 53 26.683, E 06 49.484
51	Water collumn	GZP net	18-9-2024	N 53 26.685, E 06 49.473
52	Water collumn	GZP net	18-9-2024	N 53 26.687, E 06 49.458
53	Littoral zone dike	Visual inspection	17-9-2024	N 53 26.641, E 06 49.529
54	Bottom	Petit ponar	18-9-2024	N 53 26.683, E 06 49.484
55	Bottom	Petit ponar	18-9-2024	N 53 26.685, E 06 49.473
56	Bottom	Petit ponar	18-9-2024	N 53 26.687, E 06 49.458
57	Bottom	Dredge sample	18-9-2024	N 53 26.685, E 06 49.469
HARLINGEN (loc 3; Fig. 2)				
58	Floating Dock	Visual inspection	17-9-2024	N 53 11.026, E 05 25.296
59	Floating Dock	Underwater video	17-9-2024	N 53 11.026, E 05 25.296
60	Littoral zone dike	Scrape sample	17-9-2024	N 53 11.100, E 05 25.421
61	Littoral zone dike	Visual inspection	17-9-2024	N 53 11.101, E 05 25.420
62	Littoral zone dike	Visual inspection	17-9-2024	N 53 11.100, E 05 25.421
63	Bottom	Petit ponar	17-9-2024	N 53 11.035, E 05 25.291
64	Bottom	Petit ponar	17-9-2024	N 53 11.029, E 05 25.295
DEN HELDER (loc 4; Fig. 2)				
65-73	Floating Dock	SETL	5-3-2024	N 52 57.692, E 04 46.856*
74-83	Floating Dock	SETL	3-6-2024	N 52 57.692, E 04 46.856*
84-93	Floating Dock	SETL	2-9-2024	N 52 57.692, E 04 46.856*
94-102	Floating Dock	SETL	3-12-2024	N 52 57.776, E 04 46.854*
103	Floating Dock	Visual inspection	2-9-2024	N 52 57.692, E 04 46.856
104	Floating Dock	Scrape sample	3-6-2024	N 52 57.692, E 04 46.856
105	Floating Dock	Scrape sample	2-9-2024	N 52 57.692, E 04 46.856

Sample	Habitat	Method	Date	GPS
DEN HELDER (loc 4; Fig. 2)				
106	Water collumn	GZP net	2-9-2024	N 52 57.698, E 04 46.851
107	Water collumn	GZP net	2-9-2024	N 52 57.695, E 04 46.858
108	Water collumn	GZP net	2-9-2024	N 52 57.691, E 04 46.868
109	Littoral zone dike	Visual inspection	2-9-2024	N 52 57.730, E 04 46.786
110	Bottom	Petit ponar	2-9-2024	N 52 57.698, E 04 46.851
111	Bottom	Petit ponar	2-9-2024	N 52 57.695, E 04 46.858
112	Bottom	Petit ponar	2-9-2024	N 52 57.691, E 04 46.868
VELSEN NOORD (loc 5; Fig. 2)				
113	Jetty	Visual inspection	6-9-2024	N 52 28.256, E 04 37.066
114	Littoral zone dike	Visual inspection	6-9-2024	N 52 28.256, E 04 37.065
115	Jetty	Trap	6-9-2024	N 52 28.256, E 04 37.066
116	Jetty	Trap	6-9-2024	N 52 28.256, E 04 37.065
117	Jetty	Trap	6-9-2024	N 52 28.174, E 04 38.017
IJMUIDEN PONTPLEIN (loc 7; Fig. 2)				
118	jetty	SETL	5-3-2024	N 52 27.775, E 04 37.987*
119-121	jetty	SETL	3-6-2024	N 52 27.775, E 04 37.987*
122-123	jetty	SETL	2-9-2024	N 52 27.775, E 04 37.987*
124-125	jetty	SETL	3-12-2024	N 52 27.775, E 04 37.987*
126	jetty	Visual inspection	2-9-2024	N 52 27.775, E 04 37.986
127	jetty	Scrape sample	3-6-2024	N 52 27.775, E 04 37.986
128	jetty	Scrape sample	2-9-2024	N 52 27.775, E 04 37.986
129	Water collumn	GZP net	2-9-2024	N 52 27.775, E 04 37.986
130	Water collumn	GZP net	2-9-2024	N 52 27.777, E 04 37.993
131	Water collumn	GZP net	2-9-2024	N 52 27.776, E 04 38.004
132	Bottom	Petit ponar	2-9-2024	N 52 27.775, E 04 37.986
133	Bottom	Petit ponar	2-9-2024	N 52 27.777, E 04 37.993
134	Bottom	Petit ponar	2-9-2024	N 52 27.776, E 04 38.004
135	Bottom	Dredge sample	2-9-2024	N 52 27.777, E 04 37.993
IJMUIDEN SEAPORT (loc 6; Fig. 2)				
136-140	Floating Dock	SETL	5-3-2024	N 52 27.519, E 04 33.660*
141-146	Floating Dock	SETL	3-6-2024	N 52 27.519, E 04 33.660*
147-152	Floating Dock	SETL	2-9-2024	N 52 27.519, E 04 33.660*
153-158	Floating Dock	SETL	3-12-2024	N 52 27.519, E 04 33.660*
159	Floating Dock	Visual inspection	2-9-2024	N 52 27.549, E 04 33.622
160	Floating Dock	Scrape sample	3-6-2024	N 52 27.519, E 04 33.660
161	Floating Dock	Scrape sample	2-9-2024	N 52 27.543, E 04 33.599
162	Water collumn	GZP net	2-9-2024	N 52 27.538, E 04 33.558
163	Water collumn	GZP net	2-9-2024	N 52 27.543, E 04 33.586
164	Water collumn	GZP net	2-9-2024	N 52 27.549, E 04 33.633
165	Littoral zone dike	Visual inspection	2-9-2024	N 52 27.487, E 04 33.550
166	Bottom	Petit ponar	2-9-2024	N 52 27.538, E 04 33.558
167	Bottom	Petit ponar	2-9-2024	N 52 27.543, E 04 33.586
168	Bottom	Petit ponar	2-9-2024	N 52 27.549, E 04 33.633
169	Bottom	Dredge sample	2-9-2024	N 52 27.542, E 04 33.580

Sample	Habitat	Method	Date	GPS
ROTTERDAM, 8E PETROLEUMHAVEN (loc 8; Fig. 2)				
170-178	Floating Dock	SETL	21-3-2024	N 51 58.159, E 04 04.106*
179-189	Floating Dock	SETL	20-6-2024	N 51 58.159, E 04 04.106*
190-200	Floating Dock	SETL	3-9-2024	N 51 58.159, E 04 04.106*
201-211	Floating Dock	SETL	6-12-2024	N 51 58.159, E 04 04.106*
212	Floating Dock	Visual inspection	3-9-2024	N 51 58.157, E 04 04.095
213	Floating Dock	Scrape sample	20-6-2024	N 51 58.157, E 04 04.095
214	Floating Dock	Scrape sample	3-9-2024	N 51 58.157, E 04 04.095
215	Water collumn	GZP net	3-9-2024	N 51 58.162, E 04 04.116
216	Water collumn	GZP net	3-9-2024	N 51 58.159, E 04 04.106
217	Water collumn	GZP net	3-9-2024	N 51 58.157, E 04 04.097
218	Littoral zone dike	Visual inspection	3-9-2024	N 51 58.175, E 04 04.108
219	Bottom	Petit ponar	3-9-2024	N 51 58.162, E 04 04.116
220	Bottom	Petit ponar	3-9-2024	N 51 58.159, E 04 04.106
221	Bottom	Petit ponar	3-9-2024	N 51 58.157, E 04 04.097
222	Bottom	Dredge sample	3-9-2024	N 51 58.159, E 04 04.106
ROTTERDAM, BEERKANAAL (loc 9; Fig. 2)				
223	Jetty	Scrape sample	20-6-2024	N 51 57.705, E 04 00.876
224	Littoral zone dike	Visual inspection	20-6-2024	N 51 57.696, E 04 00.886
225	Bottom	Dredge sample	20-6-2024	N 51 57.705, E 04 00.877
ROTTERDAM, BENELUXHAVEN (loc 10; Fig. 2)				
226-236	Floating Dock	SETL	21-3-2024	N 51 57.170, E 04 07.515*
237-247	Floating Dock	SETL	20-6-2024	N 51 57.170, E 04 07.515*
248-257	Floating Dock	SETL	3-9-2024	N 51 57.170, E 04 07.515*
258-267	Floating Dock	SETL	6-12-2024	N 51 57.170, E 04 07.515*
268	Floating Dock	Visual inspection	3-9-2024	N 51 57.166, E 04 07.511
269	Floating Dock	Scrape sample	20-6-2024	N 51 57.166, E 04 07.511
270	Floating Dock	Scrape sample	3-9-2024	N 51 57.166, E 04 07.511
271	Water collumn	GZP net	3-9-2024	N 51 57.169, E 04 07.519
272	Water collumn	GZP net	3-9-2024	N 51 57.172, E 04 07.515
273	Water collumn	GZP net	3-9-2024	N 51 57.175, E 04 07.515
274	Littoral zone dike	Visual inspection	3-9-2024	N 51 57.181, E 04 07.502
275	Bottom	Petit ponar	3-9-2024	N 51 57.169, E 04 07.519
276	Bottom	Petit ponar	3-9-2024	N 51 57.167, E 04 07.510
277	Bottom	Petit ponar	3-9-2024	N 51 57.170, E 04 07.509
278	Bottom	Dredge sample	3-9-2024	N 51 57.167, E 04 07.510
HOMPELVOET (loc 11; Fig. 2)				
279-287	Floating Dock	SETL	12-3-2024	N 51 46.566, E 03 56.782*
288-298	Floating Dock	SETL	18-6-2024	N 51 46.566, E 03 56.782*
299-309	Floating Dock	SETL	11-9-2024	N 51 46.566, E 03 56.782*
310-320	Floating Dock	SETL	18-12-2024	N 51 46.566, E 03 56.782*

Sample	Habitat	Method	Date	GPS
BOMMENEDE (loc 12; Fig. 2)				
321-335	Floating Dock	SETL	12-3-2024	N 51 43.900, E 03 58.374*
336-348	Floating Dock	SETL	18-6-2024	N 51 43.900, E 03 58.374*
349-362	Floating Dock	SETL	11-9-2024	N 51 43.900, E 03 58.374*
363-375	Floating Dock	SETL	18-12-2024	N 51 43.900, E 03 58.374*
376	Floating Dock	Visual inspection	11-9-2024	N 51 43.892, E 03 58.374
377	Floating Dock	Scrape sample	18-6-2024	N 51 43.902, E 03 58.381
378	Floating Dock	Scrape sample	11-9-2024	N 51 43.892, E 03 58.374
379	Water collumn	GZP net	11-9-2024	N 51 43.892, E 03 58.374
380	Water collumn	GZP net	11-9-2024	N 51 43.901, E 03 58.379
381	Water collumn	GZP net	11-9-2024	N 51 43.909, E 03 58.382
382	Bottom	Petit ponar	11-9-2024	N 51 43.892, E 03 58.374
383	Bottom	Petit ponar	11-9-2024	N 51 43.901, E 03 58.379
384	Bottom	Petit ponar	11-9-2024	N 51 43.909, E 03 58.382
385	Bottom	Dredge sample	11-9-2024	N 51 43.907, E 03 58.380
HERKINGEN (loc 13; Fig. 2)				
386-387	Floating Dock	SETL	15-3-2024	N 51 42.470, E 04 05.188*
388-391	Floating Dock	SETL	15-3-2024	N 51 42.427, E 04 05.255*
392-397	Floating Dock	SETL	15-3-2024	N 51 42.484, E 04 05.153*
398-404	Floating Dock	SETL	15-3-2024	N 51 42.408, E 04 04.962*
405-408	Floating Dock	SETL	15-3-2024	N 51 42.411, E 04 05.121*
409-115	Floating Dock	SETL	4-6-2024	N 51 42.484, E 04 05.153*
416-422	Floating Dock	SETL	4-6-2024	N 51 42.408, E 04 04.962*
423-427	Floating Dock	SETL	4-6-2024	N 51 42.411, E 04 05.121*
428-435	Floating Dock	SETL	9-9-2024	N 51 42.484, E 04 05.153*
436-444	Floating Dock	SETL	9-9-2024	N 51 42.408, E 04 04.962*
445-451	Floating Dock	SETL	9-9-2024	N 51 42.411, E 04 05.121*
452-459	Floating Dock	SETL	10-12-2024	N 51 42.484, E 04 05.153*
460-468	Floating Dock	SETL	10-12-2024	N 51 42.408, E 04 04.962*
469-475	Floating Dock	SETL	10-12-2024	N 51 42.411, E 04 05.121*
COLIJNSPLAAT (loc 14; Fig. 2)				
476-485	Floating Dock	SETL	19-3-2024	N 51 36.171, E 03 50.988*
486-494	Floating Dock	SETL	11-6-2024	N 51 36.171, E 03 50.988*
495-505	Floating Dock	SETL	5-9-2024	N 51 36.171, E 03 50.988*
506-516	Floating Dock	SETL	10-12-2024	N 51 36.171, E 03 50.988*
517	Floating Dock	Visual inspection	5-9-2024	N 51 36.180, E 03 50.980
518	Floating Dock	Scrape sample	11-6-2024	N 51 36.167, E 03 50.977
519	Floating Dock	Scrape sample	5-9-2024	N 51 36.167, E 03 50.977
520	Water collumn	GZP net	5-9-2024	N 51 36.167, E 03 50.977
521	Water collumn	GZP net	5-9-2024	N 51 36.177, E 03 50.979
522	Water collumn	GZP net	5-9-2024	N 51 36.162, E 03 50.970
523	Littoral zone dike	Visual inspection	5-9-2024	N 51 36.147, E 03 50.978
524	Bottom	Petit ponar	5-9-2024	N 51 36.167, E 03 50.977
525	Bottom	Petit ponar	5-9-2024	N 51 36.177, E 03 50.979
526	Bottom	Petit ponar	5-9-2024	N 51 36.162, E 03 50.970
527	Bottom	Dredge sample	5-9-2024	N 51 36.171, E 03 50.974

Sample	Habitat	Method	Date	GPS
KORTEGENE (loc 15; Fig. 2)				
528-513	Floating Dock	SETL	19-3-2024	N 51 33.121, E 03 48.662*
532-535	Floating Dock	SETL	11-6-2024	N 51 33.121, E 03 48.662*
536-540	Floating Dock	SETL	5-9-2024	N 51 33.121, E 03 48.662*
541-545	Floating Dock	SETL	10-12-2024	N 51 33.121, E 03 48.662*
546	Floating Dock	Visual inspection	5-9-2024	N 51 33.128, E 03 48.669
547	Floating Dock	Scrape sample	11-6-2024	N 51 33.121, E 03 48.662
548	Floating Dock	Scrape sample	5-9-2024	N 51 33.121, E 03 48.662
549	Water collumn	GZP net	5-9-2024	N 51 33.121, E 03 48.662
550	Water collumn	GZP net	5-9-2024	N 51 33.127, E 03 48.661
551	Water collumn	GZP net	5-9-2024	N 51 33.125, E 03 48.680
552	Bottom	Petit ponar	5-9-2024	N 51 33.121, E 03 48.662
553	Bottom	Petit ponar	5-9-2024	N 51 33.127, E 03 48.661
554	Bottom	Petit ponar	5-9-2024	N 51 33.125, E 03 48.680
555	Bottom	Dredge sample	5-9-2024	N 51 33.117, E 03 48.650
VLISSINGEN (loc 16; Fig. 2)				
556-565	Floating Dock	SETL	19-3-2024	N 51 27.633, E 03 40.399*
566	Floating Dock	SETL	11-6-2024	N 51 27.633, E 03 40.399*
567-575	Floating Dock	SETL	24-9-2024	N 51 27.633, E 03 40.399*
576-585	Floating Dock	SETL	5-12-2024	N 51 27.633, E 03 40.399*
586	Floating Dock	Visual inspection	24-9-2024	N 51 27.639, E 03 40.389
587	Floating Dock	Scrape sample	11-6-2024	N 51 27.633, E 03 40.399
588	Floating Dock	Scrape sample	24-9-2024	N 51 27.639, E 03 40.389
589	Water collumn	GZP net	24-9-2024	N 51 27.635, E 03 40.396
590	Water collumn	GZP net	24-9-2024	N 51 27.643, E 03 40.389
591	Water collumn	GZP net	24-9-2024	N 51 27.651, E 03 40.382
592	Bottom	Petit ponar	24-9-2024	N 51 27.635, E 03 40.396
593	Bottom	Petit ponar	24-9-2024	N 51 27.643, E 03 40.389
594	Bottom	Petit ponar	24-9-2024	N 51 27.651, E 03 40.382
595	Bottom	Dredge sample	24-9-2024	N 51 27.637, E 03 40.395
KALOOT (loc 17; Fig. 2)				
596	Littoral zone dike	Visual inspection	24-9-2024	N 51 25.900, E 03 42.616
597	Littoral zone dike	Visual inspection	19-8-2024	N 51 25.904, E 03 42.388
598	Littoral zone dike	Visual inspection	19-8-2024	N 51 25.903, E 03 42.388
599	Littoral zone dike	Visual inspection	19-8-2024	N 51 25.889, E 03 42.563
600	Wall cooling-water outlet	Visual inspection	19-8-2024	N 51 25.898, E 03 42.747
HOEDEKENSKERKE (loc 18; Fig. 2)				
601-604	Floating Dock	SETL	3-3-2024	N 51 25.197, E 03 54.892*
605-608	Floating Dock	SETL	11-6-2024	N 51 25.197, E 03 54.892*
609-612	Floating Dock	SETL	24-9-2024	N 51 25.197, E 03 54.892*
613-616	Floating Dock	SETL	5-12-2024	N 51 25.197, E 03 54.892*
617	Bottom	Dredge sample	24-9-2024	N 51 25.197, E 03 54.892

Sample	Habitat	Method	Date	GPS
TERNEUZEN (loc 19; Fig. 2)				
618	Littoral zone dike	Visual inspection	8-12-2024	N 51 21.050, E 03 46.735
619	Littoral zone dike	Visual inspection	8-12-2024	N 51 21.012, E 03 46.746
620	Littoral zone dike	Visual inspection	8-12-2024	N 51 21.012, E 03 46.835
621	Littoral zone dike	Visual inspection	8-12-2024	N 51 21.009, E 03 46.880
BRESKENS (loc 20; Fig. 2)				
622-640	Floating Dock	SETL	3-3-2024	N 51 23.741, E 03 34.250*
641-659	Floating Dock	SETL	27-6-2024	N 51 23.741, E 03 34.250*
660-677	Floating Dock	SETL	19-9-2024	N 51 23.741, E 03 34.250*
678-695	Floating Dock	SETL	8-12-2024	N 51 23.741, E 03 34.250*
696	Floating Dock	Visual inspection	19-9-2024	N 51 23.744, E 03 34.246
697	Floating Dock	Visual inspection	19-9-2024	N 51 23.738, E 03 34.254
698	Floating Dock	Scrape sample	27-6-2024	N 51 23.745, E 03 34.218
699	Floating Dock	Scrape sample	19-9-2024	N 51 23.744, E 03 34.246
700	Water collumn	GZP net	19-9-2024	N 51 23.747, E 03 34.236
701	Water collumn	GZP net	19-9-2024	N 51 23.740, E 03 34.253
702	Water collumn	GZP net	19-9-2024	N 51 23.731, E 03 34.267
703	Littoral zone dike	Visual inspection	19-9-2024	N 51 23.728, E 03 34.229
704	Bottom	Petit ponar	19-9-2024	N 51 23.747, E 03 34.236
705	Bottom	Petit ponar	19-9-2024	N 51 23.740, E 03 34.253
706	Bottom	Petit ponar	19-9-2024	N 51 23.731, E 03 34.267
707	Bottom	Dredge sample	19-9-2024	N 51 23.747, E 03 34.236
BUOYS ON NORTH SEA (locs 21-25; Fig. 2)				
747	Buoy NHR	Scrape sample	4-12-2024	N 52 00.051, E 02 51.062
748	Buoy ODAS-B	Scrape sample	4-12-2024	N 51 54.900, E 03 42.120
749	Buoy Ewo E	Scrape sample	30-7-2024	N 52 00.552, E 03 44.082
750	Buoy MN4	Scrape sample	10-7-2024	N 52 22.680, E 03 47.730
751	Buoy HZ PA4	Scrape sample	10-7-2024	N 52 20.437, E 03 59.988

Appendix II

List of species found in 2024, the location numbers were they were recorded, are specified in Appendix I.

Species	Location
ALGAE	
Agardhiella subulata	376-378, 538-539, 542, 544-545, 547-548, 555
Aglaothamnion halliae	105, 159, 161, 214
Aglaothamnion pseudobyssoides	176-177, 198, 201, 205-207, 209-210, 230-232, 234, 241-242, 248-249, 251-253, 258-259, 261-264, 266
Antithamnion sparsum	378
Antithamnionella spirographidis	518-519, 527
Ascophyllum nodosum	3, 47-48, 53, 61, 218, 523, 587, 697-698, 703
Blidingia marginata	218, 274, 587
Blidingia minima	58-62, 167, 223-224, 618
Bonnemaisonia hamifera	696, 698-699
Bryopsis plumosa	48, 100, 104, 159-161, 212-214, 223, 225, 229-233, 254, 269, 296, 300, 306, 309, 329, 350, 363, 365-366, 373, 376-378, 388-390, 402-404, 452, 461, 467, 469, 474, 481, 484, 491, 493-494, 501, 504, 508, 517-519, 546-548, 586-588, 595, 598, 611, 618-619, 696-697, 699
Callithamnion corymbosum	47, 48, 111, 160-161, 270, 518
Carradoriella denudata	519
Carradoriella elongata	518
Caulacanthus okamurae	212, 214, 218, 223, 225, 274, 523, 552, 596-598, 600
Ceramium cimbricum	48, 377
Ceramium secundatum	269, 396-397, 411-412, 423-425, 427, 446, 469-470, 474
Ceramium sungminbooi	46, 48-49, 51, 104, 229, 230-231, 234-235, 240, 242, 244, 248, 250, 252-254, 256-257, 269, 278, 376-378, 381, 518-519, 527, 547-548, 586-588, 595, 599, 696, 699
Ceramium tenuicorne	49, 104, 111, 141-142, 147-148, 153, 159-161, 269-270, 396-397, 402, 404-405, 408, 411-412, 415-416, 420-425, 427, 446, 453, 460-461, 465, 467-470, 474, 519
Ceramium virgatum	494, 507-508, 514, 516, 586, 588
Chaetomorpha aerea	481-485, 493, 502, 513-514, 516, 555
Chaetomorpha linum	295-296, 301-303, 307, 312-313, 315-316, 320, 380, 381, 402, 404, 407-408, 416, 422, 425, 428, 433, 436, 438-441, 444, 446, 448-450, 460, 546-548
Chondrus crispus	212-214, 523, 697-699
Cladophora albida	328-329, 366, 376-378, 698
Cladophora glomerata	121, 127-128, 377
Cladophora laetevirens	46-51
Cladophora vagabunda	153-156, 158, 160, 223, 268, 270, 698
Codium fragile	548
Dasysiphonia japonica	21-23, 25, 27, 31-32, 35-40, 44-45, 143, 146, 148, 150, 152-158, 160, 169, 176-178, 187-189, 198, 201, 205-207, 209-210, 213, 283-285, 288, 289-296, 299, 301-303, 305-308, 310-311, 313-314, 316-321, 325, 328-329, 332, 343, 349-352, 358, 360-364, 366, 369, 371, 373, 377, 383-384, 421, 455, 479, 481-485, 491-494, 496-497, 505, 509, 513, 515-516, 546-547, 587, 612, 618, 696-699
Ectocarpus siliculosus	529, 530
Fucus spiralis	165
Fucus vesiculosus	3, 47, 58-59, 109, 159, 160, 165, 213, 218, 223-224, 269, 274, 519, 523, 586, 588, 596, 618-619, 697
Gaillona rosea	104, 109, 518
Gelidium vagum	295, 377
Gracilaria vermiculophylla	618-620
Gracilariopsis longissima	553
Grateloupia turuturu	212-214
Griffithsia corallinoides	501
Leptosiphonia brodiei	159, 161, 518
Melanothamnus harveyi	517, 519, 527, 586-588

Species	Location
ALGAE	
Phymatolithon squamulosum	618, 620
Polysiphonia stricta	538-539, 542, 544-545, 698
Porphyra dioica	597-598
Porphyra purpurea	269
Porphyra umbilicalis	596, 598
Pterothamnion plumula	481, 483, 485, 507, 516, 518-519, 587, 697
Pyropia collinsii	518
Pyropia elongata	519
Pyropia suborbiculata	223, 224
Sargassum muticum	269, 286, 289-290, 292, 294-295, 307, 319, 377, 547
Ulva australis	159-161, 212-214, 218, 268-271, 378, 546-548, 554, 555, 599-600, 696, 697, 699, 703
Ulva californica	618-619
Ulva compressa	3, 109, 165, 213, 223, 269, 518, 523, 587, 596, 598
Ulva intestinalis	518
Ulva lactuca	46-49, 109, 112, 223-224, 517-519, 523-524, 587, 596, 598, 698
Ulva linza	48, 53, 59-62, 64, 127, 135, 212, 214, 586, 588, 594-595
Ulva meridionalis	600
Ulva prolifera	104, 698
Ulva cf. *shanxiensis*	377
Undaria pinnatifida	494, 518, 548, 698-699
Vertebrata fucoides	518, 587-588, 595, 612, 698
ANNELIDA	
Alitta succinea	48-49, 53, 61, 64, 104-105, 127, 132, 160, 212-214, 270
Amphitrite figulus	377, 587, 600
Arenicola marina	618
Bispira polyomma	333, 335, 340, 343, 346, 348, 352-353, 355-357, 359, 361, 366-370, 372, 374, 376, 378, 481-483, 485, 491-494, 502-504, 513-514, 547, 625, 628, 632, 635, 637, 647, 650-651, 654-656, 664, 670, 672-673, 690, 692
Eulalia viridis	48
Eunereis longissima	709
Ficopomatus cf. enigmaticus	1, 3-4, 59-62, 64, 87, 94-97, 99, 103, 105, 113-115, 122-128, 132-134, 139-140, 145-150, 152-153, 155-161, 165-166, 169, 177-178, 190-192, 198-199, 202, 204, 209-210, 213, 221-222, 229, 234-236, 245, 247-250, 255, 386-391, 395-475, 518-519, 527-528, 536-539, 540, 544-545, 547, 554, 559-562, 564, 567-568, 570-582, 587, 609, 611, 618, 620
Harmothoe extenuata	711
Harmothoe imbricata	48-49, 104, 377-378, 382, 518-519, 547-548
Hediste diversicolor	161, 270
Heteromastus filiformis	1
Hydroides ezoensis	151, 199, 209, 212-214, 220-222, 225, 235, 260, 268-270, 277, 283-284, 295, 299, 302-308, 310-313, 315-319, 349-351, 353-354, 357, 359, 360, 362-365, 369, 371, 373, 375, 377-378, 474, 484, 547, 560-567, 569, 571-572, 574-576, 578-582, 587-588, 598, 600, 660
Lepidonotus squamatus	48, 105, 378, 712
Neodexiospira brasiliensis	11-12, 109, 139-156, 158, 160-161, 165, 169, 177-178, 190-192, 201, 203, 213, 220-222, 226, 229, 234-236, 239, 258-260, 269, 277, 282-284, 286-291, 294, 296-297, 302, 304-306, 308, 310-314, 316, 318, 326, 328, 333, 340, 349, 350-351, 360, 363-365, 369, 373, 376-378, 398, 401-403, 405-407, 409-412, 414, 417-421, 423-424, 426-431, 434, 437-442, 446, 448, 451-453, 455-457, 459, 461-462, 464-466, 469-470, 473-475, 484, 506-508, 510-511, 516, 518-519, 523, 537-538, 541-545, 547-548, 553, 555, 559-565, 568-569, 572, 574, 576, 583-585, 587-588, 605, 607, 609-610, 612-616, 618, 625-628, 630-636, 638, 641-643, 646-647, 650-653, 657, 659-662, 664-668, 670-671, 673, 676, 678-680, 682, 684-685, 687, 689-691, 693, 696-699
Phyllodoce laminosa	711

Species	Location
ANNELIDA	
Platynereis dumerilii	518, 587
Sabella pavonina	354, 377, 479-484, 491-492, 501-503, 505, 511-513, 515-516, 528, 532, 539, 544, 547
Serpula vermicularis	560-562, 565, 575-576, 579, 581, 641-642, 651, 653, 655, 676
Spirobranchus lamarcki	160, 367, 561, 660
Spirobranchus triqueter	53, 94-97, 103, 105, 178, 210, 235, 283-285, 294, 302, 304-306, 311, 313-314, 316-318, 325-326, 330, 340, 349, 353, 358, 363, 365, 367-368, 370, 371, 374, 377, 382-383, 430, 458, 479, 483, 485, 487-488, 495, 498, 501, 504, 507, 509-511, 515-516, 518-519, 540, 561, 564-568, 570-572, 574, 576, 583, 585, 587-588, 626, 630-631, 633, 635, 641-643, 658, 660, 662, 671, 677-678, 682, 690-691, 694, 708, 710-711
Spirorbis cf. spirorbis	630, 636, 643, 649, 657, 661-662, 665, 668, 676, 685, 693
ASCIDIACEA	
Aplidium glabrum	48, 281-283, 285, 287, 294, 298, 301, 303, 306, 309-310, 314-315, 318, 328, 331, 335, 342-345, 348, 353-355, 357-358, 361-362, 366, 368, 370-371, 373, 375, 377, 430, 479-485, 489-494, 498, 500-502, 504-505, 509-512, 514, 518-519, 532, 540, 546-548, 562-633, 647, 649, 653, 656, 664, 670, 675-676, 698
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