OSPAR COMMISSION

Non-Indigenous Species Thematic Assessment

OSPAR

QUALITY STATUS REPORT 2023

2023

OSPAR's Quality Status Report 2023

Non-Indigenous Species Thematic Assessment

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l´Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d´Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l´Allemagne, la Belgique, le Danemark, l´Espagne, la Finlande, la France, l´Irlande, l´Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume- Uni de Grande Bretagne et d´Irlande du Nord, la Suède, la Suisse et l´Union européenne

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Executive Summary

Non-indigenous species (NIS) may cause unpredictable and irreversible changes to marine ecosystems, such as predation of or competition with indigenous species, modification of habitats, and trophic impacts. A variety of economic or human health impacts are possible through, for example, fouling, harmful non-indigenous algal blooms or damage to structures. Of the known pathways, shipping and mariculture are responsible for most introductions into the OSPAR Maritime Area.

The results of this assessment indicate that in the last assessment period (2015-2020) there was a statistically significant reduction in introductions compared with the first assessment period (2003-2008). This indicates that the range of management measures adopted since QSR 2010 might be having a positive effect. However, there are uncertainties around monitoring effort and the timing of the data reporting for the assessment, suggesting a higher rate of introductions than was assessed for this period.

It is therefore important for OSPAR not to become complacent. With ever increasing global shipping, and the effects of climate change warming the waters of the North-East Atlantic, there is a continued risk of new non-indigenous species being translocated and establishing themselves as our climate changes. Therefore, continued and strengthened monitoring are required.

Q1. Identify the problems? Are they the same in all OSPAR Regions?

QSR 2010 provided evidence of 160 non-indigenous species in the OSPAR Maritime Area, of which 30 were identified as having an adverse impact on ecosystems or human health.

The growing demand for goods, energy and food means that the activities which provide pathways for non-indigenous species are likely to increase in the future. The introduction and translocation of non-indigenous species can cause declines in the abundance of native species, increase parasites and pathogens, negatively affect the food web, and impact on the provision of ecosystem services. Climate change, primarily increases in ocean temperature, may facilitate the introduction and establishment of new NIS as conditions become more suitable for them, as well as potential increases in global maritime trade.

Over the recent assessment period (2015-2020) the rate of introductions appears to have fallen in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast, with much lower rates in the Celtic Seas. This suggests that the measures adopted are having a positive effect, although several new non-indigenous species were introduced in the OSPAR Maritime Area in the assessment period. However, there are uncertainties around the monitoring effort and the timing of the data reporting for assessments, potentially leading to a higher rate of introductions than was assessed for this period. Continued effort is required to reduce or prevent the introduction of new non-indigenous species.

Q2. What has been done?

Preventing the introduction of NIS is currently considered the only feasible management option for the marine environment. This is because there are limited practical and cost-effective means available for eradicating or controlling NIS in the marine environment without harming the local ecosystem.

OSPAR has taken action to reduce the introduction of NIS from ships' ballast water by developing general guidance on voluntary ballast water exchange (Agreements 2010-07, 2014-11) and by establishing a joint task group with HELCOM to manage non-indigenous species in relation to ballast water management exemptions and to manage ballast water and biofouling (JTG BALLAST & Biofouling). This has resulted in the adoption of the Joint Harmonised Procedure […] on the granting of exemptions under the International Convention for the Control and Management of Ship's Ballast Water and Sediments (Agreement 2020-01) by both OSPAR and HELCOM.

The International Maritime Organization (IMO) has adopted a range of measures in relation to ballast water and biofouling aimed at reducing the risk from the transfer of non-indigenous species.

OSPAR has taken action to reduce the introduction of NIS from ships' ballast water © Shutterstock

Q3. Did it work?

The assessment of the Common Indicator "Trends in New Records of Non-indigenous Species Introduced by Human Activities" showed an overall reduction in the rate of introduction of non-indigenous species, which indicates that the applied threshold (a decreasing trend) is generally being achieved in the assessed regions of the Greater North Sea, Celtic Sea and Bay of Biscay and Iberian Coast. Thus, while the annual rate of new non-indigenous species introduction remains high, the indication of a decreasing trend towards the most recent assessment period might suggest that the current measures have the effect of reducing the introduction and spread of non-indigenous species in the OSPAR Maritime Area. However, these findings must be used with caution due to publication lag and uncertainties in monitoring effort. Since the 2010 QSR, there has been significant progress made in the responses to address non-indigenous species; nevertheless, the introductions continue, and this issue will require continued effort to prevent further introductions.

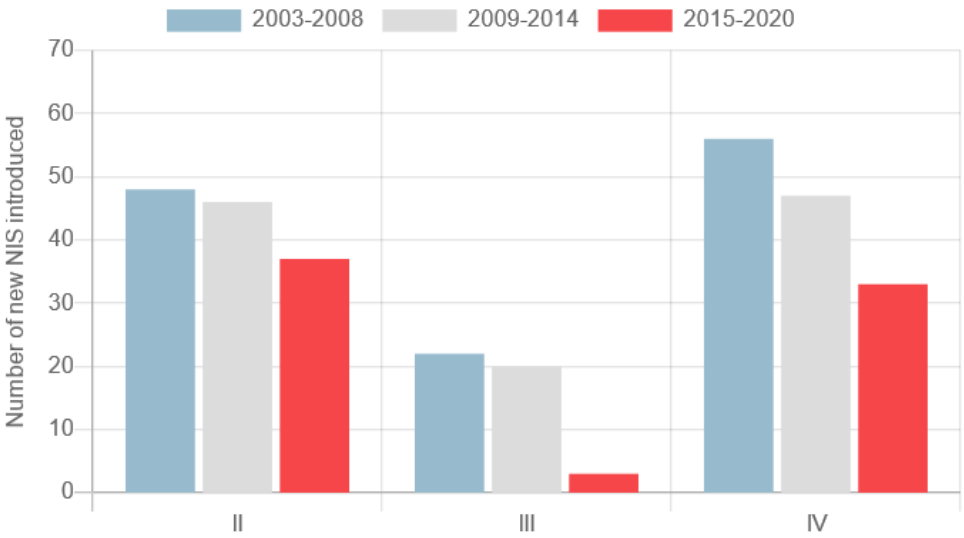

Figure 1: The total number of new NIS records in each Region and period assessed

Q4. How does this field affect the overall quality status?

The non-indigenous species objective in NEAES 2010-2020 was to "endeavour to limit the introduction of non-indigenous species by human activities to levels that do not adversely alter ecosystems". The evidence presented in the assessment suggests that progress has been made in terms of achieving this. However, it is also evident that the threat to marine ecosystems from non-indigenous species will remain, given the potential impact of the NIS already introduced and the increasing pressure from several activities known to be pathways for new introductions.

Q5. What do we do next?

NEAES 2030 Operational Objective S7.O2 states that by 2025, OSPAR will develop a coordinated management approach to ensure the number of non-indigenous species introduced by human activity is minimised and, where possible, reduced to zero.

Continued implementation of the joint response by OSPAR and HELCOM, the EU Marine Strategy Framework Directive (MSFD), the EU Invasive Alien Species Regulation (1143/2014) and the IMO Ballast Water Management Convention should ensure that some of the identified gaps in monitoring are addressed and should strengthen monitoring so that bias and data gaps are reduced. The potential for developing new monitoring approaches such as eDNA should be explored.

Other potential responses have been identified, including the strengthening of national biosecurity plans, consideration of NIS in relation to ecosystem restoration, addressing the issue of the potential for offshore renewables infrastructure to act as a vector for the spread of NIS, and linkage to S7.O2.

D - Drivers

Social and economic drivers for activities affecting non-indigenous species

Growing global populations and the associated need for food and energy continue to increase the risk of the input and spread of non-indigenous species, especially through shipping, release via aquaculture, and marine littering. In addition, alterations in marine environmental conditions due to climate change will also affect the introduction and spread of NIS.

All social and economic drivers have the potential to influence the input and spread of non-indigenous species. Energy security, food security, climate change and the acquisition of resources and production of goods underpin political and economic stability.

Growing global populations increase the demand for food, and aquaculture will help to meet this growing demand. Aquaculture is a key pathway for the introduction and spread of non-indigenous species. In particular, non-indigenous species can contaminate aquaculture stock and be introduced into new locations as the stock moves about. Although the EU has regulated to prevent contamination by NIS between countries (Council Regulation (EC) 708/2007 of 11 June 2007 concerning the use of alien and locally absent species in aquaculture), NIS may still be introduced and spread within an EU country, through cultivation. The introduction of the hard substrate associated with aquaculture into the marine environment can provide the opportunity for colonisation by marine organisms. Moreover, aquaculture can also transfer NIS in “living wrappers” as part of the trade in aquaculture goods.

Aquaculture is a key pathway for the introduction and spread of non-indigenous species. © Shutterstock

Growing populations increase societies' demand for energy. The introduction of the infrastructure associated with renewable and non-renewable energy into the marine environment (e.g. offshore wind turbines, oil and gas platforms) provides hard substrate suitable for colonisation by marine organisms. Such structures may provide stepping-stones for the accelerated spread of NIS.

The movement of cargo, fishing, military and recreational vessels at sea is a major pathway for NIS introduction. As maritime traffic continues to increase, it may result in even more substantial transport of marine organisms between locations (e.g. in the ballast water or attached to ship hulls) and the introduction of novel NIS. The marine-built structures associated with increasing shipping and leisure boating, such as ports and marinas, offer suitable habitats for many NIS and are recognized introduction hotspots.

The increased demand for housing and utilities, for materials and their processing and for the manufacturing and processing of goods can introduce pollutants to the marine environment which alter habitat suitability for marine organisms, including NIS, as these are often opportunistic species (Piola *et al.*, 2008). Associated with this driver is the thermal pollution related to power plants. Here, the localised temperature changes associated with power station outlets (e.g. discharge of coolant water at increased temperature) may alter habitat suitability in favour of heat-tolerant NIS.

Marine litter is another driver that alters habitat and favours new introductions of NIS (Miralles *et al.*, 2018). While tourism and recreation contribute to societal health and wellbeing, their associated infrastructure may introduce substrate for colonisation by marine organisms.

Recreational activities including sailing and angling, and the collection of marine organisms for other purposes supporting societal health and wellbeing (e.g. medicinal, ornamental) can result in the translocation of marine organisms.

Policy responses to manage human activities need to consider all these driving forces to meet society's needs while reducing the risks of the introduction and spread of non-indigenous species, and to facilitate societal change.

A – Activities

Human activities associated with non-indigenous species

The drivers are related to a series of human activities which may affect the rate of NIS introduction, and eventually their impact on marine biodiversity. The human activities addressed in this assessment are: 1) Aggregates extraction; 2) Agriculture; 3) Aquaculture; 4) Fisheries; 5) Oil/gas production (structures or pipelines); 6) Renewable energy structures; 7) Shipping; 8) Recreational boating, angling; and 9) Climate change (global change) as an indirect consequence of human activity. Human activities associated with these nine areas are distributed widely across the North-East Atlantic, but the intensity of the activities and of the pressures they impose on the marine environment and NIS vary greatly between OSPAR Regions and sub-divisions. Some sea areas are affected by multiple activities; in others, only a few may be significant. Overall, there is an expectation of higher activity towards 2030 for Aquaculture, Renewable energy and Tourism, and of increasing impacts from Climate change. (see Table A.1 of the Human Activity Thematic Assessment)

Below is a short description of the most important human activities identified as relevant to the introduction and spread of non-indigenous species:

Extraction of oil and gas, including infrastructure [Extraction of non-living resources]:
The need for energy security has meant that oil and gas development has remained constant in most areas, although there are decreases in some (see:Offshore Industry Thematic Assessment). The addition of infrastructure associated with oil and gas extraction to the marine environment can introduce hard substrate for colonisation by marine organisms, including non-indigenous species. The shipping of oil and gas can also translocate non-indigenous species (see Transport - Shipping below).

Extraction of minerals [Extraction of non-living resources]:
The extraction of sand and gravel for use in construction projects results in habitat changes, which may then be conducive to NIS settlement. (See: Extraction of Non-Living Resources Feeder Report)

Renewable energy generation (wind, wave and tidal power), including infrastructure [Production of energy]:
The addition of infrastructure associated with renewable energy generation to the marine environment can introduce hard substrate which provides stepping-stones for accelerating colonisation by marine organisms, including non-indigenous species. (See: Offshore Renewable Energy Generation Feeder Report).

Marine aquaculture including infrastructure (and potentially freshwater aquaculture) [Cultivation of living resources]:
Non-indigenous species can also be cultivated, and the infrastructure associated with such aquaculture can introduce substrate into the marine environment for colonisation by marine organisms, including non-indigenous species. NIS escapees from aquaculture may also be sources of spread. (See: Aquaculture Feeder Report).

Tourism and leisure infrastructure [Tourism and leisure]:
The addition of infrastructure associated with tourism and leisure to the marine environment can introduce substrate for colonisation by marine organisms, including non-indigenous species. Where equipment is moved between sites (vessels, trailers, storage containers) and not properly cleaned, there is the potential to translocate NIS. Marina and port construction is increasing (see: Recreation and Tourism Feeder Report)

Tourism and leisure activities [Tourism and leisure] and Education and Research:
Marine organisms may be transported between locations by the movement of leisure and passenger boats, equipment, and people (e.g., by (un)intentional release of unused fresh bait from recreational fishing; transfer on clothing), which can include non-indigenous species. Trends over the last decade show incremental increases in tourism and recreation activities in all OSPAR Regions. (See: Recreation and Tourism Feeder Report).

Transport – shipping [Transport]:
Shipping can transport marine organisms between locations, for example in ballast water or attached to ship hulls; these can include non-indigenous species. Over the last decade, trends in the gross weight of goods handled in North-East Atlantic ports and in passenger numbers have shown little change, but future increases are anticipated. (See: Shipping and Ports Feeder Report).

Climate change: Numerous drivers and activities (e.g., burning of fossil fuels, agriculture, deforestation) contribute to climate change, together with associated pressures linked to the distribution and abundance of non-indigenous species.

P – Pressures

Pressures associated with non-indigenous species

The assessment of the Trends in New Records of Non-Indigenous Species Common Indicator demonstrates an overall reduction in their rate of introduction (trend). The pressure from new arrivals of NIS on marine biodiversity state is generally decreasing for Greater North Sea (Region II), Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV). No assessment was made for Arctic Waters (Region I) and Wider Atlantic (Region V). For Regions II, III and IV there was a statistically significant decrease in introduction rates over time, in particular between period 1 (2003–2008) and period 3 (2015–2020), and especially for Region II (Celtic Sea), for which there were only very few new NIS recordings (**Figure P.1**). Overall, this assessment is associated with high confidence where sources of information are concerned. However, there is uncertainty about the monitoring effort and the publication time lag. Thus, while the rate of new NIS introduction is high (range 0,5 – 9,3 new NIS per year), the provided data indicate a downward trend towards the most recent assessment period, which might be the effect of the current measures to reduce the introduction and spread of NIS in the OSPAR Maritime Area. This conclusion should, however, be treated with great caution owing to the lack of a harmonized NIS monitoring programme across OSPAR Regions.

	Arctic Waters (Region I)	Greater North Sea (Region II)	Celtic Seas (Region III)	Bay of Biscay and Iberian Coast (Region IV)	Wider Atlantic (Region V)
Pressure	N/A	Decreasing trend in introduction of new NIS	Decreasing trend in introduction of new NIS	Decreasing trend in introduction of new NIS	N/A
	N/A	Few new NIS	Very few new NIS	Few new NIS	N/A
Confidence in trends	N/A	Moderate	Moderate	Moderate	N/A
Confidence in data	N/A	High	High	High	N/A

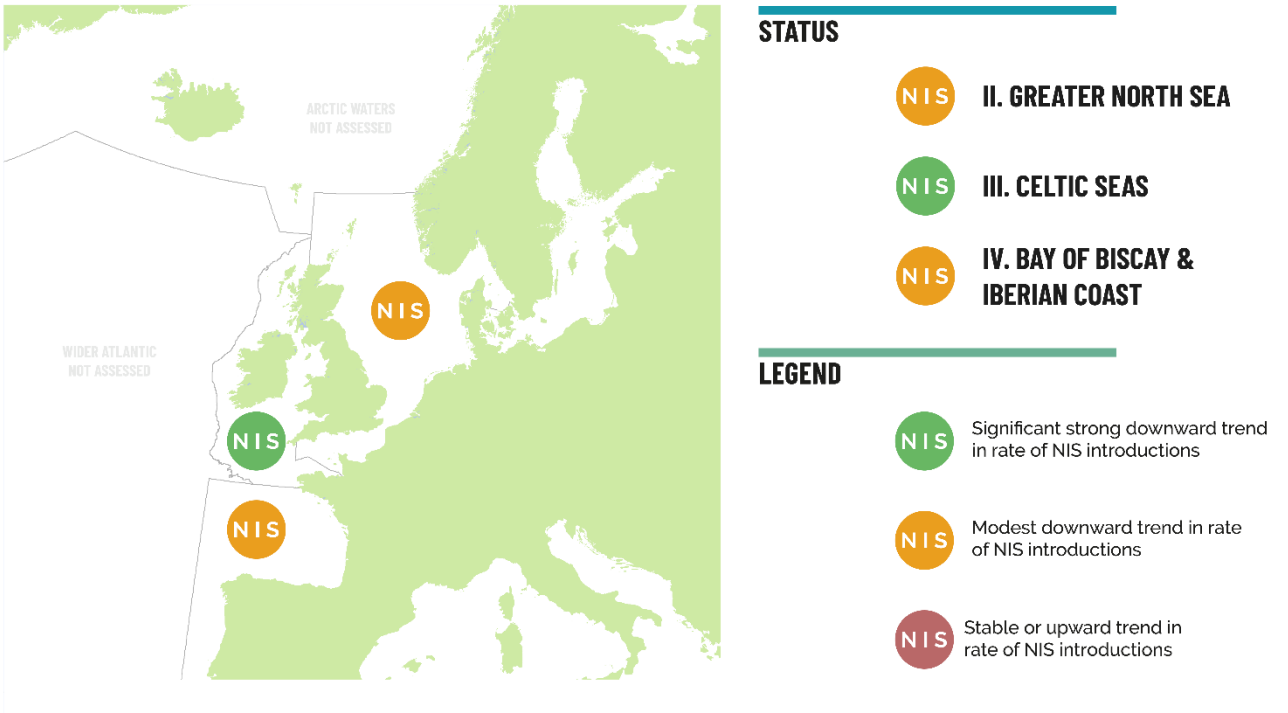

Figure P.1: Graphical summary of the pressure associated with non-indigenous species (NIS) rate of introduction observed in the data used in the QSR 2023 thematic assessment

The following text gives a detailed description of the OSPAR assessment of trends in new records of NIS introduced by human activities.

Despite the overall decreasing trends, several new NIS were introduced to each OSPAR Region during the latest assessment period. This shows that continued effort is required in order to reduce and prevent new NIS introductions. It should also be noted that there is substantial uncertainty as to whether the observed decline is due to an actual reduction in introductions or to a change in the monitoring effort, which it was not possible to account for. Also, the current assessment is potentially biased owing to a delay in the reporting of new NIS in the most recent years and to gaps in monitoring in general (Tsiamis *et al.*, 2019, 2021). These conditions weaken the interpretation of decreasing trends, which should be investigated further in future assessments.

Newly introduced NIS are extremely difficult to detect. The assessment of new NIS is therefore ideally based on efficient and standardized monitoring approaches which reduce potential bias among Contracting Parties arising from differences in applied methodologies, as these may affect the quality and quantity of collected NIS data. Such harmonisation is necessary in order to enhance the quality of future regional assessments of trends in new NIS arrivals (see: Trends in New Records of Non-Indigenous Species Common Indicator). To optimise the monitoring effort and reduce costs, the implementation of a harmonised monitoring programme should apply a cost-efficient and risk-based approach, with the emphasis on high-risk areas such as harbours (from commercial ports to marinas) and marine aquaculture sites. The existing monitoring may need to be complemented and supplemented with efficient new techniques which reflect the importance of adapting sampling effort to regional needs and current data gaps. For this purpose, efficient new

technologies such as those based on DNA studies (e.g., metabarcoding) or deep-learning techniques (e.g. image analyses) may be useful. Although monitoring per se does not reduce the risk or rate of new NIS introductions, early detection in risk areas and up-to-date information on NIS introductions and spread are essential in order to improve the future assessment and management of NIS spread and NIS impact. Indeed, it is well documented that cost-efficient management needs to be implemented at the start of the introduction process. Furthermore, cost-efficient monitoring is important for assessing the effectiveness of the NIS management efforts aimed at reducing their impact. These considerations relate primarily to the Ballast Water Convention and the International Convention on the Control of Harmful Anti-fouling Systems on Ships, both IMO instruments.

There are considerable differences in rates of introduction between Regions and Contracting Parties, with lower rates in Celtic Seas (Region III) indicated by the available NIS observations (**Figure P.1**). As the NIS monitoring effort (e.g., number of samples taken per year) for each Contracting Party is not known, it is possible that the observed trends in new NIS introductions partly depend on variation in monitoring activity. It is also not possible to determine the reasons for the observed differences between Contracting Parties. Two factors in particular may explain the observed discrepancies: there was no control for the length of the coast that was monitored and none for the type of habitats that were surveyed. Part of the explanation might relate to the number of high-risk areas that were surveyed.

Regarding the effects of responses (management), it is of interest to identify the most important pathways of NIS introductions. According to the records provided by 11 Contracting Parties, the pathways of 56% of the species remain uncertain/unknown. Many NIS may be introduced through multiple pathways and from multiple sources, making it difficult to identify a specific one. This could partly explain the large unknown group. Of the known pathways, introduction via ships hull fouling (14%) or ballast water (13%) are the most important, followed by aquaculture/mariculture and associated epibionts (12%). Natural spread only accounted for 5% of NIS introductions, but as such spread may result from a combination of natural dispersal and human-mediated dispersal, it could be argued that this vector should not be specified. The remaining pathways (1,6%) relate to game fishing, intentional release, bait escape and nursery material. Given the absence of a standardised method offering quantifiable quality assessment for determining pathways of introduction, it is currently very difficult to assess their relative importance.

S - State

Non-indigenous species impact the state of biodiversity

The pressures from human activities collectively contribute to the introduction and translocation of NIS in the North-East Atlantic, which can impact the state of Atlantic biodiversity in the following ways:

1. NIS outcompeting and preying on native species, resulting in declines in the latter's abundance;
2. Introduction of parasites and pathogens;
3. NIS changing ecosystem functioning, e.g., food web structure changes;
4. Changes in species assemblages and biotic homogenisation;
5. NIS changing the provision of ecosystem services.

The current assessment has not quantified these impacts on biodiversity state. *OSPAR acts as a coordination platform in the North-East Atlantic for the regional implementation of the EU Marine Strategy Framework Directive (MSFD) that aims to achieve a Good Environmental Status (GES) in European marine environments, as well as for the coordination of other national frameworks. The characteristics of GES are determined by the individual EU member states, based on criteria elements, threshold values and methodological standards set regionally or at EU level.*

Norwegian, Icelandic, United Kingdom, Greenlandic and Faroese marine areas are not covered by the MSFD.

The following text provides a few examples of documented NIS impacts on biodiversity state.

A well-known marine invader is Rugulopterix okamurae, a brown macroalgal species native to the north-east Pacific Ocean and occurring along temperate zones of the coasts of the Philippines, Taiwan, China, the Republic of Korea and Japan. This alga was introduced in 2002 into European seas (Thau lagoon, Mediterranean Sea) (Verlaque *et al*., 2009; Boudouresque *et al*., 2011), from which it did not spread until last year when it suddenly appeared in the Calanque Parc (Marseille, Marine Protected Area), where it showed very invasive behaviour. It is a novel NIS for OSPAR Region IV, first reported in 2015 and becoming invasive in 2018. It is believed to have been introduced by ballast water transport as well as aquaculture seed contamination, and then to have spread by pathways such as fishing transport and the movement of discards. It has impacts on tourism and fishing. Recently, it has occurred on several occasions in huge amounts off the beaches around the Strait of Gibraltar.

Another example is the red king crab, released by the then Soviet Union in the period between the 1960s and 1980s, and now well established in Region I. It is slowly spreading west and south along the Norwegian coast. In 2020, local populations were found in Troms County. Further dispersal to the north is expected as the sea warms further. Since 2010, the population has peaked and it is now managed through fisheries, with populations becoming less dense and reproduction reduced as compared with the initial decades. Red king crabs have made an impact on benthic communities, several species of which now occur with reduced average size and lower local abundance.

Piles of the invasive brown algae, Rugulopterix okamurae seen here in the western Algarve, Portugal. © Shutterstock

I – Impact (on Ecosystem Services)

Impact of non-indigenous species on ecosystem services

The impact of the introduction of non-indigenous species (NIS) on ecosystem services in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast has not been quantified in this assessment, as common indicators for NIS impact have not yet been developed and implemented.

Based on expert judgement, a few overall comments on NIS impact are provided:

- Impacts by a smaller group of invasive NIS are reported by Contracting Parties across the whole OSPAR Maritime Area. Several NIS however, have low or unknown impacts.
- The impacts include the out-competing of native species; increased disease spread; biodiversity loss / decline; and food web structure changes.
- Thematic assessment experts identified both negative and positive impacts by NIS on marine ecosystem services. The highest impact identified was on the provision of aquatic biomass.
- For several marine ecosystem services, the impact of NIS was defined as uncertain.

- While NIS are shown to have negative global impact on marine biodiversity, it is currently very difficult to provide a general assessment of the NIS impact on marine ecosystem services in the OSPAR Regions.
- A thorough assessment of NIS impact requires the development and implementation of NIS impact indicators.

Impacts on Ecosystem Services: Method for the development of the Schematic

This section evaluates the impact that changes in the state of NIS observed in the QSR thematic assessments have had on the ecosystem services that the North-East Atlantic provides. It was developed through literature review combined with expert judgement, using the same methodology across all Thematic Assessments. Several workshops involving experts on ecosystem services and NIS were held to discuss and agree on the results presented below.

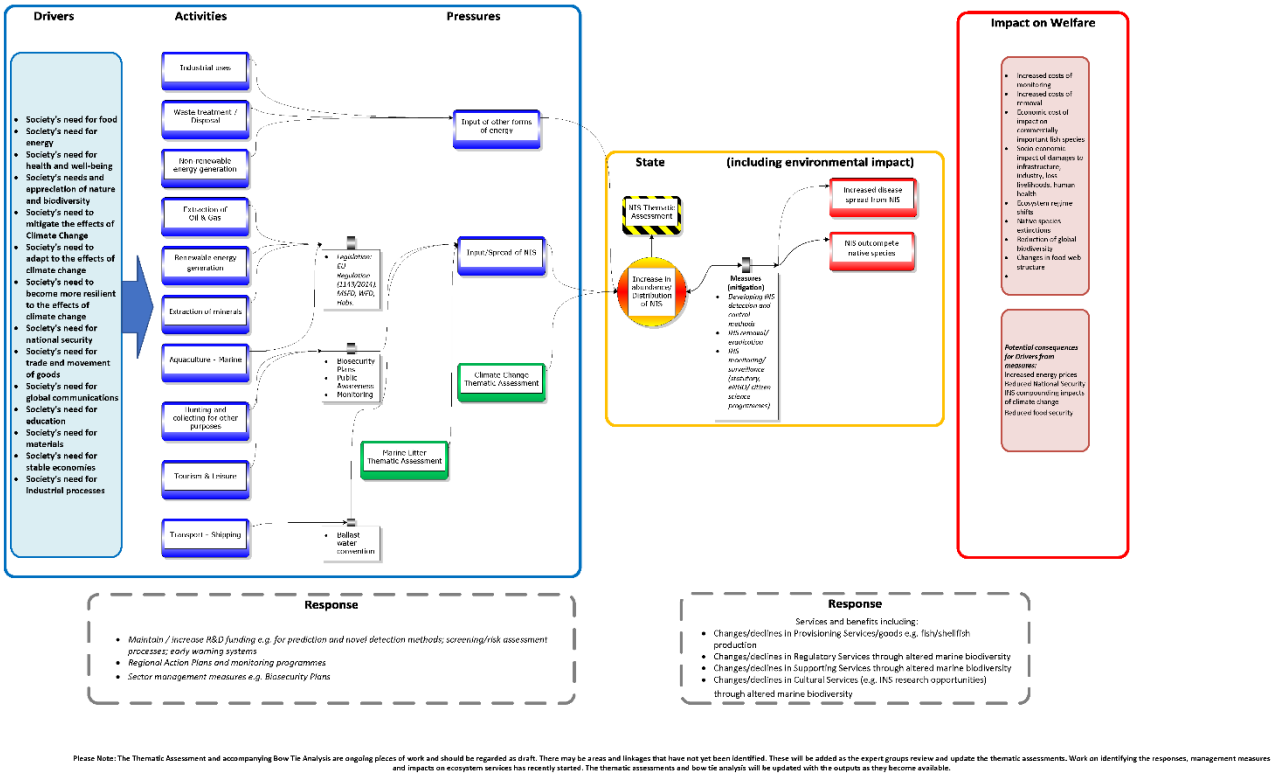

Figure I.1: Overview of the impact of NIS state changes on related marine ecosystem services

R – Response

Measures taken to respond to the pressures from the introduction of non-indigenous species

In terms of responses, preventing the introduction of non-indigenous species (NIS) is currently considered the only feasible management option for the marine environment. This is a result of the limited practical and cost-effective means available for eradicating or controlling established NIS in the marine environment. OSPAR has taken action towards reducing the introduction of NIS from ships' ballast water by developing general guidance on voluntary ballast water exchange as well as establishing a joint task group with HELCOM for the management of NIS in relation to ballast water management exemptions and the management of

ballast water and biofouling (JTG BALLAST & Biofouling) This has resulted in the adoption of a joint harmonised procedure for the management of ship's ballast water and sediments (Agreement 2020-01) by both OSPAR and HELCOM.

NEAES 2030 Operational Objective S7.O2 states that "*by 2025 OSPAR will develop a coordinated management approach to ensure the number of non-indigenous species introduced by human activity is minimised and where possible reduced to zero*". To achieve this objective there are opportunities for OSPAR to consider developing measures, including by sharing best practice with respect to the inclusion of marine NIS in national biosecurity plans and by considering the role of emerging vectors for NIS such as offshore renewables or restoration.

NIS R-section metadata Annex: The section development has been supported by the collation of relevant measures: measures of relevance to benthic habitats included in this section.

Section Overview

This section describes the responses that have been implemented to address non-indigenous species (NIS) within the North-East Atlantic. These responses include the development of policy, legislation and measures to manage or regulate specific human activities or to mitigate impacts on ecosystem services.

The section considers NIS across all Regions of the OSPAR Maritime Area, in coastal, shelf and deep seas within and outside national jurisdiction. The primary focus is on responses that have been adopted by the OSPAR Commission for implementing the Contracting Parties' commitments under the OSPAR Convention and the strategic objectives of the North-East Atlantic Environment Strategy. Article 22 of the OSPAR Convention requires that the Contracting Parties report to the OSPAR Commission at regular intervals on the steps they have taken to implement OSPAR Decisions and Recommendations, the effectiveness of these measures and the problems encountered in their implementation. This section aims to describe the progress made in implementing these measures and to assess whether they are working in terms of achieving the ambitions set out in the North-East Atlantic Environment Strategy 2030. The section attempts to set OSPAR's responses in the wider policy context and looks at responses by other competent organizations, where these are pertinent to addressing NIS in the context of the North-East Atlantic.

There are limited practical and cost-effective means available for eradicating or controlling NIS in the marine environment once these are established. The most feasible and efficient measures are those aimed at preventing the introduction of NIS in the first place, for example through biosecurity or pathway management, awareness raising and education. Monitoring is also a crucial aid to early detection, and thus rapid response and containment.

NEAES 2030 sets out the ambition for OSPAR's response to addressing NIS under Strategic Objective 7, "Ensure that uses of the marine environment are sustainable, through the integrated management of current and emerging human activities, including addressing their cumulative impacts", and specifically under Strategic Objective S7.O2, which states that by 2025 OSPAR "*will develop a coordinated management approach to ensure the number of non-indigenous species introduced via human activity is minimised and where possible reduced to zero.*"

There are a number of linkages to other thematic assessments, including Benthic Habitats, Food Webs, Pelagic Habitats, Marine Litter, Climate Change.

The reader is referred to the following feeder reports for additional information on some of the key human activities affecting NIS: Shipping and Ports, Aquaculture, Offshore Renewable Energy Generation and Recreation and Tourism.

Measures adopted by OSPAR

This section focuses on the measures adopted by OSPAR to control NIS in the North-East Atlantic, including where NIS are considered as a pressure on the OSPAR listed species and habitats.

The implementation status of all OSPAR measures was reported on in 2021

Addressing species and habitats in decline and under threat

The OSPAR List of threatened and/or declining species and habitats (Agreement 2008-06) (the OSPAR List) was first adopted in 2003 and updated in 2008 and 2021. The List guides the OSPAR Commission in setting priorities for its further work to conserve and protect marine biodiversity in implementing Annex V to the OSPAR Convention. The purpose of the Recommendations adopted by OSPAR to further the protection and conservation of OSPAR listed species and habitats is to achieve agreement on the actions to be taken nationally and collectively to strengthen the protection of the listed species and habitats, recover their status and ensure that they are effectively conserved in the OSPAR Maritime Area. A 'Common Understanding' of the Recommendations was adopted in 2013 (Agreement 2013-13). The recommendations are broad in nature, addressing a range of human activities and pressures. Four of the OSPAR Recommendations for the protection and conservation of threatened and/or declining species and habitats specify actions relating to NIS: Recommendation 2020-01 on Ostrea edulis in Region II and III and Ostrea edulis beds in Region II, III and IV, Recommendation 2016-03 on Atlantic salmon in Regions I, II, III and IV, Recommendation 2020-01 on European sturgeon in Regions II, III and IV, Recommendation 2013-01 on littoral chalk communities in Region II.

The most recent implementation reporting took place in 2019, with the next reporting due in 2025. A detailed overview of the scope and range of actions implemented in this reporting round can be found in the 2019 overview assessment report.

The 2020 status assessment for Ostrea edulis (flat oyster) beds reports that the introduction and further distribution of NIS is one aspect that still poses a significant threat to native oyster beds. In the process of implementing recommended actions for the flat oyster, Norway raised awareness of the invasive Pacific oyster and the measures being undertaken to address this issue.

One of the collective actions from the Recommendation for littoral chalk communities was to "Monitor key pressures including loss and change of substratum, levels of eutrophication, removal of species, introduction and spread of non-indigenous species and physical damage". However, according to the 2019 reporting there had not yet been any progress made with this action, and the overview assessment states that its implementation needs to be reconsidered, as it is only addressed through the regular cycle of assessments.

For the European sturgeon, at least two Contracting Parties refer to measures to regulate or prohibit non-native sturgeon. While the species is considered extinct in the UK, with the exception of occasional migrants, the keeping of non-native sturgeon is regulated in order to reduce the risk of such populations becoming established in the wild. Spain prohibits the introduction of non-indigenous sturgeon species. The 2020 status assessment of the European sturgeon indicates that the introduction of non-native sturgeon into open water

remains a pressure on this species in the Greater North Sea, Celtic Seas and the Bay of Biscay and Iberian Peninsula.

Next to aquaculture escapees, the greatest threat to wild Atlantic salmon is the freshwater parasitic lice, *Gyrodactylus salaris*. Although native to some parts of the Baltic, it does not naturally occur in the Atlantic distribution of Atlantic salmon populations (Johnsen, 2006, OSPAR 2010a). *Gyrodactylus salaris* is a freshwater parasite which has spread mainly through anthropogenic movement of infected fish between hatcheries/fish farms/rivers and by migration of infected fish from rivers and brackish water in fjords to rivers in Norway, Sweden and Russia. In Norway, catastrophic losses of Atlantic salmon were seen following the introduction of *G. salaris* to the country in the 1970s. Measures are in place to restrict movements of live fish and eggs and baitfish. In Norway there is also a concern that sea lice may be a carrier and vector of several fish diseases, including new pathogens such as microsporidium (NASCO, 2009).

Monitoring for the parasite and strict control of the movement of stocks between rivers has been an integral part of the Norwegian strategy to prevent the spread of *G. salaris*. Monitoring programmes to demonstrate freedom from *G. salaris* are being planned or executed by an increasing number of countries. These programmes can be complicated by difficulties in identifying *Gyrodactylus* specimens to species level.

Combatting this parasite will be a high priority, the aim being to eradicate the parasite where possible and minimize the risk of transmission to new areas. Measures will be based on the best available technology and systematic follow-up.

At regional scale, numbers of invasive species in littoral chalk communities are noted in the supporting OSPAR background document as being limited. Similarly, the brown alga *Sargassum muticum* has been reported as present on numerous coastal sites in Upper Normandy but does not give rise to massive exclusions of indigenous species (OSPAR, 2010b). The crab *Hemigrapsus saguineus* is increasingly common among rock slides and boulders on the upper beach, probably as a result of dispersal from the port of Le Havre. The recommendation calls for collective action to monitor the introduction and spread of NIS with respect to this habitat. To date this has not been implemented.

Are these measures working?:

This assessment indicates that while rates of NIS introduction are declining overall, NIS remains a pressure for certain species and habitats of concern in the North-East Atlantic, which implies that the measures taken to date are not yet having the desired outcome.

Next to aquaculture escapees, the greatest threat to wild Atlantic salmon is the freshwater parasitic lice, Gyrodactylus salaris. © Shutterstock

Marine Protected Area Network

Within OSPAR, MPAs are understood as areas for which protective, conservation, restorative or precautionary measures have been instituted for the purpose of protecting and conserving species, habitats, ecosystems or ecological processes of the marine environment (as defined in Recommendation 2003-03 implementing Annex V of the OSPAR Convention).

There are unfortunately very few datasets documenting the effect of MPAs on invasive species, and in particular to determine whether MPAs can increase resilience to biological invasions (Giakoumi *et al*., 2017). The few existing studies have shown contrasting effects (either positive or negative or non-significant) on NIS, except that NIS density is usually greater outside than inside MPAs (Giakoumi *et al.,* 2017). MPAs are generally not a response for addressing the spread or establishment of NIS. However, there may be potentially important management actions that can be taken within protected areas, such as the protection of seabird nesting grounds through predator eradication programmes, or measures to manage some NIS pathways within protected areas to reduce the risk of introduction and spread of other NIS.

Other OSPAR measures responding to relevant human activities and pressures

Transport – Shipping:

Prior to the entry into force of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention - see section 3 below), OSPAR adopted an agreement providing general guidance on voluntary interim application of the D-1 ballast water exchange standard by vessels operating between the Mediterranean Sea and the North-East Atlantic and/or the Baltic Sea (OSPAR Agreement 2010-07) and guidance on intra North Sea Ballast Water Exchange Areas (OSPAR Agreement 2014-11). The aim of these agreements was to reduce the introduction of NIS from ballast water in the period up to the full entry into force of the BWM Convention.

One of the other principal responses undertaken by OSPAR to address NIS has been through the "Joint HELCOM/OSPAR Harmonized Procedure for the Contracting Parties of OSPAR and HELCOM on the granting of exemptions under the International Convention for the Control and Management of Ship's Ballast Water and Sediments, Regulation A-4" (JHP). This is based on the Guidelines for Risk Assessment under Regulation A-4 of the Ballast Water Management (BWM) Convention (G7) (IMO Resolution MEPC.289(71) and was originally agreed by HELCOM and OSPAR Contracting Parties in 2013 (OSPAR Agreement 2020-01). The JHP procedure aims to ensure that exemptions are granted in a consistent manner that does not impair or damage the environment, human health, property or resources. The main users of this procedure include ship owners/operators, port State administrations and relevant experts and researchers. Based on Regulation A-4 of the Ballast Water Management Convention, exemptions from ballast water management requirements described in the JHP can be issued to a ship on voyages between specified ports or locations for a maximum of five years. A port State may grant such an exemption if the risk is acceptably low, based on the results of a risk assessment. In the initial transitional period of the BWM Convention (2017-2024), the JHP is to be implemented in a flexible and practicable way in order to gain experience and to enable further development and improvements.

OSPAR and HELCOM have established a joint task group for the management of NIS in relation to ballast water management exemptions, and the management of ballast water and biofouling (JTG BALLAST & Biofouling). The group's work includes the development of a system for managing information about priority species of NIS and their occurrence in the region, to be used as a basis for decision making, for example when considering whether an exchange of ballast water by a ship between two port areas gives rise to particular concern.

Are these measures working?:
The measure has supported a consistent approach to the implementation of the BWM Convention. In 2014, OSPAR endorsed the decision to designate ballast water exchange areas in the North Sea. These ballast water exchange areas are intended for intra-North Sea traffic only and the regulation is only temporary. The measure will cease when ships meet regulation D-2 of the BWM Convention.

In 2020 Denmark and Sweden established a bilateral agreement to implement BWC Regulation A-4 and create a 'Same Risk Area' designation for the Öresund.

Other relevant activities

The Bow-tie analysis identified a number of other human activities and pressures that could have relevance to NIS, but for which OSPAR has not taken any specific measures; these include hunting and collecting, input of other forms of energy (including electromagnetic fields, light and heat), industrial uses, waste treatment and disposal, marine litter, Aquaculture Feeder Report (§6.5), coastal protection infrastructure,

port expansion, extraction of minerals, extraction of oil and gas and non-renewable energy generation (production of energy).

There are potential future opportunities for OSPAR to develop measures with respect to tourism and leisure infrastructure and activities, and renewable energy generation.

Other important measures

This section highlights measures taken by other competent bodies which complement OSPAR's response for addressing NIS within the North-East Atlantic.

Invasive alien species have been identified as one of the key causes of loss of native species and harm to biodiversity (IPBES, 2019; Diaz *et al*., 2019). Article 8(h) of the Convention on Biological Diversity (CBD) provides a high-level framework for responses with specific objectives and at different geographic scales. According to this article, Parties to the CBD must, as far as possible and as appropriate, "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". Decision VI/23 of COP 6 under the CBD, on "Alien species that threaten ecosystems, habitats and species", sets out in its Annex the Guiding Principles for the prevention, introduction and mitigation of impacts of such alien species and urges Parties to develop national action plans. Concerning the marine environment, the Decision refers to the IMO Ballast Water Convention and calls on Parties to implement it (see also under "Transport - Shipping").

Within the context of the European Union, efforts under the Marine Framework Strategy Directive (EU/56/2008) are focused on limiting the environmental pressure from NIS by reducing the rate of their introduction and spread through the management of the pathways that they use. Descriptor 2 states that "NIS introduced as a result of human activities are at levels that do not adversely alter the ecosystem". A similar approach to managing NIS pathways is taken by EU Regulation 1143/2014 on the prevention and management of the introduction and spread of invasive alien species. This measure is a response to Article 8(h) of the CBD and requires Member States to establish a surveillance system for early detection of Invasive Alien Species (IAS) of Union concern. It was not possible to evaluate the national plans that have been developed to determine the extent to which marine and coastal IAS have been taken into account; however, the 2018 reporting in relation to the MSFD stated that Good Environmental Status with regard to NIS would be achieved only after 2020, there being only limited examples of sub-regions or specific locations where D-2 had been achieved. It was also stated that new introductions are under-reported, owing to continuing challenges with consistency in the understanding of terms, data availability and comparability (Tsiamis *et al*., 2021)

The EU Water Framework Directive (2000/60/EC) does not specifically mention NIS but considers it to be a human pressure that could impact the quality of a water body.

The Arctic Invasive Alien Species (ARIAS) Strategy and Action Plan, produced by Conservation of Arctic Flora and Fauna (CAFF) and the Protection of the Arctic Marine Environment (PAME), sets out the priority actions that the Arctic Council and its partners are encouraged to take to protect the Arctic region from the adverse impacts of invasive alien species or NIS, including in marine ecosystems. The actions take environmental, cultural, and economic perspectives into consideration, including drivers, impacts, and response measures. The actions again focus on the prevention of new introductions as the effort that can bring the largest return on investment. As part of ARIAS implementation, a joint CAFF-PAME project is underway for 2021-2023.

Transport – Shipping is a significant vector for NIS to enter the marine environment in the OSPAR area and primarily transfers marine NIS in two ways: the exchange of ballast water or through organisms transported on ships' hulls (biofouling).

The International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention) is a global response for preventing the effects of the spread of invasive species carried by ships' ballast water and sediments, which entered into force globally on 8 September 2017. This is a crucial step towards reducing the spread of NIS regionally and worldwide. The BWM Convention requires ships in international traffic to apply ballast water management measures, such as ballast water exchange (D-1), or to fulfil a certain discharge standard (D-2). The latter requires the installation of a certified ballast water treatment device which sterilizes the ballast water and thus prevents it from transferring species. Existing ships must initially meet the D-1 standard, but by 2024, all must meet the D-2 standard. Every ship is required to have a Ballast Water Management Plan and International Ballast Water Management Certificate, and to keep a Ballast Water Record Book. The IMO has also issued guidelines on aspects of implementation and continues to review the operation of the Convention during the current experience-building phase. Several amendments to the Convention and the Code for Approval of Ballast Water Management Systems (BWMS Code), which replaces the former G8 Guidelines, came into force in October 2019; amendments and revised guidance were also adopted in 2020. As of 15 September 2020, 88 States and IMO Associate Members had ratified the Convention (IMO, 2020), including all OSPAR Contracting Parties other than the United Kingdom, although the latter is drafting legislation and operates in accordance with the Convention's guidelines.

A Risk Assessment approach is applied for the granting of exemptions from ballast water management requirements, and guidelines have been adopted to ensure that the provisions of regulation A-4 of the BWM Convention are applied in a consistent manner and based on scientifically robust risk assessment. This ensures that the general and specific obligations of a Party to the Convention are achieved (Resolution MEPC.289(71)). In the case of the North-East Atlantic and the Baltic Sea, this is delivered through the Joint OSPAR/ HELCOM procedure (see section 2.3 above).

For biofouling, IMO adopted the Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines) (IMO resolution MEPC.207(62) in 2011. These guidelines are intended to provide a globally consistent approach to the management of biofouling, which is the accumulation of various aquatic organisms on ships' hulls. The guidelines have been supplemented by two guidance documents:

1. in 2012, the Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft (MEP.1/Circ.792); and
2. in 2013, the Guidance for evaluating the 2011 guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (MEPC.1/Circ.811).

At its seventy-second session in April 2018, the MEPC agreed to a new output enabling the Sub-Committee on Pollution Prevention and Response (PPR) to review the Biofouling Guidelines, which will be based on the principles of the 2013 Guidance. The Glofouling project was established in 2018 for five years, to help build capacity for the implementation of the guidelines https://www.glofouling.imo.org/.

Globally, a proposal submitted to the IMO Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) highlighted that the application of the IMO Biofouling Guidelines had been inconsistent and mentioned challenges such as dealing with irregular surfaces and cavities and

assessing the efficacy of new in-water cleaning technologies (GESAMP, 2019). The International Council for the Exploration of the Sea (ICES) has also highlighted improvements that could be made such as targeted guidelines dependent on vessel type and operational profiles, hull form optimisation, and better assessment of compliance (Galil *et al.*, 2019).

Aquaculture - marine, including infrastructure:

At the EU level, Council Regulation (EC) No 708/2007, concerning the use of alien and locally absent species in aquaculture, aims to optimise the benefits associated with introductions and translocations while at the same time avoiding alterations to ecosystems, preventing negative biological interaction - including genetic change - with indigenous populations, and restricting the spread of non-target species and detrimental impacts on natural habitats. This response does not apply to the Pacific oyster, which is identified as a species of concern in relation to the OSPAR- listed flat oyster.

Regional differences

The majority of the responses identified are measures taken in respect of coastal and shelf areas rather than the open ocean and deep seas, reflecting the focus of human activities and the highest risk for introduction pathways – particularly in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast. The Contracting Parties of the Arctic region are also delivering the Arctic Invasive Alien Species (ARIAS) Strategy and Action Plan under the Arctic Council. The sharing of information and approaches could help to ensure consistency in the approaches adopted across this region of the OSPAR Maritime Area.

Management of leisure boating in terms of introduction and spread of NIS is still in the early stages. © Shutterstock

Gaps and opportunities

Are we doing enough?:

The latest OSPAR Indicator Assessment on Trends in New Records of NIS shows an overall reduction in the rate of NIS introduction, which indicates that reduced pressure (a decreasing NIS trend) has generally been achieved in the assessed regions of the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast. This trend is, however, associated with great uncertainty. Thus, while the rate of new NIS introduction is high, the indication of a decreasing trend towards the most recent assessment period might suggest that the current measures are having the effect of reducing the introduction and spread of NIS in the OSPAR Maritime Area. Since the 2010 QSR, there has been significant progress in the responses to address NIS. However, introductions continue, and this issue will require continued effort to prevent further introductions. Continued implementation of the joint response by OSPAR and HELCOM, the MSFD, the Invasive Alien Species Regulation and the IMO Ballast Water Management Convention should ensure that some of the identified gaps in monitoring are addressed and also strengthen standardised monitoring so as to reduce bias and data gaps. Some vectors of introduction and spread could also be better targeted. For instance, while (commercial) shipping has been well targeted (see above), management of leisure boating is still in the early stages. There are national examples such as the Recreational Boating Pathway Action Plan of the GB Non-native Species Secretariat (2020).

Climate change-induced change in marine environmental conditions is anticipated to affect the introduction and spread of NIS, but more climate modelling is required to quantify this risk. Consideration of such developments will need to be a part of the response development and adaptation process.

Are there other types of responses that could be undertaken by OSPAR to improve the status of benthic habitats?

NEAES 2030 Operational Objective S7.O2 states that by 2025, OSPAR "will develop a coordinated management approach to ensure the number of non-indigenous species introduced by human activity is minimised, and where possible reduced to zero." As a contribution to this objective, OSPAR may wish to consider the following opportunities for additional responses.

Strengthening national biosecurity plans:

In the framework of CBD Decision VI/23 and its Europe-wide implementation through EU Regulation 1143/2014, countries are required to develop national action plans. Understanding the extent to which these national biosecurity action plans are being used as a management tool within the OSPAR Maritime Area could help contribute to the 2030 objectives.

Restoration and NIS:

OSPAR has committed to contribute to achieving the ambitions of the CBD Post-2020 Global Biodiversity Framework, which has established a target for the restoration of ecosystems, including marine ecosystems, as well as the aims of the UN Decade for Ecosystem Restoration. This commitment is articulated in the 2030 NEAES, which contains a specific strategic objective to restore degraded ecosystems and four operational objectives relating to clean seas, biologically diverse and healthy seas and seas resilient to climate change and ocean acidification (Strategic Objective 6), in particular S6.O1. By 2023, OSPAR aims to identify habitats suitable for restoration and develop a common knowledge base on the most appropriate and effective methods for restoration of degraded habitats. There is an opportunity to continue to develop best practice

in restoration while also avoiding the potential introduction or spread of NIS through these initiatives, for example by building on current guidance such as the European Guidelines on Biosecurity in Native Oyster Restoration (zu Ermgassen *et al.*, 2020).

Offshore renewables as stepping stones for NIS:

Construction for the purposes of offshore renewable energy production is considered to have a positive benefit on biodiversity (in terms of species richness) in soft-bottomed habitats, by providing hard substrate on which organisms can settle. However, there is also potential for these submerged structures to act as stepping- stones for the spread of NIS, and / or to expand their distributional range and facilitate their spread (Langhamer, 2012). The ICES advice covers potential impacts on marine life, including benthos, fish, birds, and marine mammals. In the case of benthos, most changes would be local and site-specific, with broader spatial effects mainly associated with tidal barriers or lagoons. Benefits for the benthic habitat can be achieved through infrastructural design or the exclusion of bottom fishing. However, colonisation of structures by non-indigenous species could also occur.

It is suggested that the 2008 OSPAR guidance on environmental considerations for the development of offshore wind farms (Agreement 2008-03) should be used as part of the licensing procedure for offshore developments. Currently, this guidance does not address NIS and how to reduce the opportunity for renewable structures to facilitate their spread. There is perhaps an opportunity to update this guidance, for example by including consideration of the types of construction materials to be used. OSPAR has established an intersessional correspondence group on renewable developments (ICG-ORED) which will contribute to delivery of the OSPAR NEAES 2030 Strategic Objectives and operational objective S7.O2. This new ICG presents an opportunity to consider possible measures relating to windfarm development as a vector for NIS spread.

Recreational boating and NIS:

Recreational boating activities can also be responsible for the introduction of NIS. In the case of the *Didemnum vexillum* – a high-impact, globally-invasive sea squirt – McKenzie *et al.* (2017) consider recreational boating to be a high-risk vector for primary introduction and secondary spread of non-native ascidians. Within OSPAR, the Netherlands, France, Ireland, the United Kingdom and Spain are affected, and specimens are also found on the west coast of Norway.

In general, such biofouling species create a range of complications. They are considered one of the primary issues affecting the marine aquaculture industry, can outgrow and out-compete other species, and might also disturb the spawning of the Atlantic herring (McKenzie, *et al.*, 2017).

Another important gap in our knowledge of the responses needed to reduce NIS spread concerns climate change and human settlements. The ICES highlights that the disappearance of summer Arctic Sea ice as a consequence of climate change may lead to an increased invasion of the Arctic by non-native species, owing to more extensive human development (Ruiz and Hewitt, 2009).

Currently, OSPAR does not directly address the recreation and tourism sector in its work. However, it does address various pressures which can be associated with this sector. Through its Regional Action Plan on Marine Litter, OSPAR is taking various measures to reduce marine litter in the North-East Atlantic. Furthermore, OSPAR addresses issues like eutrophication, hazardous substances, biological diversity and the protection of species and habitats. To reduce the pressures and impacts from the recreation and tourism sector, OSPAR might also address them via these other existing working areas.

References

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A. and Zayas, C. N. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. Science, 366(6471), eaax3100. doi:10.1126/science.aax3100

Eiswerth, M.E., Darden, T.D., Johnson, W.S., Agapoff, J. and Harris, T.R. (2005). Input–output modeling, outdoor recreation, and the economic impacts of weeds. Weed Science, 53(1), pp.130-137.

GESAMP (2019). Proposal to establish a GESAMP Biofouling Management Working Group. Available at: http://www.gesamp.org/site/assets/files/2044/46_7_1.pdf

Galil, B.S., McKenzie, C., Bailey, S., Campbell M., Davidson, I., Drake, L., Hewitt, C., Occhipinti-Ambrogi, A. and Piola, R. (2019). *ICES Viewpoint background document: Evaluating and mitigating introduction of marine non-native species via vessel biofouling. ICES Ad Hoc Report 2019*. 17 pp. Available at: http://doi.org/10.17895/ices.pub.4680

Giakoumi, S. and Pey, A. (2017). Assessing the effects of marine protected areas on biological invasions: A global review. Frontiers in Marine Science, 4(49). doi:10.3389/fmars.2017.00049

IMO (2020). Status of Conventions. Data as of 15/09/2020. Available at: https://www.imo.org/en/About/Conventions/Pages/StatusOfConventions.aspx

IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (J. S. S. Díaz, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas Ed.). Bonn, Germany: IPBES secretariat

Johnsen B.O. (2006). NOBANIS – Invasive Alien Species Fact Sheet – *Gyrodactylus salaris.* – From: Online Database of the North European and Baltic Network on Invasive Alien Species – NOBANIS www.nobanis.org, Accessed at https://www.nobanis.org/globalassets/speciesinfo/g/gyrodactylus-salaris/gyrodactylus_salaris.pdf

Langhamer, O. (2012). Artificial reef effect in relation to offshore renewable energy conversion: state of the art. *The Scientific World Journal, 2012*.

Miralles, L., Gomez-Agenjo, M., Rayon-Viña, F., Gyraitė, G. and Garcia-Vazquez, E. (2018). Alert calling in port areas: Marine litter as possible secondary dispersal vector for hitchhiking invasive species. *Journal for nature conservation, 42*, 12-18.

McKenzie, C., Reid, V., Lambert, G., Matheson, K., Minchin, D., Pederson, J. and Brown, L. (2017). *Alien Species Alert: Didemnum vexillum Kott, 2002: Invasion, impact, and control. ICES Cooperative Research Report No.355.* NASCO (2009). Summary of Annual Reports on Implementation Plans CNL (0916) Accessed at https://nasco.int/wp-content/uploads/2020/02/cnl0916.pdf

OSPAR (2010a) Atlantic Salmon Background document . https://www.ospar.org/documents?d=7229 Accessed

OSPAR (2010b) Background document for Littoral Chalk Communities. Accessed at Littoral Chalk Communities | OSPAR Commission

Piola, R. F. and Johnston, E. L. (2008). Pollution reduces native diversity and increases invader dominance in marine hard-substrate communities. *Diversity and Distributions*, *14*(2), 329-342.

Ruiz, G. and Hewitt, C. (2009). Latitudinal Patterns of Biological Invasions in Marine Ecosystems: A Polar Perspective. *Smithsonian at the Poles: Contributions to International Polar Year Science*, pp. 347-358.

Tsiamis K, Boschetti S, Palialexis A, Somma F, Cardoso AC, Marine Strategy Framework Directive - Review and analysis of EU Member States' 2018 reports - Descriptor 2: Non-indigenous species; Assessment (Art. 8), Good Environmental Status (Art.9) and Targets (Art. 10), EUR 30520 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-79-27700-2, doi:10.2760/7897, JRC123179. Accessed at https://easin.jrc.ec.europa.eu/easin/Document/IDA_report_D2.pdf

Tsirintanis, K., Azzurro, E., Crocetta, F., Dimiza, M., Froglia, C., Gerovasileiou, V., Langeneck, J., Mancinelli, G., Rosso, A., Stern, N. and Triantaphyllou, M.V. (2022). Bioinvasion impacts on biodiversity, ecosystem services, and human health in the Mediterranean Sea.

Cumulative Effects

Cumulative Effects Assessment for non-indigenous species

The bow-tie diagram for non-indigenous species (NIS) (**Figure CE.1**) aligns with the DAPSIR narrative in the Thematic Assessment (provisional confidence assessment: Medium (Medium Agreement on DAPSIR content + Medium Evidence to support connections) based on the approach described in Agreement 2019-02).

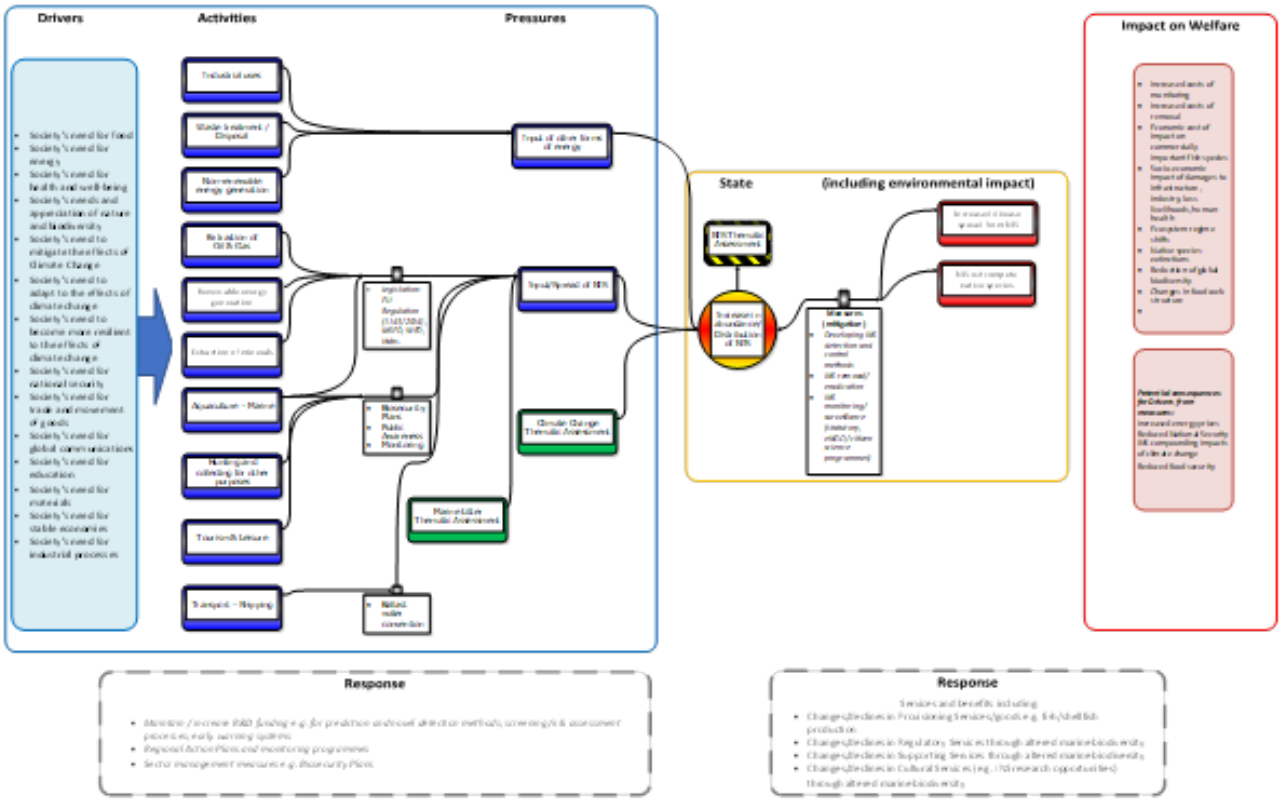

Figure CE.1: Bow-tie analysis describing DAPSIR connections for non-indigenous species

The bow-tie analysis for NIS shows the relationships between the DAPSIR components which need to be considered in a cumulative effects assessment. Human activities which contribute to the introduction and spread of NIS pressures with the potential to both individually and cumulatively contribute to biodiversity state changes have been identified in the following thematic assessments:

Benthic Habitats Input of NIS: The direct or indirect introduction of NIS, for example Chinese mitten crabs, slipper limpets, Pacific oyster and their subsequent spread and out-competing of native species. Ballast water, hull fouling, and stepping-stone effects (e.g. offshore wind farms) may facilitate the spread of such species. This pressure could be associated with aquaculture mussel or shellfishery activities, either through the use of imported seed stock or from accidental releases.

Pelagic Habitats: Coastal and offshore structures provide substrate for meroplankton, including NIS, to colonise, and discharges of ballast water from shipping contributes to their introduction and spread.

Fish: The introduction and spread of NIS through international shipping, fishing, aquaculture, aquarium trade and canal construction / operation (Woods *et al*., 2016). Invasive species can affect food web dynamics, displace native species, introduce diseases and lead to changes in habitat type, thereby significantly altering marine ecosystems (Crain *et al*., 2009; Gestoso *et al*., 2018).

Marine Birds: Breeding colonies of birds can be pressured by invasive non-indigenous mammalian predators. Predation of eggs and young birds can cause reductions in breeding success and could lead to the desertion of whole colonies. In the OSPAR area, seabird colonies are at risk from introduced non-native predatory mammals such as brown rats, cats and American mink, and also from native mammals such as hedgehogs, stoats and foxes which have been introduced by humans to offshore islands.

Marine Mammals: The introduction and spread of NIS have been linked to alterations in reproductive rates in marine mammals.

Input of litter (solid waste matter, including micro-sized litter) [Substances, litter and energy]:
Marine litter can contribute to the input/spread of NIS by providing mobile artificial substrate that can transport non-indigenous species from location to location.

The State section describes the potential ecological impacts associated with the introduction and spread of NIS in the marine environment. The input levels, frequency of occurrence, spatial extent, and exposure to different human activities all collectively contribute to the extent to which NIS pressures are exerted on pelagic habitats, benthic habitats, fish, marine birds and marine mammals. NIS can out-compete and prey on native species, resulting in declines in their abundance. Impacts are associated with the introduction of parasites and pathogens; NIS-induced changes in ecosystem functioning (e.g. food-web structure changes); changes in species assemblages and biotic homogenization; and NIS-induced changes in the provision of ecosystem services. To undertake a full quantitative analysis of cumulative effects requires consideration of the exposure pathways and ecological impacts. Further analyses and evidence of ecological impacts are required in order to progress the assessment of cumulative effects.

NIS can also combine with other pressures to affect marine species and habitats collectively. The assessment of cumulative effects is considered in these biodiversity thematic assessments: Pelagic Habitats, Benthic Habitats, Fish, Marine Bird, Marine Mammal and Marine Litter.

Climate change

Climate change effects on non-indigenous species

Climate change, primarily ocean temperature increases, may facilitate the introduction and establishment of non-indigenous species (NIS). In addition, climate change may increase the magnitude of impacts associated with invasive NIS, for example by reducing the resilience of native ecosystems and habitats. In addition to the impacts from climate change, higher rates of intercontinental dispersal events, associated with increasing levels of international trade and human travelling, are expected (Hewitt *et al.*, 2018; Sardain *et al.*, 2019).

The combined effects of climate and rapid transport are likely to bring worldwide changes to the earth's biota, including largescale biotic homogenisation, which could easily exceed the impact of either climate change or of NIS invasion considered individually. Proper management of NIS introductions is therefore essential, considering the risk associated with the continually changing climate. Despite the hypothesis that global climate change can lead to the degradation of marine ecosystems through invasive NIS (Dukes and Mooney, 1999), climate change and invasive species are most commonly treated as independent issues (Pyke *et al.*, 2008).

The effects of ocean climate change and acidification on NIS introductions and impacts are frequently discussed in the literature (Occhipinti-Ambrogi, 2021). However, there seems to be limited documentation of the causal effects. The primary stressor appears to be warming, whereas less emphasis is placed on altered ocean pH, wind speed and precipitation and climate-related changes in salinity. A general poleward expansion of marine species due to the effect of seawater warming is expected (Pinsky *et al.*, 2013; Poloczanska *et al.*, 2016), with some evidence and indications of climate-related changes on increasing abundances of NIS in marine systems (García-Gómez *et al.*, 2020; Sorte *et al.*, 2010; Staehr *et al.*, 2020). Considering the different pathways of NIS introduction, poleward expansion related to ocean warming would be most relevant in the case of secondary introductions. The reasoning for this is that hotspots of NIS introduction in southern seas would provide source populations for further introductions of NIS in northerly regions as temperature conditions gradually become favourable there.

In the Greater North Sea (Region II), Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV), the rate of new NIS introductions has been significantly decreasing during the last three assessment periods (2003 to 2020) (see: pressure section). However, due to time lags in data reporting, sparse monitoring of NIS, and lack of a thorough analysis of the importance of environmental conditions, it is likely that the NIS introduction rate, especially in the most recent assessment period, is underestimated, and thus temperature-mediated effects on selected NIS species cannot be ruled out. Considering the expectation of a climate-driven poleward expansion of NIS, the observed trends in NIS development among OSPAR Regions do not support the hypothesis of southern regions acting as a donor for northerly regions. Among the 426 NIS records provided by the 11 Contracting Parties from 2003 to 2020, there were a total of 250 non-duplicated NIS records across the three OSPAR Regions, with a tendency for more NIS to be observed in southern countries (see Figure 3 in the NIS trend indicator assessment).

This broad trend gives support to the previously published records of higher NIS arrivals in southern seas (Tsiamis *et al.*, 2019; Tsiamis *et al.*, 2018), with up to 76% of all NIS primary introductions in Europe having been reported first from the Mediterranean Sea. This could indicate the importance of secondary non-assisted dispersal for many of the northerly observed NIS species. However, differences in monitoring efforts between regions makes it difficult to conclude on the importance of secondary-assisted dispersal of NIS.

Secondary introductions (i.e. the spread) accounted for only 5% of NIS introductions in the OSPAR Regions (see Figure d in the NIS trend indicator assessment). The influence of climate-related warming on NIS introductions is therefore not strongly supported by the data collected for this assessment and this issue will require a more targeted species-specific analysis.

References

Dukes, J.S. and Mooney, H.A. 1999. Does global change increase the success of biological invaders? Trends in ecology & evolution 14(4), 135-139.

García-Gómez, J.C., Sempere-Valverde, J., González, A.R., Martínez-Chacón, M., Olaya-Ponzone, L., Sánchez-Moyano, E., Ostalé-Valriberas, E. and Megina, C. (2020). From exotic to invasive in record time: The extreme impact of Rugulopteryx okamurae (Dictyotales, Ochrophyta) in the strait of Gibraltar. Science of the Total Environment 704, 135408.

Hewitt, M.J., Hourston, M. and McDonald, J.I. (2018). A long way from home: Biosecurity lessons learnt from the impact of La Niña on the transportation and establishment of tropical portunid species. Plos one 13(8), e0202766.

Occhipinti-Ambrogi, A. 2021. Biopollution by invasive marine non-indigenous species: a review of potential adverse ecological effects in a changing climate. International Journal of Environmental Research and Public Health 18(8), 4268.

Pinsky, M.L., Worm, B., Fogarty, M.J., Sarmiento, J.L. and Levin, S.A. (2013). Marine taxa track local climate velocities. Science 341(6151), 1239-1242.

Poloczanska, E.S., Burrows, M.T., Brown, C.J., García Molinos, J., Halpern, B.S., Hoegh-Guldberg, O., Kappel, C.V., Moore, P.J., Richardson, A.J. and Schoeman, D.S. (2016). Responses of marine organisms to climate change across oceans. Frontiers in Marine Science, 62.

Thematic Metadata

Field	Data Type	Explanation
Relevant OSPAR Documentation	Text	OSPAR Agreement 2018-04 CEMP Guideline: Common Indicator - Changes to non-indigenous species communities (NIS3) OSPAR Publication 2022-910 Trends in New Records of Non-Indigenous Species (NIS) Introduced by Human Activities

OSPAR's Quality Status Report 2023

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Our vision is a clean, healthy and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification.

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