WORKING GROUP ON INTEGRATED ASSESSMENTS OF THE NORTH SEA (WGINOSE)

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Contents

i Executive summary

The objective of this study was to conduct an impact risk assessment of Greater North Sea Ecoregion activities and pressures. Specifically, to conduct a revision of the EO wire-diagram of the Greater North Sea based upon ICES published guidelines for the conduct of EOs ICES Technical Guidelines (2021) and to identify the top-ranked sectors and pressures contributing the most to the overall impact risk in the North Sea. A group of 21 experts familiar with different elements of the North Sea assessed the links between a total of 16 sectors, 8 pressures and 6 ecological characteristics in line with the ICES published technical guidance. A total of 309 separate sector/pressure/ecological characteristics combinations were evaluated to determine their impact risk (e.g. as determined by the product of the spatial overlap, frequency of exposure and degree of impact). An analysis of the relative contribution of the sector and pressures scores to the overall impact risk revealed the largest contribution to the overall impact risk was from fishing (60%), followed by shipping (16%), whereas species extraction, marine litter and contaminants are considered to be the primary pressures impacting the North Sea ecosystem.

ii Expert group information

Expert group name	Working Group on Integrated Assessments of the North Sea (WGINOSE)
Expert group cycle	Multi-annual fixed term
Year cycle started	2021
Reporting year in cycle	2/3
Chairs	Andrew Kenny, UK
	Morten Skogen, Norway
Meeting venues and dates	10–14 May 2021, online meeting (8 participants)
	9–13 May 2022, Copenhagen, Denmark (19 participants)

1 North Sea Ecosystem Overview impact risk assessment (ToR d)

The focus of the 2022 meeting was to address ToR d, (Update the greater North Sea Ecosystem Overview as required). Specifically, a revision of the EO wire-diagram of the Greater North Sea based upon ICES published guidelines for the conduct of ecoregion EO impact risk assessments ICES Technical Guidelines (2021) to identify the top-ranked sectors and pressures contributing the most to the overall impact risk in the North Sea ecoregion.

This task was successfully completed at the meeting with input from several experts who attended the meeting in person and virtually, representing different sectors and pressures deemed to be important in the context of the North Sea ecoregion, namely; fishing, shipping, renewables, and contaminants. The meeting was also joined by members of the Working Group on Economics (WGECON) who provided an overview of North Sea fisheries economic, and landings data as input for the EO. A full list of those who attended the meeting is given in Annex 1.

The assessment was conducted in two steps, e.g. step 1 consisted of completing a 'linkage' template which identified any potential connections between sectors or activities, pressures and ecological characteristics. Links between a total of 16 sectors, 8 pressures and 6 ecological characteristics were considered (Table 4.1) in line with the ICES published technical guidance (see link above).

Table 4.1. Assessed North Sea ecoregion sectors, pressures and ecological characteristics[1].

Sectors (Activities)	Pressures	Ecological Characteristics
Aggregate extraction	Physical seabed disturbance	Benthic habitats and associated biota
Agriculture	Contaminants	Cephalopods
Aquaculture	Marine litter	Fish
Fishing	Noise	Marine mammals
Harvesting/ collecting	Non-indigenous species	Pelagic habitats and associated biota
Land-based industry	Removal of non-living resources	Seabirds
Military/ defense	Nutrient and organic enrichment	
Navigation dredging	Species extraction	
Nuclear energy		
Oil and gas		
Renewable energy		
Research		

[1] For details of component definitions and acknowledged limitations see Technical Guidelines - ICES ecosystem overviews (2021)

Shipping
Telecommunications
Tourism/ recreation
Wastewater

Step 2 of the assessment involved the group scoring the links identified in Step 1 with respect to the amount of spatial overlap between the sector and the North Sea ecoregion, the frequency of exposure of the ecoregion to the sector and the degree of impact caused by the pressure to the ecological characteristics following the approach described in the ICES technical guidelines.

The task of quantifying the spatial overlap or exposure of selected sectors was informed by the results from ToR b (mapping human activities and pressures) where for selected sectors the spatial extent of human activities has been quantified for the North Sea ecoregion. However, the group had a discussion on how to assess diffuse pressures and sources of pollution such as contaminants and marine litter. It was not clear if such pressures should be assessed as having wide spatial overlap on account of the pressure being widely dispersed in the marine environment, or if the pressure should be assessed more locally at the point of discharge. Clearly a pressure that is widely dispersed at low levels of concentration will have a low, but widespread effect, whereas assessing higher concentrations of contaminants at the point of discharge will be associated with greater potential effects but at a more localized and site-specific scale. In the present study the group decided to assess contaminants and other types of diffuse pressure at local and site-specific scale associated with location of the point source discharge.

A total of 274 separate sector/pressure/ecological characteristic combinations were evaluated (Annex 3) to determine their impact risk (e.g. as determined by the product of the spatial overlap, frequency of exposure and degree of impact scores).

1.1 Results

Connectance

The outcome of step 1 of the assessment can be summarized with respect to the total number of connections between the sectors, pressures, and ecological characteristics, and provides an indication of the relative importance of a sector in terms of the potential number of impact pathways the sector can exert on the ecosystem. It does not necessarily follow that a top ranked sector in terms of connectance, e.g. shipping which is ranked the most connected in the present assessment, will also be the same top-ranked sector with respect to its ecosystem impact risk. Plots of proportional connectance by sector, pressure and ecological characteristics are shown in Figure 4.1.

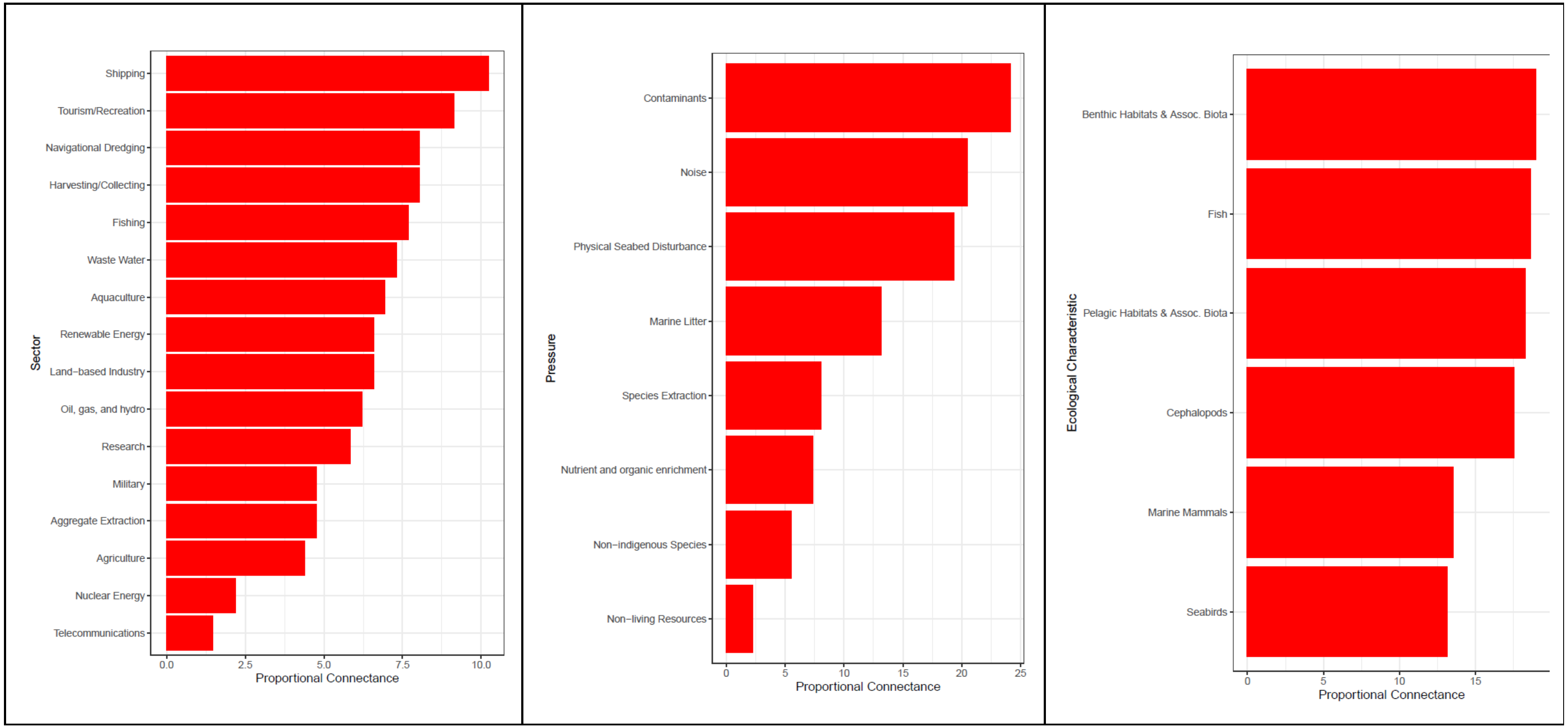

Figure 4.1. Plots of proportional connectance for sectors, pressures and ecological characteristics as determined by the Step 1 linkage framework analysis.

Impact risk scores (cross-checking)

The results of the Step 2 assessment of the assigned scores for the spatial overlap, frequency of exposure and degree of impact risk for each combination of sector/pressure/ecological characteristic can be visualized as a set of cross-check plots as shown in Figures 4.2–4.4.

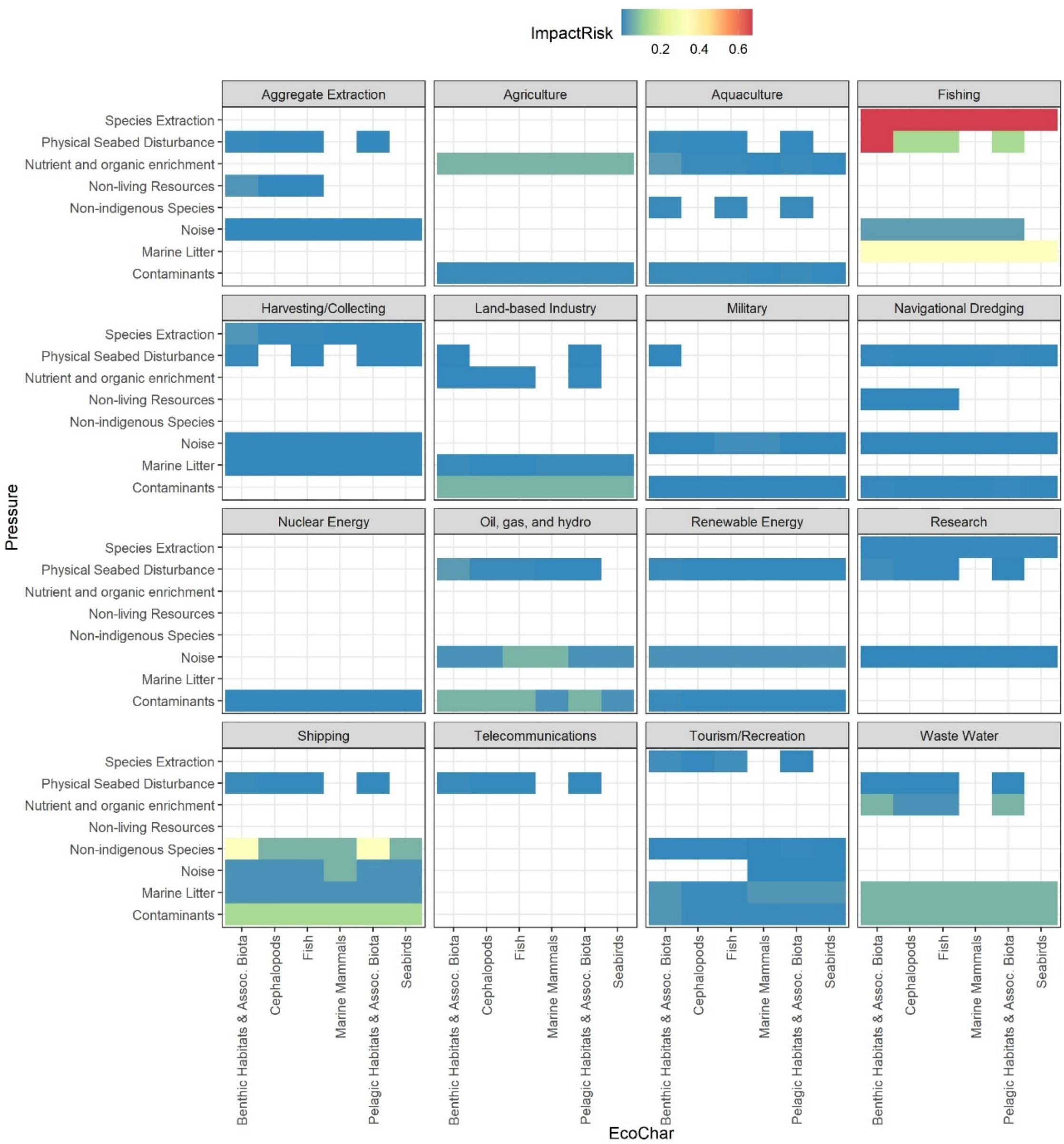

Figure 4.2. Cross-check plot showing the impact risk scores for the assessed ecological characteristics in response to the assessed pressures in the North Sea ecoregion (red is relatively high risk and blue is relatively low risk).

It can be seen from Figure 4.2 the greatest impact risk is caused by fishing followed by shipping. Figure 4.3 shows the spatial overlap between the sectors and ecological characteristics, again it can be seen that fishing and shipping have the greatest spatial overlap with the North Sea ecoregion. With respect to the frequency of the sector-based pressures (Figure 4.4) three frequency clusters were identified, e.g. the highest frequency of disturbance is associated with fishing, aquaculture, land-based industry, nuclear energy, renewable energy, oil and gas, wastewater and telecommunication cables, an intermediate frequency of disturbance is associated with aggregate extraction and harvesting/collecting, and the lowest frequency of disturbance is associated with tourism, military operations, research activities and navigational dredging.

Figure 4.3. Cross-check plot showing the score categories for the spatial overlap between the sectors and ecological characteristics. WP is widescale patchy (>50% of area), L is local (5–50% of area), S is site-specific (<5% of area) and E is exogenous.

Figure 4.4. Cross-check plot showing the frequency score categories for each sector where P is persistent (12 months per year), C is common (8 months per year) and O is occasional (4 months per year).

Top-ranked sectors, pressures and ecological characteristics.

From a combination of the analysis, it is apparent that fishing, shipping, wastewater, oil and gas, and agriculture are the top 5 ranked sectors which contribute to the greatest impact risk in the North Sea ecoregion (Table 4.2). With respect to the pressures, the top-ranked pressures are species extraction, marine litter, contaminants, siltation and smothering, and abrasion (Table 4.3). And with respect to the ecological characteristics the top ranked characteristics are benthic habitats and associated fauna, pelagic habitats and associated fauna, fish, and cephalopods (Table 4.4)

Table 4.2. Top-ranked sectors based upon the sum of the impact risk scores.

Sector	RankAverage	AvgIR	RankSum	SumIR
Fishing	1	3.45e−01	1	7.24e+00
Shipping	2	7.09e−02	2	1.99e+00
Waste Water	3	4.82e−02	3	9.63e−01
Oil, gas, and hydro	5	3.18e−02	4	5.40e−01
Agriculture	4	3.60e−02	5	4.32e−01
Land−based Industry	6	2.39e−02	6	4.30e−01
Tourism/Recreation	7	7.25e−03	7	1.81e−01
Renewable Energy	8	7.00e−03	8	1.26e−01
Aquaculture	9	5.61e−03	9	1.06e−01
Harvesting/Collecting	12	2.28e−03	10	5.03e−02
Aggregate Extraction	10	2.71e−03	11	3.52e−02
Research	14	1.83e−03	12	2.92e−02
Military	13	1.94e−03	13	2.52e−02
Navigational Dredging	15	7.65e−04	14	1.68e−02
Telecommunications	11	2.63e−03	15	1.05e−02
Nuclear Energy	16	5.00e−04	16	3.00e−03

Table 4.3. Top-ranked pressures based upon the sum of the impact risk scores.

Pressure	RankAverage	AvgIR	RankSum	SumIR
Species Extraction	1	1.86e−01	1	4.09e+00
Marine Litter	2	7.24e−02	2	2.61e+00
Contaminants	5	3.08e−02	3	2.03e+00
Physical Seabed Disturbance	6	2.27e−02	4	1.20e+00
Non−indigenous Species	3	6.34e−02	5	9.51e−01
Noise	7	1.17e−02	6	6.54e−01
Nutrient and organic enrichment	4	3.09e−02	7	6.18e−01
Non−living Resources	8	3.93e−03	8	2.36e−02

Table 4.4. Top-ranked ecological characteristics based upon the sum of the impact risk scores.

EcoChar	RankAverage	AvgIR	RankSum	SumIR
Benthic Habitats & Assoc. Biota	1	5.52e−02	1	2.87e+00
Pelagic Habitats & Assoc. Biota	4	4.37e−02	2	2.18e+00
Fish	6	3.77e−02	3	1.92e+00
Cephalopods	5	3.85e−02	4	1.85e+00
Marine Mammals	2	4.72e−02	5	1.75e+00
Seabirds	3	4.45e−02	6	1.60e+00

An analysis of the relative contribution of the sector and pressures scores to the overall impact risk is shown in Table 4.5. This reveals the largest contribution to the overall impact risk is from fishing (60%), followed by shipping (16%), whereas species extraction, marine litter and contaminants are considered to be the primary pressures impacting the North Sea ecosystem (Table 4.5).

Table 4.5. The % relative contribution to the overall sum of impact scores for sectors and pressures in the North Sea ecoregion.

	Sectors		Pressures
	% relative contribution		% relative contribution
Agriculture	3.5	Contaminants	17
Fishing	59.5	Marine Litter	21
Oil and Gas	4.4	Non-indigenous Species	8
Shipping	16.3	Physical Seabed Disturbance	10
Waste Water	8	Species Extraction	34
Grand Total	**92**	**Grand Total**	**89**

Comparative connectance and box plot score summaries

The results from Steps 1 and 2 of the assessment are combined and summarized, by sector, pressure and ecological characteristics in Figures 4.5–4.7, respectively.

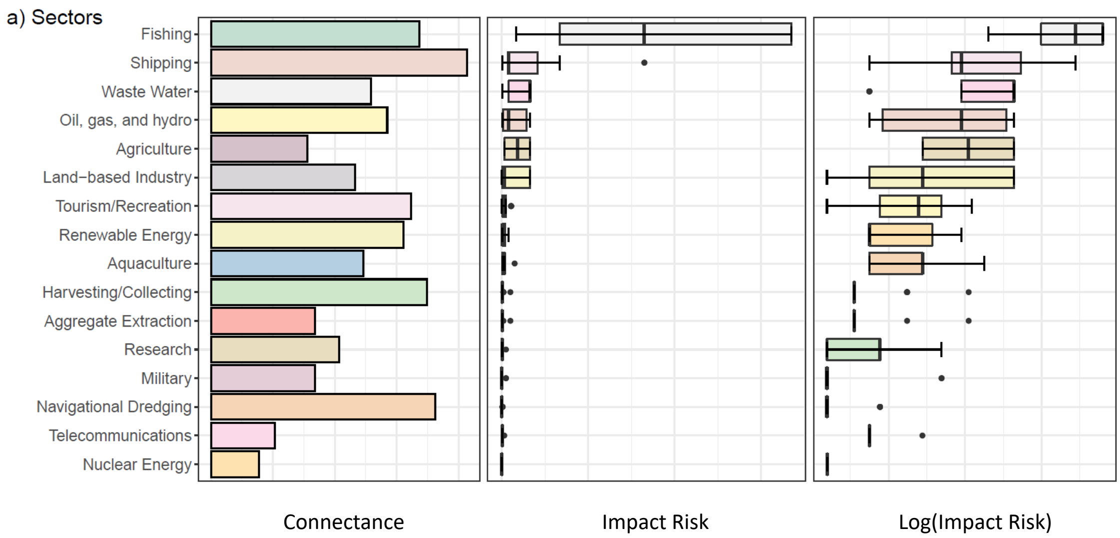

Figure 4.5. Comparative sector connectance and impact risk score box plots, ranked by impact risk.

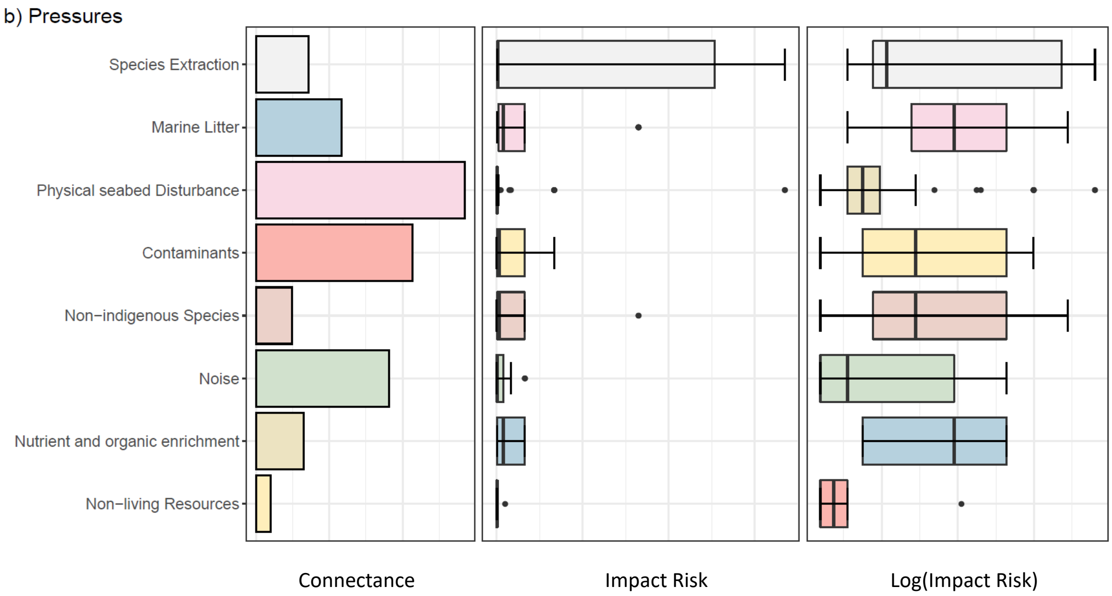

Figure 4.6. Comparative pressure connectance and impact risk score box plots, ranked by impact risk.

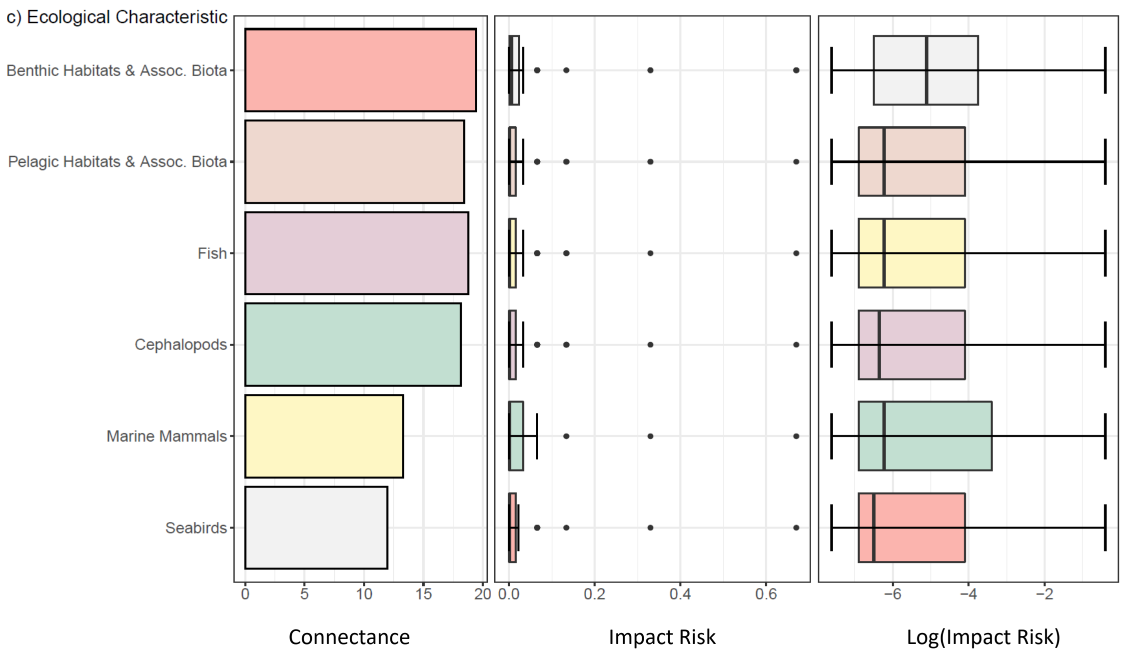

Figure 4.7. Comparative ecological characteristics connectance and impact risk score box plots, ranked by impact risk.

Sankey diagram

The relationship between all 16 sectors, 8 pressures and 6 ecological characteristics connections can be visualized in the form of a Sankey diagram (Figure 4.8).

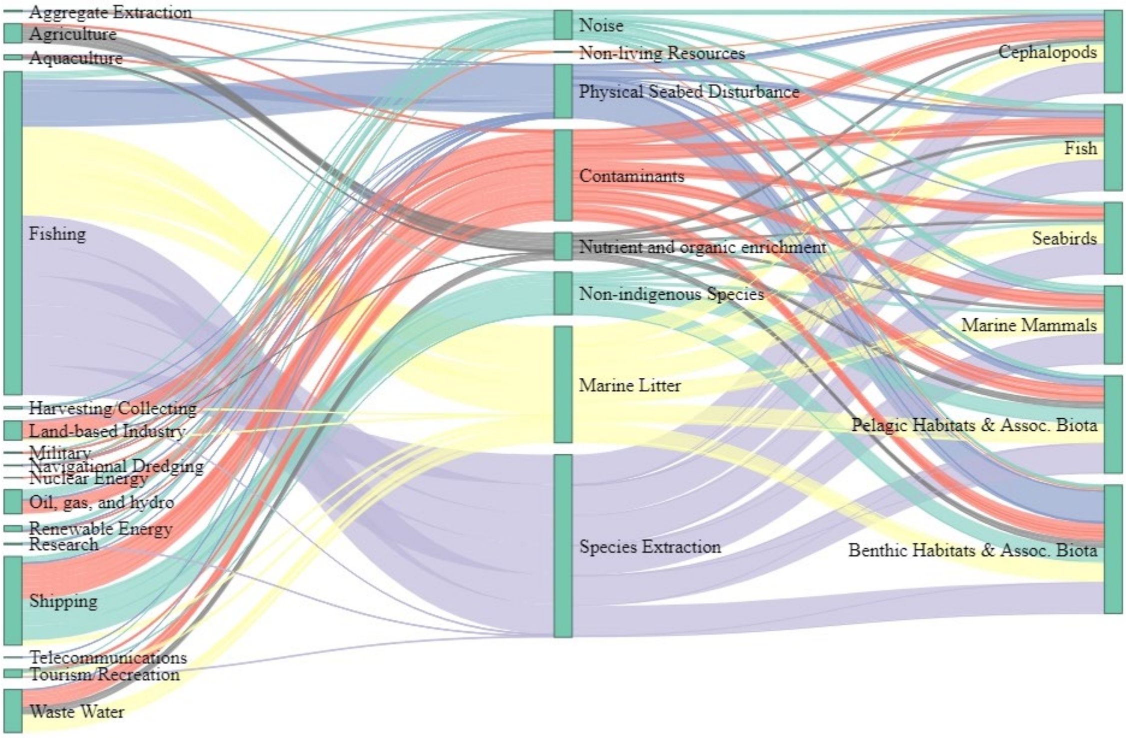

Figure 4.8. Sankey diagram showing the connections between all the sectors, pressures and ecological components. Note the size of the sector, pressure and ecological component bars is proportional to the number of connections.

Annex 1: List of participants

List of participants from the 2022 meeting

Name	Institute	Country (of institute)	E-mail
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Annex 2: Resolutions

2020/FT/IEASG01 The **Working Group on North Sea Integrated Ecosystem Assessment (WGINOSE)**, chaired by Andrew Kenny, UK and Morten Skogen*, Norway, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2021	10 – 14 May	Online meeting	E-evaluation	Change of chairs: Morten Skogen, replacing Erik Olsen.
Year 2022	9-13 May	ICES HQ	E-evaluation	
Year 2023	TBD April/May	ICES HQ	Final ICES Scientific Report by 31 May to IEASG	

ToR descriptors[2]

ToR	Description	Background	Science Plan Codes	Duration	Expected Deliverables
a	Update and operationalise strata specific ecosystem trends analysis including the development and/or application of 'warning' indicators of ecosystem state by working closely with WGECO, WGSFD and WKINTRA. Investigate methods for communicating trends in ecosystem state, especially significant changes, using ecosystem summary sheet or report card style approaches.	a) Science Requirements b) Support Advisory Requirements c) Requirements from other EGs	1.1, 2.1	3 years and on-going annually	Review paper on report card/ESS methods in supporting IEA science that supports advice
b	Operationalise the integration of human activity and pressure data, including data pathways, into strata specific IEAs for the Greater North Sea Ecoregion distinguishing between fixed structures (e.g. pipelines, windfarms) and ongoing activities (e.g. dredging, fishing, shipping, underwater noise, litter) by working with WGSFD, WGSHIP, WGCEAM to establish appropriate methods for CEAs	a) Science Requirements c) Requirements from other EGs	4.1	3 years and on-going annually	Updated dynamic map of assessed human activities, pressures and impacts for WGINOSE webpage.

[2] Avoid generic terms such as "Discuss" or "Consider". Aim at drafting specific and clear ToR, the delivery of which can be assessed

c	Continue to develop and test/validate strata specific decision support tools to support ecosystem management and advice (e.g. through mental models, bow-tie and EwE/Ecospace models and network analysis)	a) Science Requirements	2.2, 2.3, 3.2	3 years and on-going annually	Paper on application of validated qualitative ecosystem models in supporting ecosystem assessments and management advice
d	Update the greater North Sea Ecosystem Overview as required	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	1.2, 2.1	As required - ongoing	Updated North Sea ecosystem overview

Summary of the Work Plan

Year 1	The first year will focus on further development of strata specific trend analysis and communication, especially in relation to 'warning' indcators and scoping ecosystem summary sheet/report card reporting at the North Sea scale. Work will also begin on drafting a review paper on trend analysis methods and communication approaches for IEA science that supports advice. Updates on human activities, pressures and impacts, especially in relation to CPUE and fisheries data from the English Channel will be undertaken. Further development of ecosystem assessment support tools, especially in relation to validating conceptual model outputs will be undertaken and a paper describing the integration of quantitative/qualitative models will be finalised.
Year 2	In addition to continuing work on the above items, a stakeholder workshop will be convened for the Kattegat so as to update stakeholders and managers on the validation and refinement of the Kattegat asessment tool/model, effectively as a follow on to WKKEMSSP. Plans will also be initiated to implement additional strata specific EwE models of the North Sea (e.g. Southern Bight and Norwegian Trench) so as to initaite subsequent follow-up engagement with stakeholders in these two regions. An update of the North Sea ecosystem overview will also be initiated this year.
Year 3	In addition to continuing with activities initiated in year 1 and 2, additional stakeholder workshops wil be organised as follow-on to either the Norwegian Trench and/or Southern Bight strata.

Supporting information

Priority	The current activities of this Group will lead ICES into issues related to the development of Integrated Ecosystem Assessments for the North Sea (a data rich ecosystem) as a step towards implementing the ICES Science Plan and the ecosystem approach, these activities are considered to have a very high priority.
Resource requirements	Assistance of the Secretariat in maintaining and exchanging information and data to potential partcipants, especially the services of the ICES data centre to generate data tables for analysis from selected variables held in the database and potentially web-hosting relevant material
Participants	The Group is generally attended by 10–20 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and grou[under ACOM	Relevant to the work of ACOM and SCICOM
Linkages to other committees or groups	There is a very close working relationship with all the IEASG working groups. It is also very relevant to the following ICES expert groups: WGSFD, WGECO, WGSHIP, WGCEAM, WKINTRA, WGBESIO, WGFBIT
Linkages to other organizatio[	OSPAR, NAFO, DG-ENV, DG-MARE

Annex 3: North Sea Risk Assessment Data

Table A3.1. Degree of impact (DoI) scores assigned to each relevant sector, pressures and ecological characteristic combination for the North Sea by experts attending WGINOSE in 2022.

Sector	Pressure	Ecological Characteristic	Over-lap	Fre-quency	DoI	Overlap Score	Frequency Score	DoI.Score	Impact Risk Score	IR relative contribu-tion
Aggregate Extrac-tion	Noise	Cephalopods	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Noise	Fish	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Noise	Seabirds	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Noise	Marine Mammals	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Noise	Pelagic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Noise	Benthic Habitats and As-soc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Non-living Resources	Cephalopods	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Non-living Resources	Fish	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extrac-tion	Non-living Resources	Benthic Habitats and As-soc. Biota	S	C	A	0.03	0.67	1	0.0201	0.165101013
Aggregate Extrac-tion	Physical Seabed Disturbance	Cephalopods	S	C	L	0.03	0.67	0.05	0.001005	0.008255051

Aggregate Extraction	Physical Seabed Disturbance	Fish	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extraction	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Aggregate Extraction	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	C	C	0.03	0.67	0.2	0.00402	0.033020203
Agriculture	Contaminants	Cephalopods	S	P	C	0.03	1	0.2	0.006	0.049283885
Agriculture	Contaminants	Fish	S	P	C	0.03	1	0.2	0.006	0.049283885
Agriculture	Contaminants	Seabirds	S	P	C	0.03	1	0.2	0.006	0.049283885
Agriculture	Contaminants	Marine Mammals	S	P	C	0.03	1	0.2	0.006	0.049283885
Agriculture	Contaminants	Pelagic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Agriculture	Contaminants	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Agriculture	Nutrient and organic enrichment	Cephalopods	L	P	C	0.33	1	0.2	0.066	0.542122731
Agriculture	Nutrient and organic enrichment	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731
Agriculture	Nutrient and organic enrichment	Seabirds	L	P	C	0.33	1	0.2	0.066	0.542122731
Agriculture	Nutrient and organic enrichment	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731
Agriculture	Nutrient and organic enrichment	Pelagic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731

Agriculture	Nutrient and organic enrichment	Benthic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Aquaculture	Contaminants	Cephalopods	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Contaminants	Fish	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Contaminants	Seabirds	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Contaminants	Marine Mammals	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Contaminants	Pelagic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Contaminants	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Non-indigenous Species	Fish	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Non-indigenous Species	Pelagic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Non-indigenous Species	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Nutrient and organic enrichment	Cephalopods	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Nutrient and organic enrichment	Fish	S	P	C	0.03	1	0.2	0.006	0.049283885
Aquaculture	Nutrient and organic enrichment	Seabirds	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Nutrient and organic enrichment	Marine Mammals	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Nutrient and organic enrichment	Pelagic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885

Aquaculture	Nutrient and organic enrichment	Benthic Habitats and Assoc. Biota	S	P	A	0.03	1	1	0.03	0.246419423
Aquaculture	Physical Seabed Disturbance	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Physical Seabed Disturbance	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Aquaculture	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Fishing	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	WP	P	A	0.67	1	1	0.67	5.503367116
Fishing	Physical Seabed Disturbance	Cephalopods	WP	P	C	0.67	1	0.2	0.134	1.100673423
Fishing	Physical Seabed Disturbance	Fish	WP	P	C	0.67	1	0.2	0.134	1.100673423
Fishing	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	WP	P	C	0.67	1	0.2	0.134	1.100673423
Fishing	Marine Litter	Cephalopods	L	P	A	0.33	1	1	0.33	2.710613654
Fishing	Marine Litter	Fish	L	P	A	0.33	1	1	0.33	2.710613654
Fishing	Marine Litter	Seabirds	L	P	A	0.33	1	1	0.33	2.710613654
Fishing	Marine Litter	Marine Mammals	L	P	A	0.33	1	1	0.33	2.710613654
Fishing	Marine Litter	Pelagic Habitats and Assoc. Biota	L	P	A	0.33	1	1	0.33	2.710613654
Fishing	Marine Litter	Benthic Habitats and Assoc. Biota	L	P	A	0.33	1	1	0.33	2.710613654
Fishing	Noise	Cephalopods	WP	P	L	0.67	1	0.05	0.0335	0.275168356

Fishing	Noise	Fish	WP	P	L	0.67	1	0.05	0.0335	0.275168356
Fishing	Noise	Marine Mammals	WP	P	L	0.67	1	0.05	0.0335	0.275168356
Fishing	Noise	Pelagic Habitats and Assoc. Biota	WP	P	L	0.67	1	0.05	0.0335	0.275168356
Fishing	Noise	Benthic Habitats and Assoc. Biota	WP	P	L	0.67	1	0.05	0.0335	0.275168356
Fishing	Species Extraction	Cephalopods	WP	P	A	0.67	1	1	0.67	5.503367116
Fishing	Species Extraction	Fish	WP	P	A	0.67	1	1	0.67	5.503367116
Fishing	Species Extraction	Seabirds	WP	P	A	0.67	1	1	0.67	5.503367116
Fishing	Species Extraction	Marine Mammals	WP	P	A	0.67	1	1	0.67	5.503367116
Fishing	Species Extraction	Pelagic Habitats and Assoc. Biota	WP	P	A	0.67	1	1	0.67	5.503367116
Fishing	Species Extraction	Benthic Habitats and Assoc. Biota	WP	P	A	0.67	1	1	0.67	5.503367116
Harvesting/Collecting	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	C	C	0.03	0.67	0.2	0.00402	0.033020203
Harvesting/Collecting	Physical Seabed Disturbance	Fish	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Marine Litter	Pelagic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Marine Litter	Cephalopods	S	C	L	0.03	0.67	0.05	0.001005	0.008255051

Harvesting/Collecting	Marine Litter	Fish	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Marine Litter	Seabirds	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Marine Litter	Marine Mammals	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Marine Litter	Benthic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Noise	Cephalopods	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Noise	Fish	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Noise	Marine Mammals	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Noise	Pelagic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Noise	Benthic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Noise	Seabirds	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Physical Seabed Disturbance	Seabirds	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Species Extraction	Cephalopods	S	C	C	0.03	0.67	0.2	0.00402	0.033020203
Harvesting/Collecting	Species Extraction	Fish	S	C	C	0.03	0.67	0.2	0.00402	0.033020203

Harvesting/Collecting	Species Extraction	Marine Mammals	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Species Extraction	Pelagic Habitats and Assoc. Biota	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Species Extraction	Seabirds	S	C	L	0.03	0.67	0.05	0.001005	0.008255051
Harvesting/Collecting	Species Extraction	Benthic Habitats and Assoc. Biota	S	C	A	0.03	0.67	1	0.0201	0.165101013
Land-based Industry	Contaminants	Cephalopods	L	P	C	0.33	1	0.2	0.066	0.542122731
Land-based Industry	Contaminants	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731
Land-based Industry	Contaminants	Seabirds	L	P	C	0.33	1	0.2	0.066	0.542122731
Land-based Industry	Contaminants	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731
Land-based Industry	Contaminants	Pelagic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Land-based Industry	Contaminants	Benthic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Land-based Industry	Marine Litter	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Land-based Industry	Marine Litter	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Land-based Industry	Marine Litter	Seabirds	S	P	C	0.03	1	0.2	0.006	0.049283885

Land-based Industry	Marine Litter	Marine Mammals	S	P	C	0.03	1	0.2	0.006	0.049283885
Land-based Industry	Marine Litter	Pelagic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Land-based Industry	Marine Litter	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Land-based Industry	Nutrient and organic enrichment	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Land-based Industry	Nutrient and organic enrichment	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Land-based Industry	Nutrient and organic enrichment	Benthic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Land-based Industry	Nutrient and organic enrichment	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Land-based Industry	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Land-based Industry	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Contaminants	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Contaminants	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Contaminants	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Contaminants	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Contaminants	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592

Military	Contaminants	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Noise	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Noise	Fish	S	O	A	0.03	0.33	1	0.0099	0.08131841
Military	Noise	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Noise	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Noise	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Military	Noise	Marine Mammals	S	O	A	0.03	0.33	1	0.0099	0.08131841
Military	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Physical Seabed Disturbance	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Physical Seabed Disturbance	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Contaminants	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Contaminants	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Contaminants	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Contaminants	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592

Navigational Dredging	Contaminants	Pelagic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Navigational Dredging	Contaminants	Benthic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Navigational Dredging	Noise	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Noise	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Noise	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Noise	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Noise	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Noise	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Non-living Resources	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Non-living Resources	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Non-living Resources	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Physical Seabed Disturbance	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682

Navigational Dredging	Physical Seabed Disturbance	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Physical Seabed Disturbance	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Navigational Dredging	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Nuclear Energy	Contaminants	Cephalopods	E	P	L	0.01	1	0.05	0.0005	0.00410699
Nuclear Energy	Contaminants	Fish	E	P	L	0.01	1	0.05	0.0005	0.00410699
Nuclear Energy	Contaminants	Seabirds	E	P	L	0.01	1	0.05	0.0005	0.00410699
Nuclear Energy	Contaminants	Marine Mammals	E	P	L	0.01	1	0.05	0.0005	0.00410699
Nuclear Energy	Contaminants	Pelagic Habitats and Assoc. Biota	E	P	L	0.01	1	0.05	0.0005	0.00410699
Nuclear Energy	Contaminants	Benthic Habitats and Assoc. Biota	E	P	L	0.01	1	0.05	0.0005	0.00410699
Oil, gas, and hydro	Contaminants	Cephalopods	L	P	C	0.33	1	0.2	0.066	0.542122731
Oil, gas, and hydro	Contaminants	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731
Oil, gas, and hydro	Contaminants	Seabirds	L	P	L	0.33	1	0.05	0.0165	0.135530683
Oil, gas, and hydro	Contaminants	Marine Mammals	L	P	L	0.33	1	0.05	0.0165	0.135530683
Oil, gas, and hydro	Contaminants	Pelagic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Oil, gas, and hydro	Contaminants	Benthic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Oil, gas, and hydro	Noise	Cephalopods	L	P	L	0.33	1	0.05	0.0165	0.135530683

Oil, gas, and hydro	Noise	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731
Oil, gas, and hydro	Noise	Seabirds	L	P	L	0.33	1	0.05	0.0165	0.135530683
Oil, gas, and hydro	Noise	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731
Oil, gas, and hydro	Noise	Pelagic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Oil, gas, and hydro	Noise	Benthic Habitats and As-soc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Oil, gas, and hydro	Physical Seabed Disturbance	Cephalopods	S	P	C	0.03	1	0.2	0.006	0.049283885
Oil, gas, and hydro	Physical Seabed Disturbance	Fish	S	P	C	0.03	1	0.2	0.006	0.049283885
Oil, gas, and hydro	Physical Seabed Disturbance	Marine Mammals	S	P	L	0.03	1	0.05	0.0015	0.012320971
Oil, gas, and hydro	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Oil, gas, and hydro	Physical Seabed Disturbance	Benthic Habitats and As-soc. Biota	S	P	A	0.03	1	1	0.03	0.246419423
Renewable Energy	Contaminants	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Contaminants	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Contaminants	Seabirds	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Contaminants	Marine Mammals	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Contaminants	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Contaminants	Benthic Habitats and As-soc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Renewable Energy	Noise	Cephalopods	L	P	L	0.33	1	0.05	0.0165	0.135530683

Renewable Energy	Noise	Fish	L	P	L	0.33	1	0.05	0.0165	0.135530683
Renewable Energy	Noise	Seabirds	L	P	L	0.33	1	0.05	0.0165	0.135530683
Renewable Energy	Noise	Marine Mammals	L	P	L	0.33	1	0.05	0.0165	0.135530683
Renewable Energy	Noise	Pelagic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Renewable Energy	Noise	Benthic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Renewable Energy	Physical Seabed Disturbance	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Physical Seabed Disturbance	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Physical Seabed Disturbance	Seabirds	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Physical Seabed Disturbance	Marine Mammals	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Renewable Energy	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Research	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	O	A	0.03	0.33	1	0.0099	0.08131841
Research	Physical Seabed Disturbance	Cephalopods	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Physical Seabed Disturbance	Fish	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Research	Noise	Cephalopods	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Research	Noise	Fish	S	O	L	0.03	0.33	0.05	0.000495	0.00406592

Research	Noise	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Research	Noise	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Research	Noise	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Research	Noise	Benthic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Research	Species Extraction	Cephalopods	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Species Extraction	Fish	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Species Extraction	Seabirds	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Species Extraction	Marine Mammals	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Species Extraction	Pelagic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Research	Species Extraction	Benthic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Shipping	Physical Seabed Disturbance	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Shipping	Physical Seabed Disturbance	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Shipping	Contaminants	Cephalopods	WP	P	C	0.67	1	0.2	0.134	1.100673423
Shipping	Contaminants	Fish	WP	P	C	0.67	1	0.2	0.134	1.100673423
Shipping	Contaminants	Seabirds	WP	P	C	0.67	1	0.2	0.134	1.100673423
Shipping	Contaminants	Marine Mammals	WP	P	C	0.67	1	0.2	0.134	1.100673423
Shipping	Contaminants	Pelagic Habitats and Assoc. Biota	WP	P	C	0.67	1	0.2	0.134	1.100673423

Shipping	Contaminants	Benthic Habitats and Assoc. Biota	WP	P	C	0.67	1	0.2	0.134	1.100673423
Shipping	Marine Litter	Cephalopods	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Marine Litter	Fish	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Marine Litter	Seabirds	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Marine Litter	Marine Mammals	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Marine Litter	Pelagic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Marine Litter	Benthic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Noise	Cephalopods	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Noise	Fish	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Noise	Seabirds	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Noise	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731
Shipping	Noise	Pelagic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Noise	Benthic Habitats and Assoc. Biota	L	P	L	0.33	1	0.05	0.0165	0.135530683
Shipping	Non-indigenous Species	Cephalopods	L	P	C	0.33	1	0.2	0.066	0.542122731
Shipping	Non-indigenous Species	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731
Shipping	Non-indigenous Species	Seabirds	L	P	C	0.33	1	0.2	0.066	0.542122731
Shipping	Non-indigenous Species	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731

Shipping	Non-indigenous Species	Pelagic Habitats and Assoc. Biota	L	P	A	0.33	1	1	0.33	2.710613654
Shipping	Non-indigenous Species	Benthic Habitats and Assoc. Biota	L	P	A	0.33	1	1	0.33	2.710613654
Shipping	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Shipping	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Telecommunications	Physical Seabed Disturbance	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Telecommunications	Physical Seabed Disturbance	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Telecommunications	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Telecommunications	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	P	C	0.03	1	0.2	0.006	0.049283885
Tourism/Recreation	Contaminants	Cephalopods	L	O	L	0.33	0.33	0.05	0.005445	0.044725125
Tourism/Recreation	Contaminants	Fish	L	O	L	0.33	0.33	0.05	0.005445	0.044725125
Tourism/Recreation	Contaminants	Seabirds	L	O	L	0.33	0.33	0.05	0.005445	0.044725125
Tourism/Recreation	Contaminants	Marine Mammals	L	O	L	0.33	0.33	0.05	0.005445	0.044725125
Tourism/Recreation	Contaminants	Pelagic Habitats and Assoc. Biota	L	O	L	0.33	0.33	0.05	0.005445	0.044725125

Tourism/Recreation	Contaminants	Benthic Habitats and Assoc. Biota	L	O	C	0.33	0.33	0.2	0.02178	0.178900501
Tourism/Recreation	Marine Litter	Cephalopods	L	O	L	0.33	0.33	0.05	0.005445	0.044725125
Tourism/Recreation	Marine Litter	Fish	L	O	L	0.33	0.33	0.05	0.005445	0.044725125
Tourism/Recreation	Marine Litter	Seabirds	L	O	C	0.33	0.33	0.2	0.02178	0.178900501
Tourism/Recreation	Marine Litter	Marine Mammals	L	O	C	0.33	0.33	0.2	0.02178	0.178900501
Tourism/Recreation	Marine Litter	Pelagic Habitats and Assoc. Biota	L	O	C	0.33	0.33	0.2	0.02178	0.178900501
Tourism/Recreation	Marine Litter	Benthic Habitats and Assoc. Biota	L	O	C	0.33	0.33	0.2	0.02178	0.178900501
Tourism/Recreation	Noise	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Tourism/Recreation	Noise	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Tourism/Recreation	Noise	Pelagic Habitats and Assoc. Biota	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Tourism/Recreation	Non-indigenous Species	Cephalopods	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Tourism/Recreation	Non-indigenous Species	Fish	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Tourism/Recreation	Non-indigenous Species	Seabirds	S	O	L	0.03	0.33	0.05	0.000495	0.00406592

Tourism/Recreation	Non-indigenous Species	Marine Mammals	S	O	L	0.03	0.33	0.05	0.000495	0.00406592
Tourism/Recreation	Non-indigenous Species	Pelagic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Tourism/Recreation	Non-indigenous Species	Benthic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Tourism/Recreation	Species Extraction	Cephalopods	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Tourism/Recreation	Species Extraction	Fish	S	O	A	0.03	0.33	1	0.0099	0.08131841
Tourism/Recreation	Species Extraction	Pelagic Habitats and Assoc. Biota	S	O	C	0.03	0.33	0.2	0.00198	0.016263682
Tourism/Recreation	Species Extraction	Benthic Habitats and Assoc. Biota	S	O	A	0.03	0.33	1	0.0099	0.08131841
Wastewater	Contaminants	Cephalopods	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Contaminants	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Contaminants	Seabirds	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Contaminants	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Contaminants	Pelagic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Contaminants	Benthic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Marine Litter	Cephalopods	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Marine Litter	Fish	L	P	C	0.33	1	0.2	0.066	0.542122731

Wastewater	Marine Litter	Seabirds	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Marine Litter	Marine Mammals	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Marine Litter	Pelagic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Marine Litter	Benthic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Nutrient and organic enrichment	Cephalopods	L	P	L	0.33	1	0.05	0.0165	0.135530683
Wastewater	Nutrient and organic enrichment	Fish	L	P	L	0.33	1	0.05	0.0165	0.135530683
Wastewater	Nutrient and organic enrichment	Pelagic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Nutrient and organic enrichment	Benthic Habitats and Assoc. Biota	L	P	C	0.33	1	0.2	0.066	0.542122731
Wastewater	Physical Seabed Disturbance	Cephalopods	S	P	L	0.03	1	0.05	0.0015	0.012320971
Wastewater	Physical Seabed Disturbance	Fish	S	P	L	0.03	1	0.05	0.0015	0.012320971
Wastewater	Physical Seabed Disturbance	Pelagic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971
Wastewater	Physical Seabed Disturbance	Benthic Habitats and Assoc. Biota	S	P	L	0.03	1	0.05	0.0015	0.012320971

Annex 4: North Sea Ecosystem Overview Revision Manuscript

The manuscript of the North Sea Overview Revision as it was before the 2022 ADGEO. This manuscript was drafted with input from other ICES Expert Groups.

7.1 North Sea ecoregion – Ecosystem Overview

Table of contents

Ecoregion description

The Greater North Sea ecoregion includes the North Sea, English Channel, Skagerrak, and Kattegat. It is a temperate coastal shelf sea with a deep channel in the northwest, a permanently thermally mixed water column in the south and east, and seasonal stratification in the north.

The ecoregion consists of four key areas:

- Northern North Sea (depths 0–500 m) is strongly influenced by oceanic inflow and has a deep channel in the east. The majority of the area is stratified in summer. The dominant human activities are fishing and oil and gas production.
- Southern North Sea (depths 0–50 m) is characterized by large river inputs and strongly mixed water. The dominant human activities are fishing, shipping, ports, gas production, wind farms, and aggregate (sand) extraction.
- The Skagerrak and Kattegat forms the link to the Baltic Sea and is less saline and less tidal than the rest of the ecoregion. The water column is usually mixed. The dominant human activities are fishing, shipping, and wind farms.
- The English Channel joins the southern North Sea to the Atlantic. It is usually mixed and heavily influenced by wind events. The dominant human activities are fishing, shipping, and aggregate (gravel) extraction.

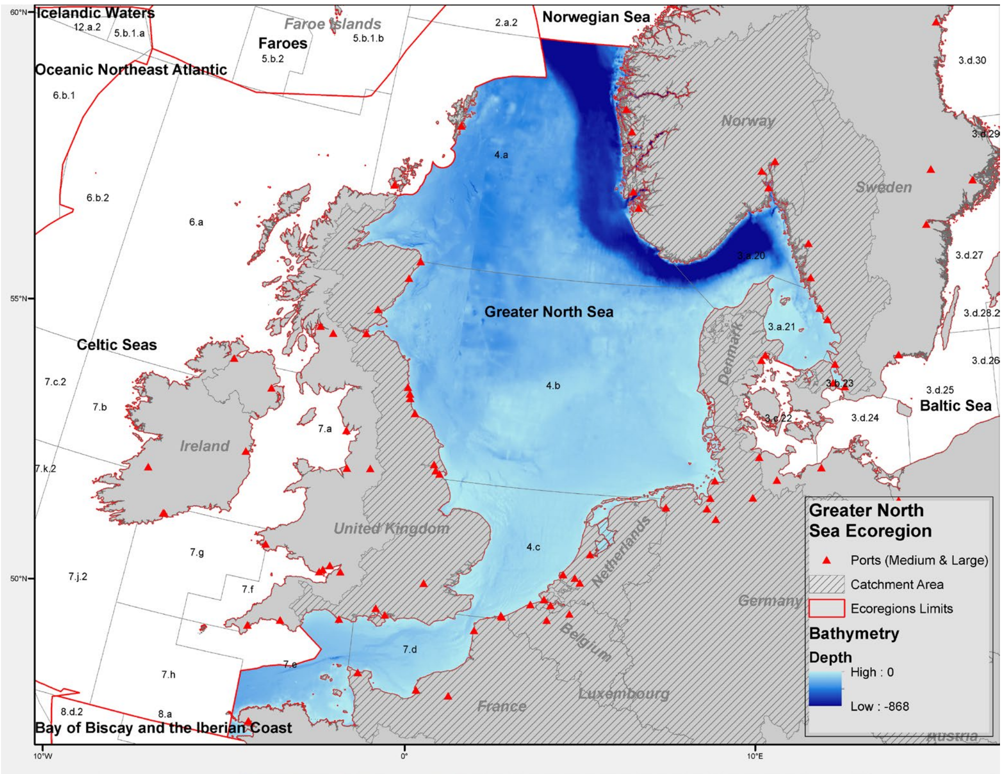

Figure 1 The Greater North Sea ecoregion, showing showing countries, catchment area, bathymetry, subregions described in the text (grey text), neighbouring ecoregions (black text, red lines), medium and large ports (red triangles), and ICES areas (grey lines).

Fisheries management in the Greater North Sea ecoregion is conducted in accordance with the EU Common Fisheries Policy (CFP), by Norway, the UK and by coastal state agreements. Managerial responsibility for salmon is taken by the North Atlantic Salmon Conservation Organization (NASCO) and for large pelagic fish by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Collective fisheries advice is provided by the International Council for the Exploration of the Sea (ICES), the European Commission's Scientific Technical and Economic Committee for Fisheries (STECF), and the North Sea and Pelagic ACs. Environmental policy is managed by national governments and agencies and OSPAR, with advice being provided by national agencies, OSPAR, the European Environment Agency (EEA), and ICES. International shipping is managed under the International Maritime Organization (IMO).

Key signals

Pressures

The five most important pressures are described below. These pressures are linked mainly to the following human activities: fishing, maritime transport (shipping), waste water (sewage), oil and gas exploration and production, and agriculture. The main pressures identified below are described in the ICES Technical Guidelines

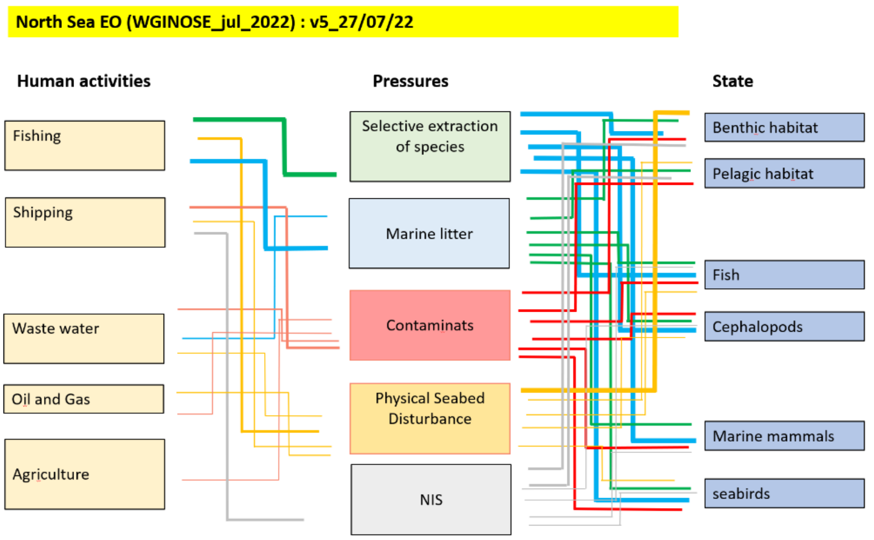

Figure 2 Greater North Sea ecoregion overview with the major regional pressures, human activities, and ecosystem state components. The width of lines indicates the relative importance of main individual links (the scaled strength of pressures should be understood as a relevant strength between the human activities listed and not as an assessment of the actual pressure on the ecosystem). Climate change affects human activities, the intensity of the pressures, and some aspects of state, as well as the links between these. For methodology and definitions, see ICES ecosystem overviews Technical Guidelines.

Selective extraction of the species

The main contributing activity to selective extraction of species in the Greater North Sea is fisheries which peaked in the 1970s at 4 million tonnes but have since declined to about 2 million tonnes (ICES, 2021). In addition, research cruises and recreational fisheries operate in the region. Sustainable fisheries management aims to minimize long-term negative effects on ecosystems while seeking long-term economic and social viability of the fisheries. There has been a significant decline in the overall fishing effort in the Greater North Sea from the 1990s until today (Figure 3). This decline in effort has resulted in a decline in the fishing mortality rate of commercial fish stocks. There have been shifts in fishing techniques. Otter trawling has been increasingly replaced by pulse beam trawling, sum-wing, twin-rigging, and flyshooting, gear types that all require less fuel. The impact of the EU landing obligation is difficult to predict, but fishing behaviour, data gathering, and stock assessments will be affected.

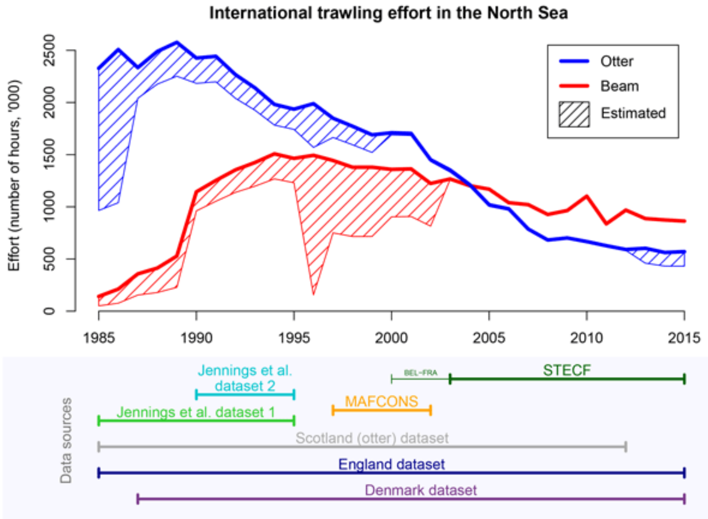

Figure 3 Upper: Reconstructed total fishing hours in the North Sea by beam (red) and otter trawlers (blue) from 1985 to 2015. White-shaded areas show the proportions of the reconstructed total based on compiled (nominal) fishing effort data, and dashed areas show the proportions based on estimated (modelled) data. Lower: timelines for seven sources of compiled (nominal) fishing effort data (Figure 1 from Couce et al., 2020)

Socio-economic indicators of Commercial Fisheries

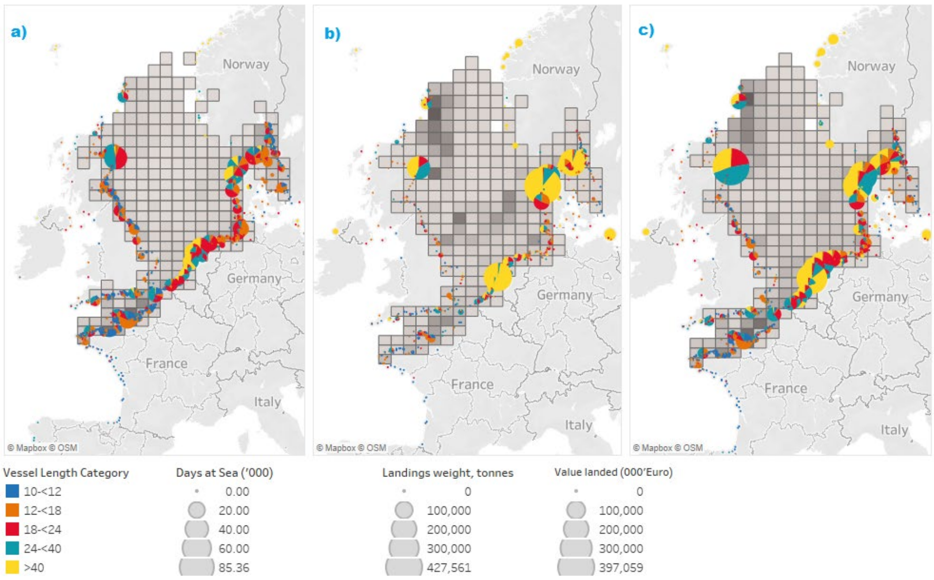

Figure 4 Fishing effort (a), landings by weight (b) and value landed (c) for each port with vessels operating in the Grater North Sea ecoregion (2017-2019). Size of circles indicted magnitude, colours indicate the vessel length category. Small scale fisheries (vessels <10 m) are not included due to a lack of data. Note: Norwegian data is missing

Fishing activity is spread widely around the coasts of the Greater North Sea ecoregion (Figure 4). The fleet varies in vessel size and time spent at sea, with busier ports indicated by larger circles (e.g. Peterhead, Hantsholdm, Skagen and Ijmuiden/Velsen). Analyses of the fishing activity in the Greater North Seas ecoregion indicate that most of the fish landed and effort are associated with the countries bordering the Greater North Sea ecoregion with few landings outside, e.g. in Ireland, Faroese Islands and Spain.

The Greater North Seas ecoregion economic overview

*note data based on STECF AER 2021 data call, recalculated to Greater North Seas ecoregion

Excluding Norwegian data that was not available for the socio economic analysis, EU countries and UK fishing effort in 2012-2019 in terms of days at sea was declining and by 2019 reduced by 11% compared to 2012. The effort reported by EU MS and UK in the Greater NS in 2019 was around 560 thousand days at sea. That includes effort reported for under 10 m boats that represented 35% of total days at sea reported. 7 EU countries fleets plus UK spent more than a thousand fishing days in the Greater North Sea ecoregion. The most fishing effort was reported by UK, followed by France, Denmark, Netherlands, Sweden, Germany and Belgium.

Landings in terms of weight have been increasing from 2012 to 2015 and reducing between 2017 and 2019, however there has been an overall 6% increase in landings between 2012 and 2019 period. The value of landings continuously increased by 18% between 2012 and 2019 in nominal value. The weight of landings of EU countries and UK fishing fleets between 2017 - 19 was about 1.6 million tonnes, while the value was about 2 billion EUR, representing 26% of the total revenue for the EU and UK fleets. The fleets operating in this ecoregion contributed EUR 1,083 million gross value added to the coastal nations economies and produced EUR 477 million gross profit in 2019. A decrease of 10% in gross value added and 16% in gross profits compared to 2018.Denmark, followed by UK, Netherlands, France and Germany landed 94% of fish caught in the North Sea ecoregion. The top 10 species landed in terms of value in 2017 - 2019 were: Atlantic mackerel (10% of total value landed), Atlantic herring (9%), common sole (8%), Great Atlantic (king) scallop (7%), European plaice (7%), common shrimp (7%), Norway lobster (5%), Atlantic cod (5), edible crab (2%) and European lobster (2%).

The Greater North Sea ecoregion in 2017 - 2019 provided jobs for around 15 thousand fishermen, or around 10 thousands jobs in full time equivalent.

Based on value, the United Kingdom, France, Denmark and Dutch fisheries have the largest landings in the Greater North Sea ecoregion region (Norwegian data was not available for the analysis). The Netherlands has the highest total percentage of national landed value (85%), and days-at-sea (98%) in the region indicating their high dependency on this area. Belgium (78%), Denmark (76%) the United Kingdom (61%) and Sweden (51%) also have a high dependence on the area in terms of days at sea. While these countries dependence in terms of value landed from the Greater North Sea ecoregion is as follows: Belgium – 72%, Denmark – 84%, UK – 62%, Sweden – 41%, Germany 53%. The fleet in the region consists of mainly small scale fleet (vessels below 12 m length not using active gears) that account for around 59% of vessels and 39% days at sea, provides job for around 18% of Full Time Equivalent (FTE) employees and produced 10% of value landed, and generate 11% of value added. The rest of the fleet is represented by larger scale vessels and distant water fleets. Distant water fleets (vessels above 40m length) represent a small proportion of vessels that contribute to 5% of total days at sea andemploy 12% of full-time equivalent employees that generate 31% of value landed in the region. The distant water fleet also contribute the most to fishing mortality by supplying 59% of lower value small pelagic fish to the Greater North Sea markets.

The most important fleets in terms of overall employment correlate to those fisheries that have the highest dependency on this area (UK 4,483 FTE on average in 2017-2019, France 2,073 FTE, the Netherlands 1506 FTE and Denmark 1210 FTE). Average wages per FTE for all fleets operating in the Greater North Sea Ecoregion slightly increased in 2019 compared to 2017.

Recent socioeconomic issues (2020-2022)

COVID-19 pandemic

The COVID-19 pandemic impacted the North Sea fisheries in several ways. Governments of coastal states of the North Sea ecoregion enforced lock-downs. Fishers were forbidden to go to sea, processing factories, were either shut or worked on low capacity. Also many retail sector hotels , restaurants and the catering branch (horeca) collapsed..

The 2020 decrease of landings were partially compensated by a reduction of fuel prices. National fleets have been impacted differently depending on the species they catch. Three countries actually performed better, Denmark, Sweden and Germany saw an increase in landings (+35%, +19% and +8% in weight, respectively) and marginal increases in landing value (+0%, +8% and +3% in value, respectively). Other fleets either saw an increase of the landing volume accompanied with a decrease in value such as the UK (+9%; -17%) or a decrease in both volume and value such as the Netherlands (-9%; -15%), France (-6%; -13%) and Belgium (-15%; -19%).

Withdrawal of United Kingdom from the European Union (Brexit)

Since the 1st of January 2021, the UK became an independent coastal state with full responsibility over their EEZ which covers a significant proportion of the Greater North Sea ecoregion. In the Greater North Sea ecoregion, the EU, Norway and now the UK have to cooperate to ensure the sustainable management of more than 100 fish stocks.

Energy price crisis

Since the Winter of 2022, disruption to the energy markets has resulted in increased fuel prices that directly impact the operating costs of fishing with bottom towed gears, these being the most fuel intensive gears. In the Greater North Sea some countries operate mainly towed gears (e.g. Germany, The Netherlands, Belgium, Denmark), while others operate maninly passive gears (Sweden, the UK and France).

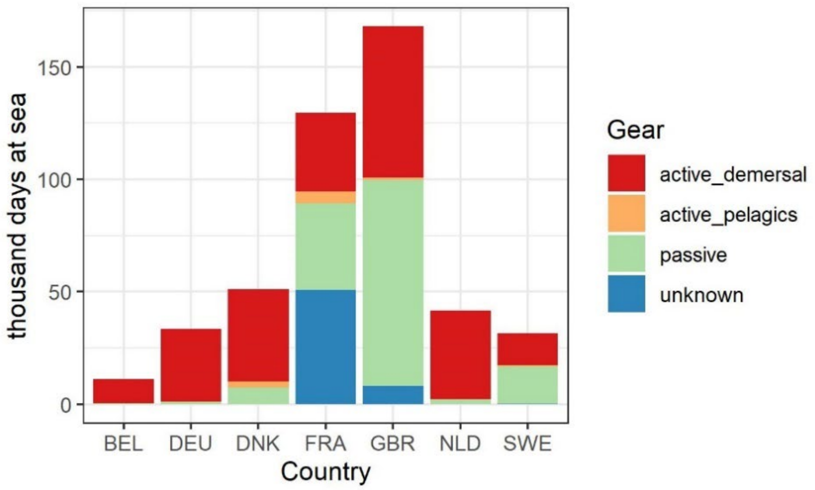

Figure 5 Average annual fishing effort in the Greater North Sea 2017-2019 per country by broad gear category Note: Norwegian data is missing Source: ICES data

Ecological impacts of species extraction, including bycatch
Impact on commercial stocks

Most North Sea fish stocks are now fished at rates at or below FMSY. Overall fishing mortality (F) for shellfish, demersal, and pelagic fish stocks has been reduced since the late 1990s (Figure 6). The relative spawning-stock biomass has also increased since 2000 and is now above or close to the biomass reference points used in stock assessments of most stocks in the Greater North Sea. Even if the mean fishing mortality and biomass ratios are in desirable conditions, several stocks still have relatively high fishing mortality rates above F_{MSY} such as cod, saithe, mackerel (*Scomber scombrus*), blue whiting (*Micromesistius poutassou*), sole (*Solea solea*) in the English Channel, and some *Nephrops* stocks. There are also fisheries on forage fish in the North Sea such as sandeel (Ammodytidae), sprat (*Sprattus sprattus)*, Norway pout (*Trisopterus esmarkii)*, and herring, primarily for fish meal and oil (except for herring, where most of the catch is for human consumption). Currently, multispecies assessment models (which include trophic interactions) are used to evaluate the impact of fisheries and main predators (gadoids, birds, and sea mammals) on the forage fish stocks. An area in the north-western North Sea is closed for sandeel fishing to protect food stocks for seabirds. Detailed information on Greater North Sea fisheries is provided in ICES Greater North Sea ecoregion Fisheries Overview (ICES, 2021).

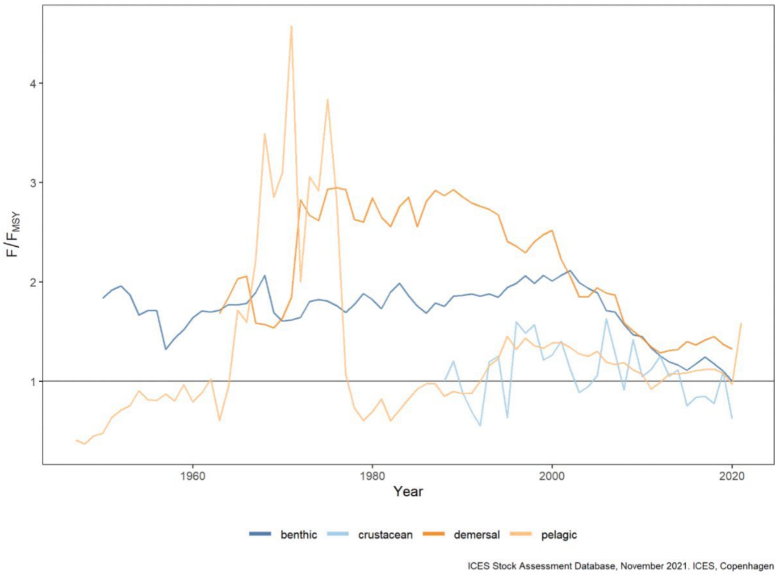

Figure 6 Time-series of annual relative fishing mortality (F to FMSY ratio) by fisheries guild for benthic, demersal, crustaceans, pelagic stocks.

Bycatch and discards of commercial species

Discard data have been collected for some North Sea fisheries since the mid-1970s. Since 2000, discard data from North Sea commercial fisheries have been collected from various observer programmes implemented under the EU Data Collection Framework (DCF). However, complete discard data are only available from 2012 onwards. In 2016–2020, discard rates are highest in the demersal (10-20%) and benthic (20-30%) fisheries, while discard rates of pelagic species were close to zero (ICES 2021). The EU's landing obligation for demersal stocks came partially into force for its Member States in 2016 and has been in full force since 2019.

Impacts on threatened and declining fish species

Incidental bycatches of protected, endangered, and threatened species occur in several North Sea fisheries, and several fish species have been depleted by fishing in the past and are now on the OSPAR list of threatened and declining species (Table 1). These include spurdog (*Squallus acanthias*), the common skate complex (*Dipturus spp*.), angel shark (*Squatina squatina*), porbeagle (*Lamna nasus*), and some deep-water sharks. Despite zero TACs or prohibited listings for these species, several elasmobranchs are caught as bycatch in some fisheries. Discard estimates of these are highly uncertain due to low encounter probabilities.

Impacts on seabirds and marine mammals

Bycatch in bottom-set gillnets is probably the greatest anthropogenic effect affecting population abundance of harbour porpoises (*Phocoena phocoena*) in the North Sea, but ICES has advised that it is within precautionary environmental limits. Bycatch of common dolphins in the western English Channel may be unsustainable in population terms (ICES, 2021). Bycatch of seabirds in the North Sea occurs but is not believed to be a large pressure on the seabird populations.

Recreational fishing

Recreational fishing is an important activity in parts of the North Sea with a diverse range of species exploited from a variety of platforms (e.g., shore, boat) using many gears (e.g., rod and line, speargun, nets, pots, traps), along with hand collecting/harvesting from the shoreline. The proportional impact of recreational fishing is increasing as commercial operations are restrained. Recreational fisheries in the North Sea target a wide range of species, but few of these fisheries are monitored or evaluated. Recreational catches of seabass and salmon (including freshwater for the latter) are significant and are included in ICES assessment of these species. Recent studies suggests that recreational anglers in western Norway (Hordaland) landed at least as much cod in coastal waters as commercial fishers (Ferter el al., in review).

Marine Litter

Occurrence of marine litter in the North Sea region

The distribution of marine litter in the North Sea region is now monitored through seafloor trawl surveys and beach litter cleaning schemes. The monitoring of plastic ingestion in fulmars is also used as an impact indicator.

Within the ICES coordinated International Bottom Trawl Survey (IBTS) and Beam Trawl Survey (BTS), litter occurrence is recorded following specific procedures on litter classification and reporting (ICES, in press).

The ICES Datras database (ICES, 2021) provides the basis for the seafloor litter assessment within the OSPAR quality status report (QSR) 2023 (Barry et al., 2022). Figure 7 shows the seafloor litter distribution covering the the North Sea Ecoregion based on 2018 seafloor litter data (ICES, 2021). Seafloor litter is widespread in the Greater North Sea (Barry et al., 2022), with plastic being the most dominant material (2012 - 2019 data) found. Based on all the standardised litter surveys samples collected to date, it has been noted there is an increasing probability of finding litter in survey samples in recent years, with an overall probability of 69% in the Greater North Sea Ecoregion. The most common litter items are plastic sheets, synthetic ropes, monofilament fishing line and plastic bags, with occurrence probabilities of 32%, 26%, 24% and 15%, respectively.

In a recent study, the link between fisheries activities and the occurrence of seafloor litter in the North Sea has been investigated revealing that (Vanavermaete, in prep.) 25% of litter items could be linked to fisheries. However, no significant spatial correlation has been established between fishing activity and fishing-related litter items within the Greater North Sea Ecoregion.

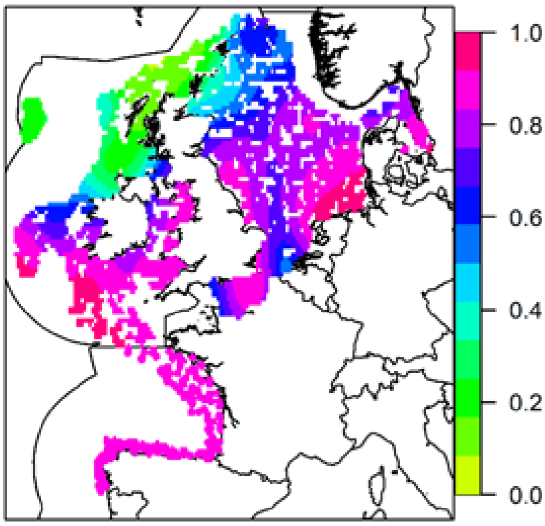

Figure 7 Smoothed probability of sampling litter items, based on 2018 data (ICES, 2021).

Beach litter is also recorded at 100m stretches of coastline according to standardized protocols (OSPAR, 2010). In the North Sea Ecoregion, the main litter items found were plastic and polystyrene pieces, nets and ropes and plastic caps and lids, counting for more than 70% of total litter items found (OSPAR, 2017a). Highest amounts of litter by weight were found in the Skagerak region (OSPAR, 2019). In the Southern North Sea 29% of the monitored beaches revealed a decreasing trend in total litter items between December 2009 and January 2018, compared to only 3% of the beaches showing an increasing trend. In the Northern North Sea, 24% of the beaches revealed a decreasing trend and 12% a increasing trend (OSPAR, 2019).

Impacts of marine litter in the North Sea region

All the possible effects of litter and especially micro- and nanoplastics on marine organisms are still under investigation. There is abundant evidence, however, that plastic debris can lead to the death of individual animals of several marine species such as whales, seabirds and seals. Litter is widespread in the marine environment and is harmful to wildlife and the ecosystem (OSPAR, 2017b). Depending on the material type, marine litter can float on the sea surface, wash up on the beach, circulate in the water column, settle on the seabed or bury itself deeper in the sediment.

Within the Marine Strategy Framework Directive (MSFD), secoundary criteria D10C3 (Litter ingested by fulmars) and D10C4 (Adverse effects of litter) are directly related to the impact assessment of marine litter. An assessment of the impact of floating plastic litter is achieved by undertaking stomach analyses of stranded birds, as in the case of the fulmar. Currently 58% of beached North Sea fulmars have more than 0.1 g of plastic in their stomachs, exceeding OSPAR's long-term goal of 10%. Ingestion of plastic litter is recognised as a potential threat contributing to the status of fulmar populations, given that it is probable that sub-lethal effects of reduced body condition and health, affect a significant proportion of individuals in the population (OSPAR, 2017b). It is proposed the MSFD environmental target for floating plastic litter should be as follows: "Over a period of at least five consecutive years, no more than 10% of fulmars in samples of at least 100 individuals shall have stomach plastic particle levels exceeding 0.1 g" (van Franeker et al., 2021).

Monitoring of stranded seabirds on North Sea coasts shows that seabirds, e.g. Gannets, can be entangled in litter. Marine mammals also regularly come into contact with litter. Whilst porpoises and seals seem to ingest very little plastic, they can become entangled in rope or drifting fishing nets.

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Contaminating compounds (synthetic and non-synthetic)

Contamination in the Greater North Sea is mainly derived from shipping (including inputs as a result of fishing effort), industrial and urban inputs (wastewater, inputs from rivers and atmospheric inputs), agricultural run-off, oil and gas extraction, and renewable energy installations. Solid wastes (litter) are covered in litter section.

Contamination appears high on the list of pressures as a result of its high prevalence. There are many sectors that are introducing various synthetic and non-synthetic compounds into the marine environment. As many of the contaminating compounds are (sometimes extremely) persistent, nearly all habitats and ecological components are affected to some degree (Figure 2). Inputs of many contaminant sources are regulated, monitored, and managed within the ecoregion. Contamination in the Greater North Sea is showing some downward trends, and concentrations measured are typically below adverse effects levels (Moffat et al, 2021). Recent monitoring trends in the Greater North sea show in some regions increases in metals (Cd, Hg and Pb) in the southern North Sea, and decreases in PAHs and PCBs in the northern North Sea, and decreases in PBDEs for both subregions (OSPAR, 2022). However, contaminants remain high risk both due to the numerous sources, as well as the broader number of chemicals being put into use with limited understanding on their fate, behaviour and ecotoxicological effects, especially in mixtures. These contaminants, defined as contaminants of emerging concern (CECs) are currently not being included in routine monitoring programmes (EEA, 2018 and ICES, 2022). Inclusion of monitoring of biological effects directly (where not already being completed) as well as development of non-targeted screening methods for potentially identifying presence of CECs are likely to be introduced in monitoring programmes to improve future assessments.

Ships can be regarded as floating industries giving rise to a range of different liquid and gaseous waste streams, which often are complex chemical mixtures. Bilge water originates from the machinery spaces and contains oily residues from fuel oil and lubricants, detergents, and metals from wear and tear (Jalkanen et al., 2021; Magnusson et al., 2018; Tiselius & Magnusson, 2017). International regulations limit the oil content of treated bilge water to maximum 15 ppm oil, but metals are yet not regulated and treated bilge water have been reported to contain metals (V, Mn, Ni, Cu and Zn) and PAHs. Although all ships produce bilge water, the total load of contaminants is small compared to metal and PAH loads from exhaust gas cleaning systems, also known as scrubbers (Hassellöv et al., 2020; ICES, 2020; Jalkanen et al., 2021; Lunde Hermansson et al., 2021; Maljutenko et al., 2021; Ytreberg et al., 2022). The use of scrubbers has increased as a response to the stricter regulations limiting the maximum allowed sulphur content in marine fuels. A scrubber installation allows the shipowner to use cheap residual oil, where the metals, e.g. vanadium, are concentrated during the refinery process, instead of switching to more expensive, cleaner fuels such as distilled marine gas oil (MGO). Outside Sulphur Emission Control Areas (SECA) most ships use Very Low Sulphur Fuel Oil (VLSFO) or Ultra Low Sulfur Fuel Oil (ULSFO), which are a mix of a residual fraction and a distilled fraction to meet maximum 0.5 %(w/w) sulphur in the fuel (IEA, 2020). These oils (VLSGO, ULSFO) behave differently as they are less buoyant and so tend to sink and then resurface. For all types of fuel, there is a knowledge gap with respect to deposition of contaminants on the sea surface, although Ito (2013) and Zhang et al. (2021) have shown that ship plumes cause deposition of metals such as e.g. Fe and V. In addition to liquid waste streams and atmospheric deposition of contaminants from ships, the single most important shipborne source of Cu, and to little less extent, Zn, is antifouling paint (Ytreberg et al., 2022).

There are also contaminant inputs of wastewater from industrial and urban inputs as well as agricultural run-off from rivers into the marine environment. While inputs are mostly regulated, the persistent nature of many of these contaminants cannot be discounted. Other noted contaminant inputs are related to oil and gas extraction, and to ever expanding renewable energy instalments. First results the OffChEm project, which is looking at metal distributions in wind-farm areas to assess the potential environmental impact of corrosion protection measures (Kirchgeorg et al. 2018), and another study on elemental composition of galvanic anodes (Reese et al. 2020), reveal that considerable amounts of trace metals from offshore windfarms corrosion protection systems are emitted into the marine environment throughout their lifespan. Among these are also ecotoxicologically critical metals such as Cd, Pb, and Zn. The ANODE project (Michelet et al, 2020) provides a hydrodynamic model for chemical risk assessment of wind farms. It highlights that the main composition of galvanic anodes is an aluminium alloy which contains a large share of aluminium (about 95%), as well as zinc (about 5%) and other trace metals (‹ 1%): copper, iron, indium or cadmium. (ICES, 2022).

Impacts

Acute and chronic impacts include toxicity to marine organisms and foodwebs (including humans). Additionally, bioaccumulation in higher trophic levels and the interacting effects of multiple contaminants remain difficult to assess. For example, marine mammals may experience immune or reproductive systems depression by bioaccumulation of contaminants (especially legacy compounds like chlorinated pesticides, CBs, BDEs,, as well as CECs such as PFAs) from their food sources.

Since the global ban on TBT (in 2008) there has been a marked improvement in the levels of imposex in marine gastropods (whelks) with continued decreases noted in North Sea (Parmentier, et al, 2019 , OSPAR, 2022).

Warford, et al, 2022 highlight that the current tributyltin action levels used for dredged sediment assessment prior to disposal at sea should be updated, as the concentrations in the marine environment are now much lower than when they were originally defined. Moreover, studies reveal that several fish larvae are even more sensitive than the dogwhelk, designed as biological effect indicator.

MOAT (Marine online assessment tool, 2022) gives current assessment on trends in biological effects of contaminants for the common dab which indicate a decreasing trend (not assessed) in EROD enzyme (7-ethoxy-resorufin-O-deethylase, an indicator of PAHs and PCBs) activity, as well as a stable trend for bile metabolite (indicator of PAH exposure), and a sharp decrease in liver neoplasms in the common dab in the Greater North Sea region.

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Physical seabed disturbance

Abrasion

Physical disturbance of benthic habitats by bottom trawl fishing gear is described by using vessel monitoring system (VMS) and logbook data. The extent, magnitude, and impact of mobile bottom-contacting fishing gear on the seabed and benthic habitats varies geographically across the North Sea.

Using vessel monitoring system (VMS) and logbook data ICES estimates that mobile bottom trawls used by commercial fisheries in the 12 m+ vessel category have been deployed over approximately 490 185 km2 of the ecoregion in 2018, corresponding to ca. 73.1 % of the ecoregion's spatial extent (Figure 8).

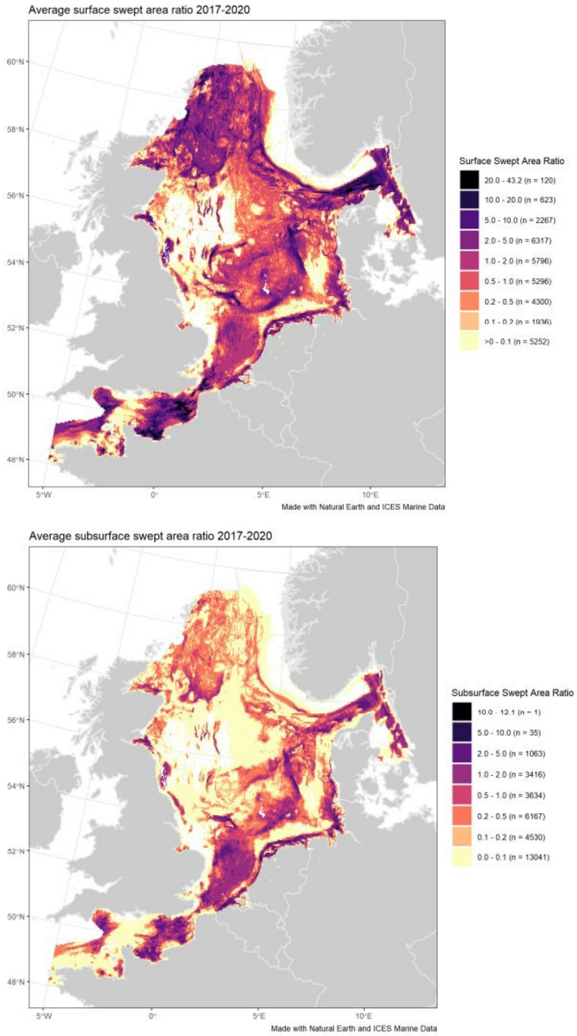

Figure 8 Average annual subsurface (left) and surface (right) disturbance by mobile bottom contacting fishing gear (Bottom otter trawls, Bottom seines, Dredges, Beam trawls) in the Greater North Sea during 2017-2020 (with available data), expressed as average swept area ratios (SAR).

Smothering

Dredging and dumping operations and techniques have not changed recently. The total annual amounts dumped at sea have varied between 80 and 130 million tonnes (dry weight); much of this activity is associated with port expansion and deepening of navigation channels. In 2005, there were around 350 dumpsites in the OSPAR area. About 90% of all sediments dumped each year are dredged and dumped in the southern North Sea. This is largely from maintaining navigation channels to major seaports such as Hull, Antwerp, Rotterdam, Hamburg, and Esbjerg. Cable laying activities have increased (and are projected to continue to increase) proportionate to current plans for offshore wind farm development. Ship traffic and vessel size are predicted to increase from the present until 2020, which will increase the need to maintain (and possibly deepen) navigation channels.

Substrate loss

Extensive lengths of coastline in the North Sea are protected against erosion by coastal defence structures. The almost unbroken line of coastal defence schemes protecting the southern coast of the North Sea has caused extensive fragmentation and loss of habitats. Since 1998, OSPAR countries have reported on the reclamation of around 145 hectares from the sea and coastal wetlands, with the majority of this activity in the Greater North Sea. The largest land reclamation in Europe, Maasvlakte 2, is in Rotterdam port. However, both UK and Dutch authorities are also allowing sea re-encroachment in the southern North Sea as part of flood defences, creating more coastal wetlands. One scheme alone in England has re-flooded some 600 hectares.
Many permanent or semi-permanent structures have been placed offshore in the North Sea, most associated with oil and gas production. Offshore wind farm development has started in the last decade with greater development planned for areas further offshore.

NIS – Nonindigenous species

The North Sea region in the ICES AquaNIS database has ≈ 470 non-indigenous species (NIS) and cryptogenic species (CS) with over 1100 introduction events recorded between 1950 to 2022. It should be noted that the North Sea in that database is defined by the IOC UNESCO Large Marine Ecosystems (LME). Within the ICES Greater North Sea (GNS) region, an estimated 142 species arrived between 1950 and 1999, and from 2000 to 2014, 60 new NIS or CS invasions to Europe were first recorded. More recently, between 2015-2022, 49 new NIS or CS species have been reported in the GNS with 55 reported introduction events. (Figure 9).

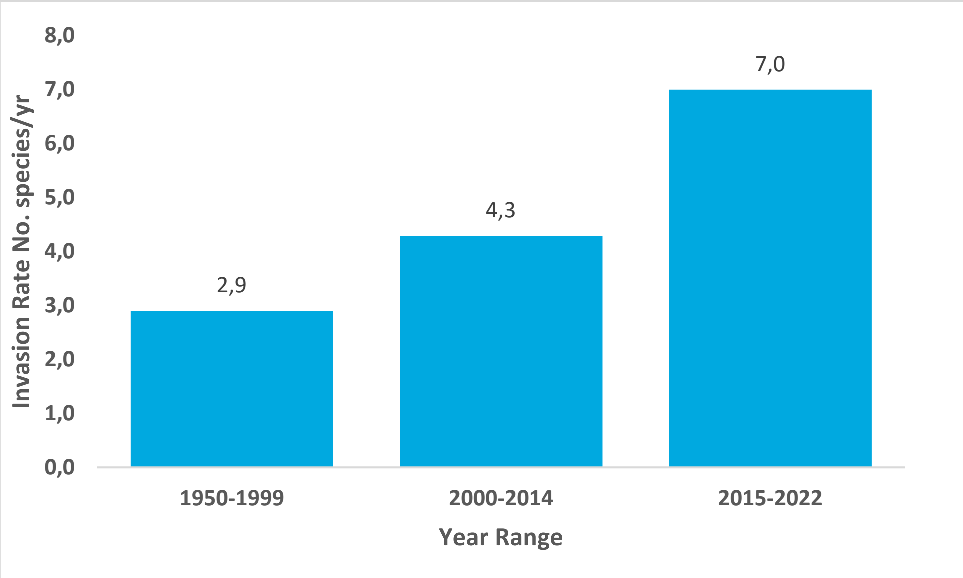

Figure 9. Annual rate of new species introductions to the Greater North Sea between 1950-1999, 2000-2014 and 2015-2022.

The pathway[3] that has contributed most to the NIS introductions into the GNS waters until 2020 was shipping (TS-Ball, TS-Hull and TS-Other, 53 %) (Figure 10). In addition, Transport Contaminant was responsible for 18 % of the introduction, whereas UNK, EC, REL and UNA pathways contributed to a lesser extent (12% or less for each pathway). As the GNS area is outright

[3] Common methodology – Each NIS was assigned with its most likely pathway of introduction, and the pathways follow the Convention on Biological Diversity (CBD) definitions (Figure 9) (CBD, 2014). The pathway designation for each species follows the EASIN classification (Pergl et al., 2020), where the assessment includes all documented or suspected introduction vectors and gives equal weight to each pathway if more than one pathway is reported for the NIS. Therefore, the total sum of pathways per species equals to one.

connected to other European seas, corridor pathway did not contribute to any of the NIS introductions to the GNS. Pathway assessment per 6-year assessment periods revealed that ballast water, hull fouling, transport contaminant and unknown introduction pathways have contributed in an increasing manner to NIS introductions in the GNS (Figure 11).

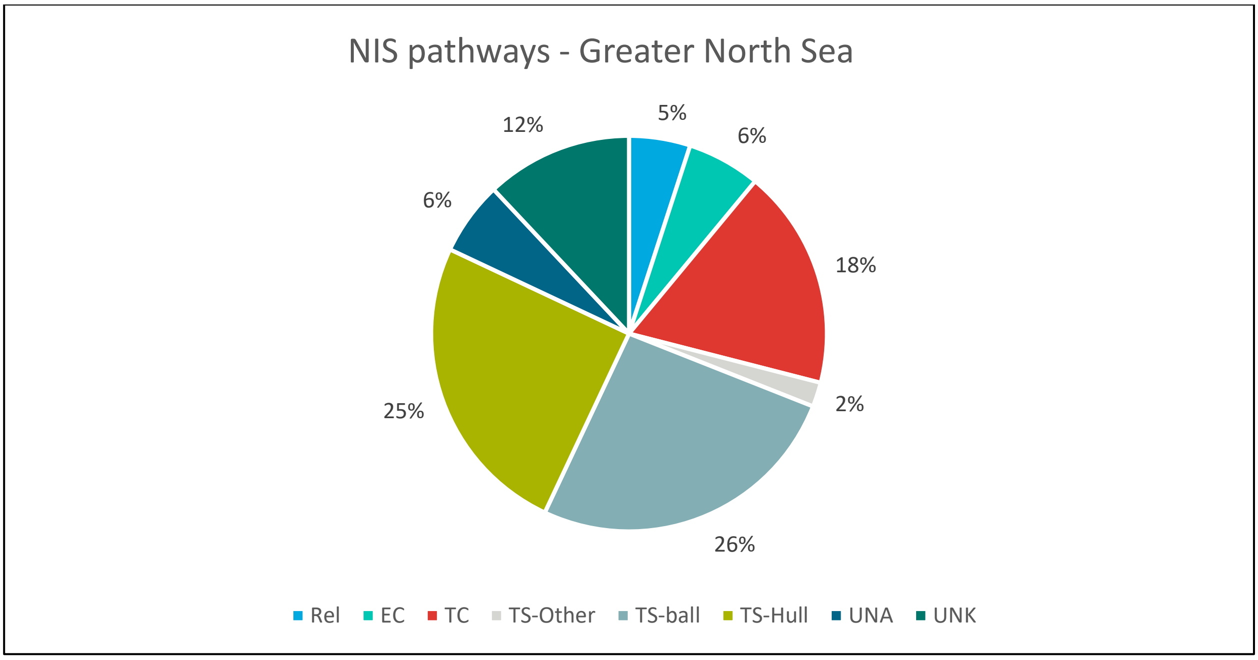

Figure 10. Contribution of each NIS pathway to Greater North Sea until 2020. Pathway abbreviations; REL= Release in nature including intentional release of aquarium species TC =TRANSPORT- CONTAMINANT, including Contaminant on animals (except parasites, species transported by host/vector) and Parasites on animals (including species transported by host and vector), EC = ESCAPE FROM CONFINEMENT, referring to the accidental escape, TS: TRANSPORT- STOWAWAY, including Ship/boat ballast water (TS-ballasts), Ship/boat hull fouling (TS hull) and Other means of transport (TS-other), COR = CORRIDOR: Interconnected waterways/basins/seas (in the current context this refers to the Suez Canal, and man-made canals), UNA= UNAIDED, secondary spread, as appropriate., UNK = UNKNOWN (CBD, 2014).

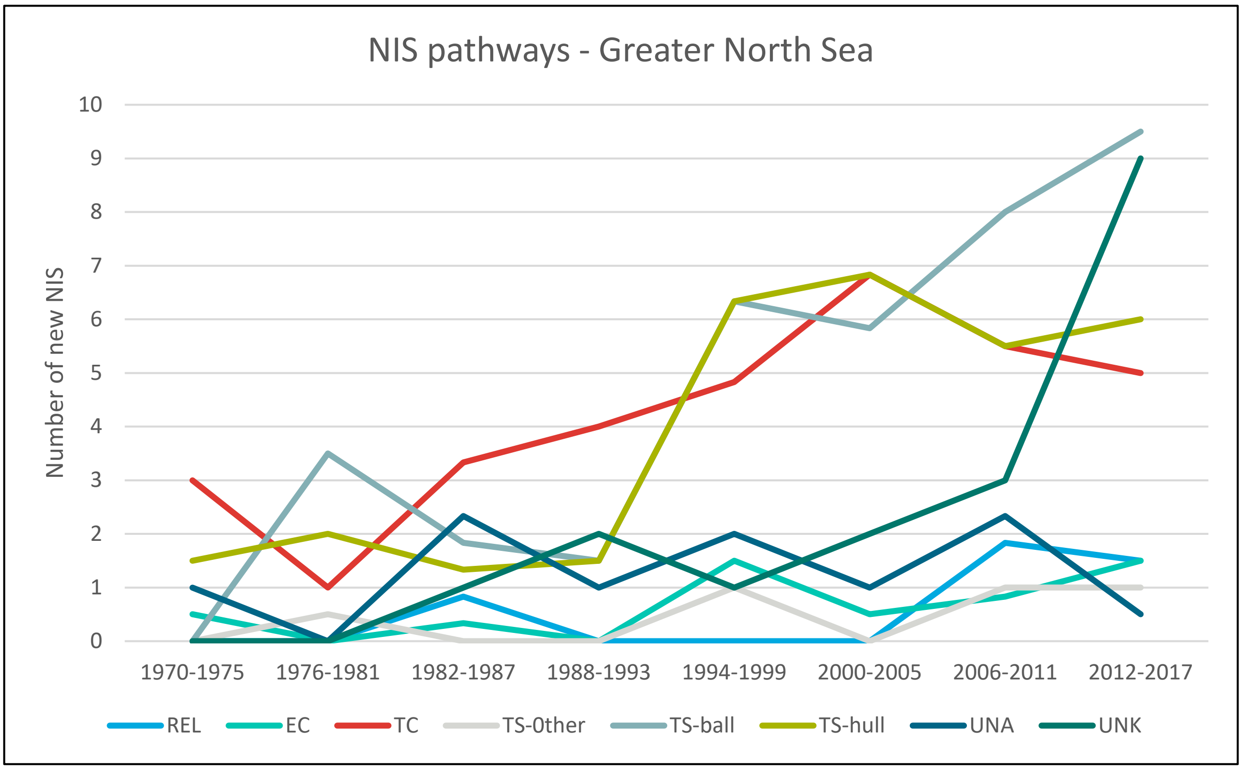

Figure 11. Contribution of each NIS pathway to Greater North Sea per 6-year assessment periods since 1970.

The observed ecological impacts include significant reductions in the abundance of several important native species, changes to the physical and chemical composition of both sediments and the water column. Additional impacts include: out-competing native commercial species, fouling of aquaculture and fishing gear and fish kills through toxin production.

Climate change impacts

Dagmar will send by Friday

Temporal changes in the solar radiation and the heat fluxes across the air-sea interface are the essential drivers of near-surface temperature variability. Differences between the mean temperature of the surface water and the mean air temperature immediately above the water are typically less than 1°C. Consequently, there is a pronounced annual cycle in the temperature of the near-surface water layer with a maximum of about 16°C in summer (averaged over the North Sea area) and a minimum of about 6°C in late winter. Further temperature variability is caused by advective water displacement via ocean currents as well as by horizontal and vertical mixing processes.

At the beginning of the seasonal warming period, between late March and early May, stratification of the temperature field starts to build up. The bathymetry and strength of tidal currents are key to whether locations remain vertically mixed year-round, or whether seasonal stratification develops. Temperature differences between the warm mixed layer and the deeper waters reach their maximum in August. The depth of the thermocline is located on average at depths between 20 and 40 m, while the deepest position is generally found in late August to mid-September. In the region of the Norwegian Trench, it can be located as deep as 100 m. From mid-September onwards and facilitated by the onset of the storm season, the North Sea is on average vertically mixed again. Climatological large-scale distributions of the near-surface temperature reveal a northwest-southeast gradient over the winter months (January-March), with higher temperatures in the northwestern North Sea and lower temperatures at the German and Danish coasts in the southeast. Summer distributions show a reversed pattern with the highest temperatures in the English Channel and the German Bight and lowest temperatures near Scotland.

The large-scale distribution of salinity is influenced by advective transports via ocean currents, in particular saline and fresh imports via the northern, southern or eastern boundaries of the North Sea, as well as by horizontal and vertical mixing processes. Runoff from major continental and UK rivers that discharge into the North Sea dilute the coastal areas. This is especially prominent in the southern North Sea and German Bight area as well as near the mouths of various British rivers. The southward propagation of Atlantic Water sets conditions in the northern North Sea, which is typically characterized by salinities exceeding $S = 35$. Mixing with the lower salinity of the Baltic Sea water reduces the salinity in the region of the Baltic outflow to values lower than $S = 34$. Both, Atlantic and Baltic inflow, show clear patterns of interannual variability. Climatological large-scale distributions of the near-surface salinity reveal strong salinity gradients that stretch along the coasts of the European mainland. Low salinity waters with $S < 32$ characterize the regions close to the coastal zones, while the large-scale interior of the North Sea shows salinities exceeding $S = 34.5$. Winter and summer months show generally rather similar spatial distributions, but surface salinities exceeding $S = 35$ tend to propagate into the central North Sea more strongly in winter while they retreat to the northwest in summer.

Recent trends

Strong natural variability and limited lengths of measured time series for certain parameters make it difficult to identify patterns and trends pointing to anthropogenic variability, thus distinguishing respective signals from the natural background noise.

Figures 11 and 12 depict the annual temperature and salinity evolution at key monitoring sites in the North Sea Ecoregion for the period 2012 to 2021. The various sites show minor differences in the patterns of interannual variability for both temperature and salinity, highlighting the dynamic nature of the system. Since 2017 (the last five years), temperatures in many time series have been close to the long-term average (between -1 and 1 standard anomaly), with a possible tendency towards cooler than average conditions (Figure 12).

Sea surface temperatures (SST) observed since 1969 and averaged over the entire North Sea (not shown) reveal frequent changes between cold and warm phases over time. Since the 1980s, SSTs show a general tendency towards a warming. SSTs in 2021 were lower than in the previous years but similarly exceeded the long-term SST average in the period 1991-2021, which is common in recent years. The annual mean temperatures in 2021 at the northern boundary were close to the 1991-2020 mean (see Fair Isle Current Water, Cooled Atlantic Water, and the two Utsira time series in Figure 12).

Annual mean salinity observed at these key monitoring sites in 2021 was mostly similar to the previous year (Figure 13). An inflow of saline Atlantic Water via the southern import route to the North Sea was not observed in 2021. In the last decade, a freshening trend has emerged at all sites along the northern boundary. During this period, a significant freshening event occurred in the wider sub-polar north-east Atlantic. While no formal attribution studies have been done, this signal is considered mainly due to the advection of lower salinity water masses to the North Sea.

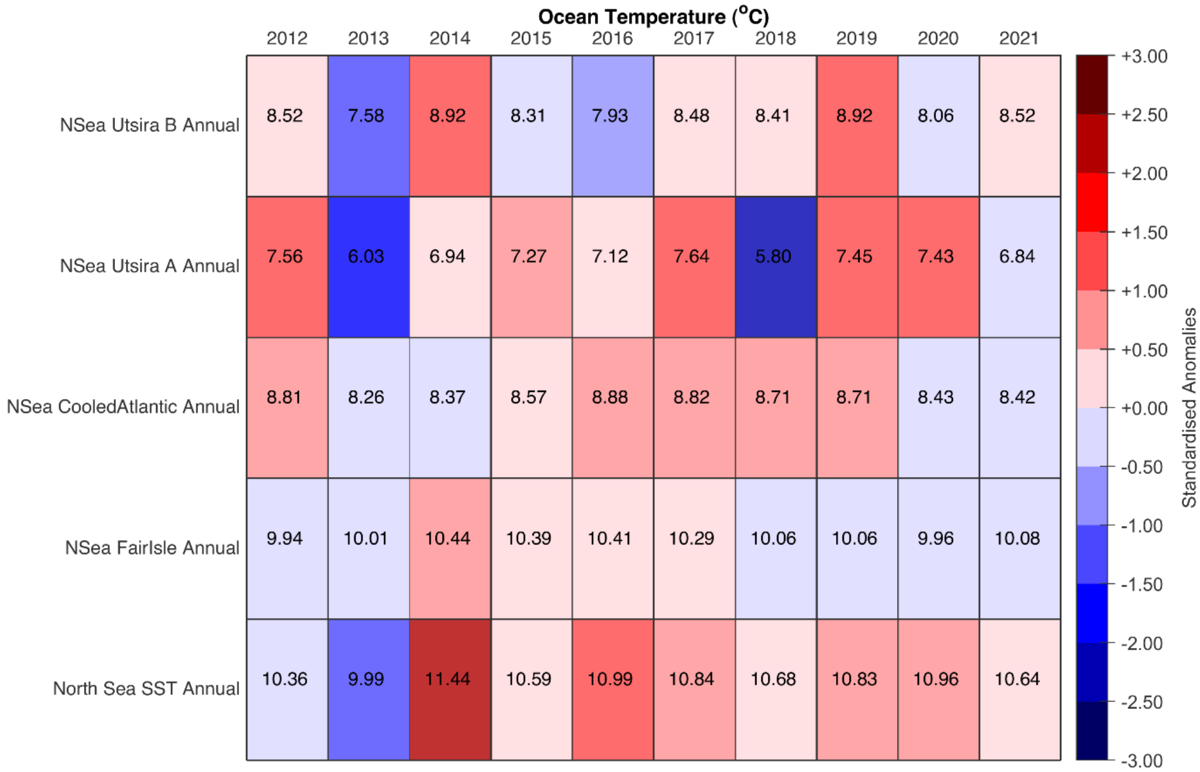

Figure 12. Annual mean sea temperatures at key monitoring sites in the North Sea Ecoregion, as reported to the ICES Report on Ocean Climate. Data provided by the Institute for Marine Research (Norway), Marine Scotland Science (UK) and the German Federal Maritime and Hydrographic Agency (Germany). Colours show the anomalies, calculated by removing the 1991-2020 mean and dividing by the standard deviation in the same period, numbers within boxes are the observed annual mean temperature in degrees Celsius.

Figure 13. Annual mean salinities at key monitoring sites at the northern boundary of the northern North Sea Ecoregion, as reported to the ICES Report on Ocean Climate. Data provided by the Institute for Marine Research (Norway) and Marine Scotland Science (UK). Colours show the anomalies, calculated by removing the 1991-2020 mean and dividing by the standard deviation in the same period, numbers within boxes are the observed annual mean practical salinity.

Computer model simulations show that the total inflow of AW into the North Sea between the Orkney Islands and Utsira (Norway) was relatively low in 2021 (6th lowest inflow since 1985, the start of the time series, bottom row in in Figure 14). Combined with the reduced total outflow, this resulted in a decrease of the net flow, which is directed to the north. While it was rather stable over many years, it was the third lowest net flow since 1985 (top row in Figure 14).

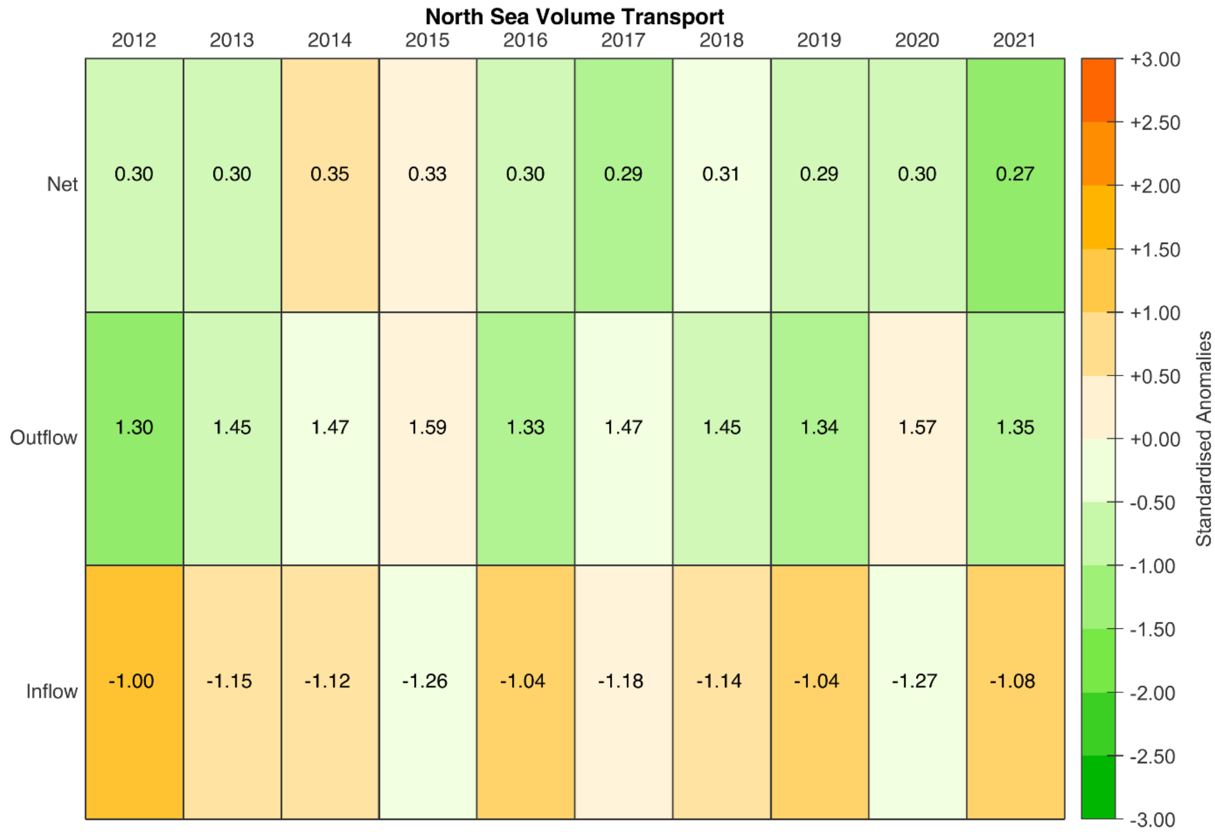

Figure 14. Annual modelled volume transport between Orkney (Scotland) and Utsira (Norway), as reported to the ICES Report on Ocean Climate by the Institute of Marine Research (Norway). Inflow (negative) is flow in a southwards direction; outflow (positive) is flow in a northward direction, and net flow (positive northward). Colours show the anomalies, calculated by removing the 1985-2021 mean and dividing by the standard deviation in the same period, numbers within the boxes are the modelled transport in Sverdrup (1 Sverdrup = 1 x 106 m3/s).

Further details on time-series at key monitoring sites can be assessed in the ICES Report on Ocean Climate and its online data portal (https://ocean.ices.dk/core/iroc).

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NIS – Nonindigenous species

Climate warming will open up new thermally defined habitats for previously denied nonindigenous species (e.g. sub-tropical species in the North Sea) and invasive species allowing them to establish viable populations in areas that were once environmentally unsuitable (Edwards et al 2016). The invasive diatom *Coscinodiscus wailesii*, which has become a persistent and significant member of the plankton community, has spread from its first record off Plymouth in 1977 throughout all coastal waters of northern Europe and out into the Atlantic in a matter of only 30 years. Edwards et al (2001). The copepod species *Pseudodiaptomus marinus* naturally occurs in east Asiatic waters but since 2007 has been subsequently spreading more widely in the North Sea over the last decade (Wootton et al 2013). The invasive ctenophore *Mnemiopsis leidyi* has been considered among the most severe invasive non-native species worldwide (Lowe et. al 2000). The species was first recorded in the North Sea in 2005 and is now widely distributed in the southern and eastern North Sea (Jaspers et al 2018).

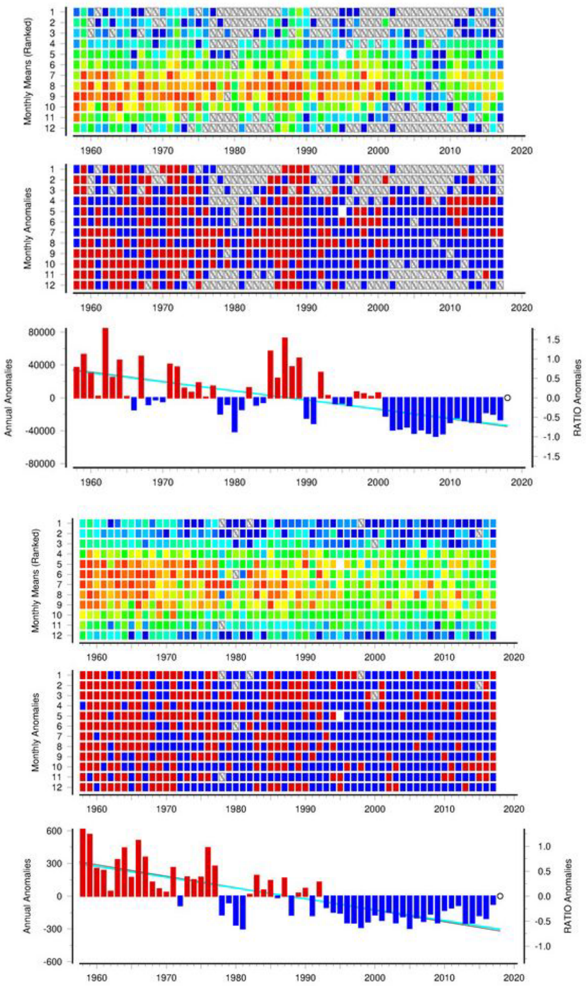

Figure: MBA/CPR Survey standard area C2 (western central North Sea) a) Total Dinoflagellates (#/m3) b) Total copepods (#/m3). Upper panels: matrix of monthly mean (total copepod) abundances over time. Mid panel: Monthly nomalies. Bottom panel: annual anomalies. The decreasing trend in total copepods is driven by “small copepods” (<

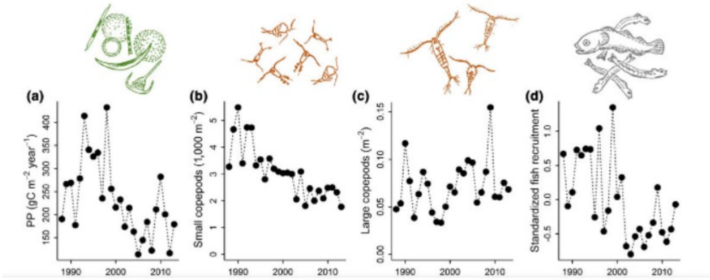

Figure: Interannual variation in annual primary production (PP, gCm2 year1), mean abundance of small copepods (1000 x m-3) and large copepods (m-2), and a standardized index og fish stock recruitment (Figure from Capuzzo et al, 2018).

State of the ecosystem

Oceanographic conditions and circulation

The North Sea is the shallow shelf sea enclosed by the British Isles to the west, and Norway, Sweden, Denmark, Germany, the Netherlands, Belgium and France to the east. It forms part of the Northwest European Shelf and is rather shallow in its central to southern part (mostly < 50 m), while the northern part reveals water depth exceeding 700 m in the Norwegian Trench. The northern boundary of the North Sea is characterized by a wide opening to the north-east Atlantic allowing a vital exchange of oceanic properties between the North Sea and the north-east Atlantic. At its south-western boundary, the connection to the Atlantic Ocean is strongly limited by the narrow English Channel and its bottleneck in the Strait of Dover. While this southern exchange route plays a minor role for the entire North Sea, it is not negligible for the oceanographic state of the southern North Sea and the German Bight. In the east, the North Sea is connected to the fresh Baltic Sea via a complex system of belts and sounds, the Kattegat and the Skagerrak.

Exchange processes between the North Sea, the north-east Atlantic, and the Baltic Sea shape the large-scale distribution of hydrographic properties in the northern and central North Sea. Inflow of warm and saline Atlantic Water (AW) mainly happens via the East Shetland Shelf, the Fair Isle Channel (between the Orkney and Shetland Islands), and the Norwegian Trench. AW import is a major supplier of heat, salt, and nutrients. About 90% of the nutrient import into the North Sea is associated with oceanic inflow from the Atlantic. In contrast, fresh outflow from the Baltic Sea enters the North Sea via the Kattegat and Skagerrak and leaves the North Sea towards the north as part of the near-surface layer of the Norwegian Coastal Current (NCC).

The continental edge in the south-eastern part of the North Sea is characterized by the shallow Wadden Sea. It can be as wide as 40 km, and modulation of the water column by a pronounced tidal cycle is strong. The Wadden Sea stretches over a distance of approximately 450 km from the Netherlands in the south-west of the German Bight to Denmark at the north-eastern edge of this region. It forms an important transition zone between the coastal waters close to the European continent and the North Sea proper. The coastal waters in this region in turn are strongly influenced by run-off from major continental rivers like the Scheldt, Meuse, Rhine, Ems, Weser, and Elbe.

The oceanographic current system of the North Sea is a superposition of tidal-, wind-, and density-driven currents. The tidal currents have a strong twice-daily pattern (i.e. semi-diurnal) and can be eliminated from the current field by averaging over one or more tidal periods (12.5 hours). Consequently, the so-called residual current field emerges, which represents the net flow of water in relation to the averaging interval. The general large-scale circulation of the North Sea (Figure 15) is dominated by a cyclonic, i.e. counter-clockwise, circulation pattern that determines the basin-wide distribution of hydrographic properties. Around the British Isles, the Fair Isle Current (between the Orkney and Shetland Islands) imports a mixture of AW and Scottish Coastal Water into the North Sea, and the East Shetland Atlantic Inflow imports AW. These waters are transferred towards the south as part of the general cyclonic circulation, while waters from the English Channel and continental coastal waters from the south-western North Sea are imported and transferred towards the north-east. Topographic steering between 58°30’N and 59°N forces major parts of the AW to flow into the central North Sea and follow the 100 m isobaths in a cyclonic direction towards the east. This flow is known as the Dooley Current. Along the western flank of the Norwegian Trench, a third inflow branch of AW can be observed. This and the Dooley Current merge with the north-bound NCC, which is the major outflow connection between the North Sea and the Norwegian Sea. The local wind field is the primary driver of the mean near-surface flow. Near-surface currents in the North Sea are thus generally highly variable. Even monthly and seasonal means show significant interannual variability.

The North Atlantic Oscillation (NAO) determines the state of the large-scale atmosphere over the North Atlantic. It impacts on the intensity and variability of the circulation in the North Sea, especially during the winter period. Phases of negative NAO, associated with more variable winds and likely more polar easterlies in these periods, cause a distinct circulation pattern, which is, however, limited to the northern North Sea. The Atlantic inflow following the western slope of the Norwegian Channel reaches the western Skagerrak before recirculating into the Baltic Outflow/ Norwegian Coastal Current. In contrast, phases of positive NAO, associated with stronger westerlies and warmer, milder weather over western Europe, are related to a circulation pattern with higher current velocities. This pattern causes the northern Atlantic inflow to be distributed more uniformly over the western slope of the Skagerrak. The Skagerrak region thus experiences a stronger influence of Atlantic Water, and the southern North Sea and the German Bight are much more strongly coupled to the northern inflow. In contrast, the inflow through the English Channel is not significantly modulated by the different NAO states.

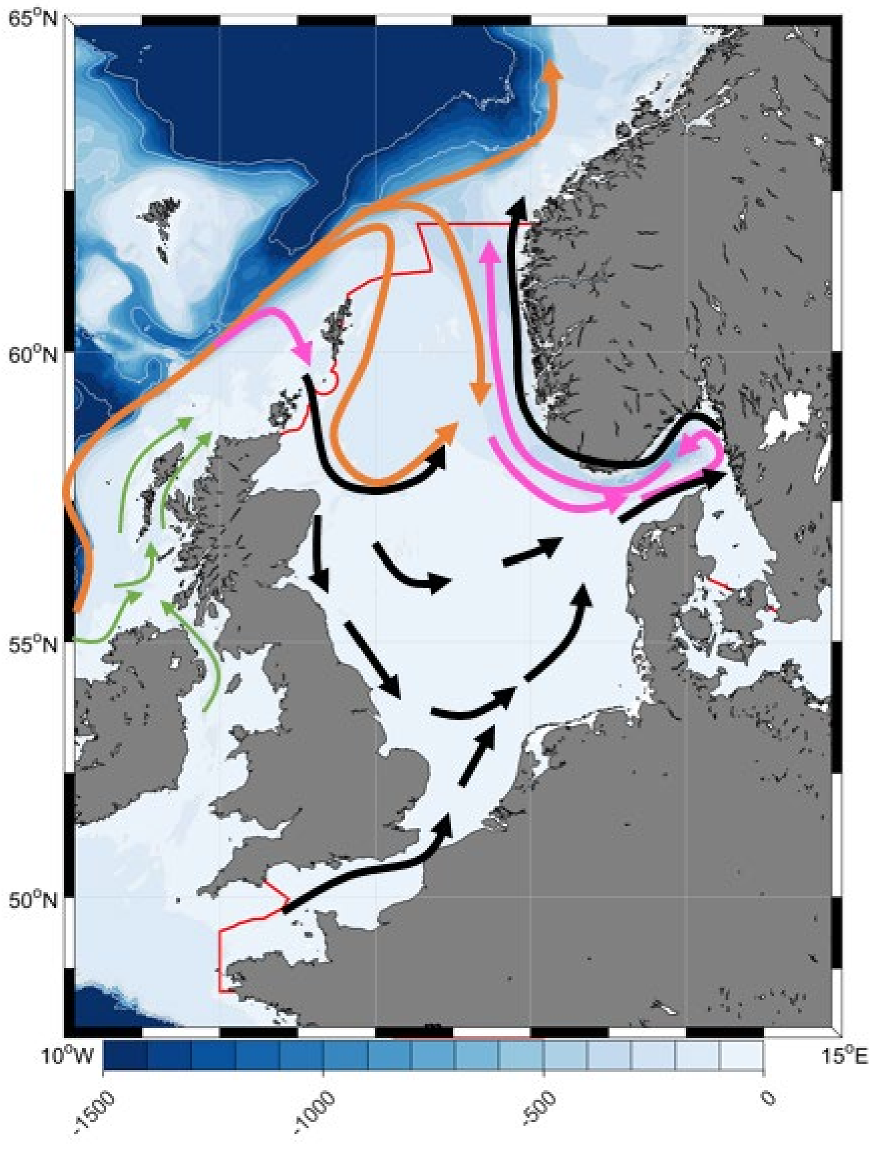

Figure 15. North Sea circulation map showing the major inflow and outflow branches at the northern, southern and eastern boundaries of the North Sea and the recirculating flow in its central part.

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Pelagic habitat (and associated biota)

Phytoplankton

Primary production is generally highest in the coastal regions of the North Sea due to nutrient inputs from the rivers and turbulent mixing in the water column. Phytoplankton biomass appears to have increased from the 1970s through to the 1990s and early 2000s (Philippart et al. 2007; Beaugrand and Reid 2003; Antoine et al. 2005; McQuatters-Gollop et al. 2007; Raitsos et al. 2014). However, several studies have shown a stabilization or in some instances a decline in phytoplankton biomass and production after the late 1990s (Cadée and Hegeman 2002; Prins et al. 2012; Capuzzo et al. 2018; Desmit et. al 2020).

At least two major trends are currently affecting phytoplankton dynamics in the North Sea: the warming trend that started between 1982 and 1987 (Beaugrand and Reid 2003; Høyer and Karagali 2016) and the de-eutrophication trend, that started in the 1980s (Burson et al. 2016; Desmit et al., 2020). Measures to reduce riverine nutrient inputs by North Sea coastal states have resulted in declining nutrient concentrations (N and P), especially in the southern North Sea (Philippart et al. 2007; Prins et al. 2012; OSPAR_Commission 2017). In addition to the de-eutrophication, increasing sea surface temperature affects the primary production through altered water column stratification and the corresponding effects on the physiology of phytoplankton species.

The Continuous plankton recorder (CPR) and coastal station records have shown a decreasing trend in dinoflagellate abundancesince 1960 whereas the total abundance of diatoms has remained unchanged (Hinder et al. 2012). This has resulted in an increase in the diatom: dinoflagellate ratio. Among the dinoflagellate species, *Ceratium furca, Protoperidinium* spp. and to a lesser extent *Prorocentrum* spp., have shown a substantial reduction in summer since the beginning of the 2000s (Brander 2016). The sea surface warming and reduced riverine nutrient inputs (de-eutrophication) are considered to be likely contributors to the observed changes in species composition as well as primary production in the Geater North Sea Ecoregion.

Zooplankton

Zooplankton communities in the northern North Sea are generally composed of Atlantic and offshore species (such as *Calanus finmarchicus* and *Metridia lucens*) owing to the stratification of the water column during the Summer months. The zooplankton community of the southern North Sea primarily consists of neritic and coastal species (such as decapod larvae *Centropages hamatus* and *Calanus helgolandicus*) which are well-suited to the mixed warmer waters of this region.

There has been a clear trend for a poleward distributional shift in the north-east Atlantic zooplankton community, progressing with a speed of around 200–250 km per decade (Edwards et al., 2020). The consequence of this shift has been to increase the diversity of calanoid copepods in the North Sea (Beaugrand et al. 2010). Population abundance of the previously dominant copepod *Calanus finmarchicus* has declined in biomass by 70% since the 1960s. Species with warmer-water affinities, e.g. *Calanus helgolandicus*, are moving northward to replace *Calanus finmarchicus*. However, *C. helgolandicus* never reaches high population densities and the species usually occurs later in the season. A successive replacement of *C. finmarchicus* with *C. helgolandicus* will therefore provide lower total zooplankton biomass available for higher trophic levels. Over the last few decades, climate warming in the southern North Sea has been noticeably faster than in the northern North Sea.

In the last 60 years, three significant and persistent regime shifts have occurred in the North Sea zooplankton community, these occurred in 1968, the lates 980s and 1996 (Edwards et al 2016). The most well-studied North Sea regime shift occurred at the end of the 1980s, and involved an increase in the abundance of dinoflagellates and a decrease in copepod size (Alheit et al. 2005). The shift at the end of the 1990s included a change in the phytoplankton assemblage, with a shift in diatom-dominance (Beaugrand 2004).

Small copepods have decreased by about 50% during the last three decades, particularly in the central and southern areas of the North Sea (Capuzzo et al., 2018; Schmidt et al., 2020, Bedford 2020). Specifically, the abundance of *Pseudocalanus*/*Paracalanus* spp. has decreased across the North Sea (Johannessen et al 2012; Alvarez-Fernandez et al 2012). The declining trends in small copepods have been attributed to a combination of earlier spring blooms and lower summer food quantity and quality, suggesting an overall bottom-up control of the food web structure in the North Sea (Pitois and Fox 2006; Capuzzo et al. 2018; Schmidt et al 2020). The decreasing *Pseudocalanus*/*Paracalanus* spp. has been linked to the decrease in dinoflagellates associated with the third regime change at the end of the 1990's (Alvarez-Fernandez et al 2012).

Continuous plankton recorder data has shown a strong increasing trend in meroplankton (Kirby et al., 2007) largely driven by an increase in echinoderm and decapod larvae. Increases in meroplankton abundance will have an impact on the benthic community, and thereby increase the bentho-pelagic coupling (Kirby et al 2007, 2008).   In contrast, the abundance of bivalve mollusc larvae has declined, suggesting that not all taxa respond similarly to climate change (Kirby et al 2008).

Zooplankton Phenology

In addition to shifts in the size composition and distributions of zooplankton, shifts in phenology are also occurring in response to warming temperatures, generally in the form of advanced spring phenology (Richardson, 2008). For example, some species have moved forward in their seasonal cycle by 4 or 5 weeks (Uriarte et. al 2021; Falkenhaug et. al 2022). Such shifts in phenology could lead to uncoupling of trophic interactions.

Benthic habitat and associated biota

Substrate

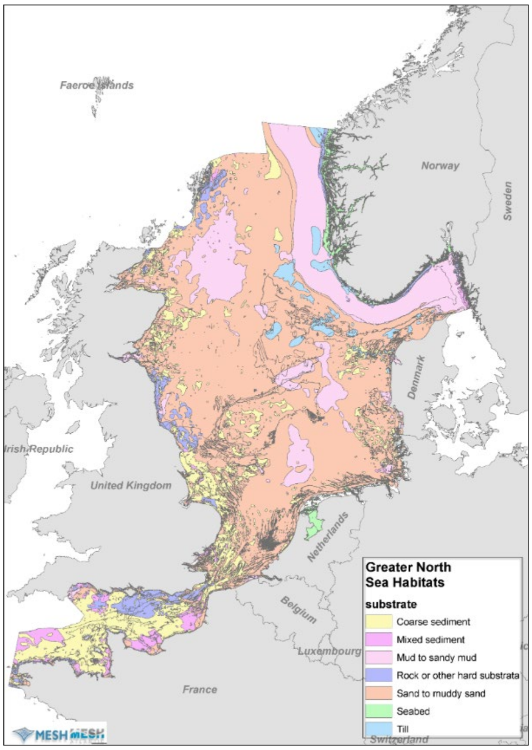

Figure 16 Major substrates on the shelf in the Greater North Sea (as compiled by EMODNET seabed habitats; www.emodnet-seabedhabitats.eu).

Benthic community

#Note to the ADG: text form Olivier Beauchard from WGBIODIV (15/10/22) out of the review process and directly to the ADG.

The benthic substrate of the Greater North Sea is predominantly characterized by soft sediments (from muds to gravel beds, Figure 9).. The distributions of sediment types are strongly spatialized, following more or less the increasing depth toward the North. Bottoms in the shallow Southern North Sea (0-30 m) undergo the effects of the very fast water current from the Channel and the East UK coast, that interact with wave energy. Although the rise of the Dogger Bank is less exposed to fast currents, it is exposed to wave action that induces relatively coarse sediments. Gravel beds are mainly distributed in the English Channel and the west and northwest of the Southern Bight whereas sand is present everywhere else, with growing mud contents in deeper areas. This is the case of Oyster Ground (54-55 °N), a deep basin (ca 50 m) with a very low hydrodynamics. Further north, beyond the Dogger Bank (56-60 °N), mud content increases to Fladen Ground, the deepest area on the shelf (100-150 m). In the northeast, the very deep zone along the Norwegian coast (Norwegian trench, ca 400 m), acts as a sedimentation basin. A lot of silt and organic material eventually ends up here, after it has been deposited and stirred up again elsewhere in the North Sea.

The combination of depth, hydrodynamics and sediment types give rise to a large diversity of benthic communities (Heip and Craeymeersch 1995, Künitzer et al. 1992). The flow rate at the bottom is an important determinant of compositional aspects of benthic species communities. Fast-flowing waters, engendering mobile sands, act as natural stressors on organism biology and select specific traits adapted to a fast life cycle whereas more stagnant and muddy conditions will favour a greater diversity of life strategies. More locally, especially in the southern part, seascape geomorphological variations induce alternations of hydrodynamic conditions and associated compositions in stress-resistant, disturbance-resilient and slow-growing species (Beauchard et al. 2022). There are two synoptic surveys of the benthic fauna of the North Sea, from 1986 and 2000 (Heip et al. 1992, Kröncke et al. 2011). They present largely the same picture, but despite the great efforts in benthic surveys in some countries, and all surveys that are done for specific projects, there is no recent area-wide overview.

The North Sea contains limited biogenic and geogenic reefs, except for patches of Sabellaria spinulosa reefs (van der Reijden et al. 2019) and scattered boulder fields. However, until the 1920s, very extensive biogenic oyster Ostrea edulis reefs used to lie in the central part of the North Sea, but these disappeared due to overfishing. Since then, disturbances caused by trawling activities steadily increased, preventing the recovery of the mega-fauna (Housiaux et al. 2011). In this respect, the North Sea remains the most impacted shelf in the world (Collie et al. 2000, Mazor et al. 2020). Other human-mediated disturbances on the sea floor consist mainly in sand and gravel extraction and the growing introduction of offshore renewable energy structures such as wind farms, leading to smothering and habitat loss. Artificial hard substrates, such as hydrocarbon production platforms, wind turbines, and ship wrecks act as new habitat types. that can locally increase biodiversity (Coolen 2017). Sea grasses (Zosteraceae) used to be common along the coasts of the southern North Sea; their extent is now more limited due to the loss of shallow intertidal and delta areas.

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Cephalopods

A total of 24 cephalopod species occur in the North Sea including important commercial inshore long-finned squids *Loligo vulgaris* and *Loligo forbesii* as well as *Alloteuthis* spp, which is normally frozen for fish bait (all three of family Loliginidae), offshore short finned squid *Illex coindetii*, *Todaropsis eblanae*, and *Todarodes sagittatus* (all three of family Ommastrephidae) and the Common cuttlefish *Sepia officinalis*. Bobtail squids family Sepiolidae are diverse but rare and have no commercial importance. Octopods are represented by a single species *Eledone cirrhosa*, the common octopus. Most of landed squid is thought to be represented by *I.coindetii*, which in recent years increased in numbers in the North Sea and began to reproduce there efficiently establishing a new stock.

Generally, cephalopods in the North Sea are of relative low abundance and play less important role in food webs than in more southerly areas such as the western English Channel and Bay of Biscay.

Fish

In the Greater North Sea, the main forage fish (herring, sandeel, sprat, and Norway pout) feed mainly on plankton and are an important food source in the North Sea foodweb. Smaller piscivorous fish (e.g., whiting *Merlangius merlangus*, haddock *Melanogrammus aeglefinus*, and grey gurnard *Eutrigla gurnardus*) and stocks that enter the North Sea only in specific seasons such as western horse mackerel (*Trachurus trachurus*) and mackerel, all eat forage fish and juvenile gadoids to a large extent. Benthic-feeding fish include all kinds of flatfish feeding on prey on or near the bottom. Fish that can eat large fish (>25 cm) are mainly large cod, saithe, and elasmobranchs, but species like seals and harbour porpoise are also important top predators. Natural mortality is now the main source of mortality for many commercial species due to a successful reduction in fishing mortality rates in recent years. The mean relative spawning-stock biomass (SSB) has increased since 2000 and is now above or close to the biomass reference points used in stock assessments of most stocks in the Greater North Sea (Figure 16). Among those with a high ratio are hake and plaice, while four stocks (North Sea cod, saithe, witch flounder and whiting) have a SSB below B_{MSY} trigger and $F > F_{MSY}$. More detailed information on Greater North Sea fisheries is provided in the ICES Greater North Sea ecoregion Fisheries Overview (ICES, 2021).

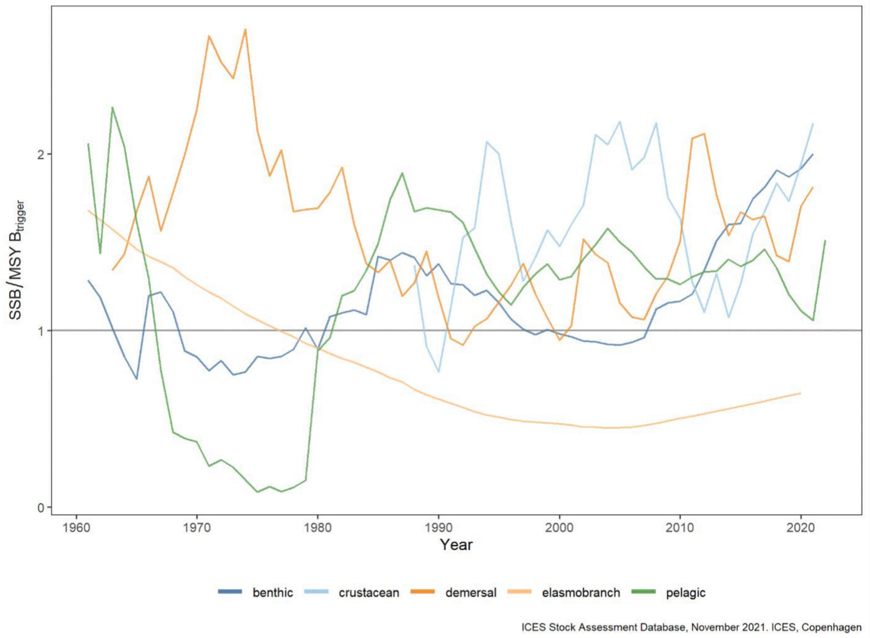

Figure 17 Time-series of mean annual biomass (SSB to BMSY trigger ratio) by fisheries guild for benthic, demersal, crustaceans, pelagic stocks.

Impacts on foodwebs

Fishing can change both the structure of fish communities and the North Sea foodweb . The depletion of larger predatory species has likely perturbed the structure and function of the North Sea ecosystem by reducing preditor top-down controls on certain lower tropic level species. Multispecies assessment methods can account for some of the interactions and indicators like the large fish indicator (LFI) index (describing the proportion, by weight of the demersal fish community catch on surveys that is larger than regional length thresholds) can be used to monitor changes in the structure of fish populations. In the Greater North Sea, the LFI index declined in the mid 1980s, buthas been relatively stable with annual changes since 2004 (Figure 18). OSPAR (2017) note a recovery in the proportion of large fish in the demersal fish community in the Greater North Sea in the period to 2010-2015 and predict that favourable assessment values could be achieved by 2022 if the current demersal fishing pressures levels are not increased substantially.

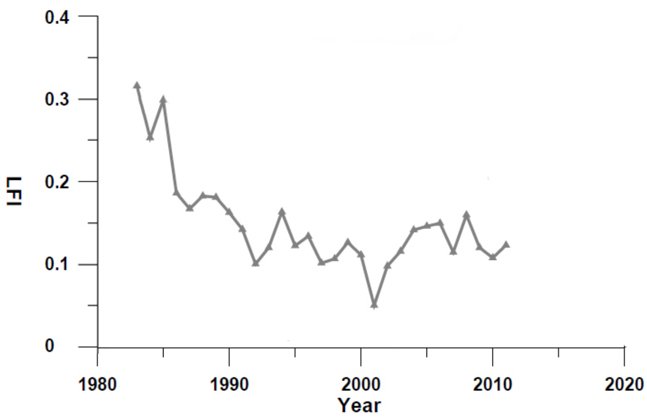

Figure 18 Time-series of the large fish indicator (LFI) for the Greater North Sea. (ICES, 2014.)

Seabirds

The Greater North Sea is an important feeding area for many breeding and non-breeding seabird populations predating on fish and invertebrates. More than 20 species of seabird breed on the coasts of the Greater North Sea Ecoregion, with numbers generally increasing until the year 2000, after which the number of species categorised as being in good status declined (Figure 19), although some species to indicate an increase in population size. Migrating birds, from northern and eastern regions are of particular importance for the Greater North Sea. Generally, the number of immigrant seabirds has declined in past years, possibly due to milder winters, suggesting that the flocks that used to reach the region in winter now remain closer to their breeding grounds. The main threats come from climate change, fishing (including bird bycatch and competition for prey items), disturbance from shipping, and detrimental interactions with offshore renewables (including collisions with wind turbine blades).

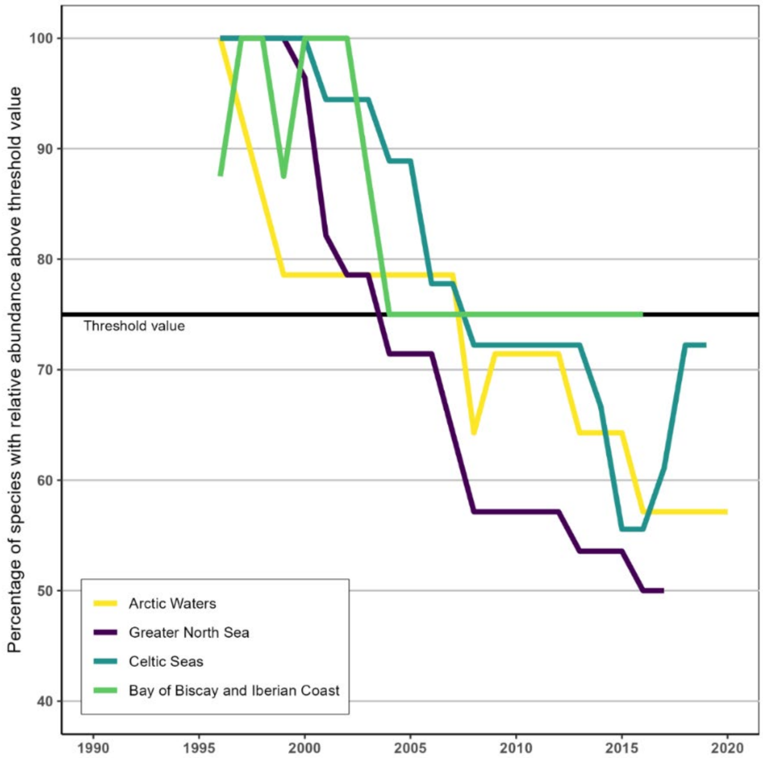

Figure 19 Change in the annual proportion of species achieving threshold values for the relative breeding abundance of marine birds in the Norwegian part of the Arctic Waters (14 species), the Greater North Sea (28 species), the Celtic Seas (18 species) and the Bay of Biscay and Iberian Coast (eight species). The black line denotes the multi-species threshold value of 75%.

***#Note to the reviewers:** The figure is taken from the current assessment of breeding seabird abundance under OSPAR QSR 2023. We aim to change it in a way showing only the North Sea and for surface feeders and water column feeders separately. Data were not ready for this by the time of submission.*

Marine mammals

#Note to the ADG: text form WGMME chair (24/10/22) out of the review process and directly to the ADG.

Twenty-six cetacean and seven seal species have been recorded in the Greater North Sea. However, many of these occur only as vagrants or occasional visitors. Two species of seal are common in the North Sea: grey seal *Halichoerus grypus* and harbour seal *Phoca vitulina*. Four cetacean species occur commonly or are resident: minke whale *Balaenoptera acutorostrata*, harbour porpoise *Phocoena phocoena*, white-beaked dolphin *Lagenorhynchus albirostris*, and bottlenose dolphin *Tursiops truncatus*. A further six species are considered regular but less common, common dolphin *Delphinus delphis*, Atlantic white-sided dolphin *Lagenorhynchus acutus*, long-finned pilot whale *Globicephala melas*, killer whale *Orcinus orca*, Risso's dolphin *Grampus griseus*., and humpback whale *Megaptera novaeangliae.*

Both seal species have experienced large population changes over the past century. The abundance of harbour seals reached an all-time low in the 1970s but subsequently increased steadily at an annual rate of 4%; however, this increase was then affected by two major interruptions due to outbreaks of the phocine distemper virus (PDV) in 1988 and 2002. Over the last 15 years, declines in the harbour seal population have occurred in the north-western sector of the North Sea. The reasons for these recent declines are unknown, although they are thought to be different in different areas. Grey seals in the North Sea occur predominantly along the British coasts where they have been increasing at an annual rate of up to 10%.

Trends in the abundance of cetaceans are less well known but between the 1990s and 2000s, the centre of summer distribution of harbour porpoises shifted southwards, possibly in response to changes in availability of prey such as sandeel. Minke whales and white-beaked dolphins are found mainly in the central and northern North Sea, with no obvious changes in overall numbers from wide-scale surveys. The coastal population of bottlenose dolphins in eastern Britain has been increasing since the 2000s and over this period has extended its range southwards from the Moray Firth to the coast off Yorkshire. Killer whales regularly occur in the northern North Sea and individuals inhabiting waters around northern Scotland have been shown through photo-identification to be part of the Icelandic population. In recent years, humpback whales have increasingly been recorded in the North Sea including the southern sector where previously it was a vagrant

Pressures upon marine mammals in the region are mainly fisheries bycatch, prey depletion, chemical pollution, underwater noise, and vessel strikes. Climate change may also be causing some distributional shifts.

Foodwebs *with inserts in yellow*

Characteristics of the North Sea foodweb are a high production by autotrophic organisms which in turn are consumed by zooplankton and benthos, followed by fish, seabirds, and mammals.

The North Sea foodweb is one of the most studied in the ICES area. In the past large-bodied fish, including elasmobranchs, were major predators in the ecosystem (Greenstreet et al 2012).

The North Sea foodweb can now be considered as perturbed as many sensitive fish species are either absent or present only in reduced numbers (e.g. Rindorf et al 2020).

Although, future projections of ecosystem models suggest that fishing at MSY should allow large-bodied species and the size-structure of communities to recover (Spence et al 2021) some species may require particular measures to reduce pressure (e.g. Bluemel et al 2021).

As predator populations recover this will likely have consequences for the forage fish populations in the North Sea (herring, sprat, sandeel, and Norway pout) and may lead to competition between species. However, there is still a need to further improve our basic understanding of bottom-up processes and the impacts of climate change (Thorpe et al 2022; Spence et al 2022)

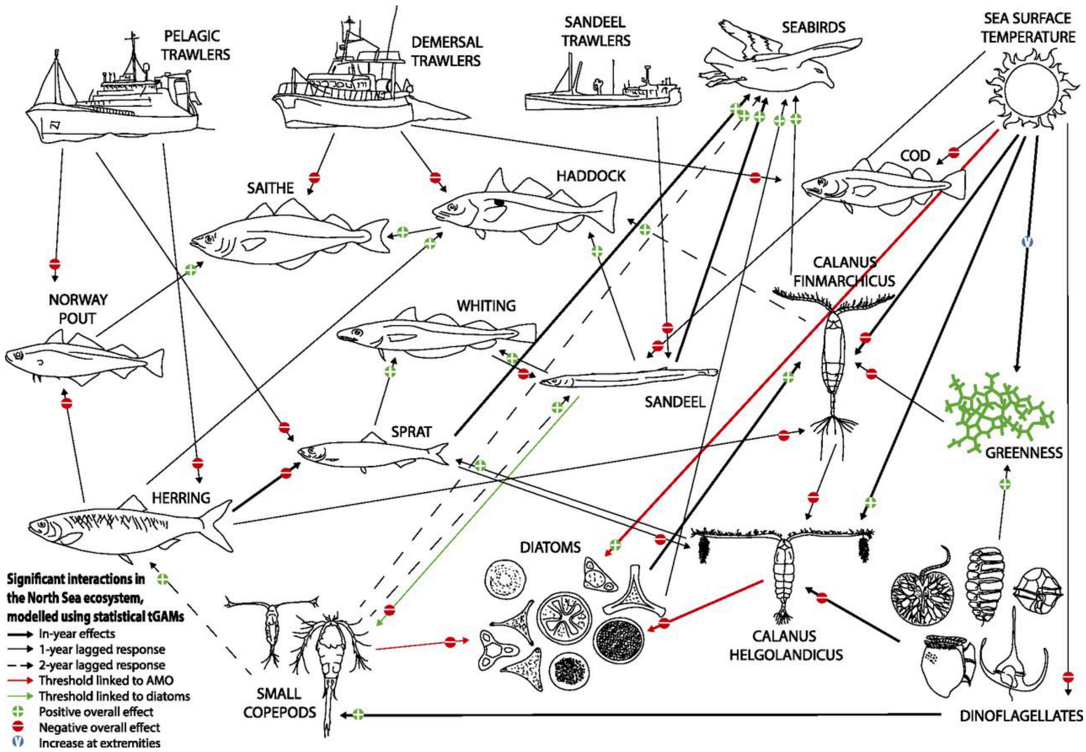

Figure 20 The major components of the Greater North Sea foodweb and key interactions between them (Lynam et al 2017).

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Sources and acknowledgments

Sources and references

Annex 1 Stocks in the XXXX ecoregion and their fisheries guilds

Table A1 Stocks with analytical assessments and guilds included in Figure X and Figure XX. Detailed information XXXX fisheries is provided in the XXX Fisheries Overviews.

Stock code	Stock name	Fishery guild

Annex 2 Threatened and declining species and habitats in the XXXX

The threatened and declining species in the XXXXX according to OSPAR (OSPAR Regions III and V) and modified for ICES Celtic Seas ecoregion are shown in the tables below.

Table A2.1 Threatened and declining species in the XXXX

Table A2.2 Threatened and declining habitats in the XXXXX

Recommended citation: ICES. 2021. XXXXX Ecoregion – Ecosystem overview. *In* Report of the ICES Advisory Committee, 2021. ICES Advice 202X, Section 7.1, https://doi.org/10.17895/ices.advice.XXXX.