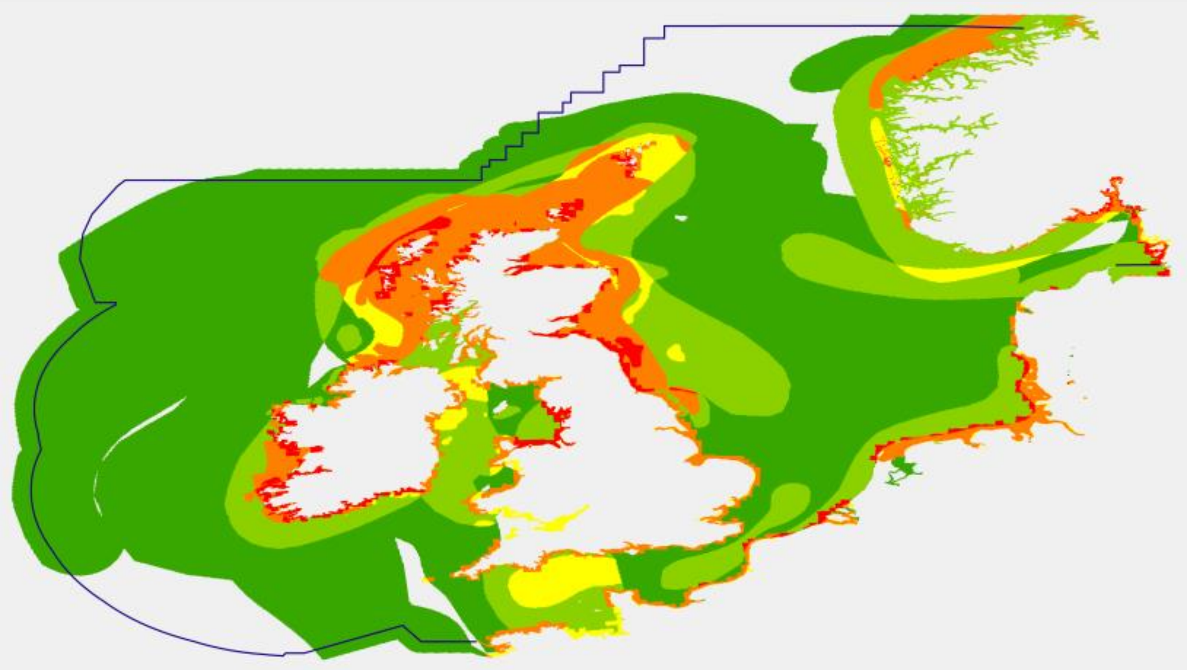
{HNS-MS}

Improving Member States preparedness
to face an HNS pollution of the Marine System

Mapping Environmental and Socio-Economic Vulnerability to HNS maritime Pollution

HNS-MS final report, part III



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About HNS-MS

The European project HNS-MS aimed at developing a decision-support system that national maritime authorities and coastguard stations can activate to forecast the drift, fate and behaviour of acute marine pollution by Harmful Noxious Substances (HNS) accidentally or deliberately released in the marine environment. Focussing on the Greater North Sea and Bay of Biscay, this 27 months project (01/01/2015-31/03/2017) had four specific objectives:

i. To develop a freely accessible data base documenting the most important HNS transported from or to the ports of Antwerp, Rotterdam, Hamburg, Nantes and Bordeaux;
ii. To conduct lab experiments in order to improve the understanding of the physico-chemical behaviour of HNS spilt at sea;
iii. To develop a 3D mathematical modelling system that can forecast the drift, fate and (SEBC) behaviours of HNS spilt at sea. Advanced processes such as chemical reactivity, explosions, fire or interaction with sediment were not considered in this first project;
iv. To produce environmental and socioeconomic vulnerability maps dedicated to HNS that will help end-users assessing the likely impacts of HNS pollution on the marine environment, human health, marine life, coastal or offshore amenities and other legitimate uses of the sea.

All these contributions have been integrated into a web application that will help coastguard stations to evaluate the risks for maritime safety, civil protection and marine environment in case of an acute pollution at sea. HNS-MS has been co-funded by the Directorate-General of European Commission for European Civil Protection and Humanitarian Aid Operations (ECHO).

About this report

This report presents the achievements of the environmental and socio-economic vulnerability analysis performed in the framework of task I of the project "HNS-MS – Improving Member States preparedness to face an HNS pollution of the Marine System".

This report is part of a series of 5 technical sub-reports presenting in detail the outcome achieved by the HNS-MS consortium in the framework of this project:

- HNS-MS Layman's report
- Sub-report I : Understanding HNS behaviour in the marine environment
- Sub-report II : Modelling drift, behaviour and fate of HNS maritime pollution
- Sub-report III : Mapping environmental and socioeconomic vulnerability to HNS maritime pollution
- Sub-report IV : HNS-MS Decision-Support System User's Guide

A copy of these reports can be obtained by downloading from the HNS-MS website https://www.hns-ms.eu/publications/.

Contents

Introduction

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1 Introduction

1.1 General context

"*Maritime services have benefited in recent years by considerable expansion fostered by globalization.*"[1] "*Around 90% of world trade is carried by the international shipping industry. Without shipping the import and export of goods on the scale necessary for the modern world would not be possible. Seaborne trade continues to expand, bringing benefits for consumers* across the world through competitive freight costs. Thanks to the growing efficiency of shipping *as a mode of transport and increased economic liberalisation, the prospects for the industry's further growth continue to be strong.*" [2]

If maritime shipping is undoubtedly a key factor of the worldwide economic growth, the constantly growing fleet of tankers, bulk carriers and ever-increasing size container ships exacerbates the risk of maritime accidents, loss of cargoes and acute maritime pollution. In particular, more than 2,000 **harmful or noxious chemical substances** (**HNS**) are regularly shipped in bulk or package forms and can potentially give rise to significant environmental and/or public health impacts in case of spillage in the marine environment.

In recent years, huge efforts have been made by IMO, EMSA as well as other maritime authorities towards greater consideration of these risks. For instance, given the importance and complexity of the matter, the Bonn Agreement, HELCOM, Lisbon Convention, Barcelona Convention/REMPEC, Copenhagen Convention, DG ECHO and EMSA have jointly identified the urgent need of improving preparedness and response to HNS spills (10th Inter-Secretariat Meeting, Helsinki, 27.02.2014).

Until now, preparedness actions at various levels have primarily aimed at classifying the general environmental or public health hazard of an HNS (e.g. development of IBC and IMDG codes; GESAMP profiles), at developing operational datasheets collating detailed, substance-specific information for responders and covering information needs at the first stage of an incident. (MAR-CIS; MIDSIS-TROCS; CAMEO) or at performing a risk analysis of HNS transported in European marine regions (e.g. EU projects HASREP and BE-AWARE). However, contrary to oil pollution preparedness and response tools, only few decision-support systems currently used by Member States authorities (Coastguard agencies or other) integrate 3D models that are able to simulate the drift, fate and behaviour of HNS spills in the marine environment. When they do, they usually rely on black box commercial software or consider simplified or steady-state environmental conditions.

[1] World Trade Organization - https://www.wto.org/english/tratop_e/serv_e/transport_e/transport_maritime_e.htm
[2] International Chamber of Shipping - http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade

HNS-MS aims at developing a 'one-stop shop' integrated decision-support system that is able to predict the drift, fate and behaviour of HNS spills under realistic environmental conditions and at providing key product information - drawing upon and in complement to existing studies and databases - to improve the understanding and evaluation of a HNS spill situation in the field and the environmental and safety-related issues at stake.

The key challenge in this project is to understand the physico-chemical processes that drive the numerous behaviours and fate of HNS spilt in the marine environment.

1.2 What are HNS precisely?

HNS-MS defines **hazardous and noxious substances** or **HNS** following the OPRC-HNS Protocol 2000:

> *"HNS are any substances other than oil which, if introduced into the marine environment, are likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea".*

This generic definition covers a wide range of chemicals with diverse intrinsic qualities (such as toxicity, flammability, corrosiveness, and reactivity with other substances or auto-reactivity). It includes:

- oil derivatives;
- liquid substances which are noxious or dangerous;
- liquefied gases;
- liquids with flashpoints not exceeding 60°C;
- packaged dangerous, harmful and hazardous materials; and
- solid bulk material with associated chemical hazards.

In the framework of HNS-MS, vegetal oils are also considered as HNS.

1.3 How does HNS behave when spilt in the marine environment?

The behaviour of a substance spilt at sea is the way in which it is altered during the first few hours after coming into contact with water. Predicting this behaviour is one of the most important stages in the development of a response strategy.

Since the early 1990's, the best HNS behaviours predictions were given by the Standard European Behaviour Classification (SEBC) [Bonn Agreement, 1991]. This classification determines the theoretical behaviour of a substance according to its density, vapour pressure and solubility. Five main behaviour classes are considered: **gas**, **evaporator**, **floater**, **dissolver** and

sinker. However, most of the time, a substance does not have one single behaviour but rather several behaviours due to its nature and the environmental conditions (wind, waves, current). This is the reason why the SEBC considers a total of 12 mixed behaviours classes (**Error! eference source not found.**). For example, ethyl acrylate is classified as FED as it floats, evaporates and dissolves.

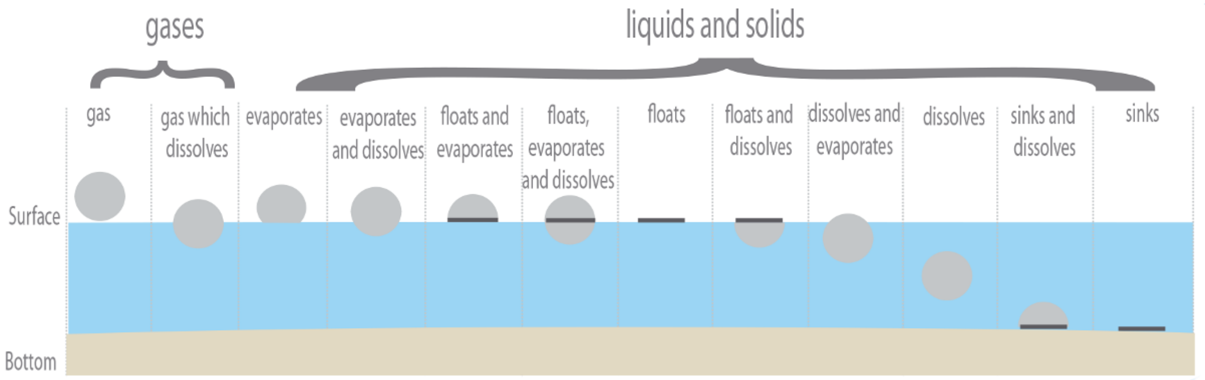

Figure 1: According the Standard European Behaviour Classification (SEBC), a substance spilt at sea will behave following one of these 12 theoretical behaviour classes.

The SEBC code has its limits. It is based on experiments conducted in the laboratory on pure products at a temperature of 20°C in fresh water. These controlled conditions are quite different from those encountered in case of a real incident at sea. In addition, the SEBC also fails to provide any information on the physico-chemical processes explaining the observed mixed behaviour, their kinetics and their eventual competitions. As a consequence, further experimental characterization of chemicals behaviour at different scales (ranging from laboratory to the field) is needed in order to gain a better understanding of the physico-chemical processes at stake, to develop more reliable mathematical models of these processes (taking into account the actual environmental conditions) and eventually to provide more accurate answers to decision makers when they plan response efforts and pollution control.

1.4 HNS-MS objectives

The project HNS-MS aimed at developing a decision-support system that national maritime authorities and coastguard stations can activate to forecast the drift, fate and behaviour of acute marine pollution by Harmful Noxious Substances (HNS) accidentally released in the marine environment.

Focussing on the Greater North Sea and Bay of Biscay, this 2 year project (01/01/2015-31/03/2016) had four specific objectives:

i. To develop a freely accessible data base documenting the most important HNS transported from or to the ports of Antwerp, Rotterdam, Hamburg, Nantes and Bordeaux;
ii. To conduct lab experiments in order to improve the understanding of the physico-chemical behaviour of HNS spilt at sea;
iii. To develop a 3D mathematical modelling system that can forecast the drift, fate and (SEBC) behaviours of HNS spilt at sea. Advanced processes such chemical reactivity, explosions, fire or interaction with sediment were not considered in this first project;
iv. To produce environmental and socioeconomic vulnerability maps dedicated to HNS that will help end-users assessing the likely impacts of HNS pollution on the marine environment, human health, marine life, coastal or offshore amenities and other legitimate uses of the sea.

All these contributions have been integrated into a web application that will help coastguard stations to evaluate the risks for maritime safety, civil protection and marine environment in case of acute pollution at sea.

1.5 HNS-MS workflow

To meet HNS-Ms objectives, the workflow has been subdivided into 10 tasks articulated around 4 main axes (Figure 2):

1. **Lab experiments:** The first axis aims at collating or producing data and information to support the development of the HNS drift and fate model. First a selection of 100+ important HNS transported in the Bonn Agreement area has been performed from a literature and database review. Then, keeping in mind that only processes fully understood can accurately be simulated; several laboratory experiments have be carried out in order to improve our understanding of HNS behaviour both in the water column and at the sea surface. For instance, for the first time, a Lab experiment has been conducted in order to quantify the competition between the evaporation and dissolution kinetics of chemical floating at the sea surface. Finally, two field campaigns have been organised.

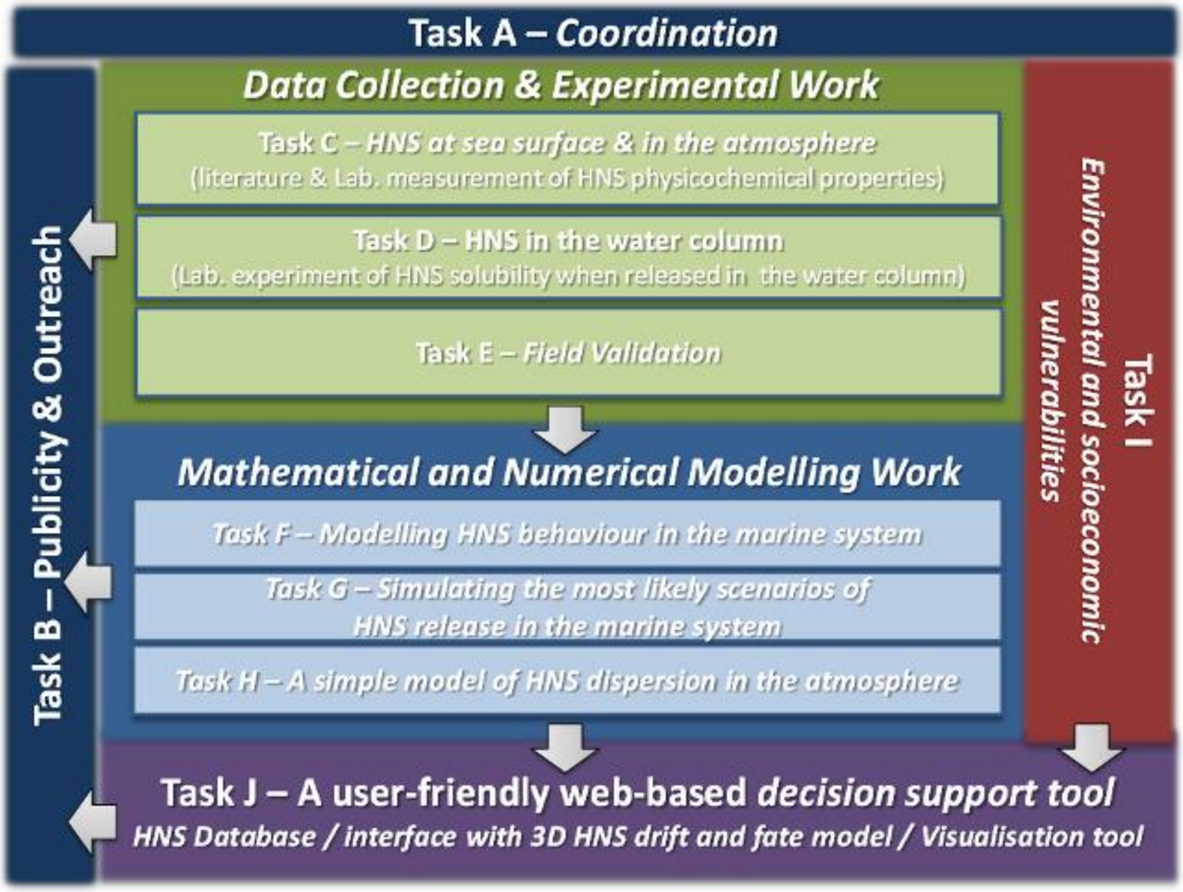

Figure 2: HNS-MS workflow is articulated around 4 main axes: Lab experiments, model development, environmental and socio-economic vulnerabilities mapping and development of a Decision Support System. (Figure from the project proposal submitted to DG-ECHO call to projects 2014)

2. **Mathematical modelling:** The second axis aims at developing a 3D HNS drift and fate modelling software. In order to handle (i) the large variety of HNS physico-chemical properties, (ii) the large variety of possible spillage scenarios and (iii) the large variety of the involved time and space scales, three different models have been developed, namely
   - ChemSPELL, HNS-MS near-field model
   - ChemDRIFT, HNS-MS far-field model
   - ChemADEL, HNS-MS atmospheric dispersion model
3. **Environmental and socio-economic vulnerabilities:** The third axis aims at developing a series of regional and local vulnerability for HNS-sensitive environmental and socioeconomic features. The HNS-MS vulnerability ranking methodology is mainly an

extension of methodology developed in the framework of the BE-AWARE projects, also funded by DG-ECHO.

4. **Decision support System:** Finally, the fourth axis aims at integrating all the previously obtained results in an intuitive, easy-to-use operational web-based HNS decision-support system for the Bonn Agreement area and the Bay of Biscay.

1.6 Why mapping environmental and socioeconomic vulnerabilities?

The fourth specific objective of the HNS-MS project is the production of environmental and socioeconomic vulnerabilities maps to be included in the decision support tool (Task I – action I.1). The motivation is to help HNS-MS end-users assessing the likely impacts of HNS pollution on the most HNS sensitive marine habitats, on human health, marine species, coastal or offshore amenities and other legitimate uses of the sea. To this purpose, the methodology developed in the framework of the BE-AWARE I and II projects (co-financed by DG-ECHO) for oil spill vulnerability mapping was adapted and extended to HNS spill scenarios.

The digital vulnerability maps atlas will be included in the 'one-stop shop' integrated HNS decision-support tool. The end-users will be able to visualise the drift of the HNS spill overlaid on environmental and socioeconomic vulnerability background layer.

This decision tool focuses on the Bonn Agreement area, one of the busiest maritime zone, since by far the largest quantities and variety of HNS carried by sea in Europa are transported from and to the ports of Rotterdam, Antwerp and Hamburg (HASREP Report, 2005).

The vulnerability analysis was conducted at two levels:

- At the regional scale of Bonn Agreement area;
- At local operational scale for Belgium chosen as a test area.

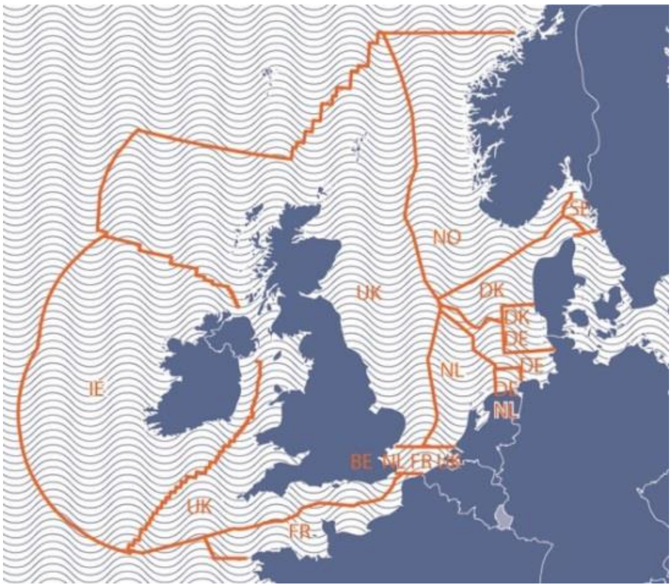

Figure 3: Bonn Agreement area

This report describes the result of the vulnerability analysis and mapping:

- **Chapter 2** outlines the **methodology** applied for the vulnerability analysis to HNS spills and ranking;
- **Chapter 3** describes the HNS spill vulnerability analysis and ranking for each of the identified **habitats** features and the associated vulnerability maps;
- **Chapter 4** describes the HNS vulnerability analysis and ranking for each of the identified **species** features and the associated vulnerability maps;
- **Chapter 5** describes the HNS spill vulnerability analysis and ranking for each of the identified **protected areas** and the associated vulnerability maps;
- **Chapter 6** describes the HNS vulnerability analysis and ranking for each of the identified **socio-economic** features and the associated vulnerability maps;
- **Chapter 7** presents how the same methodology can be adapted to produce operational vulnerability maps; the Belgian part of the North Sea having been selected as a test case.

The catalogue of the vulnerability maps presented in chapters 3 to 7 with viewing and downloading tools is available on the HNS-MS public website:

https://www.hns-ms.eu/tools/sensitivity_maps.

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Methodology

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2 Methodology

Vulnerability maps are key elements in the planning and response to HNS:

- to identify and locate the most sensitive environments or resources and to assess the likely impact of HNS pollution on the marine environment and socio-economy;
- to provide a basis for defining a response strategy and for prioritising areas to be protected or cleaned up;
- to support the choice of the most appropriate response technique.

Vulnerability and sensitivity definitions relevant to this report are the same than those used for Be-Aware project which are internationally adopted:

- A resource is defined to be vulnerable if it is likely to be exposed to either physical contact (smothering) or high concentrations of pollutant likely to affect it;
- A resource is defined as sensitive to HNS if it would be acutely affected by contact or high concentrations of HNS.

2.1 Methodology applied for BE-AWARE project

Sources: Ronny SCHALLIER (R.Schallier@mumm.ac.be), Ward VAN ROY (w.vanroy@mumm.ac.be), Maarten VAN CAPPELLEN (m.vancappellen@mumm.ac.be) Preliminary report on joint sensitivity mapping (TASK: F), 29 November 2013. Environmental and socioeconomic vulnerability – (TASK: F). E. Povlsen (COWI), M. Hjorth (COWI), 10 NOVEMBER 2015).

To comply with the findings and recommendations of the BE-AWARE I study (Schallier and al. 2013) the ranking of the vulnerability of ecological and socioeconomic features to oil spills in the different regions of the BA area was carried out in distinct steps, which include:

- the identification of ecological and socioeconomic features to be mapped and ranked according to vulnerability to oil spill;
- the mapping of the identified ecological and socioeconomic features;
- the assessment and definition of rank scores to be allocated to each of the identified ecological and socioeconomic features during 4 seasons (spring, summer, autumn and winter);
- the vulnerability mapping of the identified ecological and socioeconomic features to oil spill;
- The total seasonal vulnerability mapping by combining the results of ecological and socioeconomic ranking.

Identification of ecological and socio-economic features

Ecological and socioeconomic features to be mapped and ranked according to vulnerability to oil spill were identified during BE - AWARE I and revised during the course of the project BE-AWARE II, in terms of relevance and availability of data. The final selection includes:

- 22 'Habitat' features, divided into 15 shoreline and coastal habitats and 7 open sea habitats;
- 8 'Species' features, related to sensitive population, life-cycle and life stage aspects;
- 1 'Protected Area' feature, which comprises all coastal and marine protected areas under inter alia the EC Habitats and Birds Directive, RAMSAR Convention and OSPAR Convention;
- 18 sensitive 'Socioeconomic features' have been identified for the study area, categorized into 8 major socioeconomic groups: fisheries, aquaculture, tourism and recreation, coastal communities and heritage sites, coastal facilities with water inlet, ports, mineral extraction zones and renewable energy.

Table 1: List of identified sensitive ecological features for the BA region

Shoreline and Coastal Habitats	Higher trophic level species
• Exposed rocky shores and reefs (<20m; >20m) • Sheltered rocky shores and reefs (<20m; >20m) • Littoral chalk communities • Sandy beaches • Shingle beaches • Muddy beaches • Tidal sand and mud flats • Salt marshes • Estuaries • Large shallow inlets and bays • Coastal lagoons (open to the sea) • Underwater sandbanks (<20m; >20m) • Biogenic reefs[3] (<20m; >20m) • Maerl beds • Eelgrass meadows	• Wintering birds (incl. foraging areas) • Staging birds (incl. foraging areas) • Breeding birds (incl. foraging areas) • Moulting birds (incl. foraging areas) • Otters[4] • Seals[5] • Spawning areas for fish • Nursery areas for fish
Open Sea Habitats	**Protected Areas**
• Open water (<20m) • Deeper sea floor (>20m) • Deeper water column (>20m) • Seamounts • Coral gardens and sponge aggregations • Carbonate mounds and *Lophelia pertusa* reefs • Sea-pen and burrowing megafauna	• Protected areas

Table 2*: List of identified sensitive socio-economic features for the BA region*

Fisheries: • Offshore fisheries • Coastal fisheries (incl. fishing harbours) • Shellfish/seaweed (algae) harvesting	**Coastal Communities and heritage sites:** • Heritage sites
Aquaculture: • Fish farms • Shellfish cultures • Algacultures	**Coastal facilities with water inlets:** • Energy plants • Onshore fish farms • Industrial activities (incl. oil and chemical industry)
Tourism and recreation: • Amenity beaches • Marinas • Tourism Activity • Densely populated towns and communes • Other specific activities: - Surfing hot spots - Recreational fishing locations - Cruise liner stops	**Ports:** • Ports **Mineral extraction:** • Extraction zones **Renewable energy:** • Renewable energy (wind farm areas)

<u>Assessment and criteria for ranking</u>

During the BE-AWARE I project, it was agreed to rank the vulnerability to oil spill of each of the identified ecological and socioeconomic features using the scores and seasons applied in the BRISK project.

Table 3: Ranking scores for the Be Aware project

Scores		Seasons
Score 4 = Very high vulnerability		Winter: December, January and February
Score 3 = High vulnerability		Spring: March, April and May
Score 2 = Moderate/medium vulnerability		Summer: June, July and August
Score 1 = Low vulnerability		Autumn: September, October and November
Score 0 = Not affected/ non applicable		

The vulnerability scores were based on the following criteria:

- For habitats and species;

  - "Fate of oil": In terms of oil weathering, natural degradation and removal, onshore as well as in open water (water column);
  - "Potential Impact" of oil on habitats and organisms In terms of physical and toxic effects, tainting, and population and life-cycle considerations;
- For socio-economic features :
  - 'Length of interruption': Describing socio-economic impact in terms of the length of interruption of a human activity or service;
  - 'Compensation possibility': In terms of whether economic compensation can be sought for a damaged feature - or not.

Table 4: Criteria to establish ranking scores for the Be Aware project

Criteria	Definition	'Vulnerability' factors
Fate of oil cf. BRISK	In terms of oil weathering, natural degradation and removal. Main factors being: - Onshore: wave and tidal energy exposure, shoreline slope, substrate type (~ESI index); - Open water (3D): natural energy (waves, currents, winds), depth.	*Exposure* *(Chemical) recovery*
Impact of oil cf. BRISK	In terms of physical and toxic effects, tainting, and a selection of population and life-cycle considerations.	*(Ecological) oil-sensitivity* *(Biological) recovery*
Length of Interruption cf. CEDRE index (FR)	Describing socio-economic impact in terms of length of interruption of an activity or service. Important factors being: - Possibility (or not) of protecting an activity; - Possibility (or not) of displacing an activity.	*(Socio-economic) oil-sensitivity*
Compensation cf. MOB-method (NO)	In terms of whether a damaged feature can be economically compensated for or not. Important when comparing economic vs. ecological vulnerability.	*(Economic) recovery*

<u>Vulnerability mapping</u>

Separate environmental and socioeconomic vulnerability maps for each season were prepared in GIS format. The following maps were produced:

- Vulnerability maps for habitats for each of the four seasons and for oil on the sea surface and dispersed in the water column;
- Vulnerability maps for species for each of the four seasons and for oil on the sea surface and dispersed in the water column;

- Vulnerability maps for Protected Areas for each of the four seasons and for oil in the sea surface and dispersed in the water column;
- Vulnerability maps for socioeconomic features for each of the four seasons and for oil on the sea surface and dispersed in the water column.

The maps were based on data delivered as GIS layers with location and extent of the ecological and socioeconomic features and the vulnerability scores of each individual feature.

Each of the vulnerability maps was prepared by calculating individual vulnerability scores of all features and reclassifying the total scores into five different overall vulnerability classes.

Table 5 shows the result of scores calculation for habitats, species, protected areas and socio-economic features that correspond to each vulnerability class on the Be Aware vulnerability maps.

Table 5: Vulnerability class and corresponding ranking scores

Vulnerability class	Habitats	Species	Protected areas	Socio-economy
Very high vulnerability	6-8	13-18	16	12-24
High vulnerability	4-5	9-12	12	9-11
Medium vulnerability	3	7-8	8	6-8
Low vulnerability	2	4-6	4	3-5
Very low vulnerability	1	1-3	1	1-2

2.2 HNS-MS methodology:

HNS covers a wide range of chemical substances that have diverse behaviours in the marine environment acting as evaporators, sinkers, floaters or dissolvers (SEBC classification), and intrinsic qualities (such as toxicity, flammability, corrosiveness, and reactivity with other substances or auto-reactivity).

A feature is defined as vulnerable if it is likely that it could be directly exposed to HNS spill in relation to the behaviour of the chemical involved:

- vapours in the air;
- slicks on the sea surface or stranded on intertidal zone at low tide;
- high concentrations dissolved in the water column;
- slicks or high concentrations of HNS sinking in the sea bed.

The results of the 3D modelling of drift, fate and behaviour of a chemical released, will allow identifying:

- if the feature will be exposed: depending on the trajectory of the HNS and on its concentration in the compartment where the habitat, species or activity is present (air, surface, water column, seabed);
- if the concentration reach toxic levels likely to affect the habitat, species or activity: the model will provide the concentration and its evolution overtime to be compared to available data on toxicity limits for human, fauna or flora.

Examples:

Intertidal features are vulnerable to HNS floaters spills because the slicks could strand upon them. However, wave-exposed shores are less vulnerable than sheltered shores because wave action removes the HNS quickly on exposed shores, whereas on sheltered shores it may persist for a long time.

Subtidal features are less vulnerable to chemical remaining on the surface (floating) but are likely to be affected by a chemical spilled from a wreck, or a chemical that will rapidly sank and remain on seabed or be dissolved in the water column.

If the spill occurs in surface, shallow sub-tidal features are more vulnerable than deeper-lying features because concentrations become increasingly diluted with increasing depth.

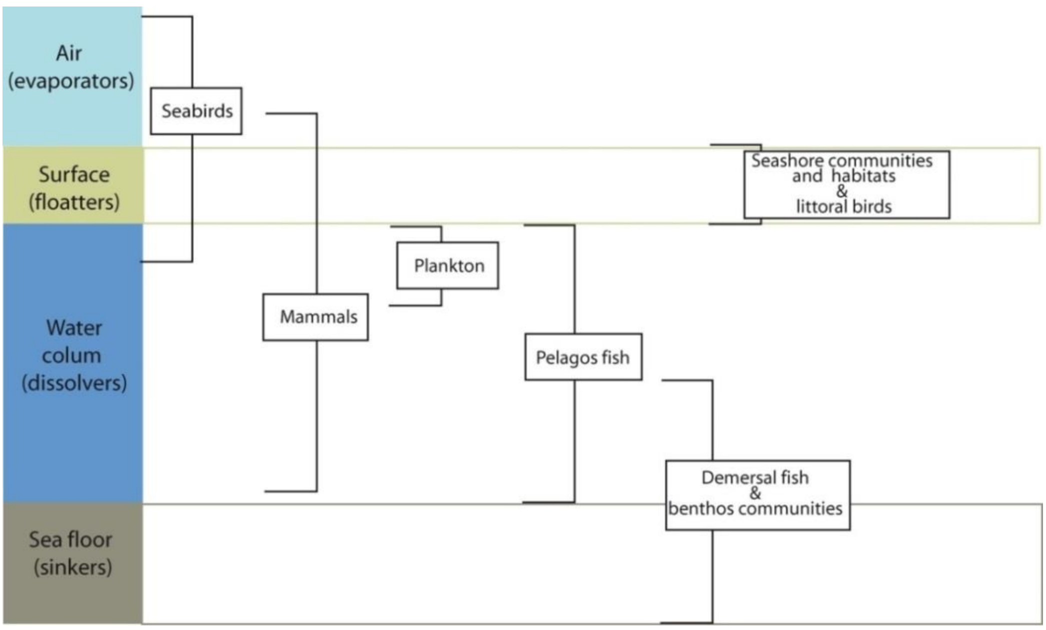

Figure 4: marine life by compartments and marine communities potentially affected by chemical pollution according to the vertical distribution of organisms

Most of the time, a chemical substance does not have one single behaviour but rather several behaviours due to its intrinsic nature and environmental processes (wind, waves, current). For necessary simplification in the frame of the HNS-MS project, the sensitivity of the selected environmental and socioeconomic features was evaluated considering the main behaviour of each chemical.

It was considered that chemicals classified respectively as floater or dissolver (SEBC classification) will have a potential impact on same ecological and socioeconomic features than "surface oil" and "dispersed oil in the water column".

For HNS-MS project:

- same features have been considered than those considered in the final report of Be-Aware II project (Nov 2015);
- same ranking scores were allocated for floater chemicals and surface oil;
- same ranking scores were allocated for dissolver chemicals and dispersed oil.

For HNS-MS project, two additional matrices were elaborated for chemicals classified as evaporator or sinker (same features, 4 seasons considered, new ranking scores defined).

Using the database developed in the frame of Be-Aware, a complementary database was built and a set of new GIS layers mapping was elaborated for air and seabed compartments.

Vulnerability mapping

The vulnerability maps were prepared by calculating vulnerability scores for each thematic (formula used to calculate these scores are presented in Appendix 1). Then, the scores were classified into five different vulnerability classes (see maps in chapters 3 to 6).

Regional vulnerability maps for habitats

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3 Regional vulnerability maps for habitats

3.1 Habitats definitions and ranking scores

The following descriptions of selected features, sensitivity and ranking score arguments are adapted and completed from BE-AWARE II report.

3.1.1 Shoreline and coastal habitats

3.1.1.1 Rocky shores and reefs

Definition: intertidal area that consists of solid rocks. Habitat physically complex where changing conditions increase the range of habitats and explain a high biodiversity. Highly variable conditions along the rock profile (light availability, degree of exposure, changes in temperature and salinity) determine distinct zonation of seaweed:

- the splash zone: only a few resistant organisms can live in this harsh environment
- The littoral zone affected by the tide:
- high tide zone, only flooded during high tides (brown algae *Pelvetia canaliculata*);
- middle tide zone is covered by water twice a day (brown algaes Fucus spiralis, *Ascophyllum nodosum, Fucus vesiculosus);*
- Low intertidal zone, only uncovered when the tide is extremely low (brown algae *Fucus serratus).*
- The subtidal zone continuously covered by water: brown algae saw wrack (*Fucus serratus*), and laminaria (*Laminaria digitata* and *Laminaria saccharina*).

Rocks and stones are substrate for epifauna such as barnacles, limpets, periwinkles (Littorina sp.) and common mussel (*Mytilus edulis*). Sub-littoral rocks and stones are important spawning and nursery areas for a number of fish species.

3.1.1.1.1 Exposed rocky shores and reefs < 20m depth

Exposed rocky shores are a mix of steep rocks and rocks with low to moderate slope (platform).

EUNIS habitats classification:

- A1.1 High energy littoral rock

Ranking score allocated:

BE-AWARE project:

Scores arguments: On shallow water toxic concentration, smothering, may affect organisms (macro algae in coastal areas can be severely affected as well as epifauna attached to rocks and stones). Recovery of algal vegetation is slow. Recolonization by most species of epifauna is however quite rapid (organisms used to harsh conditions are capable of rapid recolonization) but the recovery of certain sensitive species may be prolonged (such as species of crustaceans). High wave energy in winter limits pollutant persistence on rocks.

Surface: Spring: 3, Summer: 3, Autumn: 2, Winter: 2
Water column: Spring: 3, Summer: 3, Autumn: 2, Winter: 2

HNS-MS project:

Scores arguments: idem BE-AWARE, but seasonality has been considered: spring and summer are considered more sensitive (more organisms and presence of larva and juveniles).

Seabed: Spring: 3, Summer: 3, Autumn: 2, Winter: 2
Air: 0 for all seasons (no effect expected).

3.1.1.1.2 Exposed rocky shores and reefs > 20m depth

EUNIS habitats classification:

- A3.1 Atlantic and Mediterranean high energy infralittoral rock
- A4.1 Atlantic and Mediterranean high energy infralittoral rock

Ranking score allocated:

BE-AWARE project:

Scores arguments: low risk expected for depth > 20m that pollutant in surface reaches the reefs on deeper water. The risk is higher for seabed organisms, if the pollutant is in the water column.

Surface: Spring: 1, Summer: 1, Autumn: 1, Winter: 1
Water column: Spring: 2, Summer: 2, Autumn: 2, Winter: 2

HNS-MS project:

Scores arguments: there is some risk if the pollutant is in the water column, but dilution will limit the risk.

Seabed: Spring: 2, Summer: 2, Autumn: 2, Winter: 2
Air: 0 for all seasons (no effect expected).

3.1.1.1.3 Sheltered rocky shores and reefs < 20m depth

EUNIS habitats classification:

- A1.2 Moderate energy littoral rock
- A1.3 Low energy littoral rock

Ranking score allocated:

BE-AWARE project:

Scores arguments: organisms attached to rocks and stones, are very sensitive due to direct toxic effects and smothering on shallow water < 20 m. Recovery of algal vegetation is slow. Recolonization by most species of epifauna is however quite rapid but the recovery of certain sensitive species may be prolonged (such as species of crustaceans, echinoderms). Due to the general low energy regime spilled pollutant may persist for a long time.

Surface: Spring: 4, Summer: 4, Autumn: 3, Winter: 3
Water column: Spring: 4, Summer: 4, Autumn: 4, Winter: 4

HNS-MS project:

Scores arguments: idem Be-Aware, but seasonality has been considered: spring and summer are considered more sensitive (more organisms and presence of larva and juveniles).

Seabed: Spring: 4, Summer: 4, Autumn: 4, Winter: 4
Air: vulnerability score 0 for all seasons (no effect expected).

3.1.1.1.4 Sheltered rocky shores and reefs > 20m depth

EUNIS habitats classification:

- A3.2 Atlantic and Mediterranean moderate energy infralittoral rock
- A3.3 Atlantic and Mediterranean low energy infralittoral rock
- A4.2 Atlantic and Mediterranean moderate energy circalittoral rock
- A4.3 Atlantic and Mediterranean low energy circalittoral rock

Ranking score allocated:

BE-AWARE project:

Scores arguments: the scores for pollutant on surface have been lowered by one compared to “Sheltered rocky shores and reefs < 20 m", because the risk for the reefs to be reached in deeper waters is less. The scores for pollutant in the water column remains the same as for shallower sheltered rocky shores and reefs due to the more damaging impact than surface spills in general.

Surface: Spring: 2, Summer: 2, Autumn: 2, Winter: 2
Water column: Spring: 4, Summer: 4, Autumn: 4, Winter: 4

HNS-MS project:

Scores arguments: idem BE-AWARE:

Seabed: Spring: 4, Summer: 4, Autumn: 4, Winter: 4
Air: vulnerability score 0 for all seasons (no effect expected).

3.1.1.2 Littoral chalk communities

Definition: littoral chalk communities have developed as a result of erosion of chalk by the sea, causing the formation of vertical chalk cliffs, sea caves and intertidal chalk platforms (OSPAR 2008). This habitat is rare in Europe. The most sensitive elements are probably the algae communities that are found in the splash zone of cliffed coasts (orange, brownish or blackish gelatinous bands of algae, composed of an assemblage of Haptophyceae species) and characteristic fauna, notably 'rock-boring' invertebrates such as piddocks and *polydora* sp., is present in this habitat in intertidal and shallow water. This habitat is sensitive to contamination.

EUNIS habitats classification:

Littoral chalk communities include the following

- A1.126 Osmundea pinnatifida on moderately exposed mid eulittoral rock
- A1.2143 Fucus serratus and piddocks on lower eulittoral soft rock
- A1.441 Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock
- B3.114 Blidingia spp on vertical fringe chalk
- B3.115 Ulothrix flacca and Urospora spp on freshwater influenced vertical fringe soft rock

Ranking score allocated:

BE- AWARE project:

Scores arguments: flora and fauna present from the splash zone to shallow water level are sensitive to contamination.

Surface: Spring: 4, Summer: 4, Autumn: 3, Winter: 3.
Water column: Spring: 4, Summer: 4, Autumn: 3, Winter: 3.

HNS-MS project:

Scores arguments: idem BE- AWARE, but no effect expected in case of air contamination by evaporator HNS

Seabed: Spring: 4, Summer: 4, Autumn: 3, Winter: 3.
Air: 0 for all seasons

3.1.1.3 Sandy beaches

Definition: sandy beaches are deposits of sand, formed by deposition of material carried by water currents from land or erosion of shores. The material includes (quartz (=silica) of terrestrial origin, carbonate sands of marine origin (mollusc shells..) and other material such as heavy minerals. The grain size of sand varies from very fine to very coarse (particle diameter is in the range 0.0625 mm to 2 mm). Tidal flats (fine grain more or less muddy) which are habitats for a rich, abundant and diverse fauna are not included in sandy beaches.

The biodiversity of the beach above the high water mark is generally low. The persistence of pollutant on beaches with coarse sand is somewhat higher compared to beaches with fine-grained sand because they have the potential for higher penetration (coarser grained particles) and potential burial of pollutant. Beaches are generally exposed to waves that facilitate their cleanup and mechanical cleanup is possible.

EUNIS habitats classification:

- B1.1 Sand beach drift lines
- B 1.2 Sand beaches above the drift line

Ranking score allocated:

BE- AWARE project:

Scores arguments: low biodiversity, but score is higher during spring and summer, when the biological productivity is highest.

Surface: Spring: 2, Summer: 2, Autumn: 1, Winter: 1.
Water column: Spring: 2, Summer: 2, Autumn: 1, Winter: 1.

HNS-MS project:

Scores arguments: idem BE- AWARE, but no effect expected in case of air contamination by evaporator HNS

Seabed: Spring: 2, Summer: 2, Autumn: 1, Winter: 1.

Air: 0 for all seasons

3.1.1.4 Shingle beaches

Definition: a shingle beach is a coarse sediment beach, consisting of pebbles or small to medium-sized cobbles, typically ranging from 2 to 200 mm in diameter, the particle sizes being well sorted, or not.

Vegetated shingle communities (hosting specialist plant species) may develop out of reach of the normal tide cover. Shingle beach are extremely important to a range of other species including ground ground-nesting birds (especially waders), and to a wide variety of invertebrate species.

Pollution stranded on this type of beach penetrates rapidly and deeply into the coarse sediments and may persist for years and may seep out slowly that can re-contaminate the shoreline and damage the seabed sublittoral benthic fauna community). Shingle beaches are difficult to clean up.

EUNIS habitats classification:

- A2.11 Shingle (pebble) and gravel shores
- B2 Coastal shingle

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on ecological impact and persistence

Surface: 3 for all seasons
Water column: 3 for all seasons

HNS-MS project:

Scores arguments: idem BE- AWARE, but no effect expected in case of air contamination by evaporator HNS

Seabed: 3 for all seasons
Air: 0 for all seasons

3.1.1.5 Tidal sand and mud flat

Definition: tidal flats are found on coastlines and on the shores of lagoons and estuaries in intertidal areas where sediments from river or tides, deposits fine grain sediment (mud or sand) depending on the energy of waves beating on the shore (low energyfor mud deposits, higher for sand deposits). The upper limits of intertidal sand/mud flats are often marked by saltmarshes which are considered a part for the ranking.

Tidal sand and mud flats are very productive ecosystems (very high density and biomass of organisms, but low diversity with few rare species). Fauna species that live on tidal flats include invertebrates, birds and fishes.

Invertebrate fauna varies characteristically with salinity and composition of sediment (grain size and content of organic matter), the abundant invertebrate fauna provide food for a large number of wildfowl (feeding and resting areas for internationally important populations of migrant and wintering waterfowl). Intertidal sand and mudflats also provide an important food source for a range of fish species (plaice, sole, flounder and dab…) and are also vital nursery areas for a number of these fish species.

In most tidal flats, stranded contaminant is long-term (years) because of low wave energy (duration will depend on level of wave energy, with longer persistence in low wave energy). Cleanup is difficult.

Biological impacts on tidal flats can be severe with large scale, direct deterioration of benthic infauna communities and mass killing of birds, both being very sensitive to contamination. Benthic invertebrate fauna has a high recovery potential and in areas where oil has been removed (either naturally or due to clean up), however, the recovery of certain sensitive species may be prolonged.

<u>EUNIS habitat classification</u>:

- A2.2 Littoral sand and muddy sand
- A2.3. Littoral mud

<u>Ranking score allocated:</u>

BE- AWARE project:

<u>Scores arguments</u>: based on persistence, difficulty to cleanup and severe ecological impact

Surface: 4 for all seasons
Water column: 4 for all seasons

HNS-MS project:

<u>Scores arguments</u>: idem BE- AWARE, but no effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons

Air: 0 for all seasons (no effect expected).

3.1.1.6 Salt marshes

Definition: saltmarshes are formed by halophytic vegetation (salt tolerant species) occurring on the upper shore of sheltered coasts (estuaries, in saline lagoons…) between mean high water neap tides and high water spring tides. The diversity of plant species is relatively low (species need to be tolerant of salt, to complete or partial submersion and anoxic mud substrate.

Salt marshes are highly productive habitats which feed a broad food chain of organisms from microorganisms and invertebrates, which in turn become food for fish (sheltered nurseries), and birds (important areas for wading birds and wildfowl as refuges, breeding areas, feeding grounds especially during winter…).

Saltmarsh plants are sensitive to contamination (perennials with robust underground stems and rootstocks tend to be more resistant than annuals and shallow rooted plants). Vegetation may retain contamination for a long time. In addition, saltmarshes are very difficult to cleanup. Recovery may vary from 1 - 2 years to decades in severe cases.

EUNIS habitat classification:

- A2.5 Coastal saltmarshes and saline reed beds

EU Habitats Directive – Annex 1 habitat types:

- 1310 Salicornia and other annuals colonising mud and sand
- 1320 Spartina swards (Spartinion maritimae)
- 1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae).

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on these ecological and impact characteristics, saltmarshes have been allocated a high score for all seasons.

Surface: 4 for all seasons

Water column: 4 for all seasons

HNS-MS project:

Scores arguments: idem BE- AWARE, but no effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons

Air: 0 for all seasons

3.1.1.7 Underwater sandbanks

Definition: Underwater sandbanks are elevated, elongated topographic features, permanently submerged and predominantly surrounded by deeper water. Clean medium to fine sands or non-cohesive slightly muddy (less than 15% clay) sands on open coasts, offshore or in estuaries and marine inlets . Some occur in a layer over hard substrata. This habitat is characterised by a range of taxa including polychaetes, bivalve molluscs and amphipod crustacea, invertebrate and demersal fish communities of sandy sublittoral including *plaice (Pleuronectes platessa*) and dab (*Limanda limanda*).

Benthic fauna organisms are generally very sensitive to contamination and elevated concentrations of toxic components in the water. Impacts can be severe but are expected on shallow water where the contamination is mixed with suspended solids have settled on the seabed or directly reach the seabed.

3.1.1.7.1 Underwater sandbanks < 20m

EUNIS habitats classification:

- A5.2 Sublittoral sand

EU Habitats Directive Annex I habitat type:

- 1110 Sandbanks which are slightly covered by sea water all the time

Ranking score allocated:

BE- AWARE project:

Scores arguments: the lower score during autumn and winter reflects the lower biological productivity compared to spring and summer, the ranking score for the water column is similar for the whole season as a reflection of a higher bioavailability of pollutant in water column.

Surface: Spring: 3, Summer: 3, Autumn: 2, Winter: 2

Water column: 3 for all seasons

HNS-MS project:

Scores arguments: idem BE- AWARE, score allocated during autumn and winter reflects the lower biological productivity compared to spring and summer. No effect expected in case of air contamination by evaporator HNS

Seabed: Spring: 4, Summer: 4, Autumn: 3, Winter: 3

Air: 0 for all seasons

3.1.1.7.2 Underwater sandbanks > 20m

Ranking score allocated:

BE- AWARE project:

Scores arguments: underwater sandbanks on deeper waters (more than 20 m depth) has been allocated score 1 for all seasons when pollutant is in surface, because there is only a small risk that the product spilled at the surface will reach the seabed and affect the organisms. If the pollutant is in the water column, the vulnerability score has been raised to reflect the higher risk of pollutant reaching the seabed.

Surface: 1 for all seasons

Water column: 2 for all seasons

HNS-MS project:

Scores arguments: the score has been raised to reflect the higher risk of impact on the seabed for a "sinker" chemical. No effect expected in case of air contamination by evaporator HNS

Seabed: 3 for all seasons

Air: 0 for all seasons

3.1.1.8 Biogenic reefs

Definition: "Biogenic reefs" are those that are formed by the animal (ie. intertidal and subtidal beds of the common mussel *Mytilus edulis* or horse mussel (*Modiolus modiolus*) or created by the animals themselves (ie. reefs made of dense sub-tidal aggregations of tube-building polychaete worms (*Sabellaria alveolata, Sabellaria spinulosa*) or annelids *Serpula vermicularis*. Colonies of *Lophelia pertusa* (bank forming coral) is described in the section open sea habitats.

Depending on the species these habitats are distributed from surface (intertidal) to 100 m for horse mussels or 1800m for *Serpula vermicularis*.

Biogenic reef fauna are generally very sensitive (Smothering and toxic effects, ingestion for filter feeders) to elevated concentrations of toxic components in the water. There are numerous examples of severe impacts on benthic observed on shallow water along the coasts where toxic concentrations may reach the seabed.

EUNIS habitats classification:

The habitat "Biogenic Reefs" includes the following:

- A2.71 Littoral Sabellaria reefs
- A4.22 Sabellaria reefs on circalitttoral rock
- A561 Subittoral polychaet worm reefs on sediment
- A2.721 Mytilus edulis beds on littoral sediments
- A5.62 Sublittoral mussel beds on sediment

3.1.1.8.1 Biogenic reefs on less than 20m depth

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on their ecological and impact characteristics, biogenic reefs on shallow water (< 20 m) have been allocated high scores

Surface: 4 during all seasons

Water column: 4 during all seasons

HNS-MS project:

Scores arguments: biogenic reefs on shallow water (< 20 m) have been allocated a high score to reflect the high risk of impact on the seabed for a "sinker" chemical. No effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons

Air: 0 for all seasons (no effect expected).

3.1.1.8.2 Biogenic reefs on more than 20m depth

Ranking score allocated:

BE- AWARE project:

Scores arguments: for biogenic reefs on deeper waters, there is only a small risk that chemical spilled at the surface will reach the seabed and affect the organisms, unless the contaminant is dissolve in the water column.

Surface: 2 for all seasons

Water column: 4 for all seasons

HNS-MS project:

Scores arguments: biogenic reefs on deep water (> 20 m) have been allocated a high score to reflect the high risk of impact on the seabed for a "sinker" chemical. No effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons
Air: 0 for all seasons

3.1.1.9 Maerl beds

Definition: maerl beds are loose lying sub6tidal beds of nodular coralline red algae (3 species: *Lithothamnion corallioides*, *L. glaciale* and *Phymatolithon calcareum*) that produce a branched skeleton of calcium carbonate. The underlying structure comprises the skeletal remains of dead coralline algae, with a pink crust of living algae occupying the uppermost layer. Due to very slow growth (approximately 1 mm per year), European maerl is ecologically fragile and has a poor recovery potential. It can be encountered from the low tide mark to 20 m depth (up to 40 m). Maerl beds support high biodiversity of associated invertebrate and algal species and are important nursery areas for the juvenile stages of commercial species such as cod (*Gadus morhua*), saithe (*Pollachius virens*), pollack (*Pollachius pollachius*), juvenile scallops (*Aequipecten opercularis*). Maerl beds are considered to be of significant conservation importance due to their rarity and valuable role as a highly biodiverse habitat

EUNIS habitat classification:

- A5.51 Maerl beds.

Ranking score allocated:

BE- AWARE project:

Scores arguments:

Surface: Spring: 4, Summer: 4, Autumn: 3, Winter: 3
Water column: 4 for all seasons

HNS-MS project:

Scores arguments: idem BE- AWARE, score very reflects the high biodiversity to seabed contamination that will persist long time after contamination. No effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons
Air: 0 for all seasons (no effect expected)

3.1.1.10 Eelgrass beds

<u>Definition:</u> seagrass is found on sands and muds in intertidal and shallow subtidal areas sheltered from wave action (estuaries, inlets, bays, lagoons and sheltered channels) in intertidal zone to shallow subtidal water depending on the species (three species in the BA area: dwarf seagrass, narrow6leaved seagrass and common seagrass). Seagrass may cover extensive areas, forming seagrass beds which are very productive habitats with a high biodiversity. Seagrass beds have a rich associated fauna of benthic invertebrates and are important feeding, spawning and nursery grounds for fish. Seagrass is also food for some seabirds.

Chemical spill may affect seagrass beds either by direct smothering or by toxic effects of the water-soluble fraction.

<u>EUNIS habitats classification</u>:

- A2.61 Seagrass beds on littoral sediments
- A5.53 Sublittoral seagrass beds

<u>Ranking score allocated</u>:

BE- AWARE project:

<u>Scores arguments:</u> based on these ecological and impact characteristics, seagrass beds have been allocated a high vulnerability score for both chemical in surface or dissolving in the water column, during all seasons.

Surface: 4 for all seasons
Water column: 4 for all seasons

HNS-MS project:

<u>Scores arguments:</u> based on these ecological and impact characteristics, seagrass beds have been allocated a high vulnerability score for sinker chemical for all seasons. No effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons
Air: 0 for all seasons

3.1.1.11 Estuaries

<u>Definition</u>: estuaries are downstream parts of a river valley, subject to the tide and extending from the limit of brackish waters. They are coastal inlets where there is generally a substantial freshwater influence. They include some of the vulnerable habitats described above, especially, tidal sand and mudflats and saltmarshes as well as seagrass beds and biogenic reefs. Estuaries

are highly productive and have a high biodiversity: characteristic vegetation of brackish water and fauna (Invertebrate benthic communities, feeding areas for many birds and spawning and nursery areas for many species of fish).

If HNS enters into estuaries, natural removal rates may be slow because (little wave action) and toxic concentrations may be encountered on the shallow water. In addition, chemicals tend to adhere to the flat therefore, contamination may persist for years on them. Flora and fauna in estuaries are generally sensitive to contamination. Fate and impacts of HNS in the habitats typically encountered in estuaries are described in more detail in sections (tidal sand and mudflats, salt marshes), biogenic reefs, seagrass beds and birds).

Eunis habitat classification : none

EU Habitats directive Annex I :

- 1130 *Estuaries*

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on these ecological and impact characteristics, estuaries have been allocated high vulnerability score for both floating and dissolving HNS during all seasons.

Surface: 4 for all seasons
Water column: 4 for all seasons

HNS-MS project:

Scores arguments: based on their ecological and impact characteristics, estuaries have been allocated a high vulnerability score for sinker HNS for all seasons. No effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons
Air: 0 for all seasons

3.1.1.12 Coastal lagoons (open to the sea)

Definition: shallow inlets and bays are large indentations of the coast where, in contrast to estuaries, the influence of freshwater is generally limited. These shallow indentations are generally sheltered from wave action and contain a great diversity of sediments and substrates with a well-developed zonation of benthic communities. These communities have generally a high biodiversity (Invertebrate benthic communities, spawning and nursery areas for fish and staging areas for birds during migration and moulting). The fate of oil in coastal lagoons is similar to estuaries and they house similar organisms.

EU Habitats Directive Annex I habitat :

- 1150 Coastal lagoons.

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on these ecological and impact characteristics, coastal lagoons have been allocated high vulnerability score for both floating and dissolving HNS during all seasons.

Surface: 4 for all seasons

Water column: 4 for all seasons

HNS-MS project:

Scores arguments: based on their ecological and impact characteristics, coastal lagoons have been allocated a high vulnerability score for sinker HNS for all seasons. No effect expected in case of air contamination by evaporator HNS

Seabed: 4 for all seasons
Air: 0 for all seasons

3.1.1.13 Large shallow inlets and bays

Definition: shallow inlets and bays are large indentations of the coast where, in contrast to estuaries, the influence of freshwater is generally limited. And they are generally sheltered from wave action and contain a great diversity of sediments and substrates with a well-developed zonation of benthic communities and vegetation of high biodiversity. Shallow inlets and bays are also nursery areas for fish and staging areas for birds during migration and moulting.

The persistence of contamination in these habitats is shorter than in estuaries and lagoons open to sea due to more efficient wave energy. Fate and impacts of contamination in the habitats typically encountered in shallow inlets and bays are described in more detail in other sections (tidal sand and mudflats, salt marshes, biogenic reefs, seagrass beds and birds).

EU Habitats Directive Annex I:

- 1160 Large shallow inlets and bays.

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on these ecological and impact characteristics, large shallow inlets and bays have been allocated a lower vulnerability score than estuaries for both HNS in the surface and in the water column during all seasons.

Surface: 3 for all seasons

Water column: 3 for all seasons

HNS-MS project:

Scores arguments: based on their ecological and impact characteristics, coastal lagoons have been allocated a lower vulnerability score than estuaries for sinker HNS for all seasons. No effect expected in case of air contamination by evaporator HNS.

Seabed: 3 for all seasons

Air: 0 for all seasons

3.1.2 Open sea habitats

3.1.2.1 Open water column

Definition: plankton, pelagic fish species and seabirds dominate the fauna and flora in the open water column. Open water column includes phytoplankton (pelagic microscopic algae) and zooplankton (pelagic microscopic animals) drifting passively with currents. Phytoplankton is dominated by diatoms and dinoflagellates. Zooplankton is dominated by copepods and includes also organisms that are only planktonic in the earliest life stages such as larvae sea urchins, starfish, mussels, bristle worms, shrimps, crabs and lobsters.

Copepods are food for fish and other organisms, including larvae, juveniles and mature individuals of many commercially important fish species such as herring and sprat.

It does not include, in our case, fish eggs, fish larvae and seabirds.

EUNIS habitat classification:

- A7 Pelagic water column

3.1.2.1.1 Open water column on less than 20 m depth

Ranking score allocated:

BE- AWARE project:

Score arguments: plankton has an enormous regeneration capacity. Adult pelagic fish are highly mobile and are capable of actively avoiding contaminated areas.

The difference in scores between spring/summer and autumn/winter for surface reflects the seasonal differences in productivity of open waters.

Surface: spring: 2, summer: 2, autumn: 1, winter : 1
Water column: 2 for all seasons

HNS-MS project:

Score arguments: water column will not be reached and affected by evaporators or sinkers

Seabed: 0 for all seasons
Air: 0 for all seasons

3.1.2.1.2 Open water column on more than 20 m depth

Ranking score allocated:

BE- AWARE project:

Score arguments: floaters will not reach the deep sea. This cannot be stated for dissolvers in deep water

Surface: 1 for all seasons
Water column: 2 for all seasons

HNS-MS project:

Score arguments: water column will not be reached by evaporators or sinkers, no effect is expected.

Seabed: 0 for all seasons
Air: 0 for all seasons

3.1.2.2 Deeper sea floor on more than 20 m depth

Definition: deeper seafloor (>20 m depth) houses a wide variety of different seabed habitats:

- underwater sandbanks on waters deeper than 20 m
- biogenic reefs on waters deeper than 20 m
- seamounts
- coral gardens and sponge aggregations
- carbonate mounds
- Lophelia pertusa reefs

- seapen and burrowing megafauna

EUNIS habitats classification:

Apart above mentioned habitats, deeper seafloor habitats include also the following:

- A6.1 Deep sea rock and artificial hard substrata
- A6.2. Deep-sea mixed substrata
- A6.3. Deep-sea-sand
- A6.4. Deep-Sea muddy sand
- A6.5 Deep-sea mud
- A6.7 Raised features of the deep seabed
- A6.8 Deep sea trenches and canyons, channels slope failures and slumps on the continental slope
- A6.9 Vents, seeps, hypoxic and anoxic habitats of the deep sea

Ranking score allocated:

BE- AWARE project:

Score arguments: surface contamination will not reach the deep sea. In case of contamination in the water column, there may be a slightly bigger risk that oil will have an impact on the seabed.

Surface: 1 for all seasons

Water column: 2 for all seasons

HNS-MS project:

Score arguments: all these habitats developed on seabed could be reached by sinkers and no effect is expected in case of air contamination by evaporator HNS.

Seabed: 3 for all seasons

Air: 0 for all seasons

3.1.2.3 Seamounts

Definition: seamounts are of volcanic origin. They are undersea mountains, with a crest that rises more than 1,000 metres above the surrounding sea floor. Seamounts provide ideal conditions for suspension feeders (corals, sponges, hydroids, ascidians…) and for commercially important fish species (such as deep sea perch).

EUNIS habitat classification:

- A6.72 Seamounts, knolls and banks

Ranking score allocated:

BE- AWARE project:

Score arguments: seamounts are not vulnerable to surface pollutant because they are encountered in very deep waters. There may be a slightly higher risk that contamination in the water column will reach a seamount.

Surface: 1 for all seasons
Water column: 2 for all seasons

HNS-MS project:

Score arguments: these habitats develop on seabed, they could be reached by sinkers, but no effect is expected in case of air contamination by evaporator HNS.

Seabed: 4 for all seasons
Air: 0 for all seasons (no effect expected).

3.1.2.4 Coral gardens and sponge aggregations

Definition: a coral garden is a relatively dense aggregation of coral species. The biological diversity is typically high. The habitat can also include relatively large numbers of sponge species and basket stars (*Gorgonocephalus*), brittle stars, crinoids, molluscs, crustaceans and deep-water fish. Coral gardens can be found as shallow as 30 m and down to several thousand metres on open ocean seamounts.

Deep-sea sponge aggregations mainly include species of *Hexactinellida* and *Desmospongia*. The deep-sea sponge communities occur in water depths of 250-1300 m and are often found at the same location than cold-water corals.

EUNIS habitat classification

The coral garden habitat occurs within each of the following deep seabed types:

- A6.1 Deep-sea rock and artificial hard substrata
- A6.2 Deep-sea mixed substrata
- A6.3 Deep-sea sand
- A6.4 Deep-sea muddy sand
- A6.5 Deep-sea mud
- A6.7 Raised features of the deep-seabed
- A6.8. Deep-sea trenches and canyons, channels, slope failures and slumps on the continental slope

- A6.9 Vents, seeps, hypoxic and anoxic habitats of the deep sea
- A6.62: Deep-sea sponge aggregations.

Ranking score allocated:

BE- AWARE project:

Score arguments: There is a higher risk that contaminat in the water column will reach coral gardens and sponge aggregations than a floating contamination. Coral gardens and sponge aggregations have been allocated a relatively high score, due to their high biodiversity and slow-growing characteristics.

Surface: 2 for all seasons
Water column: 3 for all seasons

HNS-MS project:

Score arguments: coral gardens and sponge aggregations develop on seabed: they could be reached by sinkers. They have been allocated a high score due to their high biodiversity and slow-growing characteristics. No effect is expected in case of air contamination by evaporator HNS.

Seabed: 4 for all seasons
Air: 0 for all seasons

3.1.2.5 Carbonate mounds

Description: carbonate mounds are very steep-sided mounds of variety of shapes that occur in water depths of 500-1100 m. Characteristic fauna of carbonate mounds include the coral species *Lophelia pertusa* and *Madrepora oculata* as well as echiuran worms. Other species that may be encountered include large eunicid worms and sipunculids, *Ophiactis balli* (ophiuroid), *Astarte* sp. (bivalve), cerianthid anemones and caridean shrimps (OSPAR 2008).

EUNIS habitat classification:

- A6.75 Carbonate mounds

Ranking score allocated:

BE- AWARE project:

Score arguments: there is a higher risk that contaminant in the water column will reach carbonate mounds than floating pollution. Carbonates mounds have been allocated a relatively high score, due to their high biodiversity and slow-growing characteristics.

Surface: 2 for all seasons

Water column: 3 for all seasons

HNS-MS project:

Score arguments: carbonate mounds are encountered on seabed: they could be reached by sinkers. They have been allocated a high score due to their high biodiversity and slow-growing characteristics. No effect is expected in case of air contamination by evaporator HNS.

Seabed: 4 for all seasons

Air: 0 for all seasons

3.1.2.6 Lophelia pertusa reefs

Description: *Lophelia pertusa* is a reef building, deep-water coral, which grows in the deep waters between 80 metres to more than 3,000 metres depth. The growth of *Lophelia pertusa* is extremely slow (about 6mm/year). The biodiversity of these reefs is high. Lophelia beds create a specialised habitat for deep-water fish and invertebrates (brittle stars, molluscs, amphipods, crabs). It is recognized as a threatened habitat in need of protection by the OSPAR commission.

EUNIS habitat classification:

- A5.631 *Circalittoral (Lophelia pertusa) reefs*
- A6.611. *Deep sea (Lophelia pertusa) reefs*

Ranking score allocated:

BE- AWARE project:

Score arguments: there is a higher risk that contaminant in the water column will reach *Lophelia pertusa* reefs than an spill in surface. Lophelia pertusa reefs mounds have been allocated a relatively high score, due to their high biodiversity and slow-growing characteristics.

Surface: 2 for all seasons

Water column: 3 for all seasons

HNS-MS project:

Score arguments: Lophelia pertusa reefs develop on seabed, they could be reached by sinkers. They have been allocated a high score due to their high biodiversity and slow-growing characteristics.

Seabed: 4 for all seasons

Air: 0 for all seasons

3.1.2.7 Sea-pen and burrowing megafauna

Definition: this habitat occurs in areas of fine mud that is heavily bioturbated by burrowing megafauna at water depths ranging from 15-200 m or more.

No effect is expected in case of air contamination by evaporator HNS.

EUNIS habitats classification:

- A5.361 Seapens and burrowing megafauna in circalittoral fine mud
- A5.362 Burrowing megafauna and *Maxmuelleris lankestri* in circalittoral mud

Ranking score allocated:

BE- AWARE project:

Score arguments: a relatively high score has been allocated because it is a threatened/declining habitat (OSPAR, 2008) and some are in shallow water

Surface: 2 for all seasons

Water column: 3 for all seasons

HNS-MS project:

Score arguments: this habitat develop on sea floor, it could be reached by sinkers. A high score has been allocated because this habitat is a threatened/declining habitat. No effect is expected in case of air contamination by evaporator HNS.

Seabed: 4 for all seasons

Air: 0 for all seasons

3.2 Habitats ranking matrices

Table 6: Habitats ranking matrices for sea surface and water column

HABITATS	Surface				Water column			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Shoreline and Coastal habitats								
Exposed rocky shores and reefs on less than 20m depth	3	3	2	2	3	3	2	2
Exposed rocky shores and reefs on more than 20m depth	1	1	1	1	2	2	2	2
Sheltered rocky shores and reefs on less than 20m depth	4	4	3	3	4	4	4	4
Sheltered rocky shores and reefs on more than 20m depth	2	2	2	2	4	4	4	4
Littoral chalk communities	4	4	3	3	4	4	3	3
Sandy beaches	2	2	1	1	2	2	1	1
Shingle beaches	3	3	3	3	3	3	3	3
Tidal sand and mud flats	4	4	4	4	4	4	4	4
Salt marshes	4	4	4	4	4	4	4	4
Underwater sandbanks on less than 20m depth	3	3	2	2	3	3	3	3
Underwater sandbanks on more than 20m depth	1	1	1	1	2	2	2	2
Biogenic reefs on less than 20m depth	4	4	4	4	4	4	4	4
Biogenic reefs on more than 20m depth	2	2	2	2	4	4	4	4
Maerl beds	4	4	3	3	4	4	4	4
Eelgrass beds (Zostera sp. > 5%)	4	4	4	4	4	4	4	4
Estuaries	4	4	4	4	4	4	4	4
Coastal lagoons (open to the sea)	4	4	4	4	4	4	4	4
Large shallow inlets and bays	3	3	3	3	3	3	3	3
Open sea Habitats								
Open water column on less than 20 m depth	2	2	1	1	2	2	2	2
Open water column on more than 20m depth	1	1	1	1	2	2	2	2
Deeper sea floor on more than 20m depth	1	1	1	1	2	2	2	2
Seamounts	1	1	1	1	2	2	2	2
Coral gardens and sponge aggregations	2	2	2	2	3	3	3	3
Carbonate mounds	2	2	2	2	3	3	3	3
Lophelia pertusa reefs	2	2	2	2	3	3	3	3
Sea-pen and burrowing megafauna	2	2	2	2	3	3	3	3

Table 7: Habitats ranking matrices for seabed and air

HABITATS	Seabed				Air			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Shoreline and Coastal habitats								
Exposed rocky shores and reefs on less than 20m depth	3	3	2	2	1	1	1	1
Exposed rocky shores and reefs on more than 20m depth	2	2	2	2	0	0	0	0
Sheltered rocky shores and reefs on less than 20m depth	4	4	4	4	1	1	1	1
Sheltered rocky shores and reefs on more than 20m depth	4	4	4	4	0	0	0	0
Littoral chalk communities	4	4	3	3	1	1	1	1
Sandy beaches	2	2	1	1	1	1	1	1
Shingle beaches	3	3	3	3	1	1	1	1
Tidal sand and mud flats	4	4	4	4	1	1	1	1
Salt marshes	4	4	4	4	1	1	1	1
Underwater sandbanks on less than 20m depth	4	4	3	3	1	1	1	1
Underwater sandbanks on more than 20m depth	3	3	3	3	0	0	0	0
Biogenic reefs on less than 20m depth	4	4	4	4	1	1	1	1
Biogenic reefs on more than 20m depth	4	4	4	4	0	0	0	0
Maerl beds	4	4	4	4	1	1	1	1
Eelgrass beds (Zostera sp. > 5%)	4	4	4	4	1	1	1	1
Estuaries	4	4	4	4	1	1	1	1
Coastal lagoons (open to the sea)	4	4	4	4	1	1	1	1
Large shallow inlets and bays	4	4	3	3	1	1	1	1
Open sea Habitats								
Open water column on less than 20 m depth	1	1	1	1	1	1	1	1
Open water column on more than 20m depth	1	1	1	1	0	0	0	0
Deeper sea floor on more than 20m depth	3	3	3	3	0	0	0	0
Seamounts	4	4	4	4	0	0	0	0
Coral gardens and sponge aggregations	4	4	4	4	0	0	0	0
Carbonate mounds	4	4	4	4	0	0	0	0
Lophelia pertusa reefs	4	4	4	4	0	0	0	0
Sea-pen and burrowing megafauna	4	4	4	4	0	0	0	0

3.3 Habitats vulnerability maps

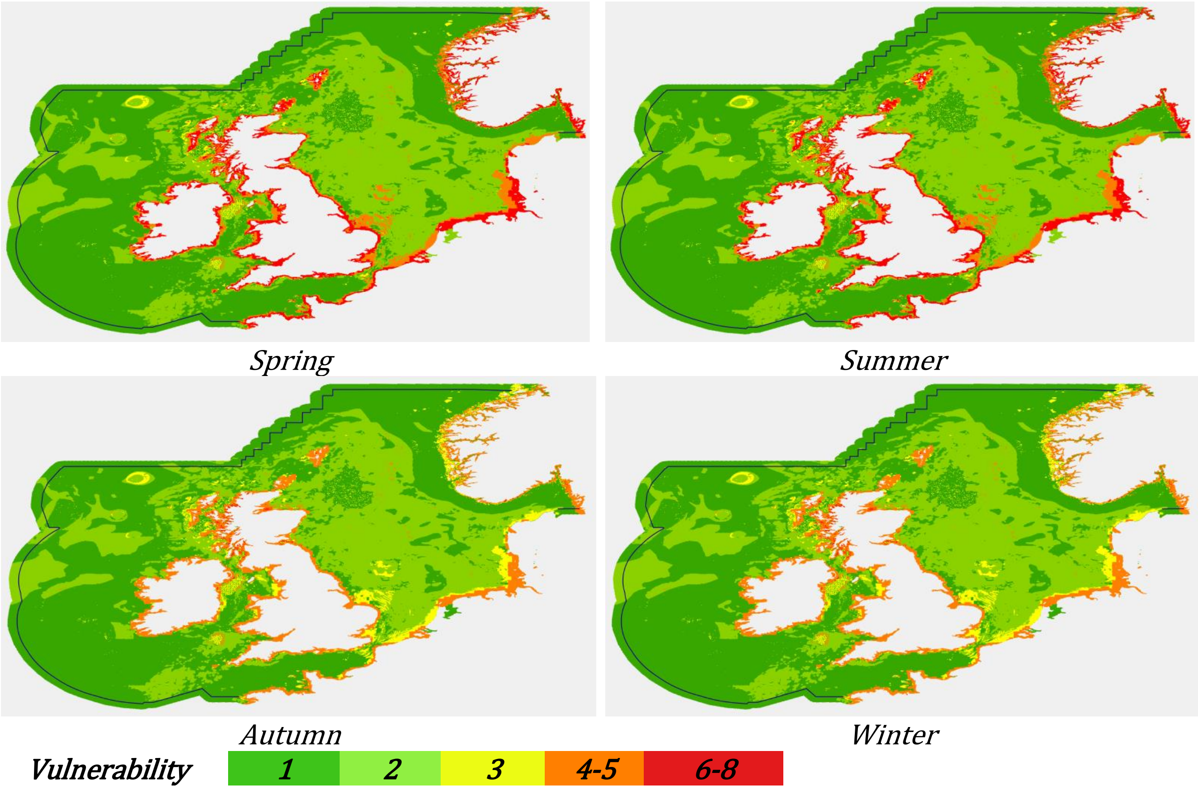

Figure 5: Seasonal habitats vulnerability to HNS pollution at the sea surface

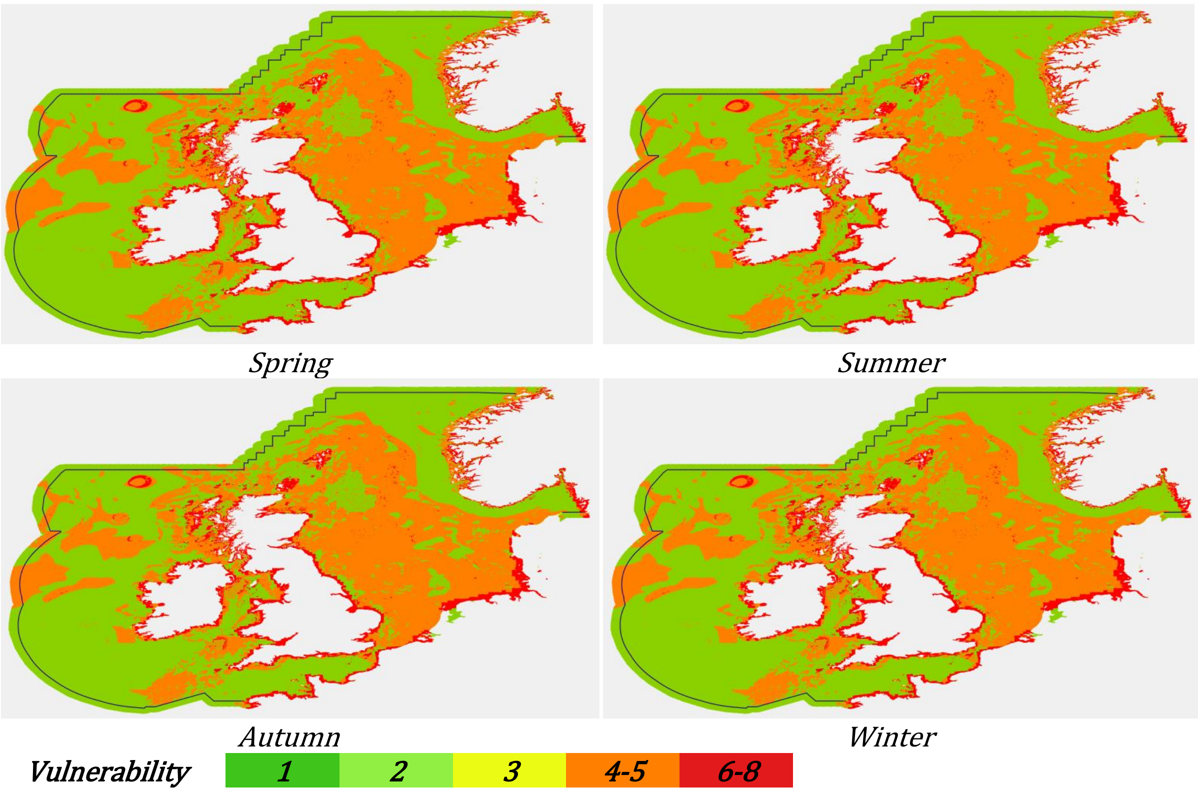

Figure 6 : Seasonal habitats vulnerability to HNS pollution in the water column

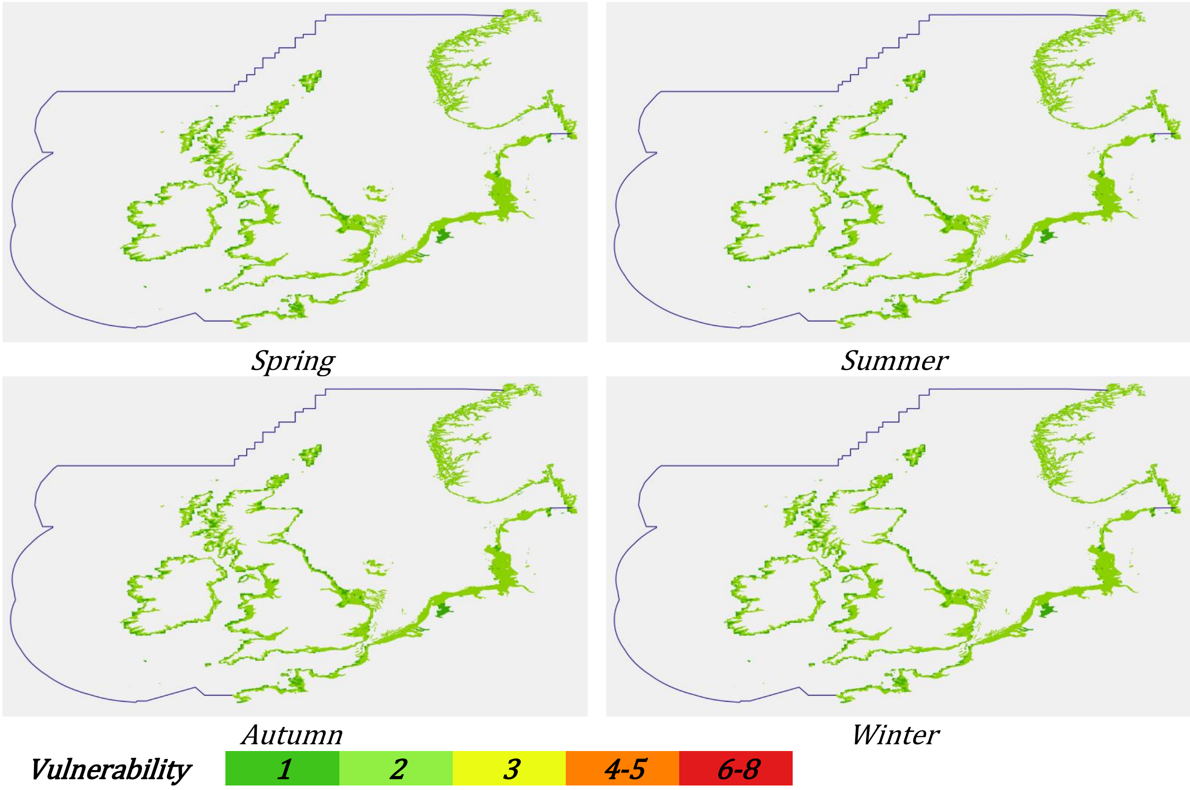

Figure 7: Seasonal habitats vulnerability to HNS pollution in the air

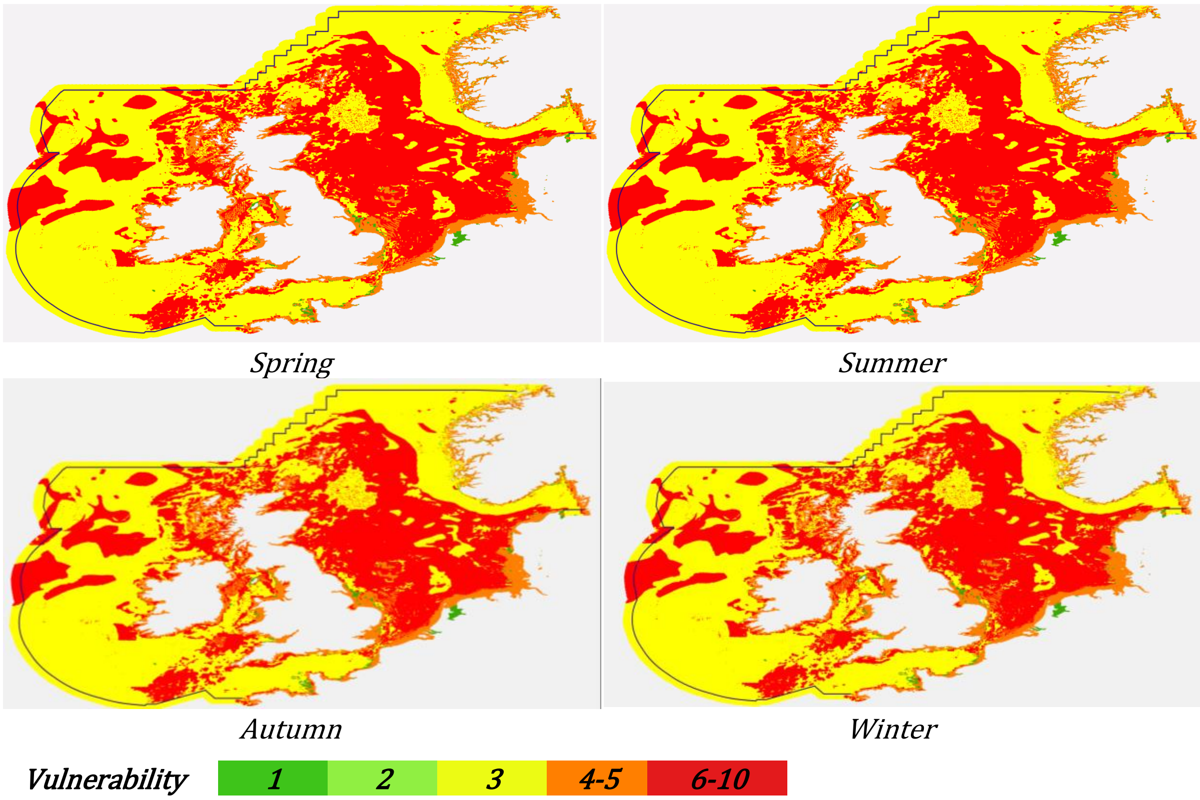

Figure 8: Seasonal habitats vulnerability to HNS pollution of the seabed

Regional vulnerability maps for species

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4 Regional vulnerability maps for species

4.1 Species definitions and ranking scores

4.1.1 Birds

Definition: seabirds include those species of bird that depend wholly or mainly on the marine environment for their survival. They spend most of their lives at sea, exploiting its surface and the water column to varying depths for food. Most of these species come ashore only to breed. They include auks, gannets, divers, cormorants, sea ducks and other migratory seabirds.

Costal birds are birds commonly found along sandy or rocky shorelines, mudflats, and shallow waters. They include gulls, terns, waders, ducks, geese, swans…

Birds can be affected by contact of feathers with oil (smothering/splashes that will affect the plumage), by ingestion (oil/oiled preys), by inhalation (fumes) or by absorption (through skin or eggs) and also by destruction of habitats or food resources.

Auks, divers, grebes, diving ducks, swans are highly vulnerable to chemical contamination while fulmars, gannets, cormorants, kittiwakes are moderately vulnerable and seagull, terns, geese, ducks are slightly vulnerable.

4.1.1.1 Breeding areas for sea and shore birds

Ranking score allocated:

BE- AWARE project:

Score arguments: the open waters and tidal flats off breeding areas are important feeding areas for breeding birds and large numbers of birds are concentrated here. Surface contamination in such areas may cause massive kills, whereas contamination in the water column may have a lesser impact (no major effects on the plumage, although increased dietary uptake of contaminant may occur).

Surface: 4 for spring and summer (peak breeding); autumn: 3, winter: 2 (contamination during these seasons may persist until breeding season)
Water column: 3 for spring and summer; 1 for autumn and winter.

HNS-MS project:

Score arguments: a spill of sinker HNS can affect the shore in shallow waters (coastal birds). In case of evaporators HNS, birds can also be affected by inhalation, but contact time will be of short duration.

Seabed: 4 for spring and summer (peak breeding); autumn: 3, winter; 1
Air: 3 for spring and summer; 1 for autumn and winter.

4.1.1.2 Wintering areas for sea and shore birds

Ranking score allocated:

BE- AWARE project:

Score arguments: wintering birds at sea spend most of the time on the sea-surface and are therefore particularly vulnerable. Effects of pollutant in the water column, on birds are much less severe compared to surface contamination. There are no major effects on the plumage, although increased dietary uptake of oil may occur.

Surface: spring: 3 (still be some "wintering"), summer: 1, autumn: 3 (wintering have started), winter: 4
Water column: 1 for spring, summer, autumn, winter: 2

HNS-MS project:

Score arguments: a spill of sinker HNS can affect the shore in shallow waters and have an impact on wintering areas of coastal birds. Birds can also be affected by inhalation but contact time will be of short duration.

Seabed: 4 in spring and summer (peak breeding), autumn: 3, winter: 1
Air: spring: 2, summer: 1, autumn: 2, winter: 3

4.1.1.3 Staging areas for migrating birds

Ranking score allocated:

BE- AWARE project:

Score arguments: The majority of birds in staging areas for migrating birds are shorebirds and waterfowl that are often concentrated on tidal flats and are very vulnerable to contamination. Effects of contamination of the water column on birds are less severe compared to floaters spills.

Surface: 4 for spring and autumn (peak numbers), 2 for summer and winter.
Water column: 2 for spring and autumn, 1 in summer and winter.

HNS-MS project:

Score arguments: a spill of a sinker HNS can affect the shore in shallow waters and have an impact on wintering areas of coastal birds. Birds can also be affected by inhalation but contact time will be of short duration.

Seabed: 4 in spring and autumn (peak numbers), 2 in summer and winter.
Air: spring: 3, summer: 1, autumn, 3, winter: 1

4.1.2 Fishes

4.1.2.1 Spawning areas for fish

Definition: the fish can be divided into demersal spawners, i.e. fish that deposit their eggs on the seabed (often on vegetation, gravel or hard substrates), and pelagic spawners that shed their eggs in the water column.

Pelagic spawners: 9 significant commercial importance species are included in the analysis (Haddock, Blue whiting, Norway pout, Saithe, Cod, Whiting, Western mackerel, Horse mackerel, Sprat). The pelagic spawning species differ markedly with regard to spawning period.

Demersal spawners: 6 different stocks of herrings are included in the analysis (Norwegian spring spawning stock, Buchan/Shetland herring, banks herring spawning off the English east coast, West of Scotland autumn spawning herring, Irish autumn/winter spawning herring, Down herring).

Pelagic spawners

Ranking score allocated:

4.1.2.2 Spawning areas for fish with pelagic eggs spawning during spring

BE- AWARE project:

Score arguments: most fish species produce vast numbers of eggs and larvae and most species have extensive spawning grounds. For situations where contaminant is in the water column, the scores have been increased a little due to the increased risk of exposure.

Surface: spring: 2, summer: 1, autumn: 0, winter: 0
Water column: spring: 3, summer: 2, autumn: 0, winter: 0

HNS-MS project:

Score arguments: pelagic eggs spawning areas will not be affected by evaporators or sinkers

Seabed: 0 for all seasons

Air: 0 for all seasons

4.1.2.3 Spawning areas for fish with pelagic eggs spawning during summer

BE- AWARE project:

Score arguments: most fish species produce vast numbers of eggs and larvae and most species have extensive spawning grounds. For situations where the contaminant is in the water column, the scores have been increased a little due to the increased risk of exposure.

Surface: spring: 1, summer: 2, autumn: 1, winter: 0

Water column: spring: 2, summer: 3, autumn: 2, winter: 0

HNS-MS project:

Score arguments: pelagic eggs spawning areas will not be affected by evaporators or sinkers

Seabed: 0 for all seasons

Air: 0 for all seasons

4.1.2.4 Spawning areas for fish with pelagic eggs spawning during autumn

BE- AWARE project:

Score arguments: most fish species produce vast numbers of eggs and larvae and most species have extensive spawning grounds. For situations where contamination is in the water column, the scores have been increased a little due to the increased risk of exposure.

Surface: spring 0, summer 1, autumn 2, winter 0

Water column: spring 0, summer 2, autumn 3, winter 0

HNS-MS project:

Score arguments: pelagic eggs spawning areas will not be affected by evaporators or sinkers

Seabed: spring 0, summer 0, autumn 0, winter 0

Air: spring 0, summer 0, autumn 0, winter 0

4.1.2.5 Spawning areas for fish with pelagic eggs spawning during winter

BE- AWARE project:

Score arguments: Most fish species produce vast numbers of eggs and larvae and most species have extensive spawning grounds. For situations where dispersants are used, the scores have been increased a little due to the increased risk of exposure to oil components.

Surface: spring 1, summer 0, autumn 0, winter 2
Water column: spring 2, summer 0, autumn 0, winter 3

HNS-MS project:

Score arguments: pelagic eggs spawning areas will not be affected by evaporators or sinkers HNS.

Seabed: 0 for all seasons
Air: 0 for all seasons

4.1.2.6 Demersal spawners (herrings)

The Norwegian spring spawning stock (Feb-Mar)

BE- AWARE project:

Score arguments: as herring return to the same spawning grounds year after year, loss of sites that are critical for spawning due to marine pollution may have a long-term effect on herring population size.

Spawning areas on shallow water for herring have been allocated a high score during the spawning season. For the non-spawning season the score has been lowered by one unit because on the one hand it is outside the spawning season and on the other, persisting pollutant spilled during the spawning season may still affect spawning outside the spawning season due to destruction of spawning substrate.

Surface: spring: 4, summer: 3, autumn: 3, winter: 4
Water column: spring: 4, summer: 3, autumn: 3, winter 4

HNS-MS project:

Score arguments: demersal eggs spawning areas will be affected by sinkers but not by evaporators. The scores for sinkers show the same seasonal pattern as for dissolvers.

Seabed: spring: 4, summer: 3, autumn: 3, winter: 4
Air: 0 for all seasons

4.1.2.7 The Buchan/Shetland herring (Aug-Sept)

BE- AWARE project:

Score arguments: as herring return to the same spawning grounds year after year, loss of sites that are critical for spawning due to marine pollution may have a long-term effect on herring population size.

Spawning areas on shallow water for herring have been allocated a high score during the spawning season. For the non-spawning season the score has been lowered by one unit because on the one hand it is outside the spawning season and on the other, persisting pollutant spilled during the spawning season may still affect spawning outside the spawning season due to destruction of spawning substrate.

Surface: spring: 3, summer: 4, autumn: 4, winter: 3
Water column: spring: 3, summer: 4, autumn: 4, winter: 3

HNS-MS project:

Score arguments: demersal eggs spawning areas will be affected by sinkers but not by evaporators. The scores for sinkers show the same seasonal pattern as for dissolvers.

Seabed: spring: 3, summer: 4, autumn: 4, winter: 3
Air: 0 for all seasons

4.1.2.8 The Banks herring and the West of Scotland autumn spawning herring (Aug-Oct)

BE- AWARE project:

Score arguments: as herring return to the same spawning grounds year after year, loss of sites that are critical for spawning due to marine pollution may have a long-term effect on herring population size.

Spawning areas on shallow water for herring have been allocated a high score during the spawning season. For the non-spawning season the score has been lowered by one unit because on the one hand it is outside the spawning season and on the other, persisting pollutant spilled during the spawning season may still affect spawning outside the spawning season due to destruction of spawning substrate.

Surface: spring: 3, summer: 4, autumn: 4, winter: 3
Water column: spring: 3, summer: 4, autumn 4, winter 3

HNS-MS project:

Score arguments: demersal eggs spawning areas will be affected by sinkers but not by evaporators. The scores for sinkers show the same seasonal pattern as for dissolvers.

Seabed: spring 3, summer 4, autumn 4, winter 3

Air: 0 for all seasons

4.1.2.9 The Irish autumn/winter spawning herring (Sep-Feb)

BE- AWARE project:

Score arguments: as herring return to the same spawning grounds year after year, loss of sites that are critical for spawning due to marine pollution may have a long-term effect on herring population size.

Spawning areas on shallow water for herring have been allocated a high score during the spawning season. For the non-spawning season the score has been lowered by one unit, because on the one hand it is outside the spawning season and on the other, persisting pollutant spilled during the spawning season may still affect spawning outside the spawning season due to destruction of spawning substrate.

Surface: spring: 3, summer: 3, autumn: 4, winter: 4

Water column: spring: 3, summer: 3, autumn: 4, winter: 4

HNS-MS project:

Score arguments: demersal eggs spawning areas will be affected by sinkers but not by evaporators. The scores for sinkers show the same seasonal pattern as for dissolvers.

Seabed: spring 3, summer 3, autumn 4, winter 4

Air: 0 for all seasons

4.1.2.10 The Down herring (Nov-Jan)

BE- AWARE project:

Score arguments: as herring return to the same spawning grounds year after year, loss of sites that are critical for spawning due to marine pollution may have a long-term effect on herring population size.

Spawning areas on shallow water for herring have been allocated a high score during the spawning season. For the non-spawning season the score has been lowered by one unit because on the one hand it is outside the spawning season and on the other, persisting pollutant spilled during the spawning season may still affect spawning outside the spawning season due to destruction of spawning substrate.

Surface: spring 3, summer 3, autumn 4, winter 4

Water column: spring 3, summer 3, autumn 4, winter 4

HNS-MS project:

Score arguments: demersal eggs spawning areas will be affected by sinkers but not by evaporators. The scores for sinkers show the same seasonal pattern as for dissolvers.

Seabed: spring 3, summer 3, autumn 4, winter 4
Air: 0 for all seasons.

4.2 Species ranking matrices

Table 8: Ranking matrices for species at sea surface and in the water column

SPECIES	Surface				Water column			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Species Features								
Breeding areas for birds (incl. foraging areas)	4	4	3	**2**	3	3	2	1
Wintering areas for birds	3	1	3	4	1	1	1	2
Staging areas for birds	4	2	4	2	2	1	2	1
Spawning areas for fish: during SPRING	2	1	0	0	3	2	0	0
Spawning areas for fish: during SUMMER	1	2	1	0	2	3	2	0
Spawning areas for fish: during AUTUMN	0	1	2	0	0	2	3	0
Spawning areas for fish: during WINTER	1	0	0	2	2	0	0	3
· Norwegian spring spawning stock	4	3	3	4	4	3	3	4
· Buchan/Shetland herring	3	4	4	3	3	4	4	3
· Banks herring and the West of Scotland autumn spawning herring	3	4	4	3	3	4	4	3
· Irish autumn/winter spawning herring	3	3	3	4	3	3	**4**	4
· Down herring	3	3	4	4	3	3	4	4

Table 9: Ranking matrices for species at the seabed and in the air

SPECIES	Seabed				Air			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Species Features								
Breeding areas for birds (incl. foraging areas)	4	4	3	1	3	3	2	1
Wintering areas for birds	3	1	3	4	2	1	2	3
Staging areas for birds	4	2	4	2	3	1	3	1
Spawning areas for fish: during SPRING	1	1	0	0	1	1	0	0
Spawning areas for fish: during SUMMER	1	1	1	0	1	1	1	0
Spawning areas for fish: during AUTUMN	0	1	1	0	0	1	1	0
Spawning areas for fish: during WINTER	1	0	0	1	1	0	0	1
· Norwegian spring spawning stock	4	3	3	4	0	0	0	0
· Buchan/Shetland herring	3	4	4	3	0	0	0	0
· Banks herring and the West of Scotland autumn spawning herring	3	4	4	3	0	0	0	0
· Irish autumn/winter spawning herring	3	3	4	4	0	0	0	0
· Down herring	3	3	4	4	0	0	0	0

4.3 Species vulnerability maps

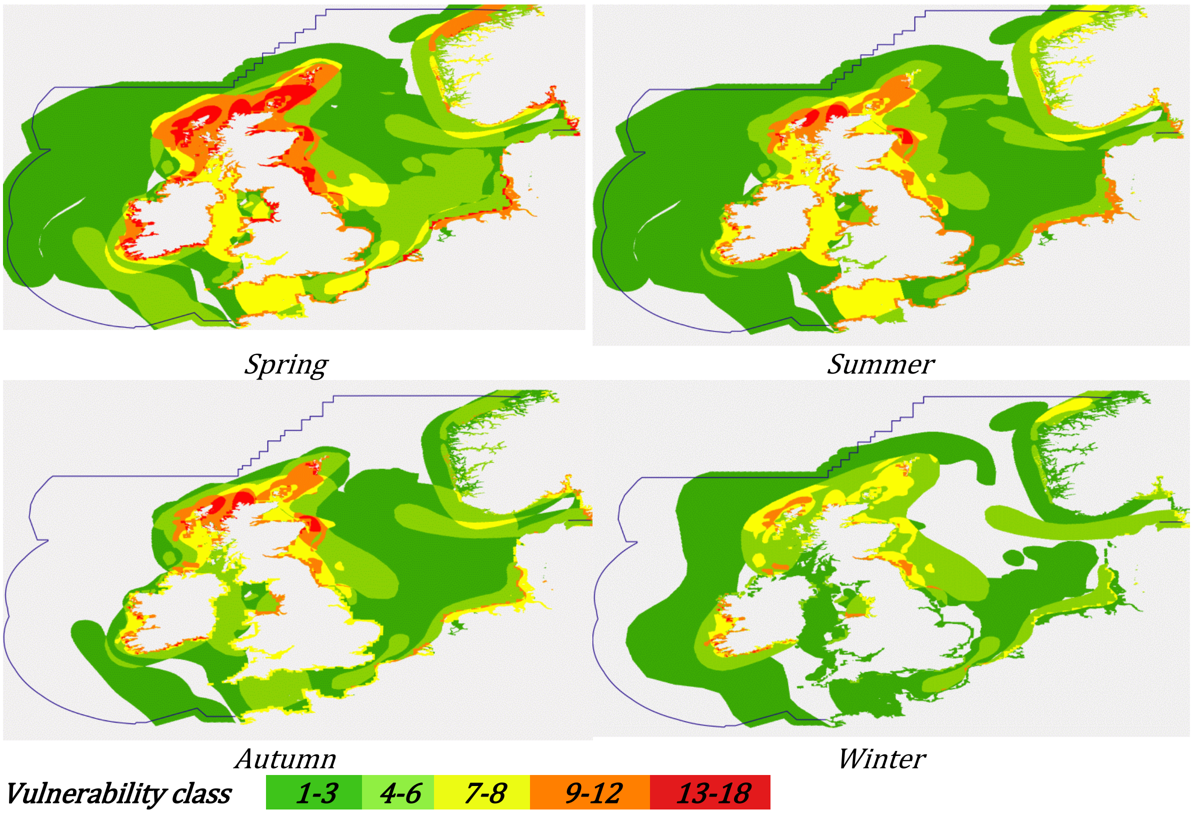

Figure 9: Seasonal vulnerability of species to HNS pollution at the sea surface

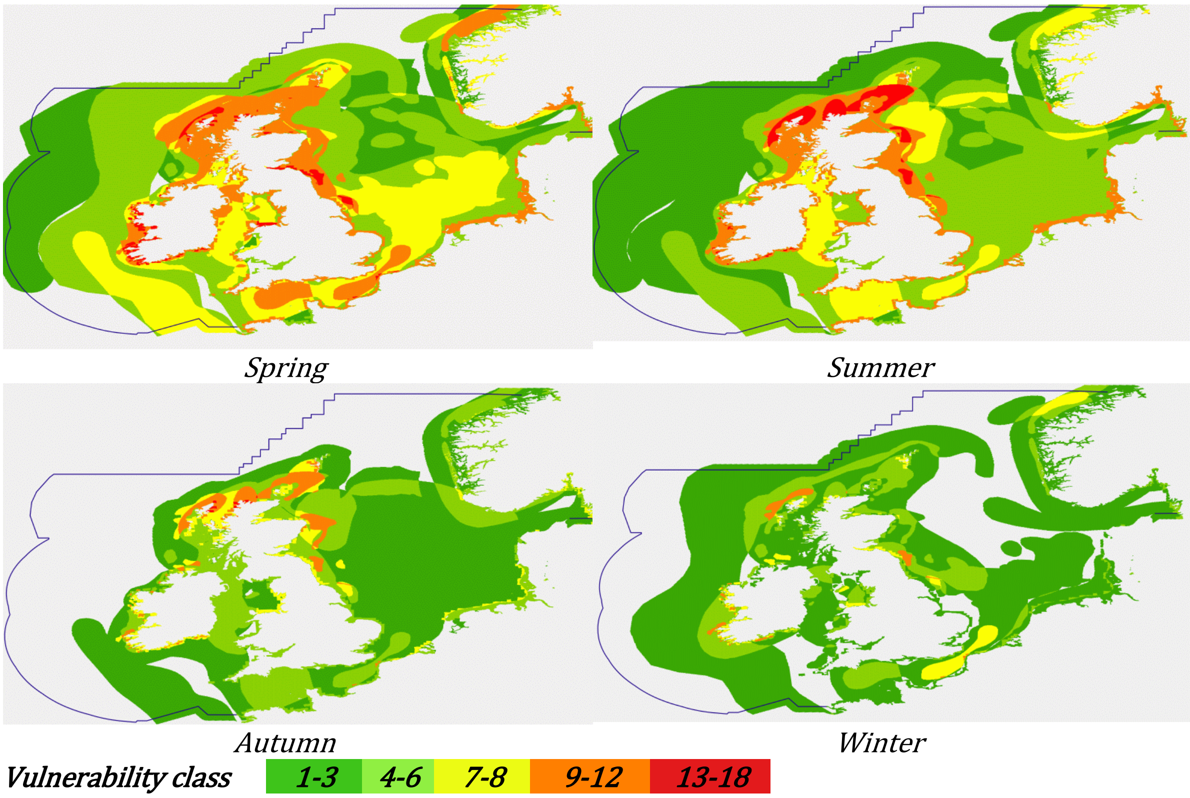

Figure 10: Seasonal vulnerability of species to HNS pollution in the water column

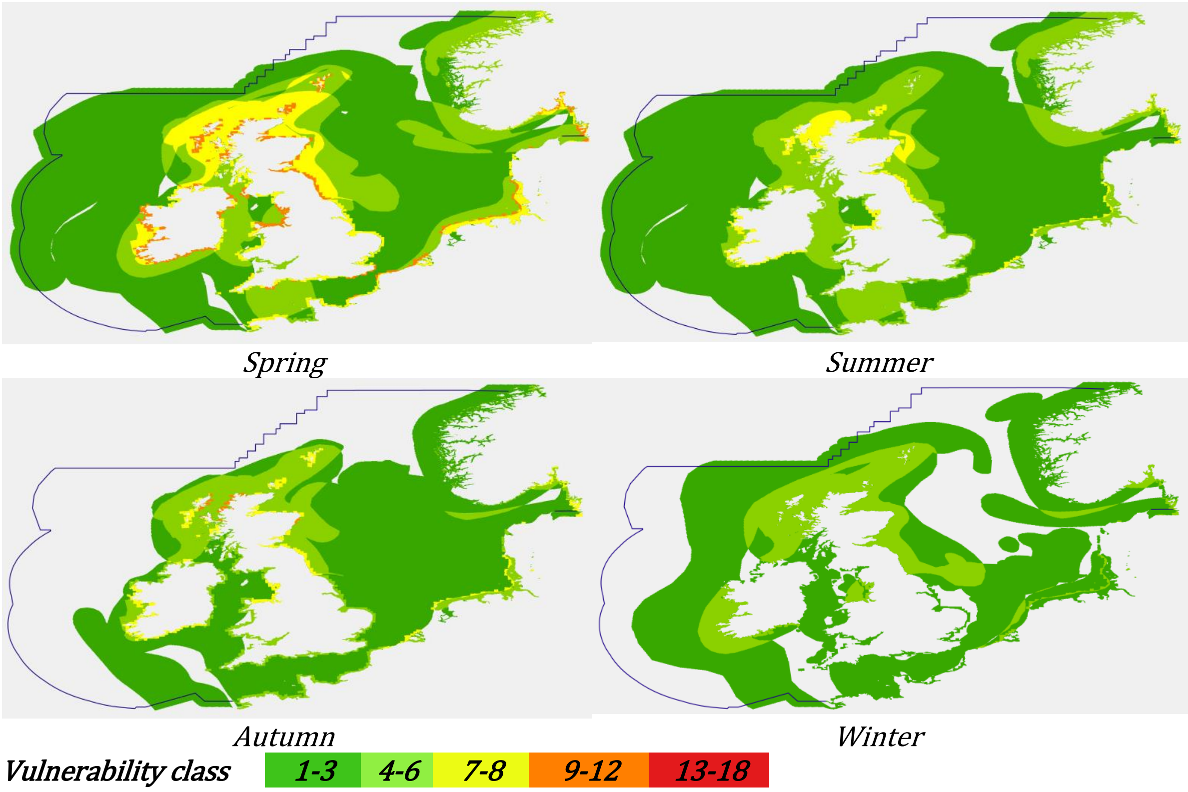

Figure 11: Seasonal vulnerability of species to HNS pollution in the air

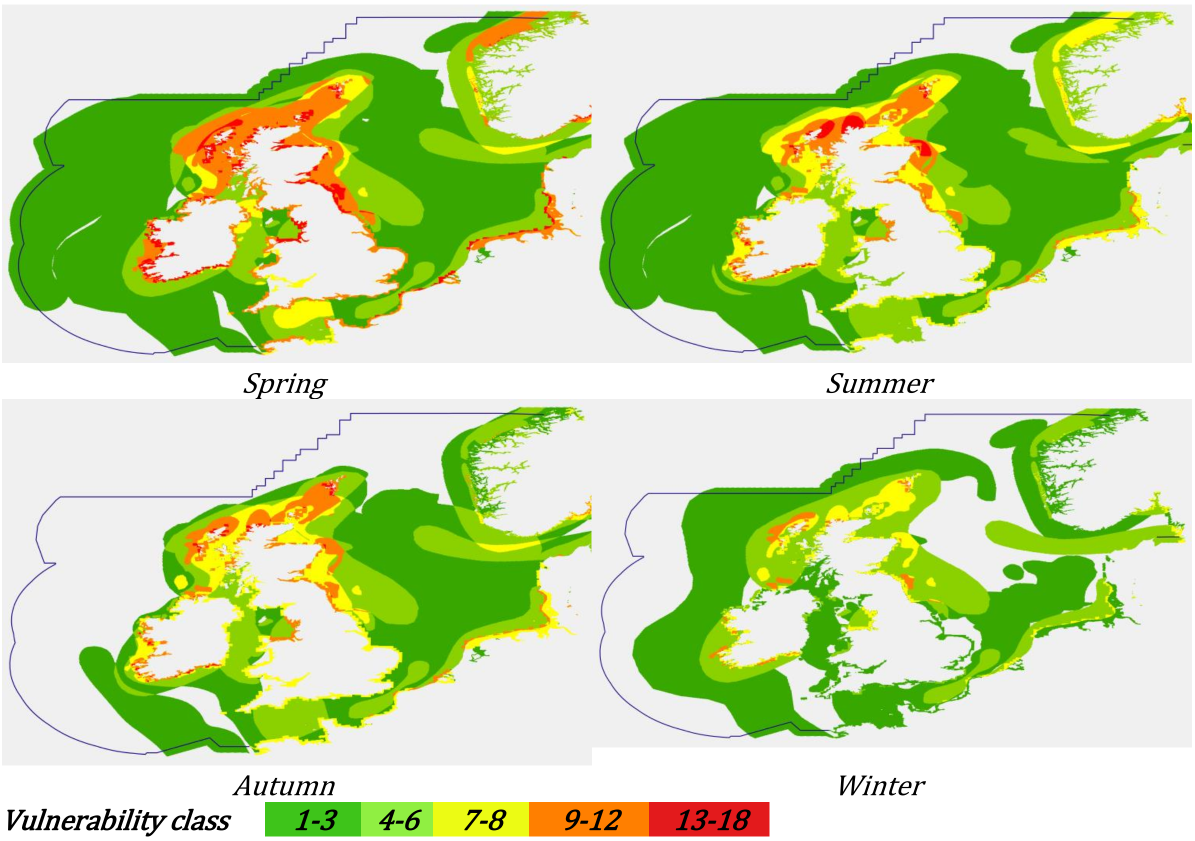

Figure 12: Seasonal vulnerability of species to HNS pollution at the seabed

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Regional vulnerability maps for marine protected areas

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5 Regional vulnerability maps for marine protected areas

5.1 Protected areas definitions and ranking scores

5.1.1 Natura 2000 areas

Definition: Natura 2000 is a network of nature protection areas in the territory of the European Union. It is made up of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

A Special Area of Conservation (SAC) is defined in the European Union's Habitats Directive (92/43/EEC), also known as the Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora.

A special protection area (SPA) is a designation under the European Union Directive on the Conservation of Wild Birds.

5.1.2 RAMSAR Convention areas

Definition: the Ramsar Convention (formally, the Convention on Wetlands of International Importance, especially as Waterfowl Habitat) is an international treaty for the conservation and sustainable utilisation of wetlands.

5.1.3 OSPAR Marine Protected Areas

Definition: the Convention for the Protection of the Marine Environment of the North-East Atlantic or OSPAR Convention is the current legislative instrument regulating international cooperation on environmental protection in the North-East Atlantic. OSPAR has established a network of Marine Protected Areas (MPA).

5.1.4 World Heritage Sites

Definition: a World Heritage Site is a place that is listed by UNESCO as being of special cultural or physical significance.

BE- AWARE project:

Score arguments: these protected areas house some of the sensitive species and habitats described earlier in this document. As these areas have already been selected for protection, they have been allocated and extra vulnerability score i.e. score 4 for all seasons for both pollution in surface or in the water column.

Surface: 4 for all seasons

Water column: 4 for all seasons

HNS-MS project:

Score arguments: the scores for sinkers and evaporators show the same seasonal pattern as for floaters and dissolvers

Sea bed: 4 for all seasons

Air: 4 for all seasons

5.2 Protected areas ranking matrices

Table 10: Ranking matrices for protected areas at sea surface and in the water column

	Surface				Water column			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
MARINE PROTECTED AREA								
Coastal and marine protected areas								
Natura 2000 areas (EC Habitat and Birds Directive (SACs and SPAs))	4	4	4	4	4	4	4	4
RAMSAR Convention areas	4	4	4	4	4	4	4	4
OSPAR Convention areas	4	4	4	4	4	4	4	4
World heritage sites	4	4	4	4	4	4	4	4

Table 11: Ranking matrices for protected areas at the seabed and in the air

	Seabed				Air			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
MARINE PROTECTED AREA								
Coastal and marine protected areas								
Natura 2000 areas (EC Habitat and Birds Directive (SACs and SPAs))	4	4	4	4	4	4	4	4
RAMSAR Convention areas	4	4	4	4	4	4	4	4
OSPAR Convention areas	4	4	4	4	4	4	4	4
World heritage sites	4	4	4	4	4	4	4	4

5.3 Protected areas vulnerability maps

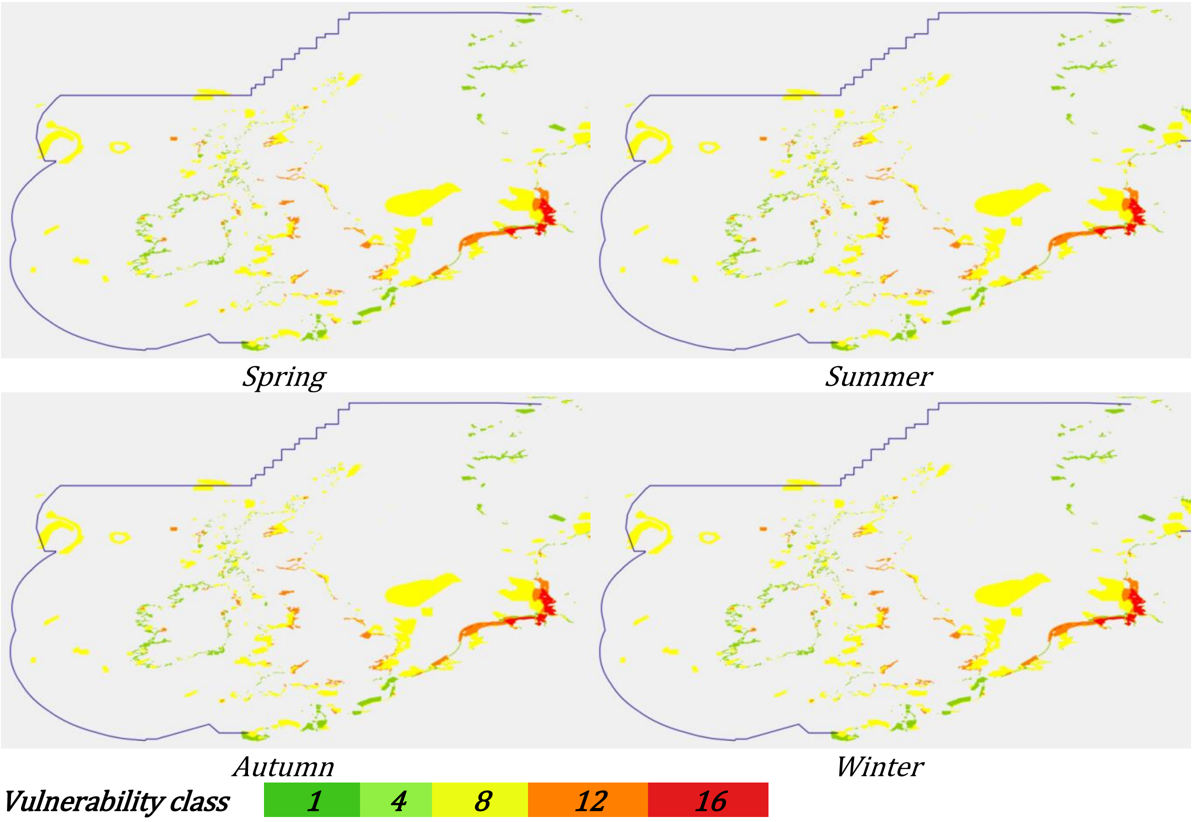

Figure 13 : Seasonal vulnerability of protected areas to pollutant in the Surface, in the Water column, in the Air, and in the Seabed

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Regional vulnerability maps for socio-economic features

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6 Regional vulnerability maps for socio-economic features

6.1 Socio-economy definitions and ranking scores

6.1.1 Fisheries

6.1.1.1 Offshore fisheries

Definition: a wide variety of different offshore fisheries exists in the BA areas which are conducted with different fishing gear (bottom trawl, pelagic trawl or purse-seine, surface drift nets…).

Different type of impacts can be identified:

- contamination of fishing gears by floater, dissolver or sinker HNS (seines and fixed traps extending above the sea surface, or bottom trawls, or gear lifted through contaminated sea surface etc.)
- the catch may become contaminated which in turn may result in the tainting;
- halting of fishing until the gear is cleaned and the contamination over.

Such impacts will be of short duration and in most cases, it will be possible to move to other fishing grounds free of contamination. Most fisheries in the BA area are carried out by the use of bottom gear that is less vulnerable compared to floating gear but in case of sinker HNS. Financial compensation may be available to some extent.

Ranking score allocated:

BE- AWARE project:

Scores arguments:

Based on these considerations offshore fisheries have been allocated a medium score:

Surface: 2 for all seasons
Water column: 2 for all seasons

HNS-MS project:

Scores arguments: a higher score was attributed for sinking HNS due to the difficulty of localization of the contamination and considering that most fisheries are carried out using bottom gear.

A medium score was attributed for evaporator HNS considering the risk for people on board.

Sea bed: 3 for all seasons
Air: 2 for all seasons

6.1.1.2 Coastal fisheries

Ranking score allocated:

BE- AWARE project:

Scores arguments: in term of impact, coastal fisheries do not have the same range and mobility as offshore fisheries. The impact is considered higher on coastal fisheries.

Surface: 3 for all seasons
Water column: 3 for all seasons

HNS-MS project:

Scores arguments: a higher score was attributed for sinking HNS due to the difficulty of localization of the contamination and considering that most fisheries are carried out using bottom gear. A medium score was attributed for evaporator HNS considering the risk for people on board.

Sea bed: 4 for all seasons
Air: 2 for all seasons

6.1.2 Aquaculture

Definition: aquaculture is an increasingly important industry in the BA area involving the farming or culture of fish, shellfish, seaweed farming or harvesting of natural growing seaweed which is also an established industry.

Aquaculture facilities and activities are very vulnerable to HNS contamination that may result in severe economic losses:

- Mass mortality of fish, that are coated and smothered by floater HNS or exposed directly to toxic components;
- Tainting can result from very low concentrations of HNS since caged fish and immobile shellfish cannot swim away;
- Worsening of existing stress effects in aquaculture facilities;
- Impacts on normal production and loss of market confidence.

6.1.2.1 Fish farms

Involving the farming or culture of fish (Atlantic salmon, Rainbow trout, halibut…),

Ranking score allocated:

BE- AWARE project:

Scores arguments: based on these considerations a high score allocated to fish farms for all seasons and for both floater and dissolver HNS:

Surface: 3 for all seasons
Water column: 3 for all seasons

HNS-MS project:

Scores arguments: in case of sinker HNS there is no risk of contamination of floating fish cages. A score was attributed for evaporator HNS considering the risk for people working on farms.

Sea bed: 0 for all seasons
Air: 2 for all seasons

6.1.2.2 Shellfish farms

Definition: culture of shellfish (blue mussels, pacific oysters, native oysters, clams and Scallops). Depending on species, shellfish are cultivated using different techniques (ropes in water column, bottom or trestles in the middle or lower shore).

Ranking score allocated:

BE-AWARE project:

Scores arguments: based on these considerations shellfish fish farms were allocated a high score for all seasons and for both floaters and dissolvers HNS

Surface: 3 for all seasons
Water column: 3 for all seasons

HNS-MS project:

Scores arguments: in case of sinker HNS the risk of contamination of bottom shellfish is high. A medium score was attributed for evaporator HNS considering the risk for people working on farm.

Sea bed: 3 for all seasons

Air: 2 for all seasons

6.1.2.3 Algae culture

Definition: seaweed farming is not very well developed in Europe, but harvesting of natural growing seaweed is also an established industry. This activity is very vulnerable HNS contamination that may result in severe economic losses as explain above.

Ranking score allocated:

BE-AWARE project:

Scores arguments: based on these considerations algae culture or harvesting, was allocated a high score for all seasons and for both Floater and dissolver

Surface: 3 for all seasons

Water column: 3 for all seasons

HNS-MS project:

Scores arguments: in case of sinker HNS the risk of contamination of algae is high. A medium score was attributed for evaporator HNS considering the risk for people on activity.

Sea bed: 3 for all seasons

Air: 2 for all seasons

6.1.3 Coastal tourism

Definition: coastal tourism is a key economic sector for many countries. Tourists participate in the traditional activities such as bathing, sunbathing on the beach, boating, angling, diving, sightseeing etc. and generate income to a wide variety of businesses such as hotels, campsites, caravan parks, summerhouse rentals, restaurants, bars, suppliers to hotels and restaurants, various shops and many other businesses whose livelihoods depend on tourism.

In this analysis, coastal tourism is described and analysed in terms of the following features:

- Magnitude of tourist activities indicated by number of overnight stays in coastal hotels of more than 20,000 annual overnight stays

- Amenity beaches

• Recreational fishery areas

The tourist industry may be severely affected by pollution with the most serious consequences just before and during the tourist season. Affected beaches may have to be closed during clean up. Activities suffer economic losses due to these impacts even in areas along the coast not directly affected by the contamination. Amenity beaches and other coastal tourist assets represent the highest value in the tourist season, which culminates in summer, but also with some activity in spring and autumn. There is some recreational use of beaches in winter.

6.1.3.1 Tourist activities, (number of overnight stays)

Ranking score allocated:

BE-AWARE project:

Scores arguments: for hotels, the duration of interruption of business can be prolonged, even after cleanup has taken place because negative media attention and public perception.

Surface: Spring: 2, Summer: 3, Autumn: 3, Winter: 2
Water column: Spring: 1, Summer: 2, Autumn: 1, Winter: 1

HNS-MS project:

Scores arguments: for sinker HNS, contamination won't be visible and limited negative impact and public perception is expected on hotel booking. In case of contamination by evaporator HNS, even if short-lived impact, a high score has been allocated considering the risk for crowded areas.

Sea bed: Spring: 1, Summer: 1, Autumn: 1, Winter: 1
Air: Spring: 2, Summer: 3, Autumn: 3, Winter: 2

6.1.3.2 Amenity beaches

Ranking score allocated:

BE- AWARE project:

Scores arguments: typical bathing beaches are easy to clean (fine grain sand and generally easy access by road), the disturbance is usually short-lived. For a dissolver HNS the duration will be less than for a floater HNS.

Surface: Spring: 3, Summer: 4, Autumn: 3, Winter: 2

Water column: Spring: 2, Summer: 3, Autumn: 2, Winter: 1

HNS-MS project:

Scores arguments: beach activities such as bathing, diving, etc. would be affected by a contamination by a sinker HNS, the most during summer. In case of contamination by evaporator HNS, a high score has been allocated considering the risk for crowded areas.

Sea bed: Spring: 3, Summer: 4, Autumn: 3, Winter: 2

Air: Spring: 4, Summer: 4, Autumn: 4, Winter: 3

6.1.3.3 Recreational fishing areas

Ranking score allocated:

BE- AWARE project:

Scores arguments: recreational fisheries are also exposed to losses in sales and wages (organised activities).

Surface: Spring: 3, Summer: 4, Autumn: 3, Winter: 2

Water column: Spring: 3, Summer: 3, Autumn: 2, Winter: 2

HNS-MS project:

Scores arguments: recreational fishing would be affected by a contamination due to sinker HNS, the most during summer. In case of contamination by evaporator HNS, a high score has been allocated to consider the risk for people (crowed areas).

Sea bed: Spring: 3, Summer: 4, Autumn: 3, Winter: 2

Air: Spring: 4, Summer: 4, Autumn: 4, Winter: 3

6.1.4 Ports, marinas and cruise liner stops

Definition: pollution in or near ports, marinas and cruise liner stops' harbour areas will hamper normal ship traffic due to different reasons:

- Contamination of vessels waterline, mooring lines and berths, operational problems to water intakes for cooling the engine;
- Habour structures may be affected (breakwaters of rock or concrete tetrapod armour may be difficult to clean);
- Deployment of combat equipment (e.g. booms) might also hamper usual shipping operations.

The consequences for the ports, marinas and cruise liner stops of oil spills are economic losses and claims, temporary unemployment for workers at the harbour. Prevention of floating contamination entering the port or marina may be done by placing booms across the narrow entrances of ports, harbour and marinas. Port and harbour basins allow for a rapid and effective response, implying that the length of interruption will be short. Ports are vulnerable all the year round, whereas marinas are least vulnerable outside the holiday season. The traffic at cruise liner stops is highest during May - September.

6.1.4.1 Ports

Ranking score allocated:

BE- AWARE project:

Scores arguments: the score allocated is medium, based on the short length of interruption, the possibility to prevent entrance of floating contamination and the possibility for a rapid response in most ports.

Surface: 2 for all seasons

Water column: 1 for all seasons

HNS-MS project:

Scores arguments: no risk of contamination of waterline, other mooring lines and berth. The impact is considered limited in case contamination by a sinker HNS. In case of contamination by an evaporator HNS, a high score has been allocated to consider the risk for the numerous workers.

Sea bed: 1 for all seasons

Air: 4 for all seasons

6.1.4.2 Marinas

Ranking score allocated:

BE- AWARE project:

Scores arguments: seasonality is important for marinas and surface contamination may affect boats. Limited impact is expected if the product is in the water column.

Surface: Spring: 2, Summer: 3, Autumn: 3, Winter: 1

Water column: 1 for all seasons

HNS-MS project:

Scores arguments: a very low score has been attributed in case of sinker HNS, as no, or low effect is expected on the boats and activity. A higher score, including seasonality consideration, has been attributed in case of contamination by an evaporator HNS to consider the risk for people

Sea bed: 1 for all seasons

Air: Spring: 2, Summer: 3, Autumn: 3, Winter: 2

6.1.4.3 Cruise liner stops

Ranking score allocated:

BE- AWARE project:

Scores arguments: seasonality is important for cruise liner, and traffic could be interrupted by a contamination in surface, but no effect is expected in case of product dissolved in the water column.

Surface: Spring: 1, Summer: 2, Autumn: 1, Winter: 1

Water column: Spring: 1, Summer: 1, Autumn: 1, Winter: 1

HNS-MS project:

Scores arguments: a very low score has been attributed in case of sinker HNS, as no or low effect is expected on the boats and activity. A higher score, including seasonality consideration, has been attributed in case of contamination by an evaporator HNS to consider the risk for people, with a maximum in summer.

Sea bed: 1 for all seasons

Air: Spring: 2, Summer: 3, Autumn: 2, Winter: 2

6.1.5 Heritage sites

Definition: heritage sites include cultural buildings, artefacts and nature sites and may be in coastal or intertidal areas (i.e. cultural site of Mont Saint-Michel in Normandy France, which is an Island on a tidal flat, housing historic monuments established in 708 or the Cliffs of Dover in southern England and the Wadden Sea (natural sites).

In most cases, a spill will not have a direct impact on the buildings or sites but will affect negatively the perception to the visitors. However, some artefacts such as historical quays or berths could be affected. In nature sites spill may cause severe impacts

Ranking score allocated:

BE- AWARE project:

Scores arguments: heritage sites and their socio-economic value are therefore estimated to be very sensitive to a spill by a floater pollutant. The risk will be reduced in case of pollution in the water column.

Surface: 4 for all seasons

Water column: 2 for all seasons

HNS-MS project:

Scores arguments: a sinker HNS could affect the intertidal zone and with an evaporator HNS visitors could be affected.

Sea bed: 4 for all seasons

Air: 4 for all seasons

6.1.6 Densely populated towns and communities

Definition: a major spill of volatile HNS close to a center of populations is likely to raise health concerns and some time to necessitate the evacuation of such communities. In addition, the smell of oil can be very unpleasant and presents a severe nuisance to people living close to the affected coastline.

Ranking score allocated:

BE- AWARE project:

Scores arguments: a medium score has been allocated in case of contamination in surface and lower score in case of contamination of the water column.

Surface: 2 for all seasons

Water column: Spring: 1, Summer: 2, Autumn: 1, Winter: 1

HNS-MS project:

Scores arguments: no impact is expected in case of contamination by a sinker HNS, but due to the potential impact on population a high score has benne allocated in case of volatile HNS.

Sea bed: 0 for all seasons

Air: 4 for all seasons

6.1.7 Mineral extraction sites

Definition: marine mineral deposits are extracted from the seabed in the BA area (sand and gravel for the construction industry or sand for beach nourishment but also non-aggregate marine mineral resources such as maerl or shelly sands).

Ranking score allocated:

BE- AWARE project:

Scores arguments: if contaminant is in surface or in the water column, the risk to contaminate the material on the seabed is small, but vessels that are extracting the materials may be smeared by floating pollutant. The duration and risk of impact is low.

Surface: 1 for all seasons

Water column: 1 for all seasons

HNS-MS project:

Scores arguments: the mineral deposit will be affected in case of sinker contaminant and the duration will depend on the persistence of the pollutant and hydrodynamism. People on vessels extracting the material may be affected in case of evaporator HNS, a medium score has been allocated.

Sea bed: 4 for all seasons

Air: 2 for all seasons

6.1.8 Offshore windfarm

Definition: if a surface pollution hits an offshore wind, the contamination will generally be limited to a narrow band on the leg of the turbine in the transition area between air and water.

Ranking score allocated:

BE- AWARE project:

Scores arguments: if the contamination is in surface or in the water column, the risk to contaminate the material is small, but vessels that are extracting the materials may be smeared by floating pollutant. The duration and risk of impact is low.

Surface: 1 for all seasons

Water column: 1 for all seasons

HNS-MS project:

Scores arguments: a low score has been allocated in case of contamination of the sea bed as well as for evaporator HNS, taking in consideration that workers are rarely onsite.

Sea bed: 1 for all seasons
Air: 1 for all seasons

6.1.9 Water intakes

Definition: numerous industries rely on the ability to draw clean seawater from the sea. For instance, seawater is used for:

- cooling water for thermal or nuclear power plants;
- process water in seafood processing plants;
- water for aquariums or onshore aquaculture facilities.

Contamination in the water intakes could cause severe economic effects. If the pollutant is taken into the water circulation system of the facilities, which are vital for normal operations, machinery or products could be destroyed.

Ranking score allocated:

BE- AWARE project:

Scores arguments: temporary closure of the intake, as a precaution against damage, might affect the entire operation of the plant and thus vital economic interests (electric power plant, for instance). A high score has been allocated in in case of contaminant in the surface or in the water column (aquariums, aquaculture facilities, thalassotherapy…)

Surface: 3 for all seasons
Water column: 3 for all seasons

HNS-MS project:

Scores arguments: high score has been allocated for contaminant on the seabed but no effect expected in case of evaporator HNS.

Sea bed: 3 for all seasons
Air: 0 for all seasons

6.2 Socio-economic features ranking matrices

Table 12 : Ranking matrices for socio-economic features at sea surface and in the water column

	Surface				Water column			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Fisheries								
Offshore fisheries	2	2	2	2	2	2	2	2
Coastal fisheries	3	3	3	3	3	3	3	3
Aquaculture								
Fish farms	3	3	3	3	3	3	3	3
Shellfish cultures	3	3	3	3	3	3	3	3
Algae cultures	3	3	3	3	3	3	3	3
Coastal tourism								
Overnight stays coastal tourist hotels	2	3	3	2	1	2	1	1
Amenity beaches	3	4	3	2	2	3	2	1
Main recreational fishing locations	3	4	3	2	3	3	2	2
Ports, marinas and cruise liner stops								
Ports	2	2	2	2	1	1	1	1
Marinas	2	3	3	1	1	1	1	1
Cruise liner stops	1	2	1	1	1	1	1	1
Other								
Heritage sites	4	4	4	4	2	2	2	2
Densely populated towns and communities	2	2	2	2	1	2	1	1
Mineral extraction sites	1	1	1	1	1	1	1	1
Offshore wind farms	1	1	1	1	1	1	1	1
Water intakes	3	3	3	3	3	3	3	3

Table 13: Ranking matrices for socio-economic features at the seabed and in the air

	Air				Seabed			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Fisheries								
Offshore fisheries	3	3	3	3	2	2	2	2
Coastal fisheries	4	4	4	4	2	2	2	2
Aquaculture								
Fish farms	1	1	1	1	2	2	2	2
Shellfish cultures	3	3	3	3	2	2	2	2
Algae cultures	3	4	3	2	3	4	3	2
Coastal tourism								
Overnight stays coastal tourist hotels	1	1	1	1	2	3	3	2
Amenity beaches	3	4	3	2	4	4	4	3
Main recreational fishing locations	3	4	3	2	4	4	4	3
Ports, marinas and cruise liner stops								
Ports	1	1	1	1	2	2	2	2
Marinas	1	1	1	1	2	3	3	2
Cruise liner stops	1	1	1	1	2	3	2	2
Other								
Heritage sites	4	4	4	4	4	4	4	4
Densely populated towns and communities	0	0	0	0	4	4	4	4
Mineral extraction sites	4	4	4	4	2	2	2	2
Offshore wind farms	1	1	1	1	1	1	1	1
Water intakes	3	3	3	3	1	1	1	1

6.3 Socio-economic features vulnerability maps

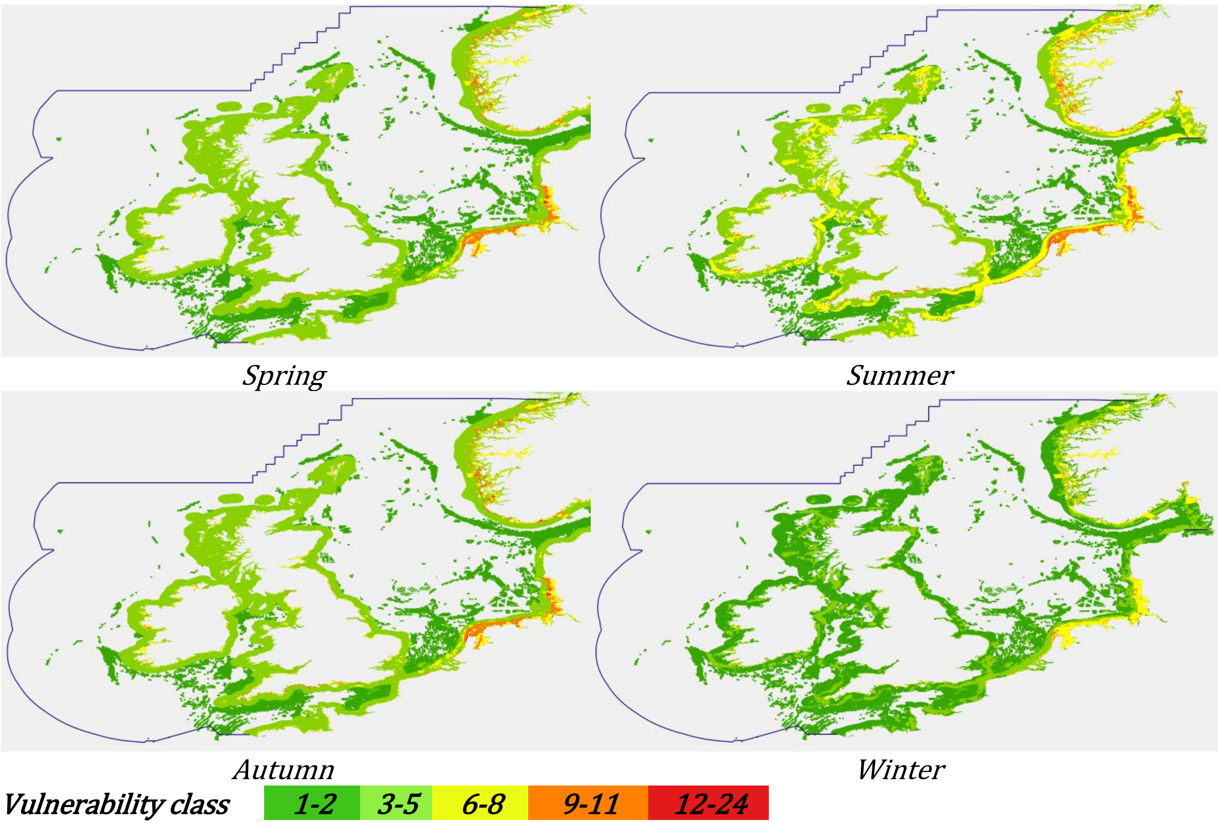

Figure 14 : Seasonal vulnerability of socio-economic features to HNS pollution at the sea surface

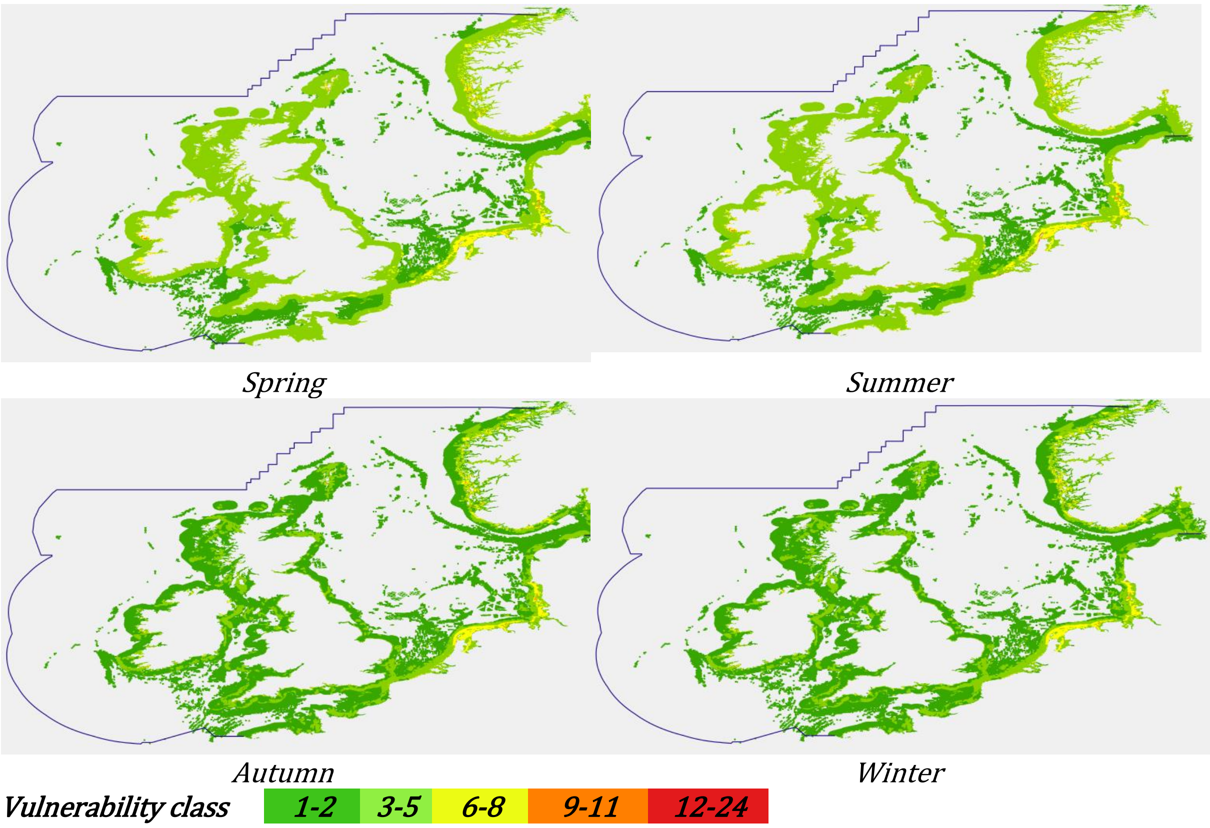

Figure 15 Seasonal vulnerability of socio-economic features to HNS pollution in the water column

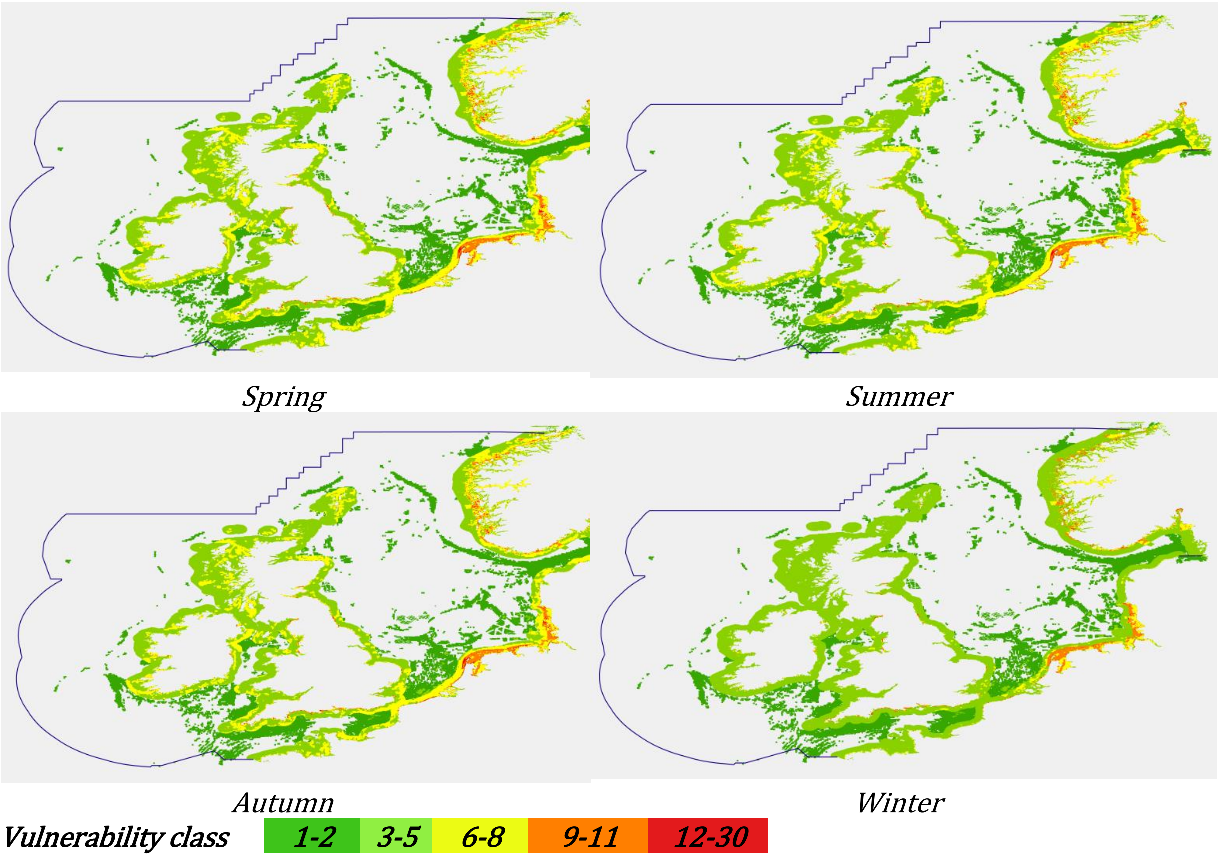

Figure 16 : Seasonal vulnerability of socio-economic features to HNS pollution in the air

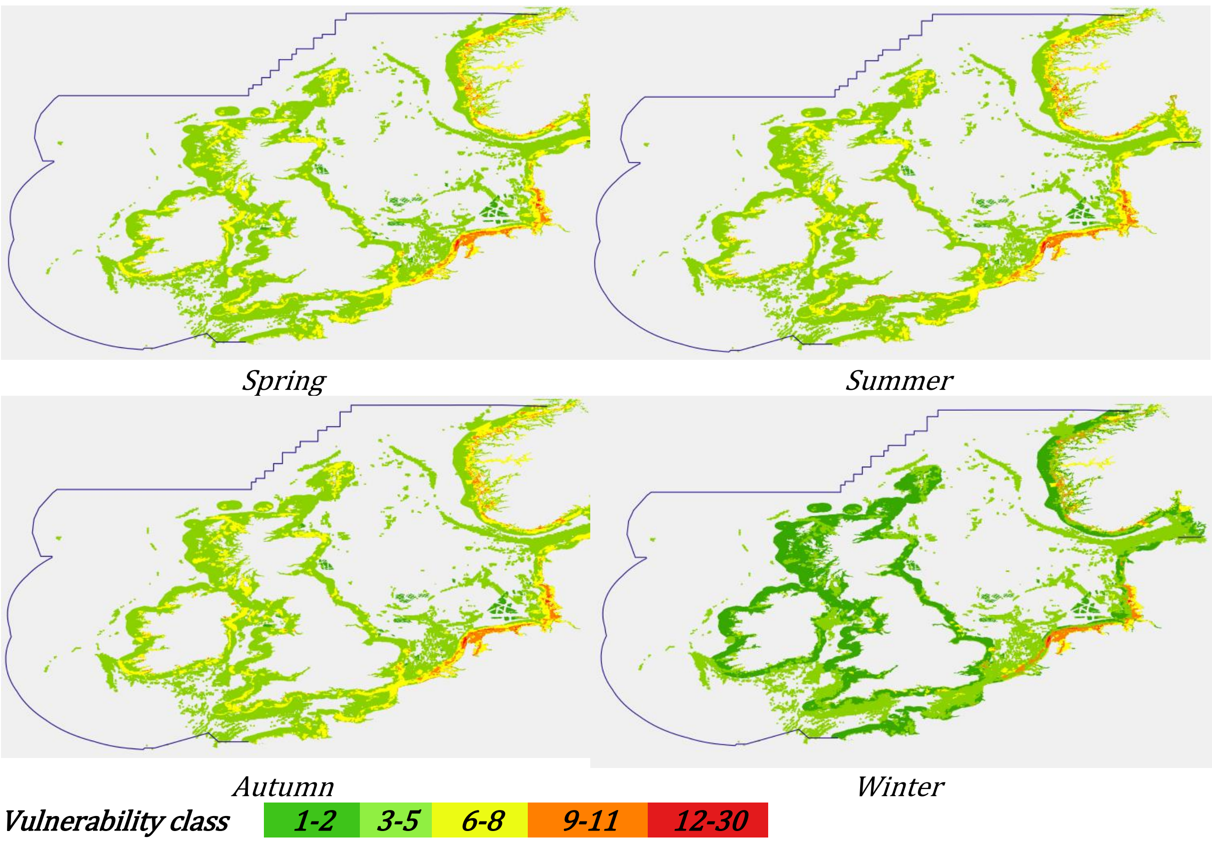

Figure 17 : Seasonal vulnerability of socio-economic features to HNS pollution at the seabed

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Operational thematic and vulnerability maps for Belgium

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7 Operational thematic and vulnerability maps for Belgium waters

7.1 Introduction

The Belgian part of the North Sea has been selected to test the regional methodology at "operational scale". For this purpose, some adaptations have been introduced in the methodology:

- in addition to vulnerability maps, a set of "thematic maps" was established, to allow response teams identifying the location of sensitive environmental and socio-economic resources (3 maps were elaborated: Habitats and protected area dedicated to habitats, Species and Marine protected areas, Socioeconomic features);
- the maps show the geographic location and extent of the resources (polygons, vector mode) compared to the regional maps for BA area established with a grid and cells (raster mode);
- for the shoreline, socio-economic vulnerability was evaluated at the level of the municipality (sum of ranking scores of all existing activities on the municipal territory).

In reality, authorities and response teams need to know the exact location and extent of a sensitive resource in case of HNS spill. They cannot simply rely on the information of presence/absence in a cell of a geographical grid, more adapted to elaborate a strategy at regional scale.

Belgian authorities provided GIS layers which were organised in 3 maps by thematic. The same ranking scores elaborated for BA area were applied. Matrices and GIS maps were elaborated to produce a vulnerability atlas.

7.2 Thematic map for habitats and protected areas

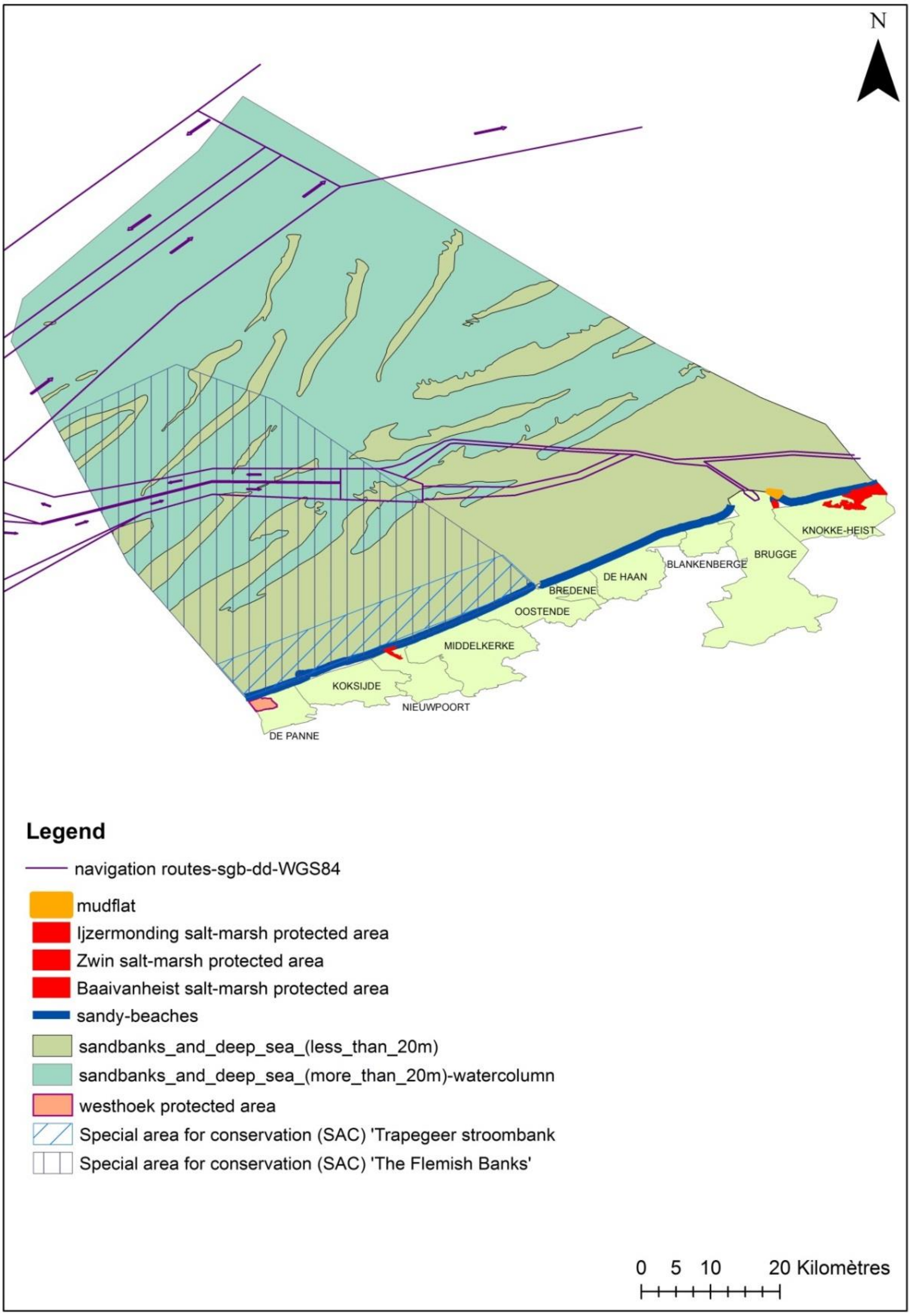


Figure 18 : Thematic map for habitats and marine protected areas

7.3 Thematic map for species and protected areas

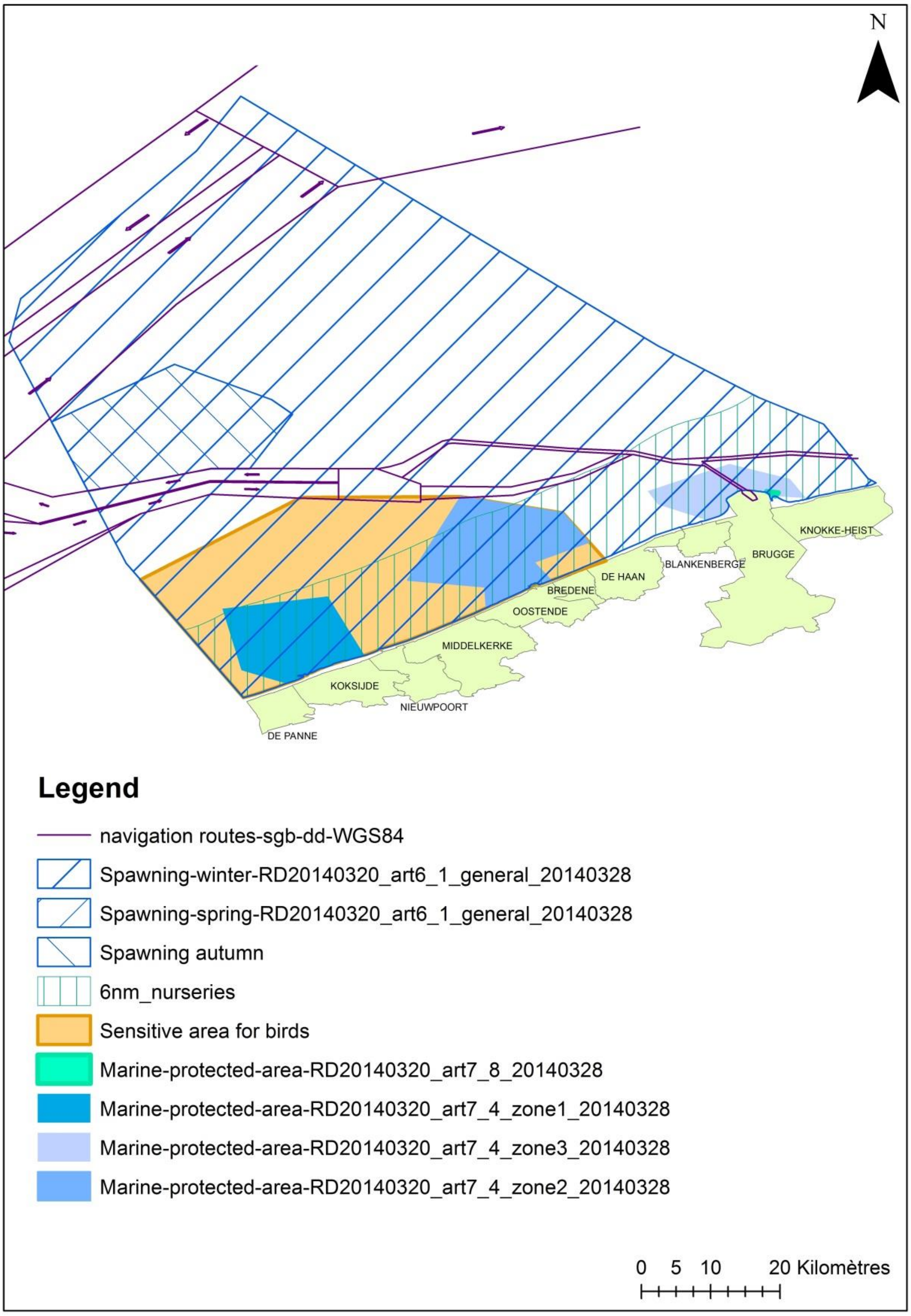


Figure 19 : Thematic map for species and marine protected areas

7.4 Thematic map of the socio-economic features

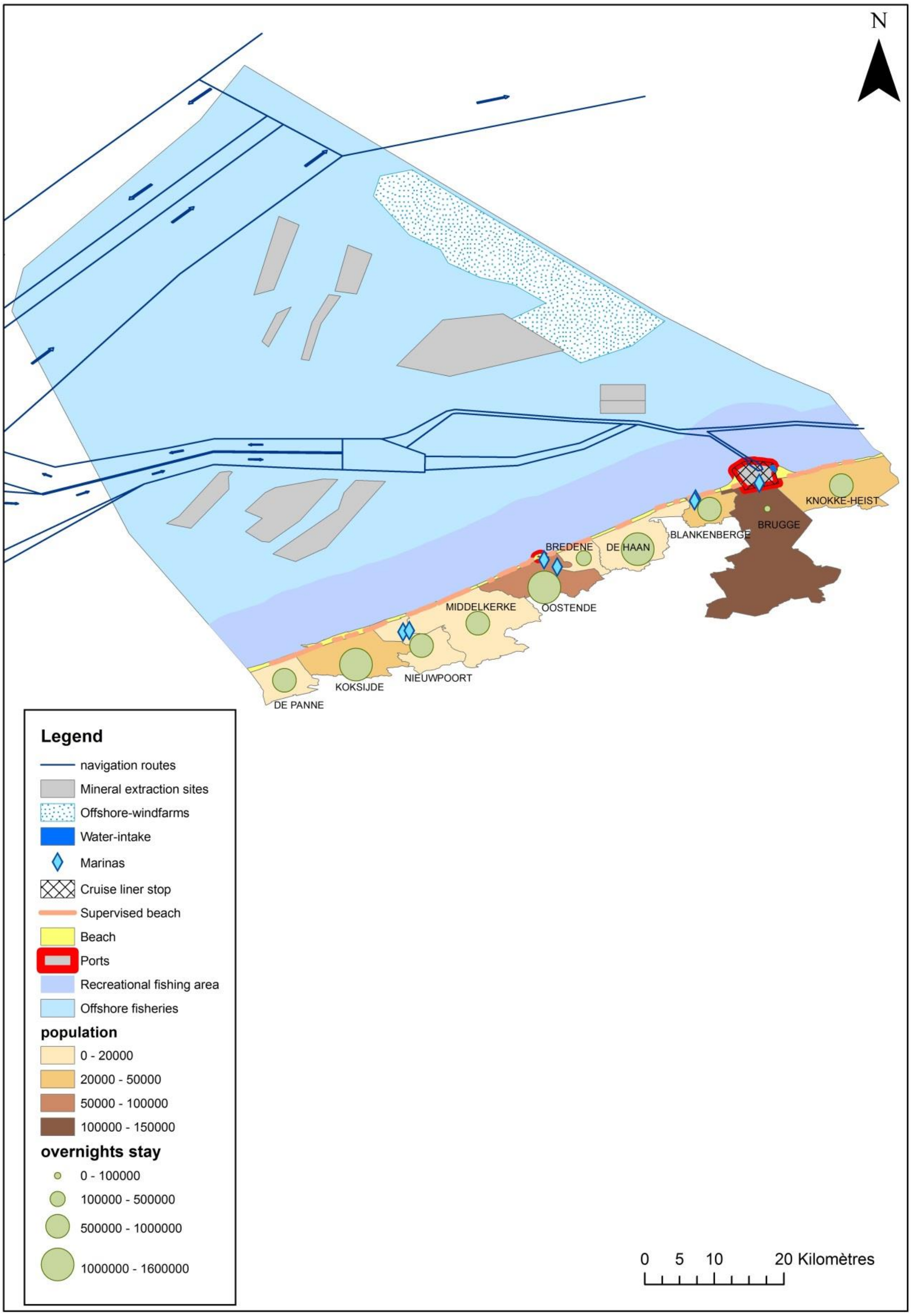
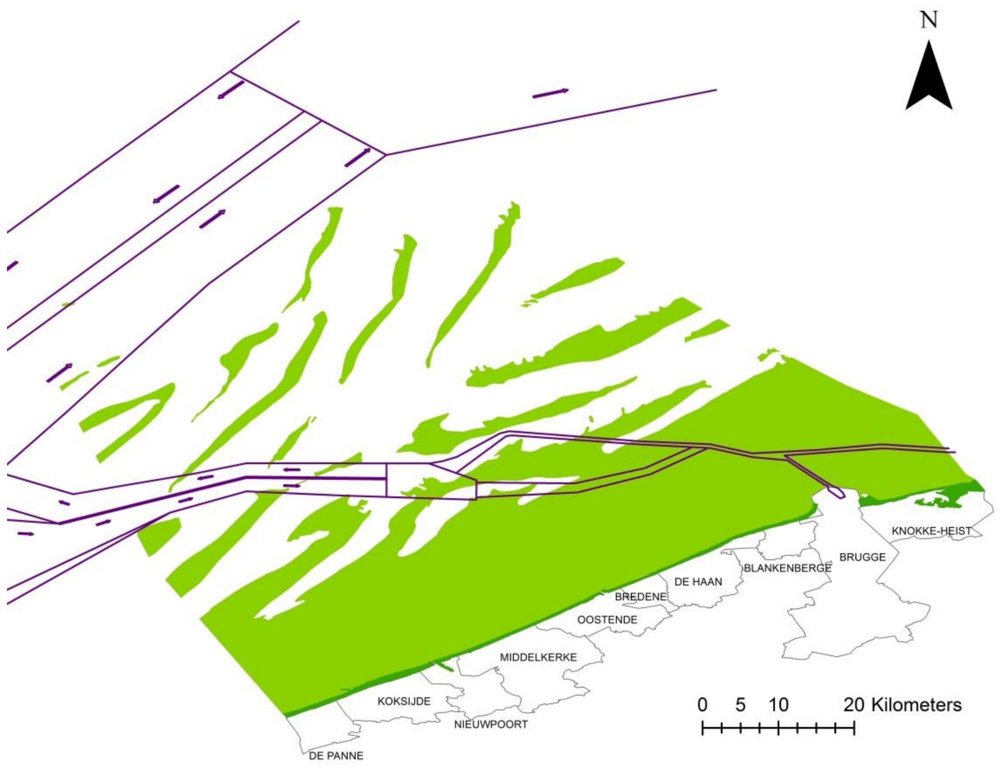


Figure 20 : Thematic map of the socio-economic features

7.5 Operational vulnerability maps for habitats



Legend: navigation routes-sgb-dd-WGS84

Vulnerability classes:

- Very low (1)
- Low (2)
- Medium
- High
- Very high

Figure 21 : Seasonal vulnerability of habitats to HNS pollution in the Air

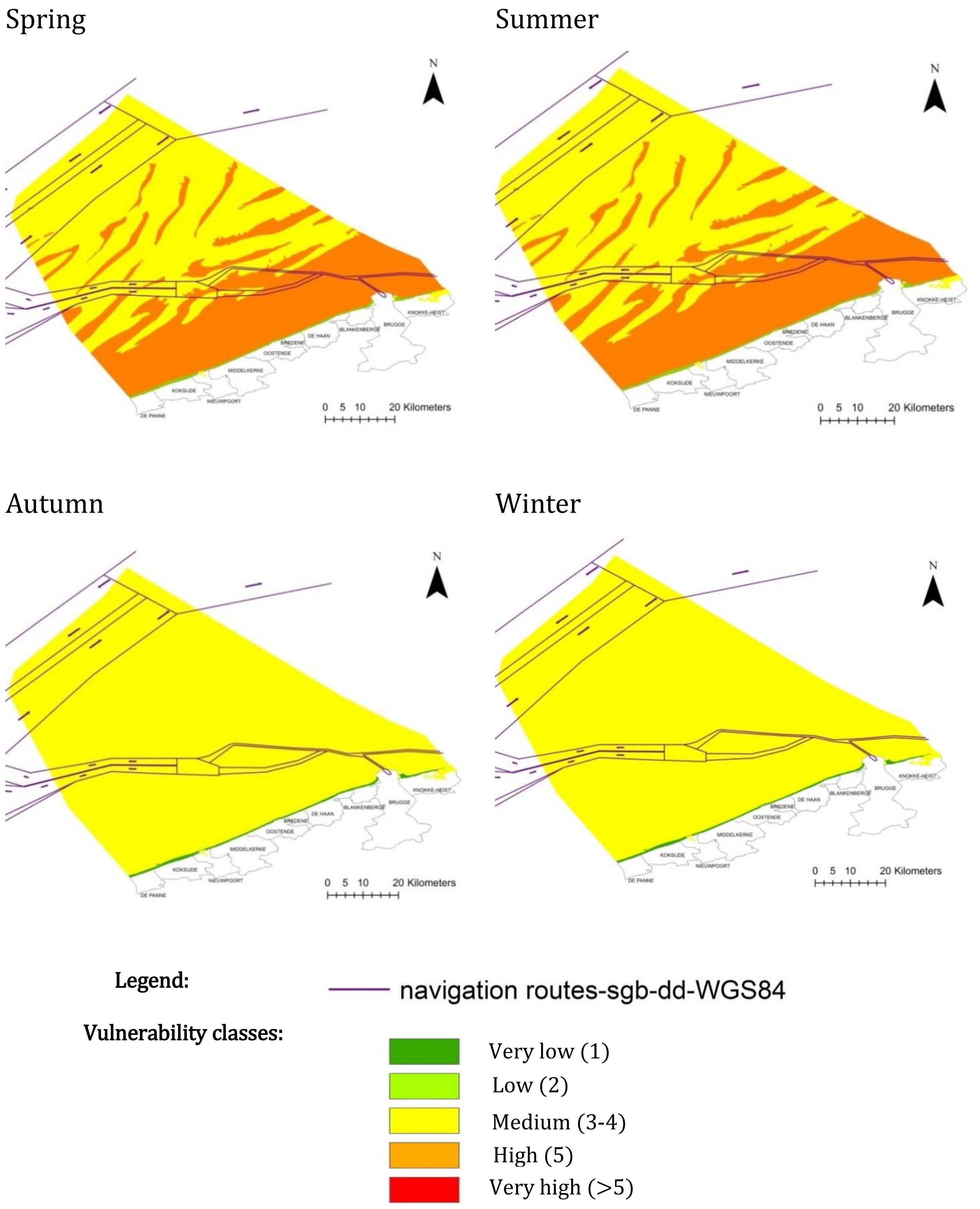


Figure 22 : Seasonal vulnerability of habitats to HNS pollution at the seabed

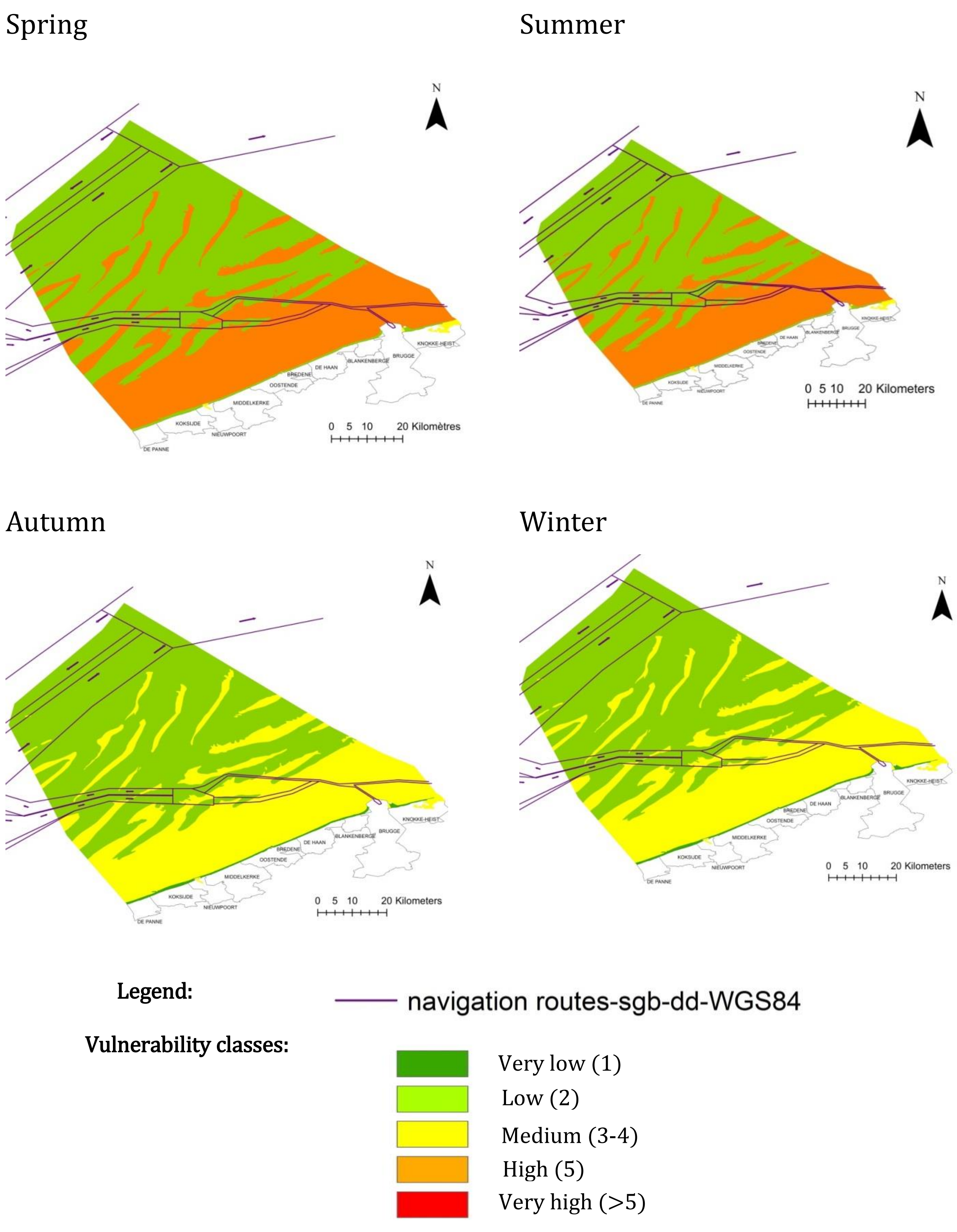


Figure 23 : Seasonal vulnerability of habitats to HNS pollution at the sea surface

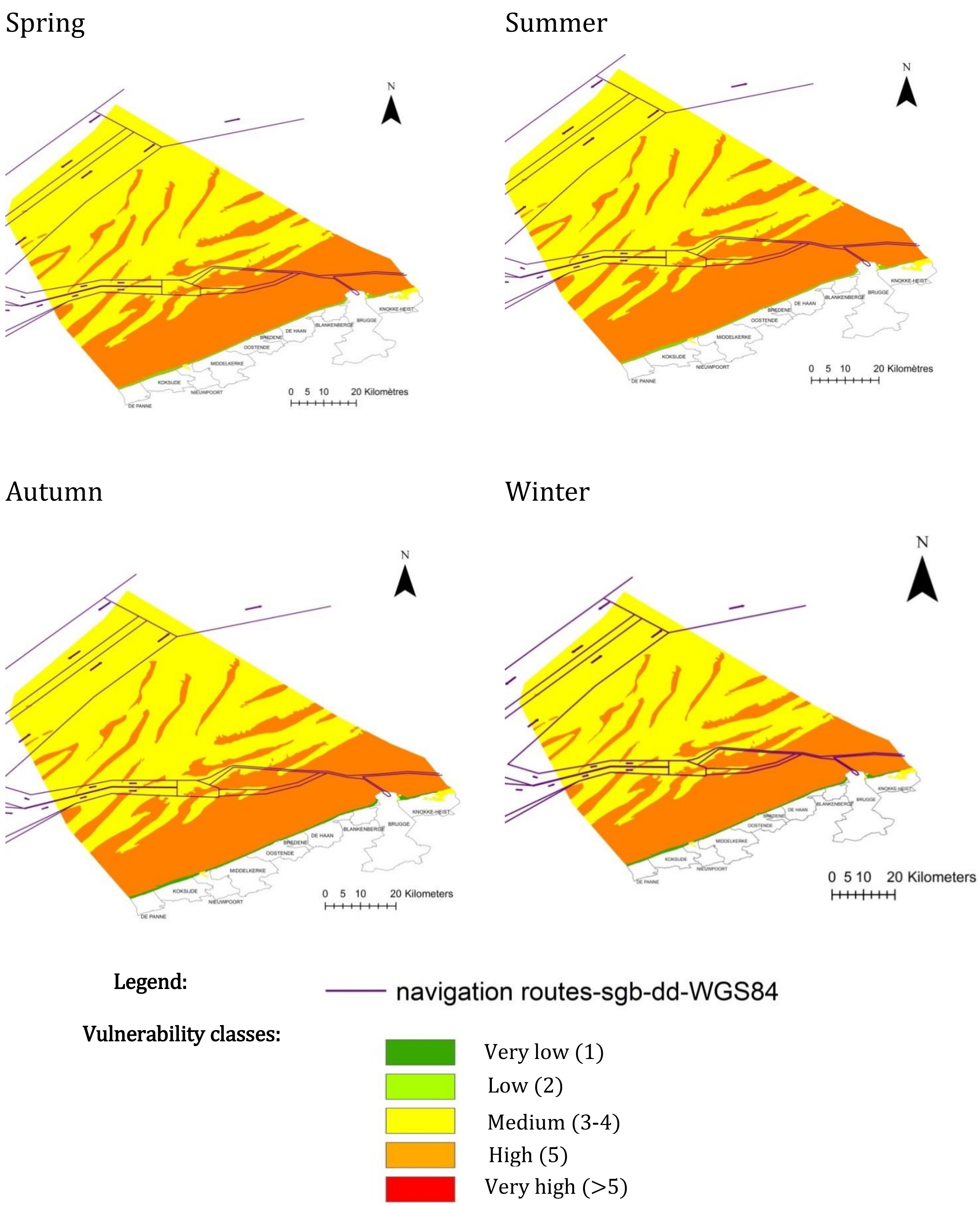


Figure 24 : Seasonal vulnerability of habitats to HNS pollution in the water-column

7.6 Operational vulnerability maps for species

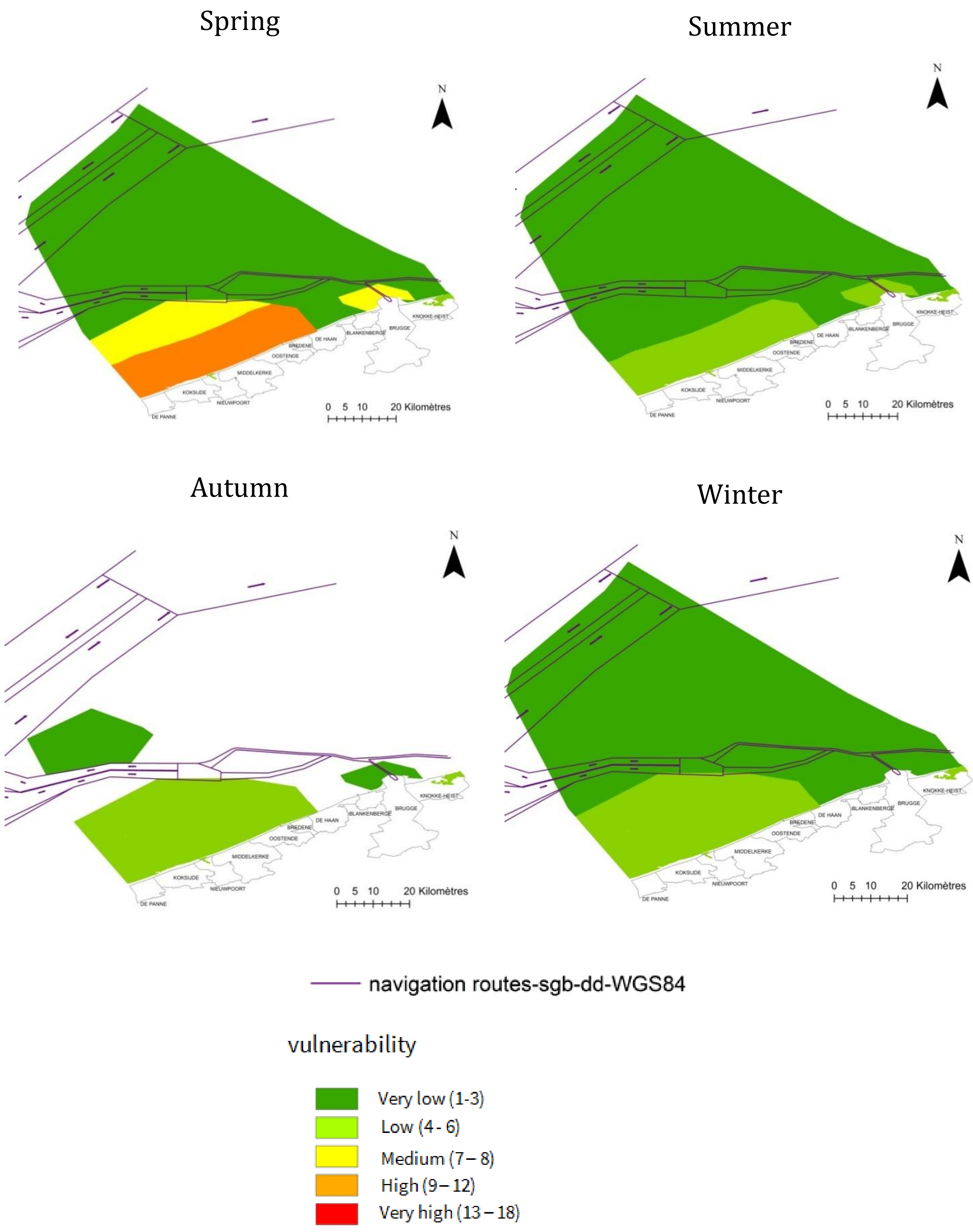


Figure 25 : Seasonal vulnerability of species to HNS pollution in the air

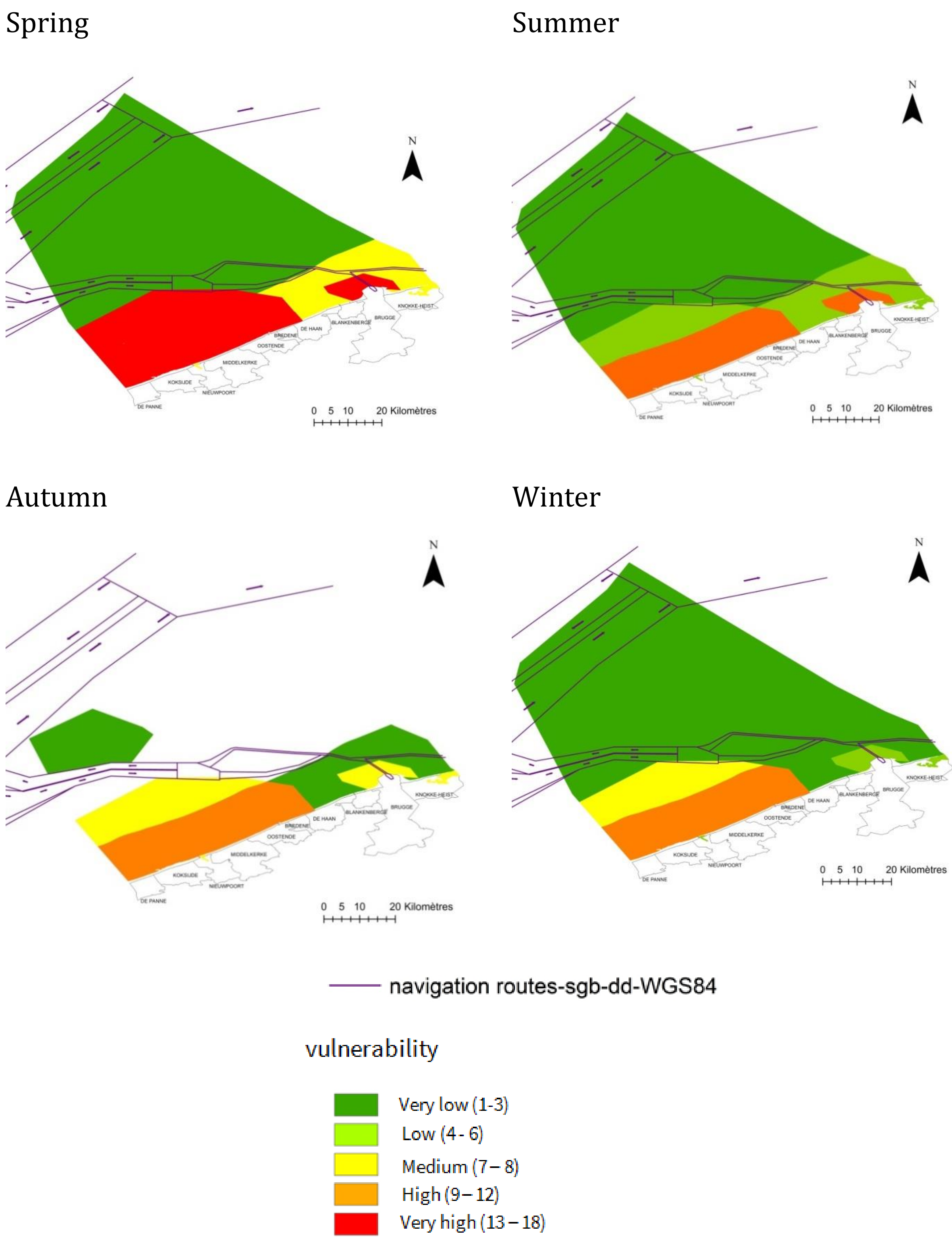


Figure 26 : Seasonal vulnerability of Species to HNS pollution at the seabed

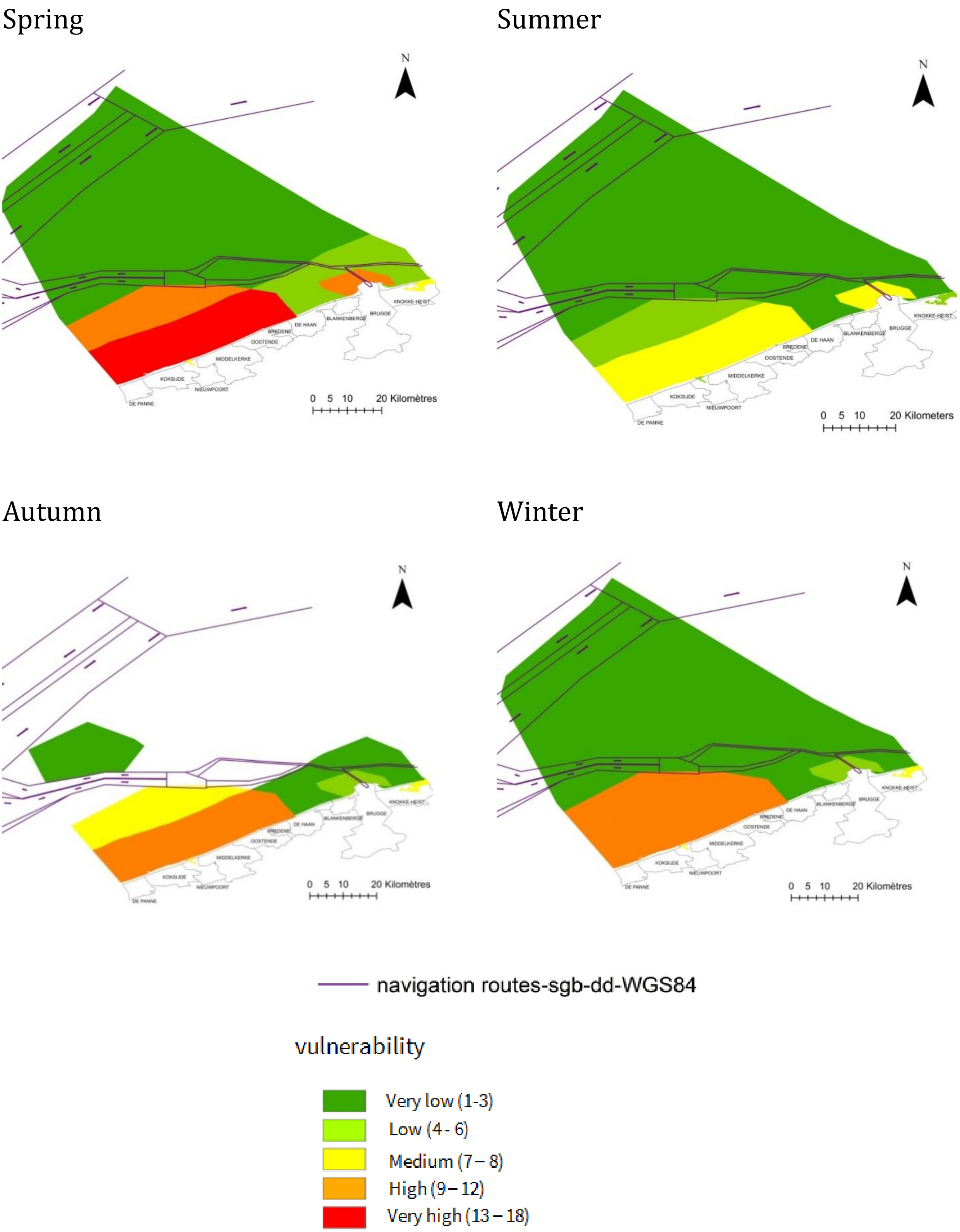


Figure 27 : Seasonal vulnerability of species to HNS pollution at the sea surface

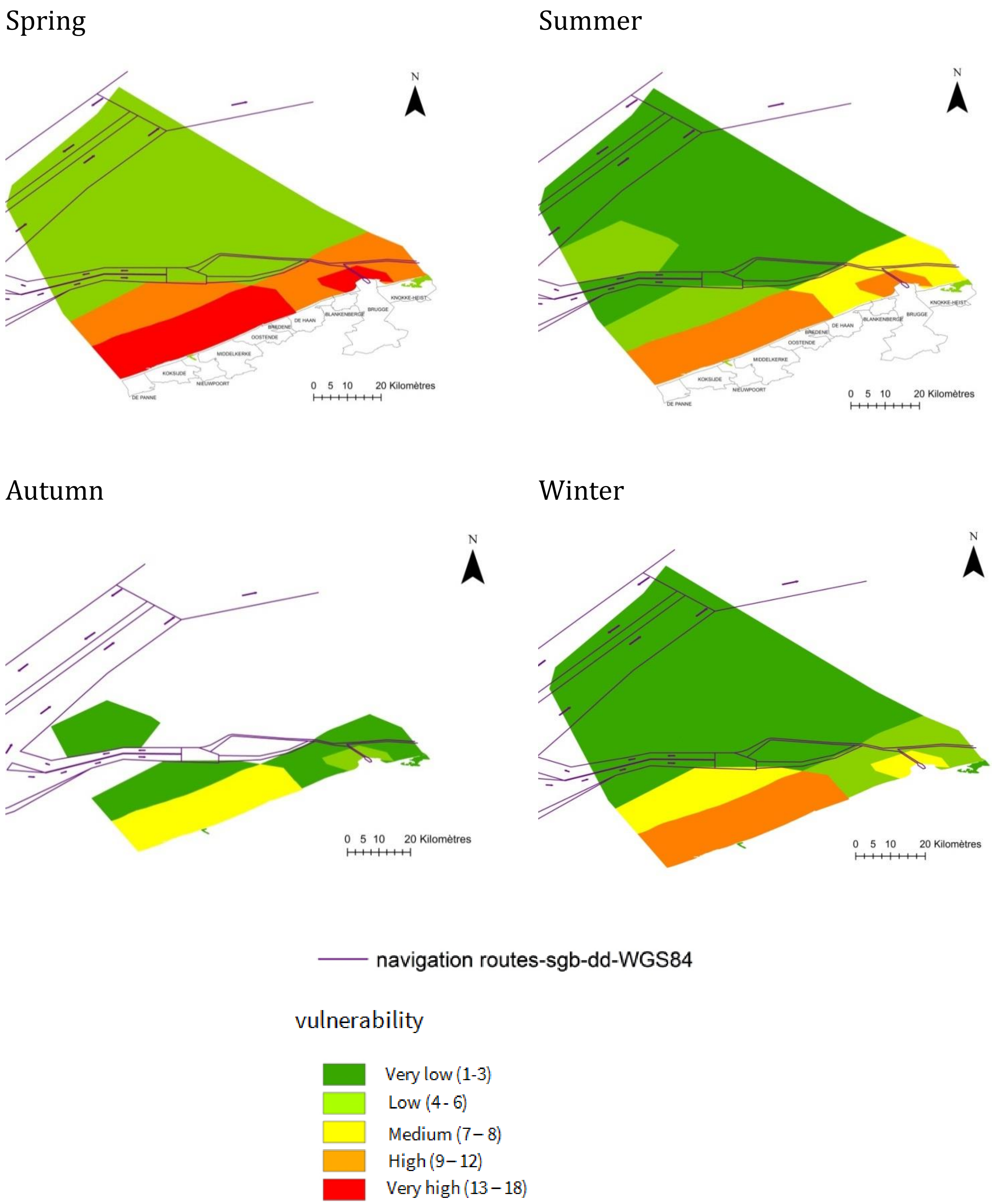


Figure 28 : Seasonal vulnerability of species to HNS pollution in the water-column

7.7 Operational vulnerability maps for marine protected areas

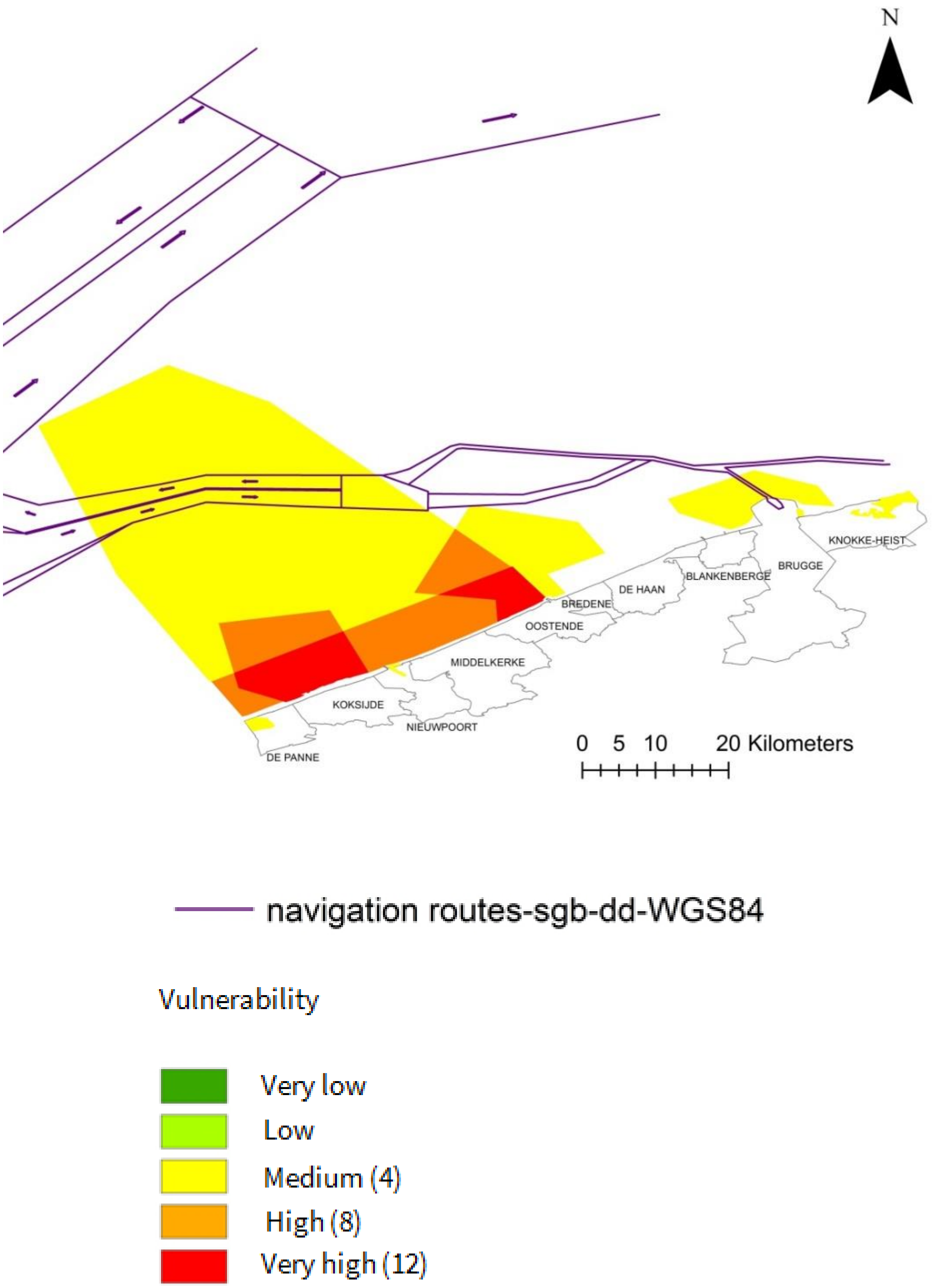


Figure 29 : Seasonal vulnerability of marine protected areas to HNS pollution in any compartment (Air, Seabed, Surface, Water-column - All seasons)

7.8 Operational vulnerability maps for socio-economic features

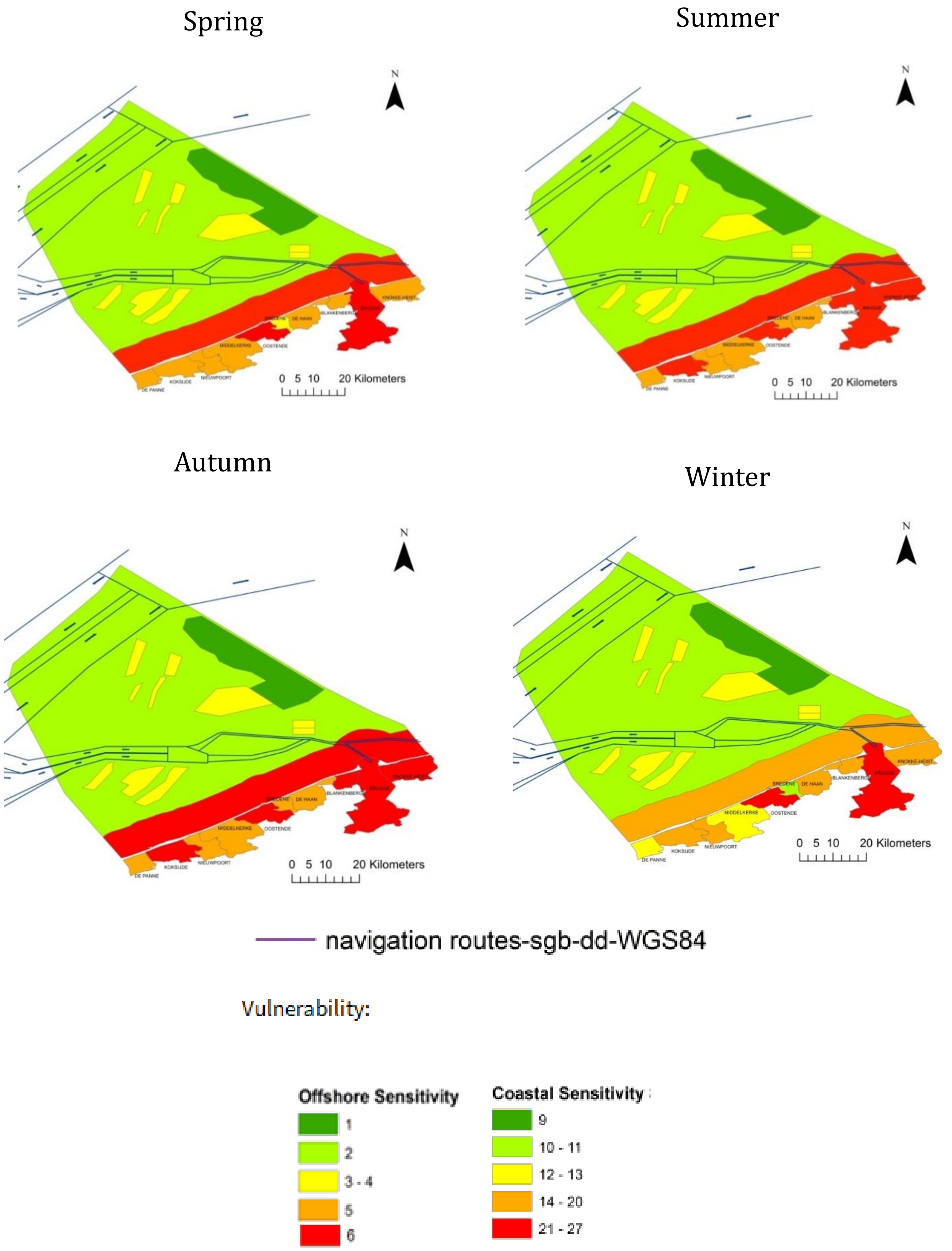


Figure 30 : Seasonal vulnerability of socio-economic features to HNS pollution in the air

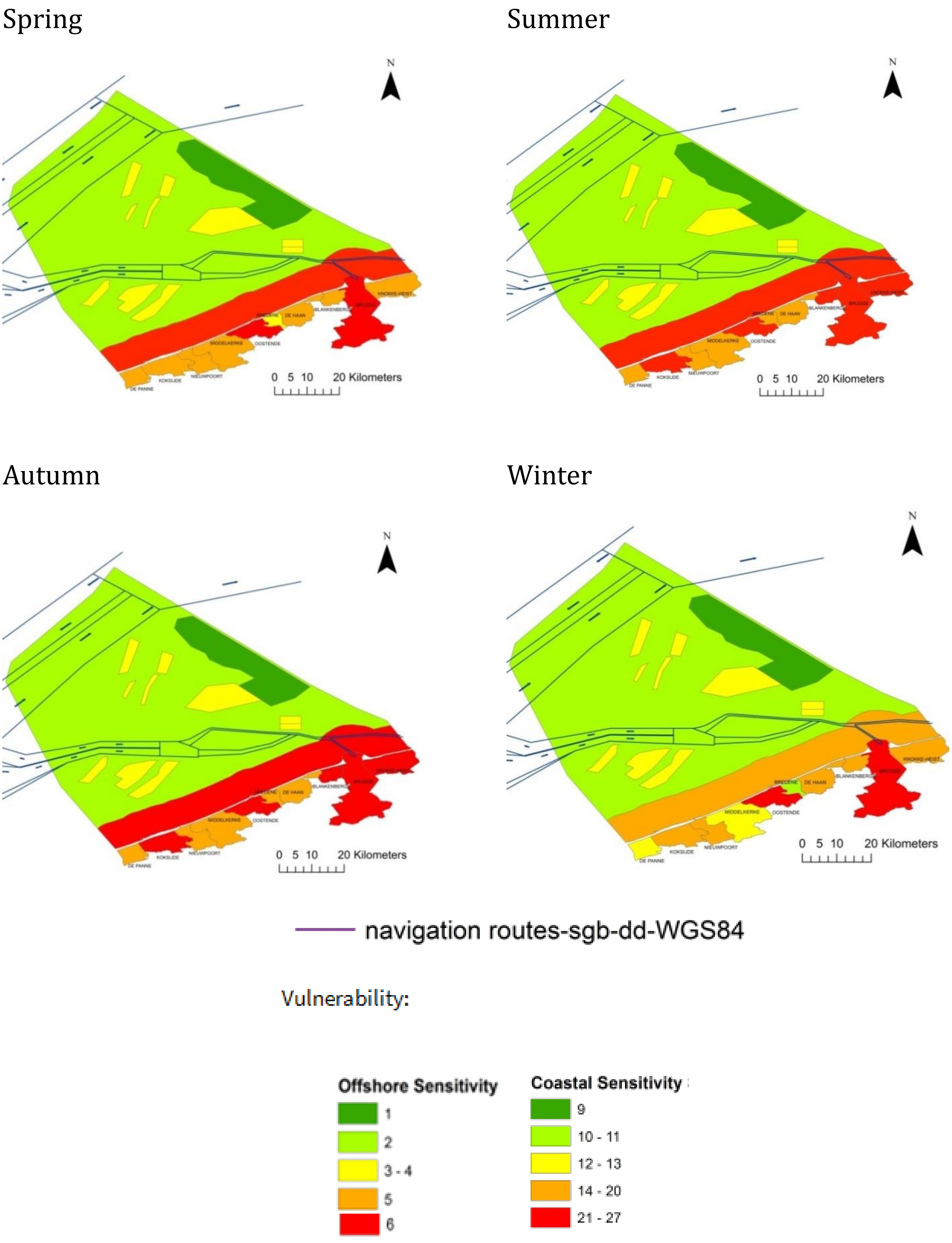


Figure 31 : Seasonal vulnerability of socio-economic features to HNS pollution at the seabed

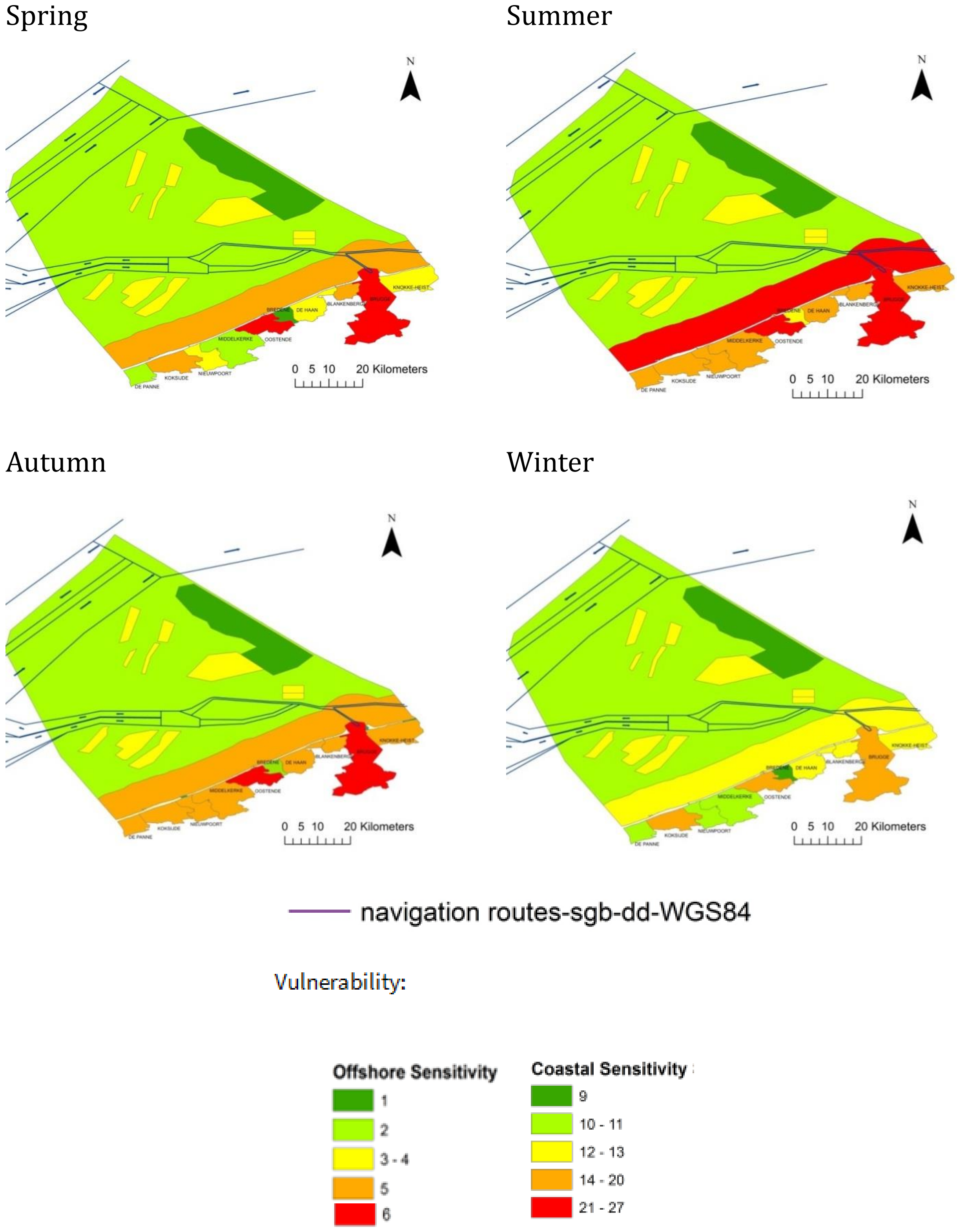


Figure 32 : Seasonal vulnerability of socio-economic features to HNS pollution at the sea surface

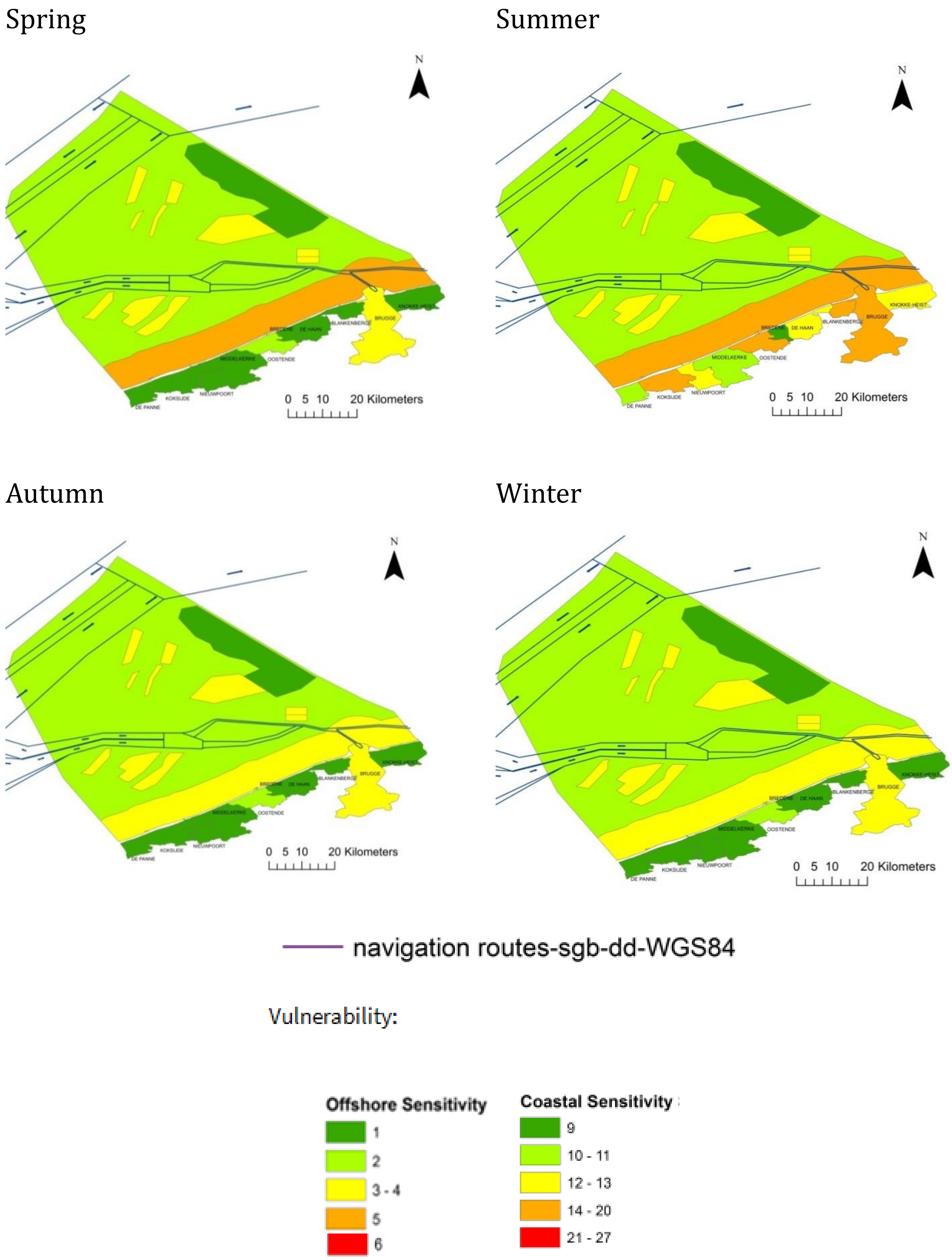


Figure 33 : Seasonal vulnerability of socio-economic features to HNS pollution in the water-column

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Conclusion

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8 Conclusion

18 shoreline habitats, 8 open sea habitats, 4 types of environmental protections, 12 species features and 16 socio-economic ones were selected for assessment and attribution of vulnerability ranking score (5 levels of vulnerability ranking scores were defined).

The vulnerability analysis was conducted at two levels:

- At the regional scale of the Bonn Agreement area;
- At a local operational scale for the Belgian part of the North Sea, chosen as a test area.

The digital vulnerability atlas contains 72 maps:

- 39 vulnerability maps at regional scale for the Bonn Agreement area;
- 3 thematic maps at local operational scale for Belgium;
- 32 vulnerability maps at local operational scale for Belgium.

The vulnerability maps catalogue with viewing and downloading tools is available on the HNS-MS public website: https://www.hns-ms.eu/tools/sensitivity_maps.

The methodology developed in the frame of HNS-MS project, using the SEBC behaviour classification allowed to overcome the difficulty due to the great number of chemicals and their varying properties. The results of the project demonstrated that the methodology can be used at regional strategic scale and be adapted to local operational needs of any country.

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Annex

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Annex : GIS tables structure and content

Habitat table: fields definition

Presence of the habitat type (0 or 1)	Ranking	*Habitat type*
Shoreline and coastal habitats		
Ex_ro_u20	Ex_ro_u20R	*Exposed rocky shores and reefs on less than 20m depth*
Ex_ro_o20	Ex_ro_o20R	*Exposed rocky shores and reefs on more than 20m depth*
Sh_ro_u20	Sh_ro_u20R	*Sheltered rocky shores and reefs on less than 20m depth*
Sh_ro_o20	Sh_ro_o20R	*Sheltered rocky shores and reefs on more than 20m depth*
Lit_chalk	Lit_chalkR	*Littoral chalk communities*
Sandy_bea	Sandy_beaR	*Sandy beaches*
Shing_bea	Shing_beaR	*Shingle beaches*
Tidal_san	Tidal_sanR	*Tidal sand and mud flats*
Salt_mars	Salt_marsR	*Salt marshes*
Sha_inlet	Sha_inletR	*Large shallow inlets and bays*
Estuaries	EstuariesR	*Estuaries*
Co_lagoon	Co_lagoonR	*Coastal lagoons (open to the sea)*
U_san_u20	U_san_u20R	*Underwater sandbanks on less than 20m depth*
U_san_o20	U_san_o20R	*Underwater sandbanks on more than 20m depth*
Bi_re_u20	Bi_re_u20R	*Biogenic reefs on less than 20m depth*
Bi_re_o20	Bi_re_o20R	*Biogenic reefs on more than 20m depth*
Maerl_bed	Maerl_bedR	*Maerl beds*
Seagrass	SeagrassR	*Eelgrass beds (Zostera sp. > 5%)*
Open sea habitats		
Op_wa_u20	Op_wa_u20R	*Open water column on less than 20 m depth*
Op_wa_o20	Op_wa_o20R	*Open water column on more than 20m depth*
De_se_o20	De_se_o20R	*Deeper sea floor on more than 20m depth*
Seamounts	SeamountsR	*Seamounts*
Coral_ga	Coral_gaR	*Coral gardens and sponge aggregations*
Carb_moun	Carb_mounR	*Carbonate mounds*
Lo_reefs	Lo_reefsR	*Lophelia pertusa reefs*
Sea_pen	Sea_penR	*Sea-pen and burrowing megafauna*

Calculation	
Sh_Co_HabR	MAX (Ex_ro_u20 * Ex_ro_u20R; Ex_ro_o20 * Ex_ro_o20R ; Sh_ro_u20 * Sh_ro_u20R ; Sh_ro_o20 * Sh_ro_o20R ; Lit_chalk Lit_chalkR; Sandy_bea * Sandy_beaR; Shing_bea * Shing_beaR; Tidal_san * Tidal_sanR; Salt_mars * Salt_marsR; Sha_inlet * Sha_inletR; Estuaries * EstuariesR; Co_lagoon * Co_lagoonR; U_san_u20 * U_san_u20R ; U_san_o20 * U_san_o20R; Bi_re_u20 * Bi_re_u20R; Bi_re_o20 * Bi_re_o20R; Maerl_bed * Maerl_bedR; Seagrass * SeagrassR)
Op_Wa_HabR	MAX (Seamounts * SeamountsR; Coral_ga * Coral_gaR; Carb_moun * Carb_mounR; Lo_reefs * Lo_reefsR; Sea_pen * Sea_penR)+ (Op_wa_u20 * Op_wa_u20R) + (De_se_o20 * De_se_o20R)

Final score	
All_HabR	Sh_Co_HabR + Op_Wa_HabR

Species table: fields definition

Presence of the species (0 or 1)	Ranking
Fish_spri	Fish_spriR
Fish_sum	Fish_sumR
Fish_fall	Fish_fallR
Fish_win	Fish_winR
No_spr_he	No_spr_heR
Buc_her	Buc_herR
Scot_her	Scot_herR
Ir_her	Ir_herR
Down_her	Down_herR
Bird_win	Bird_winR
Bird_stag	Bird_stagR
Bird_bree	Bird_breeR

Species features
Spawning areas for fish: during SPRING
Spawning areas for fish: during SUMMER
Spawning areas for fish: during AUTUMN
Spawning areas for fish: during WINTER
· Norwegian spring spawning stock
· Buchan/Shetland herring
· Banks herring and the West of Scotland autumn spawning herring
· Irish autumn/winter spawning herring
· Down herring
Wintering areas for birds
Staging areas for birds
Breeding areas for birds (incl. foraging areas)

Calculation	
FishR	(Fish_spri * Fish_spriR) + (Fish_sum * Fish_sumR) + (Fish_fall * Fish_fallR) + (Fish_win * Fish_winR) + (No_spr_he * No_spr_heR) + (Buc_her * Buc_herR) + (Scot_her * Scot_herR) + (Ir_her * Ir_herR) + (Down_her * Down_herR)
BirdsR	(Bird_win * Bird_winR) + (Bird_stag * Bird_stagR) + (Bird_bree * Bird_breeR)

Final score	
SpeciesR	BirdsR + FishR

Protected areas table: fields definition

Presence of the protected areas (0 or 1)	Ranking
Ramsar	RamsarR
Nat2000	Nat2000R
Ospar	OsparR
W_herita	W_heritaR

Protected areas features
Natura 2000 areas (EC Habitat and Birds Directive (SACs and SPAs))
RAMSAR Convention areas
OSPAR Convention areas
World heritage sites

Final score	
Protect_aR	(Ramsar * RamsarR) + (Nat2000 * Nat2000R) + (Ospar * OsparR) + (W_herita * W_heritaR)

Socio-economic features table: fields definition

Presence of the socio-economic feature (0 or 1)	Ranking
Fisheries	FisheriesR
Fishfarms	FishfarmsR
Shellfish	ShellfishR
Algae	AlgaeR
Am_beach	Am_beachR
Marinas	MarinasR
Tou_stays	Tou_staysR
Dens_pop	Dens_popR
Rec_fish	Rec_fishR
Cruise_li	Cruise_liR
Heritage	HeritageR
Ports	PortsR
Mineral	MineralR
Windfarms	WindfarmsR
Wa_inlets	Wa_inletsR

Socio-economic features
Offshore fisheries
Fish farms
Shellfish cultures
Algae cultures
Amenity beaches
Marinas
Overnight stays coastal tourist hotels
Densely populated towns and communities
Main recreational fishing locations
Cruise liner stops
Heritage sites
Ports
Mineral extraction sites
Offshore wind farms
Water intakes

Calculation	
SumR_1_8	(Fisheries * FisheriesR) + (Fishfarms * FishfarmsR) + (Shellfish * ShellfishR) + (Algae * AlgaeR) + (Am_beach * Am_beachR) + (Marinas * MarinasR) + (Tou_stays * Tou_staysR) + (Dens_pop * Dens_popR)
SumR_9_15	(Rec_fish * Rec_fishR) + (Cruise_li * Cruise_liR) + (Heritage * HeritageR) + (Ports * PortsR) + (Mineral * MineralR) + (Windfarms * WindfarmsR) + (Wa_inlets * Wa_inletsR)

Final score	
SocioecoR	SumR_1_8 + SumR_9_15

{HNS-MS}

Improving Member States preparedness
to face an HNS pollution of the Marine System