DELIVERABLE 5.1

Report on key drivers and impacts of changes in spatial distribution of fisheries and fished stocks

Version 1.0

WP 5
Deliverable 5.1
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Executive summary

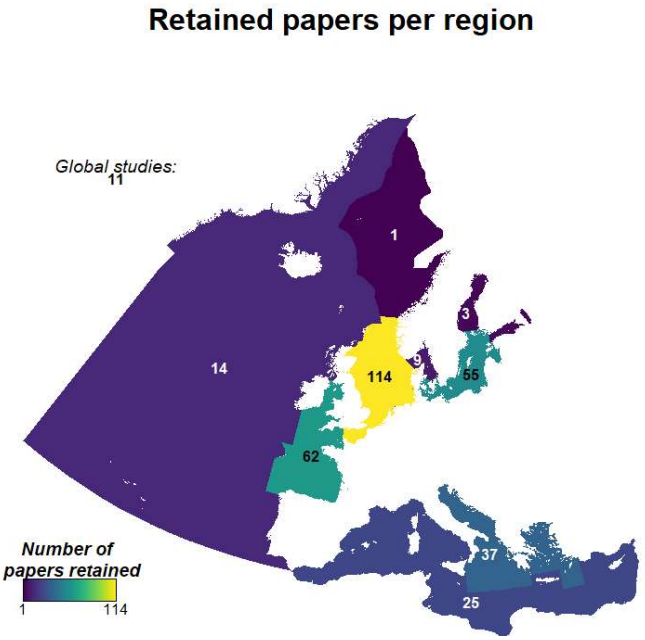
An ecosystem approach to fisheries management requires the consideration of spatially explicit management measures and other impacts on species and the links between the distribution of fished species, their surrounding environment and productivity. Quantification of the spatial aspects of fisheries and ecology of commercially fished stocks may improve the accuracy of the predicted changes in fish productivity, fisheries yield and costs, benefits and selectivity.

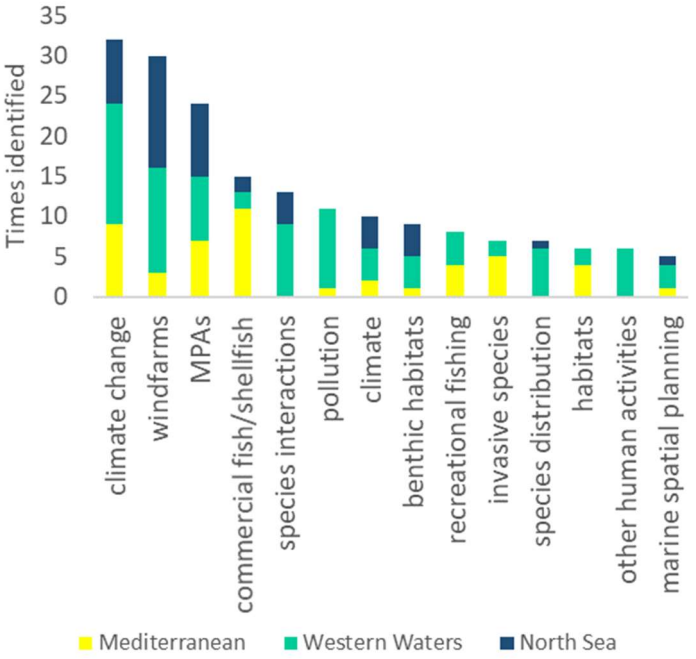
To provide a knowledge base for spatially explicit considerations, SEAwise consulted stakeholders throughout Europe and conducted a systematic review of the scientific literature. As a first step, engagement with relevant stakeholder groups in each Case Study identified key issues of relevance to spatial management. The input from this stakeholder consultation was supplemented by a systematic literature review with careful consideration of the objectives, search terms, inclusion/exclusion criteria, the method for data/knowledge extraction and ultimately how these data and knowledge will be used. The purpose of the task was to quantify the key drivers and pressures behind the changes occurring in commercial fish stocks and fisheries distribution that have a spatially explicit content, map the relevant existing scientific knowledge and provide input to the subsequent WP5 tasks.

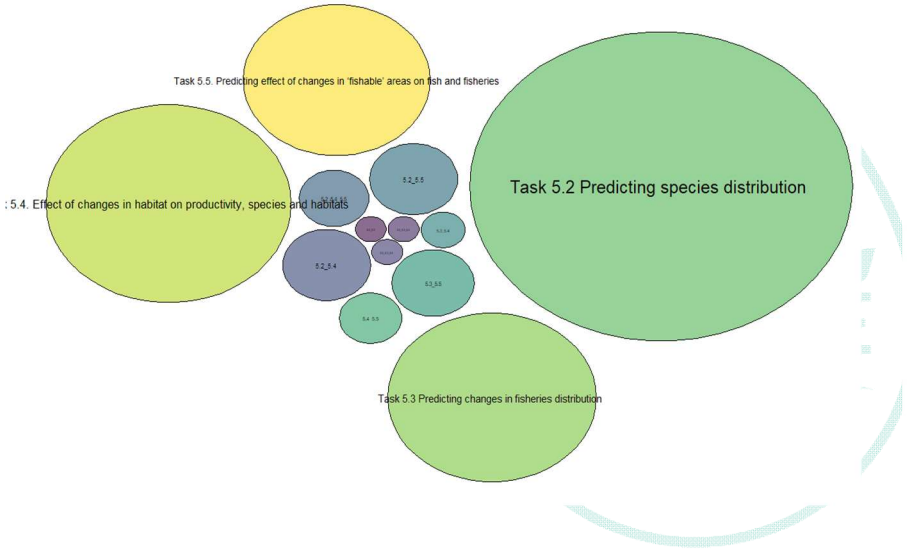
The words identified by the stakeholders consulted focused on factors causing changes to the distribution of commercial fish/shellfish (climate change, MPAs, species interactions, pollution, habitats and invasive species) and fisheries (windfarms, MPAs, Marine spatial planning) as well as the other human impacts. The systematic review extracted data from 331 papers. The most frequently studied topic was the distribution of fish and the region with most papers was the North Sea with about the twice the amount of papers in each of the other regions. The most frequently studied species in the literature were cod, hake and plaice and by far the most frequently studied fisheries was demersal trawl fisheries.

Among the issues identified by stakeholders as key, the effects of environmental conditions on the distribution of fish were particularly well represented in the reviewed material. In contrast, factors determining the distribution of fisheries were almost exclusively studied in trawl fishing in the North Sea and papers on the effect of area restrictions on fish and fisheries were largely restricted to Western waters and the North Sea. While knowledge on the effects of habitats on species did exist, this was restricted to the Baltic Sea and North Sea and papers addressing this outside these areas were close to non-existent. This points to important areas for future work in SEAwise.

The database of knowledge produced by this review, is available internally for the project here.







Key spatial considerations for fish and fisheries

Number of papers registered by region (top left) and topic (bottom left) and spatial issues identified by most stakeholders as key (top right).

Contents

1. SEAwise background

The SEAwise project works to deliver a fully operational tool that will allow fishers, managers, and policy makers to easily apply Ecosystem Based Fisheries Management (EBFM) in their own fisheries. With the input from advice users, SEAwise identifies and addresses core challenges facing EBFM, creating tools and advice for collaborative management aimed at achieving long-terms goals under environmental change and increasing competition for space. SEAwise operates through four key stages, drawing upon existing management structures and centred on stakeholder input, to create a comprehensive overview of all fisheries interactions in the European Atlantic and Mediterranean. Working with stakeholders, SEAwise acts to:

- Build a network of experts - from fishers to advisory bodies, decision makers and scientists - to identify widely-accepted key priorities and co-design innovative approaches to EBFM.
- Assemble a new knowledge base, drawing upon existing knowledge and new insights from stakeholders and science, to create a comprehensive overview of the social, economic, and ecological interactions of fisheries in the European Atlantic and Mediterranean.
- Develop predictive models, underpinned by the new knowledge base, that allow users to evaluate the potential trade-offs of management decisions, and forecast their long-term impacts on the ecosystem.
- Provide practical, ready-for-uptake advice that is resilient to the changing landscapes of environmental change and competition for marine space.

The project links the first ecosystem-scale impact assessment of maritime activities with the welfare of the fished stocks these ecosystems support, enabling a full-circle view of ecosystem effects on fishing productivity in the European Atlantic and Mediterranean. Drawing these links will pave the way for a whole-ecosystem management approach that places fisheries at the heart of ecosystem welfare. In four cross-cutting case studies, each centred on the link between social and economic objectives, target stocks and management at regional scale SEAwise provides:

- Estimates of impacts of management measures and climate change on fisheries, fish and shellfish stocks living close to the bottom, wildlife bycatch, fisheries-related litter and conflicts in the use of marine space in the Mediterranean Sea,
- Integrated EBFM advice on fisheries in the North Sea, and their influence on sensitive species and habitats in the context of ocean warming and offshore renewable energy,
- Estimates of effects of environmental change on recruitment, fish growth, maturity and production in the Western Waters,
- Key priorities for integrating changes in productivity, spatial distribution, and fishers' decision-making in the Baltic Sea to create effective EBFM prediction models.

Each of the four case studies will be directly informed by expert local knowledge and open discussion, allowing the work to remain adaptive to change and responsive to the needs of advice users.

1.1 The role of this deliverable

This deliverable report describes the approach taken to complete steps 1 and 2 of the SEAwise EBFM in relation to the social system:

1. Identify the stakeholder community, and with them, maps of the ecoregions, their species and habitats, stakeholder interests and responsibility;

2. Establish ecological and social system priorities under current legislation and regulation, determine major factors influencing these priorities, conduct susceptibility analysis and identify potential management strategies through co-design workshops and systematic reviews

1.2 Contributors

The lead contributors to this deliverable included organisers and rapporteurs of the stakeholder scoping events and key personnel selected to drive individual reviews. The WP5 leader, being the 5.1 task leader as well, co-ordinated communication among the 27 reviewers. Task 3.1 and 4.1 leaders were instrumental in defining and selecting search parameters in Task 5.1, by sharing their methods and perceptions. As a result, the common approach followed among x.1 tasks allowed for undertaking the multiple review steps across 24 partners in a compatible way. Names and institutions of people involved in these roles are given in Table 1.

Table 1. Names and roles of contributors to this deliverable

Name	Institute	Key Review driver	Scoping consultation
D. Damalas*	HCMR	X	
E.J. Brown	DTU Aqua	X	X
F. Bastardie	DTU Aqua	X	X
Anna Rindorf	DTU Aqua		
Nis Sand Jacobsen	DTU Aqua		
M.S. Rolland	IFREMER	X	X
M. Woillez	IFREMER	X	
Y. Vermard	IFREMER	X	
G. Chust	AZTI	X	
J. Paradinas	AZTI	X	
Dorleta Garcia	AZTI		X
S. Uhlmann	MI	X	
L. Vaughan	MI	X	
D. Reid	MI	X	X
W. Zupa	COISPA	X	
A. Pierucci	COISPA	X	
M.T. Spedicato	COISPA	X	X
C. Vassilopoulou	HCMR		X
M. Brodersen	HCMR	X	
N. Fotiadis	HCMR	X	
I.Maina	HCMR	X	
N. Probst	TI-SF	X	
J. Letschert	TI-SF	X	
V. Stelzenmueller	TI-SF	X	
P. Bonsu	TI-SF	X	
A. Kempf	TI-SF		X
M.Taylor	TI-SF		X
J. Depestele	EV-ILVO	X	X
K. Sys	EV-ILVO	X	
K. van de Wolfshaar	WR	X	

M. Kraan	WR		X
G. Lambert	CEFAS	X	
S. Eliasen	CBG - AAU		X
P. Melia	POLIMI	X	
J.J. Poos	WU	X	

*WP and task 5.1 lead

1.3 Acronyms and abbreviations

EBFM	Ecosystem Based Fisheries Management
DOI	Digital Object Identifier
MPA	Marine Protected Area
PDF	Portable Document Format
PET	Protected, Endangered, Threatened
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
WoS	Web of Science
WP	Work Package
x.1	All review tasks for work packages two through six

2. Aims of scoping consultations and systematic reviews

The SEAwise stakeholder integration aims to ensure that the key issues of relevance for the social system and potential management measures are identified and prioritised for further evaluation in the project and hence that the end results are relevant to the end users. The SEAwise scoping consultations in the first half year of the project had the following specific aims

- To build trust and common understanding between SEAwise participants and identified stakeholders.
- To identify key issues of relevance for ecosystem-based fisheries advice, current ecosystem status and potential management measures
- To identify priorities of these key issues and evaluate how this varies between individuals
- To compare results between regions and group sessions
- To compare results between different scoping methods within a region

The methods used in scoping consultations are described in deliverable report D1.1[1].

In developing and implementing operational EBFM, SEAwise is building upon years of knowledge and research, which is both rich and sparse, depending on the subject area, geographical area and ecosystem components in question. The role of the systematic reviews in SEAwise is to identify and describe the available information and gaps in knowledge that exist across five key subject areas and across the different European seas covered in SEAwise's case studies.

The methods used in systematic reviews are described in deliverable report D1.1.

3. Scoping consultations

The aim of the stakeholder consultation will impact the choice of the most appropriate consultation method. The choice of consultation method was therefore carefully considered in advance. Specific attention was given to minimise the impact of the organising scientists' expectations and emergent group dynamics on group results. Comparability of results was ensured by using common methods in all regions and group sessions.

Three different approaches were used to identify key issues of relevance, current ecosystem status and potential management measures (Individual consultation, individual consultation in a group environment and group consultation). Two approaches used to identify priorities of these key issues and evaluate how this varies between individuals (Individual consultation, individual consultation in a group environment). The combination of these methods allowed the identification of key priorities with and without group dynamics. The key issues were discussed in further detail in a group consultation to allow a common understanding of their definition. Further details about the methods can be found in Deliverable 1.9.

[1] DELIVERABLE 1.1 - Report on review guidelines to be used in tasks 2.1, 3.1, 4.1, 5.1 and 6.1

3.1 Mediterranean Sea scoping for WP5

The spatial words relevant to WP5 and identified by at least two stakeholders consulted were commercial fish/shellfish, climate change, MPAs, invasive species, recreational fishing, habitats, turtles, windfarms, fishing tourism, marine mammals and PET species (fig. 3.1).

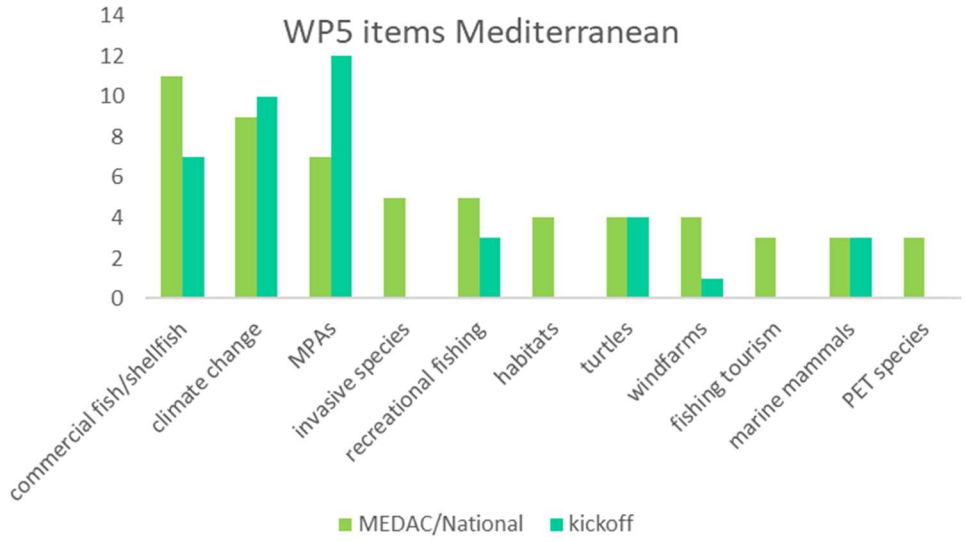


Figure 3. 1 Words identified for WP5 aspects in the scoping exercises ordered by frequency of occurrence among stakeholder input. Frequency of occurrence among the SEAwise scientists are given for comparison.

3.2 Western Waters scoping for WP5

The spatial words identified by at least three of the stakeholders consulted were climate change, windfarms, species interactions, MPAs, pollution, climate, species distribution, benthic habitats, other human activities and marine spatial planning (fig. 3.2).

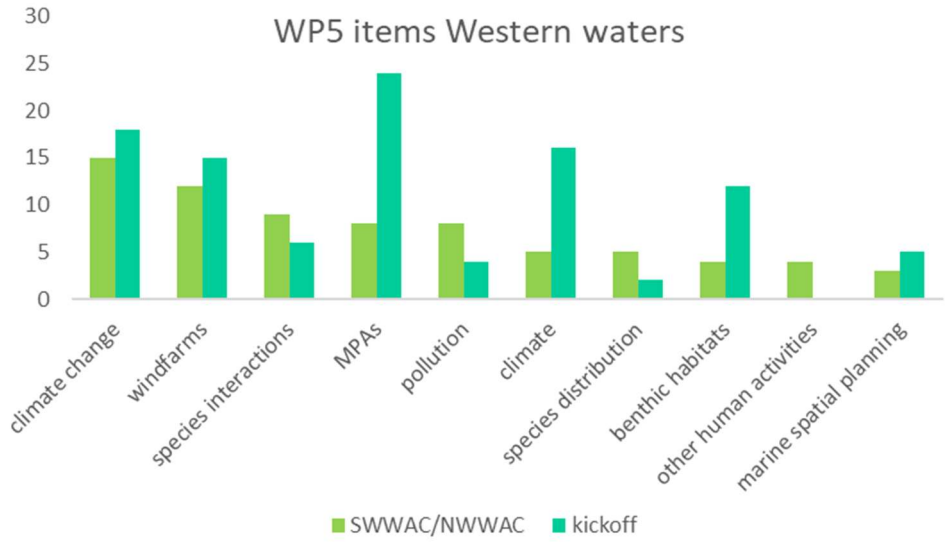


Figure 3. 2 Words identified for WP5 aspects in the scoping exercises ordered by frequency of occurrence among stakeholder input. Frequency of occurrence among the SEAwise scientists are given for comparison.

3.3 North Sea scoping for WP5

The spatial words identified by at least three of the stakeholders consulted were windfarms, climate change, MPAs, benthic habitats, climate, species interactions, closed areas and global warming (fig. 3.3).

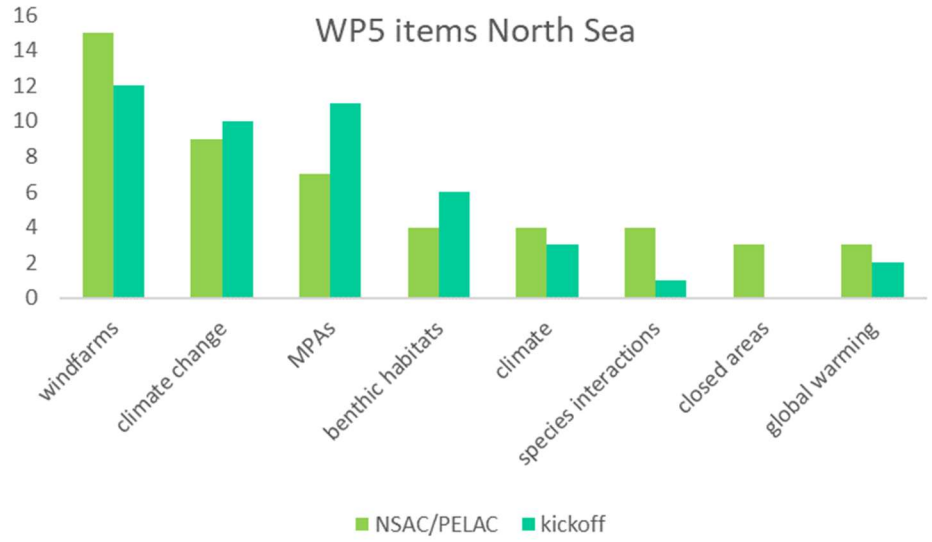


Figure 3. 3 Words identified for WP5 aspects in the scoping exercises ordered by frequency of occurrence among stakeholder input. Frequency of occurrence among the SEAwise scientists are given for comparison.

3.4 Baltic Sea scoping for WP5

The scoping by stakeholders for the Baltic Sea was postponed and instead the words identified by SEAwise participants are given in fig. 3.4. The words identified by at least three participants were benthic habitats, climate change, windfarms, global warming, invasive species, MPAs, habitat quality, recreational fishing, salinity and temperature (fig. 3.4).

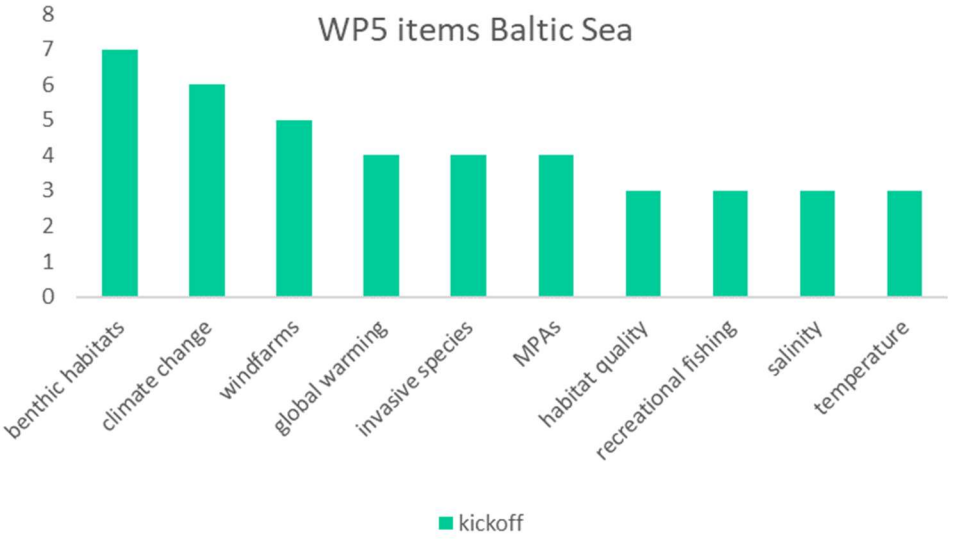


Figure 3. 4 Words identified for WP5 aspects in the scoping exercises ordered by frequency of occurrence among SEAwise scientists.

3.5 Items identified across regions

The four most frequently identified spatially relevant words identified by the stakeholders consulted were climate change, windfarms, MPAs, commercial fish/shellfish (fig. 3.5). These words were consistently frequently occurring across Mediterranean, Western waters and the North Sea.

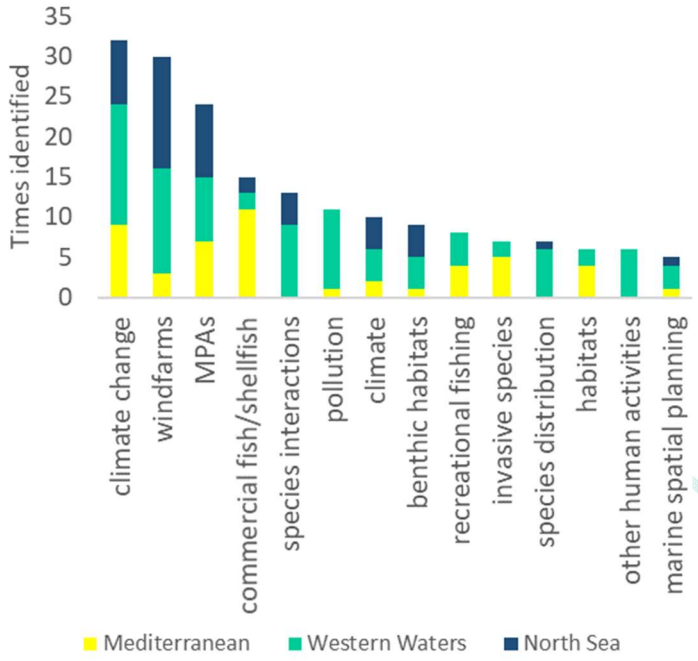


Figure 3.5 Words identified for WP5 aspects in the scoping exercises ordered by frequency of occurrence among stakeholder input across all areas.

4. Systematic reviews

As the abundance of studies and primary literature on marine fisheries has increased exponentially over the past few decades the need for reviews and syntheses of the knowledge contained has also increased. Diverse approaches have been taken in method and quality; some are unbiased but inexhaustive (Brown et al., 2018), while many rely on case-based reviews that are derived from the authors' knowledge of their geographic areas (Kraufvelin et al., 2018). Herein, to be both comprehensive and to reduce bias, a systematic approach with careful consideration of the: objectives, search terms, inclusion/exclusion criteria, the method for data/knowledge extraction and ultimately how these data and knowledge will be used, was undertaken (see Shamseer et al., 2015).

The systematic reviews provide exhaustive summaries of current knowledge and clearly document the methods used. The approach provides transparency and allows later updates as more information becomes available and is described in more detail below. The systematic reviews encompass six steps:

- Framing of the research question
- Scoping to define search terms
- Screening of studies
- Data extraction
- Description of the database produced

Following these steps, a presentation of the outcome of the systematic review.

The literature review was conducted by a team of 27 persons. The papers identified in the search were allocated to the 27 participants for screening, which means that they had to read the title, the abstract and the keywords of the papers in their list and decide whether to include or exclude them for the next phase (data extraction), according to specific exclusion criteria shared with them. The included papers were then allocated to the 27 persons. Included papers were read (whole paper) and either excluded according the same criteria as in the screening phase or used to extract specific bits of information, according to the data extraction template. After the collection of the individual data extraction results, the information was homogenized and processed.

A series of data files were produced (available on DTU Aqua shared repository):

- Bibliographic information on papers relevant to WP5 – including Abstract (search queries output)
- Detailed information extracted from papers relevant to WP5 – based on pre-defined Template (data extraction output)
- Repository of Full texts of papers relevant to WP5 – in pdf format (data extraction output)

The detailed information included the perceived link to the WP5 tasks:

- Task 5.2: Predicting species distribution
- Task 5.3: Predicting changes in fisheries distribution
- Task 5.4: Effect of changes in habitat on productivity, species and habitats
- Task 5.5: Predicting effect of changes in 'fishable' areas on fish and fisheries

The outcomes of this endeavour will be helpful during the project realization as the collected studies may become useful during the implementation of WP5 tasks as baseline reference material.

4.1 Framing of the research question

The aim of the systematic review was to investigate the spatial aspects of fisheries and ecology of commercially fished stocks that will allow for identification of drivers of spatial distribution of fish and fisheries to predict changes in resource distribution, management measures and resulting changes in fish productivity, fisheries costs, benefits and selectivity.

4.2 Scoping to define search terms

The scoping process used to determine key issues with stakeholders (see description in section 3 and deliverable 1.9 for participant number and gender balance) was also used by the scientists in SEAwise in isolation. Based on the results from this exercises, the participants in the systematic review for WP4 defined a list of spatial extents, ecosystem components, pressures, impact and fishing gears. Starting from this**Error! Reference source not found.**, the search terms were defined collectively, refined by a subgroup of 5.1 participants (HCMR, COISPA, DTU Aqua) and organised into five categories (spatial aspects, target species, driver/pressure, activity, WP5 specific terms, **Error! Reference source not found.**).

A search string was constructed including spatial extent, ecosystem components, pressures, impact and fishing gears:

Spatial x **Target species** x **Driver/Pressure** x **WP5 specific terms**

The search was conducted in Scopus and Web of Science but subsequently limited to Web of Science. Detailed description of the methodology followed is given in deliverable D.1.1. It provides the framework, guidelines, and

specific instructions for systematic reviews undertaken within SEAwise. The common review protocol for the spatial management impacts review reduced biases in this synthesis of foundational knowledge.

Table 4.1. Search terms by element used to construct the search string. Elements were separated by 'AND'. Within each element, terms were separated by 'OR'.

	SPATIAL		TARGET	DRIVER/PRESSURE	ACTIVITY	WP5 SPECIFIC
MED CS	Aegean Sea	MED CS	*Merluccius merluccius*	Accident	Agriculture	spatial
	Mediterranean Sea		*Mullus barbatus*	Alien species	Aquaculture	movement
	Ionian Sea		*Parapenaeus*	Artificial	Coastal	allocation
	Adriatic Sea		*Nephrops norvegicus*	Benthic productivity	Fishing	distrivution
	GSA17		*Nephrops**	Biodiversity loss	Land based	shift
	GSA18		*Aristaeomorpha*	biogeochemical	Oil and gas	mapping
	GSA19		*Aristeus antennatus*	Bottom trawling	Shipping	migration
	GSA20		Demersal species	Brexit	Tourism	displac*
	GSA22		demersal	Certification schemes	Energy	phenology
BALTIC CS	Baltic Sea		hake	Climate change	windpower	spatiotemporal
	Baltic Proper		red mullet	Competition	windfarms	
	western Baltic		deep water rose	Conflict for sea space	Recreation	
	Kattegat		Norway lobster	Contamination	Land*based	
	Skagerrak		giant red shrimp	Costs	Coastal	
	ICES Area 3*		Demersal fish	Cumulated impacts for	Spatial	
	ICES subarea 3		crustace*	Cumulative pressure	Marine Spatial	
	ICES division 3*		shrimp*	Density-dependence	Marine Protected	
	ICES subdivision 3*	BALTIC CS	*Clupea harengus*	Disease*	Sector interaction	
	ICES Area III*		*Gadus morhua*	Economic systems	Maritime	
	ICES subarea III*		*Sprattus sprattus*	Energy prices	spatial plan*	
	ICES division III*		*Pleuronectes platessa*	Environmental variability	Mineral	
	ICES subdivision		*Platichthys flesus*	Eutrophication	Dredging	
NSEA CS	North Sea		*Platichthys solemdali*	Fish prices	mining	
	English Channel		*Neogobius*	Fisheries Restricted Areas	wind*power	
	ICES Area 4*		*Salmo trutta*	Fishing	wind*farms	
	ICES Area IV*		*Salmo salar*	Fishing gear selectivity	cable	
	ICES Area 7.d		*Nephrops norvegicus*	Food web effects	pipeline	
	ICES Area VIId		*Solea solea*	FRAs	Land based	
	ICES subarea 4*		herring	Fuel consumption	Conservation	
	ICES division 4*		cod	Gear selectivity	Research	
	ICES subdivision 4*		sprat	Genetic pollution /	Renewables	
	ICES subarea IV*		plaice	Ghost fishing	wind park	
	ICES division IV*		flounder	Global warming	MSP	
	ICES subdivision		Baltic flounder	Habitat degradation	Land*based	
	ICES subarea 7.d		round goby	Habitat loss	renewable energy	
	ICES division 7.d		brown trout	Human pressures	wind*park	
	ICES subdivision		salmon	Hydrologic		
	ICES subarea VIId		*Nephrops**	Invasive species		
	ICES division VIId		Norway lobster	legislation		
	ICES subdivision		common sole	Lost fishing gears		
WW CS	Celtic Sea*	NSEA CS	*Ammodytes*	management		
	Irish Sea		*Clupea harengus*	Marine litter		
	Bay of Biscay		*Flatfish*	Marine litter pressure		

	Western waters		*Gadoids*	Marine protected areas
	North East Atlantic		*Gadus morhua*	Marine traffic
	English Channel		*Melanogrammus*	Mobile fishing gears
	ICES Area 6*		*Merlangius merlangus*	MPA
	ICES Area 7*		*Mullus surmuletus*	MPAs
	ICES Area 8*		Pelagic*	MSP
	ICES subarea 6*		*Pleuronectes platessa*	Non-native species
	ICES subarea 7*		*Pollachius virens*	Nutrients
	ICES subarea 8*		*Scomber scombrus*	Ocean dynamics
	ICES division 6*		*Solea solea*	Parasites
	ICES division 7*		*Sprattus sprattus*	Passive fishing gears
	ICES division 8*		*Trisopterus esmarkii*	Plastics
	ICES subdivision		sandeel	Political systems
	ICES subdivision 7*		herring	Pollution
	ICES subdivision 8*		cod	Population growth
	ICES Area VI*"		haddock	Predation
	ICES Area VII*		whiting	Primary productivity
	ICES Area VIII*		surmullet	Productivity changes
	ICES subarea VI*"		plaice	Quota sharing
	ICES subarea VII*		saithe	Recreational fishing
	ICES subarea VIII*		sole	Regulation
	ICES division VI*		sprat	Revenue
	ICES division VII*		Norway pout	Seabed disturbance
	ICES division VIII*		demersal	Social cultural value
	ICES subdivision	**WW CS**	*Sardina pilchardus*	Spatial planning
	ICES subdivision		*Clupea harengus*	Spill over
			Sprattus sprattus	Stock productivity
			Dicentrarchus labrax	Trawling impact on
			Merluccius merluccius	Trophic
			Solea solea	Zooplankton
			*Nephrops**	
			Lophius	
			Gadus morhua	
			Merlangius merlangus	
			Melanogrammus	
			Lepidorhombus	
			Pollachius virens	
			Pollachius pollachius	
			Engraulis encrasicolus	
			Trachurus trachurus	
			Scomber scombrus	
			Elasmobranch	
			Demersal species	
			Gadoids	
			Flatfish species	
			Benthic species	
			cristacea*	
			Small pelagic	
			Engraulidae	
			sardine	
			pilchard	

	herring
	sprat
	seabass
	hake
	common sole
	Norway lobster
	angerfish
	cod
	whiting
	haddock
	megrim
	saithe
	pollock
	pollack
	anchovy
	horse mackerel
	mackerel

Prior to the Screening/Data extraction phases, trials over a small number of selected studies were undertaken with a group of people to fine-tune the processes. A series of R-scripts allowed for processing the large number of records and generating the repository of relevant studies.

Search Outcome

Searches were conducted by case study. An investigation on the performance of the two widely used databases, Scopus and Web of Science (WoS), conducted between 19th and 24th of January 2022, resulted in using WoS since it proved to be more proliferate, consistent and relevant in context than Scopus. Note that throughout the text and on various graphs the cumulative sum of unique papers may exceed the number of papers retained (n=331). This is due to overlapping (e.g.: some papers dealt with more than one region, species, habitat, driver etc…).

A total of 1049 papers were generated from WoS; 934 papers after removal of duplicates: Mediterranean Sea 181, Baltic Sea 165, North Sea 470, Western Waters 118 (Fig. 4.1).

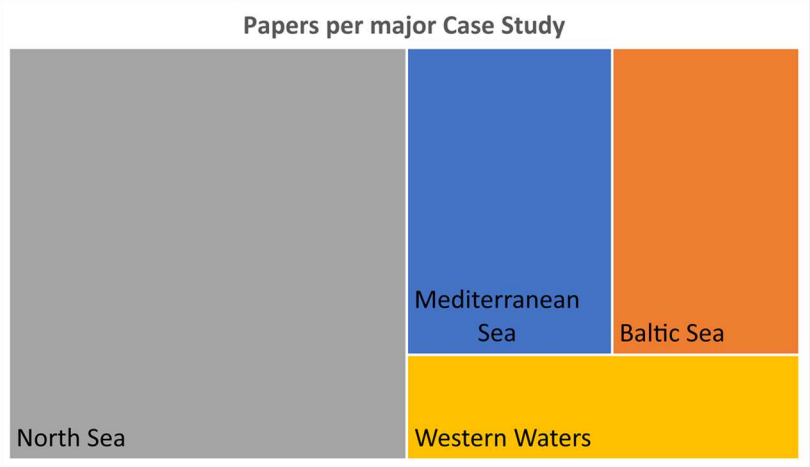


Figure 4. 1 Search results per major Case study in the 5.1 systematic review

4.3 Screening of studies

The studies were screened using the Abstract text by two independent reviewers. A sizeable proportion of papers (41%) revealed disagreement in the decision on inclusion/exclusion among reviewers. Highest level was observed for the Western waters studies (48%) and lower for the Baltic Sea studies (34%)(Figure 4.2). These papers were re-assessed by a super-screener (5.1 task leader) before proceeding to the next phase.

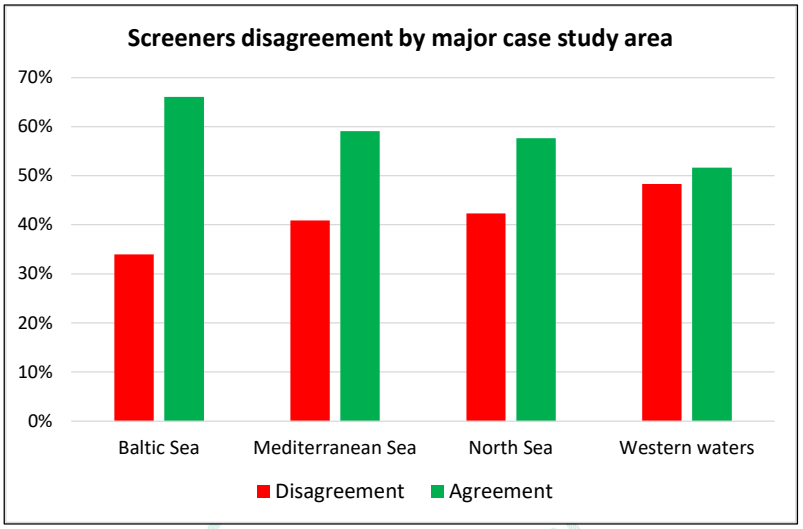


Figure 4.2 Screeners disagreement per major Case study in the 5.1 systematic review

Out of the 934 papers resulted from the search queries, the screening process identified 395 as relevant and were passed over to the data extraction phase: Mediterranean Sea 67 out of 181, Baltic Sea 73 out of 165, North Sea 187 out of 470, Western Waters 68 out of 118. The highest rejection/exclusion rate occurred in the Mediterranean studies (63%) while the lowest was in Western waters (42%). The overall rejection rate was 58%.

Full Text Exclusions

Exclusion of studies during the data extraction phase was based on pre-defined criteria relating to spatially explicit context, region, target species, driver/pressure, document type and language. 64 papers were excluded, mostly on the 'lack of spatial context' (see Fig. 4.3) while 331 papers were retained for data extraction.

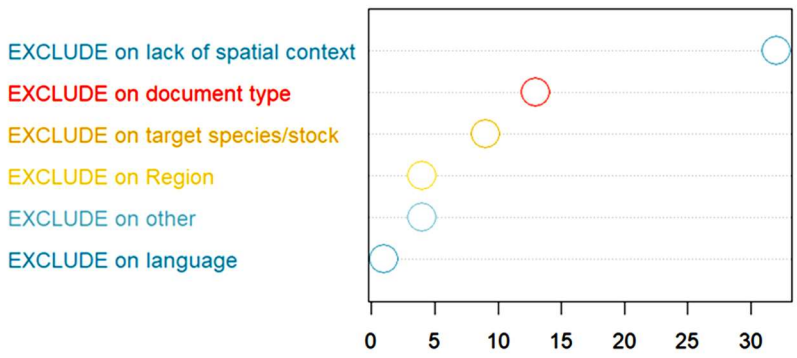


Figure 4.3 Number of papers excluded based on certain criteria

4.4 Data extraction

The data extracted from the 331 retained papers was assembled in a database together with bibliographic information as well as quality metrics. This database is available to inform subsequent tasks. The quality of the individual studies was assessed according to whether analytical methods match the data and support the inference and whether the coverage and resolution match the claims being made (at a spatial and temporal scale). A nominal rating scale was used:

- suitable, doubtful, not suitable (for analytical methods used)
- sufficient, appears sufficient, not sufficient (for spatial and temporal coverage)

Potential Biases

The choices of target species by region ('spatial') potentially affects the regional balance in the number of papers retained. For example, in the Mediterranean Sea only demersal species were selected for further investigation, elasmobranchs were the focus of investigation only in the Western Waters region and round goby was queried only in Baltic Sea studies. The same applies to the combination of habitats or fisheries/gears studied per region. As a result, lack of studies on e.g. elasmobranchs outside the Western waters should not be considered as evidence of a gap in knowledge and the same applies to the non-existent studies on Mediterranean pelagic fish in this endeavour.

4.5 Description of the database produced

The regions, species, drivers and habitats most frequently occurring were North Sea for regions, cod for species, environmental factors for drivers and demersal environment for habitats. Cod dominated the North and Baltic Sea studies, hake the Mediterranean Sea. A sizeable number of papers investigated more than one species ('various') (Figure 4.4). Environmental parameters were the most influential drivers/pressures followed by fishing, for all case studies (regions)(Figure 4.5).

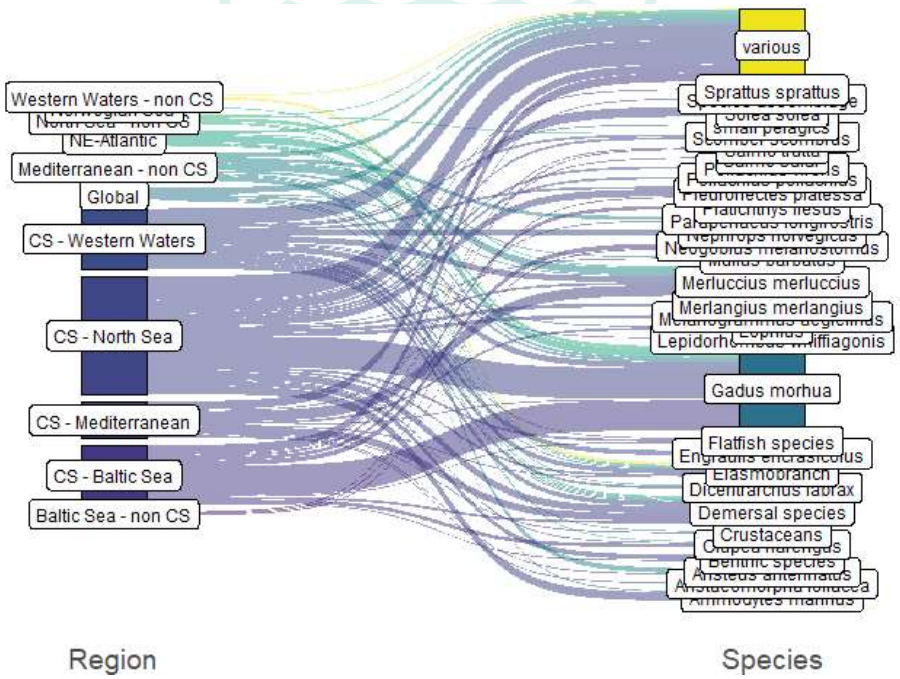


Figure 4.4 Sankey diagram revealing the association between case studies (Regions) and Species studied per Region.(Width of the arrows is proportional to the flow rate)

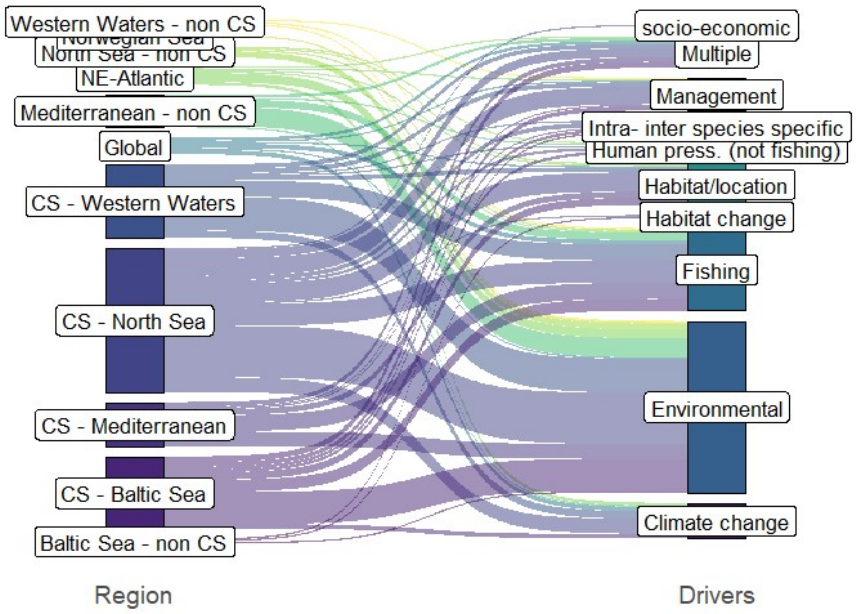


Figure 4.5 Sankey diagram revealing the association between case studies (Regions) and Drivers/Pressures studied. (Width of the arrows is proportional to the flow rate)

Demersal and bentho-pelagic habitats were the most common habitats studied, for all case studies (Regions)(Figure 4.6) while environment and fishing were the main drivers for the most common species (or assemblages) studied: cod, hake, various (Figure 4.7).

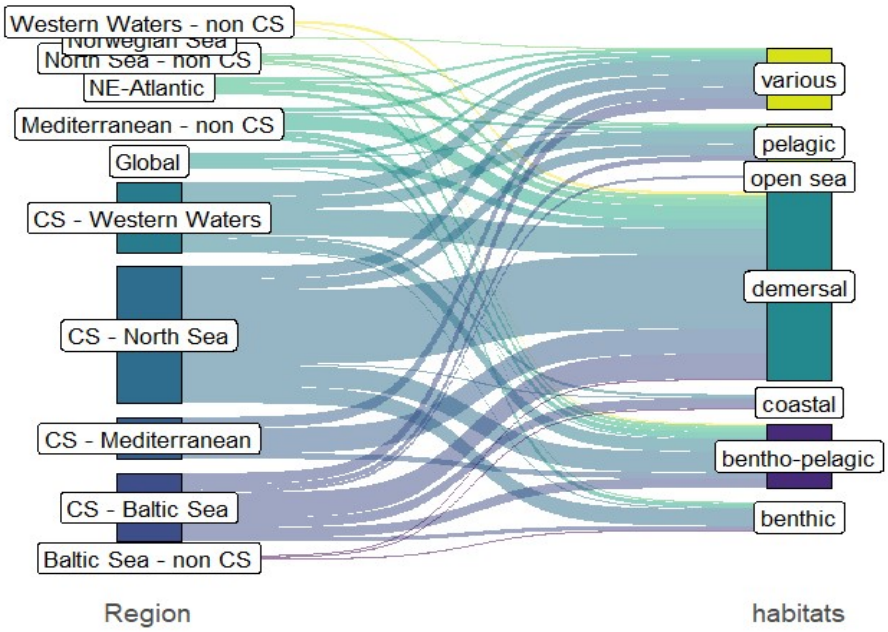


Figure 4.6 Sankey diagram revealing the association between case studies (Regions) and Habitats studied. (Width of the arrows is proportional to the flow rate)

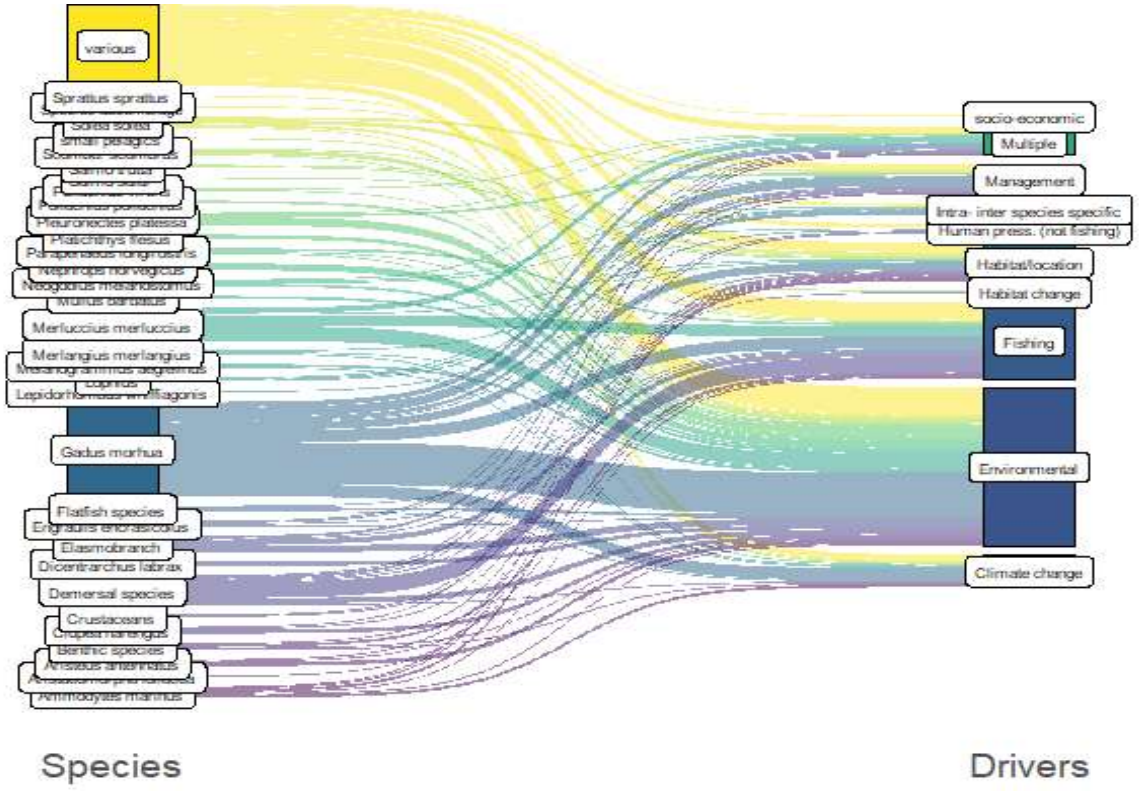


Figure 4.7. Sankey diagram revealing the association between Drivers/Pressures and Species studied.(Width of the arrows is proportional to the flow rate)

Temporal representation

The bulk of papers reatined were produced after 2005; only 10% of the papers were before 2005. No paper before 1994 was retrieved (Fig. 4.8). The temporal development in the number of studies was similar in all regions (Fig. 4.8).

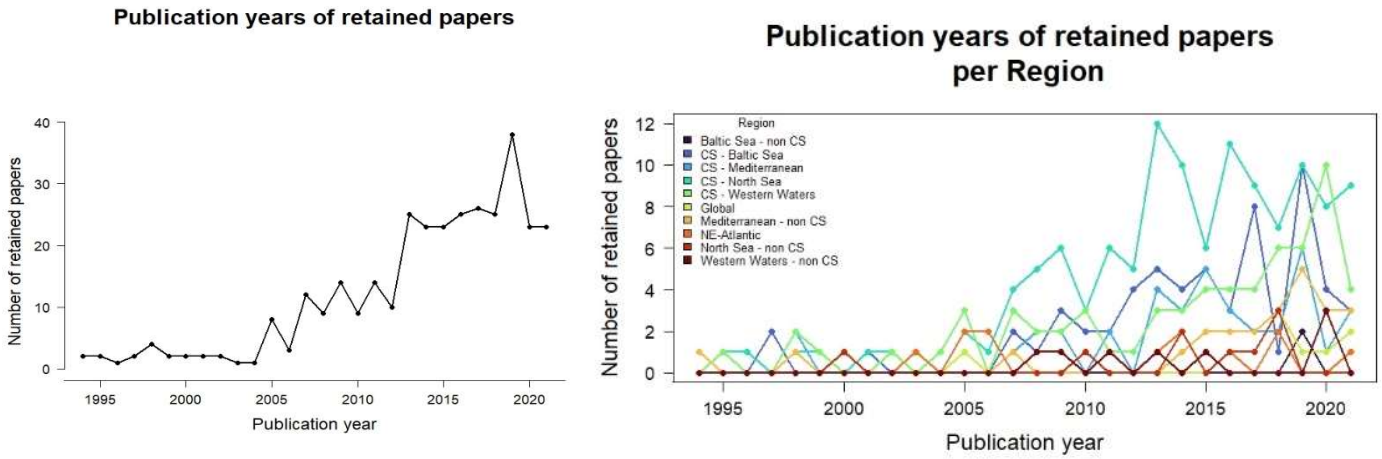


Figure 4.8 Paper allocation per publication year in total (left) and per region (right).

Case Study and Spatial Representation

North Sea Case study areas were the focus of most studies (112 out of 331), followed by the Western waters CS (59) and the Baltic Sea CS (54). Mediterranean CS region scored a lower number of papers (37), however combining them with Mediterranean studies outside the CS region (Mediterranean – non CS = 22), it ranked second after the North Sea (Fig. 4.9).

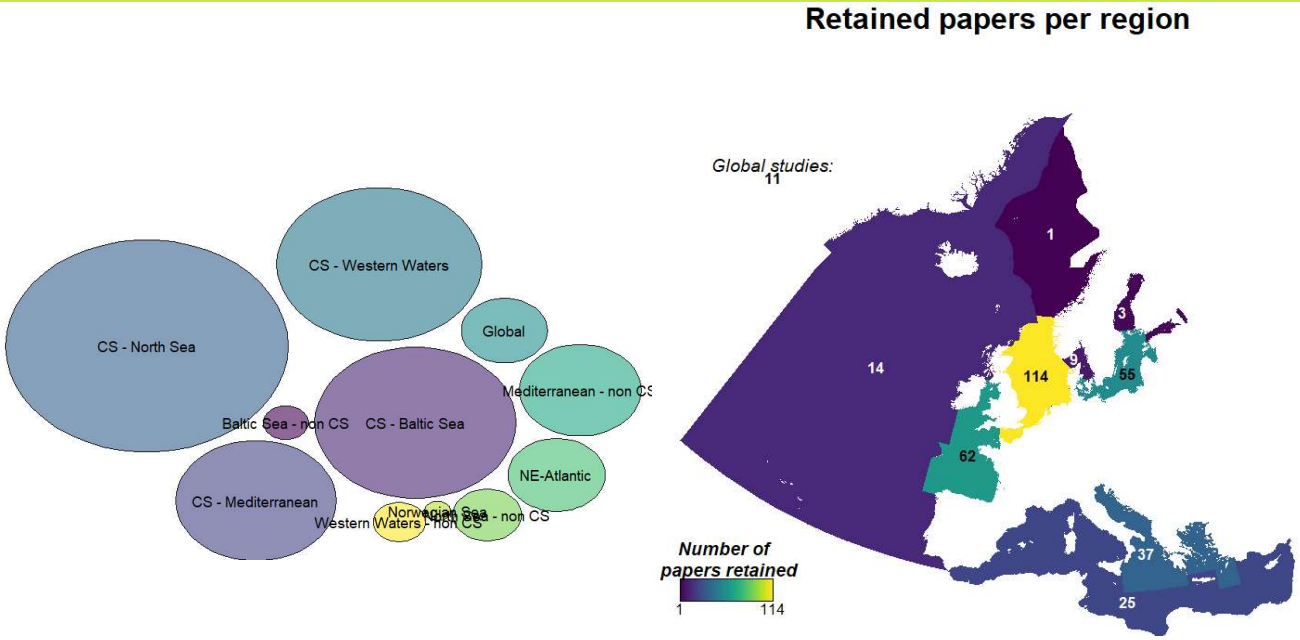


Figure 4.9 Allocation of studies based on study Region (left: circle vertices; right: overlayed on map)

Species representation

Cod dominated the WP5 related studies (n=74). Studies linked to more than one species were also very common (66). Demersal species assemblages, hake and elasmobranchs followed in ranking order. (Fig. 4.10).

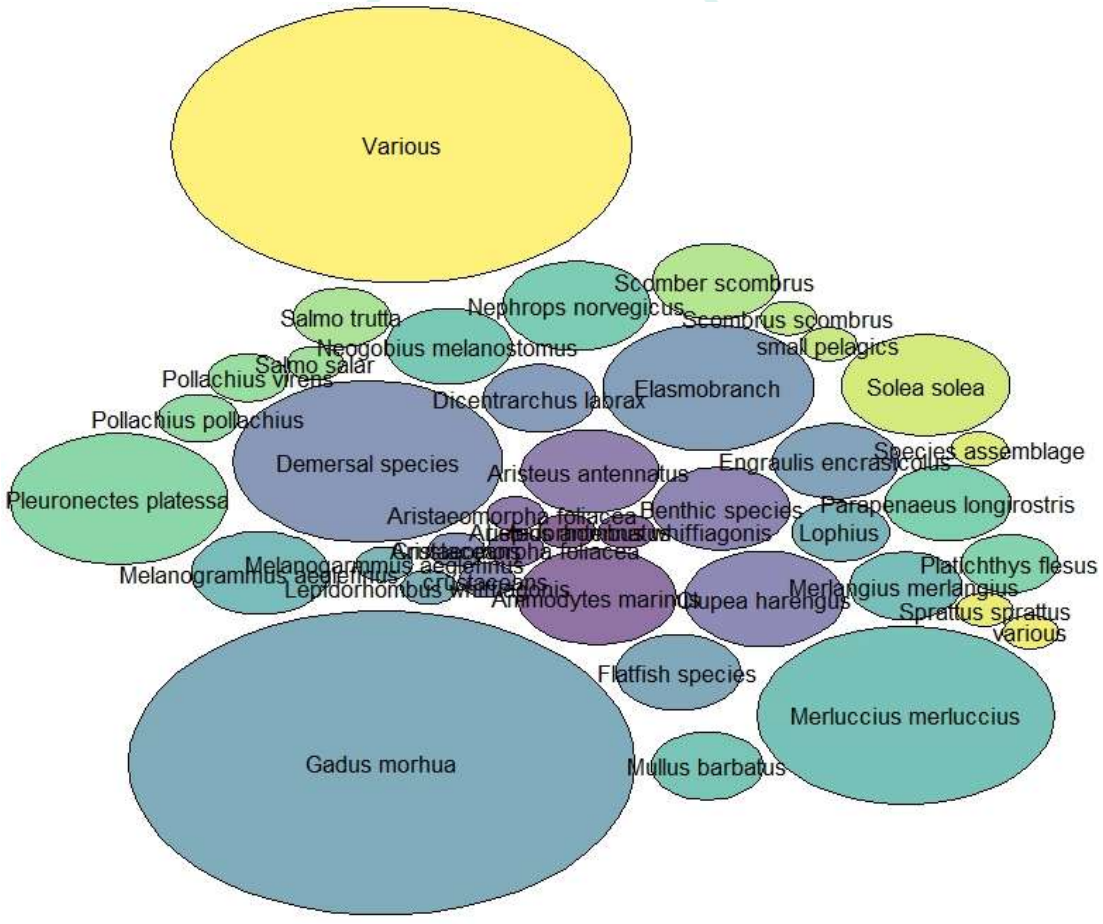


Figure 4.10 Allocation of studies based on target species/stocks studied

Driver/Pressure representation

Most influential Driver/Pressure on fish stocks and fisheries were the Environmental parameters (n=122) ranking higher than Fishing (n=59). The effect of environment was manifested in numerous forms: temperature, salinity, ocean productivity, etc. Studies on climate change were much less frequent (n=24); only studies with multi-decadal time series were deemed appropriate for assessing global warming (Fig. 4.11). However, some studies investigating explicit environmental drivers, may do so in the context of climate change, without making explicit claims to the effects of climate change, generally.

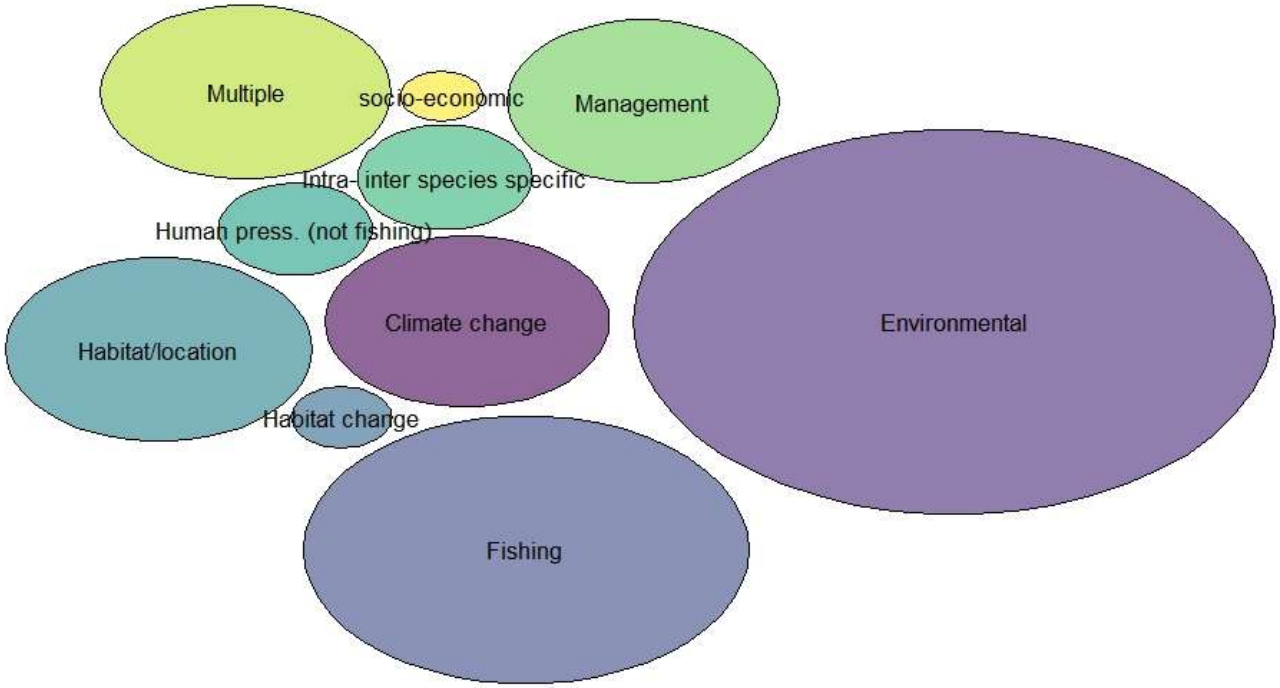


Figure 4.11 Allocation of studies based on drivers/Pressures investigated

Habitat representation

Demersal and bentho-pelagic habitats accounted for 2/3 of the habitats studied (153 and 46 respectively). On the other hand, few papers addressed coastal waters and only 2 papers dealt with the open sea (Fig. 4.12).

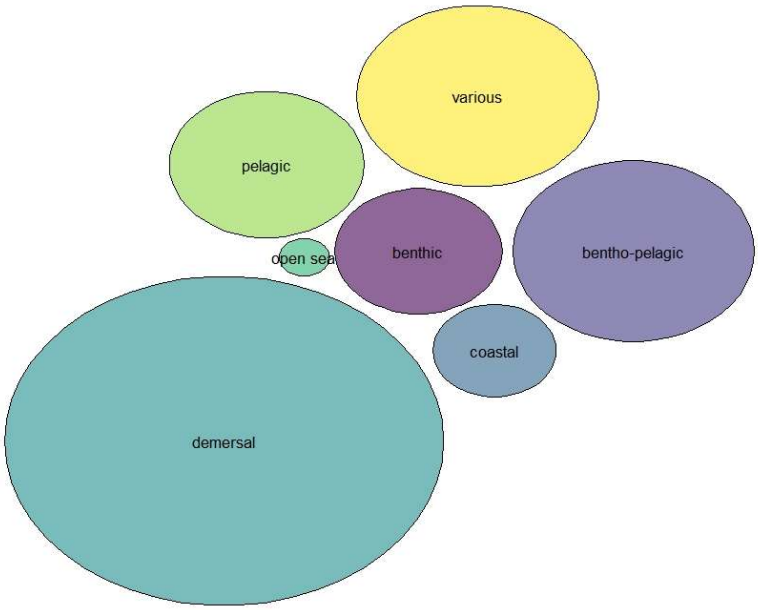


Figure 4.12. Allocation of studies based on habitats investigated

Gear/fisheries representation

Demersal trawls dominated the studies reviewed (63% of all studies, Figure 4.13). A sizeable 17% of studies dealt with more than one gear ('multiple'). Few studies investigated the drivers and impacts of changes in spatial distribution of fisheries other than demersal trawlers.

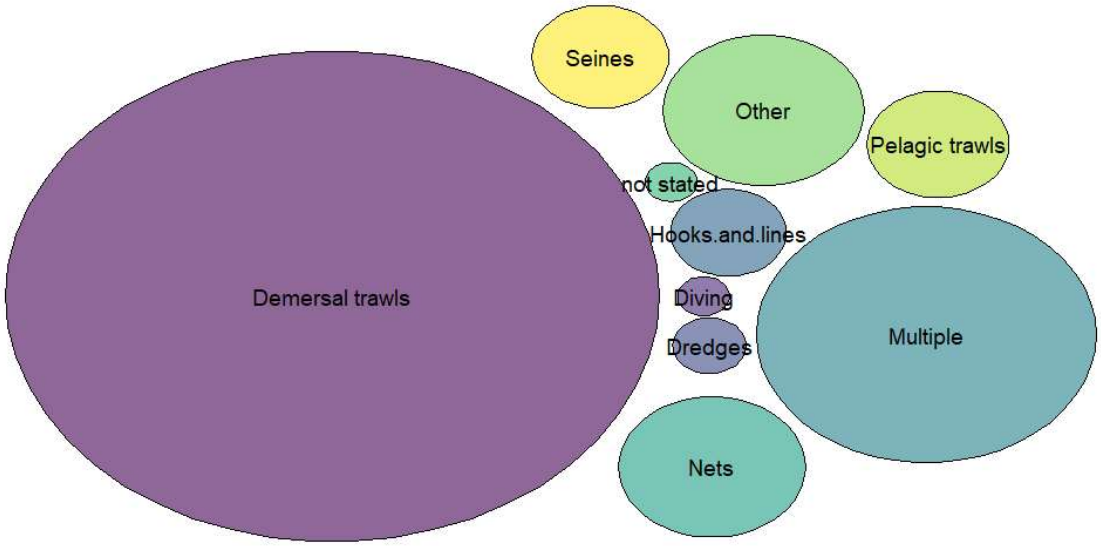


Figure 4.13 Allocation of studies based on Gears/Fisheries investigated.

Drivers/Pressures studies by species/stocks

For major commercial species like cod, hake, Nephrops and flatfish, environmental drivers were most frequently investigated in studies of their distribution. Only for elasmobranchs, fishing was studied as frequently as the environment (Fig. 4.14-4.15).

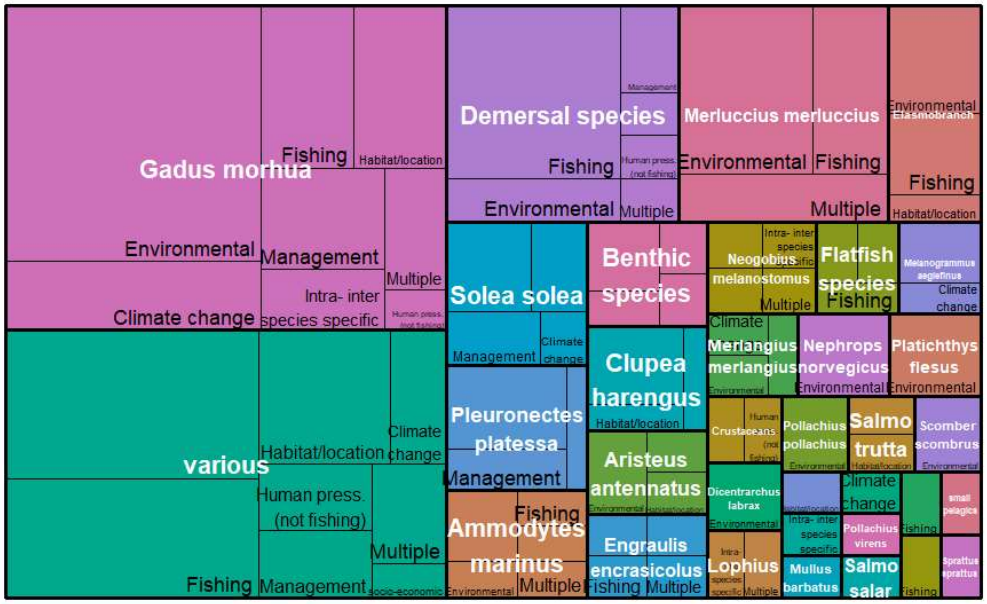


Figure 4.14 Hierarchical view of Drivers/Pressures over target species/stocks through a treemap plot

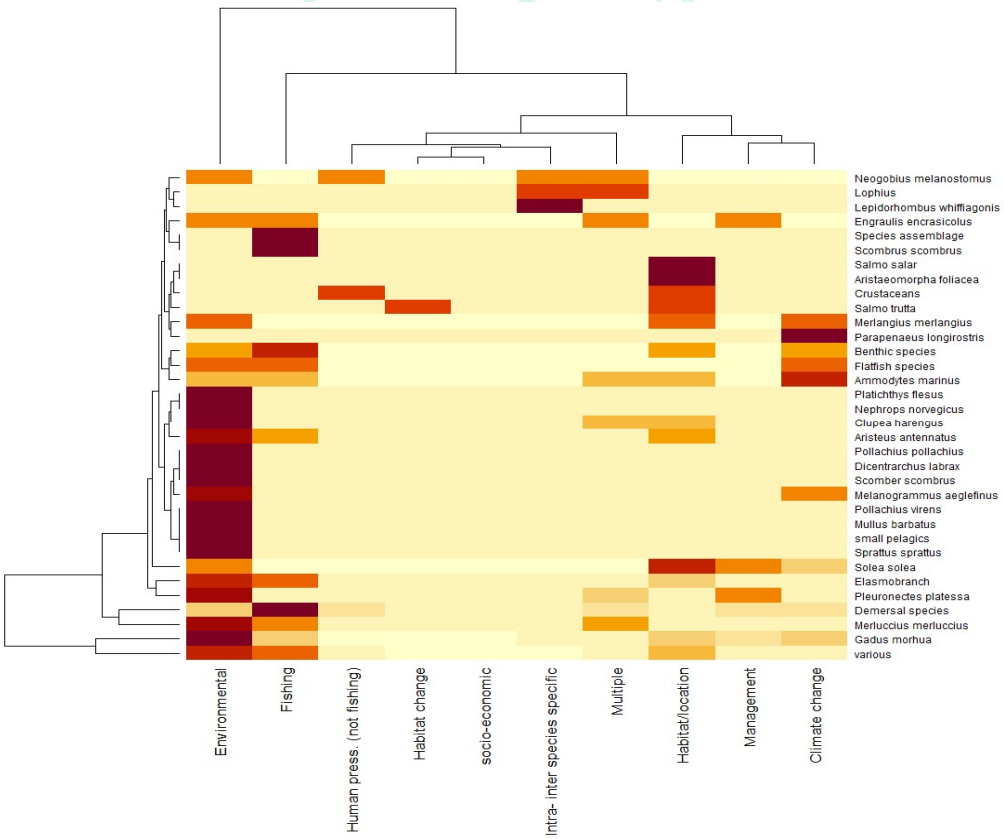


Figure 4.15 Heatmap plot depicting the magnitude of association among Drivers/Pressures and Target species

Drivers/pressures studied by habitats

Environmental variables were the most studied driver of species in demersal, bentho-pelagic and pelagic habitats, followed by fishing. For the benthic habitats, fishing studied as often as the environment (Figs 4.17 – 4.18).

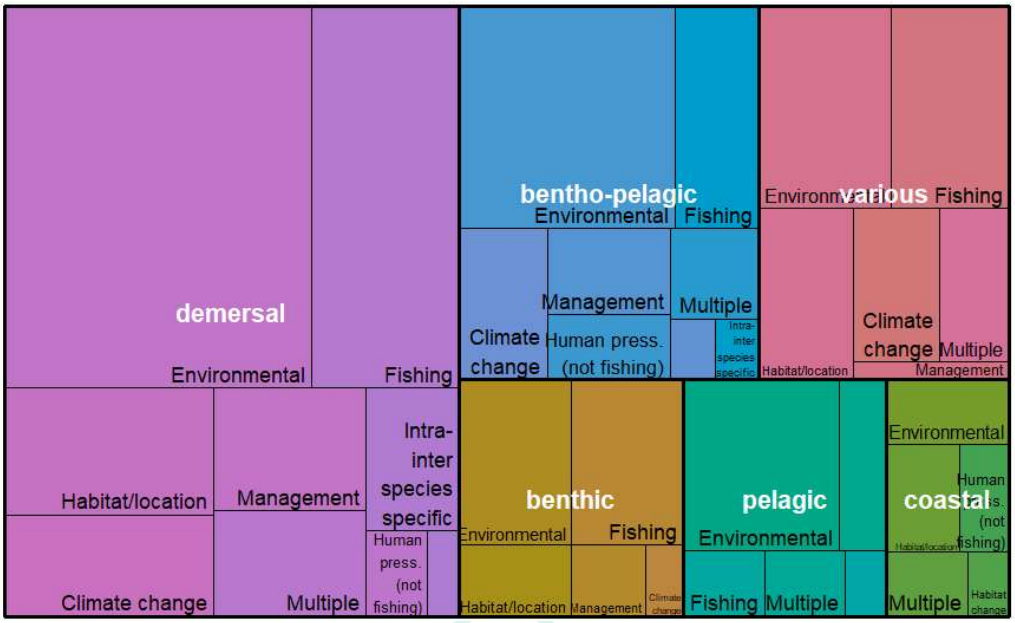


Figure 4.16 Hierarchical view of Drivers/Pressures over habitats through a treemap plot

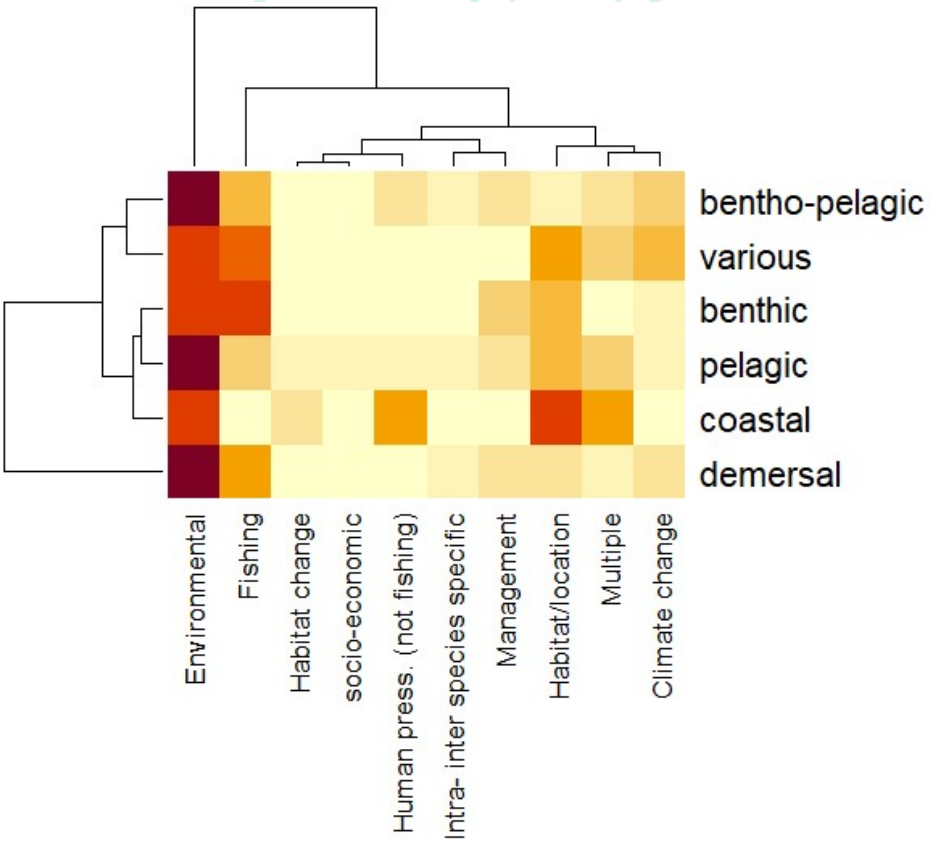


Figure 4.17 Heatmap plot depicting the magnitude of association among Drivers/Pressures and habitats.

Drivers/pressures studied in different regions

Environmental drivers were the most frequently studied driver or pressure in all regions. The exception was the group of studies that focused on a wider global scale, where Climate change and fishing prevailed. (Figs. 4.19-4.20)

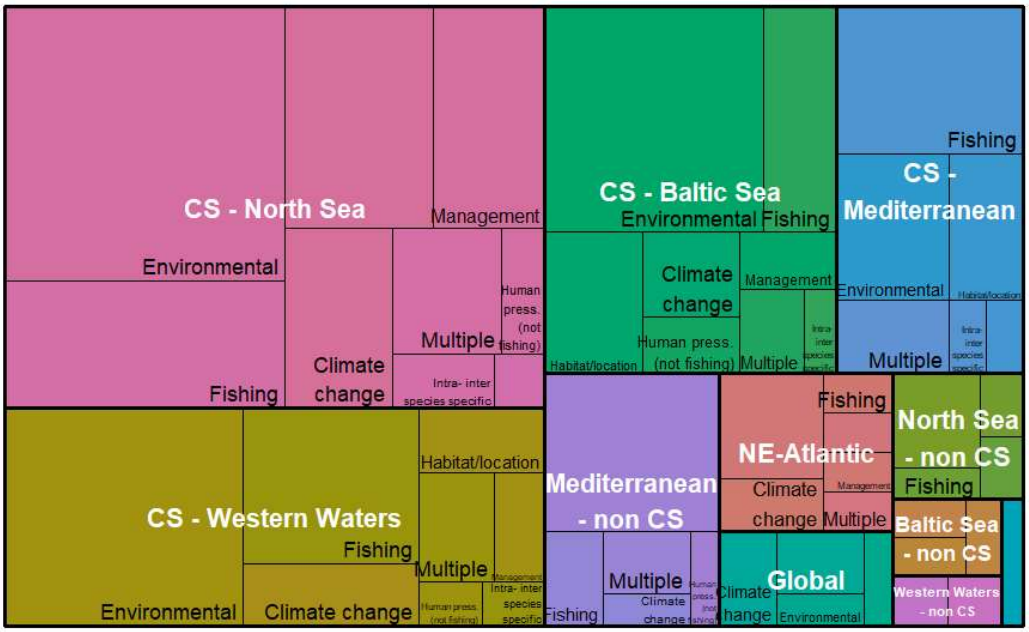


Figure 4.18 Hierarchical view of Drivers/Pressures over Regions through a treemap plot

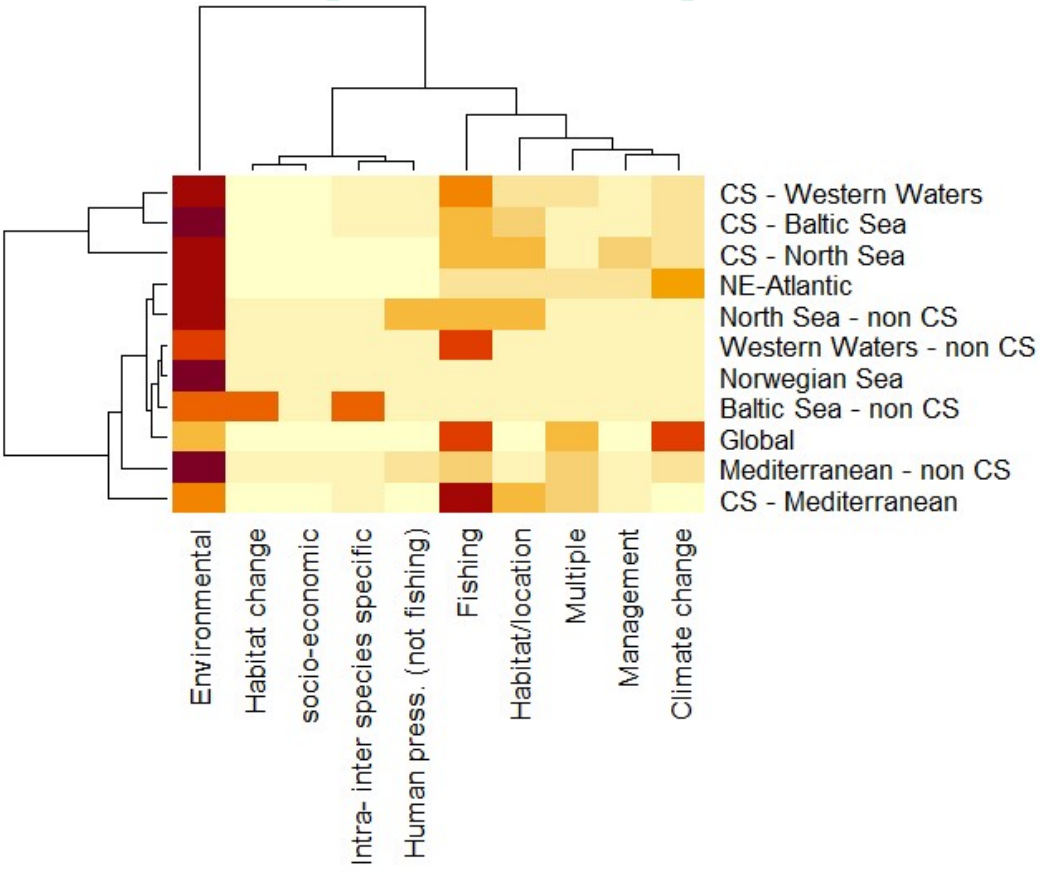


Figure 4.19. Heatmap plot depicting the magnitude of association among Drivers/Pressures and Regions

Drivers/Pressures studied for different fisheries

The environmental variables and the 'success' of fishing, were the most significant drivers of spatial distribution of demersal trawlers. Interestingly, for netters environment, management and habitat/location were equally frequently studied (Figs 4.20 – 4.21).

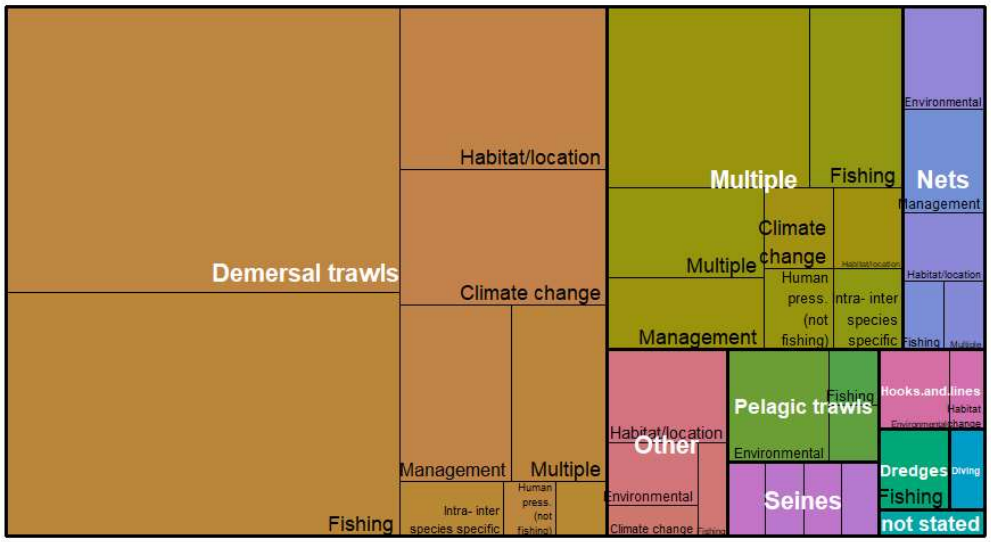


Figure 4 20 Hierarchical view of Drivers/Pressures over Gears through a treemap plot

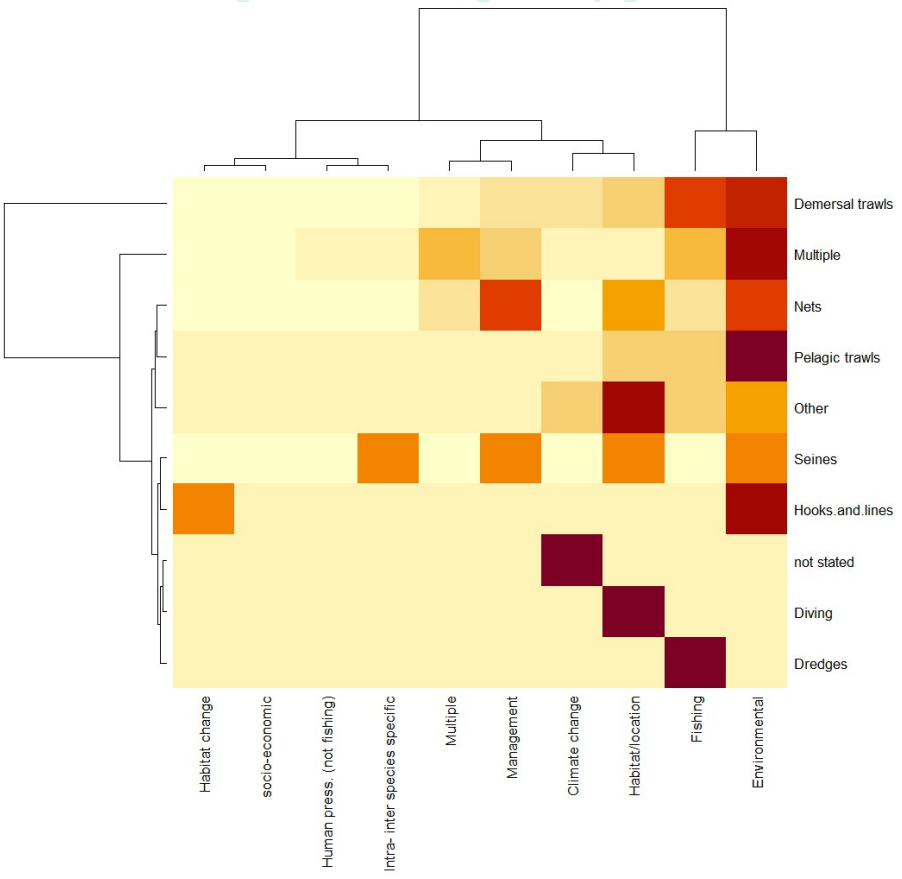


Figure 4.21 Heatmap plot depicting the magnitude of association among Drivers/Pressures and Gears

Target species/stocks studied in different regions

Cod, Nephrops and flatfish species were the main stocks studied in the North Sea, followed by the Baltic Sea. Sandeels were exclusively investigated in the North Sea, in and round goby was present only in Baltic Sea studies. Hake was the only species almost equally represented in all regions, while elasmobranchs studies originated almost exclusively from the Western Waters region (Fig. 4.22-4.23).

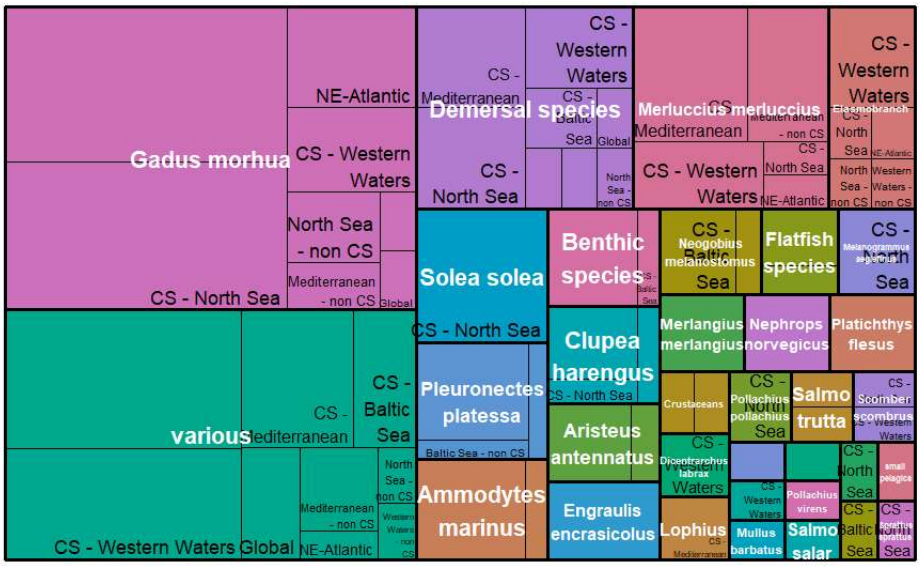


Figure 4.22 Hierarchical view of target species/stocks over Region through a treemap plot

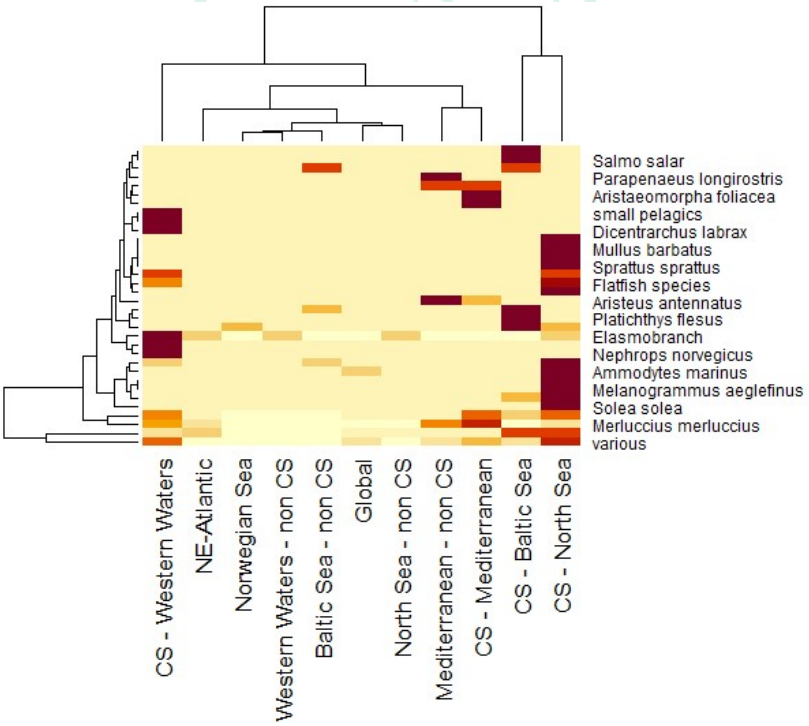


Figure 4.23. Heatmap plot depicting the magnitude of association among Target species/stocks and Regions

Fisheries/gears studied in different regions

Demersal trawl studies were frequent in all investigated regions, while pelagic trawlers were limited to the North Sea and Western waters. Note that the lack of papers on pelagic trawlers in the Mediterranean is likely due to the exclusion of pelagic species from the search criteria. Net studies were predominantly from the Baltic Sea (Fig. 4.24-4.25).

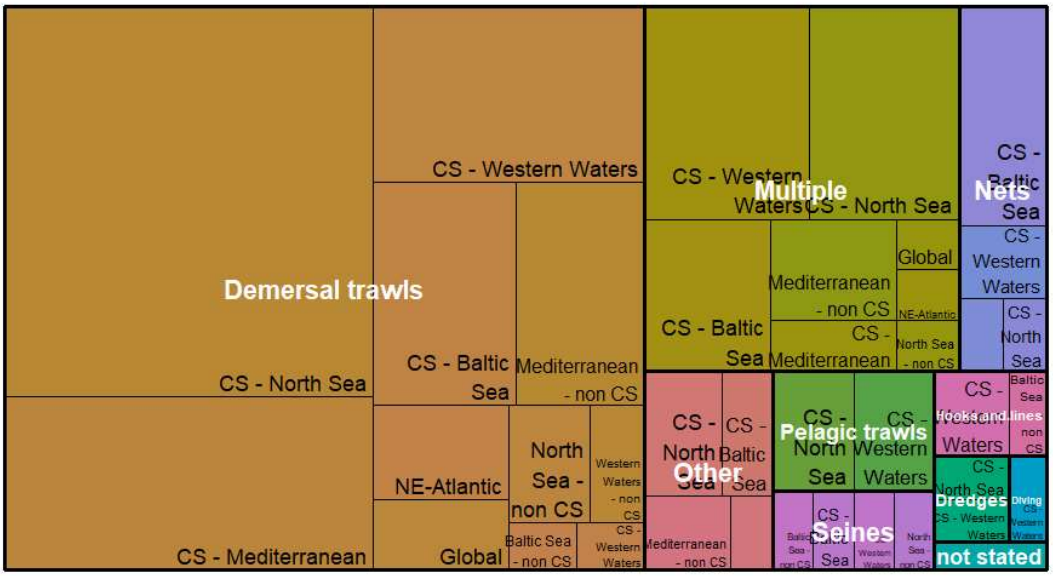


Figure 4.24 Hierarchical view of Gears over Regions through a treemap plot

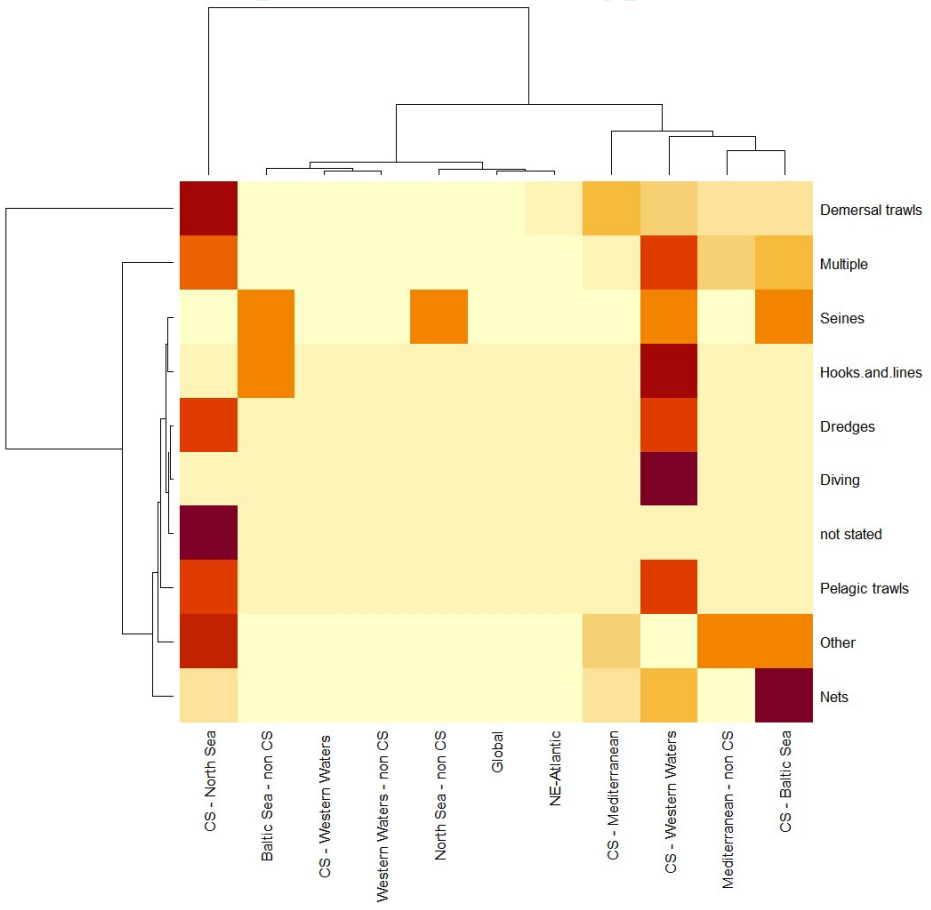


Figure 4.25. Heatmap plot depicting the magnitude of association among Gears and Regions

Spatial and temporal resolution and coverage of the studies

The vast majority of studies surveyed wide areas of more than 100 km (86%, table 4.2). The resolution at which data were collected was quite diverse; most studies sampled at distances > 5km (table 4.3, Fig. 4.26). More than half of the studies (58%) spanned periods over a decade (table 4.4, Fig. 4.26).

Table 4.2. Allocation of papers by their spatial scale extent.

Spatial scale (m)	% of studies
>100,000	86.1
50,000-100,000	6.7
10,000-50,000	4.6
5,000-10,000	1.2
1,000-5,000	0.9
100-500	0.3

Table 4.3 Allocation of papers by their spatial resolution of data collection.

Spatial resolution (m)	% of studies
>100,000	10.4
50,000-100,000	20.8
10,000-50,000	23.9
5,000-10,000	17.9
1,000-5,000	17.6
500-1,000	4.5
100-500	3.1
50-100	0.7
10-50	0.7
0-5	0.3

Table 4.4. Allocation of papers by their temporal scale

Temporal scale	% of studies
multidecadal	38.3
decade	20.4
five year	16.7
two year	9.9
year	8.6
quarter	2.2
month	1.2
two week	1.2
half year	0.9
two month	0.6

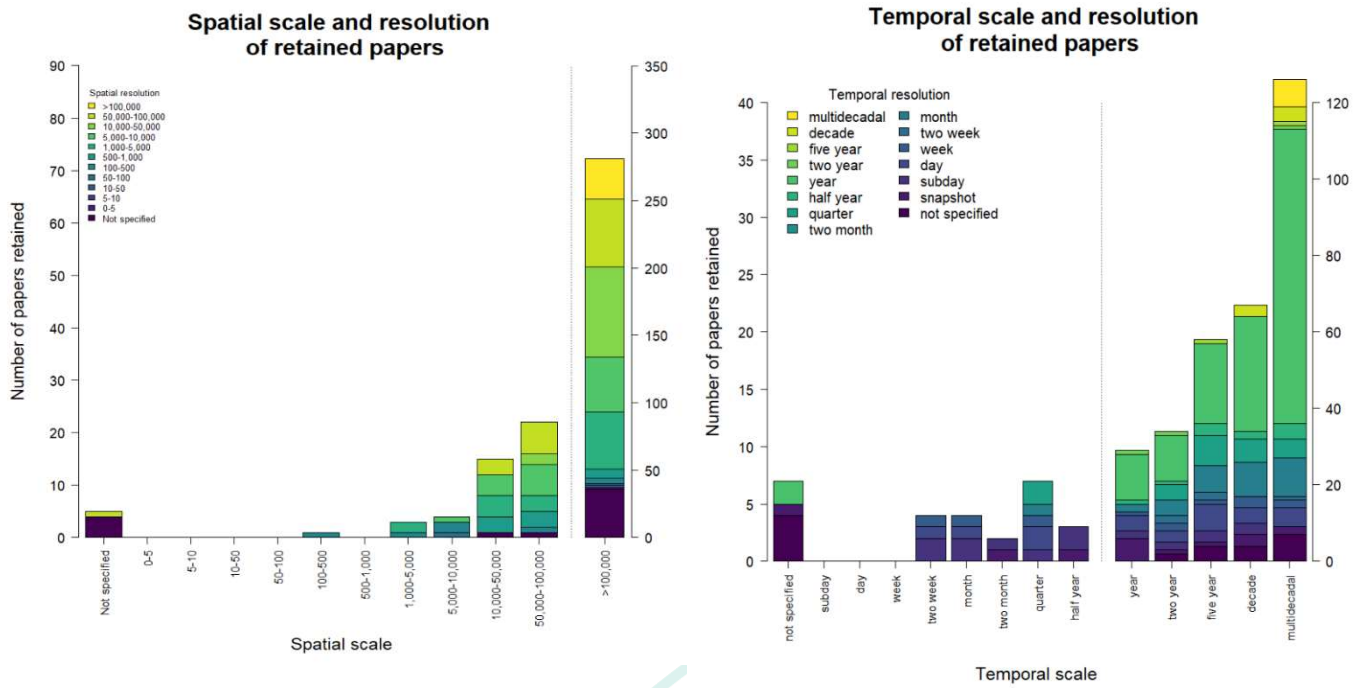


Figure 4.26. Allocation of studies based on spatial scale (left) and temporal (right) extent and resolution. Note the difference in y-axis scale of studies with a scale of more than 100 000 m and a temporal scale greater than a year.

Quality of studies

In terms of spatial coverage/resolution, 82% of the studies were deemed as having a 'sufficient coverage/resolution to support claims'; 7% were assessed as insufficient to capture the processes. Temporal coverage was sufficient to match the claims made in 81% of the studies; only 4% were found to be insufficient. 70% of the research papers were considered suitable for the data with their outputs being interpreted correctly. Interestingly, a sizeable 25% of the studies inspired doubts about their ability to disentangle multiple effects.

Investigating the quality of methods by region, one can deduce that the papers from the Mediterranean and studies across multiple regions (e.g. Baltic Sea & North Sea) suffered from low scores (see Fig. 4.27). The quality of methods by species/stocks revealed that doubts were associated with pelagic species such as anchovy and sprat; salmon and plaice studies were also assessed of medium quality (see Fig. 4.28).

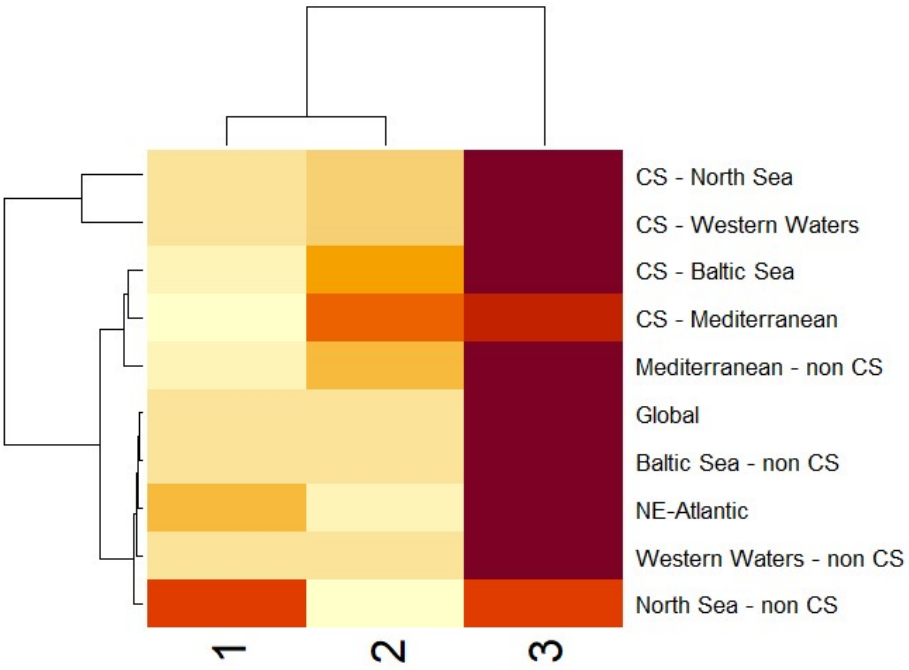


Figure 4.27 Heatmap plot depicting the magnitude of the quality of method applied over the various regions. (Quality 1: not suitable; 2: doubtful; 3: suitable)

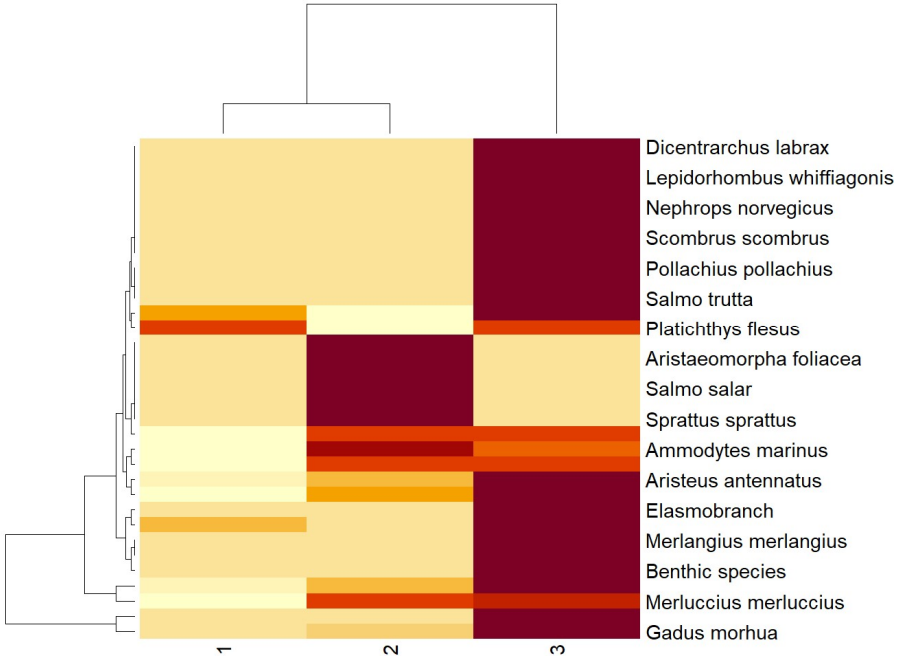


Figure 4.28. Heatmap plot depicting the magnitude of the quality of method applied over the various species studied.(Quality 1: not suitable; 2: doubtful; 3: suitable)

4.6 Subject coverage

The papers included were allocated to four broad subjects (Tasks):

- Drivers/impacts/changes in/on fished stocks affecting their distribution (Task 5.2)
- Drivers/impacts/changes in/on fisheries affecting their distribution (Task 5.3)
- Changes in productivity related to spatial availability/suitability/habitat extent (e.g through recruitment, growth, natural mortality, maturity, fisheries yield) (Task 5.4)
- Impact of spatial management options/MPAs/NTZ/FRAs on fish & fisheries distribution (Task 5.5)

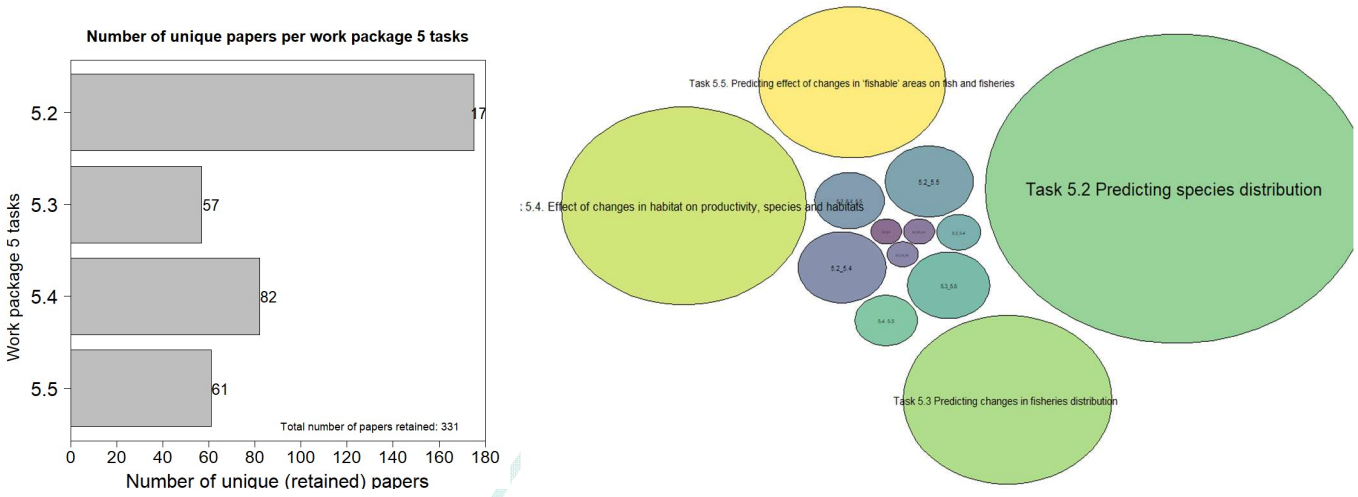


Figure 4.29. Allocation of studies based on relevance to WP5 tasks (left: unique papers per task; right: papers allocated to one or more tasks)

Studies on **species distribution (Task 5.2)** were the most abundant in the retained papers, with cod, hake and demersal species having the largest share. The majority of species had rarely over 3 studies (Figure 4.29).

On the other hand, drivers behind **distribution of fishing footprint (Task 5.3)** were quite few and for certain regions (e.g. Mediterranean) information on gears other than demersal trawls, is limited. This is probably driven by the scoping driven search terms, where the focus was solely on demersal fisheries.

Knowledge on **changes in productivity related to spatial availability/suitability/habitat extent (Task 5.4)** was available from the North Sea, Baltic Sea and NE Atlantic. Very few studies investigated the topic in the Mediterranean and Western waters. Furthermore, only 6 species were included in these investigations; the relevant studies focused mostly on species assemblages (e.g. elasmobranchs, demersal fish, flatfish).

Information on the **impact of spatial management options on fish/fisheries (Task 5.5)** was mainly from the North Sea region. For the remaining areas information was scarce or absent. The distribution of just 5 species was linked to spatial management.

A visual depiction of the Information flow among the different topics and the aforementioned tasks is given in the following Sankey diagrams (Figs 4.30-4.31).

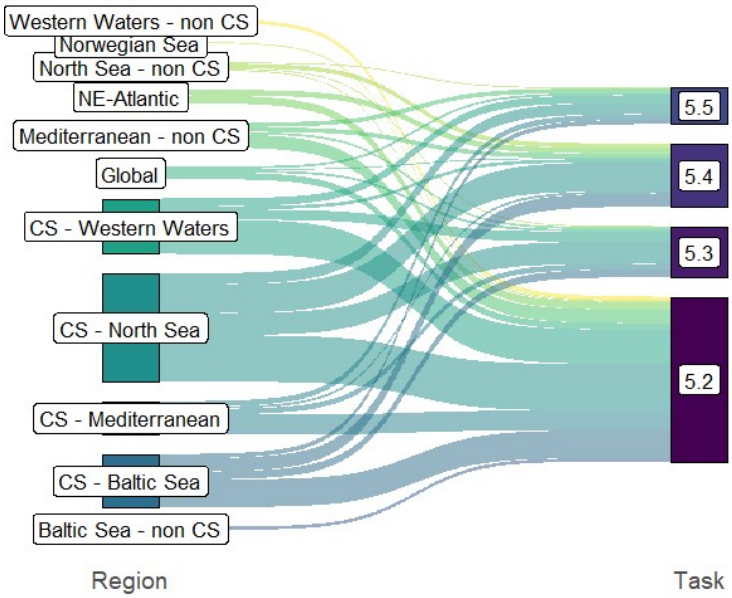


Figure 4.30. Sankey diagram revealing the flow of information between Tasks and Regions studied.(Width of the arrows is proportional to the flow rate)

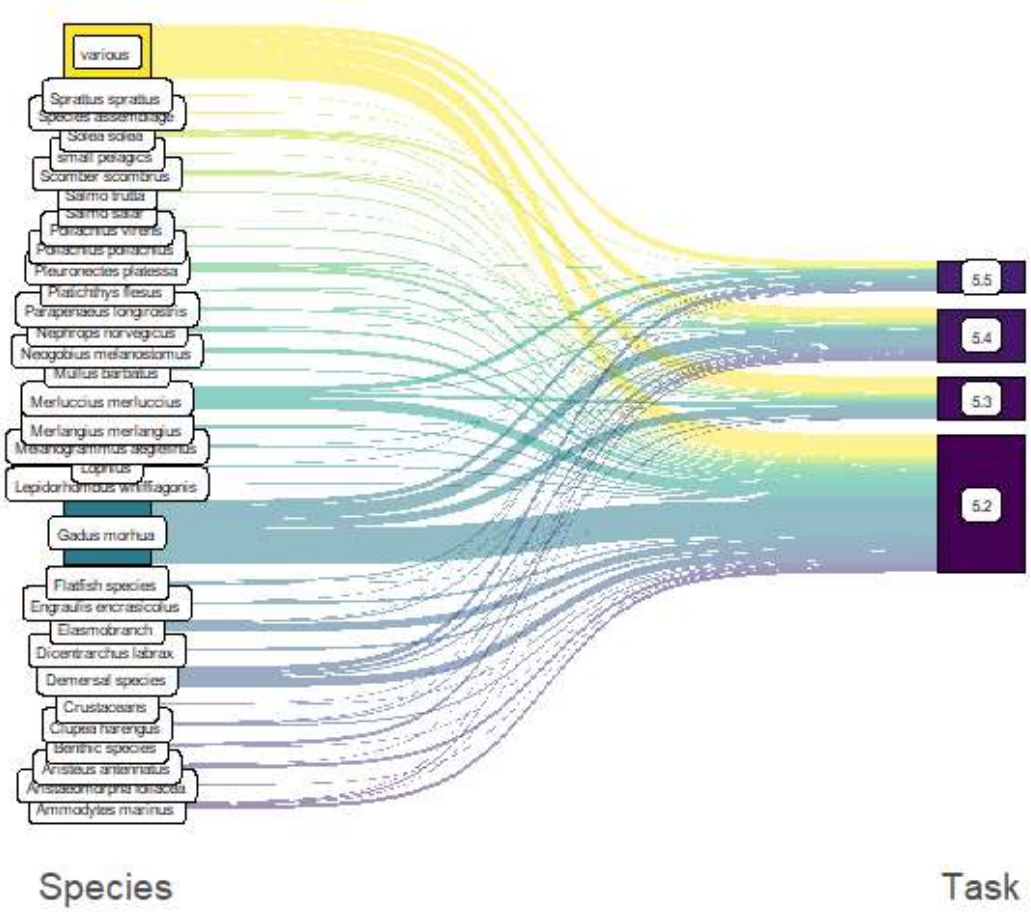


Figure 4.31 Sankey diagram revealing the flow of information between Tasks and Species studied. (Width of the arrows is proportional to the flow rate)

5. Comparison of knowledge identified by stakeholders and systematic review

The words identified by the stakeholders consulted focused on factors causing changes to the distribution of commercial fish/shellfish (climate change, MPAs, species interactions, pollution, habitats and invasive species) and fisheries (windfarms, MPAs, Marine spatial planning) as well as the other human impacts with spatial characteristics (other human activities). Among these issues, the effects of environmental conditions on the distribution of fish were particularly well represented in the reviewed material with environment identified as a driver in 122 papers and species distribution (task 5.2) as a topic in 170. In contrast, papers on factors determining the distribution of fisheries were the least frequently encountered, and when available were almost exclusively on trawl fishing in the North Sea. Knowledge on the effect of area restrictions on fish and fisheries were largely restricted to Western waters and the North Sea. This makes the current knowledge of the effect of spatial management measures on fisheries insufficient outside a single gear in the North Sea. While knowledge on the effects of habitats on species did exist, this was restricted to the Baltic Sea and North Sea and papers addressing this outside these areas were close to non-existent. This points to these areas as important for future work in SEAwise.

The database of knowledge produced by this review, is available internally for the project here.

6. References

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Kraufvelin, P., Pekcan-Hekim, Z., Bergström, U., Florin, A.-B., Lehikoinen, A., Mattila, J., … Olsson, J. (2018). Essential coastal habitats for fish in the Baltic Sea. Estuarine, Coastal and Shelf Science, 204, 14–30. https://doi.org/10.1016/j.ecss.2018.02.014

Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation BMJ 2015; 349 :g7647 https://doi.org/10.1136/bmj.g7647

7. Document Information

EU Project	No 862428		Acronym	SEAwise
Full Title	Shaping ecosystem based fisheries management			
Project website	https://www.seawiseproject.org/			
Deliverable	N°	D5.1	Title	Report on key drivers and impacts of changes in spatial distribution of fisheries and fished stocks
Work Package	N°	5	Title	Spatial management impacts on ecological systems and fisheries
Work Package Leader	Dimitrios Damalas, HCMR			
Work Participants	D. Damalas HCMR, E.J. Brown DTU Aqua, F. Bastardie DTU Aqua, Anna Rindorf DTU Aqua, Nis Sand Jacobsen DTU Aqua, M.S. Rolland IFREMER, M. Woillez IFREMER, Y. Vermard IFREMER, G. Chust AZTI, J. Paradinas AZTI, Dorleta Garcia AZTI, S. Uhlmann MI, L. Vaughan MI, D. Reid MI, W. Zupa COISPA, A. Pierucci COISPA, M.T. Spedicato COISPA, C. Vassilopoulou HCMR, M. Brodersen HCMR, N. Fotiadis HCMR, I.Maina HCMR, N. Probst TI-SF, J. Letschert TI-SF, V. Stelzenmueller TI-SF, P. Bonsu TI-SF, A. Kempf TI-SF, M.Taylor TI-SF, J. Depestele EV-ILVO, K. Sys EV-ILVO, K. van de Wolfshaar WR, M. Kraan WR, G. Lambert CEFAS, S. Eliasen CBG – AAU, P. Melia POLIMI, J.J. Poos WU			
Lead Beneficiary	HCMR -6			
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Version log			
Issue Date	Revision N°	Author	Change
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