GEOGRAPHIC INFORMATION SYSTEM IN FISHERIES

Commercial Fisheries As a Component of Marine Spatial Planning in The North Sea: Using GIS to Explore Future Developments

Masters Dissertation

By

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DECLARATION

I, Tugba Kaya, confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (e.g. ideas, equations, figures, text, tables, programmes) are properly acknowledged at the point of their use. A full list of references employed has been included.

Signed……………………………………..

Date: 15/08/2018

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Abstract

Geographic Information System in fisheries studies has been increasing significantly over the last two decades. It is widely accepted that produced maps can be much more understandable thousands of than written words. GIS contributes to easy understanding of many subject areas. Fisheries science is undoubtfully one of the most important commercial areas all over the world. Commercially important species locations are being determined by GIS. Definitely, geo-technologies such as geographic information systems are contributing to improved marine resource management and are signifying the technical possibility of inclusive marine spatial planning (MSP).

The North Sea is one of the most important marine regions in the world. The North Sea is located among the European Continent and 8 different countries have a boundary with it. The main commercial activities in the North Sea are offshore energy, transportation, recreation, gas and oil exploitation, dumping, military use and gravel extraction and very significant for commercially important fisheries.

In this study The North Sea's commercially important fisheries locations and fisheries species are determined by using GIS, ArcMap programme. 21 different commercially important fisheries species abundance catch numbers are determined in the North Sea in 2017. By applying GIS, particular recommendations for improving this technology were presented. The produced maps related to the subject are suitable and easy to understand to explore the future developments for decision making in commercially important fisheries locations.

Glossary of Abbreviations

DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
EU	Europe Union
GIS	Geographic Information System
ICES	International Council for the Exploration of the Sea
IUCN	International Union for the Conservation of Nature
MaRS	Marine Resource System
MPAs	Marine Protected Areas
MSP	Marine Spatial Planning
NSRAC	North Sea Regional Advisory Council
NOINP	Number of individuals in the sub-sample is specified
NGO	Non-governmental Organization
SAC	Special Areas of Conservation
TIGER	Topologically Integrated Geographic Encoding & Referencing
USGS	The United States Geological Survey
VMS	Vessel Monitoring System
WGS	World Geodetic System

Chapter 1

1. Introduction

Almost 70% of the world is made up of aquatic ecosystems. Aquatic ecosystems are an indispensable element for people. There are some amenities including by aquatic ecosystems, for instance; offshore energy, transportation, recreation, fisheries, gas and oil exploitation, dumping, military use and gravel extraction (Fock, 2007). Of these possibilities, the fisheries sector has a particularly large commercial scale because there are nearly 4 times the number of living aquatic species than in the terrestrial environment. These aquatic creatures constitute the source of food for many live species in the world.

Spatial planning is an important implement for dealing with the use of land in relation to many portions of the flora and fauna (Hall, 2002). Marine Spatial Planning (MSP) is very necessary for ‘sectoral zoning’ for example; shipping channels, military security zones, disposal areas, aquaculture sites, concession areas for mineral extractions and most recently marine protected areas (MPA) (Young *et al*; 2007). Marine Spatial Planning (MSP) contributes a combined procedure that can deal efficiently with; spatial and temporal overlap of human activities and goals, causing conflict (user-user and user-environment), conflicts in coastal and marine environments, lack of connection between various responsible authorities for individual activities or for protection and management the whole world as a whole, lack of connectivity between offshore activities and resources usage and coastal communities dependent on them, lack of biologically and ecologically sensitive protection of sea areas and lack of investment for maritime developers to engage with ocean resources users (CoastNET, 2003).

The North Sea is one of the most important and very crowded marine areas in the world. Seven countries border the North Sea (UK, France, Belgium, Netherlands, Germany, Denmark and Norway) (Halpern *et al*; 2008). Moreover, The North Sea is very plentiful marine area for fisheries because of the water quality (Jay 2012a). Exploitation of the North Sea fisheries has changed considerably in recent decades due to widespread urbanization, technological advances and increases in global populations (Aswani and Lourer, 2006). Anthropogenic impacts especially overfishing is very serious problem in fisheries, it causes habitat loss, pollution and large fluctuations in environmental conditions (Booth and Wood 2004, Battista and Monaco 2004). As a result, these anthropogenic and natural disturbances cause significant increase fisheries problems and negatively impact on fisheries managers (Zanden *et al*. 2007).

Geographic Information System (GIS) in fisheries is very good and effective opportunity for fisheries management decision makers. GIS is also having significantly important data on biological, socio-economic and ecological benefits resulting from better understanding of fisheries. Maps are usually using for identifying fishing habitat, designatinge marine protected areas or determininge fishing hotspots locations. Moreover, the majority previous work has focussed on the use of catch and effort knowledge for commercial fishermen’s reports. This contributes more ways to maintain the efficient fishery statistics (Riolo 2006).

In this report, the aim is to determine the commercially important fisheries locations, species to enable production of strategic planned maps in the North Sea using ArcMap software programme and make some contributions for future decisions related to Marine Spatial Planning.

1.1. Marine Spatial Planning (MSP)

Marine Spatial Planning (MSP) is defined a three-dimensional approach, including ecological, social and economic objectives. Social objectives usually depend on the political processes (Douvere and Ehler 2009:78).

Already determined marine protected areas (MPAs) are useful for marine spatial planning (MSP) (Jay *et al.* 2012c). Two ecosystem perspective holistic and integrated approaches are, logical extensions of marine protected areas (Kidd *et al*. 2011).

Marine Spatial Planning's main vision targeted clean, safe, healthy, productive and attractive marine and coastal ecology which supports plentiful and wealthy biodiversity, under the control management. MSP's also has the following guiding principles; sustainable developments, multiple use of marine space, cooperatively working with stakeholders and ecosystems approach to the human activities management, adaptation for climate change and mitigating the circumstances.

The main aims of the marine spatial planning are;

• Create a consistent strategic vision, goals and policies for sustainable development, including protection, and, where appropriate, to improve the health of the Plan area.

• Informing and directing the regulation, management and use of the area where the plan is applied

• Providing reliable and robust information to support plan policies

• Identifying all maritime uses and activities and ensuring that they are in the most appropriate and least vulnerable areas

• To minimize conflicts of interest and encourage the harmonized use

• Provide clarity and guidance on how marine users will be managed and organized, and where the decisions will be taken.

• Identify sustainable development goals that respect environmental boundaries to ensure healthy and productive seas in the future

• Develop a policy framework to support integrated maritime and terrestrial planning and development

The diagram below, Figure 1-1 also indicates the Marine Spatial Planning's goals.

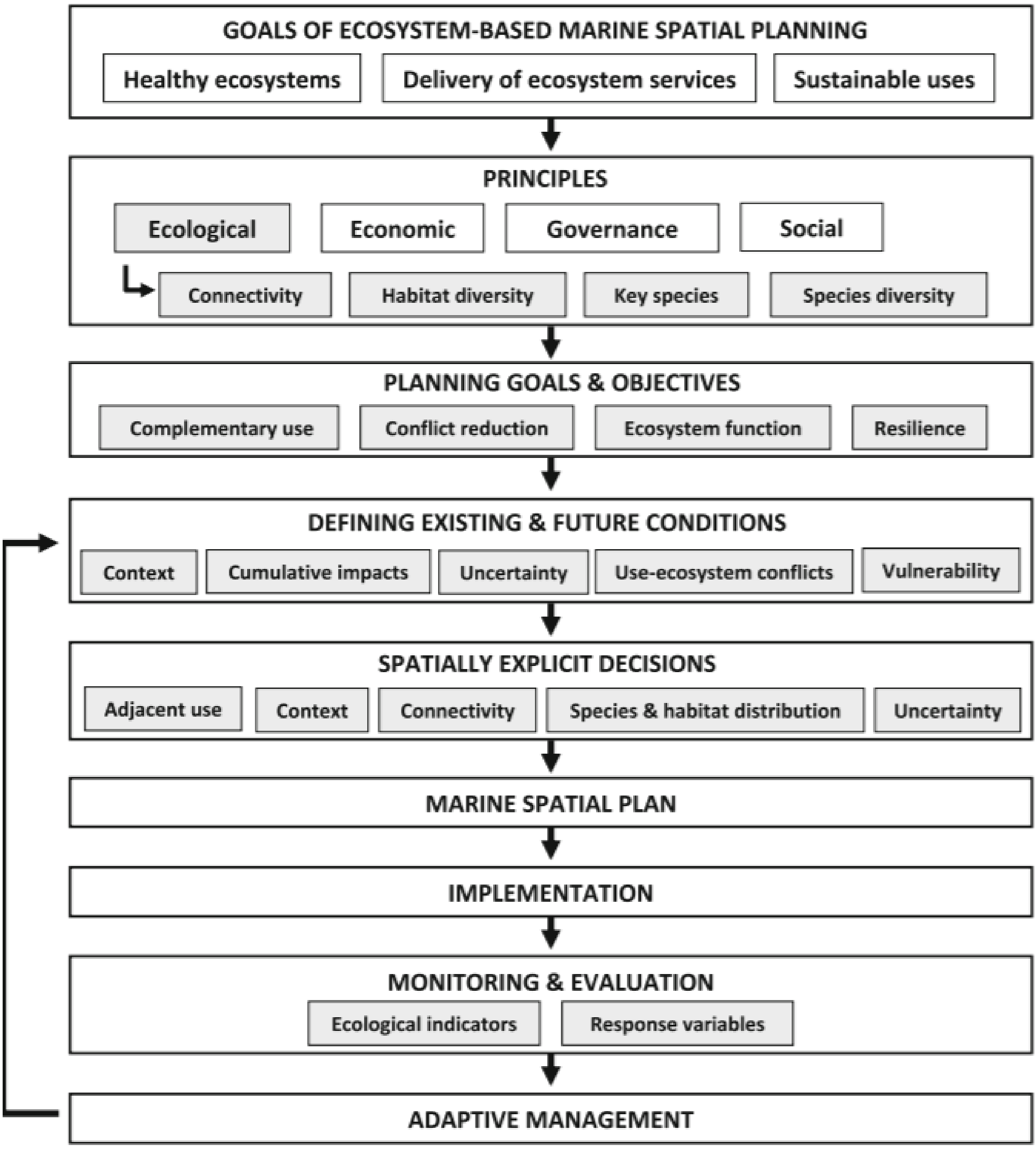

Figure 1- 1: MSP (Marine spatial planning) targets demonstrated in each box (Ehler & Douvere, 2009)

1.2. Commercial Fisheries in the North Sea

The North Sea is located in the northern hemisphere, part of Atlantic Ocean and among eight countries (UK (Scotland & England), France, Belgium, Netherlands, Germany, Denmark, Sweden and Norway) and the longest boundary belongs to the UK (Figure 1-2).

Figure 1- 2: North Sea map (Worldatlas.com, 2018)

The North Sea covers 750 000 km² area. On average 94 m depth in the North Sea and approximately 80 million people are living around the sea (Encyclopedia Britannica, 2018).

Below the map, Figure 1-3 shows the North Sea' s bathymetry map. Northern locations are deeper than southern locations.

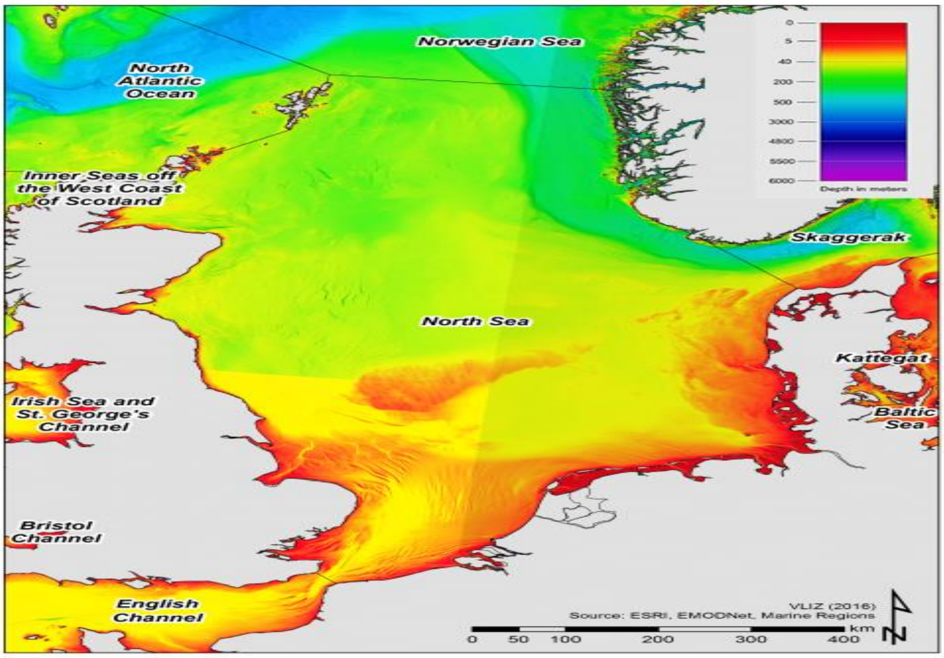

Figure 1- 3: The North Sea's bathymetry map (Marineregions.org, 2018)

The North Sea is one of the most important fisheries areas in the world, more than 230 fish species around the North Sea (Jay 2012a). Commercially important fish species in the North Sea include herring, cod, haddock, whiting, saithe, sandeel, monkfish, Norway pout, plaice, shrimp, mackerel, Norway lobster, sprat, scallop, edible crab, lemon sole and sole. OSPAR (2000) declared that these fish stocks mostly not sustainably exploited at present.

Commercially important fish and shellfish populations in the offshore waters of the North Sea will be described the biology below headlines. Current researches, during the 20th century, have been advised that there have been considerable deviations in the fish groups of the North Sea. These groups consist of species that have multiple relations with each other and the natural ecology and many of which groups act as predators at higher trophic levels, provided that prey substances for greater predators or consuming an extensive array of benthic invertebrates. These fish groups undertake natural variation in their population dimensions, consequently large variation in year by year achievement of the recruitment. Additionally, these groups trends will be also impacted by human exploitation and broad scale patterns of climate change (Assets.publishing.service.gov.uk, 2018).

1.2.1. Whiting

Whiting is one of the most valuable and ubiquitous species in the North Sea. And this species also contains inshore and offshore inhabitants (Hislop & MacKenzie, 1976). Whiting usually feeds on juvenile fish, shrimps and crabs and this species is one of the main predator species of among commercially significant fish species. Whiting species usually attain sexual maturity around the second years of life (Knijin *et al*, 1993).

At four years old matured female whiting species nearly sized 30 cm produces around 40,000 ripe eggs while the spawning season, which takes around 10 weeks (Hislop & Hall, 1974). The whiting also migrates the northern areas in the North Sea for spawning usually takes in April-May and 8-12 days enough for hatching (Knudsen, 1964). Below the Figure 1-4 shows the whiting species shape.

Figure 1- 4: Whiting, Merlangius merlangus (Britishseafishing.co.uk, 2018)

1.2.2. Cod

Cod usually occur northern and central locations in the North Sea and west of Scotland. This species also predators and feed on shrimps, polychaetes, nephrops and other benthic organisms. Cod spawn occurs all over the North Sea but northern locations more preferable especially Scotland areas. January and April are convenient spawning times but the peak spawning time between February and March (Daan, 1978). Below the Figure 1-5 shows the cod shape.

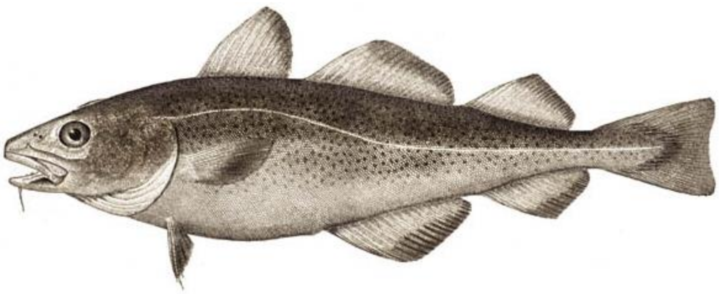

Figure 1- 5: Cod, Gadus morhua (En.wikipedia.org, 2018)

1.2.3. Haddock

Haddock is a kind of benthic fish species occurs 80 m and 200 m depth throughout the northern North Sea (Albert, 1994). Haddock usually occurs in northern, although in the summer this species can be seen south of the Dogger Bank.

Haddock is also predator species and usually feed on gobies, sprat and herring, Norway pout and long rough dab (Villemarque, 1985; Cranmer, 1986). Haddock larvae and eggs are mainly distributed nearly 40 m deep surface waters (Bjorke and Saetre, 1994). The highest density for haddock juveniles occurs northeast of Scotland during the late summer season (Albert, 1991). Below the Figure 1-6 shows the Haddock shape.

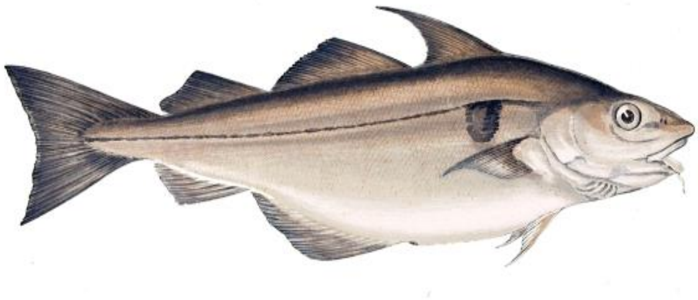

Figure 1- 6: Haddock, Melanogrammus aeglefinus (Britishseafishing.co.uk, 2018)

1.2.4. Herring

Herring is a kind of pelagic species distributed all over the North Sea and nearly occurs around 200 m depth and this depth can be changed pelagic or benthic zones to maturation cycle stages, spawning and availability for preying (Harden- Jones, 1968). Spawning season is widely distributed between November and January. Herring pelagic larvae usually feed on fish eggs, juvenile sandeel and copepods (Last, 1989). Adult individuals feed on larger organisms and also zooplankton, crustaceans, tiny animals found in surface waters. Below the Figure 1-7 shows the herring shape.

Figure 1- 7: Herring, Clupea harengus (Britishseafishing.co.uk, 2018)

1.2.5. Mackerel

Mackerel are fast swimmers and usually located pelagic zones fish species. Mackerel feed on crustaceans, sprat, Norway pout, herring and sandeel. Spawning season is between May and June and usually the southern coast of Norway (Lockwood, 1978; Dawson, 1991). Pelagic larvae usually located in the centre of the North Sea approximately 60 m depth, but the majority of larvae occur 26 m depth (Coombs *et al*., 1981). Below the Figure 1-8 shows the mackerel shape.

Figure 1- 8: Mackerel, Scomber scombrus (Fitday.com, 2018)

1.2.6. Sandeel

Five different species in the North Sea occur as a sandeel (Wheeler 1969). These are lesser sandeel (*Ammodytes marinus*), small sandeel (*Ammodytes tobianus*), greater sandeel (*Hyperoplus lanceolatus and Hyperoplus immaculatus*) and lastly, smooth sandeel

(*Gymnammodytes semisquamatus*). This species typical speciality is burying themselves in the sand during the night and catch for prey semi-pelagic waters during the morning (Winslade, 1974). This species usually feed on amphipods, small fish polychaete worms, copepods and crustaceans. Spawning period is between November and February and occur usually in southern areas and also the central North Sea. Sandeel adopt to live demersal areas (Wrigth and Bailey, 1996). Below the Figure 1-9 shows the sandeel shape.

Figure 1- 9: Sandeel, Ammodytes marinus (Fly Addict Community Forums - New England Fly Fishing Connecticut Rhode Island New York Massachusetts Maine Vermont New Hampshire, 2018)

1.2.7. Norway pout

Norway pout usually distributed 80-200 m depth, but they can be seen also 450 m depth too (Bergstad, 1990). They can be seen usually central areas in the North Sea and northern locations (Knijin *et al*., 1993). They are benthic predators and feed on crustaceans, shrimps, amphipods and small fish (Mattson, 1981). Spawning time between January and April. Approximately one year enough for Norway pout to get mature (Raitt and Mason, 1968). Below the Figure 1-10 shows the Norway pout shape.

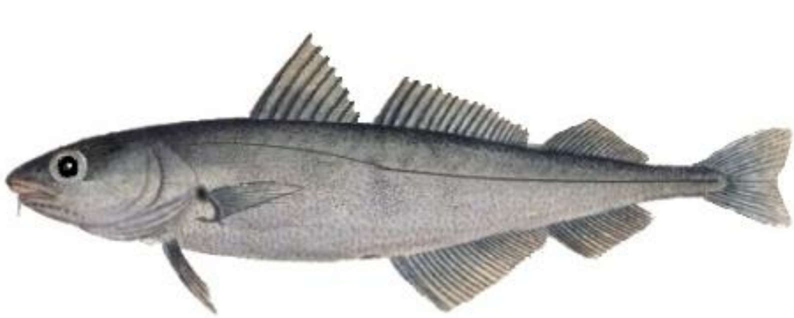

Figure 1- 10: Norway pout, Trisopterus esmarkii (Britishseafishing.co.uk, 2018)

1.2.8. Saithe

Saithe is commonly occurring in northern European waters from Greenland to the Celtic Sea, Spitzbergen and Iceland and adult ones are usually occurring in slope waters and continental shelf waters at nearly 80-450m depths (Jakobsen & Olsen 1987). Also, adults feed on a range of demersal creatures, including fish species and crustaceans, haddock and Norway pout (Gislason, 1983).

Spawning areas are in the northern North Sea along the edge of Norwegian Deep and east of the Shetland Islands. Spawning time is mainly between January and March. Juvenile life is pelagic for this species after then they migrate deep waters. They usually feed on fish species, such cod, herring, and sandeel and also benthic invertebrates. Below the Figure 1-11 shows the saithe shape.

Figure 1- 11: Saithe, Pollachius virens (Seafoodscotland.org, 2018)

1.2.9. Plaice

This species is a kind of coastal species, the most abundant area for them in the Southern part of the North Sea, in the eastern Channel, Kattegat and Skagerrak and east coast of the UK nearly 200 m depths (Whitehead *et al.*,1986). Spawning begins January in the southern areas when the temperature indicates nearly 6ºC (Fox *et al.*, 2000).

Plaice feeds on crustacean species, amphipods, bivalve molluscs, mysids, polychaeta worms are important prey items for this species (Clerck & Buseyne, 1989). Below the Figure 1-12 shows the plaice shape.

Figure 1- 12: Plaice, Pleuronectes platessa (Young's Seafood, 2018)

1.2.10. Sole

This species usually occurs in southern locations of the North Sea (Horwood, 1993). Sole spawning areas usually 30 m depth inshore and close to sandbanks, between April and May. In southern areas spawning happens earlier than northern areas (Rjinsdorp *et al*., 1992). First life phase for this species pelagic, after a month metamorphose they migrate into demersal phase (Beek *et al*., 1989). Sole feeds on amphipods, polychaete worms and opisthobranchs (Braber & De Grot, 1973). Below the Figure 1-13 shows the sole shape.

Figure 1- 13: Sole, Solea solea (Fisheries - European Commission, 2018)

1.2.11. Lemon Sole

Although the lemon sole name this species does not belong to the sole family. They widespread are found northern Scotland's coastal waters, Shetland and Orkney Islands. They are also found northeaster cost of England and the northern and central parts of the North Sea.

This species feeds on a variety of benthic creatures, including crustaceans, polychaete worms, echinoderms and molluscs. Spawning time is between April and September. Below the Figure 1-14 shows the lemon sole shape.

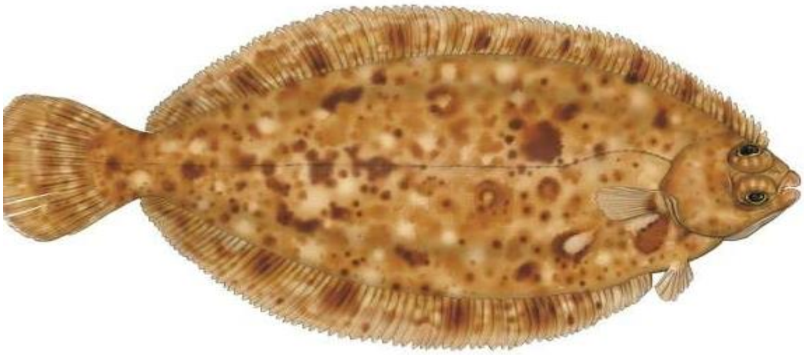

Figure 1- 14: Lemon sole, Microstomus kitt (Fish is the Dish, 2018)

1.2.12. Monkfish

In the UK there are two species occur for monkfish or anglerfish. One of them is *Lophius budegassa* and the other one is *Lophius piscatorius*. These two species' biology is very similar to each other. Juvenile monkfish usually occurs northern locations of the North Sea and nearly 150 m depths. Spawning time is during between January and June in deeper waters (Afonso-Dias & Hislop 1996). They cannot be adult before seven years especially female ones (Hislop *et al*., 2001). They feed on small kind of fish species. Below the Figure 1-15 shows the monkfish shape.

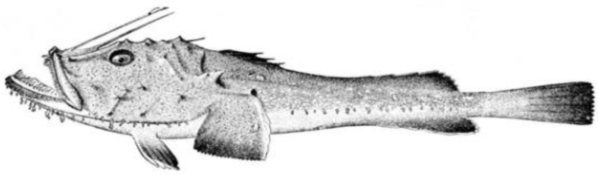

Figure 1- 15: Monkfish, Lophius piscatorius (Britishseafishing.co.uk, 2018)

1.2.13. Sprat

This species is the most plentiful one in the shallow waters of the southern North Sea and are also found abundantly in the UK coastal waters, Orkney Islands. Sprat species usually gets mature nearly two years, and the Inner German Bight is the most important spawning areas for this species. Larval sprat usually feeds in mid-water on mysids, bivalve larvae and copepods. And spawning times between May and August. Below the Figure 1-16 shows the sprat shape.

Figure 1- 16: Sprat, Sprattus sprattus (Britishseafishing.co.uk, 2018)

1.2.14. Shrimp

There are different varieties of shrimps in the North Sea and most of them exploited because of commercially importance, the most significant one is *Pandalus borealis* generally an offshore species.

P. borealis generally occurs to 100m depth, on soft sediments in coastal waters of the northern North Sea. During the October and November, adult ones undertake an offshore movement to deeper waters, and eggs are laid from November to February. In the Spring, offshore migration is followed to inshore migration towards to shallower waters. Spawning period is between April and May. Adults feed on worms and small crustacean species (Muus & Dahlstrom 1974). Below the Figure 1-17 shows the shrimp shape.

Figure 1- 17: Shrimp Pandalus borealis (Marinespecies.org, 2018)

1.2.15. Scallop

The scallop (especially *Pecten maximus*) is a kind of filter feeder bivalve and widespread on the suitable sediments all around the British Isles. This species is very valuable for fishermen. Spawning time is spring months for them. Sometimes later spawning also occurs in autumn. Larvae are free swimming and larvae time lasts nearly 3-4 weeks before settling onto the sea-bed. Scallops lifespan can be above 20 years and they also can be excess of 175mm in length. Below the Figure 1-18 shows the scallop shape.

Figure 1- 18: Scallop Pecten maximus (Cornwallgoodseafoodguide.org.uk, 2018)

1.2.16. Norway lobster

This species identified the Latin name of *Nephrops norvegicus*. These are mud-burrowing kind of animals. They distribute suitable sediments (70% sand, 30% clay and silt). They do not migrate they settle as larvae. *Nephrops* feed on worms and other small invertabrates and crustacea species (Muus & Dahlstrom 1974). Spawning period is between September and April or May (Farmer, 1975). Females get mature nearly 3 years old. Female individuals exploit rate less than male individuals by trawlers. Below the Figure 1-19 shows the Norway lobster shape.

Figure 1- 19: Norway lobster, Nephrops norvegicus (Fisheries - European Commission, 2018)

1.2.17. Edible Crab

Edible crab is ubiquitous on mixed substrates of rock, gravel and sand around the coasts of UK. They feed on marine worms, shellfish and fish. Crabs are moulting from July to October. Female crabs moult firstly and then spawns in November or December. The larvae live in plankton forms for approximately one month before settling down the seabed. Below the Figure 1-20 shows the edible crab shape.

Figure 1- 20: Edible crab Cancer pagurus (poweredbyreason.co.uk, 2018)

1.2.18. Ling

Ling is a demersal kind distributed 15-600 m depth and catching with demersal trawl and one of the commercially important fish species in the North Sea. This species is as known as cod-like fish and the longest one it can reach lengths 200 cm and can also reach weights of 30 kg. It is slender and long. Ling can get mature at 5 years for males and 5-6 years for females when they are nearly 90-100 cm length. Each female ling can carry 20 to 60 million eggs. This species feeds on crustaceans, cephalopods and echinoderms (En.wikipedia.org, 2018). Below the Figure 1-21 shows ling shape.

Figure 1- 21: Ling, Molva molva (Ling, 2018)

1.2.19. Halibut

This species can be found in the northern North Sea's demersal areas. Halibut is the largest flatfish in the world and carnivore, feed on the closest benthic species such as crustaceans, demersal fish species, octopus and squid. This species is commercially important and exploited dramatically in recent years (Britishseafishing.co.uk, 2018). Halibut can get mature 8 years this means they cannot reproduce before 8 years old nearly 76 cm (En.wikipedia.org, 2018). Below the Figure 1-22 shows the halibut shape.

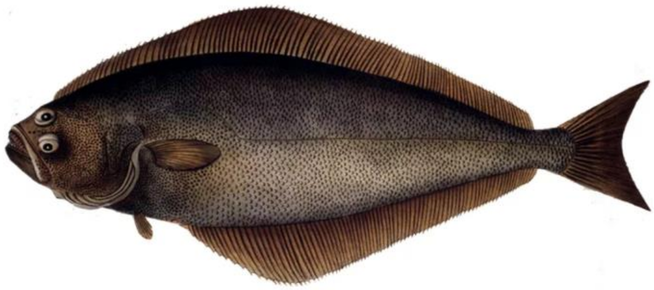

Figure 1- 22: Halibut, Hippoglossus hippoglossus (Welch, 2018)

1.2.20. Hake

Hake is coming from the same family with cod and haddock. This species maximum life span approximately 14 years the maximum length about 1 m and maximum weight 27 kg. This is also one of demersal species and lives generally 200-350 m depth. Hake is carnivore fish species and feeds on herring, cod, mackerel, squid, e.g. They are found colder waters in the North Sea. The IUCN (International Union for the Conservation of Nature) declared that the hake is exposing to overfishing because of this circumstance eradicating from the sea and they recommend reducing the fishing pressure for hake species (Britishseafishing.co.uk, 2018). Below the Figure 1-23 shows the hake species shape.

Figure 1- 23: Hake, Merluccius merluccius (Fisheries - European Commission, 2018)

1.2.21. Pollack

Pollack is a semi-pelagic member of the cod family. They prefer to live 40-100 m depth and also one of predator fish species feed on small fish, crustaceans, squid, e.g. Maximum lifespan for this species nearly 15 years and maximum length 130 cm, can weight up to 21 kg. They generally get mature at 3 years old and, spawning time between January and March. Pollack are catching with demersal otter trawl, set gillnet and trolling line fisheries aiming varied finfish species (ICES, 2015). Below the Figure 1-24 shows the pollack species shape.

Figure 1- 24: Pollack, Gadus pollachius (Fish is the Dish, 2018)

Below the line graph Figure 1-25 shows the North Sea's commercially important ten fisheries species catch amounts (thousand tonnes between) 1950 and 2015.

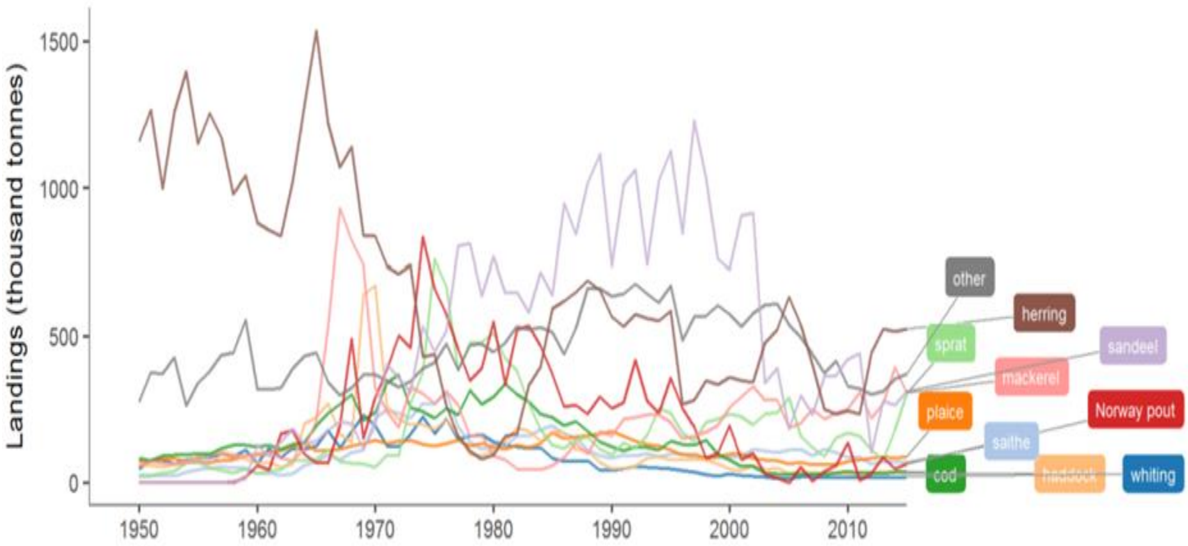

Figure 1- 25: The North Sea (thousand tonnes) between 1950 and 2015, by ten species (Ices.dk, 2018)

1.3. Structure of the Paper

This research project is subdivided into 6 chapters.

Chapter-1 Introduction: This section provides a framework of the research project as well as a background.

Chapter-2 Literature Review: The next section will present the literature review of The North Sea's Commercially important fisheries locations topics. The definition of MSP, MPA, SAC, will be discussed and their meanings, in this paper, will be revealed. GIS in fisheries will be explored at the end of the second chapter.

Chapter-3 Methodology: The use of ArcGIS programme will be described and detailed and the data used in the maps will be presented.

Chapter-4 Results: The North Sea's commercially important fisheries areas will be determined by maps in this chapter.

Chapter-5 Discussions: The maps will be reviewed and discussed for the purpose of evaluating The North Sea's commercially important fisheries locations in this chapter.

Chapter-6 Conclusion: The concluding points will be highlighted under consideration of both results and discussions sections.

This dissertation is dedicated to exploring past experiences, current data and missing points about the North Sea's commercially important fisheries locations. In this involvement, future works will be familiarised in the sixth chapter to light the way ahead.

Chapter 2

2. Literature Review

In this chapter, the general literature that assisted to shape this study will be presented. By this way, the main definitions and concepts are introduced. At that time, Geographic Information System (GIS) in Fisheries is discussed comprehensively. Consequently, a summary part goals and objectives are described.

2.1. Introducing Main Concepts and Definitions

In this part will introduce the definitions the basis of this dissertation. The explanation on the abbreviations will be allocated to support reflective knowledge resource to reinforce Geographic Information System.

Fisheries science is developing with GIS using, the headlines are habitat mapping, water quality modelling, wildlife management, surficial land use assessment. Although the GIS in fisheries research is not being developed enough.

2.1.1. GIS (Geographic Information Systems)

GIS is an "organized gathering of computer software, geographic data, hardware, and personnel designed to professionally capture, store, manipulate, update, analyse and display all forms of geographically referenced information" [Environmental Systems Research Institute (ESRI) 1990].

GIS answers four types of questions while working (ESRI 1990).

1.What are the characteristics related to a specific location? (location coordinate, display the data, depth of water, e.g.)

2.What are the given a set of criteria and which locations meet those criteria? (for instance, display the mackerel locations that occurred at midnight and 10 m of shore).

3.What spatial forms are? (for instance, display mackerel areas that exist inshore or in a limited area of the sea).

4. "What-if" model data sets can be answered by GIS (for instance, if the water level of the sea were to drop by 5 m, how much mackerel habitat would be lost?).

Bellowed the Figure 2-1 shows how to integrate data layers with each other: one of the data is bathymetric data layer and the other one is habitat type data layer integration with fish location data layer and newly created data layer; Complex, between layer questions possible.

Separate Data Layers; Simple,

Within-layer Questions Possible

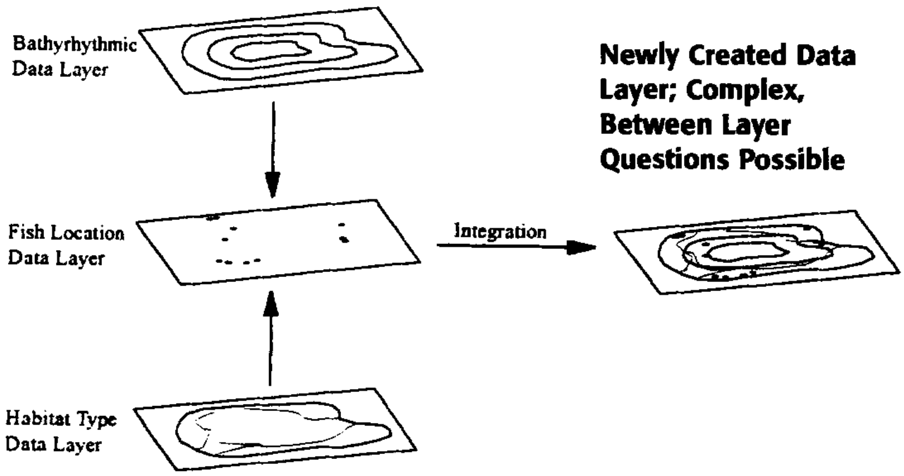

Figure 2- 1: Demonstrates using a GIS to assimilate and produce a new data layers (Isaak & Hubert, 1997)

2.1.1.1. Developing a GIS

The most important tool for a GIS is the sets of geographically referenced spatial data. Since many governments, universities and private organizations are already using GIS, many places have been included in the data layers. These digitized files are generally available to anyone in need. Alternatively, the US government produces and distributes several types of spatial digital files. The US Geological Survey (USGS) has both Digital Line Graphic (DLG) and Digital Elevation Model (DEM) files (USGS 1987). DLG files contain information about an object type found on a map. Examples are land use, land cover, property boundaries and hydrographic layers. DEM files can be used to simulate the topography of an area, so that the slope, appearance, climate, etc. It contains elevated data about which you can obtain information. The US Census Bureau (USCB) provides the Topology Integrated Geocoding and Referencing (TIGER) system files. demand (USCB 1991). The TIGER files contain several digitized features derived from the 1990 census, including digital roads, rivers, railroads, and political borders (Congalton and Green 1992). DLG, TIGER and DEM files are geographically referenced and can easily be combined with existing layers in a GIS. Land formats that are not currently digitized can be incorporated into a GIS by obtaining their location with global positioning system (GPS) receivers or by digitizing existing maps or remote sensing images. The most time-consuming aspects of GIS operation are data collection, organization and intervention, so it is advisable for the initial users to search the existing data layers in a comprehensive way.

There are two types of GIS traditionally: raster-based or vector-based systems. The vector-based approach is more popular, but the project properties will determine which approach will be taken. The vector GIS uses the data found in the DLG or TIGER files and is best to describe features with different boundaries or linear nature as they have the best points, lines and polygons (ESRI 1990). Storage requirements for vector data are less than raster counterparts, but certain analysis types are more time-consuming with vector approaches (Congalton and Green 1992). Raster GIS uses data obtained from DEM files, aerial photographs, Land Satellite System images or other remoteness sources, and is best suited for displaying and modelling as the best-represented data surfaces. Raster GIS stores data in a grid structure. The grid cell size determines the resolution at which the objects are depicted and is responsible for any corruption of an object's shape. The resolution of the network depends on the quality of the data, on which inputs are entered, and on the GIS itself. The data in the raster CBS is easier to calculate for processing, but the storage requirements are higher (Congalton and Green 1992).

2.1.1.2. Applying GIS technology to Fisheries Science

Even though limited, there are examples of GIS use in fish. Nelson *et al*. (1992) used a GIS to produce original maps of terrestrial-type associations and geological areas related to the distribution of trout species and physical habitat characters. In another study, a GPS receiver was used to record locations on a dam tail (Isaak & Bjornn 1996) of a northwest fish (*Ptychocheilus oregonensis*). This data was loaded into a GIS and used to generate maps of fish distribution and to calculate distances between fish locations. In the modelling approach, Rahel *et al*. (1996) used regression equations to describe the areas of Wyoming northern Platte River drainage that are thermally suitable for trout. Then, according to a series of global warming scenarios, a GIS was used to model changes in trout distribution and habitat linkage. In a similar study, Keleher and Rahel (1996) simulated the impact of global climate change on trout distributions in the western Wyoming and Rocky Mountains. Finally, Angermeir and Bailey (1992) used GIS technology to describe areas with rare species or high species richness in Virginia and may therefore require special management considerations.

The review of the summaries from the 1995 American Association of Aquaculture shows that the use of GIS is increasing. Four studies have used GIS in several applications, including habitat-based assessments for rockfish (*Habes spp*.), Optimization of sampling designs for small pit bass (*Micropterus dolomieui*), and the creation of maps of fish distribution and taxon density.

Another possible application of GIS is in reservoirs where the abundance of age-0 fish is associated with water-level fluctuations (Martin *et al*., 1981) and coastal habitat types (Meals and Miranda 1991). A GIS containing bathyrhythmic and habitat-type strata can be used to calculate the area of different habitat types at various water levels, thus helping to predict the year-class strength. Fisheries managers can use this information to develop improved management plans or to leverage when demanding certain water levels at critical times of the year (spawning or winter seasons).

GIS is developing a powerful tool to classify habitat quality sampling surveys and expanding population abundance estimates. Estimating the abundance of fish populations in the unexplored regions of habitats in the water has traditionally offered a challenge to biologists against fisheries. GIS technology can greatly improve the expansion of population estimates and facilitate sampling designs through habitat mapping and classification (Wilde and Fisher 1996). For example, to determine the abundance of threatened leopards (*Percina pantherina*), we used quantitative measures of GIS and microhabitat to determine the quality (i.e., optimal, appropriate, unfavourable) of habitats (Toepfer 1997). The predicted habitat quality was then used to stratify sampling efforts for leopard decisions. From these data, the logistic functions related to the longitudinal position of the fish density in the stream have not been established and have been applied to habitat species using GIS to predict abundance in areas where we cannot sample. We used a similar approach to broaden populations estimates of black-bass (*Micropterus spp.*) Species in two eastern Oklahoma streams (Balkenbush 1996) to areas not sampled from sampling areas through sampling designs and weighting habitat species by observed habitats. In both cases, the investment of time and expenditure in the preparation of habitat maps and the analysis of current habitat classes by GIS prior to sampling provided significant time and resource savings in subsequent sampling studies. In the end, we believe that our final estimates are much more realistic than we can do without the help of GIS.

GIS has spread to other fisheries in science and management. One of the most valuable uses of GIS is to produce spatially related questions. GIS allows fishermen and water science researchers to easily visualize the relationship between species, communities, habitats, and physio-chemical properties of aquatic environments on multiple scales. The integration of GIS with existing water basin models (e.g., erosion, sediment guidance) and databases (altitude, road systems, land cover) could improve our ability to assess local habitat conditions for river fish (Toepfer 1997) and strengthen fisheries management decisions (Radko 1997). Combining GIS spatially with open temperature and bioenergetic models (e.g., Brandt et al., 1992) provides enhanced opportunities to visualize and understand complex spatial relationships of fish and environments. GIS becomes a tool to frame ecological questions and research objectives. The application of GIS to human dimensions of the fishery is ripe for exploration. There is a growing need to promote recreational fishing programs and services among private fisheries management organizations (Ditton 1996). Businesses are increasingly using GIS to target sales efforts in tightly defined geographic areas, such as ethnic neighbourhoods, to improve marketing plans, or to match ads to potential buyers (Taylor 1994). Similar approaches can be used by fishing agencies to match selected spatial groups with selected fishing resources. The relevant research areas may include spatial and prime mapping and modelling of stream and lake angler creel studies and population demographic trend data (e.g. from TIGER census data files) with national or regional trend data from urban fishermen or US anglers. surveys on hunting, fishing and wildlife.

2.2. The North Sea

The North Sea is located 56°N 03°E, the surface area 570.000 km², the maximum length 960 km, maximum width 580 km, average depth 95 m; maximum depth 700 m, water volume 54.000 km³, salinity 3.4 to 3.5%, the maximum temperature degree 17°C and minimum temperature degree 6°C, the boundaries of countries are the UK (England and Scotland), Norway, Sweden, Denmark, Belgium, Germany, Netherland, France (En.wikipedia.org, 2018).

Decision making for the North Sea is done by North Sea Regional Advisory Council (NS RAC).

Below the Figure 2-2 flowchart demonstrates the North Sea Regional Advisory Council (NS RAC) generally overview the working Centre for Environment Fisheries and Aquaculture Science (CEFAS) working for the data mapping project.

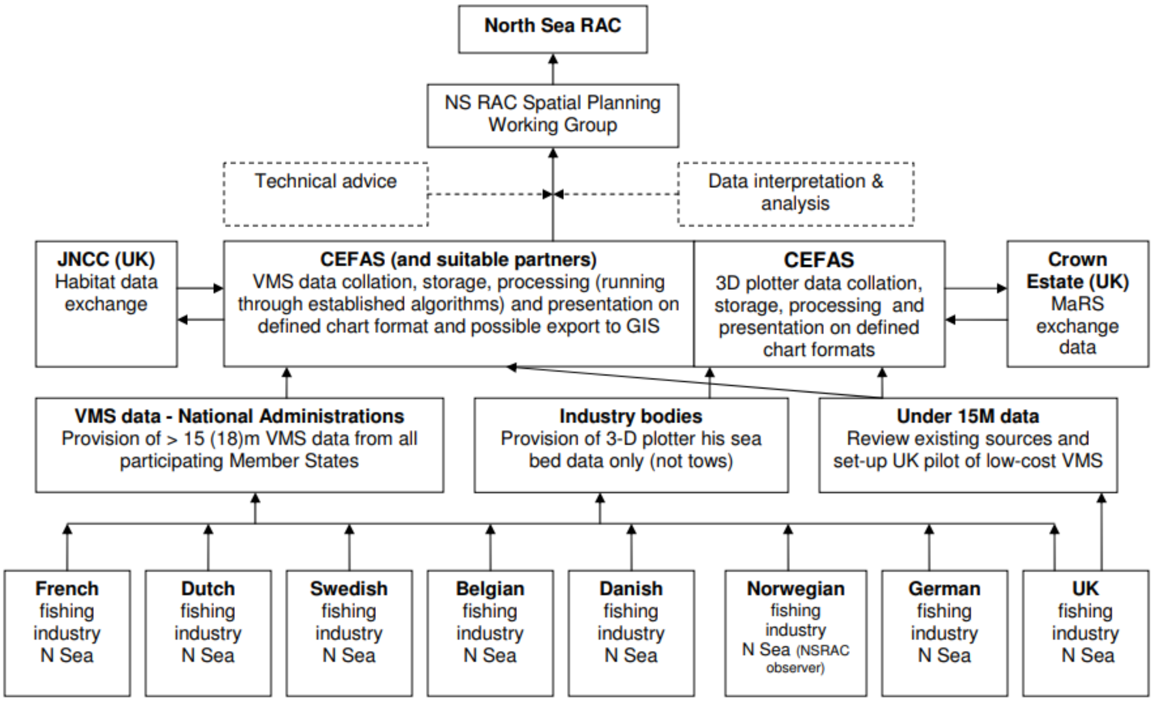

Figure 2- 2: North Sea Fishing is shown with flow-chart governance and data flows for the data mapping project (Nsrac.org, 2018)

Marine Protected Areas generally defined “A globally appropriate universal term for describing any protected area in the marine realm that aims to protect nature and protect the healthy oceans” (Biodiversitya-z.org, 2018).

Below the Figure 2-3 indicates the Marine Protected Areas (MPAs) in the North Sea by countries boundary.

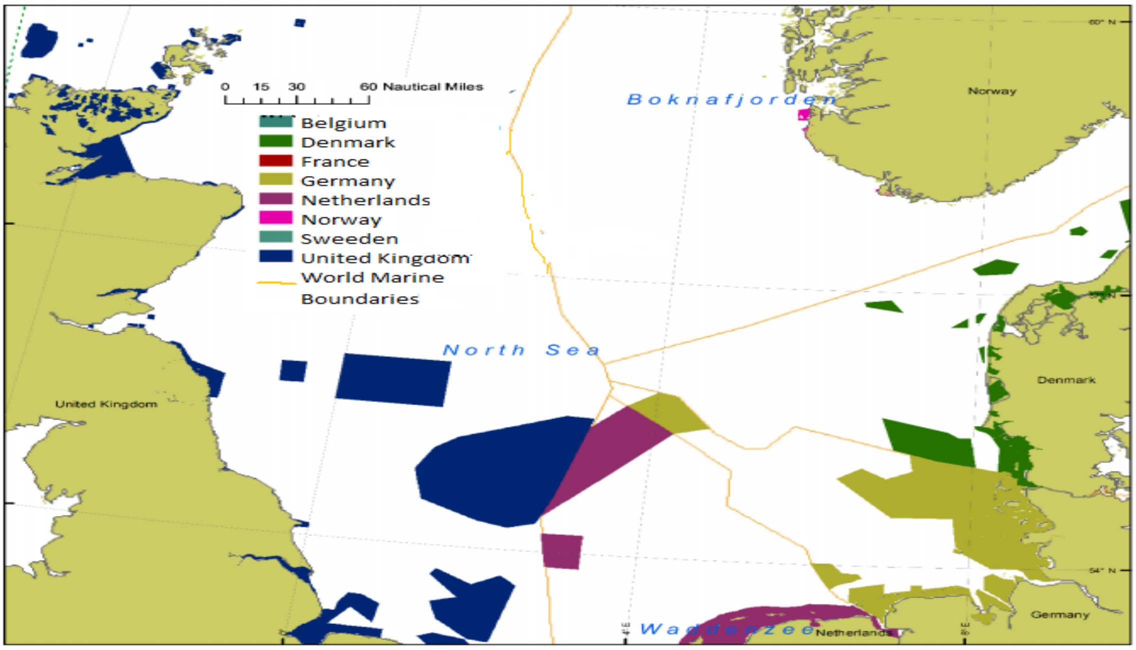

Figure 2- 3: Marine Protected Areas locations by countries (Emodnet.eu, 2018)

MPAs usually located in the UK (Scotland, England) boundary, Netherlands and Germany have nearly same rate MPAs, Denmark also has some MPAs locations and Norway has just a tiny MPAs location. The largest MPAs located middle of the North Sea.

Below the Figure 2-4 shows the Marine Protected Areas (MPAs) with 40 km buffer in the North Sea. Marine Protected Areas (MPAs) generally determined middle and southern regions.

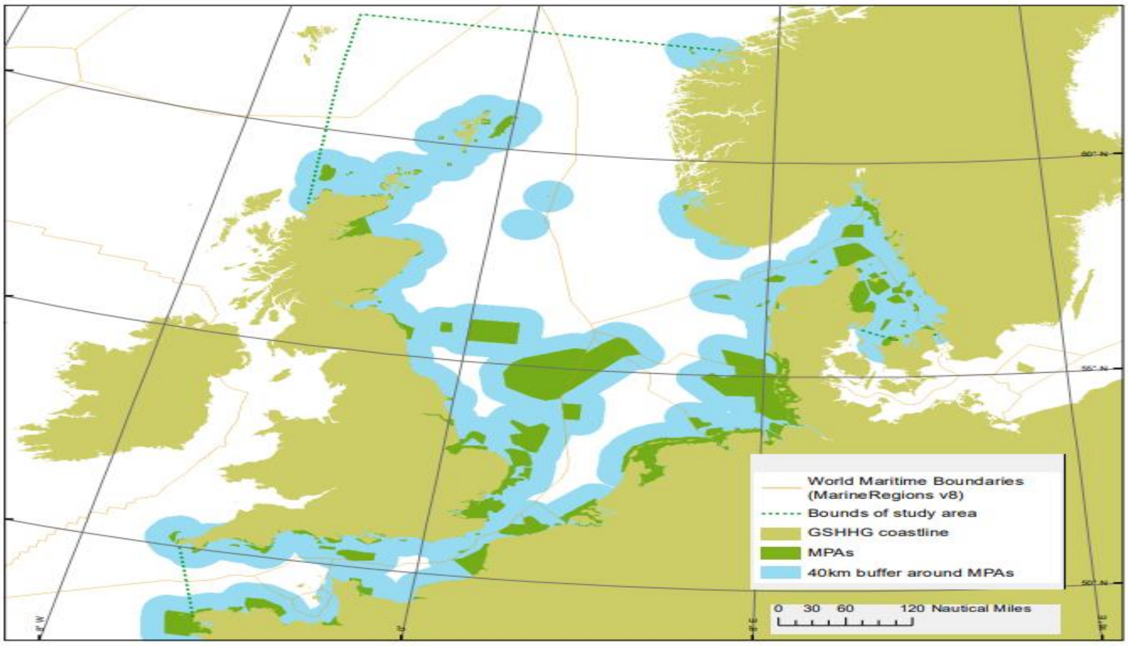

Figure 2- 4: North Sea's MPAs with 40 km buffer (Emodnet.eu, 2018)

Fisheries in the North Sea is very important for commercially because of this circumstance there are different fish categories (pelagic, demersal, benthic) and catching for these categories methods such as trawl, dredge, pots, gillnets, longline, e.g. are being used.

Below the Figure 2-5 shows the fish categories, such as pelagic, demersal, benthic, elasmobranch and crustacean for 7 decades period between 1950 and 2010 and the largest proportion belongs to pelagic and demersal fishing.

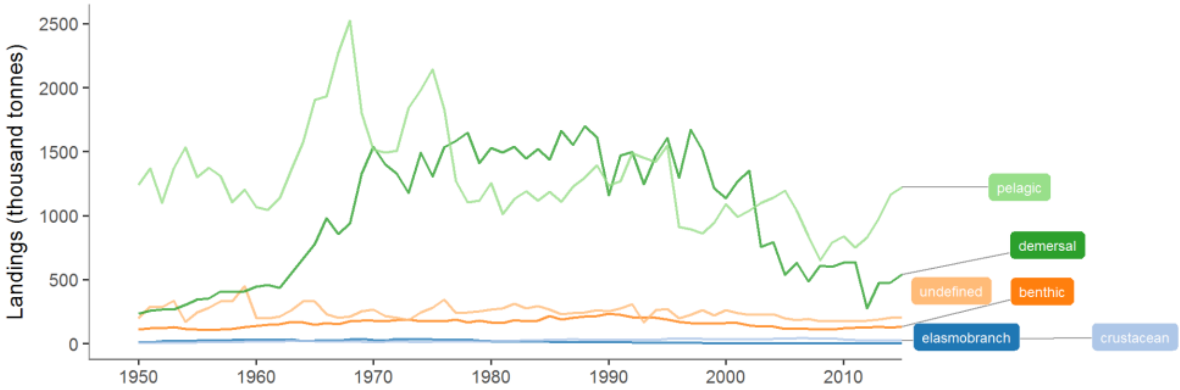

Figure 2- 5: The North Sea Landings (thousand tonnes) in 1950–2015, by fish category (Ices.dk, 2018)

Catching tools are also important for fishing. Every species has own catching material for fishing. For example, mackerel is one of the pelagic species and mackerel hunts are usually done by pelagic trawl.

Below the Figure 2-6 demonstrates catching methods between 2003 and 2015 in the North Sea, these methods are pelagic trawl, otter trawl, dredge, beam trawl, static/Gill net/LL(Longline), pots and other. The largest proportion belongs to pelagic trawl/seine.

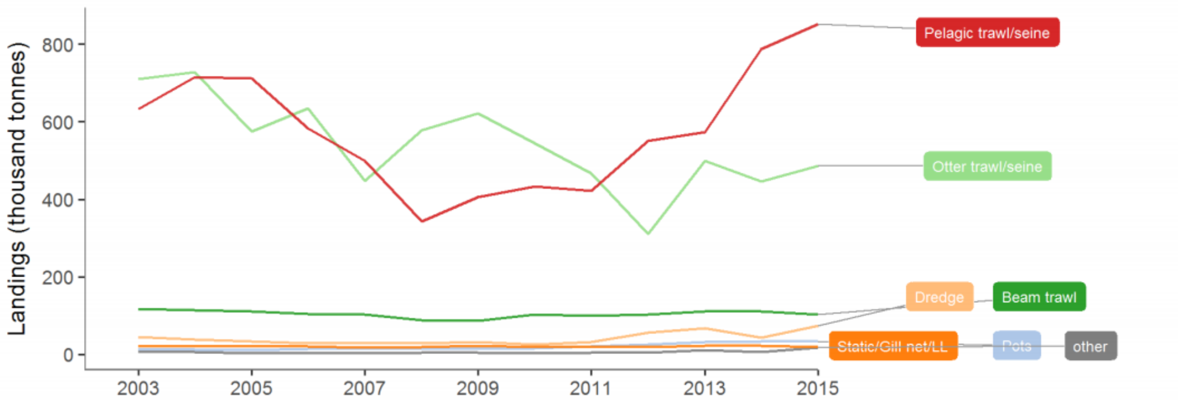

Figure 2- 6: The North Sea (thousand tonnes) between 2003 and 2015, by catching methods (Ices.dk, 2018)

The countries, which have a boundary with the North Sea, are explained below:

2.2.1. Belgium

The Belgian fishermen's fleet consists of approximately 75 ships, they are approximately 24 m in length and under. A few ships are smaller than 12 meters. Demersal fisheries amount is larger than pelagic fisheries. Sole is the dominant species and following this plaice, lemon sole, anglerfish, turbot, cod, rays, shrimp and lastly scallops (Ices.dk, 2018).

2.2.2. Denmark

The Danish fishermen’s fleet consists of nearly 600 vessels in the North Sea mostly demersal fishing. The largest proportion belongs to smaller vessels (<12 m) of the fleet, but this is just 5% Danish fisheries hunt amount. The most important commercially important fish species in Denmark is cod. Following this, plaice, saithe, nephrobs and northern shrimp using the seines and bottom trawls. For pelagic fisheries nearly 30 bigger vessels (>40 m) catching saithe, which is the most important pelagic species, and approximately 200 smaller vessels (12-40 m) catching herring and mackerel for human consumption and sprat, Norway pout and sandeel for reduction drives, such as oils and fish meal in Denmark (Ices.dk, 2018).

2.2.3. France

The French fishermen’s fleet consists of nearly 600 vessels in the North Sea. The demersal fisheries operate mainly the southern North Sea and catching a diversity of finfish and shellfish species. Scallops are hunted by dredgers, a large diversity of fish and cephalopod species are hunted by demersal trawlers (12-24 m), sole is hunted by trammel netters (10-18 m). France has 6 large (>40 m) demersal trawlers and targets usually saithe in the northern areas and the west of Scotland. Herring, mackerel and horse mackerel species are very important for pelagic fisheries in France (Ices.dk, 2018).

2.2.4. Germany

The German fishing fleet consists of more than 200 vessels. The largest proportion of Beam trolls belongs to approximately 180 vessels and is 12-24 m in length. Brown shrimp species is targeted in the southern North Sea. Saithe species is hunted with 6 large vessels (>40 m) for demersal fishing in the northern North Sea. Mid-sized trawlers (24-40 m) also are used for several species (e.g. saithe, sole, cod, plaice). For pelagic fisheries such as mackerel, sprat, sandeel, horse mackerel and herring are hunted by nearly 10 large vessels (>40 m) (Ices.dk, 2018).

2.2.5. Netherlands

The Dutch fishing fleet consists of nearly 500 vessels. Beam trawl fleet for demersal fisheries are 275 and which 190 are <24 m and 85 are >24 m vessels and mostly targeting sole and plaice species. 7 vessels (>60 m) for Pelagic trawlers, target herring, mackerel, and horse mackerel. Most of the small vessels for beam trawling seasonally target flatfish or shrimp (Ices.dk, 2018).

2.2.6. Norway

The Norwegian fishing fleet consists of 1585 vessels. Most proportion belongs to demersal fisheries (%85) including cephalopods, crustaceans and elasmobranchs. Demersal fisheries consist of %60 with small vessels (<10 m) they are catching squid, crabs and several fish species. Medium-sized vessels (24-40 m) mostly catch crabs and Nephrops using traps and pots, saithe, cod, shrimp using trawls, monkfish using gillnets. Pelagic species including blue whiting, herring, sprat and mackerel are hunted by beam trawlers.

The industrial vessels (25 vessels >40 m: 5 vessels 25-40 m) catch sandeel and Norway pout for reduction purposes (Ices.dk, 2018).

2.2.7. Sweden

The Swedish fishing fleet consists of more than 500 vessels. Mainly demersal fleet is extremely expanded, Nephrops cod, shrimp, saithe. Nearly 400 vessels for the passive gear fleet (of which 100 vessels; 70 of them <10 m and 30 of them 10-18 m) usually target Nephrops and for the pelagic fleet nearly 16 vessels target sandeel, sprat and herring (Ices.dk, 2018).

2.2.8. UK (England & Scotland)

The UK fishing fleet has the largest amount with nearly 2120 vessels. Approximately 1120 vessels belong to England and 1000 of them belong to Scotland. The largest boundary with the North Sea among all countries belongs to the UK.

Medium-size demersal trawlers in England (80 vessels and some of them 18-24 m and the others 40-40 m in length) primarily target cod, Nephrops and whiting. The smaller vessel fleet

(<10 m) (nearly 1000 active ships) catch a variety of fish and shellfish species. About 40 vessels, which are medium and large beam trawlers, account for the plaice landings and 3 vessels and >50 m in length are using for pelagic fisheries and targeting herring, mackerel and horse mackerel.

More than 120 demersal trawlers in Scotland (almost all of them >10 m) fishing for diverse gadoids (haddock, cod, saithe, whitening) and for groundfish such as megrim and anglerfish. Nearly 116 fleet trawlers fish mainly for Nephrops in the North Sea. 79 of these vessels for offshore grounds and 37 of them for inshore grounds. Over the 500 vessels (>10 m) for pot or creel fishing. Scallop fishing also around 70 dredgers (>10 m) and limited amounts of longlining and gill netting can be conducted by Scottish vessels. Important captures of pelagic species are being gathered by 20 greater vessels, principally using pelagic trawls (Ices.dk, 2018).

Below the figure indicates the fisheries effort among the EU member countries from 2003 to 2015.

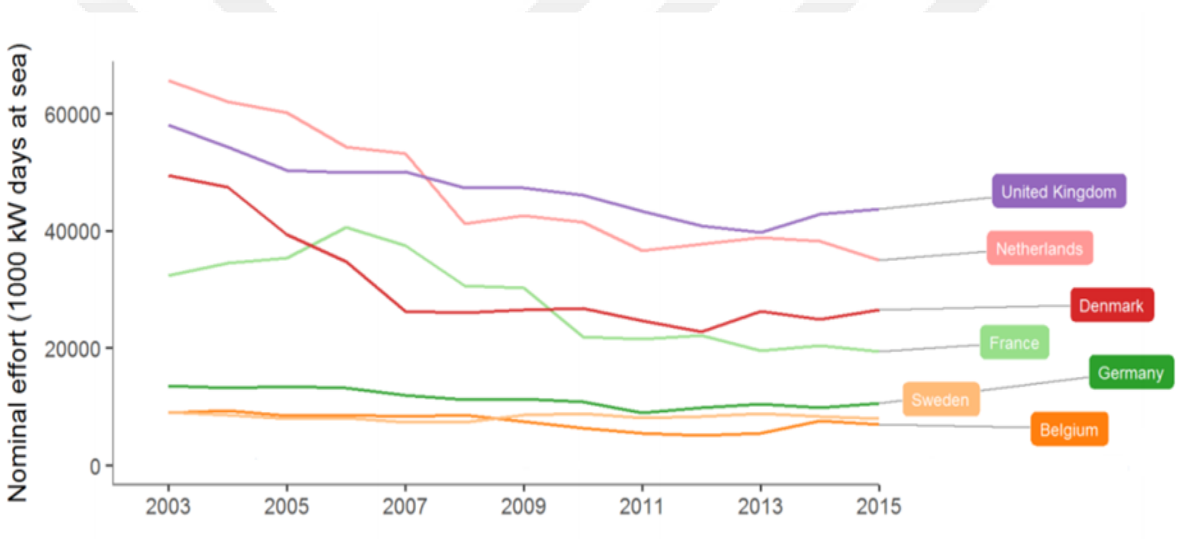

Figure 2- 7: The North Sea (EU members) fisheries effort (thousand kW days at sea) between 2003 and 2015 (Ices.dk, 2018)

2.3. Summary

Geographic Information Systems (GIS) is developing gradually for the last 3 decades all over the world. Almost every sector is using this technology because produced maps can be introduced too many things instead of thousands of words and also produced maps are visual it makes easier to understand the subject. This is also valid for the fisheries sector because the largest proportion belongs to aquatic ecosystems almost with 70% rate, because of this GIS is an essential tool for fisheries. To determine fish species locations and where are the specific areas for fishing can be identified easily by this way.

Marine Spatial Planning (MSP) is very essential for utilize the seasonal areas. By this way, Marine Protected Areas (MPAs) can be determined. Nursery grounds, spawning locations for fisheries are determined with this. MSP contributes the natural resources efficiently using (fishing, oil-gas, shipping, recreation, touristic areas i.e.). MSP is supported by governments with legislations.

The North Sea is a very plentiful area for fisheries, 8 counties have a boundary with the North Sea, the largest boundary belong to the UK (Scotland and England) and following this Norway. Nearly 17 species are commercially important for fisheries. Catching methods (trawls, dredge, pot, i.e.), fish categories (pelagic, benthic, demersal, i.e.) are also worth to mention.

Sustainability is a very important tool for every sector, especially fisheries. To contribute the sustainability Marine Spatial Planning (MSP) is necessary. Marine Protected Areas (MPAs) are very essential to determine spawning areas or nursery locations for fishing. The North Sea is one of the extremely important fisheries areas in the world. Commercially important fisheries species sustainability depends on MSP and MPAs. Geographic Information System (GIS) makes easier to understand the circumstances with produces maps. Produced efficient maps indicate useful knowledge for stakeholders, governments, local communities and researchers. GIS in fisheries also makes beneficial contributions for future planning, such as stock control.

2.4. Aims and Objective

The general aim to focus on GIS, in this paper, to present commercially important fisheries locations determination in the North Sea. GIS is an efficient tool for producing maps. This study contributes to exploring future developments GIS in fisheries. Marine Protected Areas (MPAs) and Marine Spatial Planning (MSP) contribution in the North Sea.

By using GIS, it is expected to answer to the following questions. The reason behind asking these research questions is to explore determinations for fisheries in the current management plan.

- Which locations for efficient to find pelagic, benthic or demersal species in the North Sea?
- Which species are commercially important for fisheries and where the species can be found easily in The North Sea?
- Where are the Marine Protected Areas (MPAs) in the North Sea?

Chapter 3

3. Methodology

In this study, measurement values, bottom trawl abundances catch records for 21commercially important fish species in the North Sea region in 2017.

The values obtained are mapped with the help of GIS program ArcMap 10. 6 version. The values are classified in the map drawing and the values in this class range are plotted according to their sizes. Based on this plot, the spatial distribution of fish species is evaluated.

First of all, ArcMap software programme was opened and selected view, data frame properties below the Figure 3.1 indicates that.

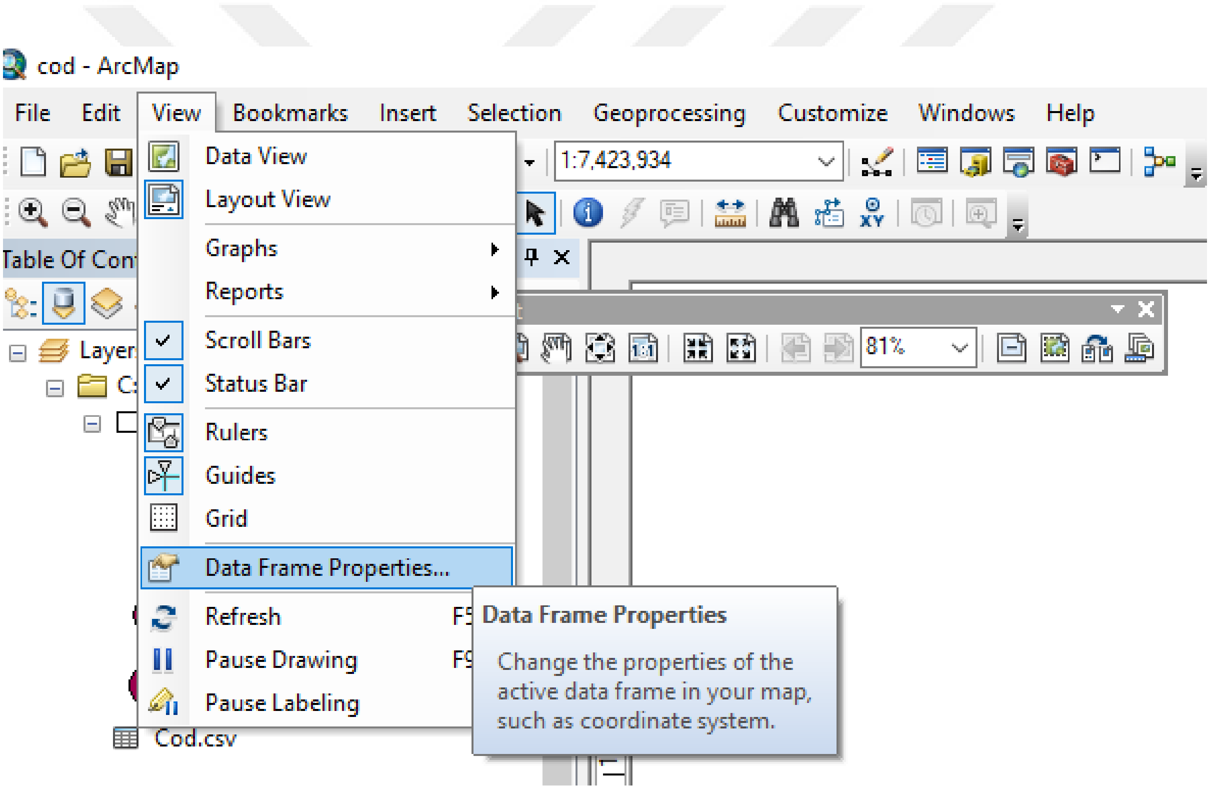

Figure 3- 1: ArcMap software programmes first step

And then, WGS 1984 was selected as a coordinate system. WGS is determined with World Geodetic System.

WGS84 is one of the positioning methods used by the Global Positioning Array. WGS84 consists of a three-dimensional Cartesian station matrix and associated ellipsoid. WGS84 locations are defined either as X-Y-Z cartesian locations or as latitude, longitude, and ellipsoidal height locations. The middle of the earth mass was taken as the middle of this string.

The positions of the maps of the vehicle navigation system currently used in automobiles are stored in the memory of the device as WGS84.

Gravimetry data orientation, the latest version, WGS 84 (4326, alias WGS 1984, EPSG), which was founded in 1984 and passed on in 2004, is the latest version. The previous drafts are WGS 72, WGS 66 and WGS 60. The reference coordinate system used by the WGS 84 Global Positioning System.

Below the Figure 3-2 shows how to select WGS 1984.

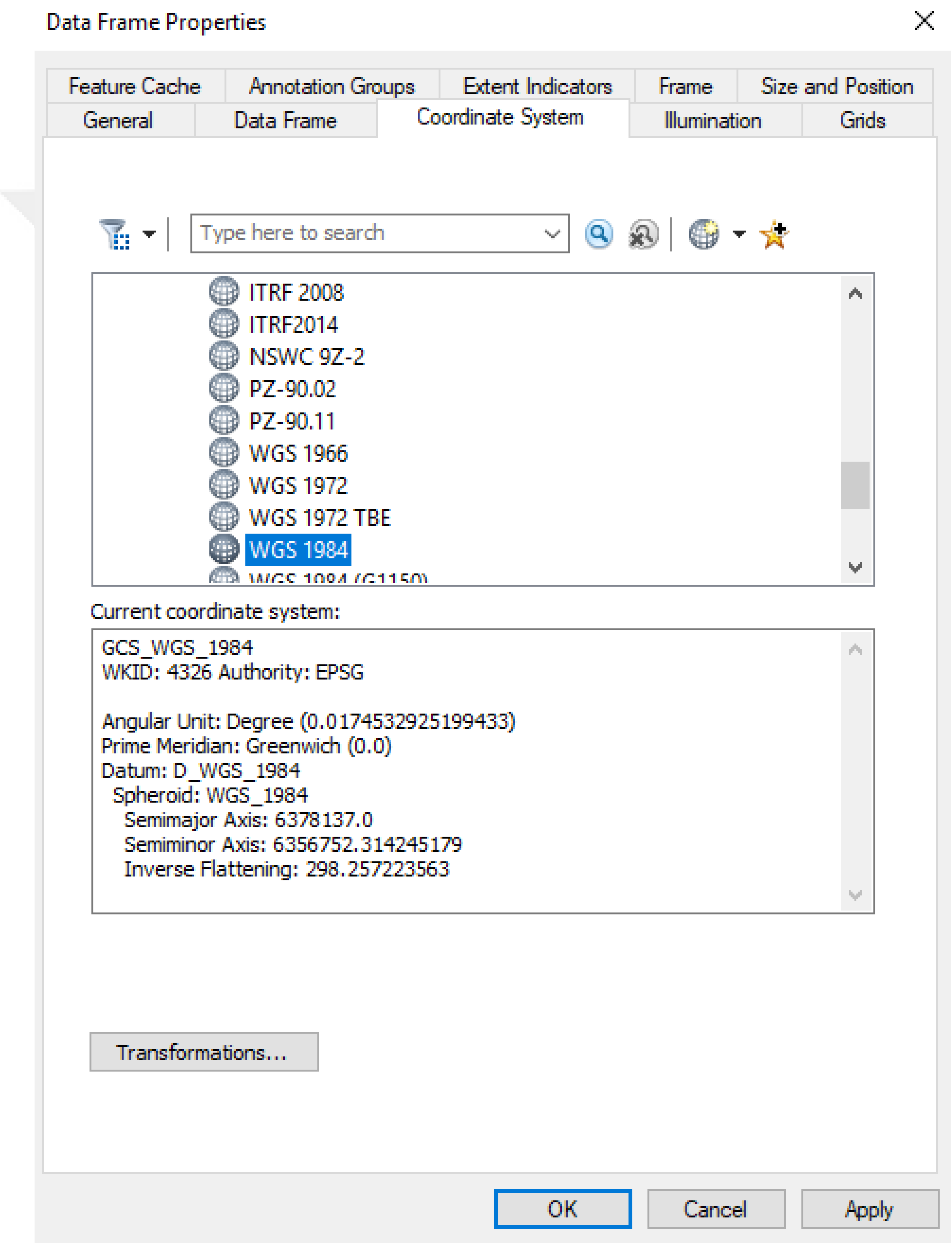

Figure 3- 2: WGS 1984 selection on the ArcGIS software programme

The world map downloaded, and the North Sea area selected. After the 8 countries boundaries are signed using the attribution table and coloured on the map. ICES fish map website is used for the data collection.

Below the Figure 3-3 shows the ICES website and how to download the data. For instance, the dataset was selected North Sea International Bottom Trawl Survey (Datatype/Survey), Parameter was selected Abundance number (number of specimens counted in trawl surveys, Species (TAXA) was selected for 21 different species usually common names such as herring, Matrix was selected all, year was selected for 2017 and lastly area was selected all in the North Sea. Displaying table demonstrates the wanted information and download options. ARCGIS 10,6 version uses csv files to input as data. After downloading the data put into the map and showed with the points abundances numbers.

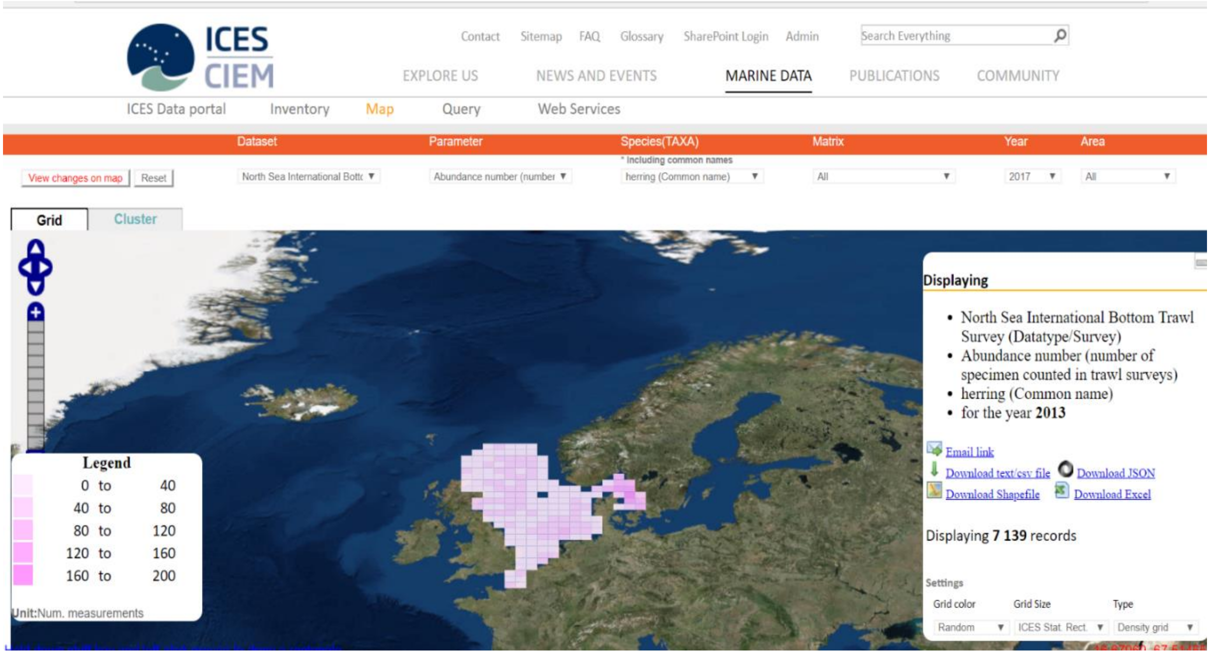

Figure 3- 3: ICES website use for downloading the fish species data

After the map base is established and the country boundaries are determined and coloured, the catch records amount and locations of the year 2017 are input for each species. For this, selected symbology show table and selected quantities then graduated symbols, then the NOINP (Number of individuals in the sub-sample is specified) is arranged as shown on the below Figure 3-4.

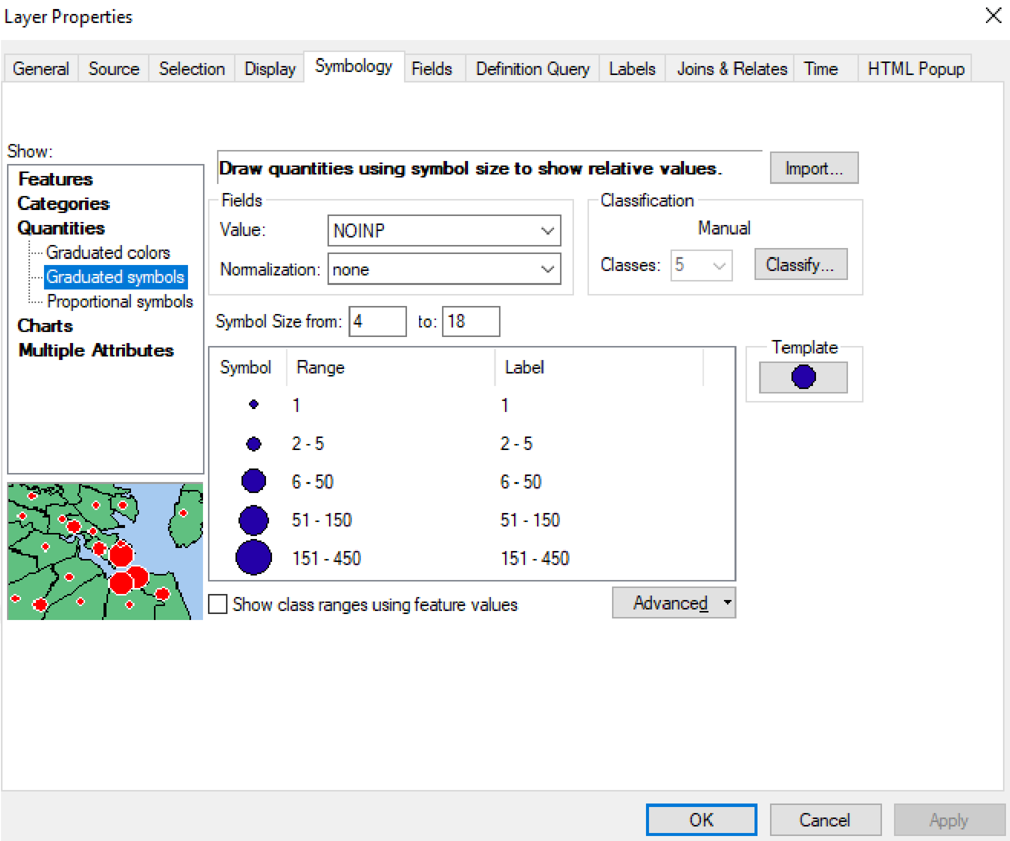

Figure 3- 4: NOINP arrangement on the map

After the maps produced in the ARCGIS software programme, the file is selected and clicked export map and saved as JPEG file. Maps measurements are occurred 1:6,300,000.

Chapter 4

4. Results

The produced maps in the ARCGIS software programme will be presented in this chapter. There are 21 different commercially important fisheries species with bottom trawl survey abundance numbers indicated on the maps in the North Sea in 2017.

4.1. Cod

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Cod (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 33665
- Depths (m) = 5-26

Below the map indicates that cod fish is one of the ubiquitous species, except Belgium, highest catch numbers belong to Denmark and Sweden, but the largest proportion belongs to the UK because of the largest boundary in the North Sea, and lastly, the least catch number belongs to France.

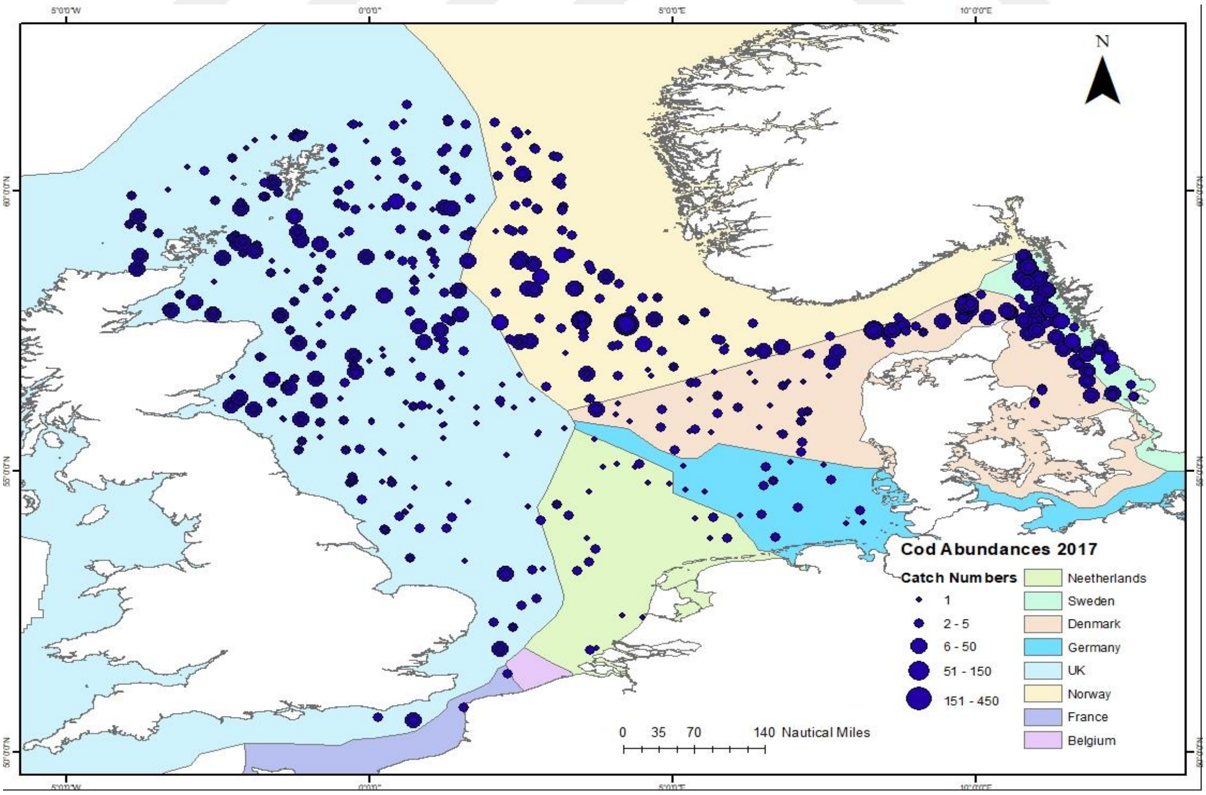

Figure 4- 1: Cod Abundances catch numbers in the North Sea in 2017

4.2. Decapoda

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Decapoda (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 19374
- Depths (m) = 5-27

These decapods consist of Edible Crab, Norway lobster, lobster and velvet swimming crab. Below the map Figure 4-2 shows the Decapoda abundance catch numbers distribution in the North Sea in 2017. Briefly, the largest proportion belongs to the UK and following this, Denmark, Sweden, Netherlands, Norway, Germany, France and Belgium.

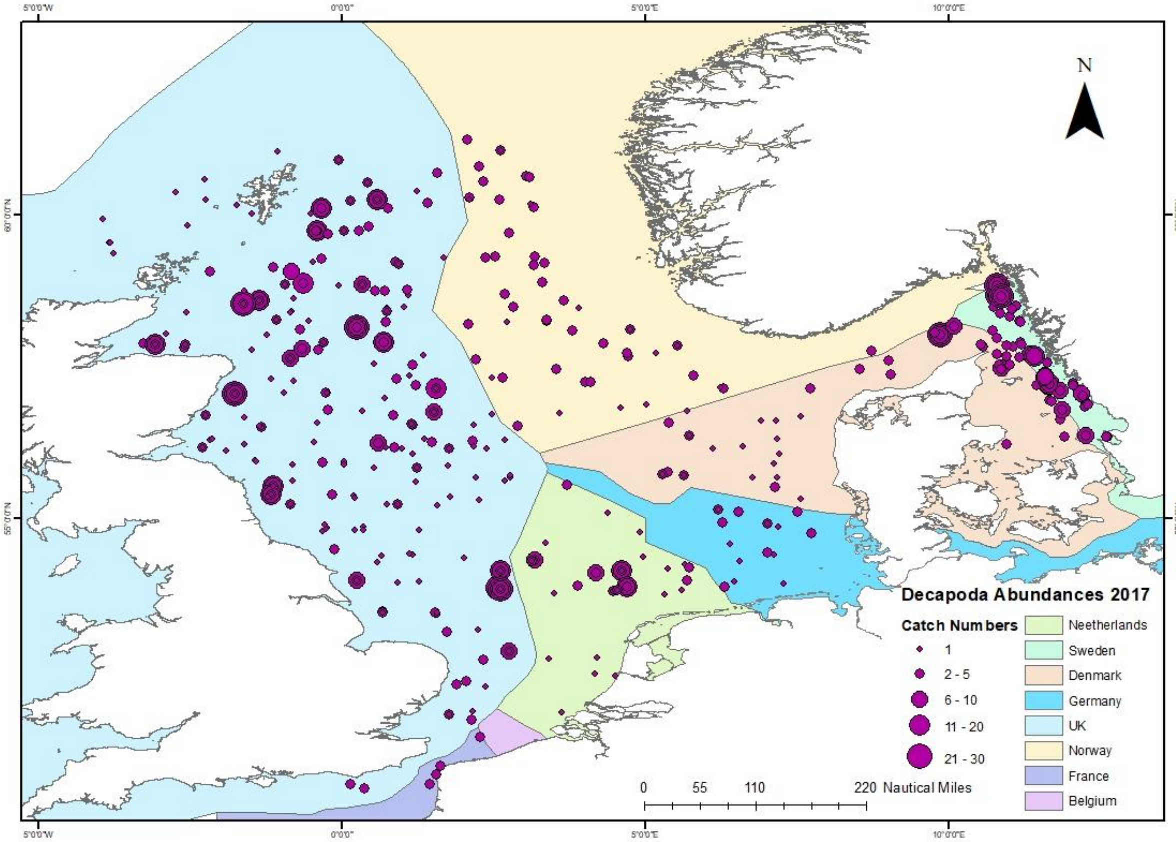

Figure 4- 2: Decapoda Abundances catch numbers in the North Sea in 2017

4.3. Edible Crab

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Edible Crab (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 955
- Depths (m) = 5-23

Below the map Figure 4-3 indicates the edible crab’s abundance in 2017 and catch numbers in the North Sea. Briefly, there are no catch numbers showed for Norway and Belgium. The highest catch record belongs to the UK and following this, Denmark, Sweden, Germany, Netherlands and lastly France.

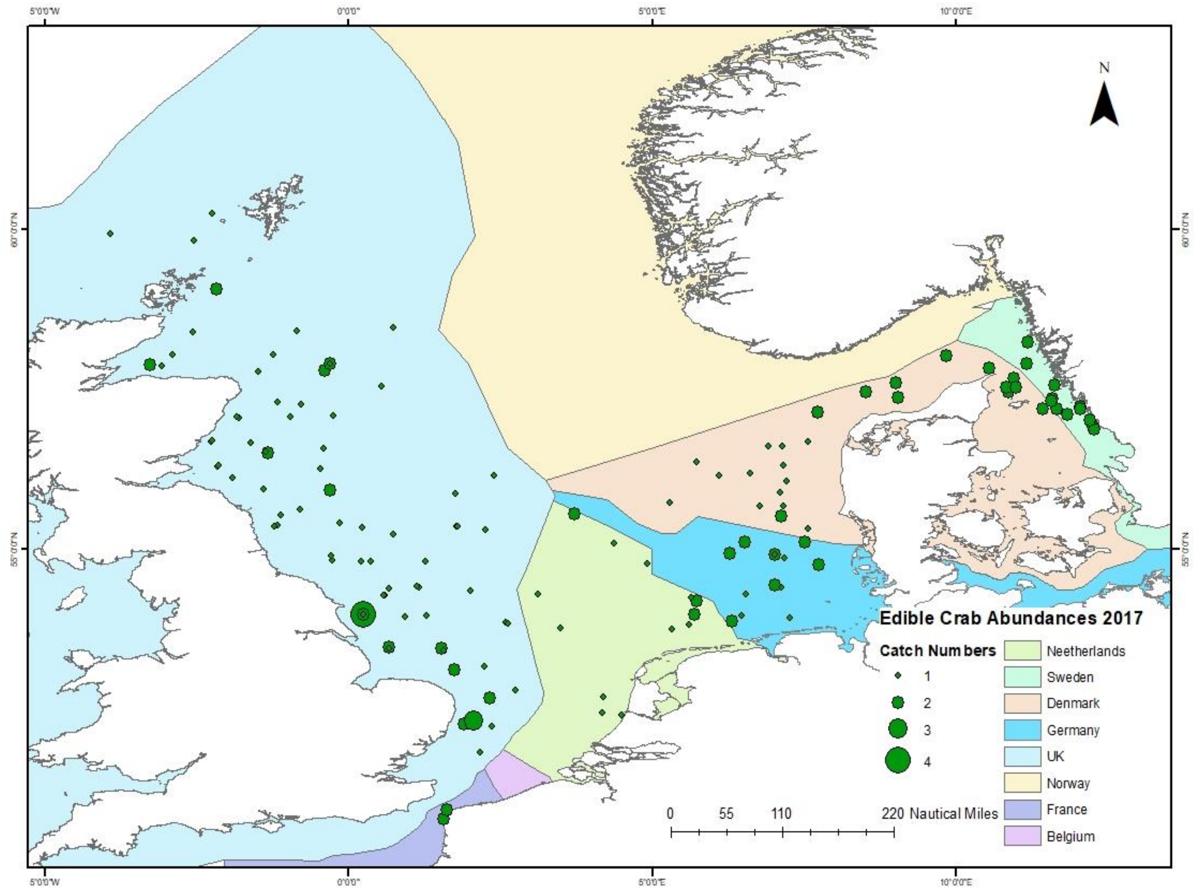

Figure 4- 3: Edible Crab Abundances catch numbers in the North Sea in 2017

4.4. Haddock

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Haddock (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 3522340
- Depths (m) = 7-28

Below the map Figure 4-4 shows the haddock abundance catch numbers record in 2017. There is no catch record belong to Germany, Belgium and France. The Netherlands has the least catch numbers and Denmark and Sweden almost same rate, and lastly, the highest record goes to the UK and secondly catch record goes to Norway.

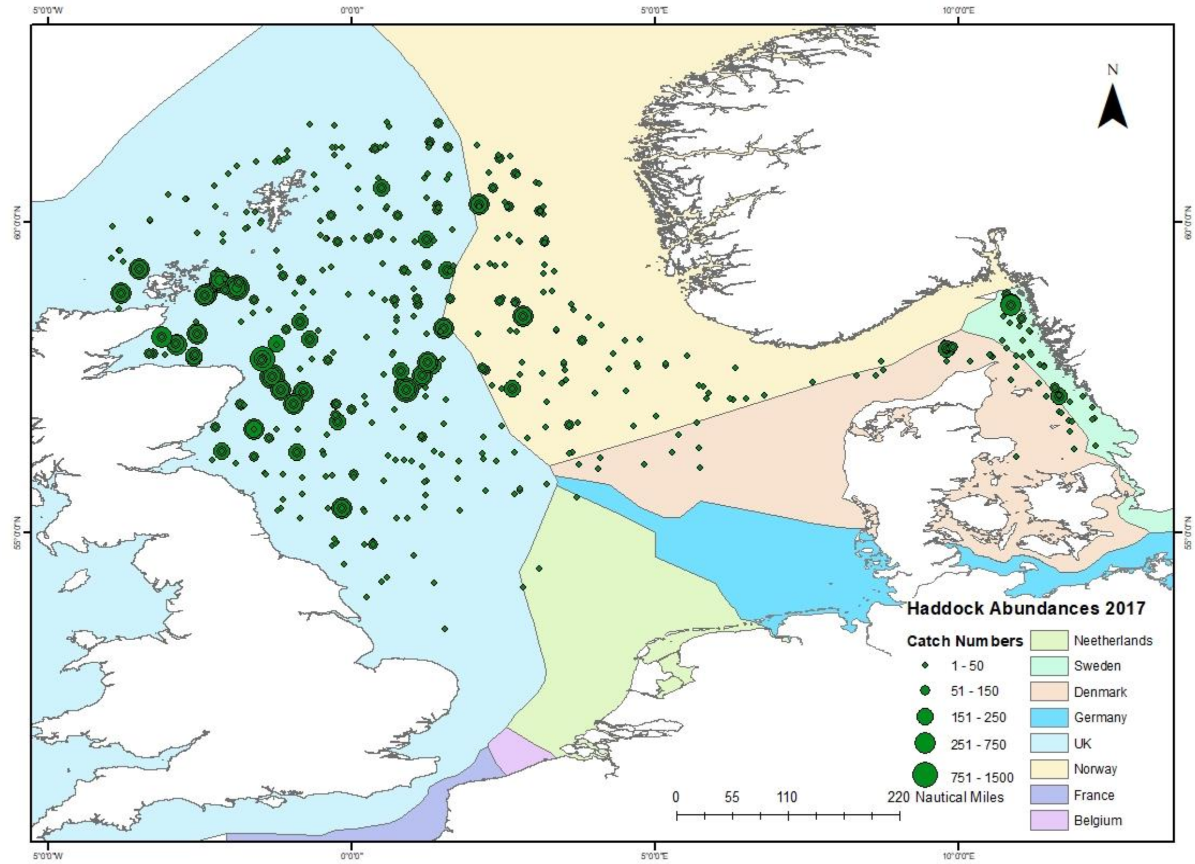

Figure 4- 4: Haddock Abundances catch numbers in the North Sea in 2017

4.5. Hake

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Hake (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 8549
- Depths (m) = 7-28

Below the map Figure 4-5 indicates the catch number for hake species in the North Sea. There is no catch record for France, Belgium and Netherlands, Germany's northwest side amount is a little and there is no record for the northeast side. Denmark catch record slightly more than Sweden and lastly the UK's east side has the largest proportion for the hake catch record and Norway follows it secondly.

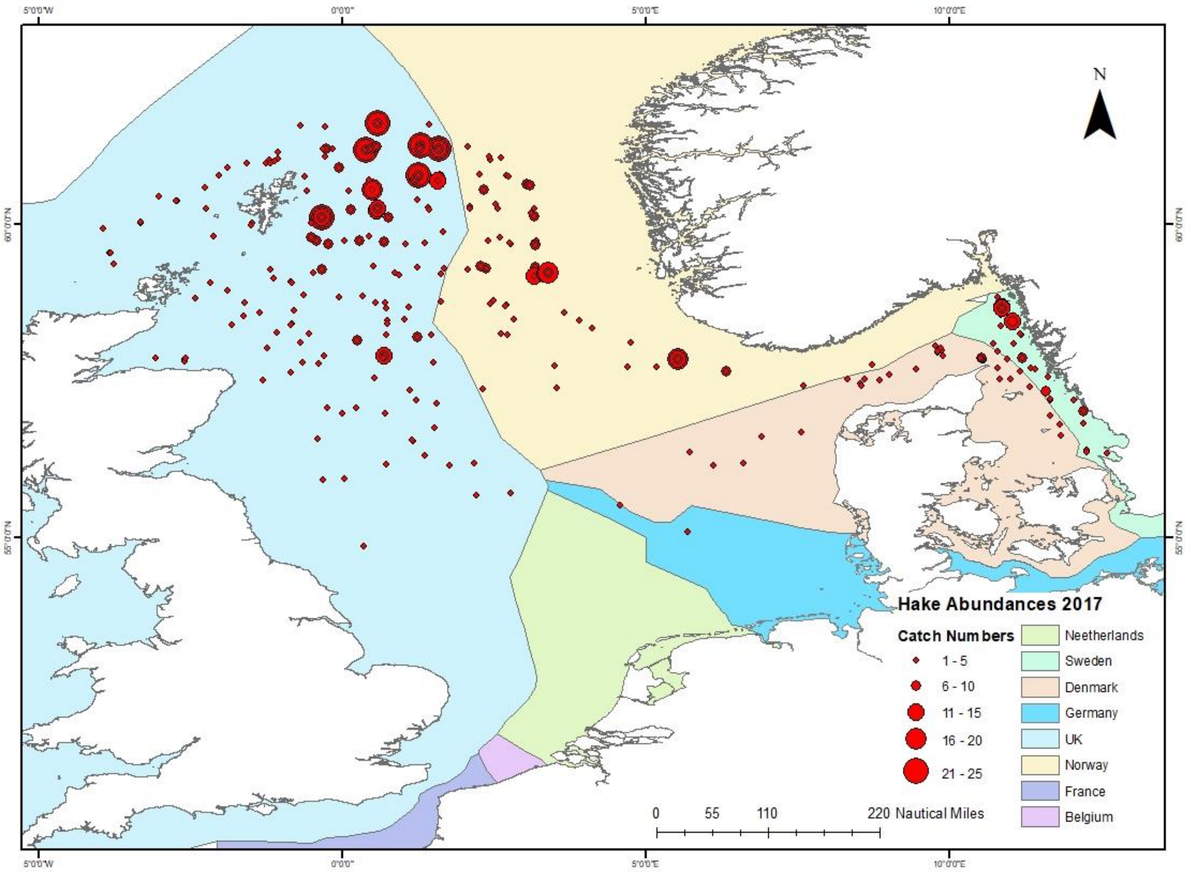

Figure 4- 5: Hake Abundances catch numbers in the North Sea in 2017

4.6. Halibut

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Halibut (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 26
- Depths (m) = 16-24

Below the map 4-6 shows the halibut catch number record in the North Sea in 2017. Two countries have catch record for this species which are Norway and the UK. Norway catch record is more than the UK. The other countries, which have a boundary in the North Sea (France, Belgium, Netherlands, Denmark, Sweden and Germany), are no record for this species.

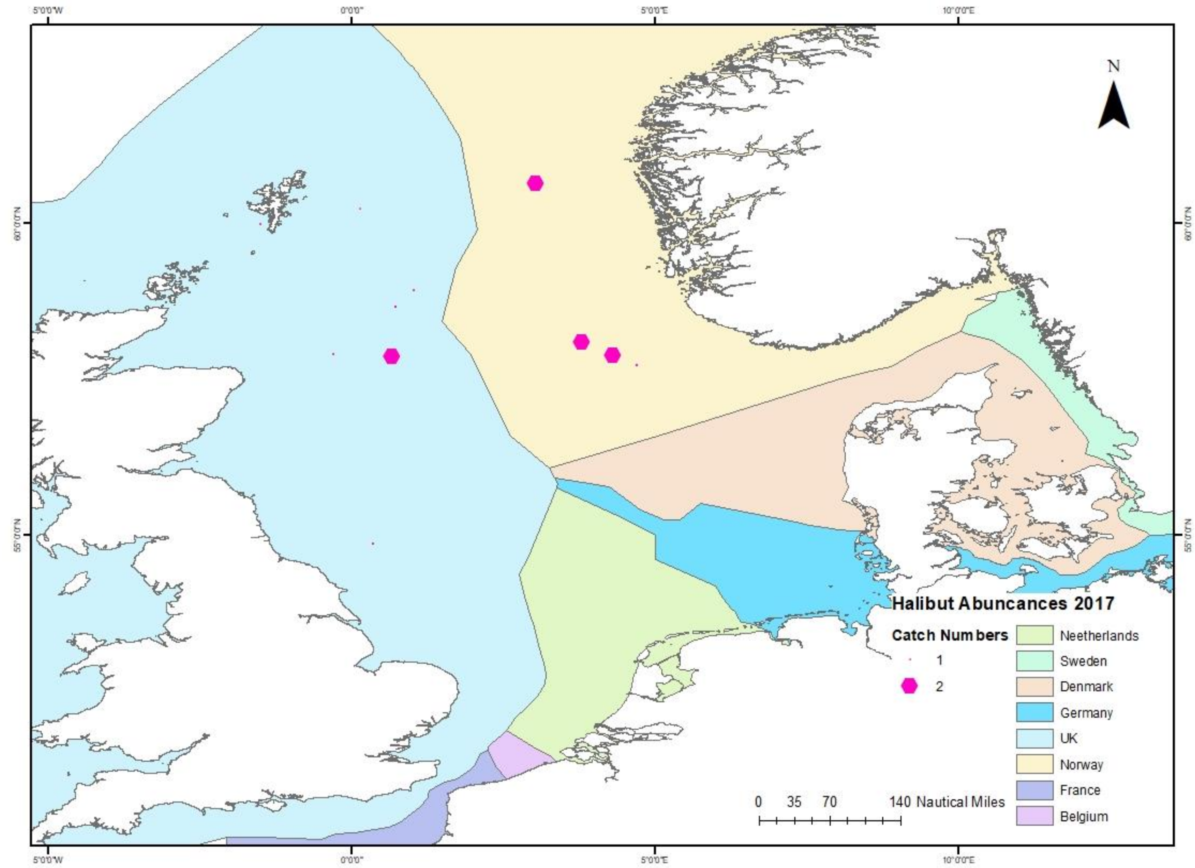

Figure 4- 6: Halibut Abundances catch numbers in the North Sea in 2017

4.7. Herring

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Herring (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 4323360
- Depths (m) = 4-28

Below the map Figure 4-7 shows the catch records of the herring species in the North Sea in 2017. Briefly, every country has the catch record for herring, this species ubiquitous one. The highest catch record to lowest catch record in order, the UK, Norway, Denmark, Sweden, Germany, Netherlands, France and lastly Belgium.

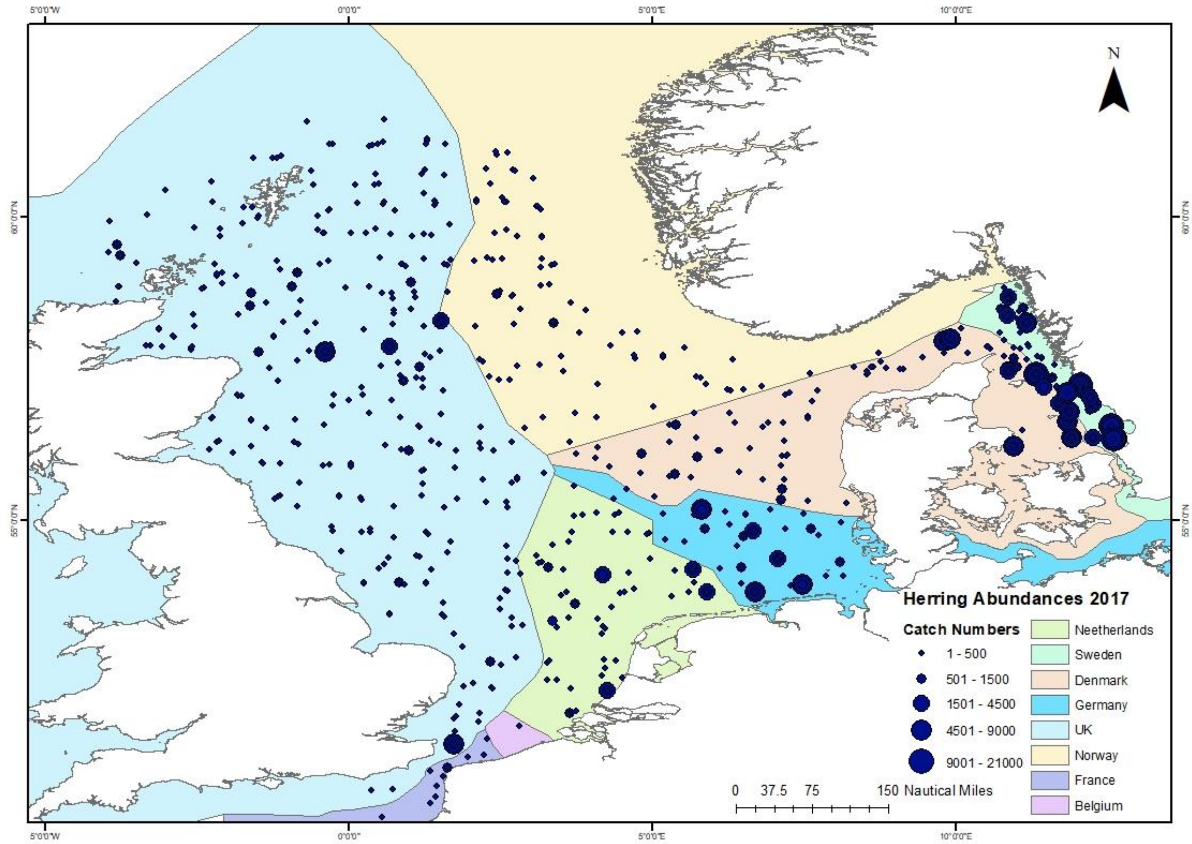

Figure 4- 7: Herring Abundances catch numbers in the North Sea in 2017

4.8. Lemonsole

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Lemonsole (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 19749
- Depths (m) = 4-24

Below the map Figure 4-8 shows the lemonsole species abundance catch record numbers in the North Sea in 2017. This species also ubiquitous one. The lowest catch records belong to Belgium and France. Germany and Denmark's east sides have almost no catch record numbers, but west sides have catch records. Generally, the highest catch number can be seen the middle of the North Sea part easily by this way the UK has the largest proportion with catch record.

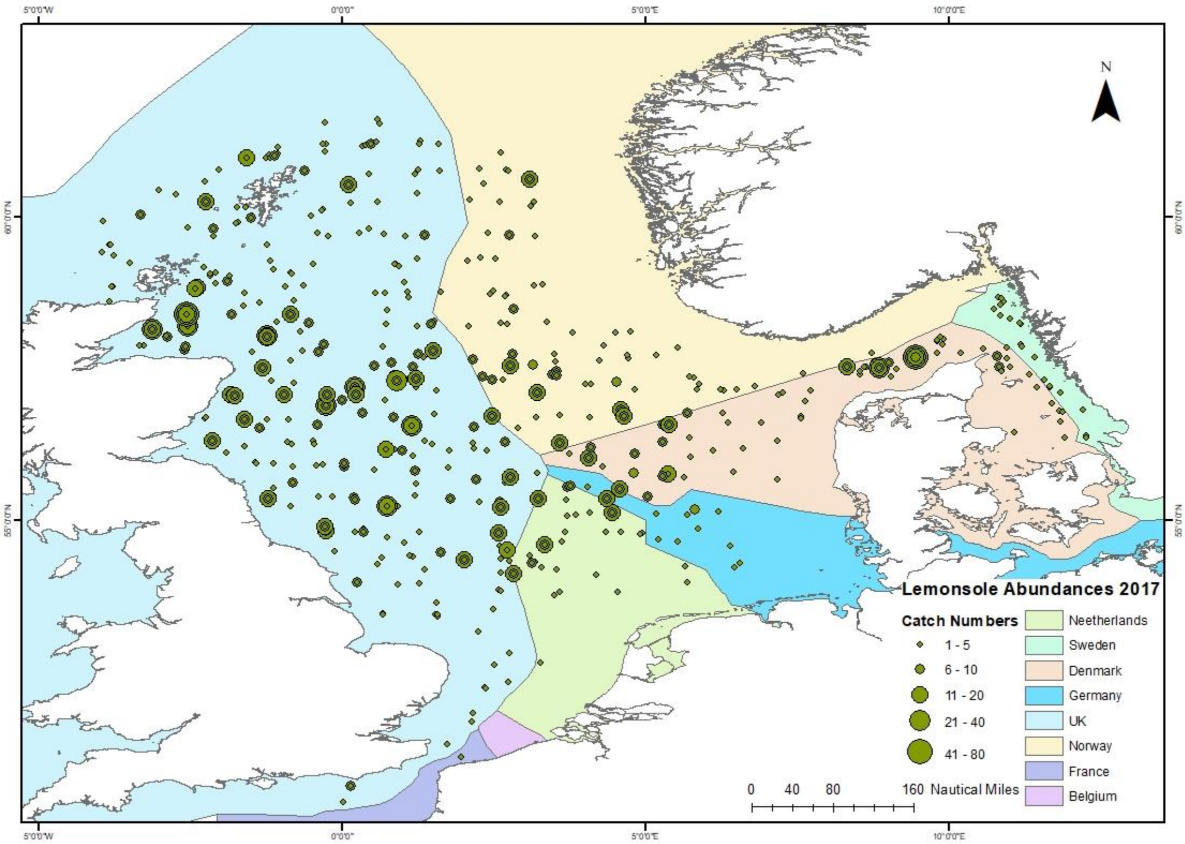

Figure 4- 8: Lemonsole Abundances catch numbers in the North Sea in 2017

4.9. Ling

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Ling (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 679
- Depths (m) = 5-23

Below the Figure 4-9 shows the ling abundance catch records distribution in the North Sea in 2017. Ling species can be found in the northern North Sea locations. Norway and the UK have the boundary of the northern North Sea areas, since the catch records belong to the UK and Norway and a little bit records also belong to Denmark and Sweden. The rest of the countries (France, Belgium, Netherlands and Germany) have no catch records in 2017.

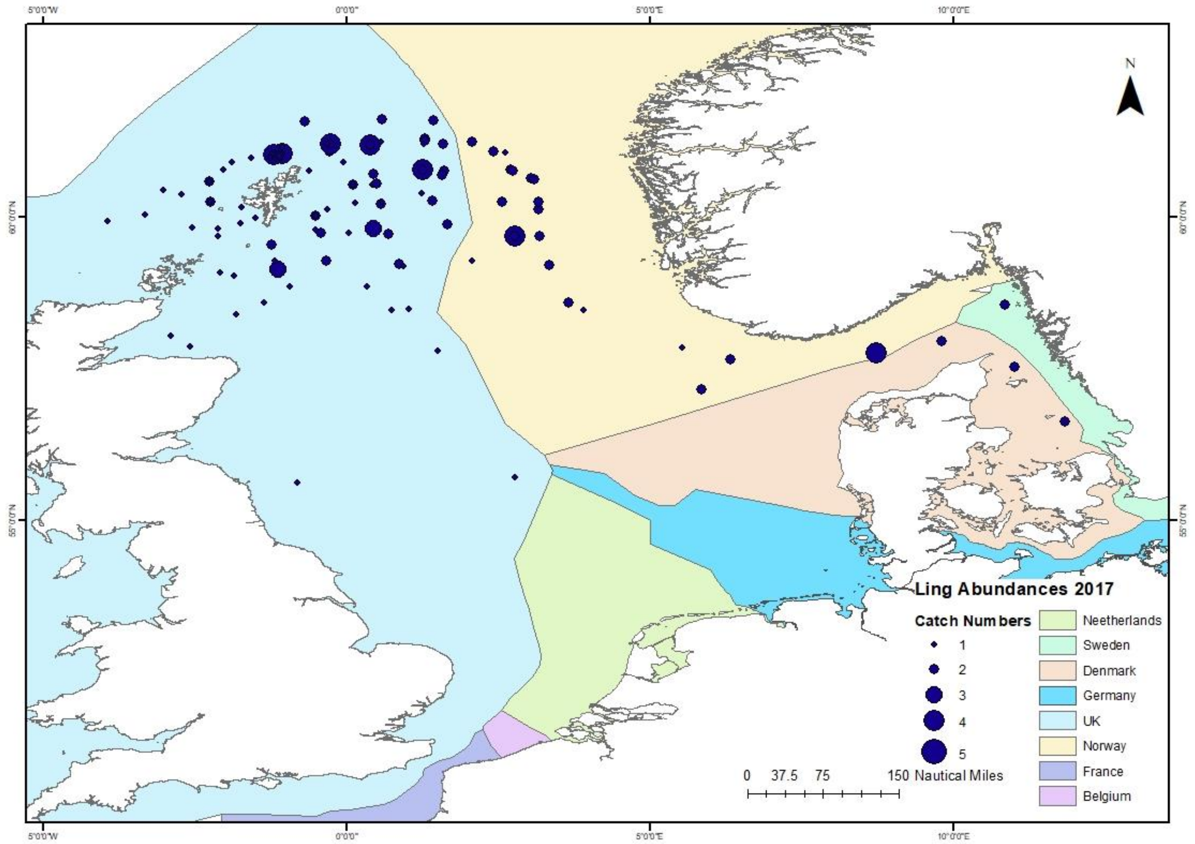

Figure 4- 9: Ling Abundances catch numbers in the North Sea in 2017

4.10. Mackerel

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Decapoda (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 579140
- Depths (m) = 5-26

Below the map Figure 4-10 shows the mackerel abundance catch numbers record in the North Sea in 2017. Mackerel is also one of the ubiquitous species can be found almost every location, except from Denmark and Germany's east sides. The largest catch record belongs to the UK and Norway. The lowest catch record belongs to Belgium, because of the least boundary in the North Sea area.

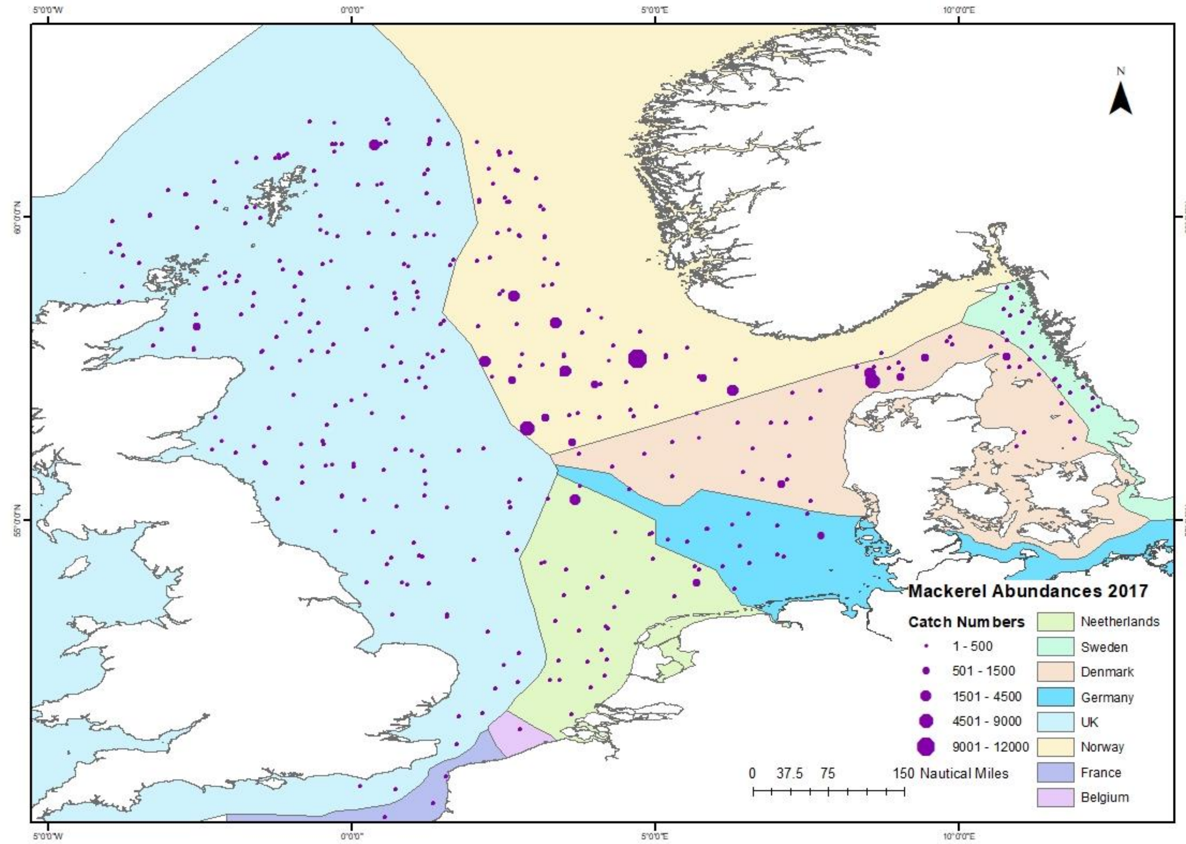

Figure 4- 10: Mackerel Abundances catch numbers in the North Sea in 2017

4.11. Monkfish

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Decapoda (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 1003
- Depths (m) = 11-26

Below the Figure 4-11 shows the monkfish abundance catch number records in the North Sea in 2017. Briefly monkfish species can be found northern North Sea locations plentifully since Norway and the UK have the largest proportions for the catch records. Denmark and Sweden also have the catch numbers records, but this rate is so low. France, Belgium, Netherlands and Germany have no records for monkfish in 2017.

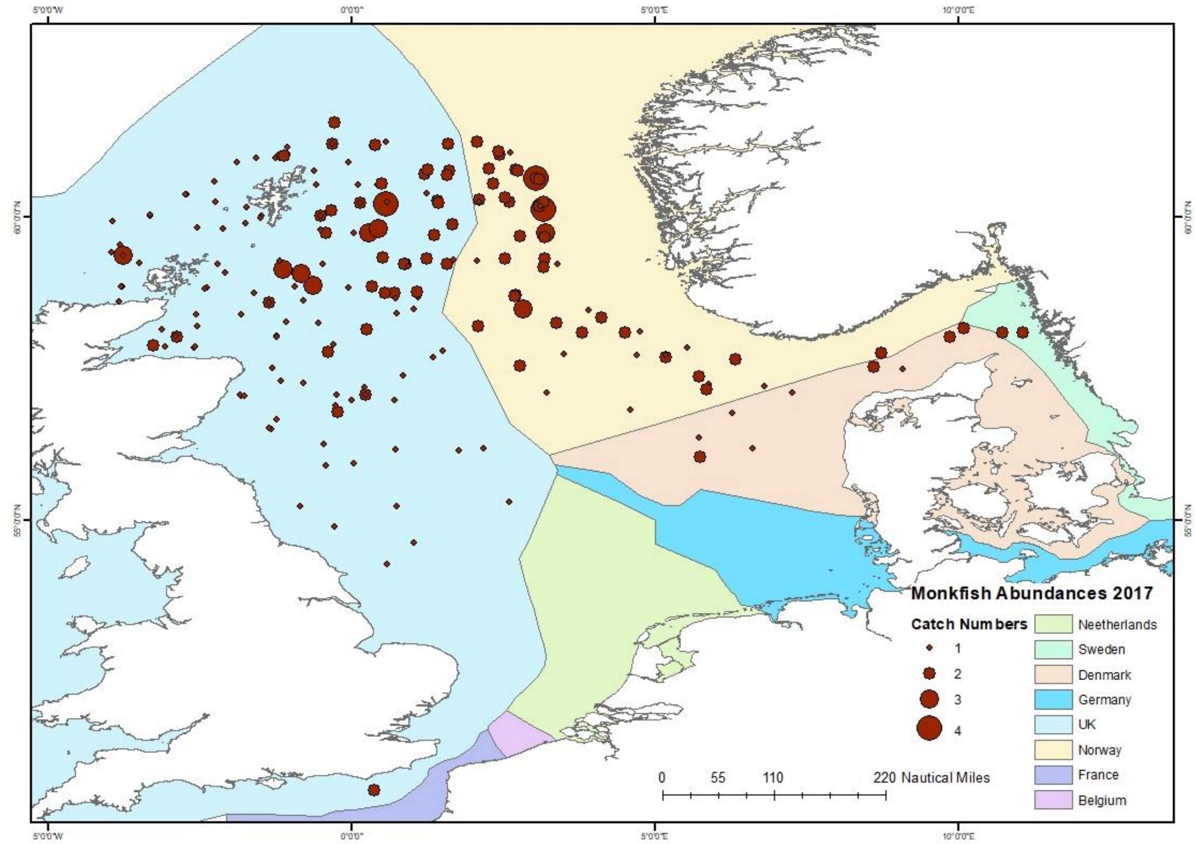

Figure 4- 11: Monkfish Abundances catch numbers in the North Sea in 2017

4.12. Norway Lobster

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Norway Lobster (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 16618
- Depths (m) = 6-26

Below the map Figure 4-12 indicates the Norway lobster abundance catch numbers record distribution in the North Sea in 2017. At first glance, Belgium and France have no catch numbers record for this species and Denmark and Germany's southeast locations have no catch records in 2017. The largest proportion belongs to the UK and following this Sweden, Denmark, Netherlands, Norway and Germany.

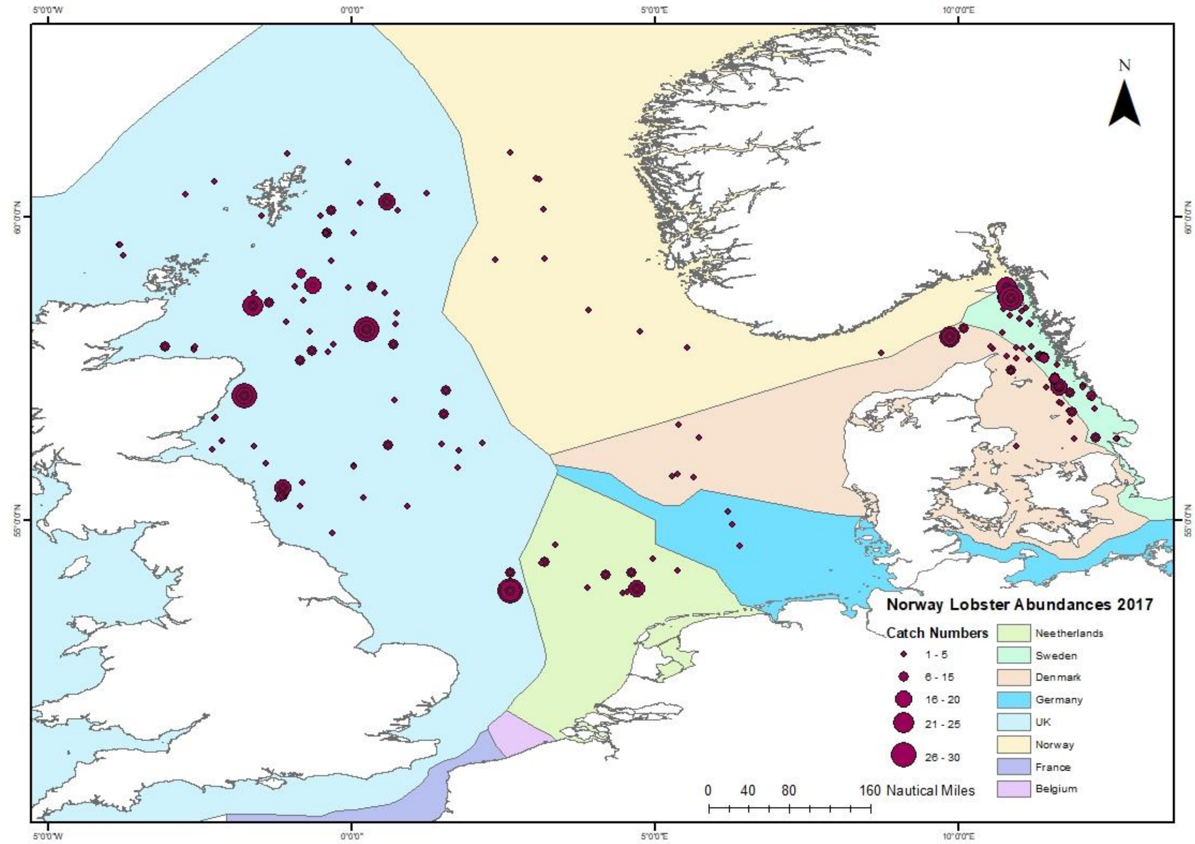

Figure 4- 12: Norway Lobster Abundances catch numbers in the North Sea in 2017

4.13. Norway Pout

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Norway Pout (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 3857942
- Depths (m) = 9-28

Below the map Figure 4-13 shows the Norway pout abundance catch records in the North Sea in 2017. Norway pout catch numbers are generally distributed northern North Sea locations. Since the UK and Norway have the largest proportion catch records in 2017. Norway has offshore fisheries zones and catches abundance numbers records comes from the offshore areas. Sweden and Denmark nearly same catch abundance records, Netherland has a little catch numbers record and lastly Germany, France and Belgium have no catch numbers records for Norway pout in the North Sea in 2017.

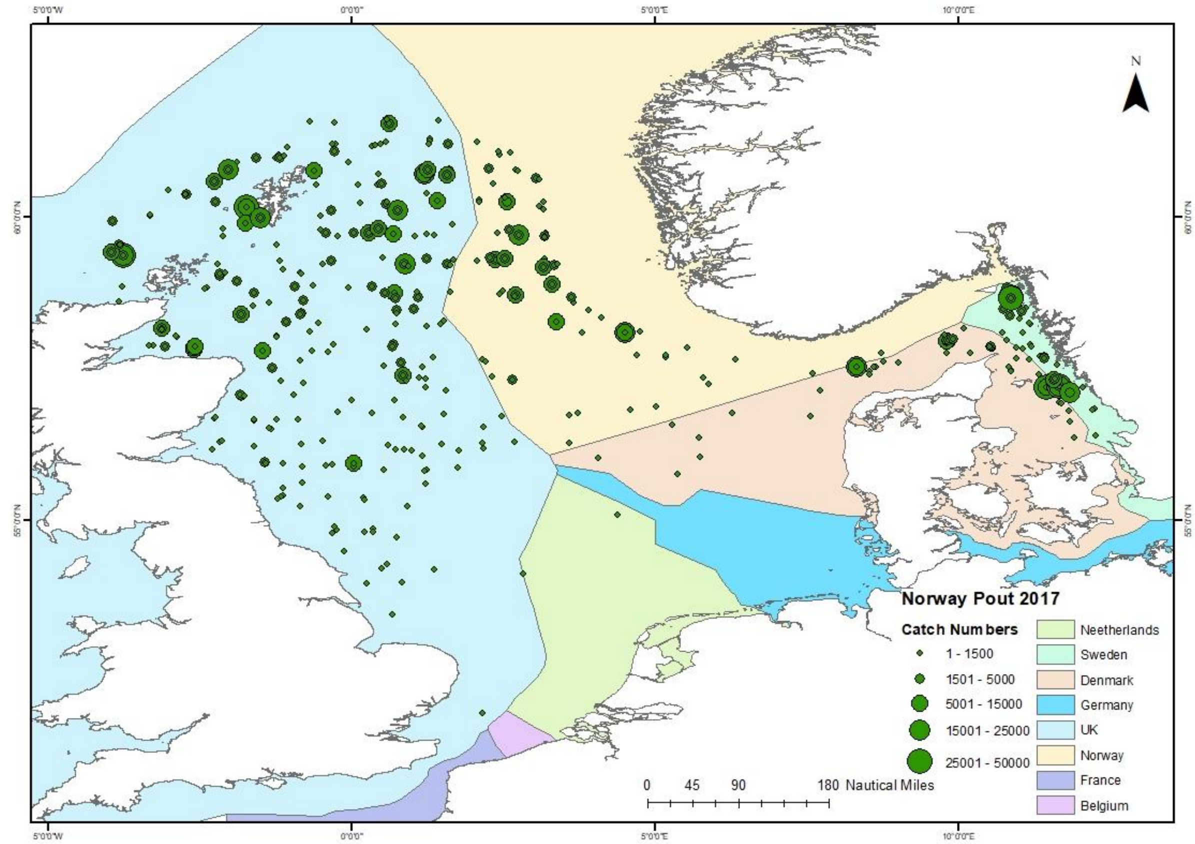

Figure 4- 13: Norway Pout Abundances catch numbers in the North Sea in 2017

4.14. Plaice

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Plaice (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 69192
- Depths (m) = 5-21

Below the map Figure 4-14 shows the plaice abundance catch number records in the North Sea in 2017. At first glance, plaice is one of the ubiquitous species in the North Sea, it can be found almost everywhere. Norway has only offshore catch records and the rest of the other countries have normally distribution catch rates according to their boundary.

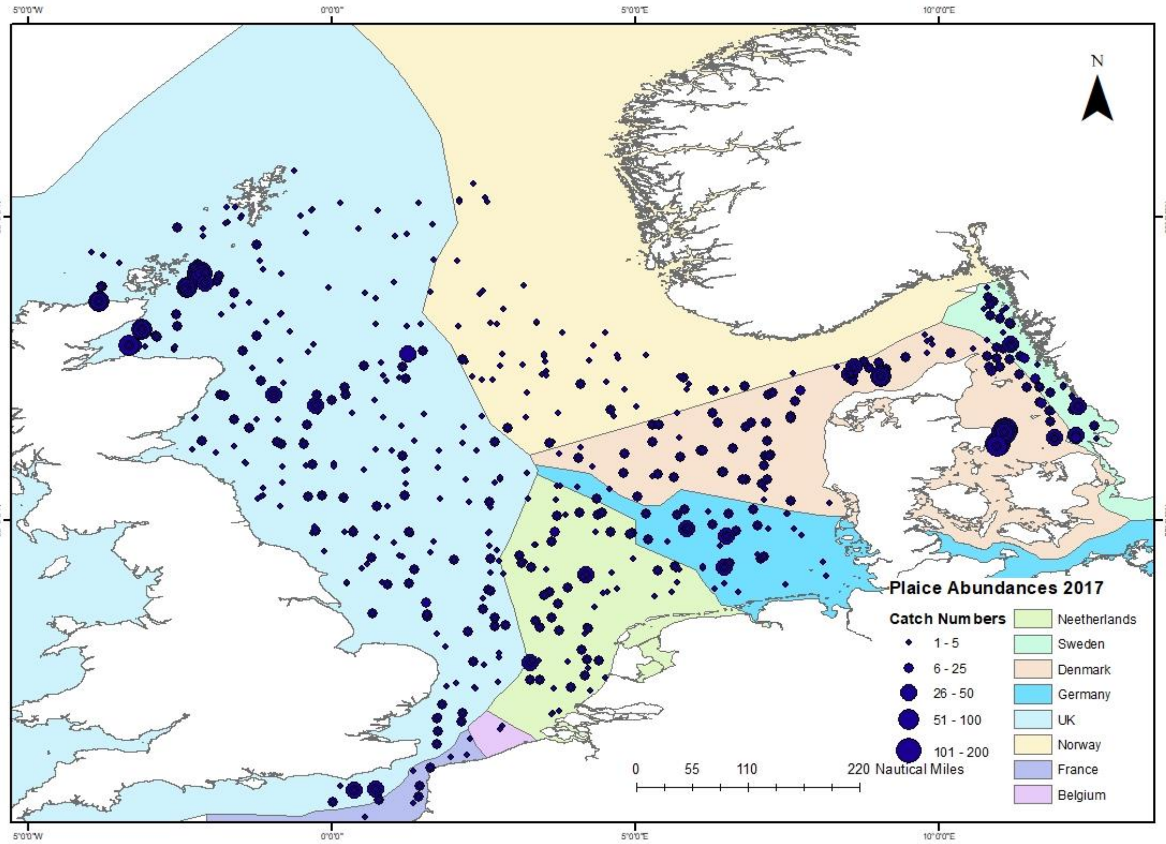

Figure 4- 14: Plaice Abundances catch numbers in the North Sea in 2017

4.15. Pollack

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Pollack (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 100
- Depths (m) = 15-28

Below the map Figure 4-15 shows the pollack abundances catch numbers record in the North Sea in 2017. This species has a little location to catch and this location belongs to Norway's offshore areas. The UK, Denmark and Sweden also have a small location for catch number records for pollack. There are no catch number records for pollack abundance in France, Belgium, Netherlands and Germany in 2017.

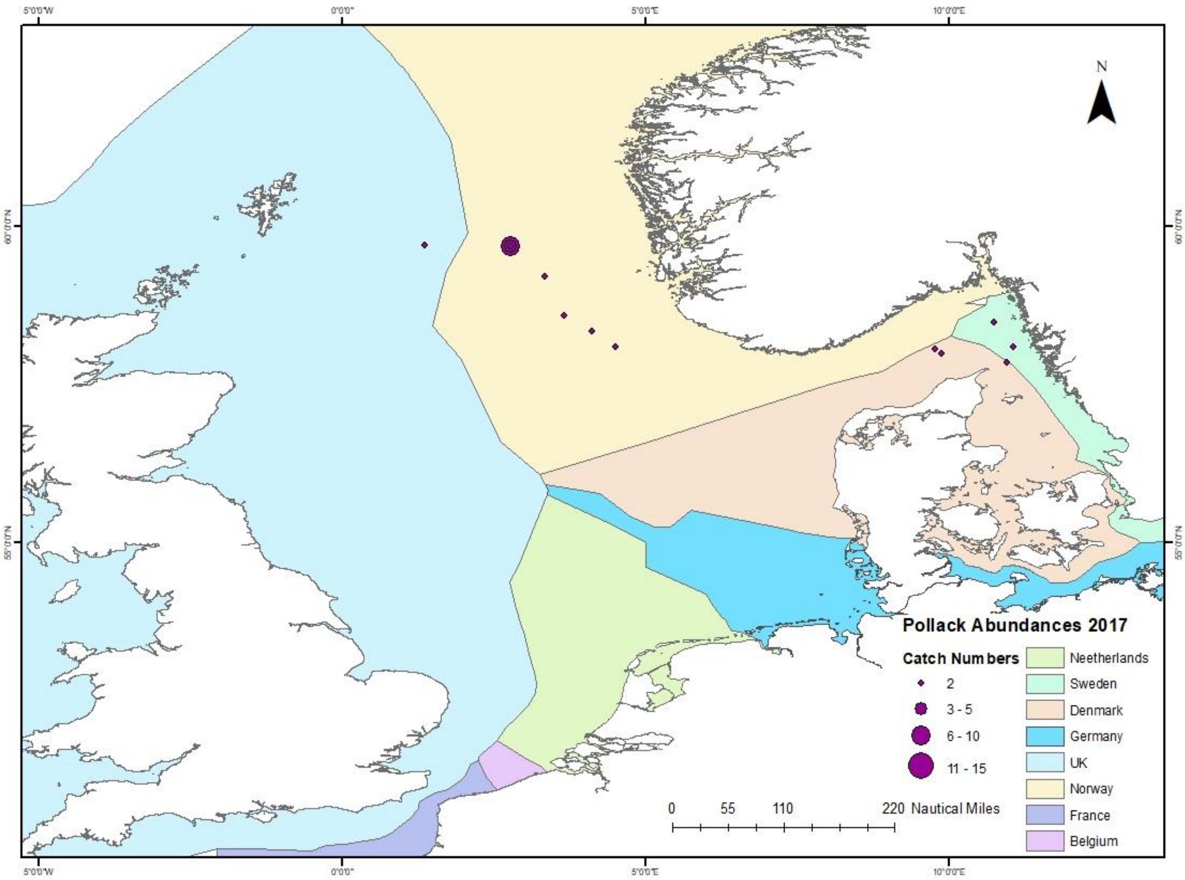

Figure 4- 15: Pollack Abundances catch numbers in the North Sea in 2017

4.16. Saithe

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Saithe (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 15174
- Depths (m) = 8-26

Below the map figure 4-16 indicates the saithe species abundance catch numbers record in the North Sea in 2017. Briefly, saithe species catch distribution belongs to northern locations. Since, the largest proportion for saithe catch number records goes to the UK and Norway. Following this Sweden, Denmark, Netherlands and France. Additionally, Belgium and Germany have no catch number records for saithe species in 2017.

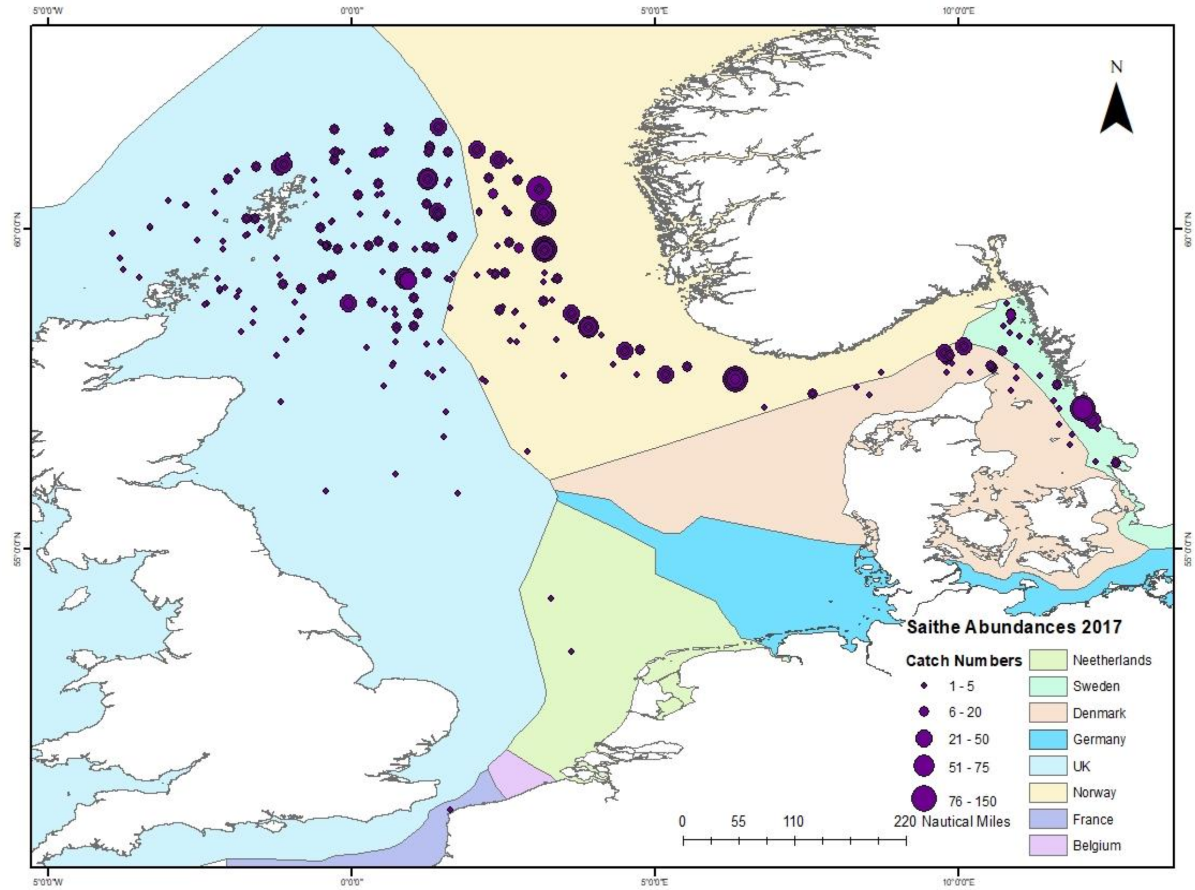

Figure 4- 16: Saithe Abundances catch numbers in the North Sea in 2017

4.17. Sandeel

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Sandeel (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 52
- Depths (m) = 5-13

Below the map Figure 4-17 shows the sand eel abundance catch numbers in the North Sea in 2017. Although, the largest boundaries belong to the UK and Norway, there are nearly no catch records for sand eel. The highest record belongs to the Netherlands and following this Denmark. Germany, Belgium and Sweden have no catch number record for sand eel abundance in 2017.

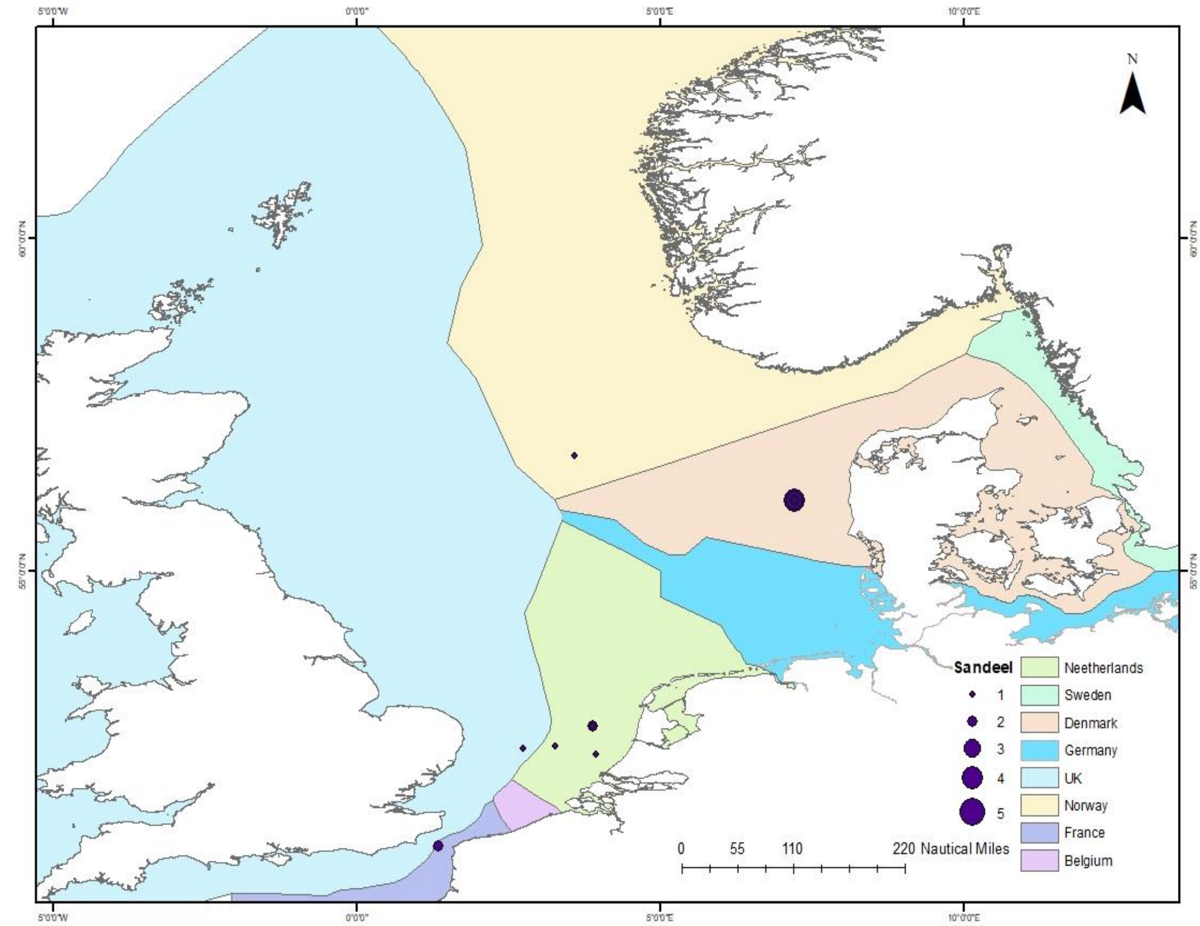

Figure 4- 17: Sandeel Abundances catch numbers in the North Sea in 2017

4.18. Scallop

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Scallop, *Pecten maximus* (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 41
- Depths (m) = 11-20

Below the map Figure 4-18 shows the scallop, especially *Pecten maximus* abundances catch records in the North Sea in 2017. The map shows clearly just the UK has the catch records and the locations closer to continental locations' middle to southern areas in the UK. The other countries have no records for scallop species.

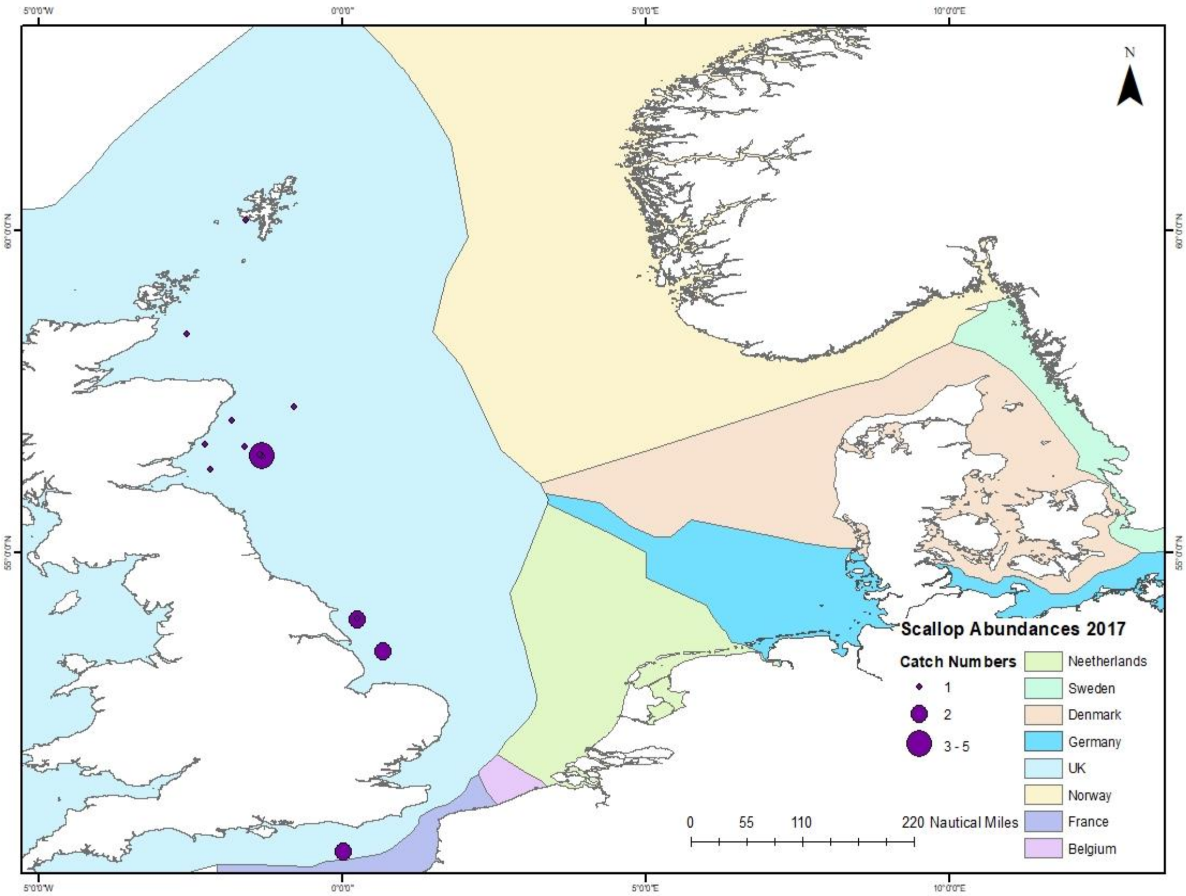

Figure 4- 18: Scallop Abundances catch numbers in the North Sea in 2017

4.19. Sole

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Sole (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 1159
- Depths (m) = 4-21

Below the map Figure 4-19 shows the sole abundance catch number record in the North Sea in 2017. Sole distributes the middle, southwest and south-east locations. Norway has no catch records, and Denmark and Germany's southeast locations have no catch records for sole species in 2017. The highest rate belongs to the UK's southern locations. Denmark is following the UK secondly and the Netherlands coming thirdly.

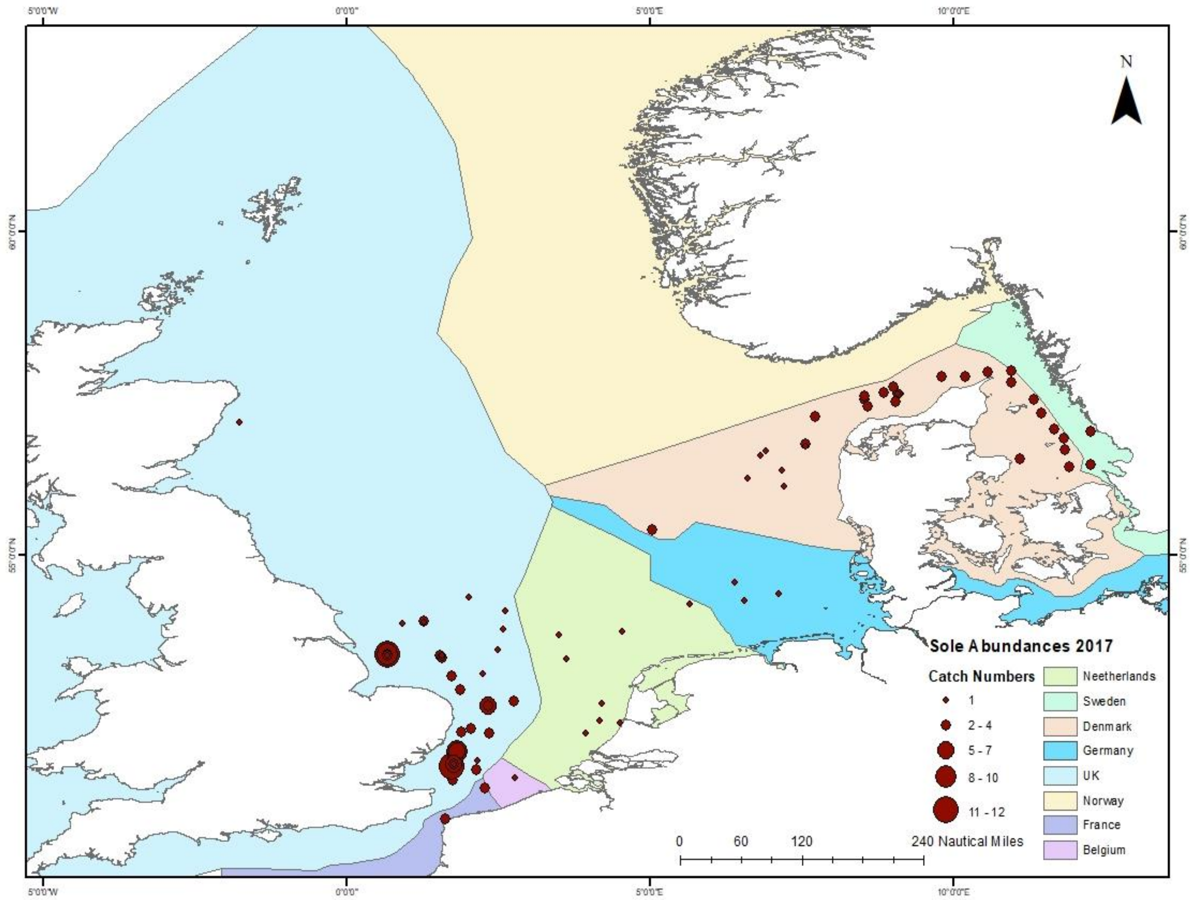

Figure 4- 19: Sole Abundances catch numbers in the North Sea in 2017

4.20. Sprat

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens counted in trawl surveys)
- Sprat (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 4779594
- Depths (m) = 4-20

Below the map Figure 4-20 shows the sprat abundance catch numbers record in the North Sea in 2017. Sprat species generally can be found in the middle and southern locations in the North Sea. Even though Norway has a very long location in the North Sea, Norway has a little bit sprat catch record in 2017. The largest catch number record belongs to the UK.

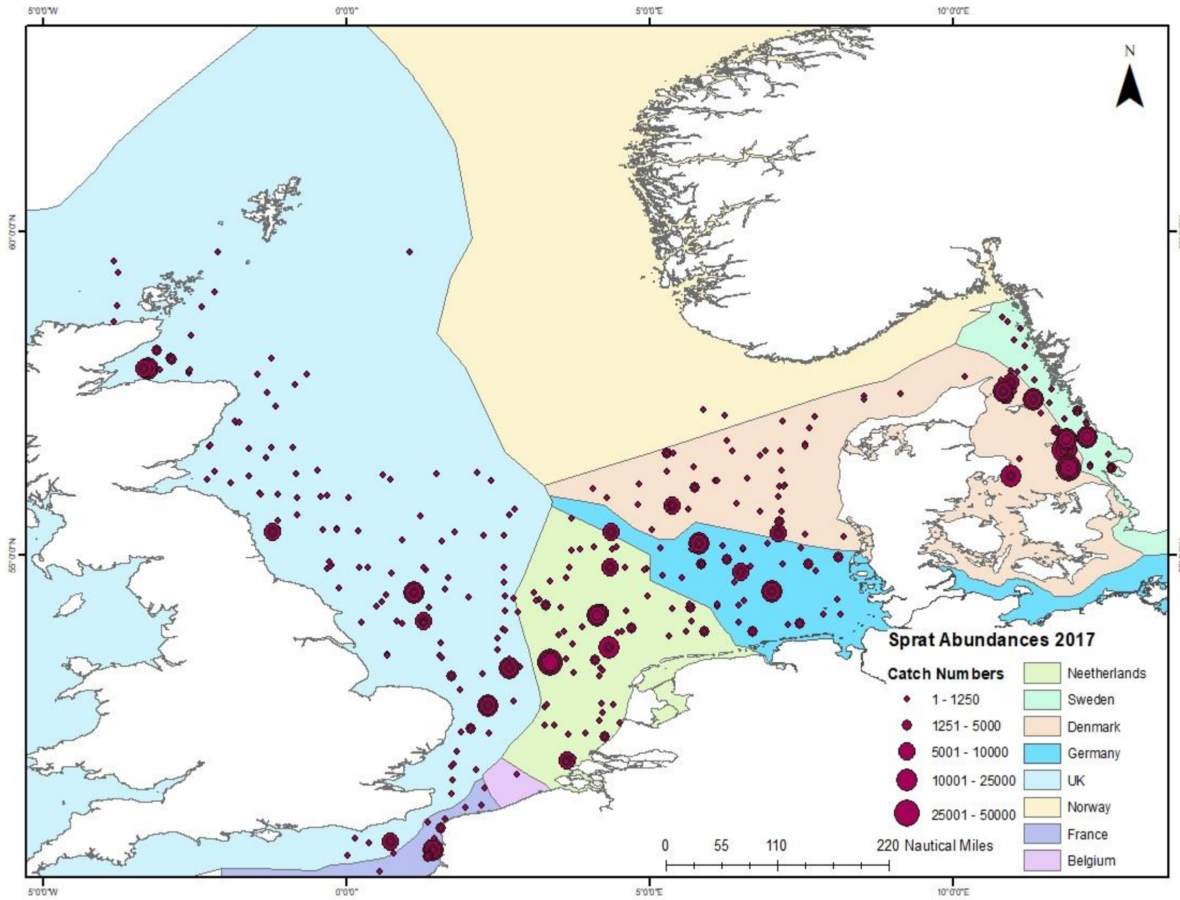

Figure 4- 20: Sprat Abundances catch numbers in the North Sea in 2017

4.21. Whiting

- North Sea International Bottom Trawl Survey (Datatype/Survey)
- Abundance number (number of specimens
- counted in trawl surveys)
- Whiting (Common name)
- for the year **2017**
- NOINP (Number of individuals in the sub-sample is specified) = 460059
- Depths (m) = 4-23

Below the map Figure 4-21 shows the whiting abundance catch numbers record in the North Sea in 2017. This species one of the plentiful ones and located almost everywhere in The North Sea. The highest catch record belongs to the UK. Although Sweden has a little location in the North Sea, Sweden's whiting catch record extremely significant among the other countries. Additionally, Norway's whiting abundance catch records looks offshore locations and Germany and Denmark's southeast locations almost have no catch records.

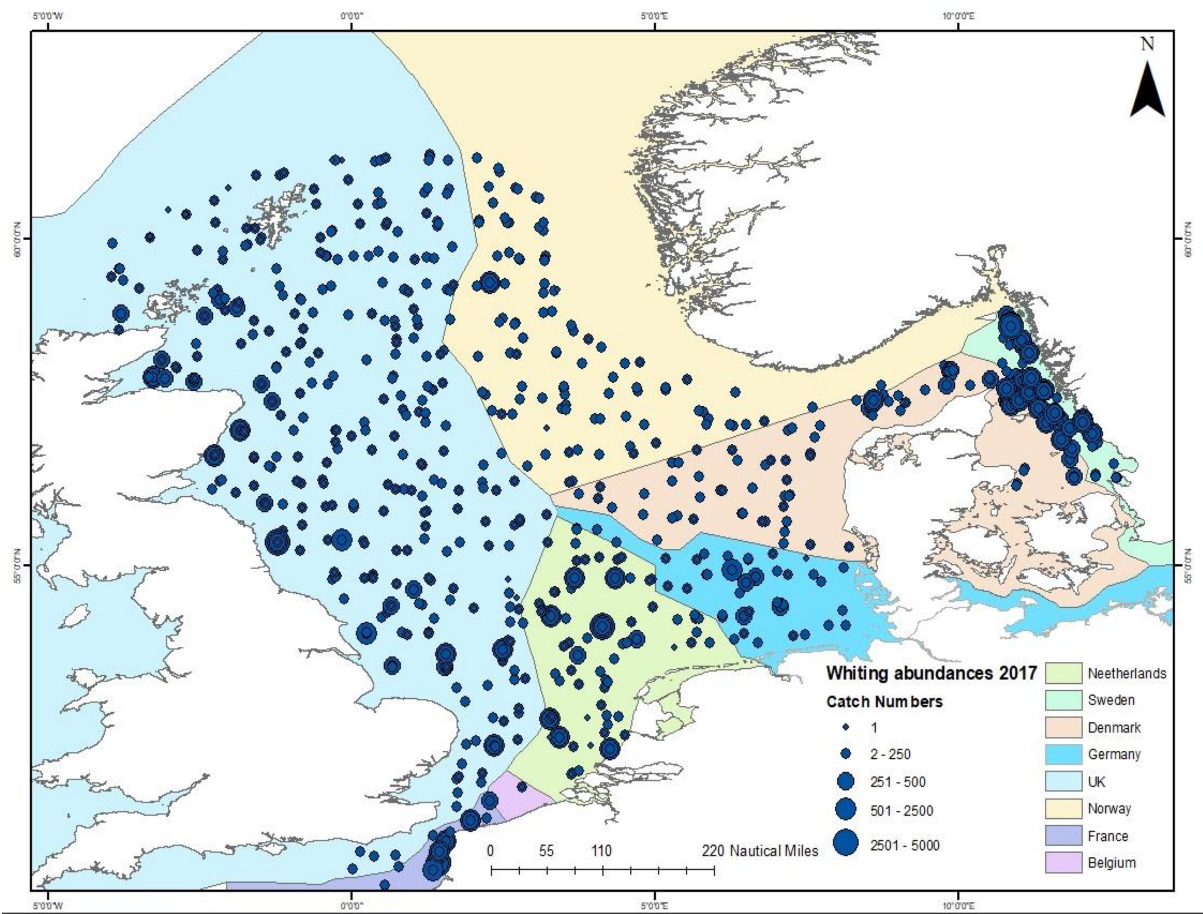

Figure 4- 21: Whiting Abundances catch numbers in the North Sea in 2017

Chapter 5

5. Discussions

Fisheries is one of the most significantly important commercial area all over the world. Increasing populations cause more necessities and because of this overexploitation cannot be unavoidable. Technological advances have both facilities positive and negative. Whilst new catching methods are being discovered, simultaneously it also causes eradicating some commercially important finfish species. Everything should be controlled by governments and non-governmental organisations. For these reasons Marine protected areas (MPA's) are very important for marine spatial planning (MSP).

Marine protection area (MPA) is a sea area in particular. Dedicated to the preservation and maintenance of biodiversity, and natural and related cultural resources legal or other effective means. MPAs include marine parks, nature reserves and locally reefs, management of marine areas that protect sea otter beds, wrecks, archaeological sites, tidal lagoons, salty wetlands, mudflats, mangroves, rock platforms, underwater areas deep in the water and on the seacoast, as well as open water (water column).

In 1988, the World Conservation Union (IUCN) General Parliament calls for international governments agencies and non-governmental community: Provide for protection, restoration, smart use, to understand and enjoy the maritime heritage world with the creation of a global representative the system of marine protected areas and in accordance with management principles World Conservation Strategy for human activities or the sea environment. There is a growing focus in many parts of the world and more MPA and better needs are usually appreciated management of coastal and marine environments.

Modern technology has increased its range of use, and maritime circles, access to supporting industries such as fisheries, tourism, aquaculture and development, but new forms of drugs from marine biological diversity Marine uses and users, unless sustainable ecosystems can be very threatening, can change and destroy the processes and resources they depend on. Existing management systems, productivity, biodiversity and ecosystems, marine ecosystems. The consequences of this failure; serious and extensive. The most obvious effect is seen long-term and widespread use marine resources for seafood. There is global catch of fish stable decline since 1989 and downward the trend is expected to continue. Marine biodiversity, ecosystems and resources threatened by the effects of reaching the sea from the sea, pollution with foodstuffs, chemicals and silt, and through altered river flows.

Marine protected areas help protect important habitats and representations of marine life and can help to restore and prevent the productivity of the oceans further deterioration. They are also scientific sites It can generate income through tourism and sustainable fishery.

Well-designed and managed MPAs play an important role for:

• conservation of biological diversity and representative samples of relevant ecosystems;

• maintaining critical areas for reproduction and growth of species;

• Protect sites directly with minimal human impact to help them get rid of other stresses, such as rising ocean temperatures

• preserving the settlement and growth areas for marine species in order to provide spillage in adjacent areas;

• Provide focus points for training on marine ecosystems and human interactions with them;

• Provision of lands for nature-based recreation and tourism; and

• Provision of uncontrolled or reference sites serving as the basis for scientific research and design evaluation of the management of other areas. The basic component of the ecosystem-based management of oceans (Environment.gov.au, 2018).

GIS (Geographic Information System) is very useful technology to indicate the knowledges, which are related to fisheries, with maps. Maps are extremely easy to understandable than lots of words. Maps can be use instead of too long sentences (Hersoug and Johnson 2012). Fish stocks, spawning locations, migration ways, water quality areas, pelagic, semi-pelagic, benthic and demersal species, countries annual catch amounts, which countries are declaring the catch rate and which countries are not declaring the catch rates…etc can be indicated by maps. Because of these reasons mapping should be developed with new methods.

Unfortunately, studies on GIS in fisheries are very limited, but it is also difficult to get the information necessary to create a map. The aquatic ecosystems, which constitutes a very important part of the earth, is in a difficult process in terms of sustainability due to reasons such as anthropogenic impacts and climate change. Sustainability is crucial because the fisheries industry has considerable precaution in the world. Because of this circumstance, it is very important to get to know the seas well. GIS should be indispensable for fishing as well as serving in many areas. Enough expert training in this area is one of the essential elements for forensic and academic studies. One of the governments' strategic management issues should be this issue and strengthened with serious investment and support.

North Sea is a very plentiful marine location for fisheries. Eight countries have a boundary in the North Sea. Decision-making should be done cooperatively with eight different countries. Mutual decisions should be applied by governments with legislation. Sustainability is very important for fisheries and for sustainability new legislation should be done and applied. Some species catch records are diminishing year by year, when making a comparison. To supply protection of fish and shellfish species it is necessary to make new legislation by governments. Maps are the easiest way to pay attention to local communities and stakeholders. By this way GIS should be developed day by day.

This study shows the North Sea’s 21 commercially important fisheries species bottom trawl catch number records in 2017. Sprat, Herring and Norway Pout species are the most plentiful harvested species whereas pollack, sandeel and scallop are the least abundant harvested species in the North Sea. These species are usually harvested between 4 and 28 m depths. If the maps are to be examined, it is understood that offshore fishing is done in Norway. In Belgium there seems to be a very little importance in fishing.

Fisheries species are not only important for localisation, but also important for consuming habits. For instance, sprat, herring and Norway pout species are three of the commonly consuming species all of the North Sea region, but scallop is not consuming in Norway. If the maps are compared, this difference can be seen easily.

Chapter 6

6. Conclusion

In this study, GIS gave a reliable opportunity to available commercially important fish locations in the North Sea in 2017. The North Sea is one of the most crowded seas all over the world and there are significantly important facilities occurring such as shipping, oil and gas, renewable energy facilities, fisheries, tourism, dumping, military use i.e. (Fock, 2007). Because of this intensity Marine Spatial Planning (MSP) is efficient to utilise the North Sea.

The MSP is useful for creating a consistent strategic vision, goals and policies for sustainable development, including conservation, and, where necessary, improving the health of the plan area. It is also important to identify all maritime uses and activities and ensure that they are in the most appropriate and least vulnerable areas, while being extremely important in terms of providing reliable and robust information to organize, manage and use the plan, manage and use the plan, and support plan policies. In addition to the important tasks of reducing the most conflicts of interest between individuals or organizations and promoting harmonized use, how to manage and organize marine users and to make decisions, and to identify sustainable development goals that are respectful of environmental boundaries for ensuring future healthy and productive seas and preserving existing ones. As a result, developing a policy framework to support integrated maritime and terrestrial planning and development is of crucial importance.

The iconic seas and shores of the North Sea are home to the world's one of the most colourful, fascinating and beautiful marine life, supporting valuable fish stocks, delicate jewel anemones, Basking sharks and Angel sharks. The richness of the North Sea's lies in diversity. An ecologically compatible network of Marine Protected Areas (MPAs) is required to ensure that some of the North Sea's are protected and rescued. And also, Marine Protected Areas (MPAs) are very important for sustainable developments. For instance, nursery and spawning areas can be identified and protected by MPAs.

In the North Sea, the showed maps indicate the MPAs are usually located middle, east, west and southern areas and the largest proportion belongs to the UK. Even though, Norway has a very long boundary in the North Sea, Norway has a little MPA zone. Germany, the Netherlands and Denmark's MPAs largest proportions are usually located coastal areas.

The produced maps indicate the commercially important 21 fisheries species' catch abundance records in the North Sea in 2017. These species are divided into 3 parts, pelagic, benthic and demersal. Pelagic species usually live close the surface waters, benthic species are usually live close the bottom and demersal species usually live the bottom or near the bottom areas.

Pelagic species are herring and mackerel very plentiful species and distributed almost every area in the North Sea. The maps, which are indicated herring and mackerel, indicating that both two species can be found every location in 2017. Pelagic species are catching with static gear (lift net and gill net, trap), towed gear (trawl net) and surrounding gear (ring net and lampara net, purse seine).

Benthic and demersal fish species are haddock, cod, plaice, saithe, pollack, hake, whiting, monkfish, sprat, sole, lemon sole, sand eel, halibut and ling in the North Sea. The produced maps indicate the abundance of catch number records by species. Halibut, pollack and sandeel species are the lowest catch number records in 2017. Sandeel abundance is located west coast of Denmark and Netherlands. Norway and the UK have tiny catch records. Pollack abundance is located Norway offshore waters and the UK, Denmark and Sweden have a little abundance catch records. Halibut species usually caught Norway offshore waters mostly and tiny amount come from the UK. Whiting, cod, plaice and lemon sole species are very plentiful abundances and can be found almost every location in the North Sea. Sprat and sole located southern locations monkfish, hake and ling located northern locations. Haddock usually harvested in the UK and following this Norway, Sweden and Netherlands. The North Sea's southern countries have no noteworthy for haddock catch numbers. Benthic species are catching with bottom trawling (single boat or pair), Seine netting, twin beam trawling, longlining and set nets (Gov.scot, 2018).

Decapoda and shellfish species are Norway pout, Norway lobster, edible crab and scallop (*Pecten maximus*), these species are catching with bottom trawling (single boat), scallop dredging and potting and creeling methods (Gov.scot, 2018). The produced maps indicate edible crab harvested usually southern locations in the North Sea, Norway and Belgium have no significant catch records. Norway lobster mostly harvested from the UK and Denmark, Sweden and Netherlands. Norway pout harvesting usually located northern and eastern locations in the North Sea. Lastly, scallop harvesting located just the UK's boundary in 2017. Below the table shows the overall of this work.

Table 6- 1 Commercially important 21 fisheries species NOINP (Number of individuals in the sub-sample is specified) and Depths (M)

Species	**NOINP**	**Depths (m)**
Cod	33665	5~26
Decapoda	19374	5~27
Edible Crab	955	5~23
Haddock	352340	7~28
Hake	8549	7~28
Halibut	26	16~24
Herring	4323360	4~28
Lemonsole	19749	4~24
Ling	679	5~23
Mackerel	579140	5~26
Monkfish	1003	11~26
Norway Lobster	16618	6~26
Norway Pout	3857942	9~28
Plaice	69192	5~21
Pollack	100	15~28

Saithe	15174	8~26
Sandeel	52	5~13
Scallop	41	11~20
Species	**NOINP**	**Depths (m)**
Sole	1159	4~21
Sprat	4779594	4~20
Whiting	460059	4~23

Overall, this dissertation presents the North Sea's commercially important 21 different fisheries species' (pelagic, benthic and demersal) abundances and catch number records with GIS maps in 2017 and also shows Marine Protected Areas (MPAs) are in which countries boundaries and with 40 m buffer demonstrates.

6.1. Future Work

In this dissertation, the North Sea's commercially important fisheries in 2017 catch number records indicated species by species abundances with maps. Some further research should be done in further studies to maintain this dissertation work. As a first step, it might be useful to access the GIS information easily. If every country shares the fish vessels catch record, the availability to producing maps could be easier. Also, another commercially important fisheries species may be done with different combinations by maps.

GIS technology offers new opportunities for fisheries scientists. Standing stocks, distributions of species, year-class powers, etc. Predictions can be made at almost any spatial scale, depending only on the resolution and scope of the data used to construct the GIS. The examples presented in this article provide a glimpse of the possible applications of this powerful tool. Of course, as the use of GIS becomes more widespread in fisheries science, many new applications will be developed.

It can be also recommended that the use of GIS in fisheries should be applied every aquatic ecosystem. Consideration should be given to strengthening the connection between theoretical and practical dimensions. Future studies might consider the application and comparison of using different GIS methods to achieve more effective marine management plans.

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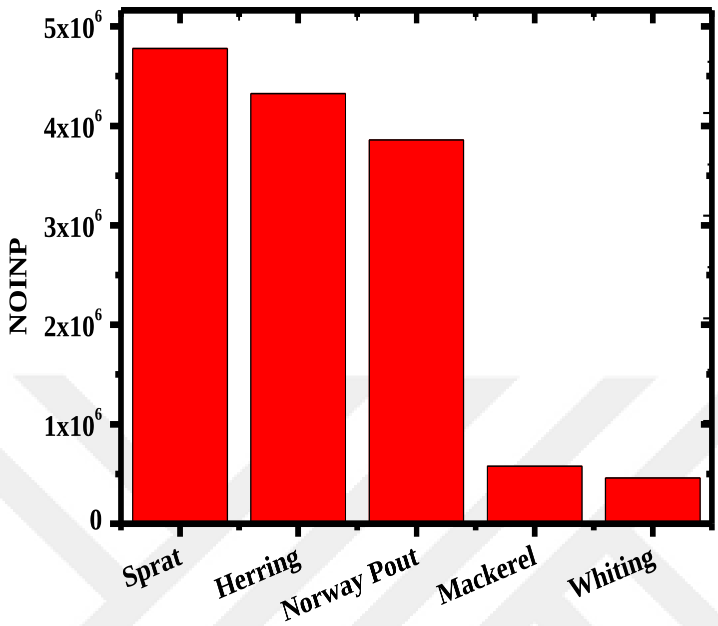
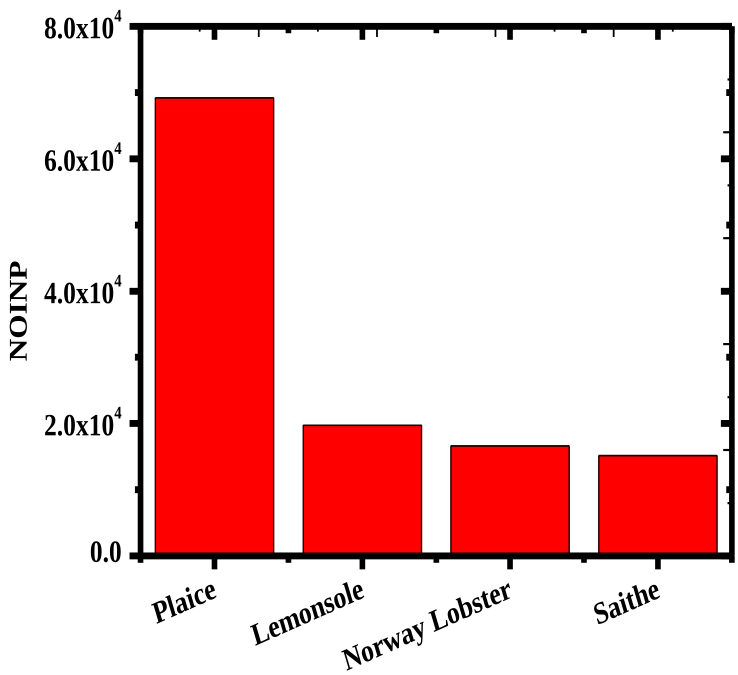
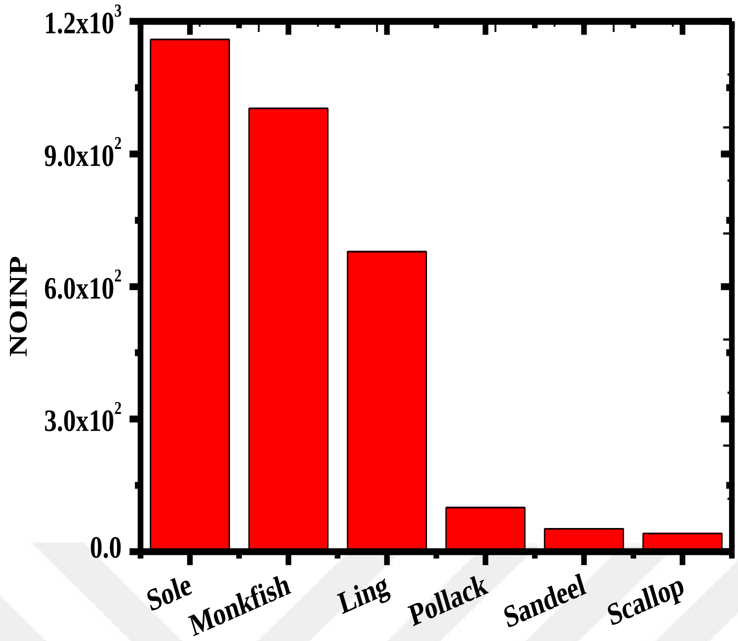
Appendices

Appendices: The fish catch with trawl abundances records in the North Sea in 2017 are demonstrated in the graphs







NOINP: Number of individuals in the sub-sample is specified