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# Reducing the environmental impacts of North Sea fisheries using Alaska's strategy as example

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## Reducing the environmental impacts of North Sea fisheries using Alaska's strategy as example

Par : Hadjer SMATI



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*Soutenu à Brest*

*le 08 / 09 / 2023*

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*Les analyses et les conclusions de ce travail d'étudiant n'engagent que la responsabilité de son auteur et non celle de l'Institut Agro Rennes-Angers*

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## Table of contents

Acknowledgement	
Liste of Figures.....	
Liste of Tables.....	
Liste of Annexes.....	
Acronyms .....	
Terminology .....	
Introduction .....	1
1. Chapter I: the Alaska's Management Strategy Overview .....	4
1.1. Alaskan management strategy .....	4
1.2. Economic dimension of the groundfish fisheries off Alaska .....	7
1.3. Contrasting Alaska and Europe's Management Approaches .....	7
2. Chapter II: Material and Methods .....	13
2.1. Study area .....	13
2.2. Material .....	13
2.3. Methods.....	14
2.3.1. Species selection process.....	15
2.3.2. Scenarios construction.....	16
2.3.2.1. Scenario 1: Exploring Harvest Level Scenario.....	17
2.3.2.2. Scenario 2: Setting Maximum Ecosystem Catches Limits.....	19
2.3.2.3. Quota Allocation: Insights from GINI Index Analysis and Lorenz curves .....	21
3. Chapter III: Results and Discussion .....	23
3.1. Results .....	23
3.1.1. Species selection results .....	23
3.1.2. Scenario 1: TAC reduction results.....	23
3.1.3. Scenario 2: Establishment of Ecosystem Catches results.....	25
3.1.4. Quotas share between countries .....	26
3.2. Discussion .....	28
3.2.1. Scenario (1): TAC reduction .....	28
3.2.2. Scenario (2): Ecosystem catches establishments.....	28
3.2.3. Quotas share among countries.....	29
Conclusion.....	32
Bibliography	
Annexes	
Abstract	

## *Liste of Figures*

Figure 1: The groundfish management areas in the Gulf of Alaska (GOA) (Western, Central, Eastern), excluding Aleutian Islands and Bering Sea.....	5
Figure 2: Studied area: North Sea Ecoregion IV Area (a, b, c).....	13
Figure 3: Visual Representation of the Selection Process.....	16
Figure 4: Top 10 demersal species in landed weight and value by EU fleets operating in the North Sea ecoregion IV, 2011 to 2021.....	23
Figure 5: Reported estimated TACs species using Alaska’s tiers system in the .....	24
Figure 6: Comparaisn between ICES advised TAC’s in 2022 and the estimated TACs based on Alaska’s strategy and quantification of the percentage of change. ....	25
Figure 7: Time series graph of the main demersal species annual catches in the North sea ecoregion IV from 1965 to 2021.....	26
Figure 8: Quotas Allocation Disparity among the North sea ecoregion (IV) Countries, comparison between the ICES advised quotas allocation and the estimated quotas. ....	27

### *Liste of Tables*

Table 1: Pestel analysis: comparison between the EU and Alaskan management strategies .....	9
Table 2: The agreed percentages for allocating shares between the UK, EU and Norway. ....	21
Table 3: The agreed percentages for share allocation among UE members. ....	21

*List of Annexes*

Annexe I: Species selection (R-code).....

Annexe II: Scenario (1) : TAC reduction (R-code).....

Annexe III: Scenario (2) : Ecosystem catches limit establishment (R-code).....

Annexe IV: Quotas share (R-code).....

Annexe V: Gini index (R-code) .....



## Acronyms

<b>ABC</b>	<i>acceptable biological catch</i>
<b>ABC<sub>t6</sub></b>	<i>The estimated acceptable biological catches using tier 6</i>
<b>ABC<sub>t1</sub></b>	<i>The estimated acceptable biological catches using tier 1b</i>
<b>ADF&amp;G</b>	<i>Alaska Department of Fish and Game</i>
<b>AER</b>	<i>Annual Economic Report</i>
<b>B</b>	<i>Biomass</i>
<b>BEL</b>	<i>Belgium</i>
<b>BLL</b>	<i>Brill</i>
<b>BSAI</b>	<i>Bering Sea and Aleutian Islands</i>
<b>CFP</b>	<i>Common fisheries policy</i>
<b>COD</b>	<i>Cod</i>
<b>DEU</b>	<i>Germany</i>
<b>DNK</b>	<i>Denmark</i>
<b>EEZ</b>	<i>exclusive economic zone</i>
<b>ER</b>	<i>Equilibrium rate</i>
<b>EU</b>	<i>European Union</i>
<b>Eumofa</b>	<i>The European Market Observatory for Fisheries and Aquaculture</i>
<b>EUR</b>	<i>Euro</i>
<b>F</b>	<i>fishing mortality rate,</i>
<b>FMP</b>	<i>Fisheries management plan</i>
<b>FRA</b>	<i>France</i>
<b>GOA</b>	<i>Gulf Of Alaska</i>
<b>HAD</b>	<i>Haddock</i>
<b>HKE</b>	<i>Hake</i>
<b>ICES</b>	<i>International Council for the Exploration of the Sea</i>
<b>IFQ</b>	<i>Individual fishing quota</i>
<b>IPHC</b>	<i>International Pacific Halibut Commission</i>
<b>Kg</b>	<i>Kilogram</i>
<b>LEM</b>	<i>Lemon Sole</i>
<b>LO</b>	<i>Landing obligation</i>
<b>M</b>	<i>natural mortality rate</i>
<b>mA</b>	<i>arithmetic mean</i>
<b>mH</b>	<i>harmonic mean</i>
<b>MSA</b>	<i>Magnuson-Stevens Fishery Conservation and Management Act</i>
<b>MSY</b>	<i>maximum sustainable yield</i>
<b>NLD</b>	<i>Netherlands</i>
<b>nm</b>	<i>Nautical mile</i>
<b>NMFS</b>	<i>National Marine Fisheries Service</i>
<b>NOAA</b>	<i>National Oceanic and Atmospheric Administration</i>
<b>NPFMC</b>	<i>North Pacific Fishery Management Council</i>
<b>OFL</b>	<i>overfishing level</i>
<b>OY</b>	<i>optimum yield</i>
<b>PDF</b>	<i>probability density function</i>
<b>PLE</b>	<i>Plaice</i>
<b>POK</b>	<i>Saithe</i>
<b>PSB</b>	<i>Prohibited species bycatches</i>
<b>PSC</b>	<i>prohibited species catch</i>
<b>QS</b>	<i>quota share(s)</i>
<b>SOL</b>	<i>Common Sole</i>
<b>SPR</b>	<i>Spawning per recruits</i>
<b>SSB</b>	<i>Spawning stock biomass</i>
<b>STECF</b>	<i>Scientific, Technical and Economic Committee for Fisheries</i>
<b>STECF</b>	<i>Scientific, Technical and Economic Committee for Fisheries</i>
<b>SWE</b>	<i>Sweden</i>
<b>TUR</b>	<i>Turbot</i>
<b>UK</b>	<i>United Kingdom</i>
<b>VAT</b>	<i>Value-added tax</i>
<b>WHG</b>	<i>Whiting</i>
<b>\$</b>	<i>dollars</i>
<b>€</b>	<i>Euros</i>

## Terminology

<b>ABC</b>	<i>acceptable biological catch, is the catch level recommended by a Council's scientific committee that accounts for scientific uncertainty in the estimate of OFL.</i>
<b>FMSY</b>	<i>Fishing mortality consistent with achieving MSY</i>
<b>F35%</b>	<i>fishing mortality rate at which the SPR level would be reduced to 35% of the SPR level in the absence of fishing. Also is a reasonable proxy for FMSY.</i>
<b>F40%</b>	<i>fishing mortality rate at which the SPR level would be reduced to 40% of the SPR level in the absence of fishing</i>
<b>IFQ</b>	<i>Individual fishing quota</i>
<b>FOFL</b>	<i>Is defined as being equal to FMSY when estimating the OFL.</i>
<b>LO</b>	<i>Landing obligation, are regulations and policies implemented in fisheries management to minimize or eliminate the practice of discarding unwanted or non-target fish and other marine species back into the sea.</i>
<b>M</b>	<i>natural mortality rate, It represents the rate at which fish and other marine organisms die of natural causes, excluding fishing-related mortality.</i>
<b>mA</b>	<i>arithmetic mean of the pdf of the FMSY</i>
<b>mH</b>	<i>harmonic mean of the pdf of the FMSY</i>
<b>OFL</b>	<i>overfishing level, It represents the maximum amount of fish that can be sustainably harvested from a fish stock without causing overfishing, which is a situation where the rate of fishing exceeds the stock's ability to reproduce and replenish itself.</i>
<b>OY</b>	<i>optimum yield, in fisheries management, It represents the maximum amount of fish that can be sustainably harvested from a fishery while simultaneously achieving the long-term conservation and management goals of the fishery.</i>
<b>PDF</b>	<i>probability density function of FMSY, is not a standard statistical distribution like a normal distribution or a Poisson distribution. Instead, it represents a point on a curve or a reference value used in fisheries management.</i>
<b>PSC</b>	<i>prohibited species catch</i>
<b>ER</b>	<i>Equilibrium rate, The concept is closely related to MSY, which is the highest level of fishing that can be sustained over the long term without depleting the fish population</i>
<b>QS</b>	<i>quota share(s), refers to the allocation or portion of TAC to the countries, vessels, regions...</i>
<b>SPR</b>	<i>Spawning per recruits</i>
<b>SSB</b>	<i>Spawning stock biomass. Total weight of all sexually mature fish in the stock.</i>
<b>MSYBtrigger</b>	<i>A biomass reference point that triggers a cautious response within the ICES MSY framework.</i>
<b>EBFM</b>	<i>Is a holistic approach that recognizes all the interactions within an ecosystem rather than considering a single species or issue isolation</i>
<b>TAC</b>	<i>Total allowable catches, or fishing opportunities, are catch limits(in tonnes or numbers) that are set for most commercial fish stocks.</i>
<b>MSY</b>	<i>Maximum sustainable Yield. The largest average catch or yield that can continuously be taken from stock under existing environmental conditions.</i>
<b>B40%</b>	<i>biomass that results from a fishing mortality rate of F40%, 40% of unfished biomass (size of fish stock without fishing)</i>
<b>F35%</b>	<i>fishing mortality rate at which the SPR level would be reduced to 35% of the SPR level in the absence of fishing. Also is a reasonable proxy for FMSY.</i>
<b>F40%</b>	<i>fishing mortality rate at which the SPR level would be reduced to 40% of the SPR level in the absence of fishing</i>
<b>BMSY</b>	<i>The biomass that allows maximum sustainable yield to be taken</i>
<b>B</b>	<i>Biomass, the total weight of a stock of fish.</i>

## *Introduction*

The mixed fisheries in the North Sea region, involving the simultaneous harvesting of multiple species, are confronted with various challenges (Ulrich et al. 2017). These issues. These challenges include ecological concerns, such as the impact of temperature on recruitment and biomass of North Sea fish stocks. Additionally, ensuring the safe biomass levels of certain species remains a challenge, however, sustainable fishing practices can potentially achieve higher yields, by reducing the fishing pressure (Cook et Heath 2005).

Amoroso states that the extraction of marine resources through bottom trawling has a considerable impact on marine landings, capturing significant quantities of fish and invertebrates each year. The range of trawling activity and its variable footprint across different regions amplifies the need to adopt sustainable fishing practices to safeguard untouched seabed areas and promote environmental benefits (Amoroso et al. 2018). The complexities of managing demersal fisheries in the face of shifting environmental conditions are accentuated by the interplay between the effects of climate change and the considerable influences of fishing practices on fish yield, stock collapse risk, and fish community indicators (Thorpe et De Oliveira 2019).

Fisheries management has traditionally focused on individual species and their sustainable utilization, as noted by (Witherell, Pautzke, et Fluharty 2000). This highlights the urgent requirement to adjust management approaches to include wider ecological considerations, particularly in light of the changing climate circumstances.

Policy changes that mandate the landing and recording of all commercial species catches could exacerbate management difficulties and restrict fishing opportunities for healthier stocks, due to the technical and ecological interactions in mixed-fishery contexts which have an impact on the references assessment parameters, the objectives for single species stocks and the mixed fishery stocks can't be achieved at the same time, the progress towards a goal for one stock, compromises the status or the MSY of others (Thorpe et De Oliveira 2019).

The complex interactions and trade-offs among multiple species and mixed-fishery dynamics over a longer timeframe bring to light the challenges and management pressures in achieving the social, economic, and environmental objectives outlined in the Common Fisheries Policy (CFP)(Kempf et al. 2016; Thorpe et De Oliveira 2019).

Thorpe et al. accentuate the importance of maintaining stocks above MSY in fisheries management. Achieving MSY for multiple species involves balancing trade-offs and considering stakeholder preferences . Scenario modelling indicates that adopting flexible targets, such as  $F_{MSY}$  within sustainable ranges, can prevent unfavourable outcomes and promote inclusive governance for informed decision-making in complex trade-off scenarios. In the context of the North Sea's mixed fisheries, the complexities call for adaptive management approaches that address trade-offs and species interactions while accommodating stakeholder preferences (Kempf et al. 2016)

In light of the intricate challenges facing mixed fisheries in the North Sea, there is a growing recognition of the need for a more holistic approach that considers the broader ecosystem within which these fisheries operate (Witherell et al. 2000).

A portfolio framework for fisheries management is considered as a technical method that systematically combines fish stocks linked by ecology and non-specialized fishing techniques into

a portfolio, that balances expected total returns against the risks associated with stock characteristics and other uncertainties (Rădulescu et al. 2010). The adoption of a portfolio approach has gained significant attention as a potential solution to address the complex dynamics and uncertainties inherent in mixed fisheries. By integrating diverse management strategies and considering the interdependencies among species and stakeholder objectives, the portfolio approach offers a promising framework for promoting long-term sustainability and resilience in the North Sea's fisheries (J. Link 2010).

Furthermore, drawing inspiration from successful endeavours like the EBFM implemented in Alaska, there is a valuable opportunity to learn from best practices and lessons in order to develop effective management strategies tailored to the context of the North Sea. The management of groundfish fisheries off the coast of Alaska in the North Pacific Ocean is implementing an ecosystem-based approach that takes into account both biological and socioeconomic considerations (Witherell et al. 2000).

This approach involves precautionary measures in fish extraction, conservative catch limits, extensive monitoring, by-catch controls, habitat conservation, and minimizing the effects on marine mammals and seabirds (J. s Link 2010; Witherell et al. 2000). The North Pacific Fishery Management Council has been actively developing this approach, resulting in sustainable fisheries and the maintenance of healthy fish stocks in the Gulf of Alaska, Bering Sea, and Aleutian Islands region (Witherell et al. 2000).

The motivation behind this research stems from the need to address the mixed fishery challenges, reduce environmental impacts, and ensure the long-term viability of the North Sea's groundfish populations and fisheries. By understanding the potential benefits and obstacles of implementing an EBFM approach, including the fair allocation of TAC and quotas among countries, we can provide guidance and inform decision-making processes for sustainable fisheries management in the region.

The main aim of this research is to investigate and analyse the potential benefits and implications of implementing the Alaskan management style in the North Sea. The study seeks to assess its effectiveness in achieving fisheries sustainability, reducing fishing mortalities, facilitating stock recovery, and mitigating environmental impacts.

The central issue of this research is to investigate how implementing the Alaskan management Approach in the North Sea can effectively reduce fishing mortalities, facilitate stock recovery, and minimize environmental impacts.

The research is guided by the following questions: (1) How can the adoption of an EBFM approach and treating commercial species as part of the broader ecosystem, contribute to the recovery of specific stocks? (2) What are the potential impacts of TAC reduction on the fleets of different countries, and which fleets and countries would be affected?

This study adopts a methodology that involves examining Alaskan management methods. Select the main commercial species in the North Sea through the use of statistical analysis of European data. By integrating quantitative and qualitative analysis, the study will construct two This including three scenarios. The first scenario explores harvest level estimation, while the second scenario focuses on establishing maximum ecosystem catch limits. This includes reducing TAC and quotas, as well as analyzing quota allocation using the GINI Index.

The aim of this study is to reduce the ecological impacts on north sea groundfish fisheries and

accelerate the recovery of certain stocks. contribute valuable insights to fisheries management and sustainability. This thesis is structured as follows:

Chapter 1 provides an overview of Alaska's management strategy, accentuating its originality and specificity. The Alaskan strategy will be compared to the European strategy using a PESTEL analysis to identify the main differences and similarities between the two approaches. The PESTEL analysis framework can be employed to examine the political, economic, social, technological, environmental, and legal factors that influence the fisheries management strategies in both regions, particularly for groundfish or demersal fish. By conducting such an analysis, a comprehensive comparison of these factors can be made, shedding light on the similarities and differences between Europe and Alaska in managing their fisheries resources.

In Chapter 2, the methodology utilized in this research is introduced, providing an overview of the data collection process, analysis techniques, and the selection of key commercial species. It also details the construction of scenarios to explore different outcomes.

the methodology utilized in this research is introduced, providing an overview of the data collection process, analysis techniques, and the selection of key commercial species. It also details the construction of scenarios to explore different outcomes.

Finally, Chapter 3 serves as the conclusion of the thesis, summarizing the key results derived from the research. It examines the implications of these results, discussing their significance in relation to the research questions. The chapter also provides recommendations for future research directions and policy initiatives, suggesting areas that require further investigation or potential actions to address the identified issues.

## ***1. Chapter I: the Alaska's Management Strategy Overview***

This chapter gives a summary of how Alaska manages its fisheries to keep them sustainable. Alaska's approach to management considers ecological, economic, and social factors within a comprehensive framework. The state has developed its legal framework for fisheries management, which includes rules on limited entry IFQs, gear restrictions, and conservation measures (NPFMC 2020).

The research investigates how Alaska appropriately and sustainably handles its fish reserves, following national laws and global deals. They achieve this by using scientific research, data analysis, and involving stakeholders. Their aim is to maintain healthy fish populations and support fishing communities' long-term sustainability. This chapter shows how Alaska manages its fisheries sustainably, especially the groundfish fishery. It shares the successes, challenges, and ongoing efforts to achieve this.

Additionally, we compare the fishery management tactics used in Alaska and Europe, looking at key indicators while using the PESTEL framework. The analysis of Political, Economic, Social, Technological, Environmental, and Legal factors affecting fisheries management in these regions seeks to offer understanding of the similarities, disparities, and efficiency of their methods.

### ***1.1. Alaskan management strategy***

The originality of the Alaskan strategy lies in its pioneering approach to ecosystem-based management of sustainable marine fisheries (Witherell et al. 2000).

It was one of the first strategies to consider the complex interactions and factors that affect ecosystems, going beyond simple stock management. By integrating multiple elements such as selective fish removals, habitat protection, and conservation measures, the strategy demonstrates a proactive and comprehensive approach to ensure the long-term sustainability of both fish stocks and the marine ecosystem. Its emphasis on precautionary measures showcases its innovative and forward-thinking nature.

The Alaskan fisheries management strategy demonstrates specificity through measures like annual catch limits, conservative harvest rates, by-catch limits, gear restrictions, and marine protected areas (Witherell et al. 2000). Alaska's marine fisheries target a diverse range of species and are primarily managed by the NMFS through the FMPs.

The groundfish fisheries in GOA and BSAI (Figure 1), are subject to annual stock assessments and fishery evaluations (Woodby et al. 2005). The federal authority governs fisheries in the U.S. EEZ, while the State of Alaska manages resources within state territorial waters (0-3 nm), implementing emergency orders and separate state-managed fisheries. Lingcod and certain rockfish species not covered by federal FMPs are managed by the state throughout the EEZ (NOAA 2023b)

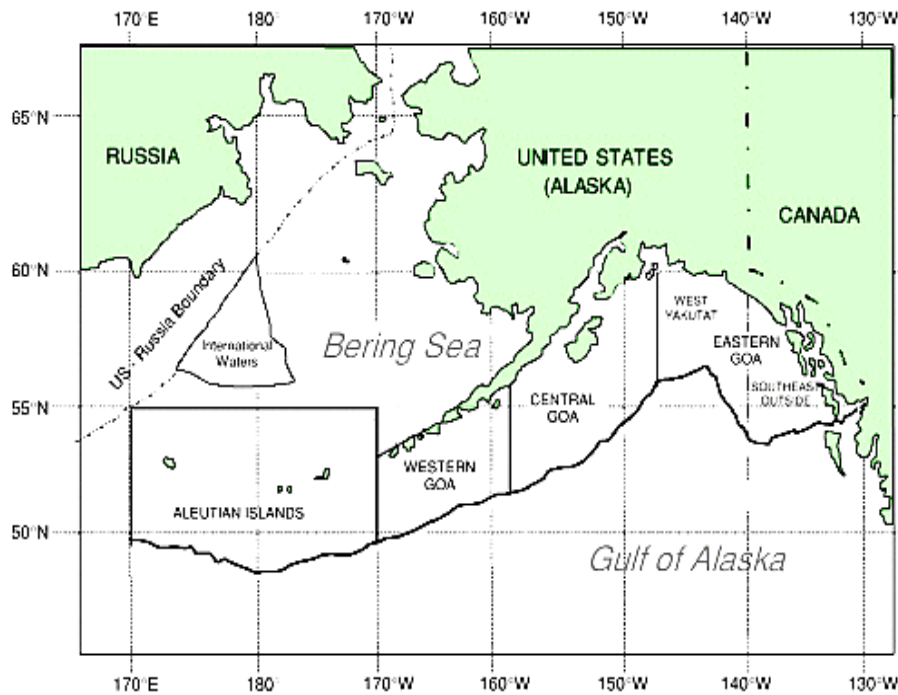


Figure 1: The groundfish management areas in the Gulf of Alaska (GOA) (Western, Central, Eastern), excluding Aleutian Islands and Bering Sea<sup>1</sup>.

According to the Federal Register (ADF&G 2023a) and the official management plan for groundfish fisheries in the Gulf of Alaska (NPFMC 2020), several categories of species are managed according to their status. These categories are:

### 1.1.1. Category 1: Target species

The first category involves species allowed to be caught, known as target species. Each type of species has a specific management system. There is a wide diversity of species, including Wall-eye pollock, Pacific cod, Sablefish, Pacific Ocean perch, and Arrowtooth flounder. These five species are commercially and ecologically important, as revealed by (Sidon et al. 2019). The target groundfish species are managed according to the fisheries' management plan (FMP) through different amendments. Stock monitoring in Alaskan fisheries employs a 6-tier system to determine ABC and OFL for certain species, while others are assessed using population dynamics models and statistical data (NOAA, 2023).

#### 1.1.1.1. Alaska's tier system

According to Amendment 56, the tier system holds a pivotal role in the determination of key parameters such as OFL and ABC within fisheries management. Each tier within this system corresponds to a specific level of information accessibility and provides guidelines for the estimation of essential parameters. Gaining a clear grasp of the terminology and concepts affiliated with each tier is indispensable for accurately evaluating and overseeing fish stocks (NOAA 1978).

The tier system is a framework for managing fish stocks in the Bering Sea, Aleutian Islands, and Gulf of Alaska, developed by the North Pacific Fishery Management Council. This system

<sup>1</sup> Sources : (NOAA 2023a)

categorises fish populations into six tiers according to the volume of available data and the complexity of the assessment methods, tiers 4 and 5 utilise data from bottom trawl surveys conducted by the Alaska Fisheries Science Centre to determine management quantities, such as Acceptable Biological Catch and Overfishing Limit, by estimating the total biomass. This study introduces a novel technique that integrates longline survey data into the existing model, specifically for fish species in the Gulf of Alaska, this inclusion enhances the stability of biomass estimation and sub-region allocation over time, the method also assesses the catchability coefficient and survey index weighting. It has potential uses for other Tier 5 species and for allocating biomass in sub-regions of Tier 3 stocks caught by both surveys (Hulson 2022).

The tier system, which is used to manage fish stocks in the Bering Sea, Aleutian Islands, and Gulf of Alaska, differs from the approach taken by the European Union. In the European Union, a comparable mechanism known as "category" is utilised as established benchmarks for fisheries management. Though not the same as the tier system, these categories offer a similar framework for arranging and assessing fish stocks according to diverse data accessibility and evaluation intricacies. This European approach ensures well-informed decision-making while mirroring the principles of tiered management observed in the North Pacific Fishery Management Council's system (Youen et Girardin 2019).

#### **1.1.1.2.Example of Alaska Pollock**

The Alaska pollock fishery serves as a prime illustration of how a management approach rooted in scientific principles and vigilant monitoring can safeguard the resource's long-term sustainability (NOAA 2023a).

In GOA, pollock is managed as a separate stock from those in the Bering Sea and Aleutian Islands. As of 2004, the exploitable biomass (age 3+) of GOA was estimated to be 769,420 tonnes, with an ABC of 71,260 tonnes (including both Western/Central and Eastern GOA ABCs) being the norm. Although the biomass has declined since the mid-1980s, recent fisheries have been backed by above-average year-classes in 1994 and 1999. Measures including seasonally and spatially allocated TAC and restrictions within Steller sea lion habitats were implemented to safeguard these creatures, in response to concerns raised in a 1998 biological assessment (NPFMC 2020).

In 2022, the projected female spawning biomass for GOA pollock is 204,554 tonnes, representing 43.61% of unfished spawning biomass and exceeding the  $B_{40\%}$  threshold (188,000 tonnes), categorizing it as sub-tier "a" within Tier 3 (Monnahan et al. 2022).

Fishery Management for Alaska Pollock is overseen by NOAA Fisheries and the NPFMC. It is governed by the FMPs for the GOA and the BSAI (NOAA 2023).

#### **1.1.2. Category 2: Prohibited species**

The second category regroup the prohibited species such as Halibut, as a prohibited species, is managed separately by the IPHC under the Pacific Halibut treaty. Stock assessment for halibut is based on age-structured models, and fishery management involves estimating Prohibited Species Catch and allocating IFQ, catch limits are shared among U.S. fishermen based on quotas, and there are specific management measures for the charter boat fleet and a catch sharing plan for halibut allocation. Sablefish fishermen hold halibut exploitation permits to compete with



halibut fisheries, allowing them to retain the species instead of immediate release (ADF&G 2023b)

### ***1.2. Economic dimension of the groundfish fisheries off Alaska***

The 2021 report on Alaska's FMP groundfish fisheries reveals a 4% decrease in total catch, totalling 2.01 million tonnes, with groundfish accounting for 81.84%, the ex-vessel value was \$759.57 million, with a 1.2% real price decline, COVID-19 had significant economic impacts, additionally, Alaska's groundfish fisheries contribute substantially to the state's economy, but employment data is limited, with a 10.4% decrease in crew weeks in 2021 (Abelman et al. 2023).

### ***1.3. Contrasting Alaska and Europe's Management Approaches***

A comparative analysis between EU and Alaska is needed for two reasons. Firstly, it facilitates a better comprehension of the CFP by situating it within a broader context. By equating the CFP with the GOA Fishery Management system, which operates under the Magnuson-Stevens Act and has a similar degree of complexity, we can discern comparisons and contrasts in approaches.

Additionally, studying the Alaskan experience provides valuable insights into both favourable and unfavourable aspects of fisheries management, providing practical examples and lessons that can inform policy-making and improve practices in the EU and beyond (Penas 2017).

The Pestel analysis presented in (Table 1) outlines the issues, objectives, and actions/results of both the EU and Alaska. The economic factors play an important role in shaping fisheries management in both the EU and Alaska. The EU prioritises efficient resource utilisation for economic sustainability when addressing challenges such as the Landing Obligation. Similarly, Alaska demonstrates its dedication to economic growth through initiatives like the Prohibited Species Bycatch, seeking to achieve a balance between economic development and ecological integrity.

Both regions display commitment towards enhancing sustainability and ecological awareness in their fisheries management approaches. They aim to tackle specific issues and promote ecosystem well-being through tailored strategies for targeted species within their unique contexts.

The EU and Alaska both prioritize social considerations as fundamental components of their fisheries management strategies. They recognise the importance of conserving employment, livelihoods, and cultural heritage, whilst aligning these priorities with sustainable resource practices.

To tackle climate change, the EU and Alaska incorporate climate concerns into their strategies proactively. They protect their fisheries and ecosystems against changing environmental conditions by using benchmarks such as  $F_{MSY}$  and  $B_{MSY}$ . International collaboration and adherence to global agreements are central to the strategies of both the EU and Alaska.

They advocate for responsible fisheries management and conservation, contributing collectively to the protection of marine resources, ensuring their vitality and longevity for future generations.

The management strategies for fisheries in the European Union (EU) and Alaska differ in

several significant ways according to the Pestel analysis (Table 1).

From a political standpoint, the EU follows the CFP and distributes fishing opportunities based on relative stability to ensure fairness. On the other hand, Alaska privatizes access to fishing rights through permits and quotas, promoting responsible practices and providing economic incentives.

In terms of economic factors, the EU confronts challenges of overfishing and sustainability due to fluctuations in prices and costs. These challenges are being addressed through the LO, aimed at reducing waste. Alaska's fishing industry is essential and addresses concerns about non-target species captures through the PSC Initiative.

In terms of social aspects, the EU seeks stakeholder involvement in decision-making to balance fishing practices with community welfare. But Alaska involves local communities and indigenous groups, upholding cultural connections to fishing and traditional knowledge.

In technical terms, the EU implements TAC, transitioning towards an ecosystem-based approach with advanced data collection. Alaska tailors TAC levels by species and region, utilizing advanced stock assessment methods and prioritising ecosystem-based management.

The EU's Environmental Focus strives for sustainable fishing by employing  $F_{MSY}$  and  $B_{MSY}$  while considering climate change. Alaska adopts  $F_{MSY}$  and  $B_{MSY}$  alongside adaptable  $F_{MSY}$  restrictions and climate-sensitive management, giving precedence to ecosystem wellbeing.

The EU adheres to worldwide agreements to maintain consistent standards and preservation legally. Alaska's EBFM promotes global conservation, positioning Alaska as a responsible leader.

The differences between the EU and Alaska in managing their fisheries reflect their distinct characteristics and priorities to achieve sustainable fisheries. Furthermore the EU follow the single species management approach in mixed fisheries, whilst Alaska used the six tiers system to determine the OFL and ABC.

Table 1: Pestel analysis: comparison between the EU and Alaskan management strategies

Type		EUROPEAN UNION / NORTH SEA	GULF OF ALASKA
		Factors Issues, Objectives, Actions and / or Results	Political <sup>2</sup>
Economic <sup>3</sup>	<ul style="list-style-type: none"> <li>Economic sustainability is influenced by a variety of factors, such as: Overfishing and illegal fishing practices threaten the sustainability of marine resources in the EU.</li> <li>Variations in fish prices and fuel costs have a direct impact on the fishing industry's profitability, affecting both revenue and costs.</li> <li>The LO aims to reduce the amount of waste produced and maximise resource usage, thereby enhancing economic efficiency and promoting sustainability.</li> <li>The implementation of the LO can lead to reduced waste and better utilization of catches, aligning with economic and environmental goals. The LO can create new revenue streams and maintain market competitiveness for fishing businesses.</li> </ul>		<ul style="list-style-type: none"> <li>Alaska's fishing industry is a significant contributor to the economy. Nonetheless, concerns arise over the unintentional capture of non-target species, which negatively impacts the ecosystem's health and long-term financial sustainability.</li> <li>The Prohibited Species Bycatch (PSB) initiative aims to reduce such unintentional catches, supporting economic interests and the ecosystem's health.</li> <li>The implementation of the PSB initiative contributes to sustaining Alaska's valuable fisheries by minimizing unintended catches and enhancing economic efficiency.</li> </ul>

<sup>2</sup> Sources : (Harte et al. 2019; Penas 2017; Ringer et al. 2018)

<sup>3</sup> Sources : (Bastardie et al. 2022; Battista et al. 2018; Prellezo et Villasante 2023; Witherell, Pautzke, et Fluharty 2000)

	Social <sup>4</sup>	<ul style="list-style-type: none"> <li>▪ Fisheries management in the EU can directly impact the employment and livelihoods of individuals and communities dependent on fishery-related activities.</li> <li>▪ The EU seeks to incorporate social aspects into fisheries management by engaging stakeholders, including fishers, fishing communities, and industry representatives, in decision-making procedures.</li> <li>▪ The EU aims to achieve a sustainable balance between fisheries practices and the socioeconomic welfare of fishing communities.</li> <li>▪ In terms of social aspects, participatory decision-making is a key concern. By involving stakeholders, the EU ensures that management decisions reflect the needs and concerns of those who depend on fishing for their livelihoods.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Challenge of preserving the livelihoods of local communities and indigenous groups that depend on fishing as an essential part of their way of life.</li> <li>▪ The objectives include community involvement and sustainable livelihoods.</li> <li>▪ Alaska places great importance on involving local communities and indigenous groups in fisheries management decisions since they possess unique perspectives and traditional knowledge.</li> <li>▪ Involvement of indigenous groups and local communities in Alaska's fisheries management acknowledges and maintains cultural practices and traditions linked to fishing.</li> </ul>
	Technical <sup>5</sup>	<ul style="list-style-type: none"> <li>▪ TAC levels remain high in the EU, however the specific consumption of fish diverges between member states and regions due to factors such as cultural preferences, economic circumstances, and market demand.</li> <li>▪ The European Union (EU) aims to achieve sustainable fisheries by setting (TAC) levels that ensure the long-term health and viability of fish populations.</li> <li>▪ To support this goal, the EU seeks to transition from a single-species approach to an ecosystem-based approach that takes into account the interactions between different species and their roles in the ecosystem.</li> <li>▪ As a result, there has been an improvement in the collection and analysis of data, which has benefited technical aspects of this initiative. To tackle consumption fluctuations, the EU improves data collection and analysis methods to gain a deeper understanding of consumption patterns and adjust TAC levels accordingly.</li> </ul>	<ul style="list-style-type: none"> <li>▪ The TAC levels in Alaska vary depending on the particular species being targeted and the specific geographical region, resulting in distinct management challenges and outcomes.</li> <li>▪ Alaska acknowledges the importance of groundfish species in the ecosystem and aims to adopt an ecosystem-based approach to fishing that considers the interdependence of various species.</li> <li>▪ Alaska aims to establish TAC levels customised to the biology and population dynamics of each targeted species, guaranteeing sustainable harvests and preventing overfishing.</li> <li>▪ The state of Alaska strives to manage its fisheries utilising an ecosystem-based approach that accounts for the interactions between different species, their respective positions in the food web, and wider ecological impacts.</li> <li>▪ Technical results manifested in methods of stock assessment tools. Alaska employs advanced stock assessment methods, including mathematical models and scientific surveys, to estimate with precision the abundance and health of target species, thus guiding decisions on TAC levels.</li> </ul>

<sup>4</sup> Sources : (Bastardie et al. 2022; Li 2022; Witherell et al. 2000)

<sup>5</sup> Sources : (NPFMC 2020; Penas 2017)

	Environmental <sup>6</sup>	<ul style="list-style-type: none"> <li>Ensuring the sustainability of fish stocks and preventing overfishing are essential challenges within EU fisheries management.</li> <li>The impact of climate change can exert influence on fish stocks and their habitats, potentially resulting in shifts in distribution, abundance, and ecosystem dynamics.</li> <li>The objectives are to achieve <math>F_{MSY}</math> and <math>B_{MSY}</math> targets. The EU seeks to establish fishing mortality rates <math>F_{MSY}</math> and <math>B_{MSY}</math> that enable optimal sustainable yields whilst preventing the depletion of fish stocks to support sustainable fisheries.</li> <li>The EU further endeavours to incorporate climate change considerations into fisheries management strategies to account for their potential impact on fish stocks and ecosystems.</li> <li>The outcomes of these efforts aim to promote sustainable fishing practices and environmental sustainability. By adhering to <math>F_{MSY}</math> targets, the EU promotes sustainable fishing practices that maintain fish populations at levels that support long-term productivity.</li> <li>In terms of biomass conservation, implementing aspirational goals to keep fish stocks above half of <math>B_{MSY}</math> helps ensure that ecosystems remain resilient and fish populations are maintained at healthy levels.</li> </ul>	<ul style="list-style-type: none"> <li>Ensuring sustainable levels of fish stocks while mitigating the impacts of climate change are paramount in managing Alaskan fisheries.</li> <li>The implications of climate change on Alaska's diverse ecosystems can have consequences for fishery resources and their interactions.</li> <li><math>F_{MSY}</math> and <math>B_{MSY}</math> Guidelines. Alaska endeavours to manage its fisheries by utilising <math>F_{MSY}</math> and <math>B_{MSY}</math> as reference points to prevent overfishing and maintain stock abundance.</li> <li>The state prioritises the incorporation of climate change considerations into fisheries planning and management to promote the resilience of fish stocks and ecosystems.</li> <li>Environmental outcomes include sustainable harvests. Adhering to flexible <math>F_{MSY}</math> limits enables Alaska to adjust fishing mortality rates based on changing stock dynamics, thus contributing to sustainable harvesting practices.</li> <li>Additionally, maintaining fish stocks above half of <math>B_{MSY}</math> is an aspirational goal that promotes ecosystem health and prevents stock collapse.</li> <li>This approach is also in line with climate-smart management practices. Integrating climate change considerations into management decisions facilitates Alaska's readiness and adaptability to environmental changes, ensuring the long-term viability of fisheries resources.</li> </ul>
	Legal <sup>7</sup>	<ul style="list-style-type: none"> <li>The EU operates within a complex international framework that involves sharing fish stocks and necessitates coordinated conservation efforts to prevent over-exploitation and ensure sustainable fisheries.</li> <li>The EU aims to align with international agreements. The EU's CFP aims to align its fisheries management regulations and practices with international agreements and regional management organizations, aiming to set consistent standards, quotas, and conservation measures.</li> <li>The EU focuses on contributing to the responsible management of shared fish stocks by collaborating with other nations to establish and implement successful conservation strategies, leading to notable legal outcomes.</li> <li>The EU establishes a common legal framework that promotes responsible fishing practices and ensures the sustainability of fish stocks across</li> </ul>	<ul style="list-style-type: none"> <li>Alaska's fisheries operate within the concept of international marine ecosystems. Therefore, a comprehensive approach is necessary which takes into consideration the interconnectedness of species and habitats.</li> <li>Alaska has implemented EBFM approach, which aligns with international efforts to promote responsible and holistic fisheries management, considering the broader ecosystem and its health.</li> <li>Through involvement in international conservation initiatives, Alaska aims to support the long-term sustainability and health of marine resources in its waters and beyond.</li> <li>The implementation of EBFM in Alaska results in legal frameworks that prioritize the health of the entire ecosystem. This, in turn, leads to the creation of regulations that promote sustainable fisheries and safeguard the marine environment. Alaska's participation in initiatives towards sustainable marine resource management positions the state as a global leader.</li> <li>Alaska's involvement in international conservation endeavours contributes to its</li> </ul>

<sup>6</sup> Sources : (Bastardie et al. 2022; Penas 2017)

<sup>7</sup> Sources : (Seung et al. 2021; Beaudreau et al. 2019)

		<p>various jurisdictions.</p> <ul style="list-style-type: none"><li>▪ The EU's participation in international efforts strengthens its commitment to conservation, allowing for the enforcement of regulations that prevent overfishing and protect shared marine resources.</li></ul>	<p>reputation as a responsible leader in fisheries management while demonstrating its dedication to the long-term welfare of marine resources worldwide.</p>
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## 2. Chapter II: Material and Methods

This chapter provides an overview of the materials and methods used in the research study. It outlines the data collection process, sampling techniques, and analytical methods employed to address the research objectives. By detailing the materials and methods, this chapter ensures transparency, reproducibility, and validity of the research findings.

### 2.1. Study area

This research is centred on the North Sea Ecoregion IV(a,b,c) Figure 2, considered as an important area in European waters for managing fisheries. It covers the UK, Norway, Sweden, Denmark, the Netherlands, Germany, Belgium, France's national and EU waters. With a long history of fishing activities, this region is of great significance. The North Sea is home to various kinds of groundfish, such as Cod, Saithe, Plaice, and Sole. These fish help provide seafood for coastal communities (Carvalho, Keatinge, et Guillen 2019).

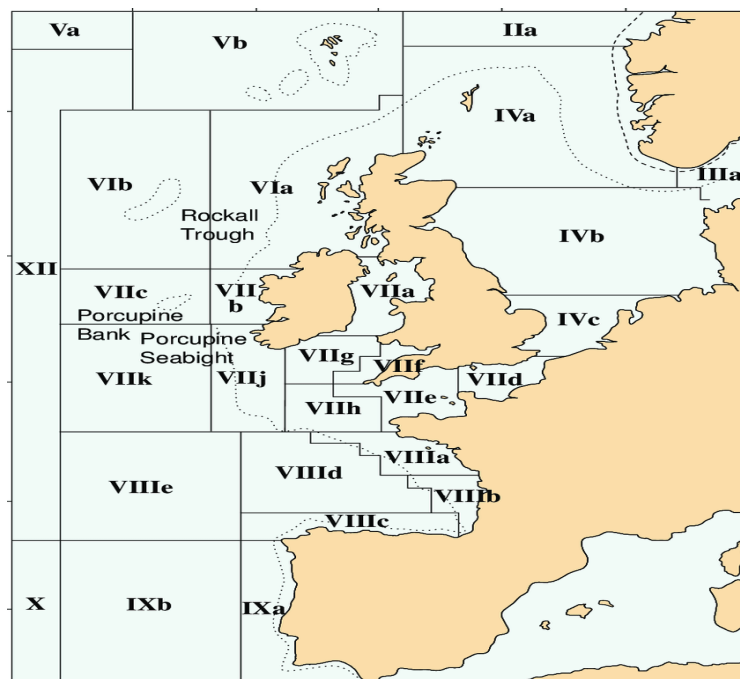


Figure 2: Studied area: North Sea Ecoregion IV Area (a, b, c)<sup>8</sup>.

### 2.2. Material

The analysis used both quantitative and qualitative data extracted from two principals distinct databases:

The initial Database 1, titled Annual Economic Report (AER) and covering the years 2011 to 2021, is applicable for the species selection procedure. Nonetheless, it is widely accepted that a span of ten years is required to perform a substantial analysis of fishing operations and the

<sup>8</sup> Sources : (Clarke et al. 2003)

status of fish populations (STECF 2022).

The second Database2, ICES (International Council for the Exploration of the Sea), provides quantitative data on reference points ( $F_{MSY}$ ,  $MSYBtrigger$ ,  $SSB$ ) utilized in constructing the scenarios. The construction of scenarios is discussed (ICES 2022).

These datasets were filtered based on various parameters to ensure robustness in the analysis. The first dataset derived from the AER featured a range of quantitative variables. These variables included “country codes, species codes, values, units (expressed in kilograms or euros), variable codes (Value and Weight), vessel lengths, fishing techniques, gear types, years of observation (spanning from 2011 to 2021), and sub-regions”.

The incorporation of these quantitative parameters enabled a comprehensive assessment of the economic aspects of fisheries management. The values were meticulously recorded in either kilograms and euros.

The qualitative dimension of the study was fortified by insights extracted from the same AER. These reports contributed qualitative perspectives, complementing the quantitative data by offering contextual understanding of catches, landings, and discards within the studied region. This qualitative layer added depth to the analysis by capturing socio-economic and ecological dynamics not solely represented by numerical values.

The second database sourced from ICES (International Council for the Exploration of the Sea) contained quantitative information. This database was focused on ecoregion IV (North Sea, region VI - subregions 27.4; 27.4.a; 27.4.b; 27.4.c). It covers a comprehensive set of data, including metrics such as  $F_{MSY}$ ,  $MSYBtrigger$ ,  $SSB$ , as well as detailed records of catches, landings, and discards. Additionally, it featured species designations and corresponding ICES-defined areas for precise referencing (STECF 2022).

Together, these two distinct databases provided a multifaceted foundation for the analysis, including quantitative and qualitative dimensions. The comprehensive nature of the data, filtered by various parameters such as region, species code, year, and ecological indicators, facilitated an understanding of the dynamics of fisheries management within ecoregion IV (North Sea) over the specified period.

Additionally the R programming codes were used based on the R-help section. In this study, the prices used were sourced from Eumofa, with monthly data presented in EUR/Kg (excluding VAT) for the month of June 2022 for groundfish and flatfish (Eumofa 2022).

### **2.3.Methods**

The methodology used in this study comprises several steps: Data Collection and Preprocessing: The cornerstone of this study lies in the aggregation of data from two primary sources: AER and the ICES database. These datasets contain a spectrum of parameters including: country codes, species codes, values, weights, and essential indicators like  $F_{MSY}$ ,  $MSYBtrigger$ , and  $SSB$ . With a laser focus on the North Sea's ecoregion, specifically subregions 27.4, these datasets serve as the bedrock for the analysis, lending geographic precision to the study's scope. We have conducted a thorough selection process to identify clear commercial entities. Our selection criteria prioritizes such species. These entities are species that have significant economic value and weight across various countries. We began with the top 50 species and



further refined our list by ranking them based on their value-to-weight ratio. Through this adjustment, we have compiled a list of ten bottom-dwelling species that embody a merging of monetary importance.

As we study specific species, we also explore the wider ecosystem. These ten species play important roles in the ecosystem of the North Sea as they transform and become interconnected. By studying this panorama, we can understand how these species work together, their interdependence, and their impact on the overall ecosystem.

The first scenario concerns determining the optimal harvest levels for each species. This task requires considering various factors, including achieving sustainable yield and conservation goals. The aim is to balance economic exploitation with long-term ecological stability. This deliberation is conducted in a species-specific manner, acknowledging the nuanced ecological traits and economic value of each species.

The second scenario analyses the ecosystem catch limit. Building on the individual species accounts, the study provides a global view of the ecosystem. After synthesising the optimal harvest levels of the individual species TAC, the study presents a comprehensive analysis of the ecosystem's vitality, resilience, and potential sustainable yield. To achieve ideal TAC levels, it is indispensable to balance the ecosystem's needs with human activity requirements. Overexploitation must be avoided to guarantee species' long-term survival. The scenario entails an intricate interplay of species' interactions and time and space scales to reveal sustainable production's optimal strategies.

### *2.3.1. Species selection process*

The method for selecting species for this study was based on a particular subset of species in the North Sea ecosystem<sup>9</sup>.

Firstly, a compilation of all the species landed by the European fleet in the North Sea between the years 2011 and 2021 was created. Following this, a ranking process centred on value and weight was carried out to designate the top 50 species demonstrating the greatest economic significance and landings quantity.

To improve the selection, the focus was restricted to demersal species exclusively. Demersal species, identified by their association with seafloor or near-bottom habitats, were given priority as a result of their economic importance in the North Sea. Only the demersal species with the highest value and weight were identified and separated from the initial top 50 species.

This method facilitated the formation of an independent list specifically involving the chosen highest demersal species.

The exclusion of pelagic, crustacean and other species was a conscious decision to ensure a more precise and thorough examination of the demersal segment of the North Sea ecosystem. In this analysis, the choice to concentrate on a subset of ten species within the demersal category was based on an assessment of the overall dataset.

One the top demersal species selected in weight and value, the list was formed and then the last selection was based on value as important criteria.

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<sup>9</sup> R-code : Annexe I (value and weight)

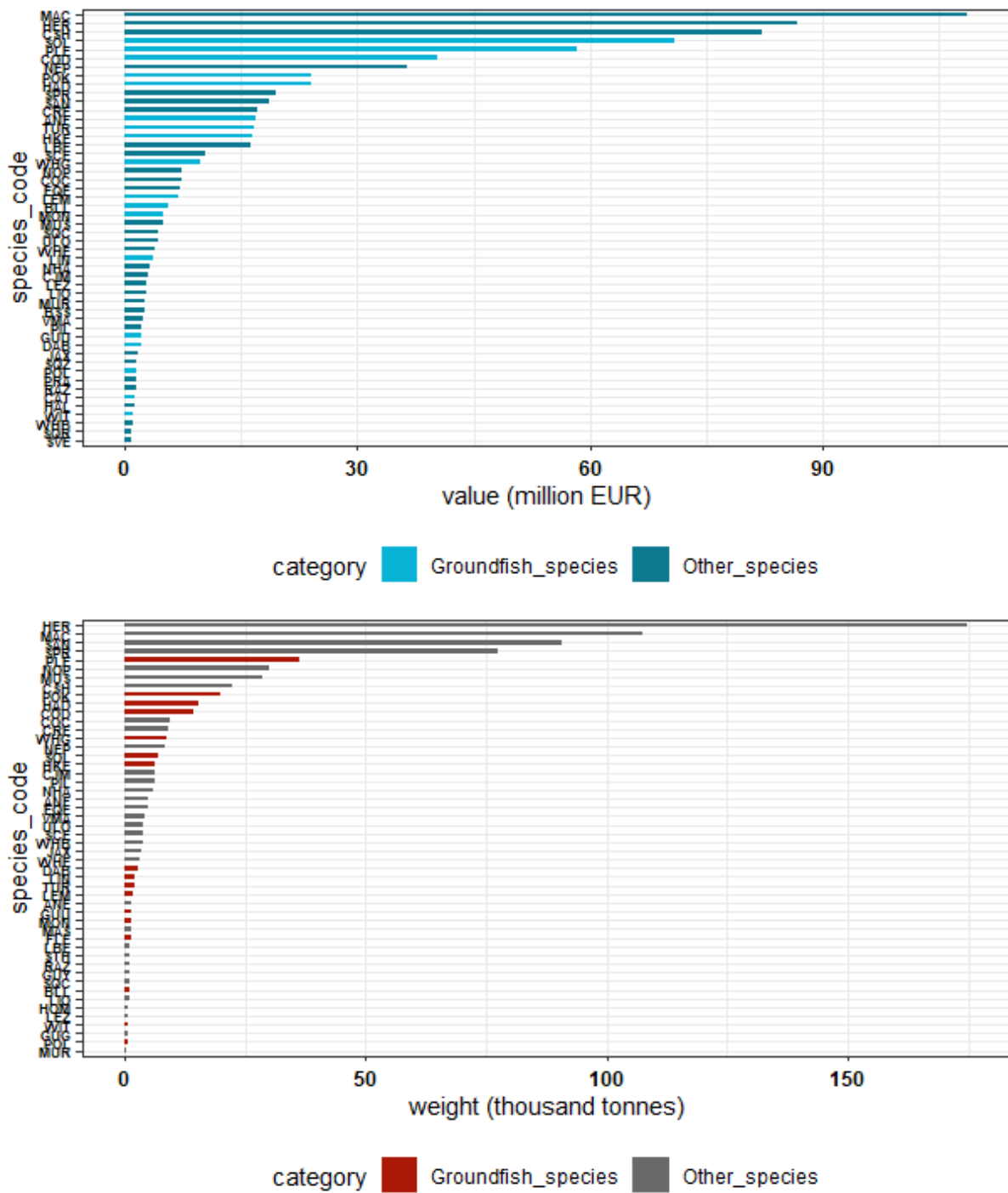


Figure 3: Visual Representation of the Selection Process<sup>10</sup>.

### 2.3.2. Scenarios construction

The study encircle two distinct scenarios, following the identification of primary commercial species in the North Sea, the study's objective revolves around treating these species as a cohesive ecosystem. The first scenario entails the determination of optimal harvest levels for each

<sup>10</sup> Sources : data (STECF 2022)

individual species, which subsequently extends to encompass the entire ecosystem.

### 2.3.2.1.Scenario 1: Exploring Harvest Level Scenario

The process of determining TACs for groundfish involves multiple stages. Firstly, using tier systems, the OFL and the ABC are established for each stock. Following this, TACs are set, making sure that they do not exceed the ABC. This guarantees a comprehensive approach to sustainable fisheries management, adhering to the principles of the Alaska management strategy (NPFMC, 2020).

The study uses the OFL control rule, which is a precautionary approach to manage Alaska's fisheries. This control guideline consists of six separate tiers arranged in a specific sequence of decreasing preference and accessibility of information. However, progressing from tier 6 to tier 1 in order improves the information's accessibility. In simpler terms, the higher we move to level 1, the greater amount of information becomes available for managerial decisions(NPFMC, 2020)..

In this work , the determination of tiers for both the OFL and the ABC will follow an ascending order, starting with the least complex and progressing to the most complex. Each tier will incorporate a harvest indicator.

#### a. Overfishing Level (OFL)

This key parameter acts as a safety measure when calculating overfishing levels for individual fish stocks. The calculation begins by assessing six tiers in descending order, each representing a different level of preference and information availability. As the assessment moves from the sixth to the first tier in ascending order, extra modifications are introduced to further improve the accuracy of the calculation of OFL (NOAA 1978).

- Tier 6 Information available: reliable catch history from 1978 through 1995.

$OFL = \text{the average catch from 1978 through 1995.}$

- Tier 5 Information available: reliable point estimates of  $B$  and natural mortality rate  $M$ .

$$F_{OFL} = M$$

- Tier 4 Information available: reliable point estimates of  $B$ ,  $F_{35\%}$ , and  $F_{40\%}$ .

$$F_{OFL} = F_{35\%}$$

- Tier 3 Information available: reliable point estimates of  $B$ ,  $B_{40\%}$ ,  $F_{35\%}$ , and  $F_{40\%}$ .

$$3a) \text{ Stock status: } B/B_{40\%} > 1$$

$$F_{OFL} = F_{35\%}$$

$$3b) \text{ Stock status: } \alpha < B/B_{40\%} \leq 1$$

$$F_{OFL} = F_{35\%} \times (B/B_{40\%} - \alpha)/(1 - \alpha)$$

$$3c) \text{ Stock status: } B/B_{40\%} \leq \alpha$$

$$F_{OFL} = 0$$

- Tier 2 Information available: reliable point estimates of  $B$ ,  $B_{MSY}$ ,  $F_{MSY}$ ,  $F_{35\%}$ , and  $F_{40\%}$

$$\begin{array}{ll}
 2a) \text{ Stock status: } B/B_{MSY} > 1 & F_{OFL} = F_{MSY} \\
 2b) \text{ Stock status: } \alpha < B/B_{MSY} \leq 1 & F_{OFL} = F_{MSY} \times (B/B_{MSY} - \alpha)/(1 - \alpha) \\
 2c) \text{ Stock status: } B/B_{MSY} \leq \alpha & F_{OFL} = 0
 \end{array}$$

- Tier 1 Information available: reliable point estimates of  $B$  and  $B_{MSY}$  and reliable pdf of  $F_{MSY}$ .

$$\begin{array}{ll}
 1a) \text{ Stock status: } B/B_{MSY} > 1 & F_{OFL} = mA \text{ arithmetic mean of (pdf)} \\
 1b) \text{ Stock status: } \alpha < B/B_{MSY} \leq 1 & F_{OFL} = mA \times (B/B_{MSY} - \alpha)/(1 - \alpha) \\
 1c) \text{ Stock status: } B/B_{MSY} \leq \alpha & F_{OFL} = 0
 \end{array}$$

### **b. Acceptable Biological Catch (ABC)**

The assessment of ABCs is the key reference point in fisheries management, forming the basis for sustainable harvesting practices. To that end, a six-tier system is utilized to establish a comprehensive framework for evaluating overfishing levels and for endorsing responsible resource utilization.

This approach considers several factors such as data availability, ecological dynamics, and stock characteristics to ascertain the allowable levels of catch. The six-tier system is a structured methodology that accommodates varying levels of information, allowing informed decisions by fisheries managers that balance economic interests and the preservation of marine ecosystems (NOAA 1978).

As we explore the calculation of ABCs, we uncover the complex details of each level, revealing how this methodical approach helps maintain the fragile balance between human requirements and the wellbeing of our sea resources.

- Tier 6 Information available: reliable catch history from 1978 through 1995.

$$\max ABC = 0.75 \times OFL$$

- Tier 5 Information available: reliable point estimates of  $B$  and natural mortality rate  $M$ .

$$\max F_{ABC} = 0.75 \times M$$

- Tier 4 Information available: reliable point estimates of  $B$ ,  $F_{35\%}$ , and  $F_{40\%}$ .

$$\max F_{ABC} = F_{40\%}$$

- Tier 3 Information available: reliable point estimates of  $B$ ,  $B_{40\%}$ ,  $F_{35\%}$ , and  $F_{40\%}$ .

$$\text{With } \alpha = 0.05$$

$$\begin{array}{ll}
 3a) \text{ Stock status: } B/B_{40\%} > 1 & \max F_{ABC} = F_{40\%} \\
 3b) \text{ Stock status: } \alpha < B/B_{40\%} \leq 1 & \max F_{ABC} = F_{40\%} \times (B/B_{40\%} - \alpha)/(1 - \alpha) \\
 3c) \text{ Stock status: } B/B_{40\%} \leq \alpha & \max F_{ABC} = 0
 \end{array}$$

- Tier 2 Information available: reliable point estimates of  $B$ ,  $B_{MSY}$ ,  $F_{MSY}$ ,  $F_{35\%}$ , and  $F_{40\%}$

	<i>With</i>	$\alpha = 0.05$
2a) Stock status: $B/B_{MSY} > 1$	$\max F_{ABC} = F_{MSY} \times (F_{40\%} / F_{35\%})$	
2b) Stock status: $\alpha < B/B_{MSY} \leq 1$	$\max F_{ABC} = F_{MSY} \times (F_{40\%} / F_{35\%}) \times (B/B_{MSY} - \alpha) / (1 - \alpha)$	
2c) Stock status: $B/B_{MSY} \leq \alpha$	$\max F_{ABC} = 0$	

- *Tier 1 Information available: reliable point estimates of B and B<sub>MSY</sub> and reliable pdf of F<sub>MSY</sub>.*

	<i>With</i>	$\alpha = 0.05$
1a) Stock status: $B/B_{MSY} > 1$	$\max F_{ABC} = mH$	
1b) Stock status: $\alpha < B/B_{MSY} \leq 1$	$\max F_{ABC} = mH \times (B/B_{MSY} - \alpha) / (1 - \alpha)$	
1c) Stock status: $B/B_{MSY} \leq \alpha$	$\max F_{ABC} = 0$	

The process of defining the ABC is similar to determining the OFL. Both use harvest control rules comprising of six tiers, which are based on varying levels of information availability. To establish the parameters ( $F_{40\%}$ ,  $F_{35\%}$ ,  $B_{40\%}$ ,  $B_{35\%}$ ) for tiers 1 to 4, the following methods were employed:

- $B_{35\%}$  is obtained by taking 35% of the unfished biomass ( $B_0$ ), which can be calculated by dividing the MSYBtrigger value by 0.4.
- Meanwhile,  $B_{40\%}$  is equal to the MSYBtrigger value.
- The biomass values  $B_{35\%}$  and  $B_{40\%}$  can be calculated as follows:  $B_{35\%}$  is obtained by taking 35% of the unfished biomass ( $B_0$ ), which can be calculated by dividing the MSYBtrigger value by 0.4.
- As for  $F_{MSY}$ , is adjusted using equations that depend on the target rate. For instance, the equation for  $F_{40\%}$  is  $F_{MSY}$  divided by  $(1 - 0.35)$  multiplied by  $(1 - 0.4)$ . Finally, it was discovered that  $F_{35\%}$  is identical to  $F_{MSY}$ .

The analysis is based on the assumption that a fishing mortality rate of 35% of the unfished biomass ( $F_{35\%}$ ) is equivalent to the rate that results in the  $F_{MSY}$ .

In Tier 1, which requires the calculation of the pdf of MSY, the arithmetic mean and harmonic mean were replaced with  $F_{MSY}$ . This substitution was necessary as there were insufficient data points to calculate the pdf of  $F_{MSY}$  using each species' probability distribution curves.

To determine the new TAC for each tier, the Exploitation Rate (ER) parameter acted as an intermediary between  $F_{ABC}$  (the fishing mortality at which the stock is in the "healthy" range),  $F_{OFL}$  (the fishing mortality at which overfishing occurs), and the catches themselves. Essentially, the parameter ER acted as a link between the desired fishing mortalities ( $F_{ABC}$  and  $F_{OFL}$ ) and the actual catch levels. The relationship between F and ER was calculated as:

$$ER^{11} = 1 - \exp(-\max F_{ABC}) \quad , \quad ABC = ER \times SSB \text{ (StockSize)}$$

### 2.3.2.2. Scenario 2: Setting Maximum Ecosystem Catches Limits

In Scenario 2, the OY was estimated using a specific method. It is possible for the OY to have both a maximum and minimum value. Opting for the minimum value would lead to a TAC that falls significantly below the OY's minimum threshold, which isn't considered ideal.

<sup>11</sup> Sources : (van Denderen et al. 2023)

### *a. Calculation of minimum bound of OY*

The minimum range was established by computing the mean annual catches from 1965 to 1985 using EU data and Alaska's strategy. Amendment 15 was then introduced to regulate the OY, and in 1987, the limit was set after evaluating past and present catches. The minimum range value was determined using the lowest average catch observed within this period, which was recorded in 1965. Technical term abbreviations are fully explained when first used. The language is clear, objective, and free from filler words and emotional language. The writing is grammatically correct and free from spelling and punctuation errors.

### *b. Calculation of maximum bound of OY*

The methodology for determining the upper limit of the maximum OY has been revised. Specifically, this methodology was necessary because information and species MSY data for the European dataset were unavailable between 1983 and 1987.

To estimate the upper range, the fifth-to-last MSY values from the EU North Sea Ecoregion IV for 2018 to 2022 were used. By collecting the jointly agreed TACs during this five-year period, their average was computed. This average was then multiplied by 0.92 for each fish stock involved, to determine their MSYs. The MSY of the entire ecosystem was obtained by adding up all the individual MSY values.

During their time in Alaska, MSY data from the years 1983 to 1987 were used to estimate the maximum range of OY.

After completing the estimations of OY ranges, the subsequent step was to select the most reliable and valid Tier System. To accomplish this, we selected Tier (1a) and (1b) based on the decision rule applied in Alaska. Nonetheless, for Brill and Lemon Sole, we chose Tier 6 as it was the only tier with valid information available for these species<sup>12</sup>.

### *a. Allocation of TAC to countries*

Subsequently, the allocation of quotas to countries was determined based on the agreed principle of quota shares. Prior to finalising the allocation, historical catches for each country were reviewed to gain a better understanding of past and current situations, ensuring a fair distribution of quotas among them. This ensured a fair distribution of quotas among them, and informed decisions were taken to promote stability in the allocation process.

The quotas allocation principle employs council agreed TACs to estimate percentages rather than ICES advised TACs.

The allocation of quotas to Member States, expressed as a percentage of TAC for particular stocks, has undergone minimal change since 1983, even following the 2002 revision of the CFP. Despite doubts about its consistency with EU principles, the established use of relative stability has endured as the favoured method (Hoefnagel, de Vos, et Buisman 2015).

The principle of quota allocation was guided by articles, and significant time and effort was devoted, with two days specifically allocated for reading, researching, synthesising, and ensuring the precision of the methodology.

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<sup>12</sup> R-Code: Annexe II

The TAC values presented in the Council's report may differ from those proposed by ICES. These differences may arise due to variances in data sources, methodologies, or management objectives, resulting in different TAC recommendations.

In this section, two case studies are compared when examining quota shares between countries. The first case study is ICES quotas share for 2022, which is used as the baseline. The second case study is the anticipated quota share following the implementation of the Alaska strategy.

The quotas for the European Union, the United Kingdom, and Norway were calculated initially. Then, for the countries within the Union, the Union's quota value was used to calculate their allocation (refer to Tables 2,3).

Employing this technique calculated the total quotas and percentages, ensuring the Union's quotas were used as the sum of quotas for EU countries instead of overall TAC for Region IV. Subsequently, the percentages were calculated in ascending order. This is the situation following Alaska's implemented strategy.

To compare ICES recommended quotas with estimated quotas, the allocation of ICES quotas was based on the ICES TACs of 2022.

Lorenz curves were constructed using the percentages for each country in the initial scenario (ICES agreed quotas) and the current scenario (estimated quotas using Alaska's strategy).

*Table 2: The agreed percentages for allocating shares between the UK, EU and Norway<sup>13</sup>.*

Country	%COD	%SOL	%HAD	%HKE	%PLE	%POK	%WHG	%BLL _TUR	%LEM
<i>EU</i>	38.2	86.6	13.7	57.1	44.8	36.6	28.9	80.7	35.4
<i>NWY</i>	17.0	0.2	23.0	0.0	7.0	52.3	10.0	0.0	0.0
<i>UK</i>	44.8	13.4	63.3	42.9	26.5	11.2	60.6	19.3	64.6

*Table 3: The agreed percentages for share allocation among UE members<sup>14</sup>.*

Country	%COD	%SOL	%HAD	%HKE	%PLE	%POK	%WHG	%BLL _TUR	%LEM
<i>BLG</i>	6.7	8.7	4.7	1.8	8.6	0.1	6.5	8.7	13.9
<i>DNK</i>	38.6	4.0	32.4	70.3	28.0	10.4	28.0	18.6	38.3
<i>FRA</i>	8.3	1.8	35.9	16.1	1.6	61.7	42.0	2.2	10.6
<i>DEU</i>	24.4	7.0	20.6	8.1	8.1	26.2	7.3	4.8	5.0
<i>NLD</i>	21.8	78.6	3.5	4.1	53.8	0.3	16.2	65.6	31.8
<i>SWE</i>	0.3	0.0	2.9	0.0	0.0	1.4	0.1	0.2	0.4

### ***2.3.2.3. Quota Allocation: Insights from GINI Index Analysis and Lorenz curves***

<sup>13</sup> Sources :(STECF 2022)

<sup>14</sup> Sources : (Council 2022; Hoefnagel, de Vos, et Buisman 2015)

The Gini index is a measure of inequality in the distribution of quotas among different countries, and the formula used in this study is as follows (Farris 2010):

$$G := 2 \int_0^1 [x - L(x)] dx.$$

where:

G: is the Gini index for quotas allocation.

X: represents the cumulative proportion of countries (ranging from 0 to 1) ranked by increasing quotas values.

L(x): is the Lorenz curve, which represents the cumulative proportion of quotas of countries ranked by increasing quotas values.

This was applied for both case studies before and after the implementation of Alaska's strategy<sup>15</sup>.

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<sup>15</sup> R-code :Annexe V



### 3. Chapter III: Results and Discussion

#### 3.1. Results

##### 3.1.1. Species selection results

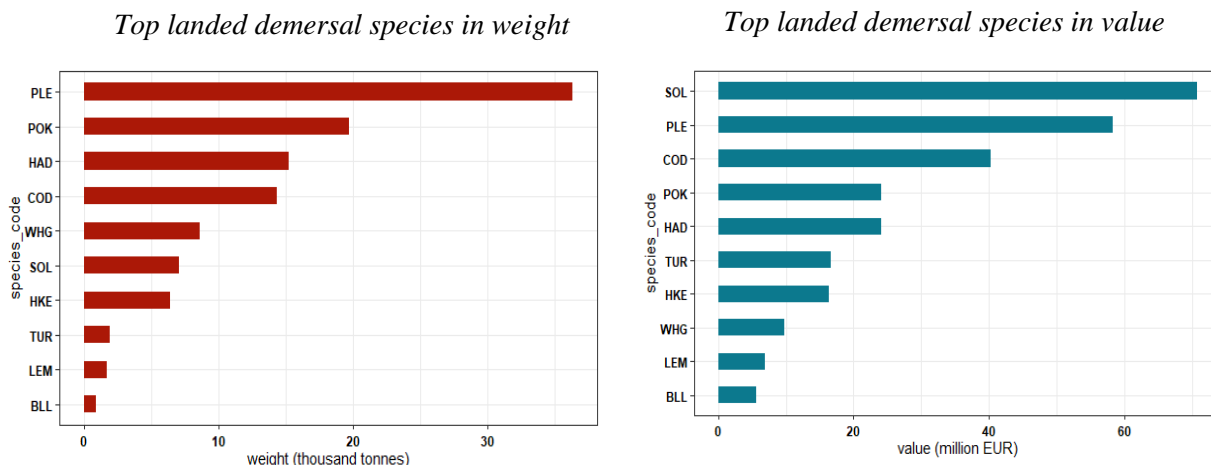


Figure 4: Top 10 demersal species in landed weight and value by EU fleets operating in the North Sea ecoregion IV, 2011 to 2021<sup>16</sup>.

The two graphs (Figure 4) represent the results of the species selection process in weight and value over ten years from 2011 to 2021, from the analysis of the AER data.

Overall, Plaice is the top landed demersal species (36.34 thousand tonnes of the total landed weight), generating the second highest value (EUR 58.31 million). Sole is the species with the highest landed value (EUR 70.83 million) and represents about 7.07 thousand tonnes of the total landings weight.

Furthermore, Cod, Saithe and Haddock are important with North sea landings of 49.32 thousand tonnes, providing value of EUR 88.54 million.

Some species like Turbot, Brill, Lemon sole are highly valued, representing about 30% of the total landings value, but have low landed weights.

##### 3.1.2. Scenario 1: TAC reduction results

Figure 5 provides the estimated TACs or ABCs for the main ten species in the North sea ecoregion IV.

For each fish stock, there are six suggested TACs, ranging from ABC\_t6 to ABC\_t1b. These suggestions result from the application of Alaska's six-tier systems on each fish stock, enabling a comparison and selection of the most appropriate tier that leads to TAC or ABC reduction.

In the case of Cod, Haddock, Saithe, the estimated TAC using the tier system number six, which is based on the average catches between (1965 and 1985), is the highest TAC for the species. The estimated TACs for Sole, Plaice, Whiting and Hake are highest based on tiers 3 and 2. While the tier 1 shows the lowest suggested TAC for all other species.

<sup>16</sup> Source: (STECF 2022)

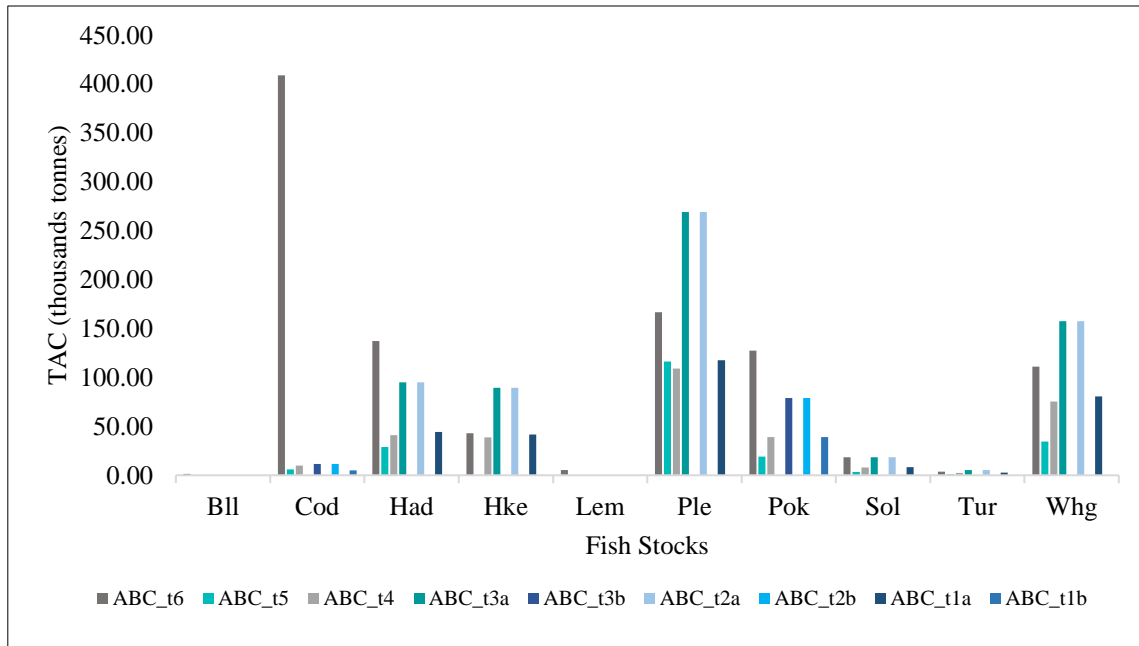
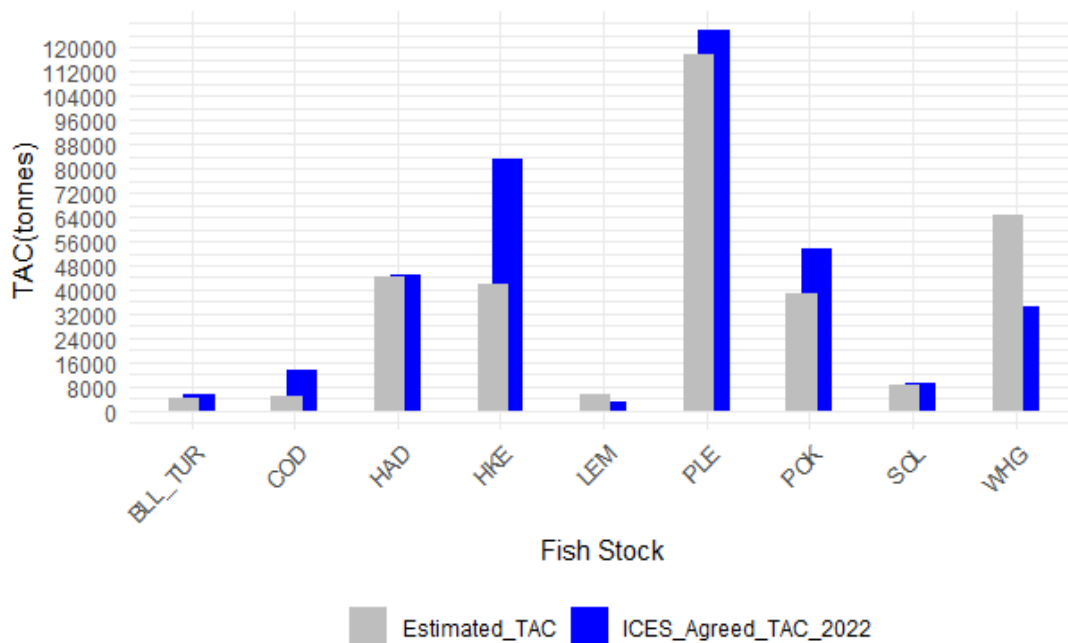


Figure 5: Reported estimated TACs species using Alaska's tiers system in the North sea ecoregion IV<sup>17</sup>.

Figure 6 provides two parts, the part (a) is the results of the comparison between the ICES advised TACs and the estimated TACs for the main species using tiers 1 for all species except Brill and Lemon sole where their suggested TACs are based on tier 6, whilst the part (b) illustrates the percentages of change between the ICES advised TACs and the estimated TACs

(a) The estimated vs the ICES advised TACs



<sup>17</sup> R-code: Annexe I

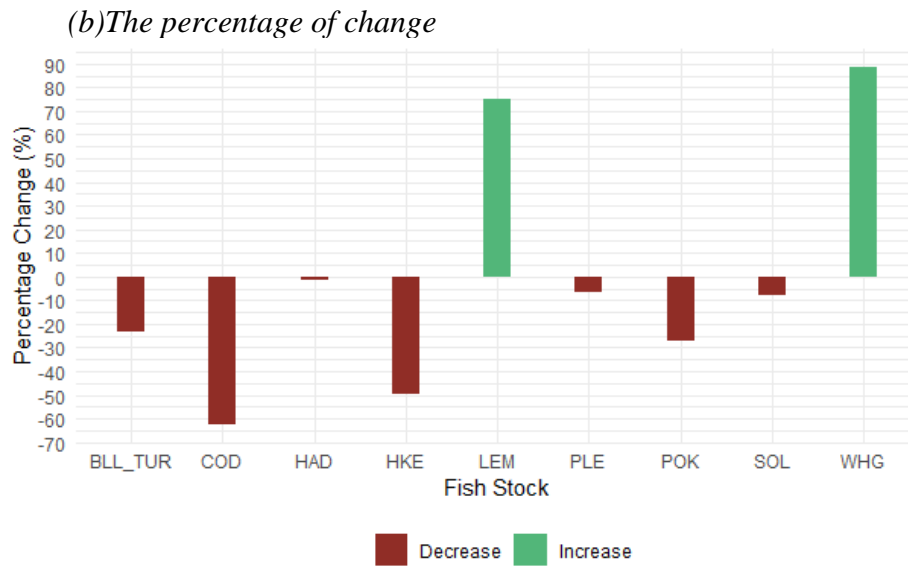


Figure 6: Comparison between ICES advised TAC's in 2022 and the estimated TACs based on Alaska's strategy and quantification of the percentage of change<sup>18</sup>.

Overall, Plaice has the highest TACs in both cases with a slight decrease in the suggested TAC by 6%. The estimated TAC for cod is reduced by 62%. Additionally, sole estimated TACs experienced a slight decrease by 8%. The estimated TACs of Lemon sole and Whiting provides an increase in the catches respectively by (75% and 90%). The TACs of the remaining species such as Hake and Saithe was reduced by (50% and 32%) respectively.

### 3.1.3. Scenario 2: Establishment of Ecosystem Catches results

The evolution of the annual historical catches of the Eu fleets in the North sea ecoregion is shown in Figure 8 for all selected demersal species, except for Brill and Lemon sole, over the period of 56 years.

The year-average catches for all ten identified species are depicted by the black time series curve. The blue line represents the minimum range estimation of the (OY), the red line represents the maximum range of the OY, and the green line represents the TAC estimation for the ecosystem of all ten species. The estimated TACs for each of the ten species, calculated through tier 1, are aggregated to derive this estimation. The grey line represents the ICES' actual agreed TAC for all ecosystems by summing the actual ICES TACs for the ten species.

In general, the catches fluctuated over all the period. In the year 1980, highest peak of catches (2 million tonnes) is observed. Moreover the catches are high between 1970 and 1990. In 1990 they experience a fall until 2000. From 2000 until 2015 there are only small changes. The year 2021 registers the lowest catches. Additionally, the estimated ranges of the OY show a counterintuitive result, the min OY is higher than the max OY.

The ICES advised TAC for the year 2022 is less than the estimated TAC using Alaska's strategy. Both TACs are below the OY min range. The ICES advised TAC is below the max OY

<sup>18</sup> R-code: Annexe IV

range, while the estimated TAC is above the max OY.

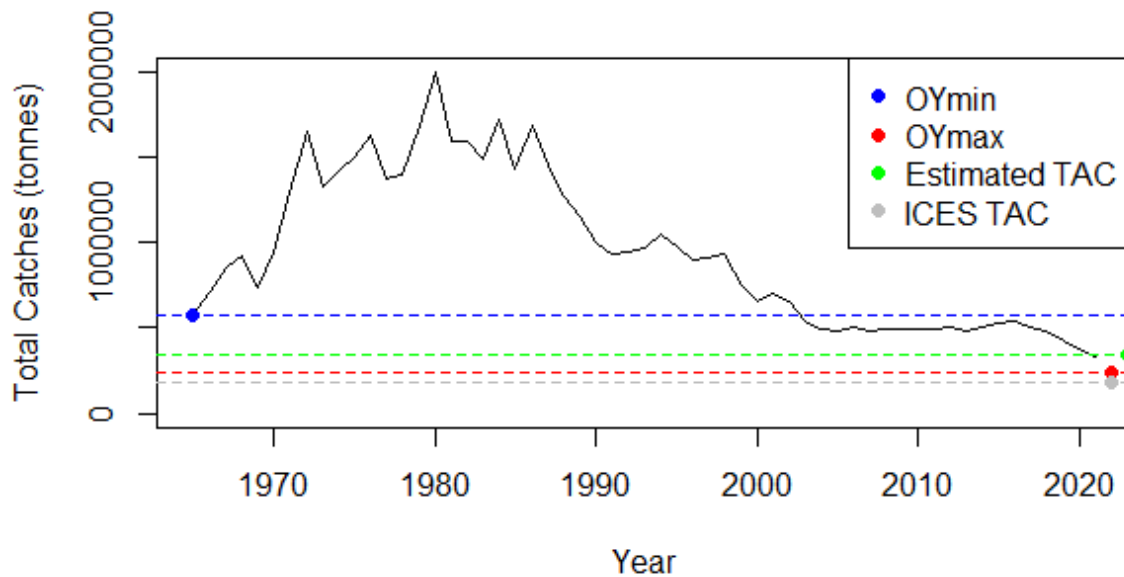


Figure 7: Time series graph of the main demersal species annual catches in the North sea ecoregion IV from 1965 to 2021<sup>19</sup>.

#### 3.1.4. Quotas share between countries

The provided information in (Figure 8) discusses the results of quotas sharing among North Sea countries in region (IV,a,b,c), with a focus on the impact of implementing Alaska's strategy. The analysis includes a comparison between quotas sharing before and after the strategy's implementation, represented by black and blue curves respectively on the graph.

The graph illustrates the distribution of quotas among countries along the x-axis (cumulative share of countries) and the cumulative share of quotas on the y-axis. The red line represents perfect equality in quotas distribution. The black curve represents quotas sharing after ICES advice in 2022, while the blue curve represents suggested quotas after implementing.

The outcome of the ICES quota allocation reveals that the countries with largest shares are UK and Denmark. The smallest share of quotas is dedicated to Germany, Belgium, and Sweden with less than 15% of the Quotas, The Netherlands shares 15%, while France and Norway share more than 25%.

<sup>19</sup> Source :(STECF 2022)

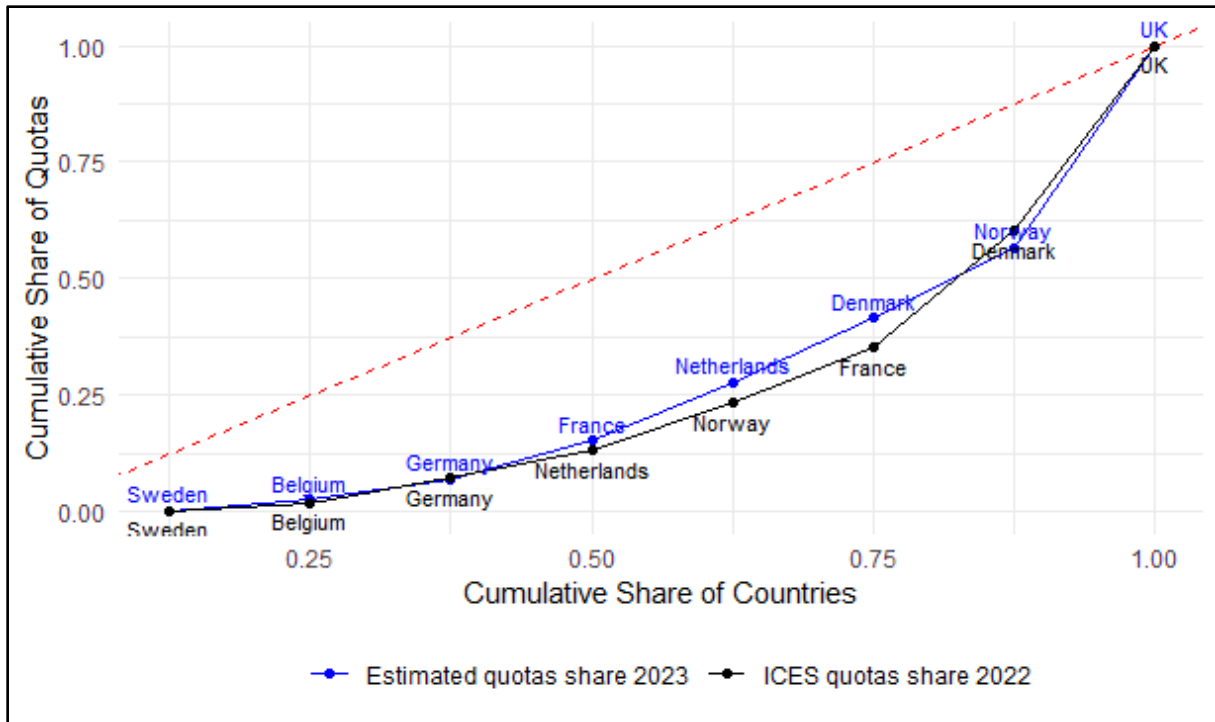


Figure 8: Quotas Allocation Disparity among the North sea ecoregion (IV) Countries, comparison between the ICES advised quotas allocation and the estimated quotas<sup>20</sup>.

After implementing Alaska's strategy, the following changes in the estimated quotas share can be observed:

1) changes in the positions of certain countries in the new scenario compared to the initial situation with Norway moving up to the 2nd position, and Denmark dropping to the 3rd position creating a slight divergence of the curve from the equality line for these countries that share more than 60% of the estimated quotas.

2) the Netherlands rises to the 4th position after Denmark, and France descends to the 5th position for a quota share of less than 25%, with a convergence of the curve towards the equality line.

Germany, Belgium, and Sweden maintain the same positions as in the initial situation, while the UK still occupies the largest part of the estimated quotas.

<sup>20</sup> R-code: Annexe V

### 3.2. Discussion

In the context of fisheries management, it is important to assess the potential advantages of implementing an EBFM to assist with stock recovery and view commercial species as a part of the overall ecosystem.

The EBFM strategy can enhance the sustainability of fish stocks by examining the interactions between individual target species and their surroundings. Examining this approach may assist in comprehending how it contributes to the recovery of specific stocks. Furthermore, investigating the impacts of decreasing TACs. These reductions can have significant consequences for the fishing fleets of various nations, affecting their economies and industries.

This section aims to discuss the previous results and answer the questions regarding the implementation of ecosystem-based fisheries management to regulate groundfish species in the North Sea and lower the TACs. It also involves some expectations about which countries' fishing fleets would primarily bear the brunt of these TAC reductions and understanding the possible outcomes for these nations.

#### 3.2.1. Scenario (1): TAC reduction

The tier system strategy was employed for all species, with varying results for each fish stock. Tier 6, based on historical catches for 21 years in the North Sea ecoregion IV, during this period, stocks like Cod were overfished. As a result, tier 6 was only applied to Brill and Lemon sole due to the lack of data. The application of tier 1, based on  $F_{MSY}$ ,  $SSB$ , and  $B_{MSY}$ , results in the reduction of most TACs, except for Whiting.

The considerable decline in the Cod TAC can be attributed to the implementation of tier 1, resulting in a decrease in the estimated  $F_{MSY}$  from 0.28 to 0.12. Additionally, the  $B/B_{MSY}$  parameter is  $< 0$  for both Cod and Saithe 0.45 and 0.92, indicating that the biomass is insufficient to provide MSY. In other words, the Cod and Saithe biomass levels are only at 45% and 92% of the minimum required for attaining MSY, with  $B_{MSY}$  representing the biomass for maximizing the long-term average catches.

For other species, the estimated  $F_{MSY}$  corresponds with the  $F_{MSY}$  advised by ICES due to the parameter  $B/B_{MSY}$  being greater than 1. In this case, the biomass matches the  $B_{MSY}$  necessary to achieve the maximum long-term average catches.

#### 3.2.2. Scenario (2): Ecosystem catches establishments

The OY scenario, indicated opposite results for the OY ranges, the minimum range of the OY is higher than the maximum range. The Alaskan strategy used to estimate the minimum bound of the OY is applied on the EU data based on the lowest historical average catches over a period of 21 years. Alaska's method to estimate the min range of the OY may not be applicable to the EU data because this period is as indicated in scenario 1 and Figure 8, the period where fishing pressure was high.

In order to estimate the maximum OY of the ecosystem, a method partially resembling the Alaska method was employed due to the absence of statistical data on the MSY history of individual species between 1983 and 1987. The most recent MSYs for 2022-2023 were used and multiplied by 0.92 as per the Alaska method. The maximum range is smaller than the minimum

range, due to the high fishing intensity in the years over which the minimum OY is estimated. This study will give an idea about the challenges of implementing the Alaska strategy to assess sustainable ecosystem yield. This finding aligns with previous research, e.g., (Collie et Gislason 2001), which stresses the importance of utilising multi-species models. (Walters et al. 2005) argue that determining MSY for multi-species systems requires more than just relying on single species cumulative MSYs. Their ecosystem models and principles show the complexity involved in this determination due to the intricate interplay of ecological interactions and fisheries impacts, a notion shared by (Mueter et Megrey 2006).

Incorporating the observations of Kempf et al. (2016), the findings of this research align with the complex challenges inherent in fisheries management today. The pursuit of the MSY for various species exposes nuances that stem from the interconnected trade-offs generated by species interactions, dynamics of mixed fisheries and discrepancies in stakeholder objectives.

This complexity underlines the necessity for a comprehensive approach rather than just focusing on maximum sustainable yield. Our work demonstrates that the intricate nature of multi-species systems requires tactics that consider these nuances and adapt to the diverse objectives of stakeholders. This method is not reliant on the exact definition of MSY ranges and can be implemented on any specified range. Furthermore, the concept of ranges has potential to incorporate various ecological and economic factors, as (Link 2018) have pointed out.

### 3.2.3. *Quotas share among countries*

Regarding the distribution of quotas among the member countries of the European Union and the two countries outside the European Union (Norway and the United Kingdom) which share several stocks with the EU countries, the method used is based on the quotas share agreed principle (Hoefnagel, de Vos, et Buisman 2015). Changes in the quotas share among countries and differences between the two situations are related to the reduction of certain TACs after using Alaska's strategy.

From a value of landing point of view, the implementation of the Alaska strategy will be beneficial for some countries, such as the UK, the Netherlands and Belgium, but not for others, in particular France, Denmark, and Norway.

This outcome is linked to various parameters, such as the market for species, in particular prices, which will play a crucial role in determining a country's overall income. Sharing a significant part of certain quotas does not necessarily guarantee economic profitability, especially when the application of price indices is considered.

Considering, for example, Norway, which has increased its quota position. However, the composition of these quotas is based on saithe (52% quota share) with a price of €2.2/kg and only 17% of the cod quota, which has been significantly reduced. Another example is France and Denmark, whose quotas have been reduced and may not be economically viable. They share significant quotas of certain species that have been substantially reduced, such as hake for Denmark (70%).

Despite increases in some quotas, such as whiting for France (42%), the low price of this stock at €1.78/kg may not compensate for the loss, as France's 60% share of Saithe also remains at a relatively unimportant price. Conversely, both countries have minimal quotas for species such as sole, turbot and brill, which have high market demand.

This analysis brings with it a complex problem: the potential for greater inequality between countries.

Hoefnagel et al. (2014) stated through his work, the lack of transparency in the swapping process. In essence, while quota swapping offers a potential solution, its lack of transparency underscores the need for careful consideration of equitable quota allocation and the promotion of a more equitable paradigm in fisheries management.

It's important to note that economic impacts can vary based on the specific fish species involved, the economic significance of those species to each country, and the overall scale of the fishing industry in each country. Countries highly dependent on fisheries for employment and revenue might face more substantial economic challenges due to changes in quotas distribution.

Given the implications of this situation, the decision-making process surrounding quotas and their allocation is essential.

Under these circumstances, according to the results of this study and due to Alaska's strategy, the quotas composition of certain countries has been changed, the results show that the Netherlands appears to be in a more favourable position, using rentable quotas to strengthen its income distribution, while France faces the challenges posed by quotas of less economically valuable species. Interestingly, while Sweden and Belgium lie on the equality line of the Lorenz curve, suggesting a relatively even quotas distribution, their placement as the last countries on this line raises questions about the intricacies of quotas dynamics within these nations.

These examples demonstrate that the equality line on the Lorenz curve is not the only indicator of a country's economic health or social well-being. It's prominent to consider the wider economic context, including the cost of living, purchasing power and the effectiveness of social policies, to get the full picture.

Ultimately, while Sweden and Belgium may show equitable patterns of quotas distribution, their placement at the bottom suggests that there are still complexities at play that influence overall quotas levels and socio-economic dynamics.

It's a reminder that a nuanced understanding of quotas distribution involves more than just a single metric and requires a holistic examination of the various factors that contribute to a country's economic landscape.

The Gini coefficients confirm the previous expectations, In the initial scenario with a Gini index of 0.69, it signifies a relatively elevated degree of inequality in the distribution of quota shares within the countries.

This indicates that there is an imbalance in the allocation of quotas, with a greater proportion of catches concentrated in a smaller group of countries. However, the implementation of Alaska's strategy has resulted in a Gini index of 0.65, indicating a positive development by reducing inequality.

#### **3.2.4. Study limitations**

The EU has encountered challenges in achieving sustainable fisheries management due to issues like overfishing and the complexity of managing resources across multiple countries. In response, this study has undertaken initiatives in order to align more closely with principles like



MSY. These efforts have aimed to curtail overfishing, facilitate the recovery of fish stocks, and enhance the overall health of marine ecosystems. Measures such as implementing TACs and introducing stricter regulations have been put in place to promote responsible fishing practices.

However, despite these endeavours, there have been instances where the desired outcomes have fallen short of expectations. The Alaska strategy, which emphasizes the conservation of fish stocks and the maintenance of MSY, may not be directly transferable to the EU context. Differences in geographical conditions, regulatory frameworks, and political considerations can significantly influence the effectiveness of these strategies within the EU's complex multi-country dynamics.

The challenge of inadequate information was encountered in tiers 2 and 3, where data for  $F_{40\%}$  and  $F_{35\%}$  were lacking. Additionally, the pdf of  $F_{MSY}$  was not generated. In the first tier, both the harmonic and arithmetic means were utilized. It is conceivable that had the data for  $F_{40\%}$  and  $F_{35\%}$  been available, other tiers could have been explored and TAC reduction might not have been enacted at this stage. The decision to employ the passive voice in this context aims to emphasize the focus on actions taken and information availability rather than attributing these actions directly to specific actors.

## *Conclusion*

In conclusion, the management of the North Sea presents challenges necessitating a multifaceted approach to address its complexities. The mixed fisheries in the region, characterized by intricate species interactions, ecological factors, and socio-economic dimensions, has emphasized the urgency for effective and sustainable management strategies. The key results from this research are:

### Scenario 1: TAC Reduction

- The tier system was utilised for all fish stocks, resulting in diverse outcomes. Tier 6 was applied to Brill and Lemon sole due to data restrictions, relying on historical catches from the past 21 years. Tier 1, which is based on  $F_{MSY}$ ,  $SSB$ , and  $B_{MSY}$  parameters, led to noteworthy reductions in TAC for many species, with the exception of Whiting.
- The significant decrease in Cod TAC has been linked to the enforcement of tier 1, which led to a reduction in estimated  $F_{MSY}$  from 0.28 to 0.12.
- Both Cod and Saithe displayed  $B/B_{MSY}$  parameters under 1 (0.45 and 0.92, respectively), signifying insufficient biomass to attain maximum sustainable yield (MSY).
- Conversely, other species showed concurrence between estimated  $F_{MSY}$  and ICES guidelines, as their  $B/B_{MSY}$  parameters surpassed 1, indicating suitable biomass levels for maximum yield.

### Scenario 2: Establishment of ecosystem catches

- The study uncovers contrasting trends in OY ranges, where the minimum exceeds the maximum.
- This is attributed to difficulties in applying Alaska's strategy to EU data, demonstrating the criticality of context-aware methodologies.
- The challenges of implementing Alaska's strategy expose the intricacy of assessing multi-species ecosystems and echo the significance of accounting for interactions and mixed fisheries dynamics when determining sustainable yield.
- The complicated dynamics of quota distribution among EU nations, Norway, and the UK, based on the principle of quotas share agreed principle. It demonstrates how Alaska's strategy affects quota distribution due to TAC reductions.
- The implementation of Alaska's tiers system strategy may will be beneficial for The UK, the Netherlands, and Belgium, while France, Denmark, and Norway may face economic challenges due to reductions in valuable quotas.

The study underscores the importance of EBFM for stock recovery and acknowledges the complexities of balancing multi-species dynamics and stakeholder objectives.

The findings emphasize the need to move beyond traditional approaches and consider the broader ecological implications. Additionally, the study showcases challenges in implementing Alaska's strategy for estimating sustainable ecosystem yields, emphasizing the need for multi-species models.

The distribution of quotas among countries presents economic disparities, with the implementation of Alaska's strategy leading to shifts in distribution patterns. The study raises questions about fairness and transparency in quota allocation and recognizes the potential impacts on economies and industries of different nations.

Overall, the study's results contribute to understanding the complexities of fisheries

management and underscore the importance of a holistic approach that considers ecological, economic, and social factors.

Furthermore, the integration of alternative gears, initially considered as a potential solution, holds promise for future exploration. Although this study doesn't delve extensively into their implementation, their consideration offers a significant avenue for further investigation. Subsequent research could delve into the practicality of alternative gear options, their potential ecological impacts, and how well they align with broader ecosystem-based management strategies.

Moreover, the relationship between TAC reduction and countries' quotas warrants in-depth examination. The complexity of this relationship demands thorough analysis to pinpoint the countries most affected by such reductions. Future research could delve into these intricacies, evaluating socio-economic consequences, potential disparities, and the adaptive capacities of different nations.

Likewise, the potential adoption of the Alaskan management style merits further investigation. Although not extensively explored in this study, the applicability, advantages, and resonance of the Alaskan approach within the North Sea's unique context provide fertile ground for future exploration. Subsequent research could explore the nuances of implementing the Alaskan strategy, assessing its effectiveness in reducing fishing mortalities, aiding stock recovery, and mitigating environmental impacts.

In summary, this research underscores the interconnectedness of ecological and socio-economic factors in fisheries management. By examining the North Sea's challenges through the lens of the Alaskan strategy, TAC reduction implications, and broader ecosystem-based approaches, this study lays a foundation for informed decision-making and sustainable progress. The findings contribute to both scientific insight and practical policy considerations, fostering a more resilient and harmonious coexistence between human activities and the marine ecosystems of the North Sea.

However, the first scenario employed Tier 1, data limitations hindered the use of other tiers.

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## Annexes

### Annexe I: Species selection (R-code)

#### Value

```
#Import data
#####
#####

datav <- read.csv("C:/Users/21366/OneDrive/Bureau/Master-
data/datav.csv", sep=";")
View(datav)

na_rows <- datav[is.na(datav$value), ]

# Convert the 'value' column to numeric
datav$value <- as.numeric(datav$value)

# Assuming you have the 'dplyr' package installed, if not, install it
using install.packages("dplyr")
library(dplyr)

# Convert the 'value' column to numeric
datav$value <- as.numeric(datav$value)

# Group, summarize, and calculate annual sum for each species_code and
year
summarized_datav <- datav %>%
  group_by(species_code, year) %>%
  summarize(annual_sum = sum(value, na.rm = TRUE)) %>%
  ungroup()

# Filter the summarized data for years between 2011 and 2021
filtered_summarized_datav <- summarized_datav %>%
  filter(year >= 2011 & year <= 2021)

averagesv <- filtered_summarized_datav %>%
  group_by(species_code) %>%
  summarise(avg_value = mean(annual_sum, na.rm = TRUE))

averagesv <- averagesv %>%
  group_by(species_code) %>%
  summarise(total_avg_value_euro = sum(avg_value)) %>%
  mutate(total_avg_value_million_euro = total_avg_value_euro / 1e6)
#Select the top important 50 species in value
Topv <- averagesv%>%
  slice_max(order_by = total_avg_value_million_euro, n = 50)
Topv <- Topv %>%
  mutate_if(is.numeric, round, digits = 2)
#####
#####
#Graphs
#Horizontale format
ggplot(Topv, aes(reorder(species_code,total_avg_value_million_euro),
total_avg_value_million_euro, width = .5)) +
  geom_col(fill="#0C798E") +
  coord_flip() +
  xlab("species_code") + ylab("weight (million EUR)") + theme_bw()+
```



## Annexes

```
theme(axis.text.x = element_text(face="bold",color="black",angle=360,size =9, vjust=0.5))+
theme(axis.text.y = element_text(face="bold",color="black",angle=360,size =9, vjust=0.5))
#####
#####
#Indicate the demersal species with different color to make a distinction
Groundfish_species <- c("SOL","ANF", "PLE", "HAD", "POK", "COD", "TUR",
"HKE", "WHG", "LEM", "BLL", "DAB", "FLE", "MON", "GUU", "WIT", "LIN",
"POL", "CAT")
other_species <- c("HER", "MAC", "CSH", "SPR", "WHB", "SAN", "NOP",
"ARU", "NEP", "ANF", "CRE", "ARY", "GUX", "SRA")

Topv2 <- Topv %>%
  mutate(category = ifelse(species_code %in% Groundfish_species,
"Groundfish_species", "Other_species"))

demersal_color <- "#09B3D5"
other_color <- "#0C798E"
#Plot
ggplot(Topv2, aes(reorder(species_code, total_avg_value_million_euro),
total_avg_value_million_euro, width = 0.5)) +
  geom_col(aes(fill = category), width = 0.5) +
  scale_fill_manual(values = c(Groundfish_species = demersal_color,
Other_species = other_color), position = "bottom") +
  coord_flip() +
  xlab("species_code") +
  ylab("value (million EUR)") +
  theme_bw() +
  theme(
    axis.text.x = element_text(face = "bold", color = "black", angle =
360, size = 9, vjust = 0.5),
    axis.text.y = element_text(face = "bold", color = "black", angle =
360, size = 6, vjust = 0.5),
    legend.position = "bottom", # Position the legend at the bottom
    legend.box = "horizontal" # Arrange legend items horizontally
  )
)

#####
#####
#select only demersal species from the 50 important
Topv_dmersal <- Topv %>%
  filter(species_code %in%
c("PLE","HAD","POK","COD","WHG","SOL","HKE","LEM","DAB","LIN","TUR","LEM",
"BLL","GUU","FLE","MON","BLL","WIT","POL","CAT"))

#plot only demersal species
ggplot(Topv_dmersal, aes(reorder(species_code, total_avg_value_mil-
lion_euro), total_avg_value_million_euro, width = .5)) +
  geom_col(fill="#0C798E") +
  coord_flip() +
  xlab("species_code") + ylab("value (million EUR)") +
  + theme_bw()+
```

## Annexes

```
theme(axis.text.x = element_text(face="bold",color="black",angle=360,size =9, vjust=0.5))+
theme(axis.text.y = element_text(face="bold",color="black",angle=360,size =9, vjust=0.5))

#####
#####
#Other selection of top 10 important demersal species in value
Topv10 <- Topv_dmersal %>%
  slice_max(order_by = total_avg_value_million_euro, n = 10)
select_Topv <- Topv %>%
  filter(species_code %in%
c("PLE","HAD","POK","COD","WHG","SOL","HKE","DAB","LIN","TUR","LEM","BL
L"))
#Plot
ggplot(select_Topv, aes(reorder(species_code, total_avg_value_mil-
lion_euro), total_avg_value_million_euro, width = .5)) +
  geom_col(fill="#0C798E") +
  coord_flip() +
  xlab("species_code") + ylab("value (million EUR)") + theme_bw()+
  theme(axis.text.x = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))+
  theme(axis.text.y = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))
#####
#####
#The final selection
select_Top <- Topv %>%
  filter(species_code %in% c("European Plaice","Had-
dock","Saithe","Cod","Whiting","Sole","Hake","Turbot","Lemon
sole","Brill"))
#####
#####
#Plot the 10 species
ggplot(Topv10, aes(reorder(species_code, total_avg_value_million_euro),
total_avg_value_million_euro, width = .5)) +
  geom_col(fill="#0C798E") +
  coord_flip() +
  xlab("species_code") + ylab("value (million EUR)") + theme_bw()+
  theme(axis.text.x = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))+
  theme(axis.text.y = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))
#####
#####
#Export results
write_xlsx(Topv_dmersal, path = file.path(file_path, "Topv_dmer-
sal.xlsx"))
write_xlsx(Topv, path = file.path(file_path, "Topv.xlsx"))
file_path <- "C:/Users/21366/OneDrive/Bureau/Masterdata/"

datak <- sum(value)

# Replace 'datak' with the actual name of your data frame
```

## Annexes

```
# Replace 'column_name' with the actual name of the column you want to
sum

# If 'datak' is a data frame
column_sum <- sum((datak$value)/1000000, na.rm = TRUE)

# If 'datak' is a matrix
# column_sum <- sum(datak[, "column_name"], na.rm = TRUE)

print(column_sum)
```

### Weight

```
#Import data
#####
#####
datak <- read.csv("C:/Users/21366/OneDrive/Bureau/Master-
data/datak.csv", sep=";")
View(datak)

na_rows <- datak[is.na(datak$value), ]

# Convert the 'value' column to numeric
datak$value <- as.numeric(datak$value)

# Assuming you have the 'dplyr' package installed, if not, install it
using install.packages("dplyr")
library(dplyr)

# Convert the 'value' column to numeric
datak$value <- as.numeric(datak$value)

# Group, summarize, and calculate annual sum for each species_code and
year
summarized_data <- datak %>%
  group_by(species_code, year) %>%
  summarize(annual_sum = sum(value, na.rm = TRUE)) %>%
  ungroup()

# Filter the summarized data for years between 2011 and 2021
filtered_summarized_data <- summarized_data %>%
  filter(year >= 2011 & year <= 2021)

averages <- filtered_summarized_data %>%
  group_by(species_code) %>%
  summarise(avg_value = mean(annual_sum, na.rm = TRUE))

averages <- averages %>%
  group_by(species_code) %>%
  summarise(total_avg_value_kg = sum(avg_value)) %>%
  mutate(total_avg_value_thousands_tonnes = total_avg_value_kg / 1e6)

#select the top 50 species
Topk <- averages %>%
  slice_max(order_by = total_avg_value_thousands_tonnes, n = 50)

Topk <- Topk %>%
```

## Annexes

```
mutate_if(is.numeric, round, digits = 2)

#####
#####

#Graphs
#Horizontale format
#Plot the 50 important species in weight
ggplot(Topk, aes(reorder(species_code, total_avg_value_thou-
sands_tonnes), total_avg_value_thousands_tonnes, width = .5)) +
  geom_col(fill="dimgrey") +
  coord_flip() +
  xlab("species_code") + ylab("weight (thousand tonnes)") +
  theme_bw()+
  theme(axis.text.x = element_text(face="bold",color="#993333",an-
gle=360,size =9, vjust=0.5))+
  theme(axis.text.y = element_text(face="bold",color="#993333",an-
gle=360,size =9, vjust=0.5))
#####
#####
#Indicate the demersal species in the graph
Groundfish_species <- c("SOL", "PLE", "HAD", "POK", "COD", "TUR",
"HKE", "WHG", "LEM", "BLL", "DAB", "FLE", "MON", "GUU", "WIT", "LIN",
"POL", "CAT")
other_species <- c("HER", "MAC", "CSH", "SPR", "WHB", "SAN", "NOP",
"ARU", "NEP", "ANF", "CRE", "ARY", "GUX", "SRA", "ANF")

Topk2 <- Topk %>%
  mutate(category = ifelse(species_code %in% Groundfish_species,
"Groundfish_species", "Other_species"))

demersal_color <- "#09B3D5"
other_color <- "dimgrey"

ggplot(Topk2, aes(reorder(species_code, total_avg_value_thou-
sands_tonnes), total_avg_value_thousands_tonnes, width = 0.5)) +
  geom_col(aes(fill = category), width = 0.5) +
  scale_fill_manual(values = c(Groundfish_species = demersal_color,
Other_species = other_color), position = "bottom") +
  coord_flip() +
  xlab("species_code") +
  ylab("weight (thousand tonnes)") +
  theme_bw() +
  theme(
    axis.text.x = element_text(face = "bold", color = "black", angle =
360, size = 9, vjust = 0.5),
    axis.text.y = element_text(face = "bold", color = "black", angle =
360, size = 6, vjust = 0.5),
    legend.position = "bottom", # Position the legend at the bottom
    legend.box = "horizontal" # Arrange legend items horizontally
  )
#####
#####
#select only demersal species
Topk_dmersal <- Topk %>%
  filter(species_code %in%
c("PLE", "HAD", "POK", "COD", "WHG", "SOL", "HKE", "LEM", "DAB", "LIN", "TUR", "LE
M", "BLL", "GUU", "FLE", "MON", "BLL", "WIT", "POL"))
```

## Annexes

```
#Plot demrsal species
ggplot(Topk_dmersal, aes(reorder(species_code, total_avg_value_thou-
sands_tonnes), total_avg_value_thousands_tonnes, width = .5)) +
  geom_col(fill="dimgrey") +
  coord_flip() +
  xlab("species_code") + ylab("weight (thousand tonnes)") + theme_bw()+
  theme(axis.text.x = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))+
  theme(axis.text.y = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))

#second selection after reduction based on the most important 10 spe-
cies in weight
Topk10 <- Topk_dmersal %>%
  slice_max(order_by = total_avg_value_thousands_tonnes, n = 10)

Select_Topk <- Topk %>%
  filter(species_code %in%
c("PLE","HAD","POK","COD","WHG","SOL","HKE","TUR","LEM","BLL"))

#plot the 10 important species
ggplot(Select_Topk , aes(reorder(species_code, total_avg_value_thou-
sands_tonnes), total_avg_value_thousands_tonnes, width = .5)) +
  geom_col(fill="#AB1807") +
  coord_flip() +
  xlab("species_code") + ylab("weight (thousand tonnes)") +
  theme_bw()+
  theme(axis.text.x = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))+
  theme(axis.text.y = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))

Topk10 <- Topk_dmersal %>%
  slice_max(order_by = total_avg_value_thousands_tonnes, n = 10)

#plot the 10 important species
ggplot(Topk10 , aes(reorder(species_code, total_avg_value_thou-
sands_tonnes), total_avg_value_thousands_tonnes, width = .5)) +
  geom_col(fill="#AB1807") +
  coord_flip() +
  xlab("species_code") + ylab("weight (thousand tonnes)") +
  theme_bw()+
  theme(axis.text.x = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))+
  theme(axis.text.y = element_text(face="bold",color="black",an-
gle=360,size =9, vjust=0.5))
#####
#####
#Export results
write_xlsx(Topk_dmersal, path = file.path(file_path, "Topk_dmer-
sal.xlsx"))
write_xlsx(Topk, path = file.path(file_path, "Topk.xlsx"))
file_path <- "C:/Users/21366/OneDrive/Bureau/Masterdata/"
```

---

**Annexe II: Scenario (1) : TAC reduction (R-code)**

---

```
#Smati Hadjer
#Scenariol: harvest
#date: 29/06/2023
#Wageningen Economic Research

#####IMPORT EU DATA
#####
Stock <- read.csv("C:/Users/21366/OneDrive/Bureau/Alaska/Stock.csv")
file_path <- "C:/Users/21366/OneDrive/Bureau/Alaska/Exploratoryre-
sults/"
#####INSTALL PACKAGES AND LIBRARIES
#####
#Packages

install.packages("ggplot2")
install.packages("dplyr")
install.packages("tidyr")
install.packages("reader")
install.packages("stringr")
install.packages("plotly")
install.packages("DiagrammeR")
install.packages("ggvis")
install.packages("openxlsx")
install.packages("sandwich")
install.packages("survival")
install.packages("reshape2")
install.packages("ggrepel")
install.packages("writexl")

#Libraries
library(writexl)
library(ggrepel)
library(reshape2)
library(ggplot2)
library(dplyr)
library(tidyr)
library(tidyverse)
library(reader)
library(stringr)
library(plotly)
library(DiagrammeR)
library(ggvis)
library(openxlsx)
library(sandwich)
library(survival)
library(writexl)

#####FILTER EU
DATA#####
# Group by on multiple columns
Stock_IV <- Stock %>%
  filter(
```

## Annexes

```
FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de"),
Year %in% c(1978:1995)
)
Stock_IV2 <- Stock_IV %>% group_by(FishStock,Year) %>%
  summarise(totale_catches=sum(Catches))
print(Stock_IV2)

#####
#####
Stock_IV <- Stock %>%
  filter(
    FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de"),
    Year %in% c(1978:1995)
  )

Stock_IV2 <- Stock_IV %>%
  group_by(FishStock, Year) %>%
  summarise(totale_catches = sum(Catches), totale_Landings = sum(Land-
ings))

print(Stock_IV2)

# delete species which the value in the catches column were not indi-
cated

Finalcatches <- Stock_IV2 %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de"))
print(Finalcatches)
# number of years between 1978 and 1995
Year_num <- Finalcatches %>%
  filter(Year >= 1978 & Year <= 1995)

#Calculate mean of catches using years,Summing the catches for each
species
Topcatches <- Year_num %>%
  group_by(FishStock) %>%
  summarise(
    TotalCatches = sum(totale_catches),
    TotalLandings = sum(totale_Landings),
    NumYears = n_distinct(Year),
    AvgCatches = TotalCatches / NumYears,
    AvgLandings = TotalLandings / NumYears
  )

print(Topcatches)

#####START TIERS SYSTEMS
#####
#####Tier_6#####
#####
```

## Annexes

```
#OFL = the average catch from 1978 through 1995, unless an alternative
value is established by the SSC on the basis of the best available sci-
entific information
#Calculate the OFL
#ABC=0.75*OFL
#Calculate the ABC

tier_6 <- Topcatches%>%
  mutate(OFL= AvgCatches)

tier_6 <- tier_6 %>%
  mutate(ABC = OFL * 0.75)
tier_6 <- tier_6 %>%
  mutate(OFLb = AvgLandings)

tier_6 <- tier_6 %>%
  mutate(ABCb = OFLb * 0.75)

# Specify the FishStock values to exclude
excluded_FishStock <- c("bll.27.3a47de", "lem.27.3a47d", "tur.27.4")
tier_6$ABCb[!(tier_6$FishStock %in% excluded_FishStock)] <- NA
tier_6$OFLb[!(tier_6$FishStock %in% excluded_FishStock)] <- NA

# Assign values to OFL column
tier_6$OFL <- ifelse(is.na(tier_6$OFL), tier_6$OFLb, tier_6$OFL)

# Remove Landings_OFL column
tier_6$OFLb <- NULL

# Assign values to maxABC column
tier_6$ABC <- ifelse(is.na(tier_6$ABC), tier_6$ABCb, tier_6$ABC)

# Remove Landings_maxABC column
tier_6$ABCb <- NULL

#####END TIER
6#####

#####START Tier
5#####
#Filter and select data

tier_5 <- Stock %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
" hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
" whg.27.47d", "lem.27.3a47d", "bll.27.3a47de")) %>%
  filter(Year == 2021) %>%
  group_by(FishStock) %>%
  summarise(Catches = sum(Catches), StockSize = first(StockSize))

#Adding a new qualitative variable to the "M= natural mortality" column
tier_5 <- tier_5 %>%
  mutate(
    M = case_when(
      FishStock == "cod.27.47d20" ~ 0.2,
      FishStock == "had.27.46a20" ~ 0.2,
      FishStock == "tur.27.4" ~ 0.2,
      FishStock == "ple.27.420" ~ 0.2,
```



## Annexes

```
FishStock == "pok.27.3a46" ~ 0.2,
FishStock == "sol.27.4" ~ 0.1,
FishStock == "whg.27.47d" ~ 0.2,
TRUE ~ NA_real_
))

#FOFL = M #Calculate the OFL
tier_5 <- tier_5 %>%
  mutate(FOFL= M)

tier_5 <- tier_5 %>%
  mutate(ER=1-exp(-FOFL))
#Calculate ER= ER=1-exp(-maxFABC)
tier_5 <- tier_5 %>%
  mutate(ER=1-exp(-FOFL))
tier_5 <- tier_5 %>%
  mutate(OFL= StockSize*ER)

#Calculate the ABC #maxFABC = 0.75 × M

tier_5 <- tier_5 %>%
  mutate(maxFABC= 0.75*M)
#Calculate ER= ER=1-exp(-maxFABC)
tier_5 <- tier_5 %>%
  mutate(ER=1-exp(-maxFABC))
#ABC= Stock_size*ER
tier_5 <- tier_5 %>%
  mutate(ABC=StockSize*ER )

#####END TIER
5#####

#####START Tier
4#####

tier_4 <- Stock %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de")) %>%
  filter(Year == 2021) %>%
  group_by(FishStock) %>%
  summarise(
    MSYBtrigger= first(MSYBtrigger),
    Landings= sum(Landings),
    Catches= sum(Catches),
    Discards= sum(Discards),
    FMSY = first(FMSY),
    StockSize = first(StockSize)
  )

#Calculate F35% F40%
#F40%      FMSY / (1-0.35) x (1-0.4)
#F35%      FMSY

tier_4 <- tier_4 %>%
  mutate(`F35%` = FMSY,
         `F40%` = FMSY/(1-0.35)*(1-0.4)
  )
```

## Annexes

```
tier_4 <- tier_4 %>%
  mutate(`B35%` = MSYBtrigger/0.4*0.35,
         `B40%` = MSYBtrigger
  )

#• B35% = MSYBtrigger/0.4 x 0.35 (is equal to B0 x 0.35)
#• B40% = MSYBtrigger
#B0 = unfished biomass = MSYBtrigger/0.4

#BMSY: Spawning stock biomass (SSB) that results from fishing at FMSY
for a long time. The biomass that allows maximum sustainable yield to be
taken. Also see B40%.

#Btrigger: Value of spawning stock biomass (SSB) that triggers a spe-
cific management action
#SSB: Spawning stock biomass. Total weight of all sexually mature fish
in the stock.
#B40%: (stocksize=SSB=BMSY=B40%), 40% of unfished biomass (size of fish
stock without fishing). This is the Council's threshold for declaring a
stock rebuilt, or the size of the stock estimated to produce maximum
sustainable yield. This is also referred to as BMSY.

#B100%
#B35%
#B0: Unfished biomass; the estimated size of a fish stock in the ab-
sence of fishing.
#Bx% biomass that results from a fishing mortality
#####rate of Fx%
#FMSY: The fishing mortality rate that maximizes catch biomass in the
long term.
#F40%
#F35%
#FX% fishing mortality rate at which the SPR level would be reduced to
X% of the SPR level in the absence of fishing
#For tiers 2 to 4, a designation of the form "FX%" refers to the fish-
ing mortality rate (F) associated with an equilibrium level of spawning
per recruit equal to X% of the equilibrium level of spawning per re-
cruit in the absence of any fishing
#FOFL = F35%
#ABC=maxFABC=F40%

#FOFL=F35%
tier_4 <- tier_4 %>%
  mutate(FOFL=`F35%`)
tier_4 <- tier_4 %>%
  mutate(ER=1-exp(-FOFL))
tier_4 <- tier_4 %>%
  mutate(OFL=StockSize*ER)

#ABC: maxFABC = F40%
tier_4 <- tier_4 %>%
  mutate(maxFABC=`F40%`)

tier_4 <- tier_4 %>%
  mutate(ER=1-exp(-maxFABC))

tier_4 <- tier_4 %>%
  mutate(ABC= StockSize*ER)
```

## Annexes

```
#####END TIER
4#####

#####START Tier
3#####

tier_3 <- Stock %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"nke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de")) %>%
  filter(Year == 2021) %>%
  group_by(FishStock) %>%
  summarise(
    MSYBtrigger= first(MSYBtrigger),
    StockSize= first(StockSize),
    Landings= sum(Landings),
    Catches= sum(Catches),
    Discards= sum(Discards),
    FMSY = first(FMSY)
  )

# The most important parameter to calculate is the (B/B40%), we have
here BMSY= B40%, B= SSB or The stock size.

tier_3 <- tier_3 %>%
  mutate(`F35%` = FMSY,
         `F40%` = FMSY/((1-0.35)*(1-0.4))
  )
tier_3 <- tier_3 %>%
  mutate(`B35%` = MSYBtrigger/(0.4*0.35),
         `B40%` = MSYBtrigger
  )

tier_3 <- tier_3 %>%
  mutate(`B/B40%` = StockSize/MSYBtrigger)

#OFL:
#3a) Stock status: B/B40% > 1 FOFL = F35%
#3b) Stock status:  $\alpha < B/B40\% \leq 1$  FOFL =  $F35\% \times (B/B40\% - \alpha) / (1 - \alpha)$ 
#3c) Stock status:  $B/B40\% \leq \alpha$  FOFL = 0

tier_3 <- tier_3 %>%
  mutate(FOFLa = ifelse(StockSize/MSYBtrigger > 1, `F35%`, NA))
tier_3 <- tier_3 %>%
  mutate(ERFa=1-exp(-FOFLa))
tier_3 <- tier_3 %>%
  mutate(OFLa = ifelse(StockSize/MSYBtrigger > 1, StockSize*ERFa, NA))

tier_3 <- tier_3 %>%
  mutate(FOFLb = ifelse(StockSize/MSYBtrigger < 1, `F35%` *
(StockSize/MSYBtrigger - 0.05) / (1 - 0.05), NA))
tier_3 <- tier_3 %>%
  mutate(ERFb=1-exp(-FOFLb))
tier_3 <- tier_3 %>%
  mutate(OFLb = ifelse(StockSize/MSYBtrigger < 1, StockSize*ERFb, NA))
```

## Annexes

```
#ABC:
#3a) Stock status:  $B/B_{40\%} > 1$  maxFABC = F40%
#3b) Stock status:  $\alpha < B/B_{40\%} \leq 1$  maxFABC = F40%  $\times (B/B_{40\%} - \alpha)/(1 - \alpha)$ 
#3c) Stock status:  $B/B_{40\%} \leq \alpha$  maxFABC = 0

tier_3 <- tier_3 %>%
  mutate(maxFABCa = ifelse(StockSize/MSYBtrigger > 1, `F40%`, NA))
tier_3 <- tier_3 %>%
  mutate(ERAA=1-exp(-maxFABCa))
tier_3 <- tier_3 %>%
  mutate(ABCa = ifelse(StockSize/MSYBtrigger > 1, StockSize*ERAA, NA))

tier_3 <- tier_3 %>%
  mutate(maxFABCb = ifelse(StockSize/MSYBtrigger < 1, `F40%` *
(StockSize/MSYBtrigger - 0.05) / (1 - 0.05), NA))
tier_3 <- tier_3 %>%
  mutate(ERAb=1-exp(-maxFABCb))
tier_3 <- tier_3 %>%
  mutate(ABCb = ifelse(StockSize/MSYBtrigger < 1, StockSize*ERAb, NA))

#####END TIER
3#####

#####START Tier
2#####

tier_2 <- Stock %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de")) %>%
  filter(Year == 2021) %>%
  group_by(FishStock) %>%
  summarise(
    MSYBtrigger= first(MSYBtrigger),
    StockSize= first(StockSize),
    Landings= sum(Landings),
    Catches= sum(Catches),
    Discards= sum(Discards),
    FMSY = first(FMSY)
  )

tier_2 <- tier_2 %>%
  mutate_if(is.numeric, round, digits = 3)

# B/BMSY

tier_2 <- tier_2 %>%
  mutate(`B/BMSY` = StockSize/MSYBtrigger)

#FOL:
#2a) Stock status:  $B/BMSY > 1$  FOFL = FMSY
#2b) Stock status:  $\alpha < B/BMSY \leq 1$  FOFL = FMSY  $\times (B/BMSY - \alpha)/(1 - \alpha)$ 
#2c) Stock status:  $B/BMSY \leq \alpha$  FOFL = 0
#select and filter data

tier_2 <- tier_2 %>%
  mutate(FOFLa = ifelse(StockSize/MSYBtrigger > 1, `FMSY`, NA))
tier_2 <- tier_2 %>%
```

## Annexes

```
mutate(ERFa=1-exp(-FOFLa))
tier_2 <- tier_2 %>%
  mutate(OFLa = ifelse(StockSize/MSYBtrigger > 1, StockSize*ERFa, NA))

tier_2 <- tier_2 %>%
  mutate(FOFLb = ifelse(StockSize/MSYBtrigger < 1, `FMSY` *
  (StockSize/MSYBtrigger - 0.05) / (1 - 0.05), NA))
tier_2 <- tier_2 %>%
  mutate(ERFb=1-exp(-FOFLb))
tier_2 <- tier_2 %>%
  mutate(OFLb = ifelse(StockSize/MSYBtrigger < 1, StockSize*ERFb, NA))

#ABC:
#2a) Stock status: B/BMSY > 1 maxFABC = FMSY × (F40% /F35%)
#2b) Stock status:  $\alpha < B/BMSY \leq 1$  maxFABC = FMSY × (F40% /F35%) × (B/BMSY
-  $\alpha$ ) / (1 -  $\alpha$ )
#2c) Stock status: B/BMSY  $\leq \alpha$  maxFABC = 0

tier_2 <- tier_2 %>%
  mutate(`F35%` = FMSY,
         `F40%` = FMSY/((1-0.35)*(1-0.4))
  )
tier_2 <- tier_2 %>%
  mutate(`B35%` = MSYBtrigger/(0.4*0.35),
         `B40%` = MSYBtrigger
  )

tier_2 <- tier_2 %>%
  mutate(maxFABCa = ifelse(StockSize/MSYBtrigger > 1,
`FMSY`*(`F40%`/`F35%`), NA))
tier_2 <- tier_2 %>%
  mutate(ERAA=1-exp(-maxFABCa))
tier_2 <- tier_2 %>%
  mutate(ABCa = ifelse(StockSize/MSYBtrigger > 1, StockSize*ERAA, NA))

tier_2 <- tier_2 %>%
  mutate(maxFABCb = ifelse(StockSize/MSYBtrigger < 1,
((`FMSY`*(`F40%`/`F35%`)* (StockSize/MSYBtrigger - 0.05))/ (1 - 0.05)),
NA))
tier_2 <- tier_2 %>%
  mutate(ERAb=1-exp(-maxFABCb))
tier_2 <- tier_2 %>%
  mutate(ABCb = ifelse(StockSize/MSYBtrigger < 1, StockSize*ERAb, NA))

#####END TIER
2#####

#####START Tier
1#####
# Filter EU data
tier_1 <- Stock %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de")) %>%
  filter(Year == 2021) %>%
  group_by(FishStock) %>%
  summarise(
```

## Annexes

```

MSYBtrigger= first(MSYBtrigger),
StockSize= first(StockSize),
Landings= sum(Landings),
Catches= sum(Catches),
Discards= sum(Discards),
FMSY = first(FMSY)
)

# B/BMSY

tier_1 <- tier_1 %>%
  mutate(`B/BMSY` = StockSize/MSYBtrigger)
#OFL:
#1a) Stock status:  $B/BMSY > 1$  FOFL =  $m_A$  , the arithmetic mean of the
pdf
#1b) Stock status:  $\alpha < B/BMSY \leq 1$  FOFL =  $m_A \times (B/BMSY - \alpha) / (1 - \alpha)$ 
#1c) Stock status:  $B/BMSY \leq \alpha$  FOFL = 0
#####OFL
#1a) Stock status:  $B/BMSY > 1$  FOFL =  $m_A$  , the arithmetic mean of the
pdf
tier_1 <- tier_1 %>%
  mutate(FOFLa = ifelse(StockSize/MSYBtrigger > 1, `FMSY`, NA))
tier_1 <- tier_1 %>%
  mutate(ERFa=1-exp(-FOFLa))
tier_1 <- tier_1 %>%
  mutate(OFLa = ifelse(StockSize/MSYBtrigger > 1, StockSize*ERFa, NA))
#####
##
#1b) Stock status:  $\alpha < B/BMSY \leq 1$  FOFL =  $m_A \times (B/BMSY - \alpha) / (1 - \alpha)$ 
tier_1 <- tier_1 %>%
  mutate(FOFLb = ifelse(StockSize/MSYBtrigger < 1, `FMSY` *
(StockSize/MSYBtrigger - 0.05) / (1 - 0.05), NA))
tier_1 <- tier_1 %>%
  mutate(ERFb=1-exp(-FOFLb))
tier_1 <- tier_1 %>%
  mutate(OFLb = ifelse(StockSize/MSYBtrigger < 1, StockSize*ERFb, NA))
#####ABC
#1a) stock status:  $B/BMSY > 1$  maxFABC =  $m_H$  , the harmonic mean of the
pdf
#1b) Stock status:  $\alpha < B/BMSY \leq 1$  maxFABC =  $m_H \times (B/BMSY - \alpha) / (1 - \alpha)$ 
#1c) Stock status:  $B/BMSY \leq \alpha$  maxFABC = 0

#1a) stock status:  $B/BMSY > 1$  maxFABC =  $m_H$  , the harmonic mean of the
pdf
tier_1 <- tier_1 %>%
  mutate(maxFABCa = ifelse(StockSize/MSYBtrigger > 1, `FMSY`, NA))
tier_1 <- tier_1 %>%
  mutate(ERAA=1-exp(-maxFABCa))
tier_1 <- tier_1 %>%
  mutate(ABCa = ifelse(StockSize/MSYBtrigger > 1, StockSize*ERAA, NA))

#1b) Stock status:  $\alpha < B/BMSY \leq 1$  maxFABC =  $m_H \times (B/BMSY - \alpha) / (1 - \alpha)$ 
tier_1 <- tier_1 %>%
  mutate(maxFABCb = ifelse(StockSize/MSYBtrigger < 1, `FMSY` *
(StockSize/MSYBtrigger - 0.05) / (1 - 0.05), NA))
tier_1 <- tier_1 %>%
  mutate(ERAb=1-exp(-maxFABCb))
tier_1 <- tier_1 %>%

```

## Annexes

```
mutate(ABCb = ifelse(StockSize/MSYBtrigger < 1, StockSize*ERAb, NA))

#####END TIER
1#####

#####END TIER SYS-
TEM#####

# Gather all Results in one table (scenario_1)
scenario_1 <- data.frame(
  FishStock = tier_6$FishStock,
  OFL_t6 = tier_6$OFL,
  ABC_t6 = tier_6$ABC
)

print(scenario_1)

scenario_1 <- scenario_1%>%
  mutate(
    OFL_t5 = tier_5$OFL,
    ABC_t5 = tier_5$ABC,
    OFL_t4 = tier_4$OFL,
    ABC_t4 = tier_4$ABC,
    OFL_t3a = tier_3$OFLa,
    ABC_t3a = tier_3$ABCa,
    OFL_t3b = tier_3$OFLb,
    ABC_t3b = tier_3$ABCb,
    OFL_t2a = tier_2$OFLa,
    ABC_t2a = tier_2$ABCa,
    OFL_t2b = tier_2$OFLb,
    ABC_t2b = tier_2$ABCb,
    OFL_t1a = tier_1$OFLa,
    ABC_t1a = tier_1$ABCa,
    OFL_t1b = tier_1$OFLb,
    ABC_t1b = tier_1$ABCb
  )

print(scenario_1)

scenario_1 <- scenario_1 %>%
  mutate_if(is.numeric, round, digits = 2)

#Filter only the ABCs in one table "chosen"
chosen <- scenario_1 %>%
  filter(FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
" hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de")) %>%
  group_by(FishStock) %>%
  summarise(
    ABC_t6 = first(ABC_t6),
    ABC_t5 = first(ABC_t5) ,
    ABC_t4 = first(ABC_t4),
    ABC_t3a = first(ABC_t3a),
    ABC_t3b = first(ABC_t3b),
    ABC_t2a = first(ABC_t2a),
    ABC_t2b = first(ABC_t2b ),
    ABC_t1a =first(ABC_t1a),
    ABC_t1b =first(ABC_t1b)
```

## Annexes

```
)

# Export the tables to an Excel file
write_xlsx(scenario_1, path = file.path(file_path, "scenario_1.xlsx"))
write_xlsx(tier_1, path = file.path(file_path, "tier_1.xlsx"))
write_xlsx(tier_2, path = file.path(file_path, "tier_2.xlsx"))
write_xlsx(tier_3, path = file.path(file_path, "tier_3.xlsx"))
write_xlsx(tier_4, path = file.path(file_path, "tier_4.xlsx"))
write_xlsx(tier_5, path = file.path(file_path, "tier_5.xlsx"))
write_xlsx(tier_6, path = file.path(file_path, "tier_6.xlsx"))
write_xlsx(chosen, path = file.path(file_path, "chosen.xlsx"))

##### PLOT GRAPHS
#####
#Graphs: representation of the ABCs of each tier system for each Fish-
Stock

FishStocks <- c("sol.27.4", "ple.27.420", "cod.27.47d20", "hke.27.3a46-
8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4", "whg.27.47d",
"bll.27.3a47de", "lem.27.3a47d")
# Extract the data for the given FishStocks
selected_data <- chosen[chosen$FishStock %in% FishStocks, ]
# Define colors for each column
colors <- c("ABC_t6" = "#3F5A54", "ABC_t5" = "#62978C", "ABC_t4" =
"#52B49F",
           "ABC_t3a" = "#9FF1E0", "ABC_t3b" = "#899C98", "ABC_t2a" =
"#419AA6",
           "ABC_t2b" = "#0590A2", "ABC_t1a" = "#5AD1B8", "ABC_t1b" =
"#09446A")
# Melt the data
melted_data_all <- melt(selected_data, id.vars = "FishStock", varia-
ble.name = "Column", value.name = "value")
# Plot the stacked column chart
ggplot(melted_data_all, aes(x = FishStock, y = value, fill = Column)) +
  geom_bar(stat = "identity", position = "dodge") + # Change position
to "stack"
  scale_fill_manual(values = colors) +
  xlab("FishStock") +
  ylab("Value") +
  ggtitle("FishStock Values by Columns") +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

#Comparaison between the ICES advised TAC for each FishStock and the
New estimated TACs:
# Create a data frame from the vectors
D1 <- data.frame(FishStock = c("COD", "SOL", "HAD", "HKE", "PLE",
"POK", "WHG", "BLL_TUR", "LEM"),
                 ICES_Agreed_TAC_2022 = c(13246,9152,
44924,83130,125692,53374,34294, 5444,3140),
                 Estimated_TAC_2023 = c(4970.33, 8421.62, 44212.84,
41632.53, 117710.28, 38945.13,64773.34
, 4178.71, 5496.25))

# Reshape the data to make it suitable for plotting
D2 <- tidyr::gather(D1, key = "TAC_Type", value = "TAC", -FishStock)
```



## Annexes

```
# Create the bar chart using ggplot2
ggplot(D2, aes(x = FishStock, y = TAC, fill = TAC_Type)) +
  geom_bar(stat = "identity", position = "dodge") +
  labs(x = "Fish Stock", y = "TAC (tonnes)", title = "Bar Chart: ICES
Agreed TACs for the year 2022 and New estimated TACs by Fish Stock us-
ing Alaska's strategy") +
  scale_fill_manual(values = c("ICES_Agreed_TAC" = "#09446A", "Esti-
mated_TAC_2023" = "#98E0EE"),
                    labels = c("ICES Agreed TAC 2022", "Esti-
mated_TAC_2023")) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1)) +
  guides(fill = guide_legend(title = "TAC Type"))
print(D2)

#####End of Scenario
1#####
#####
#####
library(ggplot2)
library(tidyr)

D1 <- data.frame(FishStock = c("COD", "SOL", "HAD", "HKE", "PLE",
"POK", "WHG", "BLL_TUR", "LEM"),
                ICES_Agreed_TAC_2022 = c(13246, 9152, 44924, 83130,
125692, 53374, 34294, 5444, 3140),
                Estimated_TAC_2023 = c(4970.33, 8421.62, 44212.84,
41632.53, 117710.28, 38945.13, 64773.34, 4178.71, 5496.25))

# Reshape the data to make it suitable for plotting
D2 <- tidyr::gather(D1, key = "TAC_Type", value = "TAC", -FishStock)

# Create the bar chart using ggplot2
ggplot(D2, aes(x = FishStock, y = TAC, fill = TAC_Type)) +
  geom_bar(stat = "identity", position = "dodge") +
  labs(x = "Fish Stock", y = "TAC (tonnes)") +
  scale_fill_manual(values = c("ICES_Agreed_TAC_2022" = "#09446A", "Es-
timated_TAC_2023" = "#98E0EE"),
                    labels = c("ICES Agreed TAC 2022", "Estimated TAC
2023")) +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1),
        legend.position = "bottom", # Move the legend to the bottom
        legend.box = "horizontal") # Arrange legend items horizontally
```

---

### Annexe III: Scenario (2) : Ecosystem catches limit establishment (R-code)

---

```
Rule:min range of OY approximately equal to the lowest historical
groundfish catch during the 21-year period 1965-1985.
#First step: the min range of the OY (MSY)
#####
#####
#Filter data in the data frame (scenario_2)

scenario_2 <- Stock %>%
  filter(
```

## Annexes

```
FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de"),
Year %in% c(1965:1985)
)
scenario_2 <- scenario_2 %>% group_by(FishStock,Year) %>%
  summarise(totale_catches=sum(Catches),)
print(scenario_2)

#Catches per year
scenario_2 <- scenario_2 %>%
  group_by(Year) %>%
  summarise(totale_catches = sum(totale_catches, na.rm = TRUE))

#The lowest value of catches during a periode of 21 year:
lowest_catches <- min(scenario_2$totale_catches)
year_with_lowest <- scenario_2$Year[which.min(scenario_2$to-
tale_catches)]

###The upper range of OY=> go Excel table (MSY_Agreed)
#####
##
#According to the Alaska's strategy, the max Range of OY (MSY) is de-
rived from MSY information. The MSY for all species of groundfish be-
tween 1983 and 1987, the result multiplied by 0.92.
#In this case we are going to use the excel to:
#1)collect the agreed TACs of each FishStock between 2018 and 2022
#2)estimate the average for each FishStock
#3)MSY for each fish Stock: Multiply the results by 0.92
#4)min range of MSY: sum of all the MSYs
#####
####

# The optimum yiel of the ecosystem is:
OYmin <- 575447
OYmax <- 235955.53

OY_ecosystem <- c(OYmin = OYmin, OYmax = OYmax)

#####
#####
#####
#The choice of new TAC is based on best available information in tier 1
except for LEM and BLL we choosed the tier 6 for them
NTAC<- chosen %>%
  summarise( NTAC= sum(ABC_t1a, na.rm = TRUE))
NTAC2<- chosen %>%
  summarise(NTAC2= sum(ABC_t1b, na.rm = TRUE))
sum (1525.54 + 5496.25 +NTAC +NTAC2)
#The ecosystem new estimated TAC is: 346302.2 tonnes

##### TIME SERIES
#####
# Filter the data
dataseries <- Stock %>%
  filter(
```

## Annexes

```
FishStock %in% c("sol.27.4", "ple.27.420", "cod.27.47d20",
"hke.27.3a46-8abd", "had.27.46a20", "pok.27.3a46", "tur.27.4",
"whg.27.47d", "lem.27.3a47d", "bll.27.3a47de"),
Year %in% c(1965:2021)
)

# Summarize the data
dataserie <- dataserie %>%
  group_by(FishStock, Year) %>%
  summarise(totale_catches = sum(Catches, na.rm = TRUE))

# Summarize by Year to get the total catches per year
dataserie <- dataserie %>%
  group_by(Year) %>%
  summarise(totale_catches = sum(totale_catches, na.rm = TRUE))

# Plot the time series
plot(dataserie$Year, dataserie$totale_catches, type = "l", xlab =
"Year", ylab = "Total Catches (tonnes)", xlim = c(1965, 2021), ylim =
c(0, max(dataserie$totale_catches)))

# Add the additional points (OYmin and OYmax)
OYmin <- 575447
OYmax <- 235955.53
points(1965, OYmin, col = "blue", pch = 16) # OYmin point
points(2022, OYmax, col = "red", pch = 16) # OYmax point

# Draw horizontal lines from OYmin and OYmax to the y-axis
abline(h = OYmin, col = "blue", lty = 2) # Horizontal line for OYmin
abline(h = OYmax, col = "red", lty = 2) # Horizontal line for OYmax
# Add a legend for the additional points
legend("topright", legend = c("OYmin", "OYmax"), col = c("blue",
"red"), pch = c(16))

#####End part 1 of scenario 2
#####

#*****#
```

### Annexe IV: Quotas share (R-code)

---

```
Relative_SUB_4 <- read.csv("C:/Users/21366/OneDrive/Bureau/Alaska/Relative_SUB_4.csv", sep=";")
View(Relative_SUB_4)
RelativeS_UE <- read.csv("C:/Users/21366/OneDrive/Bureau/Alaska/RelativeS_UE.csv", sep=";")
RelativeS_UE

#####Calculate the % of TAC allocated to EU North Sea countries by
FishStock
#we are going to use the relative stability principal:
#â€œThe actual determination of the relative stability key was based on
three elementsâ€œ
#1) historic catches based on a reference period from 1973 to 1978.
#2) a preferential treatment for regions particularly dependent on
fishing (also known as The Hague preferences)
#3)jurisdictional losses following the implementation of the 200 nauti-
cal mile Exclusive Economic Zone (EEZ) by third countries (non-EU coun-
tries) were compensated.
```

## Annexes

```
#####  
#####  
#Swaps  
#TACs and quota swapping in the EU  
#2.2. The extent of quota swapping After the TACs have been agreed by  
the Commission they can be adapted in two ways by the Member States:  
Member States can  
#1) either exchange quota with other Member States (quota swaps) or  
#2) request and be allowed to transfer quota of a certain species from  
one area to another area (quota transfers) within the same country. So  
in quota transferring only one Member State is involved while quota  
swaps are done by two or more Member States.  
#####  
#New_TAC #####add the value of new TACs for each FishStock  
#####FROM THE TABLE chosen  
#Start by calculate new TAC of NORAWAY UK EU  
value1 <- 4970.33  
value2 <- 8421.62  
value3 <- 44212.84  
value4 <- 41632.53  
value5 <- 117710.28  
value6 <- 38945.13  
value7 <- 80734.56  
value8 <- 1525.54  
value9 <- 2653.17  
value10 <- value8+value9  
print(value10)  
value11 <- 5496.25  
  
total_sum <- value1 + value2 + value3 + value4 + value5 + value6 +  
value7+ value10+ value11  
  
total_sum  
#Calculate the New TACs for each Country UK NORWAY EU  
TAC_RS_UK_N_EU<- Relative_SUB_4 %>%  
  mutate(  
    TAC_COD = ((value1*`Per_COD`/100)),  
    TAC_SOL = ((value2*`Per_SOL`/100)),  
    TAC_HAD= ((value3*`Per_HAD`/100)),  
    TAC_HKE= ((value4*`Per_HKE`/100)),  
    TAC_PLE= ((value5*`Per_PLE`/100)),  
    TAC_POK= ((value6*`Per_POK`/100)),  
    TAC_WHG= ((value7*`Per_WHG`/100)),  
    TAC_BLL_TUR= ((value10*`Per_BLL.TUR`/100)),  
    TAC_LEM= ((value11*`Per_LEM`/100))  
  )  
  
print(TAC_RS_UK_N_EU)  
TAC_RS_UK_N_EU <- TAC_RS_UK_N_EU%>%  
  mutate_if(is.numeric, round, digits = 2)  
# Export the "RelativeS" table to an Excel file  
write_xlsx(TAC_RS_UK_N_EU, path = file.path(file_path,  
"TAC_RS_UK_N_EU.xlsx"))  
#####  
#####  
#CALCULATE THE QUOTAS OF THE EU CONTRIES, In theis part we are going to  
use the results of the previous step just for the EU,sO we are going to  
allocate the TACs of the EU on the EU countries.
```

## Annexes

```
TAC_COD <- 1898.67
TAC_SOL <- 7293.12
TAC_HAD <- 6057.16
TAC_HKE <- 23772.17
TAC_PLE <- 52734.21
TAC_POK <- 14253.92
TAC_WHG <- 23332.28
TAC_BLL_TUR <- 3372.22
TAC_LEM <- 1945.67

RelativeS_UE<- RelativeS_UE %>%
  mutate(
    Quotas_COD = ((TAC_COD*`Per_COD`/100)),
    Quotas_SOL = ((TAC_SOL*`Per_SOL`/100)),
    Quotas_HAD= ((TAC_HAD*`Per_HAD`/100)),
    Quotas_HKE= ((TAC_HKE*`Per_HKE`/100)),
    Quotas_PLE= ((TAC_PLE*`Per_PLE`/100)),
    Quotas_POK= ((TAC_POK*`Per_POK`/100)),
    Quotas_WHG= ((TAC_WHG*`Per_WHG`/100)),
    Quotas_BLL_TUR= ((TAC_BLL_TUR*`Per_BLL._TUR`/100)),
    Quotas_LEM= ((TAC_LEM*`Per_LEM`/100))
  )

print (RelativeS_UE)
RelativeS_UE <- RelativeS_UE %>%
  mutate_if(is.numeric, round, digits = 2)
write_xlsx(RelativeS_UE , path = file.path(file_path, "RelativeS_UE
.xlsx"))

#Gather all results of the relative stability allocation in one table
(New_Quotas)
New_Quotas<- RelativeS_UE[, c("Country", "Quotas_COD", "Quotas_SOL",
"Quotas_HAD", "Quotas_HKE", "Quotas_PLE", "Quotas_POK", "Quotas_WHG",
"Quotas_BLL_TUR", "Quotas_LEM")]
New_Quotas <- na.omit(New_Quotas)
#Add the results of the relative stability allocation process of the
non EU countries to the same table
values_to_add <- data.frame(
  Country = c("Norway", "UK"),
  Quotas_COD = c(844.96, 2226.71),
  Quotas_SOL = c(16.84, 1128.50),
  Quotas_HAD = c(10168.95 , 27986.73),
  Quotas_HKE = c(0.00, 17860.36),
  Quotas_PLE = c(8239.72, 31193.22),
  Quotas_POK = c(20368.30, 4361.81),
  Quotas_WHG = c(8073.46, 48925.14),
  Quotas_BLL_TUR = c(0.0000, 806.491),
  Quotas_LEM = c(0.000, 3550.58)
)

# Append the new rows to 'New_TAC'
New_Quotas <- rbind(New_Quotas, values_to_add)

# Print the updated data frame 'New_TAC'
print(New_Quotas)

New_Quotas <- New_Quotas %>%
  mutate_if(is.numeric, round, digits = 2)
```

## Annexes

```
#Sum the Quotas of each country
New_Quotas$Total_Quotas <- rowSums(New_Quotas[, c("Quotas_COD", "Quo-
tas_SOL", "Quotas_HAD", "Quotas_HKE", "Quotas_PLE", "Quotas_POK", "Quo-
tas_WHG", "Quotas_BLL_TUR", "Quotas_LEM")], na.rm = TRUE)
#Import the table as excel file
write_xlsx(New_Quotas , path = file.path(file_path, "New_Quotas
.xlsx"))

Norway <-47712.23
UK <-138039.58
Union <-134659.43
```

### **Annexe V: Gini index (R-code)**

---

```
library(ggplot2)

# Calculate GINI index for the estimated quotas

country <- c("Belgium", "Denmark", "France", "Germany", "Netherlands",
"Sweden", "Norway", "UK")
total_quotas <- c(8104.12, 43852.42, 26009.12, 14115.53, 42357.45,
418.76, 47712.23, 138039.54)

# Calculate cumulative proportions of quotas for each country
cumulative_quotas <- cumsum(total_quotas) / sum(total_quotas)

# Calculate cumulative proportions of population (countries)
cumulative_population <- seq_along(country) / length(country)

# Calculate absolute differences between cumulative proportions
absolute_diff <- abs(cumulative_quotas - cumulative_population)

# Calculate Gini coefficient for each country
gini_coefficients <- 1 - (2 * sum(absolute_diff) / length(country))

# Create a data frame to store the results
gini_data <- data.frame(country = country, gini_coefficient = gini_co-
efficients)

print(gini_data)

#calculate the gini index for the ICES allocations
country <- c("Belgium", "Denmark", "France", "Germany", "Netherlands",
"Sweden", "Norway", "UK")
TAC_ICES <- c(3162.59, 41823.45, 19486.01, 8568.39, 10775.33, 228.50,
42697.17, 83827.31)

# Calculate cumulative proportions of TAC for each country
cumulative_TAC <- cumsum(TAC_ICES) / sum(TAC_ICES)

# Calculate cumulative proportions of population (countries)
cumulative_population <- seq_along(country) / length(country)

# Calculate absolute differences between cumulative proportions
absolute_diff <- abs(cumulative_TAC - cumulative_population)
```

## Annexes

```
# Calculate Gini coefficient for each country
gini_coefficients <- 1 - (2 * sum(absolute_diff) / length(country))

# Create a data frame to store the results
gini_data <- data.frame(country = country, gini_coefficient = gini_co-
efficients)

print(gini_data)

# Assuming you have loaded the necessary libraries, such as 'ggplot2'

# Data for total quotas
country_quotas <- c("UK", "Norway", "Denmark", "Netherlands", "France",
"Germany", "Belgium", "Sweden")
total_quotas <- c(137233.05, 47712.23, 43225.19, 40145.27, 25934.93,
13953.66, 7810.74, 412.02)
data_quotas <- data.frame(country_quotas, total_quotas)

# Sort data by total quotas in ascending order
data_quotas <- data_quotas[order(data_quotas$total_quotas), ]

# Calculate cumulative quotas and cumulative share of quotas
data_quotas$cumulative_quotas <- cumsum(data_quotas$total_quotas)
data_quotas$quotas_share <- data_quotas$cumulative_quotas /
sum(data_quotas$total_quotas)

# Data for TAC
country_TAC <- c("UK", "Denmark", "France", "Norway", "Netherlands",
"Germany", "Belgium", "Sweden")
TAC_ICES <- c(65700.53, 41586.11, 19457.94, 16874.15, 9938.27, 8507.14,
3051.58, 225.95)
data_TAC <- data.frame(country_TAC, TAC_ICES)

# Sort data by TAC_ICES in ascending order
data_TAC <- data_TAC[order(data_TAC$TAC_ICES), ]

# Calculate cumulative TAC_ICES and cumulative share of TAC_ICES
data_TAC$cumulative_TAC <- cumsum(data_TAC$TAC_ICES)
data_TAC$TAC_share <- data_TAC$cumulative_TAC / sum(data_TAC$TAC_ICES)

# Create the ggplot object
p <- ggplot() +
  geom_line(data = data_quotas, aes(x = seq_along(country_quotas) /
length(country_quotas), y = quotas_share, color = "Quotas Share"),
linetype = "solid", size = 0.5) +
  geom_line(data = data_TAC, aes(x = seq_along(country_TAC) /
length(country_TAC), y = TAC_share, color = "TAC Share"), linetype =
"solid", size = 0.5) +
  geom_abline(intercept = 0, slope = 1, color = "red", linetype =
"dashed") +
  geom_point(data = data_quotas, aes(x = seq_along(country_quotas) /
length(country_quotas), y = quotas_share, color = "Quotas Share"), size
= 1.5) +
```


## Annexes

```
geom_point(data = data_TAC, aes(x = seq_along(country_TAC) /
length(country_TAC), y = TAC_share, color = "TAC Share"), size = 1.5) +
geom_text(data = data_quotas, aes(x = seq_along(country_quotas) /
length(country_quotas), y = quotas_share, label = country_quotas),
color = "blue", size = 2.5, vjust = -0.5, hjust = 0.8) +
geom_text(data = data_TAC, aes(x = seq_along(country_TAC) /
length(country_TAC), y = TAC_share, label = country_TAC), color =
"black", size = 2.5, vjust = 1.5, hjust = 0.8) +
labs(
  x = "Cumulative Share of Countries",
  y = "Cumulative Share of Quotas"
) +
theme_minimal() +
theme(legend.position = "bottom")

# Adding legend for the lines
p <- p + labs(color = "Legend") +
scale_color_manual(
  values = c("Quotas Share" = "blue", "TAC Share" = "black", "Equal-
ity Line" = "red"),
  labels = c("Estimated quotas share 2023", "ICES quotas share 2022",
"Equality Line"),
  name = ""
)

print(p)
```



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Auteur(s) : Hadjer Smati Date de naissance* : 05/07/1994	Organisme d'accueil : Wageningen economic research
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Année de soutenance : 2023	Maître de stage : Katell Hamon et Pieter Daniël van Denderen
Titre français : Réduire l'impact environnemental des pêcheries de la mer du Nord en utilisant la stratégie de l'Alaska comme exemple.	
Titre anglais : Reducing the environmental impacts of North Sea fisheries using Alaska's strategy as example.	
Résumé: <p>Cette étude examine les avantages et les difficultés de l'introduction de l'approche de gestion Alaska en mer du Nord pour résoudre les problèmes rencontrés par les pêcheries mixtes. L'objectif est de réduire la mortalité par pêche, de reconstituer les stocks et de minimiser les incidences sur l'environnement. À l'aide de données européennes et de modèles de scénarios, l'étude évalue les effets de la réduction des TAC et de la mise en œuvre de limites maximales de captures sur différentes nations et flottes. Le premier scénario montre que les réductions importantes des TAC ont des effets néfastes sur différentes espèces, comme le cabillaud, ce qui suscite des inquiétudes quant à la durabilité des stocks et à la faisabilité financière de la pêche. Cependant, le merlan montre une plus grande résistance à ces réductions. En outre, la recherche met en évidence les difficultés liées à la mise en place de l'approche de l'Alaska dans l'UE en raison des disparités économiques entre les nations. Le deuxième scénario, qui examine les limites maximales de capture pour l'écosystème, révèle des résultats contradictoires en raison de l'incompatibilité avec les données de l'UE et les inégalités dans la répartition des quotas entre les pays.</p>	
Abstract: <p>This study investigates the advantages and difficulties of introducing the Alaska management approach in the North Sea for addressing the problems encountered by mixed fisheries. The goal is to lower fishing mortality, restore stocks, and minimize environmental impacts. Using European data and scenario models, the study assesses the effects of TAC decreases and the implementation of maximum catch limits on various nations and fleets. The first scenario demonstrates that significant TAC reductions have detrimental impacts on different species, like cod, which raises concerns about the sustainability of stocks and the financial feasibility of fishing. However, whiting reveals greater resistance to these reductions. Additionally, the research showcases the challenges of establishing the Alaska approach in the EU due to economic disparities between nations. The second scenario, which examines the maximum catch limits for the ecosystem, reveals conflicting outcomes due to incompatibility with EU data, and inequalities in quotas share among countries.</p>	
Mots-clés : Mer du Nord, Alaska, espèces démersales, gestion des pêcheries, Écosystème. Key Words: North Sea, Alaska, demersal fish, Fisheries management, Ecosystem.	

\* Élément qui permet d'enregistrer les notices auteurs dans le catalogue des bibliothèques universitaires