

## Programme

### Workshop on International Agreements in the Fisheries Sector

*Arranged by EAFE (European Association of Fisheries Economists) with financial support from the Nordic Council of Ministers*

#### Monday 14 May

*Location: Katrina Christiansen restaurant, Bringsnagøta 10, Tórshavn*

19.00 Welcome reception

#### Tuesday 15 May

*Location: Smæran, J.H. Schrøters gøta 7, Tórshavn*

9.00 Welcome Address

**Høgni Hoydal**, *Faroese Fisheries Minister*

9.15 **Keynote Lecture:** International Fisheries Agreements: A Game Theoretical Approach

**Pedro Pintassilgo**, *University of Algarve*

10.00 Marine food webs, environmental variability, and coastal state conflicts: A game theoretic analysis

**Niels-Arne Ekerhovd**, *SNF Centre for applied research at Norwegian School of Economics*

Stein Ivar Steinshamn, *Norwegian School of Economics*

#### 10.30 Coffee break

10.45 The influence of climate variabilities on fisheries management performance – A Northeast Atlantic pelagic fisheries case study

**Sandra Rybicki**, *Thünen Institute of Sea Fisheries*

Sarah Laura Simons, *Thünen Institute of Sea Fisheries*

Axel Temming, *Institute of Hydrobiology and Fisheries Science, University of Hamburg*

11.15 Fishing for Nitrogen - Environmental Impact of Fisheries Management on Nutrient Dynamics in the Baltic Sea

Rasmus Nielsen, *University of Copenhagen*

Ayoe Hoff, *University of Copenhagen*

**Staffan Waldo**, *Swedish University of Agricultural Sciences*

Cecilia Hammarlund, *Swedish University of Agricultural Sciences*

Jarno Virtanen, *Natural Resources Institute Finland*

11.45 Building Resilience of Fisheries Governance in the North East Atlantic

Suzannah F Walmsley, *ABPmer Ltd*

**Erin Priddle**, *Environmental Defense Fund*

## 12.15 Lunch at Smæran

### 13.00 Fishers Labour Rights: A Comparison between North Atlantic Fishing Countries

**Peter Greene**, *Marine Analytical Unit, Marine Scotland*  
Estelle Jones, *Marine Analytical Unit, Marine Scotland*  
Cornilius Chikwama, *Marine Analytical Unit, Marine Scotland*

### 13.30 Importance of external labour force for UK catching and processing sectors

**Hazel Curtis**, *Seafish*  
Arina Motova, *Seafish*  
Marta Moran Quintana, *Seafish*  
Kirsten Milliken, *Seafish*

### 14.00 Regional fishery bodies and management organizations in the context of international agreements

**Piero Mannini**, *Policy, Economics and Institutions Branch, Fishery and Aquaculture Department, FAO*  
Eliana Haberkon, *Policy, Economics and Institutions Branch, Fishery and Aquaculture Department, FAO*

## 14.30 Coffee break

### 14.45 Assessment of utilisation of EU - Faroe Islands Bilateral Fisheries Agreement

Jennifer Russell, *Anderson Solutions*  
**Arina Motova**, *Seafish*  
Hazel Curtis, *Seafish*

### 15.15 New Faroese fisheries management system

**Hans Ellefsen**, *Faroe Islands Ministry of Fisheries*

### 15.45 From open-access to private property regimes: Strategic Interactions in the Snow Crab fishery

**Melina Kourantidou**, *University of Southern Denmark*  
Brooks Kaiser, *University of Southern Denmark*

### 16.15 Options for fishing agreements in the (English) Channel after the Brexit

**Bertrand Le Gallic**, *Center for the law and Economics of the Sea, University of Brest*  
Simon Mardle, *Fishor Ltd*  
Sébastien Metz, *Sakana Consultants*

Potential short guided walking tour around old Tórshavn if weather allows (approx.. 45 minutes)

## 19.30 Dinner at Panorama Hotel Hafnia

*Location: Áarvegur 4-10, Torshavn*

## Wednesday 16 May

### **8.30** International Fisheries Access Agreements and Trade (*Presentation via skype call*)

Tatyana Chesnokova, *Waseda University*

**Stephanie McWhinnie**, *University of Adelaide*

### **9.00** Economic trends and performance of the EU external fleet

Natacha Carvalho, *European Commission, Joint Research Centre*

Angel Calvo, *DG MARE, Economic analysis unit, European Commission*

**Jordi Guillen**, *Joint Research Centre, European Commission*

### **9.30** The EU's international agreements: SFPA and Northern Agreements

**Miguel Peña Castellot**, *DG MARE, Economic analysis unit, European Commission*

## **10.00 Coffee Break**

### **10.15** A fixed catch share scheme to manage shifting transboundary fish stocks

**Xiaozhi Liu**, *Future Oceans Lab, University of Vigo*

Elena Ojea, *Future Oceans Lab, University of Vigo*

Mikko Heino, *University of Bergen*

### **10.45** Competition or Cooperation in Transboundary Fish Stocks Management: Insight from a Dynamical Model

Nguyen Trong Hieu, *Faculty of Mathematics, Mechanics, and Informatics, Vietnam National University*

**Timothée Brochier**, *IRD, UMI 209, UMMISCO & UPMC Univ Paris 06, UMI 209, UMMISCO*

Pierre Auger, *IRD, UMI 209, UMMISCO & UPMC Univ Paris 06, UMI 209, UMMISCO & Université Cheikh Anta Diop, UMMISCO-Dakar*

Trinh Viet Duoc, *Faculty of Mathematics, Mechanics, and Informatics, Vietnam National University*

Patrice Brehmer, *IRD & ISRA*

### **11.15** A stage structured model analysis with an example from the Norwegian North-East Arctic cod fishery

**Anders Skonhøft**, *Norwegian University of Science and Technology*

## **11.45 Lunch at Hafnia**

### **13.00** Optional Field trip to Pelagos fish factory

1-hour drive by bus & 1-hour return by boat

## **19.00** Back in Tórshavn

## List of Participants

### *Workshop on International Agreements in the Fisheries Sector*

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## Abstracts

## International Fisheries Agreements: A Game Theoretical Approach (Keynote Lecture)

**Pedro Pintassilgo**

*Faculty of Economics, University of Algarve, [ppintas@ualg.pt](mailto:ppintas@ualg.pt)*

The management of fish stocks harvested by several countries is an important economic and political issue at the international level. It is estimated that the harvests of these fish stocks account for about one third of world marine harvests. The cooperative management of international shared fish stocks, through International Fisheries Agreements, has proven to be difficult worldwide.

This lecture approaches the formation and stability of International Fisheries Agreements through the use of game theory, which studies the strategic interactions between decision makers, players, using mathematical models called games. Partition function games, non-cooperative games of coalition formation, will be presented and their main results regarding International Fisheries Agreements explored. A key message that emerges from these games is that self-enforcing cooperative management of internationally shared fish stocks is generally difficult to achieve.



## Marine food webs, environmental variability, and coastal state conflicts: A game theoretic analysis

**Nils-Arne Ekerhovd**

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Stein Ivar Steinshamn

*Norwegian School of Economics, NHH*

In the North East Atlantic there are several straddling stocks, including herring, mackerel, and blue whiting, which are exploited both within coastal states' 200 nautical mile Exclusive Economic Zones (EEZ) and on the high seas. The pelagic fisheries of the North East Atlantic are all harvested by the same six countries/parties: the EU, Norway, Faroe Islands, Iceland, Russia, and more recently Greenland. For several years, there has been an unsolved dispute between these nations about the size of their respective quotas. Based on their importance and roles in the fisheries, we model the exploitation as consisting of three players, namely the EU, Norway, and Iceland. The optimization model takes into account biological interaction between the species and strategic interaction between the agents simultaneously. It is assumed that when the nations act as singletons, they behave myopically. When they are member of a coalition, they act in order to maximize the coalition's long-term net revenue. The model is solved using DNLP (Nonlinear Programming with Discontinuous Derivatives), and shows that in most cases the biology (ecosystem) tends to approach a steady state without this being imposed.

Internal and external stability conditions, for all possible coalition structures in steady state, are analyzed in order to find out which coalition structures are most likely to occur, with and without side-payments. This is then compared with what we find in the real world, and political implications are discussed.



## The influence of climate variabilities on fisheries management performance – A Northeast Atlantic pelagic fisheries case study

**Sandra Rybicki**

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There is increasing interest in understanding how natural variations, such as climate change, will influence natural resources, consequently impacting fishing behaviour and fleet economics. The two most valuable pelagic species for the European fish market and known to be influenced by climate variabilities are Northeast Atlantic mackerel and herring. The question how distribution changes of these highly migratory species, induced by ocean warming, will affect key fishing opportunities will be addressed by applying an integrative optimization and simulation bio-economic model, FishRent. The model includes the economics of multiple fleet segments, the impact of fishing on stock development and the spatio-temporal interplay of fleet segments and fish stocks. In contrast to many other models, it not only considers possible effort redistribution, but accounts for the fact that ecological conditions (e.g. recruitment failure, distribution changes) and economic conditions (e.g. revenues and fishing costs) will determine fishing effort. Moreover, the model takes into account that management regulations itself may alter profitability and hence subsequent effort decisions by fleet segments, which in turn will affect the commercial fish stock. By applying this model to the Northeast Atlantic mackerel and North Sea herring fishery the current management plans and two climate scenarios will be tested. The “World Market”-Scenario will focus on a rather unsustainable exploitation, combined with significantly increasing CO<sub>2</sub>-emissions (RCP 8.5). The “Global Sustainability”-Scenario, in contrast, places emphasis on sustainable fisheries by integrating management measures such as Marine Protected Areas. Additionally, it considers low-level CO<sub>2</sub>-emissions (RCP 4.5). All scenarios will consider the increasing north-westerly spawning and feeding distribution of Northeast Atlantic mackerel and poor post yolk-sac larvae survival of North Sea herring due to potential mismatches of spawning time and plankton blooms. As this study affects the fleet economics of both European and Non-European countries, the EAFE-Workshop represents a perfect opportunity to introduce and discuss further aspects of this case study.

## Fishing for Nitrogen - Environmental Impact of Fisheries Management on Nutrient Dynamics in the Baltic Sea

Rasmus Nielsen  
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International collaboration is crucial for managing transboundary environmental problems. This is well known from both fisheries management and other areas such as air- and water pollution. In this paper, international collaboration combining fisheries management and eutrophication policies in the Baltic Sea is analysed. The Baltic Sea is considered as one of the most eutrophicated seas in the world. Although fish catches, and thereby fisheries management, play an important role in regulating nutrient dynamics in the sea, fisheries have not earlier been considered as a tool to reduce eutrophication. This article analyses the value of nutrient removals when using three different policy instruments within fisheries management in the Danish, Finnish and Swedish pelagic fisheries; Individual Transferable Quotas (ITQs), subsidies for nutrient removals, and a requirement to land fish above the Maximum Economic Yield (MEY) level. All policy instruments are analysed with different levels of international collaboration among national fishing sectors. The overall aim is to maximise socioeconomic gains from fisheries taking into account the value of nutrient reduction through fish catches. We distinguish between a private optimum maximising the net present value from fishing and a social value including the positive externality of removing nutrients. A dynamic bio-economic model, FishRent, is used to estimate the effect of the three policy scenarios. The results show that the highest socioeconomic gain is achieved when demanding catches above the MEY level and at the same time introducing a joint ITQ system for all three fishing nations. The joint ITQ system ensures an efficient uptake of quotas and the requirement to land above the MEY level generates a value of nutrient reductions that outweighs the private loss of fishing above what is economically optimal at the private level.

## Building Resilience of Fisheries Governance in the North East Atlantic

Suzannah F. Walmsley  
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Climate-related impacts on the range and distribution of commercial fish stocks are likely to intensify in coming decades and will increasingly challenge existing institutions and governance arrangements that are in place to manage associated fisheries. Furthermore, political pressures, such as the UK's EU exit, are converging under these changing environmental conditions to create an increasingly challenging picture for fisheries governance in the region, but also new opportunities for re-imagining the governance framework.

As stocks shift under climate change, 'winners and losers' are created amongst coastal states, risking the break-down of agreements between coastal states and unilateral quota setting that may result in over-fishing. Ultimately, governance needs to be developed to ensure that the benefits of being part of an agreement outweigh the risks — or penalties — of withdrawing from such an agreement.

Through an analysis of fisheries governance in the North East Atlantic region and case studies from around the world, the key features required to build an adaptive, flexible fisheries governance framework that can respond to climate-related impacts, are identified and how they might be applied in the North East Atlantic region are considered. Opportunities exist within the current landscape, and these can be built upon.

An over-arching and long-term cooperation framework, with all relevant parties involved, is needed for the management of shared stocks to coordinate setting catch limits, management measures and allocations across the North East Atlantic region for widely-distributed stocks. This should incorporate periodic revisiting and review, to promote both stability and appropriate flexibility. It needs to be supported by effective, active, mechanisms for dispute-resolution, and underpinned by responsive, robust science.

## Fishers Labour Rights: A Comparison between North Atlantic Fishing Countries

**Peter Greene**

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Estelle Jones

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Marine fishing is increasingly viewed as a ‘globalised sector of the world economy’ and employment aboard vessels described as ‘a truly global, multi-national and multi-cultural occupation’. However, while there is a wide variety of regulatory frameworks governing the seas, there is an absence of policies and laws that ensure transparent, fair and ethical employment practice on fishing vessels. Coupled with increasing allegations of poor working conditions and poor pay levelled at different nations fishing industries, this is a cause for concern.

Evidence from Scotland shows potential differentials in earnings, where pay is significantly lower for contracted crews (mainly non-EEA nationals) compared to their Scottish and EEA counterparts, even when employed on the same boats carrying out the same work (Jones, Botterill, Chikwama and Gray, 2017). If similar earnings differentials exist in the other countries’ fleets that operate in the UK’s Exclusive Economic Zone alongside the aforementioned Scottish vessels, then this could compound the disparity found by Jones et al (2017). This could in turn result in unfair and inequitable employment practices, especially if other countries’ employment regulations also sustain similar disparities to that seen in the Scottish fleet.

The implementation of the ILO Work in Fishing Convention no. 188 offers a framework for attempting to overcome some of the governance and market failures in the demand for international fishers. In this presentation I will present an exploratory analysis of North Atlantic fishing countries’ domestic legislation, their treatment of fishers’ rights and their implementation of international conventions. I will conclude by reflecting on how this could impact on a countries’ comparative advantage, which could be a key consideration in future trade agreements, and highlighting the need for multilateral action.

## Importance of external labour force for UK catching and processing sectors

**Hazel Curtis**

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Nationality of workers in the catching and fish processing sectors became part of EU Data Collection Framework (DCF) since 2017. EU Member States are obliged to collect social data on their fishing fleet every third year, starting in 2018. Under DCF provisions EU Member States also had possibility to carry out a pilot survey in 2017: to trial and develop a robust methodology for future data collection exercises. The Marine Management Organisation and Marine Scotland contracted Seafish to carry out a pilot survey of employment in the UK fishing fleet in 2017. In early 2017 Seafish requested by industry and Government also conducted a survey of UK seafood processing companies to gather information about nationality of their workforce.

The results of surveys and analyses published for both sectors by Seafish will be presented during EAFE WS. The results highlighted the importance of external labour force for UK fishing and processing industries and some sectoral differences within each of the industries.

The majority of UK seafood processing sites surveyed employ foreign workers from other EU countries. These workers represent approximately 42% of the workforce in the surveyed sites. Region and site size appear to be major factors influencing the nationality mix of the workforce. Larger sites, and sites located in areas with a higher proportion of non-British residents tend to employ larger numbers and proportion of staff from other EU countries.

In the UK fishing sector more than three quarters of the jobs in the sample were filled by UK citizens. Non-UK workers in the sample occupied mainly deckhand and engineer jobs, representing 31% of all engineers and 39% of all deckhands. The analysis also showed that in some UK regions, e.g. Northern Ireland and Scotland the importance of external labour force is higher. When looking at fleet segment level, bigger vessels operating offshore, tend to employ more non UK workers, which for example in cases of nephrops trawl sector represent >50% of workers.

## Regional fishery bodies and management organizations in the context of international agreements

### Piero Mannini

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### Eliana Haberkon

*Policy, Economics and Institutions Branch, Fishery and Aquaculture Department, FAO*

The international community has increasingly recognized that strengthening the governance of shared fishery resources is best achieved by enhancing the role of Regional Fishery Bodies (RFBs), and particularly of Regional Fishery Management Organizations (RFMOs) that have a mandate to adopt binding conservation and management measures.

The role of RFMOs has shifted significantly in the past half-century, starting first with the UNCLOS, then the UNFSA and the FAO Code of Conduct for Responsible Fisheries. In this period, attention has been given to the emerging role of RFMOs, requiring States to establish regional organizations to fulfil their duty to cooperate in ensuring the long-term conservation of fish stocks and the sustainable management of their fisheries.

The current state of many shared fishery resources has led to criticisms of the role of RFBs and RFMOs, which, in turn, has led to debates on how to strengthen and reform the international fisheries management regime.

As the functioning of RFMOs continues to face significant challenges, various processes are under way to address them including the implementation of performance reviews and the revision of these bodies' constitutive instruments.

Effective cooperation and coordination among different competent authorities may prove key to the success of regional initiatives. Relevant regional organizations need to make this cooperation effective through formal mechanisms and joint activities, i.e. by creating linkages between existing fisheries management and biodiversity conservation initiatives, while avoiding the proliferation of institutions with sometimes-conflicting mandates. Increasingly and where appropriate, the international community should pursue coordination and cooperation among regional governance mechanisms, recognizing relevant nexus such as between fisheries and environmental management.

The paper provides an analytical overview of the current regional fishery bodies and regional fisheries management organizations with focus on challenges, opportunities and emerging issues within the framework of regional and global fishery and aquaculture governance.

## Assessment of utilisation of EU - Faroe Islands Bilateral Fisheries Agreement

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The Seafish Pelagic Industry Issues Group (SPIIG) asked Seafish to undertake an independent analysis of the utilisation by the UK and rest of EU of the EU-Faroe bilateral agreement, and the utilisation of the agreement by Faroe Islands. As a result of request Seafish conducted 3 annual analyses of 2014-2016 implementation results. Estimation of the sales value of landings made under the agreement and an analysis of the utilisation of the agreement by home-nation was also requested.

The EU-Faroe bilateral agreement is negotiated annually and includes two different elements:

- **Quota Exchange** – each party in the agreement provided quota from its own quota allowance to the other party. Quota exchange includes both pelagic and demersal quota.
- **Access Entitlement** – each party in the agreement could fish for some of its own pelagic quota in the other party's waters.

The common feature is that both elements allow one party's vessels to fish in the other party's waters. The results of analysis shows that in 2016, across quota exchange and access entitlement in the bilateral agreement:

- EU vessels landed 24% of the total permitted landings that could have been made from Faroese waters in 2016 – up from 10% in 2015 and 2014; and
- Faroese vessels landed 84% of the permitted landings that could have been made from EU and Greenland waters in 2016 – up from 81% in 2015 and 83% in 2014.

## The Faroese fisheries reform

### Hans Ellefsen

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On 13 December 2017, the Faroese Parliament passed a bill that represents a major reform of national fisheries management in the Faroe Islands. According to the reform, all living marine resources in Faroese waters are the property of the people of the Faroe Islands, and as such, fishing licenses may never become private property, neither by law nor practice. Furthermore, fishing licenses cannot be traded directly between private buyers. To change hands, licenses must go through a public auction.

As of 2019, the Faroese fleet of longliners and trawlers catching demersal fish in Faroese waters will no longer be allocated fishing days based on the previous days-at-sea system, which will be replaced by a quota system. Small fishing vessels, which conduct coastal fisheries on a smaller scale will, however, continue to base their activity on annually allocated fishing days.

A new element in the fisheries legislation is the implementation of open public quota auctions. 15% to 25% of the overall quotas of major species will be publicly auctioned. Additionally, quotas for these species, which exceed certain quota levels in the future, will be auctioned off entirely. All present actors in the industry will have access to the remaining quota, but they will be required to pay a resource fee in accordance with profits in the industry in preceding years.

Fishing licenses may only be granted to Faroese-owned operators. In order to take part in Faroese fisheries, the company or individual must be registered and pay taxes in the Faroe Islands, as well as pay their crew in accordance with Faroese labor market rules and agreements. A six-year period for the phasing out of foreign ownership will be implemented. Special rules apply for Icelandic ownership with a seven-year plan.



## From open-access to private property regimes: Strategic Interactions in the Snow Crab fishery

**Melina Kourantidou**

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Brooks A. Kaiser

*University of Southern Denmark*

Depleted fish stocks across the globe, together with risk and uncertainty over future fishery resources, have raised questions about the management and ownership of increasingly northerly distributed species. The case of the invasive Snow Crab in the Barents Sea illustrates multidimensional weaknesses in existing governance structures in Arctic fisheries as species ranges shift. Commercial exploitation started in 2012 as an open-access fishery in international waters of the Loophole, but shifted into a private property management regime after the designation of the crab as sedentary in 2015. Today the fishery is managed separately by Russia and Norway in the Russian Exclusive Economic Zone, the Norwegian part of the Loophole and the Svalbard Fisheries Protection Zone (FPZ). The closing of the commons has resulted in the exclusion of European vessels, which has generated a large conflict between Norway and the EU regarding the property rights for sedentary resources. Acknowledging the invasive nature of the crab, which has largely been ignored by decision-makers so far, we analyze strategic interactions among Norwegian and EU players that accommodate for enforcement (or not) of property rights. The fishery in the Svalbard FPZ acts as a control at the invasion frontier that limits the spread further north and west. We consider the interactions between Norway and third-party countries at this frontier, by identifying their direct and indirect payoffs at stake. The decision of third-party countries to fish and accept or reject the property rights enforcement by Norway affects payoffs to fishers, other stakeholders involved in the rights dispute, and more broadly distributed ecosystem values. Our focus on the invasion externality allows for explicitly considering the implications of Snow Crab management for the rest of the world, beyond just fisheries stakeholders, and differentiates this study from previous applications of game theory in fisheries.

## Options for fishing agreements in the (English) Channel after the Brexit

**Bertrand Le Gallic**

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The British decision to leave the EU (Brexit) will have some huge consequences in a lot of sectors, but hardly as difficult to access as in the fisheries case. This can be explained by the strong interactions that exist between UK and the rest of the EU both in terms of fishing activities and trade in seafood. After a presentation of the main fishing activities by UK and other Member States and the main stocks at stake (shared jointly managed, jointly managed, shellfish, pelagics...), several scenarios are discussed (historic activity (baseline), EEZ, relative stability...), depending of the different point of views. In each case, values and opportunities (gains and losses) are presented.

## International Fisheries Access Agreements and Trade

Tatyana Chesnokova  
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International fishery access agreements allow fishermen from one country to harvest fish in another country's waters. We empirically examine, using a unique global panel dataset, why countries sign fisheries access agreements with each other and compare these to the characteristics of countries that choose the path of international trade. We show that access agreements and fish exports are driven by two key motives: a pattern of comparative advantage in fishing, which depends on fish stocks and fishing capacities; and gravity factors of economic size and distance. Our results suggest that most gravity factors work similarly for agreements and exports: larger countries that are closer to each other are more likely to sign access agreements or to trade. However, the pattern of advantage is determined differently: source countries with larger fishing capacity are more likely to export fish, while source countries with lower fishing capacity are more likely to sign agreements.



## Economic trends and performance of the EU external fleet

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This study presents the main trends and indicators on the economic performance of the EU external fleet in different Regional Management Organisations (RFMOs). The analysis is based on the data collected under the EU Data Collection Framework (DCF) and a methodology that allocates the economic activity of the different fleet segments to the RFMOs. The study also presents the latest developments on capacity, employment, landings and socio-economic indicators. It also discusses the limitation of the data available and proposes recommendations to further improve the data collection and the socio-economic analysis of the EU external fleet.



## The EU's international agreements: SFPA and Northern Agreements

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The EU has concluded fisheries agreements with third countries since the 1970's. Now, these agreements represent a significant part of the catches by the EU fleet. There are two types of agreements. The Northern Agreements with Norway and the Faroe Islands about shared stocks and the Sustainable Fisheries Partnerships Agreements (SFPA) with countries in Africa, the Indian Ocean and the Pacific Ocean. There are 12 SFPAs in force.

The presentation is about mainly the SFPAs: their history, rationale, numbers and structure & contents. The agreements with Norway and the Faroe will be briefly mentioned as well.

It will contribute to providing the seminar with a policy framework and background on the EU actions in this field.

## A fixed catch share scheme to manage shifting transboundary fish stocks

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Rising sea water temperature is driving many fish stocks to move poleward. As more evidences emerge, it becomes increasingly imperative to seek for adaptation strategies to avoid over-exploitation of shifting fish resources and the dissipation of economic rent. In this paper, we first show quantitatively why adaptation strategies are necessary, followed by demonstrating that a fixed catch share scheme can be a practical solution to minimize the impacts in transboundary stocks. We tackled our research questions in a two players' noncooperative model, where both players share a fish stock that moves from the EEZ of one country to the other due to water temperature increase. A dynamic programming algorithm is used to identify closed-loop Nash strategies, in which players are able to adjust periodically harvest policy according to stock levels. We show that the stock is exploited to a minimum level during the stock transition, as over-exploitation is at its fiercest when two players have similar stock share. To avoid this, we propose a fixed catch share (FCS) scheme where the two countries meeting annually to agree upon a specific catch share for as long as the stock is shared, until one of the countries opts out. The adaptation policy proposed mimics existing quota negotiation processes in accordance with the stability key principle that is practiced by the EU common fisheries policy. We demonstrate that this adaptation policy accounts for the stability of a coalition, assuring the sustainability of the shifting stocks and the rent from fisheries.

## Competition or Cooperation in Transboundary Fish Stocks Management: Insight from a Dynamical Model

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An idealized system of a shared fish stock associated with different exclusive economic zones (EEZ) is modelled. In each EEZ, the cost per unit fishing effort depends on local fishery policy. Parameters were estimated for the case of the small pelagic fisheries shared between Southern Morocco, Mauritania and the Senegambia. The model is a set of six ordinary differential equations describing the time dynamic of the fish biomass and the fishing effort. The fish species targeted were considered to perform displacement between the different zones at a time step faster than their growth and harvesting. We take advantage of the two time scales to obtain a reduced model governing the total fish biomass of the system and fishing efforts in each zone. At the rapid equilibrium, the fish distribution follow the ideal free distribution according to the carrying capacity in each area. The simulations show different equilibria that can be reach according to the management of cost per unit effort applied in each EEZ. In the general case, when national fishery policies are not harmonized, there is a competition and after a few decades, only one fishery remains sustainably, depending on a relationship between cost per unit fishing effort and fish density in the EEZ. In the case of sub-regional agreement acting on the cost per unit of fishing effort, we found that a large number of equilibria exists. From this last case the initial distribution of fishing effort strongly impact the optimal equilibrium that can be reached. Lastly, the country with the highest carrying capacity density may get less landings when collaborating with other countries than if it minimise its fishing costs. Such findings should foster regional fisheries organizations to get potential new ways for neighbouring fish stock management plan.

## A stage structured model analysis with an example from the Norwegian North-East Arctic cod fishery

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The paper analyses the optimal harvesting composition of mature and immature fish by the use of a *stage* structure model. The modelling framework of stage structured models is essentially the same as that of age structured models, except that each stage class typically consists of several age classes of the fish stock. In this paper we consider a model including three stages; immature and mature fish in addition to recruits. Both the immature- and the mature stocks are comprised of various age classes. The model is analysed with different assumptions about fishing selectivity, and fleet sharing rules. The latter refers to politically determined rules concerning how the harvest is shared between various vessel groups. Two vessel groups are considered; the coastal fleet and the trawler fleet. Our analysis is motivated by the North-East Arctic (NEA) cod (*Gadus morhua*) fishery, the world's largest cod fishery with a harvest of 864 000 tonnes in 2015.

Section two gives first a brief overview of the Norwegian North-East Arctic cod fishery and in section three the fishery population model is formulated. Our notion of fishing selectivity is described in section four. Throughout the paper we implicitly assume a Spence (or Baranov) catch function for both fleets, indicating that the fishing mortalities always are below one. In section five, we first analyse the fishery assuming perfect harvesting selectivity, followed by section six where the case of imperfect selectivity is studied. In section seven a numerical illustration is provided while we in section eight introduces the sharing rule where the trawler fleet is given a minimum fraction of the harvested biomass. The outcome here is also supported by a numerical illustration. Section nine finally summarises our findings.