EUROPEAN PARLIAMENT

DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B
STRUCTURAL AND COHESION POLICIES

Agriculture and Rural Development

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CHARACTERISTICS OF MULTISPECIFIC FISHERIES IN THE EUROPEAN UNION

STUDY

EN

2014

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This document was requested by the European Parliament's on Committee on Fisheries.

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Original: EN

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Manuscript completed in March 2014.

This document is available on the Internet at:
http://www.europarl.europa.eu/studies

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Abstract

The main objectives of this study are:

- Description of four case studies considered as the most representative multispecies and mixed fisheries in EU waters.
- Analysis of recent improvements on selectivity and identification of species with high survival rate.
- Discuss the application of the MSY approach in multispecies fisheries and ecosystem approach. Reviewing European stock status in relation to MSY targets.
- A roadmap for a feasible landing obligation and MSY approach in EU mixed fisheries. Qualitative assessments are presented for four selected case studies.

IP/B/PECH/IC/2013-088 March 2014

PE 529.053 EN

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LIST OF ABBREVIATIONS

ACFM	Advidsory Committe for Fisheries Management
BRP	Biological Reference Points
CFP	Common Fisheries Policy
CCTV	Closed Circuit Television
EAF	Ecosystem Approach to Fisheries
EBFM	Ecosystem Based Fisheries Management
EFTP	European Fisheries Technology Platform
ER	Explotation rate
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FDF	Fully Documented Fisheries
FED	Fish Excluding Device
FU	Fishing Unit
GFCM	General Fisheries Commission for the Mediterranean
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
LTMP	Long Term Management Plan
MCS	Monitoring, Control and Surveillance
MLS	Minimum Landing Size
MS	Member State
MSY	Maximum Sustainable Yield
PO	Producer Organisation
STECF	Scientifical Technical and Economic Committee for Fisheries
TAC	Total allowable catch
VMS	Vessel Monitoring System

GLOSSARY

Abundance	The total number of a kind of fish in a population
By-catch	Fish other than the primary target species that are caught incidental to the harvest of the primary species
Choke species	A low quota species, which, if reached, would lead to vessels having to tie up even if they still had quota for other species
Deterministic model	A model whose behavior is fully specified by its form and parameters
Discards	To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel
Ecosystem	As ecosystems are defined by the network of interactions among organisms, and between organisms and their environment
Ecosystem Approach to Fisheries Management	Taking ecosystem considerations into more conventional fisheries management
Ecosystem Based Fisheries Management	Giving environmental considerations pre-eminence over socio-economic and social ones
Equilibrium	A condition in which all acting influences are cancelled by others
Exploitation Rate	The proportion of a population that is caught during a certain period of time
Exploitation of Resources	Exploitation is the positive promotion of resources to their greatest possible advantage
Fishery	An activity leading to harvesting of fish
Fisheries Management	The integrated process of all the activities by which the relevant authority controls the present and future behaviors of the interested parties in the fishery in order to ensure the continued productivity of the living resources
Fishing Effort	The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time
Fishing mortality	Removal of fish from a population due to fishing
Food Web	A food web (or food cycle) depicts feeding connections (what-eats-what) in an ecological community
Growth Function	A mathematical function that describes fish's increase in size and weight with time
Highgrading	Form of selective sorting of fish in which higher value, more marketable fish are retained and fish that could be legally retained, but are less marketable, are discarded
Minimum conservation Reference Size	Means the size of a living marine aquatic species taking into account maturity, as established by Union law, below which restrictions or incentives apply that aim to avoid capture through fishing activity; such size replaces, where relevant, the minimum landing size

Overfishing	Overfishing is the act whereby fish stocks are depleted to unacceptable levels
Recruitment	The number of fish surviving to enter the fishery or to some life history stage such as settlement or maturity.
Reference Point	A benchmark against which the abundance of the stock or the fishing mortality rate can be measured in order to determine its status
Resilence	Capacity of a natural system to recover from heavy disturbance such as intensive fishing
Risk	The probability that a particular adverse event occurs during a stated period of time
Selectivity	Ability to target and capture fish by size and species during harvesting operations. In stock assessment, conventionally expressed as a relationship between retention and size (or age) with no reference to survival after escapement
Species	Group of animals or plants having common characteristics, able to breed together to produce fertile offspring, and maintaining their "separateness" from other groups
Stochastic model	A model whose behavior is not fully specified by its form and parameters, but which contains an allowance for unexplained effects represented by random variables
Stock	The living resources in the community or population from which catches are taken in a fishery
Surplus Model	A model that considers the stock globally, that is, it does not take into consideration the structure of the stock by age or size
Sustainability	Sustainability is the capacity to endure. In ecology the word describes how biological systems remain diverse and productive over time. Characteristic of resources that are managed so that, the natural capital stock is non-declining through time, while production opportunities are maintained for the future.
Trade-off	A balancing of factors all of which are not attainable at the same time
Utility	The level of welfare that a person gets from consuming a good

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EXECUTIVE SUMMARY

Background

Sustainable management of multispecific and mixed fisheries poses a challenge worldwide. In broad terms, a multispecific fishery is one where a multitude of species contribute to the output of the fishery. Mixed fisheries are those in which technical interactions between different gears occur. Various fishing technologies and, fishing patterns interact with these resources resulting in a variety of catch sizes, which, along with the complexity of diverse economic objectives, impose a strong challenge for Monitoring, Control and Surveillance (MCS). The complexity is exacerbated by the fact that although some species find a place in the market others have a low economic market value or no market value at all, and thus are discarded. Moreover, due to the multispecific nature of these fisheries, some resources in risk of depletion are harvested together with others that can still sustain an economic activity. In that context, conflicts between ecological and economic objectives tend to emerge (Jennings et al., 1999; Pope, 2000).

In the EU, the complexities of the fisheries sector, where so many resources are shared by several Member States' fleets, pose significant obstacles to coherent management. European fisheries are in general defined as both mixed and multispecific fisheries. The above mentioned complexities may also contribute to by-catch and to incentivize discarding of species with a lower market value. In mixed and multispecific fisheries sound scientific support is required to back up management decisions paying not only attention to biological and ecological issues but also to technological and socio-economic aspects. The problem of discards is sensitive due to its ecological implications. Ethical and economic considerations also make this a hot issue in fisheries management. Taking into account the complexity of mixed and multispecific fisheries and the many natural and human aspects to be addressed these fisheries are considered an especially critical political challenge for managers (ICES, 2009).

In fact, the new Common fisheries Policy (CFP)[1] that has entered into force and it is applied from 1st January 2014, has granted especial attention to this issue. Two of the main topics discussed in the reform of the CFP are the landing obligation and the introduction of sustainable fishing quotas to maintain fish stocks above levels that can produce the Maximum Sustainable Yield (MSY). Given that 80% of Mediterranean fish stocks and 47% of Atlantic stocks are overfished in the EU[2], strict rules are needed to restore fish stocks in the coming years. Member States will have to set sustainable fishing quotas from 2015 and only in some cases by 2020. Achieving the MSY implies that fishermen shall not exceed the amount of catch recommended by scientists in order to guarantee the sustainability of the stocks.

The discard problem

One of the problems of the multispecific fishery is the waste of fishing resources because of discarding at sea. Discards is a term used for catch which is not kept on board but returned to sea. The reasons behind discarding include the low market value of some species compared to other species or sizes of the same species (high grading), and prohibition to land undersized fish. In the case of TAC management, it may also be the case that severe

1 REGULATION (EU) No 1380/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC.

2 http://www.europarl.europa.eu/news/en/news-room/content/20130201IPR05571/html/Stop-overfishing-MEPs-vote-for-ambitious-reform.

restrictions are imposed on quota overshooting and consequently fishermen tend to discard in order to avoid being fined. Globally, discarding is estimated to be 8% (6.8 million t) of the total volume of fish caught annually (Kelleher, 2005).

In the EU, discards due to minimum landing size restrictions and quota exhaustion have been reported. However it should be pointed out that for those stocks that are not managed by quota, the biggest problem is discarding due to minimum landing size. Discarding occurs in EU fisheries sometimes at high proportions, for example, 30-60% of the catch in finfish fisheries off the Iberian Peninsula; 50% of the catch in North Sea beam trawl fleets (MRAG, 2007); between 20-98% in the North Sea nephrops trawl fleet (Enever et al., 2009); and 40% of most species through bottom-trawling in North east Atlantic fisheries (STECF, 2006).

In EU waters a landing obligation will be implemented progressively between 2015 and 2019 in combination with some complementary measures. Fishermen will be obliged to land all the commercial species that they catch. All fish caught would be landed and counted against the quotas. Exemptions will be applied to those species with known high survival rates that could be excluded from the landing obligation and released alive back into the sea. This obligation may contribute to encourage fishermen to develop and use more selective fishing gear.

The progressive implementation of the landing obligation attempts to provide the fishing sector time to develop innovative solutions to trade these fish or to find processed products that use the otherwise discarded fish as raw material. Landing obligation on commercial species has already been introduced to a certain extent in some fisheries in developed nations such as in Norway (Johnsen and Eliasen, 2011), Iceland, Canada or New Zealand (MRAG, 2007). These examples, however, are related to single-species fisheries, which are less prone to by-catch problems. The landing obligation for EU fisheries will be the first experience in the world where a large scale multispecific landing obligation is implemented.

Maximum Sustainable Yield (MSY)

MSY can be defined as the maximum annual catch which on average can be removed yearly from a fish stock without deteriorating the productivity of the fish stock (Beverton and Holt, 1957; Guillen et al., 2013). At equilibrium, the MSY should correspond to the catch of an optimally managed fishery aimed at maximizing production. 75% of EU fish stocks are overfished compared to 25% of world fishing resources.

Overexploited fish stocks cannot sustain a competitive fishing activity, hence leading to more overfishing and overcapitalization. Managing stocks according to MSY will simply going from fishing on scarce fish stocks to fishing rationally on abundant ones. The challenge of managing stocks at MSY in the mixed and multispecific fisheries is the limitation that certain MSY targets of individual stocks could cause in the capture and biomass of other stocks. Fixing the targeted fishing mortality by means of a multi annual plan may ensure stability from year to year. The multiannual plans should fix mortality rates at a level that can help obtain more abundant stocks over time.

Aim

The aim of the present study is to provide a comprehensive qualitative analysis of the EU implementation of the discard ban and the adoption of MSY as the corner stone of fisheries management. This report contributes to the preliminary basis of sound studies to fill in the knowledge gap and support decision making and legislative proposals.

The practical implementation of the landing obligation and the MSY in the multispecies fisheries has been analysed in the following case studies:

1. Cod mixed fisheries in the North Sea.
2. Mixed fisheries in the Celtic Sea.
3. Demersal multispecies and mixed fisheries in the Iberian Waters.
4. Trawl demersal multispecies fisheries in the Mediterranean Sea.

Methodologies to address the objectives of the study will be split in three sections following the objectives defined.

Description of multispecies fisheries in EU waters:

Two main fisheries groups are established for the description: ICES areas and the Mediterranean Sea.

- Case studies for the main multispecies fisheries operating in EU waters are listed including a complete description of each fishery based on the selected literature.
- Information about gear, target species, discarded species and reasons for discarding and fishing grounds is provided in a simple summary sheet table. The description of fisheries is at such a level of detail so as to support qualitative analysis of technological interactions between the main European fisheries.

Landing obligation application:

- A general understanding of the discard problems in the EU context is presented.
- Compiles information on past and on-going research and innovative projects and initiatives focused on discard reduction. Based on a complete review of the different initiatives in place across Europe to reduce discards. The output is sourced directly from results of other related projects previously completed or ongoing projects.
- A revision of species with a high survival rate for the possibility to exclude certain species/stocks from the discard ban is done. Main factors affecting mortality of discarded fish are related to fishing conditions (e.g. gear, time between catch and release or the way the fish is released) and biological attributes. A complete review of all the studies carried out that have investigated the survivability of discarded fish by species and by fishing method is carried out.
- A roadmap is provided for the design of a flexible landing obligation to work in practice in EU mixed fisheries, which would take into consideration the outputs of the previous reviews, but also caveats to the discard ban conveyed by the different stakeholders (Annex III). To design this roadmap, qualitative assessments of the feasible impact of discard bans will be drawn based on case study experiences and expert knowledge from different EU regions and abroad (Annex II).

MSY in multispecies fisheries:

- A general understanding of the MSY approach to multispecies and mixed fisheries impacting in discards and feasibility of the operational MSY implementation is presented.

- A literature review of MSY targets available for the main species caught in each of the multispecies fisheries is done.
- A synoptic stock status state compared to MSY targets is also presented by reviewing actual targets and closeness to reach them.
- Qualitative analysis is deployed on the risks for populations, and if feasible for ecosystems, by regions if no MSY ranges are accomplished (Annex II).

Limitations of the proposal of study:

This is, in fact, a desk study. Thus, estimation of MSY levels is not in the scope of this proposal. In spite of this, the contractor has analysed the viability of the MSY implementation from all multidisciplinary angles to address the objectives outlined by the European Parliament.

1. GENERAL INFORMATION: WHY CAN WE FISH? BASIC PRINCIPLES UNDERLYING FISHERIES

KEY FINDINGS

- Fishing is the act of catching aquatic wildlife and generates impacts on marine ecosystems (Pauly et al., 2002). However, the capacity of ecosystems to respond to fishing is limited; there is an optimum balance between the amount of fish that is removed by fishing and the amount of fish that remains in the ecosystem.

- Sustainability of a fishery is determined by the balance between the amount of fishing impact and populations capacity to respond to harvesting.

- Fisheries management is imposed upon the industry in order to control the rate of harvest to assure sustainability of marine ecosystems and fisheries activity.

Fishing is the act of catching aquatic wildlife and generates impacts on marine ecosystems (Pauly et al., 2002). Fisheries can be seen as a self-regulating system where fishing produces a response from ecosystems in the form of growth and recruitment of fish. The explanatory mechanism for this is simple: All animals produce more offspring than survive to adulthood and individual growth potential is limited by the availability of nutrients. When a fish stock starts to be exploited, larger/adult individuals are removed from the ecosystem and more space and nutrients are available to increase survival of larvae and growth of younger individuals. Therefore, fished populations have a higher turnover rate than unexploited populations.

However, the capacity to respond to fishing is limited; there is an optimum balance between the amount of fish that is removed by fishing and the amount of fish that remains in the ecosystem, which will produce the maximum response in the form of recruitment and individual growth. If ecosystems capacity to replace fish is exceeded, the short term catch will be high but the turnover of fish will be impaired. As a consequence, fish populations will decline and in the long term, catch will also be reduced.

Fisheries management measures are therefore imposed upon the industry in order to control the rate of harvest, i.e. the proportion of the stock biomass that can be removed by fishing within a given period.

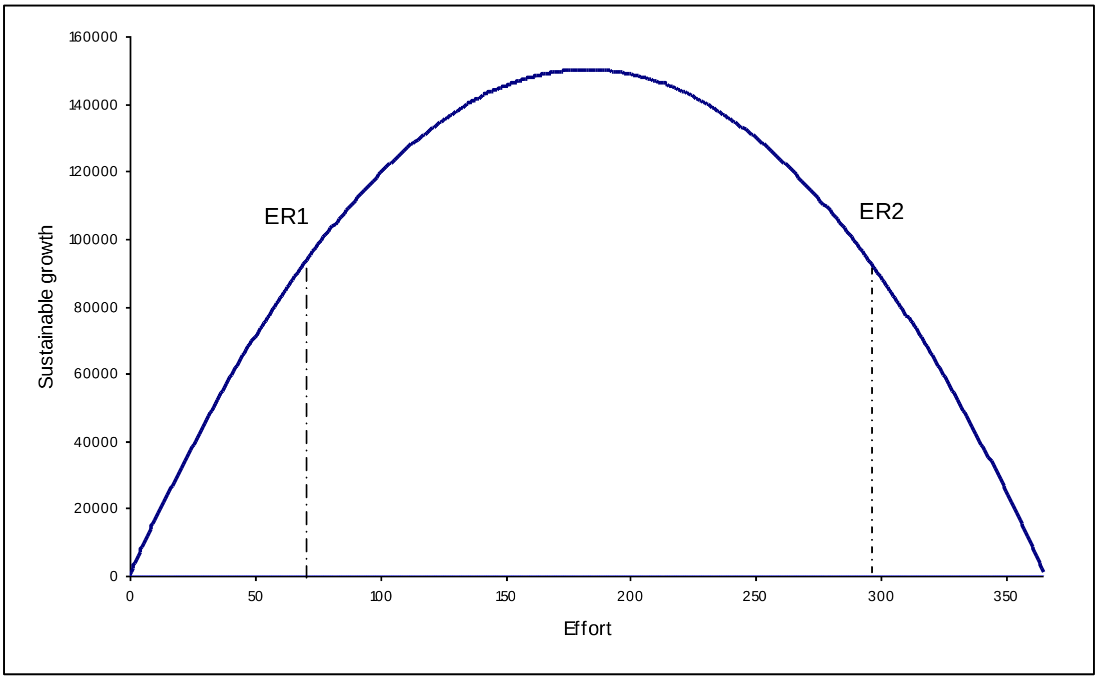
In its simplest form, a fishery consists of one fishing fleet exploiting a single stock of a single species in a single area.

Sustainability is focused on having a desired amount of resources in the future or at least a minimum probability of having so. This definition is important in the context of fisheries management given that other dimensions such as, economy or social sciences, do not propose a different way of looking at it but different ways of obtaining.

It is important to note that the sustainability of a fishery is determined by the balance between the amount of fishing impact and populations capacity to respond to harvesting. This means that sustainability can be achieved at almost any exploitation rate. The exploitation rate of a fishery is also known as "fishing mortality" and results from the combination of a measure of potential capacity to produce fishing (e.g. fishing gears, technology, knowledge) and the use of this capacity, known as fishing effort. For a given "capacity of fishing" or "catchability", the amount of fishing effort will determine the rate of fishing mortality applied to a fished population. Following the basic explanation provided above, there is curve that relates the rate of harvest (measured in fishing effort units) and the amount of sustainable catch that it will generate (Figure 1). An unexploited population (harvest rate=0) will not produce any sustainable catch. As the harvest rate increases, ecosystems response to fishing will be triggered until a maximum is reached. At this harvest rate, the amount of sustainable catch will be maximum, as the fished population will be responding to fishing at its maximum capacity. Our fishery will be removing the weight equivalent of this maximum response sustainably. For harvest rates above the one corresponding to the maximum, population's capacity to respond to fishing will be impaired and although large catches will be obtained in the short term, they will not be sustainable. For harvest rates above the one that will produce the maximum, the sustainable catch will be lower.

Figure 1 is a graphical representation of the fundamental principles underlying fisheries science and it is known as Schaefer's surplus production model. With this model, fish stocks response to fishing is known as surplus production and is estimated with a logistic growth function. At equilibrium, surplus production is equal to the sustainable catch obtained by the fishery. This model helps to explain how very different harvest rates produce the same amount of "sustainable catch". For the first (ER1), the harvesting rate is lower than ecosystems maximum capacity to respond to fishing. Therefore, our fishery will be undeveloped or "underexploited" and we will not fully benefit from the opportunities offered by marine ecosystems. In contrast, with the harvest rate of ER2 our fishery will obtain the same amount of sustainable catch but the fish stock will be "overexploited" as fish biomass will be below that, which would produce the maximum response to fishing. It is important to note that the sustainable catch, i.e. the catch that would be obtained whilst maintaining fish stocks at equilibrium levels is equal for both ER1 and ER2. A stock can reproduce itself, and be considered "sustainable", at high (virgin state), at medium, and even, at low levels of abundance.

Figure 1: Two different sustainable exploitation rates (ER) with two different fishing effort levels and hence with different stock levels in a simple surplus model.



Source: AZTI Tecnalia

2. DEFINITION OF MULTISPECIFIC AND MIXED FISHERIES

KEY FINDINGS

- For specific fisheries management, i.e. landing obligation and maximum sustainable yield, multispecies and mixed fisheries should be understood, characterised and defined at fisheries level.
- A multispecies fishery refers to the biological interactions in the food web where predators are feeding on their prey. Addressing the effect of predator-prey interactions is at the core of multispecies management advice. Whereas mixed fisheries are based on the technical interactions of different gears used in the fishery, thus aspects of mixed catches of several species and several gears are usually referred to as mixed fisheries advice.
- Multispecies and mixed fisheries case studies are defined and chosen by: geographical coverage (from north to south) in the most important European fishing regions; representativeness (volume of stocks and catches); gears, fleet interactions, data available in relation to the number of assessed stocks or management measures and finally the complexity of the implementation of the landing obligation and/or MSY approach.

Fish are part of the marine ecosystem interacting thoroughly with their physical, chemical and biological (other marine species) environment. Fish populations are dependent on the ecosystem to provide the right conditions for growth, reproduction and survival. In the same way, fish provide an important food source for other animals (including humans) such as seabirds and marine mammals and therefore form an integral part of the marine food web.

The European fisheries had long been characterised by a great diversity in exploited species and species assemblages (fish, crustaceans and molluscs) and by the use of a wide variety of fishing gears. Such characteristics are common to shelf and continental slope fisheries of the different European regions, which are multi-gear and multi-species by nature.

Under this perspective, fishing activity does not only impact on the fish stocks themselves (one or various stocks simultaneously), but also on the ecosystem within which the fish live in. In this context, direct and indirect effects of fishing on the ecosystem are identified. Direct effects of fishing include catching and/or discarding of several marine species and, also damaging the seabed with fishing gear. Whereas, the indirect effect of fishing on the ecosystem can be also indirect, for example by removing fish from the marine food web.

The highly complex nature of many European fisheries has been a major contributing factor to the limited success of certain management strategies (e.g. TAC), as different catch limits for the various stocks may lead to imperfect implementation of the single-species TAC through incentives for misreporting and discarding.

In order to integrate the new Common Fisheries Policy considerations into future fisheries advice to accomplish with discard zero policies and maximum sustainable yield approaches, there has to be a sound understanding of how fisheries, specially multispecies and mixed fisheries, are characterised. This characterisation has to be based on target species, gears used, fleet interactions, geographical coverage, discards, management measures in place and status of the stocks being exploited in relation to the maximum sustainable yield targets defined.

In the following sections four case studies are presented including main distinct features. These case studies are the base on which discard ban road maps and MSY approach are designed (Annex II).

The four case studies chosen are:

- Cod mixed fisheries in the North Sea.
- Mixed Demersal fisheries in the Celtic Sea.
- Demersal multispecies and mixed fisheries in the Iberian waters.
- Trawl Demersal multispecies fisheries in the Mediterranean Sea.

2.1 Cod Mixed Fisheries in the North Sea

@ Picture World

Demersal human consumption fisheries usually target a mixture of roundfish species (**cod**, **haddock**, and **whiting**) or a mixture of flatfish species (**plaice** and **sole**). These landings have steadily declined over the last 30 years, from over 2 million t in 1974 to the current level (around 600 000 t). The catches of the industrial fisheries are used for the production of fish oil and fish meal.

Cod is targeted by most of the demersal fisheries in the North Sea (ICES Subarea IV), Skagerrak (ICES Division IIIa) and the English Channel (ICES Division VIId). These are mainly **otter and beam trawl fisheries** (from UK, Denmark, Germany, France and Sweden) but it is also part of the **by-catch of other fisheries** such as the **beam trawl fishery targeting flatfish**. **All these fisheries have discarding problems**, except the gillnet fishery targeting cod and plaice which is a single species fishery.

Large-scale discarding is known to occur in the **mixed demersal trawl fisheries in the North Sea**. Discards are mainly composed of **small and juvenile fish below or close** to the **minimum landing size** and of **larger individuals** of species **without a reliable market**. Although keeping a decreasing trend during the last years, they were estimated to represent a **24% of the fishery** (about 10 400 t). CCTV (27% of landings in 2012) and FDF programs have been established in 2010–2013.

EU has adopted a LTMP for cod stock that shall ensure the sustainable exploitation of the cod stocks on the basis of maximum sustainable yield with a determined fishing mortality. The EU–Norway management plan is updated in December 2008. EU plan also includes effort restrictions, reducing kW-days available to community vessels in the main metiers catching cod, aiming to achieve the established goals under the MSY approach. From the **species with MSY limits** established (all except whiting and nephrops), **only haddock and plaice show a good MS status (EC, 2008a).**

2.2 Mixed Demersal Fisheries in the Celtic Sea

© Pew / Corey Arnold

The demersal mixed fisheries in the Celtic sea are predominantly oriented to human consumption fisheries. Demersal human consumption fisheries target a mixture of species such as **hake**, **anglerfish**, **cod**, **haddock**, **megrim**, **plaice**, **sole** and **nephrops**. By catch is high especially in the nephrops fisheries.

Main fishing gears involved in this fishery are **otter trawl, beam trawl, pair trawl, long-lines and gillnets.** Only gillnets and longline fisheries have not associated substantial discarding problems. **Large-scale discarding is known to occur in the trawling fisheries, with rates between 11 and 25% of landings**. **Discards** of target and non-target species are substantial especially in relation to **small sizes, quota exhaustion and low market value**. Technological improvements implemented vary from reduction of MLS to establishment of a square mesh, high vertical opening trawls and FEDs, depending on the species.

Most of these species are managed through a TAC, which has been calculated under the single-species approach. From the **three species** that **have MSY limits established** (cod, hake and whiting) in year 2012 **only cod is in red status** in relation to its limits, whereas **hake and whiting are in appropriate levels**. There is only one management plan established for Northern hake and it is also being considered for cod.

Some trials have been done to provide the mixed-fisheries forecast advice. The goal is to move forward to the integration of mixed-fisheries forecasts into stock advice and the integrated development of mixed-fishery management plans.

2.3 Demersal Multispecies and mixed Fisheries in the Iberian Waters

@ Ron Boon. Fotolibra

The fishing exploitation in Atlantic Iberian waters is mainly developed by a **multi-fleet mixed-species fishery**, i.e. multiple fleets using different gears to target different combinations of the same target species in the same area. From a total of 31 métiers operating in this area, 24 métiers have been ranked as cumulating 90% of the fishing activities. Three MS operate in this area, namely, Spain, Portugal, and lastly France.

The list of species targeted by this fishery is composed by **hake**, **megrims**, **anglerfishes**, ***Norway lobster*** (nephrops), **mackerel**, **horse mackerel** and **blue whiting**. The main fisheries involved are otter bottom and pair bottom trawlers, gillnets, longlines and trammel nets fisheries. There is also a mixed one which uses more than one type of gears.

Finfish bottom trawls targeting hake, horse mackerel, monkfish and megrim in the Iberian Peninsula **are reported to have discards**. In the **hake fishery, high-grading** is particularly high at the beginning of the fishing season due to individual vessel quota allocation and **can reach 90% of catch. Discards rates are between 30 and 60% of the landings**, composed mainly by **the undersized individuals** and some **non-commercial by-catch** species.

Species are managed based on the single-species approach. A LTMP is in place for the northern stock of hake and there is a management plan for the recovery of southern stock of hake (which aims to return this species within biological safety limits) and Iberian nephrops (Reg. CE nº 2166/2005). **Most** of these **species have target reference points under the MSY** approach (except nephrops and mackerel), but **hake and megrims are still under desirable conditions.**

In 2013, a **successful trial** has been done **to provide the mixed-fisheries forecast advice**. It is the first time in which single TAC allocations were compared for TAC reconciliation analysis between species caught in the same fleet.

2.4 Trawl Demersal Multispecies Fisheries in the Mediterranean Sea

© WWF-Canon / Isaac Vega

Mediterranean fisheries account for 22% of the tonnage of the European Community fleet, 34% of its engine power and 46% of the total fleet. Over 80% of the fleet comprises vessels under 12 meters in length. Landings account for only 12% of the Community total but their market value is high.

Target species are mainly **hake**, **red mullets**, **nephrops**, **shrimps**, **whiting**, **anchovies**, **sardines**, **bluefin tuna** and **swordfish**. The demersal trawling targets mostly young fish of many overexploited stocks, while longliners mostly target adults. Some fisheries are essentially based on targeted catches of juveniles of some species. Landings have increased by 50% during the last 25 years. Catch rates per vessel are still low compared with other EU regions although the market value of catches is generally high.

Main fishing gears involved are bottom otter trawls, purse seines, and other coastal gears such as gillnets, trammel nets, longlines, hand-lines with hooks, traps and pots. **Trawl fisheries produce high discard rates of undersized targeted species** and of **non-target species with low or no market value**. The increase in commercial fishery production over the last 50 years has been accompanied by an increase of incidental catches and discarding of a number of species. Approximately**, one quarter of the marine commercial** catch destined for human consumption **would be discarded at sea**. **Insufficient selectivity** of the fishing operations, lack of sufficient storage volume and **minimum landings size** regulation are the main **reasons for discarding**. The technological improvements implemented have been related mainly to the increase of the gear mesh size.

Two types of measures are applied for management:
-Measures for keeping fishing effort under control: fishing capacity limitations, number of vessels.
-Measures for making exploitation pattern more rational (gear specifications, fishing practices, catch limitations, fishing seasons and areas).

In **Mediterranean** European countries, **85% of the assessed stocks are currently overfished** if we consider the maximum sustainable yield as the **reference value (MSY). Only some sardine and anchovy** stocks **show a good status** in relation to those MSY targets.

3. DISCARDS

KEY FINDINGS

- Landing obligation appears to have clear positive effects on the marine ecosystems: it reduces the waste of by-catch by utilizing all of the catch (Hall et al., 2000), improves the control of scavenger species, greatly improved fisheries and ecosystem data and improved forecast abilities of population growth.
- The landing obligation will produce incentives in terms of encouraging research on by-catch reduction gear and techniques, behavioural changes in relation to areas and seasons of high by-catch. Fishers recognize the environmental benefits of by-catch reduction technology however they will not adopt it unless there is an incentive to do so.
- A ban on discards would, in overall terms, seem to be a positive step for European fisheries on the road to EFBM.
- However, there is an open debate about important caveats in the landing obligation implementation: reduction of fleet benefits in the short term, managing large amounts of biomass on board and at landing sites, actual enforcement by means of extensive monitoring and surveillance programs…also there are concerns on whether highly selective fishing has beneficial ecosystem effects.
- The design of robust management systems leads to acknowledge the incentives present in fisheries (Grafton et al., 2006). The issue of enforcement is a significant problem as the incentive to discard remains if there is no compensation to the fishers (Catchpole et al., 2005). Many of the major successes of discards reduction have taken place in settings where 100% observer coverage has existed (Grafton et al., 2006; Hilborn, 2007) and commitment is reached.
- Enforcement and commitment becomes the key aspects to the success or failure of landing obligation implementation.

One of the problems of the multispecific fishery is the waste of fishing resources because of discarding at sea. A distinction shall be made between by-catch and discards. By-catch is the extraction of non-target fish and other organisms during fishing. It also comprises the catch of individuals below the legal catch size of the species targeted. Discards is a term used for catch which is not kept on board but returned to sea due to different reasons (Pauly, 1984; Alverson & Hughes, 1996; Romanov, 2002). The reasons can be economic, legal or personal considerations.

Discard reduction has been one of the objectives for fisheries management in Europe since the first few decades of the 20th century (Jensen, 1967; Burd, 1986; Haliday and Pindhorn 1996; Pinhorn and Haliday, 2001).

Nowadays discards have reached a top position in the CFP Reform Agenda. There is a broad public consensus on the fact that unwanted catches should be reduced to almost negligible levels. The proportions of unwanted fish catches are an unacceptable waste of natural resources and a clearly inefficient practice from an economic management perspective. While awareness on accidental fishing has significantly increased during the last years, there is still unreported mortality and a lack of knowledge on the real dimension of the problem, its consequences and the means to solve it effectively. Indeed unwanted catches and discards, besides constituting a substantial waste themselves, affect negatively the sustainable exploitation of marine biological resources and marine ecosystems, as well as the financial viability of fisheries. Thus, the complexity of the problem makes the regulatory and policy framework, probably the most relevant driver to tackle discards. It is necessary that this matter is kept high in the politic agenda but also that a wide and open perspective is considered to determine the regulatory changes that can be expected more efficient in achieving the elimination of discards (Report from the workshop about fishing discards organized by the European Fisheries Technology Platform, held in Vigo on the 22nd of June 2012).

3.1 Reasons for discarding

Regulatory reasons

Many generic fishery regulations may promote discards or do little to minimize or eliminate them. As discard practices are determined by a wide range of factors, it is difficult to attribute changes in these practices to a given regulation or set of regulations. Fishery managers often face a regulatory dilemma since regulations designed to protect one species may increase by-catch or discards of another. Management agencies often indirectly accept discards which could be the result of a regulation with the purpose to reduce the short-run net economic profits of the fishery.

- Quantity limitations: Legal constraints tend to increase discarding, e.g., when the catch of a valuable by-catch species is above the allowed quantity.
- Effort limitations: Trip limits (limited days) may also cause discards through high grading.
- Regulation of minimum landing size: In the context of multispecies fisheries this regulation promotes discards since it is difficult to harmonize with the selectivity of the fishing gear, particularly in multispecies fisheries.
- Regulation of mesh size: It has an indirect effect on discarding through the influence on the size distribution of the catch.

Economic reasons

The act of discarding involves an economic decision, usually of a short-term nature (day/trip/season). Species with no market value are usually discarded at sea, and species with a positive market value may be discarded if the costs of handling, storage and landing exceed the market value. From an economic point of view, discarding is efficient in cases where the marginal costs of discarding are less than the marginal benefits of discarding (Arnason, 1994). In this case the economic waste of not discarding is greater than the waste of discarding.

Technical reasons

That is, the capability of holding and sorting and durability of the catch before turning it into a product that can be stored in the hold. For a given trip the hold capacity can induce highgrading.

The gear technology *per se* is not necessarily the limiting factor in discard and by-catch reduction. The economic consequences of introducing gear modifications are possibly the single most important constraint.

Ecosystem considerations

Due to the importance given to the ecosystem structure and functioning in order to maintain essential ecosystem services Ecosystem Based Fisheries Management (EBFM) requires the minimization of all human impacts that could negatively affect these characteristics/attributes (Halpern, 2008). Discards have been identified as a threat to ecosystem structure and functioning in a variety of ways. Discards can have direct negative ecological effects on target species and non-target species, large indirect effects on scavenger species and represent a serious problem for fisheries managers with regards to species' population data.

Traditionally, the by-catch issue has generally been seen as a waste or a legal issue and therefore those species that are not commercially or recreationally targeted by any fishery and which are not yet legally protected or endangered are forgotten by management (Hirshfield 2005). EBFM requires scientists to establish limit reference points for all target and non-target species in the ecosystem (Pope and Symes, 2002) so that species endangered by by-catch are protected earlier (Hirshfield, 2005).

With the aim of minimizing the impacts of fisheries on the wider ecosystem more selective fishing practices have been encouraged so as to reduce by-catch and discard which, apart from target species juveniles, mainly impact non-target species (Zhou et al., 2010). However, debate has opened on whether the objective of highly selective fishing, has beneficial ecosystem effects (Bundy et al., 2005), goes in line with the sustainability of fisheries (Garcia et al., 2012), and on who pays for it (Garcia et al., 2011). To some the idea of concentrated impacts on a small part of the ecosystem places too much of an impact on a single species (Zhou et al., 2010), (Bundy et al., 2005), upsetting the balance of the food web favouring the competitor species and prey of the target species to such an extent that could cause irreversible change to the structure and functioning of the ecosystem.

The concept of balanced exploitation proposed by Zhou et al. (2010) entails a paradigm shift in current fisheries management, moving away from the market based incentives to a zero waste policy whereby all fish caught in the first trawl are kept and eventually utilized onshore. From an ecosystem perspective this strategy would prevent a few species or components of the ecosystem from being overexploited and hence maintain interspecies diversity, intra-species diversity and sustainable fisheries. Nevertheless, the authors stress that in the case of vulnerable species selective fishing should be exercised.

A discard ban prohibits the discarding of unwanted fish so that all of the catch is landed. Therefore selectivity is not an explicit aspect of the management tool. Nevertheless, discard bans are known to have three main effects; they encourage research on by-catch reduction gear and techniques; they encourage behavioural changes in relation to areas and seasons of high by-catch; finally they help reduce the waste of by-catch by utilizing all of the catch (Hall et al., 2000).

The importance of incentives in the uptake of discard reduction devices is highlighted in (Wade et al., 2009). They found that fishers recognize the environmental benefits of such technology however they will not adopt it unless there is an economic incentive to do so. This finding is confirmed in relation to a discard ban (Catchpole et al., 2005), also due to the economic incentives in play.

The broadening of the focus of management from target species to ecosystems does not take into account the incentives facing fishers, (Grafton et al., 2006, Hilborn et al., 2004). Hilborn et al. (2005) posits that the institutional setting which determines these incentives must be compatible with the goal of sustainability for any significant change in behaviour to occur in current fishing practices. In European fisheries, many of which are shared and mixed, the issue of incentives becomes more complicated yet no less important.

While claiming that an incentive based approach is applicable to single and multispecies fisheries (Grafton et al., 2006) cast doubt on the ability of fishers to separately target species. Captures may not match the permitted quota catch, leading to discarding and misreporting (Squires et al., 1998). Incentives exist to discard fish that have reached their TAC before the other species so as not to create "underages", harvesting of the other species below their TAC (Squires et al., 1998). Reduced quotas on target species imposed to protect vulnerable by-catch species will impact on fishers' profitability as well as quota "underages" and overages due to low target species selectivity (Grafton et al., 2006). Some populations can be slow growing while others not, complicating the setting of TACs for each species (Squires et al., 1998). The need to implement rebuilding plans for some stocks while others are abundant, and price differentials between species' age and size classes are other factors that add complexity. Also, increased effort can be redirected to non-quota species in the fishery.

These factors point to the difficulty in applying economic instruments to counter unsustainable impacts when those impacts have no inherent commercial value. This difficulty is compounded when one sector is required to reduce its impact and hence increase its costs while other sectors which could possibly have a serious impact as well are not required to take such mitigating actions (Rice, 2011). In (Hall et al., 2000) it is concluded that the success of by-catch reduction programmes depends either on the good faith of fishers or on a very extensive system of monitoring, identifying the latter as a prerequisite to the introduction of a discard ban.

In reality what happens is that each species is managed with separate single species quotas that are often exhausted at different rates, reducing drastically the utility of the resource or forcing to continue fishing to utilise the quota of other species. This leads to highgrading, discards and/or illegal landings of their over quota catches (ICES, 2009).

What to do with landed fish

FAO report (Clucas, 1997) is followed to answer the question that should arise:

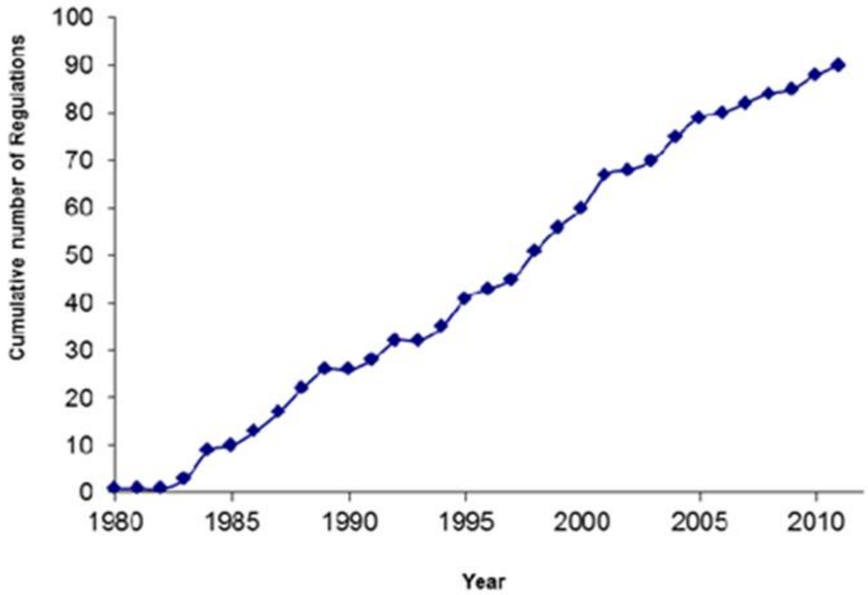
Fish dumped or used: The enforced landing allows ability to record catches. This helps to improve information on which to base management decisions and control of subsequent fishing activities to conserve stocks and sustain the fishery. However, the individual fish at this stage is dead and will not be available to replenish stocks or be caught later if released.

Catcher paid or not: If the fish catcher is paid it should encourage, or at least not deter, the capture of more of the undesirable fish. If full price is paid the user (for example the transformer) could be treated as encouraging the first capture in the first place. On the other hand, if fishermen are not compensated at all for the extra work and costs of landing the full catch, then there will be a temptation for the fishermen to continue discarding at sea. These market and pricing pressures and mechanisms run the risk of creating market forces for illegal fish and encouraging rather than discouraging first capture.

3.2 Past and on-going research and innovative projects and initiatives focused on discard reduction

Most of the discard reduction initiatives in commercial fisheries have been carried out in trawl gear due to the importance, extended use and comparative low selectivity of this gear to others. The approach for the discard reduction in this gear has been the improvement of selectivity by mean of technical measures introduced in the gear. The main factor affecting size selectivity in trawl is mesh size (Franco, 2007), that is why most of the older technical measures deal with this parameter, jointly with twine material (ICES CM 1969/B:13). Similarly, regulations on codend attachments (e.g. cow hide chafers) were introduced in both North East and North West Atlantic areas of jurisdiction. Since year 1980 no less than 90 different technical measure regulations or regulations containing technical measures have been enacted by the EU (STECF, 2012) (Figure 2).

Figure 2: Cumulative Number of Technical Measures Regulations introduced since year 1980.



Source: STECF, 2012

Initiatives to improve the selectivity in fishing gear

Size and species selectivity of commercial fishing gears is considered as an important factor in fisheries management to reduce fishing mortality and to preserve fish stocks, since the selectivity is used to model the vulnerability of fish to the gear as well as the availability. Selectivity in fishing gears has been the battle horse among the fishing technologist the last century. Many studies and sea trials have been developed to evaluate the effects of introducing selectivity changes in a fishery and help to determine a sustainable exploitation pattern for a species.

In the Norwegian-Russian fisheries management, in the Barents Sea, one of the clearest examples in the use of sorting devices in trawl gears is found making it possible to develop and implement by-catch reducing devices in trawls. In 1991/1993 the by-catch excluder device Nordmöregrid became compulsory in all northern shrimp trawling. Rigid sorting grids for size selective fish-trawls were developed in the early 1990s (Larsen and Isaksen, 1993), and became mandatory in 1997 in the Barents Sea for all fish trawl fleets (regardless of nationality). All trawlers fishing in the Norwegian waters of the Barents Sea have been required to use a sorting grid with a minimum bar spacing of 55 mm followed by a codend with a minimum diamond mesh size of 135 mm (Grimaldo, 2007).

In more recent years, apart from mesh size and twine material, other technical measures have been introduced in trawl management regulations. There are hundreds of works reported in the last decades with special concern in by-catch and discard reduction in trawl gears as reviewed by Graham (2004).These technical measures can be summarized into four main groups:

- Escape panels: usually referred to square mesh panels.
- Escape grids: Rigid sorting devices.
- Codend different configurations (T90, square mesh, twine thickness & number of twines, number of meshes around).
- Others (MLS, season/area closures, gear prohibition).

Escape panels (Broadhurst, 2000; Graham et al., 2001), grids (Larsen and Isaksen, 1993), and separator trawls (Main and Sangster, 1985) are a few examples of devices now routinely used in many fisheries worldwide. Regarding to the square mesh as selective device there are many studies in the recent years (e.g. Graham et al., 2001; Grimaldo, 2007,) reducing some of the negative impacts associated with trawling. Several works in the Mediterranean sea multispecific fisheries have been found (e.g. Campos et al., 2003; Sardá et al., 2004; Sala et al., 2008; Luchetti, 2008) related to square mesh panels and codends and several experiments on sorting grids (Sardà, 2004; Bahamon, 2007; Massutí, 2009).

Other relevant experiments in Argentina developed the DEJUPA grid (Ercoli et al., 1998). Sumalia and Hannesson (2010) studied the impact of management scenarios and fisheries gear selectivity on the potential economic gains from Namibian hake.

Concerning last ten years in the UE many projects related to the discard reduction in many fisheries, compiled by the EFTP (European Fisheries Technology Platform) are found:

- Development of a selection system for mid-water trawling for cod.
- *Estudio de los estándares de sostenibilidad y aplicación de mejoras tecnológicas para la obtención de una eco-certificación en el sector de atuneros congeladores* (ECOFAD).
- Shrimp fishing using traps.
- Selectivity of redfish (*Sebastes marinus*) and Greenland halibut (*Reinhardtius hippoglossoides*) by means of FISHSELECT.
- LIFELINES: technological platform for longlining.
- VIP VDTN: Fish behaviour in relation to towed fishing gears.
- BAKASEL: minimization of fish discard on bottom single trawl by mean of selective devices put in the trawl.
- Assessing the environmental and economic impact of modified fishing gears.
- Integral networking of fishing sector actors to organize a responsible, optimal and sustainable exploitation of marine resources. FAROS (LIFE08/ENV/000119)
- By-catch and discards: management indicators, trends and location (BADMINTON).
- Estimation and reduction of discards in the Spanish Atlantic and Mediterranean areas.
- Improving the selection capacity and selectivity of fishing gears for discards' reduction.

- Technological developments and potential impact to the fishing industry (PSE-REDES).
- Mapping of potential solutions about the use of biodegradable materials in fishing nets to reduce ghost fishing.
- MADE: mitigating adverse impacts of open ocean fisheries.
- Development of a catch control device for mid-water trawling.
- PRESPO: sustainable development of artisanal fisheries in the Atlantic area.
- Data collection framework (DCF) - discard monitoring.
- Swedish grid trials in area VIIa.
- Modelling the flow through fine-meshed pelagic trawls.
- Estimation of trawl discards in the western Mediterranean. European hake (*Merluccius merluccius*) as a case study.
- Sperimentazione e sviluppo di reti a strascico con maglie quadre.
- Discards of the western Mediterranean trawl fleets.
- Attrezzi della piccola pesca utilizzati in funzione della successione stagionale e dell'ecoetologia.
- Industry trials in area VIa.
- Development of a flexible selection system for bottom trawling (FLEXIGRID).
- Selectivity studies in the Barents sea bottom trawl gadoid fishery: gear and methods.
- Selection and by-catch in the northern cod and shrimp trawl fishery.
- Comparison of loss between different hauling techniques in the offshore longline fishery.

Technical measures are largely aimed to reduce catches of juvenile from commercial and non-commercial species, to improve species selectivity, to reduce discards and minimize the impacts on habitats. Concerning last 10 years, escape panels have been mandatory for some areas in some conditions. (e.g. square mesh panel in the ICES divisions VIIIabd). Escape grids have been recently introduced in regulations for ICES divisions VIIIabd for nephrops fisheries and are mandatory in the Barents Sea trawl fisheries since 1997.

About other gears apart from trawl, the only technical measures implemented have been mesh size changes, marine mammals deterrent pingers and area closures, all of them in gillnet fisheries. Time/area closures have been widely used in fisheries management to prevent overfishing and the destruction of marine biodiversity. To a lesser degree, such spatio-temporal management measures have been used to reduce by-catch of finfish or protected species (Dunn, 2011).

The implementation and compliance (Monitoring, Control and Surveillance) of these technical measures is a need to pursuit the aims of discard reduction in fisheries. The recent advance in digital imaging and data transmission offers new possibilities to the monitoring of the fishing activity nowadays. In this field, some initiatives have been carried out in Denmark, Scotland and Canada.

3.3 Initiatives for better use of discards

The valorisation of products and discards of fishing activity constitutes a challenge and an opportunity. In this sense many initiatives have started in more recent years, the main driver for this initiatives has been the forthcoming discard ban in UE fisheries. A compilation of these projects was carried out by the EFTP (European Fisheries Technology Platform):

- Evaluation and valorisation of by-products from fishing industry.
- VALORPESC. Integral project to use and valorise discards coming from the Basque trawl fleet.
- Posibilidades de aprovechamiento y valorización de cabezas y exoesqueletos de langostinos (*Penaeus spp*.).
- BIOTECMAR. Biotechnological exploitation of marine products and by-products.
- IBEROMARE. Centro multipolar de valorização de recursos e marinos
- Valorización de residuos da producción de productos pesqueiros: obtención de productos de alto valor engadido a partir de pel e espiñas de peixe.
- Management and first treatment on board fishing by-products (GESUPES).
- Multi-purpose plant for the integral use of the Galician fishing by-products.
- Biotechnological valorisation of marine resources (VALVIOMAR).
- PROTEUS-transformation of natural resources and marine debris in high value products for industrial applications.
- Benign and environmentally friendly fish processing practices to provide added value and innovative solutions for a responsible and sustainable management of fisheries (BE-FAIR).
- Analytical valuation red crab carapace (*Chionoecetes opilio*) for use in feed for aquaculture (ROXOCANVAL).
- Planta multipropósito para la valorización integral de residuos pesqueros de Galicia.
- Asistencia técnica para la realización de una medida innovadora para la recuperación, gestión y valorización de los descartes pesqueros generados por la flota española que faena en los caladeros atlántico y mediterráneo.
- Estudio de las posibilidades de la utilización de varias especies de crustáceos descartadas por la flota gallega en sus pesquerías tradicionales en las costas de Galicia, Portugal y Gran sol.

3.4 A complete review of species survival of already existing studies based on regionalization.

The mortality of discards has received substantial attention during the end of the last century. It was recognize the need for quantitative data to explain the implications of discarding first in the marine environment and secondly in overall fisheries management.

Requiring the landing of all catch implies changing the management of fisheries as it is now. Consideration of the use of landed fish, the ways to limit catch, the control of fishing activity and the selective fishing should be taken into account once the discard bans take effect. In the light of this, a comprehensive up-to date synthesis of discard survival data across species, fishing regions and fleets may be more necessary than ever.

There are several reviews summarizing relevant studies quantifying the fate of discards (Broadburst et al., 2006; Revill, 2012). Most of these studies had been made in the field involving towed gears and are mainly limited to north Atlantic regions. Other related reviews compiled studies on the factors influencing mortality of discards (Davis and Ryer, 2003). Most of studies agree that discard mortality varies considerably according to (a) species biology: body size, sex, presence/absence of swim bladder, tolerance to stress, catch volume and composition; (b) environmental condition: exposure to air and temperature of water and air and direct light; as well as with (c) fishing technical factors: deployment and retrieval of gear, towing speed and duration, handling procedure and duration. Generally, the estimated proportion of discarded individuals dying often exceeds those which survive. Delayed mortality of discards may be common and it is difficult to measure in the field because it can occur over an extended period of time after release (Davis and Ryer, 2003). Understanding how these factors affect survival can help determine adequate mitigation measures that ensure successful live release (Benoìt et al., 2010).

Overall, there is limited information on discard mortality on any stock/species including many of those in the article 15 of CFP reform. However, available information from previous reviews for these species are compiled and updated in Table 1. The additional information has been summarized below for the relevant species group.

Survival of flatfish

Most studies on discard survival are directed mainly to plaice and sole. Different studies show significant variability on discard survival depending on the type of the gear deployed, with survival rates decreasing with increasing weight of the gear. However, discard survival of flatfish is considered to be higher compared to gadoids due to the absence of swim bladder in adult stages; flatfishes are relatively less sensitive to the effect of changes in pressure. Species of flatfish, for example, appear to have relatively good chances of survival (Kelle, 1976 in Van Beek et al., 1990). Besides, flatfish may be more sensitive than round fish to suffocation in nets from pressure on the operculum (Davis, 2002). These characteristics make flatfish candidate for a variety of measures that could reduce discard mortality (Davis and Ryer, 2003).

Survival of gadoids

Fish with gas bladders generally experience significant mortality. However, there are studies suggesting that decompression may not be fatal in all cases; instead, injuries produced by over inflation of the gas bladder in other organs may be irreversible and lead to death. Discard survival rate studies are mainly focused on cod species, which show a significant variability depending on the type of gear used (Table 1).

Survival of small pelagics

In a recent experiment done during year 2012 and 2013 (Arregi el al., 2013) carried out in the Basque purse seine fleet, some promising results on discards survival have been achieved. About them, the use of technological equipment for fish handling has showed to be potentially effective in obtaining high survival rates for some discarded species. Experiments have been carried out with mackerel, horse mackerel, anchovy and sardine with survival rates higher than 50% for all species. It is worth to highlight that, in all cases, survival rates for horse mackerel was higher than 89%.

Major problem in these fisheries are crowding and slipping related mortality (Lockwood et al., 1983). Small pelagic species are considered to lead to high mortality rates. However discard survival rates apart from that of mackerel (Huse and Vold, 2010) are barely known.

Survival of tuna and tuna-like species

Large pelagic species have higher survival rate compared to small pelagic species, which in some cases may approach 100%. However, more than 50 % of the swordfish, for example, are discarded dead. Research using telemetry has shown survival levels of 31% to 100% for few by-catch species released from pelagic longline fisheries (Horodysky and Graves, 2005; Kerstetter and Graves, 2006). Estimates of post release survival rate available in pelagic longline fisheries show that the probability of survival decrease with increase soak time (Carruthers et al., 2009). These species are possible candidates to post release survival studies where to identify methods that could mitigate discard mortality.

Survival of deep-sea water species

There is little information on deep-sea fish survival available in the literature. When these species are captured, the changes in pressure almost guarantee that fish landed on deck and subsequently discarded will not survive (Large et al., 2003).

Survival of anglerfish: *Lophius piscatorius* and *L. budegassa*

A separate section is presented for anglerfish *Lophius piscatorius* and *L. budegassa* due to their physiological and ecological particular characteristics. Anglerfish lack of swimming bladder (Fariña et al., 2008), individuals are known to live in benthonic habitats -as their feeding behaviour and physiology shows- but records of anglerfish on more demersal habitats have been frequently reported (Fariña et al., 2008; Hislop et al., 2000; Rountree et al., 2006). *Lophius spp.* is distributed from the coast line till 1000 m depth (Fariña et al., 2008). No specific survival studies on *Lophius spp*. have been carried out but tagging experiments, aimed at the basis for studies on growth validation, migratory behaviour, bathymetric distribution at age or stock discrimination have been deployed. One of the complementary aims of DEMASSES (European Project Study Contract 97/015) (Anon., 1997) was to carry out experimental tagging of anglerfish.

A large scale tagging experiment for anglerfish, participated by Spain (IEO & AZTI) and Portugal (IPIMAR) achieved a total number of 552 *specimina* tagged on board commercial vessels. The interest of this tagging experiment was that a detailed revision of gears where, with high probability, anglerfish in good condition could be fount; was carried out.

This in depth study could be used as a proxy for indicating the high survivals if specimens would be returned to the sea. In a commercial vessel and under normal conditions of fishing in Division VIIIa,b, otter trawl and gillnets working in both shallow and deep waters seemed to be the most suitable gears to obtain anglerfish in relatively greater number, medium size and good condition (for tagging or other purposes) In ICES Division VIIIc, gillnet ("rasco") appear to be probably the best gear to obtain healthy anglerfish. Also, good health appears to be linked to the size, length range, being this directly related to the size of the specimen caught.

Tagging experiments also concluded that anglerfishes were very resilient. Anglerfish were observed to rapidly move the caudal fin when returned to sea after tagging. The resilience of these species increases their probability of survival. In fact, obtaining numerous healthy *specimina* for tagging leaded to the conclusion that tagging is worthy as a technology since the effort done for tagging program can be compensated more easily with the apparent high survival and good health of the *Lophius specimina* brought on board compared to other species (Anon., 1997).

Survival of Mediterranean demersal species

There is no information available on discard survival of these species. Few studies demonstrated that the use of sorting grids for small fish in trawl gears in the Mediterranean is an efficient and practical means of avoiding the discarding of juvenile individuals, with escape rates ranging between 50 and 90% (Sardá et al., 2004, 2005).

In summary, based on the information compiled in this section, there is little possibility to conclude at this stage if there is any species including in the article 15 of CFP reform that may be excluded from the discard ban:

- Studies on discard survival are species-specific and there are related generally to a type of gear and marine region. Therefore, it may be misleading to extrapolate the information across all fisheries, notably in view of the diversity of EU fisheries.
- Besides, there is not determine a reference point above which discard survival rate is defined as "high survival rate" and a stock/species can be considered potentially excluded from the discard ban.
- However, there are some species that offer significant opportunities to mitigation discard mortality in order to maximize potential for successful live release as flatfish, large pelagic species and anglerfish.
- There is need for obtaining reliable discard survival indicators which will require scientific monitoring and sampling programs.

Table 1: Available estimates of survival rates of discards, for species for which a landing obligation has been proposed by the Commission for year 2014.

Landing obligation proposed in	Species	Gear	Area	ICES Marine ecoregion	Mínimum survival rate	Maximum survival rate	Comments	Author
2014	Mackerel	Purse seine	North Sea	F	0	100	Discard mortality was positively correlated with crowding.	Huse and Vold (2010)
	Herring, horse mackerel, blue whiting, boarfish, anchovy, argentine, sardinella, capelin							
	Bluefin tuna, swordfish, albacore, bigeye tuna, other billfish							

Source: Updated information compiled from Broadhurst et al., 2006

Table 2 : Available estimates of survival rates of discards, for species for which a landing obligation has been proposed by the Commission for year 2015.

Landing obligation proposed in	Species	Gear	Area	ICES Marine ecoregion	Mínimum survival rate	Maximum survival rate	Comments	Author
2015	Cod	Fish beam trawl	Scottish waters	F	0	0	Discard mortality was estimated at time of landing.	Fulton (1890)
		Fish trawl	SW Gulf of St. Lawrence		0	100	Discard mortatity was positively and negatively correlated with fish size and air temperature respectively in both sexes.	Jean (1963)
		Demersal longline	US North West Atlantic		31	100	Depth and SST affected survival more than the handling technique. Discard mortality was lower at shallow depths and lower temperature.	Millikien et al. (2009)
		Hand line	North Coast Iceland	A	43	43	Discard mortality was positively and negatively correlated with depth and fish size respectively.	Palsson et al. (2003)
	Sole	Shrimp beam trawl	North Sea	F	71	100	Discard mortality was positively correlated with tow duration, catch volume and processing time and negatively with fish size.	Berghahn et al. (1992)
		Fish trawl and Beam trawl	North Sea	F	4	37	Discard mortality positively correlated with tow duration and water temperature.	Van beek et al. (1990)
			Western English Channel	E	53.1	76.4	Intermediate and short term discard mortality was inversely correlated with fish size.	Revill et al. (2013)
		Shrimp trawl	Germany	L	33	59	Discard mortality was positively correlated with tow duration, handling time, fish size and direct sunlight.	Kelle (1976)
	Hake							

Table 3: Available estimates of survival rates of discards, for species for which a landing obligation has been proposed by the Commission for year 2016.

Landing obligation proposed in	Species	Gear	Area	ICES Marine ecoregion	Mínimum survival rate	Maximum survival rate	Comments	Author
2016	Haddock	Pelagic longline	Barents Sea	B	47	61	Discard mortality on undersize individuals was reduced modification on gear technology and fishing strategy.	Huse and Soldal (2002)
		Fish trawl	Eastern Canada		22	93	Discard mortality was positively correlated with stress in both sexes.	Beamish (1966)
		Fish trawl, Danish seine	Denmark	F	35	88	Discard mortality was related to barotrauma.	Hislop and Hemmings (1971)
	Whiting	Shrimp beam trawl	North Sea	F	0	35	Discard mortality was positively correlated with tow duration, catch volume and processing time and negatively with fish size.	Berghahn et al. (1992)
		Fish beam trawl	Scottish waters		0	0	Discard mortality was estimated at time of landing.	Fulton (1890)
	Plaice	Fish beam trawl	Scottish waters		98	98	Discard mortality was estimated at time of landing.	Fulton (1890)
			Western English Channel	E	37.3	69.6	Intermediate and short term discard mortality was inversely correlated with fish size.	Revill et al. (2013)
		Fish trawl and Beam trawl	Northe Sea	F	0	48	Discard mortality positively correlated with tow duration and water temperature.	Van Beek et al. (1990)
		Shrimp beam	North Sea	F	0	100	Discard mortality was positively	Berghahn

Landing obligation proposed in	Species	Gear	Area	ICES Marine ecoregion	Mínimum survival rate	Maximum survival rate	Comments	Author
		trawl					correlated with tow duration, catch volume and processing time and negatively with fish size.	et al. (1992)
		Shrimp trawl	Germany	L	12	70	Discard mortality was positively correlated with tow duration, handling time, fish size and direct sunlight.	Kelle (1976)
	Saithe	Shrimp trawl	Northeastern USA		48	89	Discard mortality negatively and positively correlated with size and air temperature respectively.	Ross and Hokenson (1997)
	Lemon sole	Fish beam trawl	Scottish waters		43	43	Discard mortality was estimated at time of landing.	Fulton (1890)
	Megrim, turbot, brill, greenland halibut, pollock, anglerfish							
	Blue ling, black scabbard, roundnose grenadier, orange roughy, redfish, ling, tusk							
	Mediterranean demersal stock							

4. MAXIMUM SUSTAINABLE YIELD

KEY FINDINGS

- Advocating for MSY in fishing or harvesting ecosystems, in general, can be risky when managing 3 different objectives (ecological, economic and social objectives)
- In this review, situations in which MSY furthers EBFM implementation while some others ones are found in this review.
- On the topic of MSY, it appears that the real problem is not only the target. MSY and MEY differ in the outcome (Sumaila and Hannesson, 2010) but both go in the direction of sustainability (Grafton et al., 2007), hence the real question is how to approach the desired target (Beddington et al., 2007).
- This implies adaptive management (Walters, 1986) which includes appropriate monitoring of species in the ecosystem and the use of ecosystem modelling to find safe harvesting efforts or dynamically allocated total allowable catches.

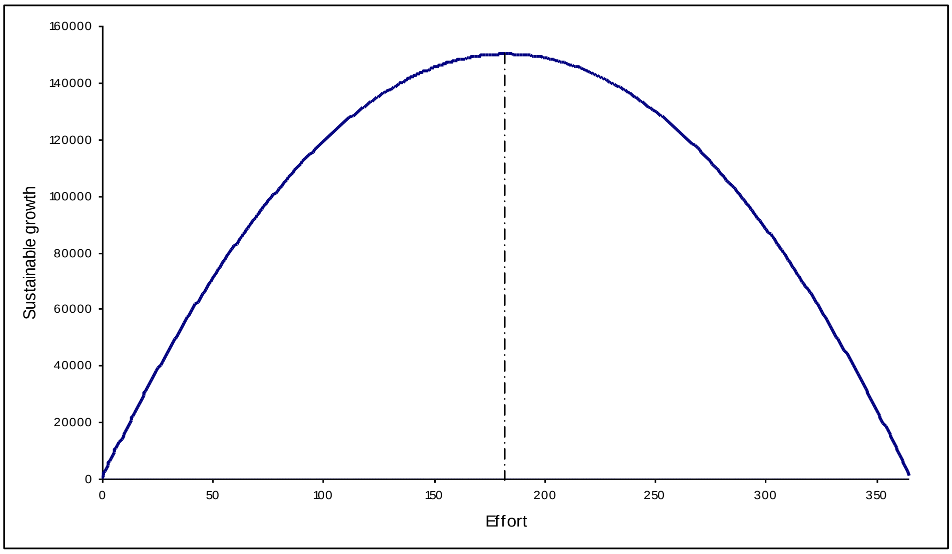
The Maximum Sustainable Yield (MSY) of a fishery is the maximum amount of fish that can be extracted without diminishing future catch.

The concept of "optimal management" requires defining management objectives. Classic fisheries management has aimed at fishing at exploitation rates that will lead fish stocks to their maximum capacity to respond to fishing and therefore, achieve their MSY. Graphically, MSY can be estimated with Schaefer's surplus production model (Figure 3). MSY is sustainable because the growth function is equal to fisheries catch and it is maximum because, theoretically, no other exploitation rate will produce larger sustainable catch.

Any of the solutions proposed should consider sustainable exploitation of fisheries, that is, when the exploitation can be conducted over the long-term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations. The concept of MSY lies in this definition.

Within this range of potential sustainable solutions it is important to understand that defining the exploitation rate can be subject to any policy choice and it will be considered optimal only if the objective selected is achieved.

Figure 3: Selecting and objective under deterministic sustainable growth: MSY.



Source: AZTI-Tecnalia

The concept of MSY is understood as the largest yield (or catch) that can be taken from a species' stock over an indefinite period. It clearly matches the definition of sustainability of fisheries presented before. The theoretical development of MSY comes from the early 1930's (Russell, 1931; Graham, 1935; Hjort et al., 1933). Between 1949 and 1955, the U.S. maneuverer to have MSY declared the goal of international fisheries management, when the Peace Treaty was being negotiated with Japan, in order to keep the Japanese fishing industry out of the Northeast Pacific. Since, and after the works done by Schaefer (Schaefer, 1954; Schaefer, 1957) this concept has had a long tradition as a guide to fisheries management worldwide.

An important remark is that it is common to talk about MSY as an optimal solution to the problem of managing fisheries (see Figure 3) but that this only holds if maximum yield is set as the main policy objective. Furthermore if we move from the target, trade-offs will appear.

From (Larkin, 1977) it is known how a major danger in choosing MSY as a policy option is that it will increase the risk of overfishing from a biological perspective. This is due to at least two factors, non-equilibrium conditions and lack of effort control. Fish populations are not in equilibrium; recruitment fluctuates, while the demand from the processing industry favours stable landings. This in turn may lead to too high exploitation rates in years of low abundance (Hilborn and Walters, 1992).

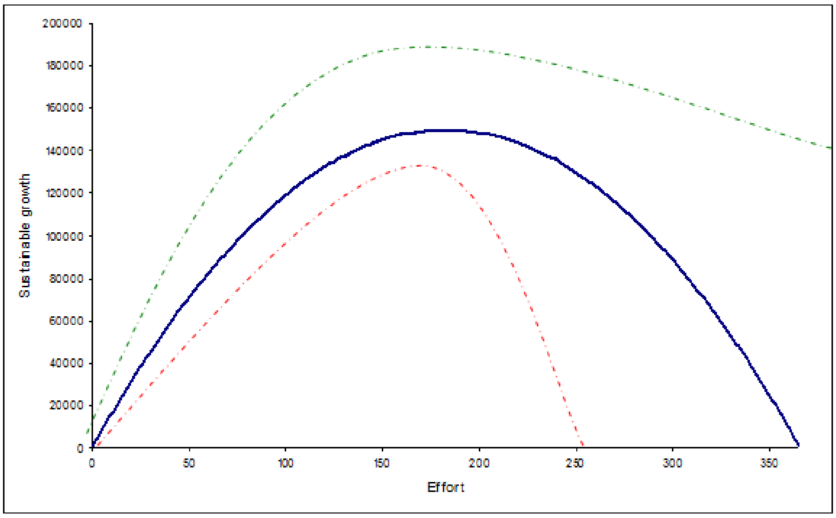
There is no danger of overfishing if effort stays at or below the MSY level, but target levels may be overshot or poorly estimated, and we should be concerned about this.

4.1 Uncertainty

One could argue that as stocks are fished down, their variability and the risk of collapse increases and it should be clear that prior believes of theoretical "sustainability" are not equivalent in terms of risk for the resource.

Any deterministic equilibrium theory is useful for framing the concept of MSY, but it is unrealistic and unworkable in practice. Fisheries and fish populations exist within very dynamic systems. The growth function is affected by fishing practices and fisheries management (e.g., minimum fish size regulations), as well as natural environmental variability and species interactions.

Figure 4: Stochastic sustainable growth: average (blue), upper bound (green) lower bound (red).



Source: AZTI- Tecnalia

In Figure 4 the same theoretically oversimplified resource dynamic as in Figure 1 is presented but in this case, a not perfect knowledge of the dynamics of the stock it is assumed. Three possible outcomes could happen: optimistic growth (the green line), average growth (blue line) or pessimistic growth (red line). It can be seen how this affect the sustainability. An exploitation rate such as the (ER2 in Figure 1) has a possibility of being unsustainable if something below the average growth occurs. A set of probabilities will determine which of the outcomes will finally occur. At the end this will imply that the higher the exploitation rate, the higher the chance of overexploiting the resource.

There are differences among the numerical models used for the assessment of individual stocks, which generally emerge from different hypotheses on the true dynamics of each of the fundamental principles underlying stocks dynamics. For example, the surplus production model described in previous sections (Figure 1) assumes that individual growth and recruitment contribute to the biomass response of fish stocks to fishing following a logistic curve. On the contrary, more sophisticated models explicitly describe fish stocks individual growth by means of an age-dependent logarithmic curve and fish recruitment depending on the amount of mature fish through a variety of shapes, expressing hypotheses about asymptotic recruitment and cannibalism. Therefore, it is important to remark that alternative models can produce different values of MSY and estimates of how fish stocks react to fishing. In order to produce more robust assessments, MSY is often expressed as a range of values, including MSY estimates obtained under different hypotheses on the true dynamics of fish stocks. Biological Reference Points (BRPs) are benchmarks against which the actual status of a fish stock can be measured (Collie and Gislason, 2001).

Different models approach the concept of MSY with alternative reference points. FMSY, is the fishing mortality rate at which, if applied constantly, would result in MSY. Used as a biological reference point, FMSY is the implicit target harvest rate of EU Common Fishery Policy among other management authorities. However, there are alternative realizations of the same concept, maximizing the maximum amount of fish that can be sustainably extracted from a fishery. A family of biological reference points are estimated from alternative harvest reference points:

- **F0.1,** the fishing mortality at which the yield per recruit of a fishery increases only 10% of the yield per recruit of the unexploited stock.
- **F50%,** the fishing mortality that will reduce the equilibrium spawning potential per recruit to 50% of what it would be without any fishing.
- **Fmax,** the fishing mortality rate that maximizes equilibrium yield per recruit. It is often used to define growth overfishing.

On the other hand, there are factors that drive fish stock dynamics which exceed our knowledge or produce unpredictable variability on fish stocks. For example, although there is evidence that sea surface temperature affects the recruitment of certain species producing abundance variability, the numerical prediction of how will it do so is extremely difficult. Therefore, estimates on fish abundance and recommended catch are also subject to uncertainty. There are alternative manners to face this uncertainty. First, derived from what is known as the "Precautionary approach" is setting conservative limits to catch, so that in case the worst case unpredictable impact affects fish stocks, they will still be under safe biological limits. Under this principle, the absence of complete knowledge on fish dynamics will not impede action to be taken to secure fish stocks sustainability. Under this principle, the fishing mortality that will lead to MSY is taken as a limit instead of a target, so that with high probability fish stocks biomass will be above that which would produce MSY. The second is, providing estimates of the state of fish stocks and recommended catch in a range, which should preferably include a risk assessment of the decisions to be made by fisheries managers in the form of allowed catch and harvest rates.

It is also important to remark that fish stocks MSY estimates are not static values. Structural ecosystem changes such as changes in environmental regimes or consistent impacts on habitats can influence fish stocks capacity to respond to fishing. In addition, the knowledge on the true dynamics of fish stocks and models predictive capacity is constantly increasing and hence, it is expected that estimations of stocks MSY will continuously be more reliable and accurate.

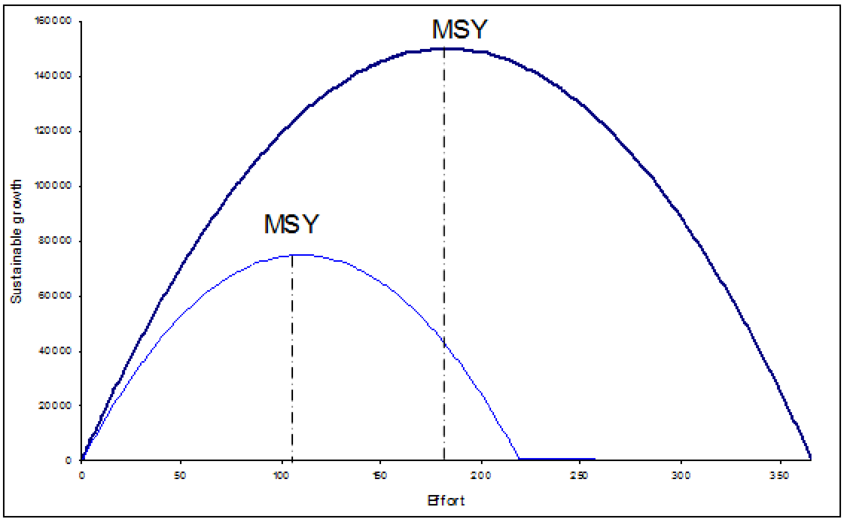
4.2 The multispecies problem

Fishing practices produce impacts in the form of harvest rates into many commercial stocks simultaneously. This fact is a hurdle to the application of MSY principles and is at the origin of the Discard Ban proposed for EU fisheries. A multispecies fishery is such with more than one species caught at the same time but generally, fish stocks MSY is calculated separately. In multispecies fisheries is not possible to apply different levels of fishing effort to the species inhabiting a single habitat and that are vulnerable to the same fishing gear. For example, in a two species fishery, when the catch limit for one species is reached but there is still more catch allowed for the other, fishing fleets will continue to operate. As a consequence, more fish from both species is caught. However, the impossibility to land more than the catch limit for the first species will encourage fishermen to throw the excess overboard. This is a waste of food that would otherwise be available for consumption. In summary, fixing single species quotas for species caught with gears that do not capture them in isolation may not be adequate.

The dynamics of two fish stocks caught simultaneously are shown in Figure 5. The MSY will be achieved for species one at the fishing effort of 100 units but for the second, 180 units will have to be applied. In order to fulfil catch limits for species one, the amount of fish of species one fished with the additional 80 units of effort will be thrown back to the sea. This is not only a waste of food but also makes fish stock assessment process more difficult as the true fishing mortality applied over species 1 is not reflected in catch statistics.

A multispecies fishery is such which more than one species is caught at the same time. Within a unique dimension in which the MSY is included (the ecological one) anyone could argue that MSY would require that all species be exploited below their MSY abundance and therefore that the overall level of exploitation be fixed at the lowest level required by the species with the lowest resilience. However, this will reduce drastically the utility of the resource and it comes from the implementation of what was established by (Larkin, 1977) about the impossibility of maximising sustainable yield simultaneously.

Figure 5: MSY and Multispecies.



Source: AZTI Tecnalia

It poses the question of whether any of the single-species biological reference points are useful in a multispecies context. A quantitative answer to this question would require simulating the entire multispecies fishery.

Nevertheless a shallow literature review could give us some light on what is the answer: Science has emphasise an important problems that can be arise from using the classical reference point, F_{MSY}, for mixed fisheries, i.e. As explained above what may be "safe" for one stock may be "dangerous" for another stock caught together with it. In this regard, (Mace, 2001) points out that in a mixed fishery the reference target should be lower than the fishing mortality associated with the MSY. Moreover, single-species objectives may not be consistent with one another in mixed fisheries where species are caught simultaneously in relatively unselective fishing operations, and can lead to over-quota catches and misreporting of catches (Vinther et al., 2004; Ulrich et al., 2011). Furthermore as Agar and Sutinen (2004) suggest it can have profound impacts on the success of the recovering strategies for fisheries in rebuilding process.

4.2.1. Ecosystem

Fish stocks do not live in isolation to other species and to the dynamics environment they inhabit. This principle underlies the development of a holistic approach to fisheries and environmental science known as Ecosystem Approach to Fisheries (EAF). The management that takes into account this principle is known as Ecosystem Approach to Fisheries Management (EAFM). The new European Union (EU) Common Fisheries Policy (CFP) to be implemented in 2014 will propose this general framework to manage EU fisheries.

Most of world's fish stocks are assessed and managed using single stock principles. According to these, fish stocks capacity to respond to fishing will only depend on its growth and recruitment characteristics. However, in most of the cases this is more complicated. Individual stocks successful live cycle requires the correct performance of marine ecosystems, including the correct functioning of marine food webs and the conservation of marine habitats. For example, let us imagine the case of a species A which predates over other species B. Species A dynamics will depend on the fishing mortality applied over it but also on the availability of preys B. If an additional fishery overexploited or collapsed species B, species A would not be able to survive, despite the fishery operating on A being managed under MSY principles. In addition, despite the apparently adequate harvest rates applied, changes on oceanographic conditions or degradation of the habitats where sensitive phases of its life cycle occur, for example larval development or nursing, can notably affect species' capacity to respond to fishing and therefore, the amount of fish that can sustainably extracted (MSY).

Therefore, under the principles of EAF and EAFM, fish stocks need to be assessed and managed taking under consideration the whole ecosystem they inhabit. Several studies suggest that overall fishing mortality reductions across the species inhabiting common ecosystems will be required to achieve sustainability objectives.

In that sense it is widely seen as an opportunity to incorporate and internalize the ecosystem-based approach to fisheries management. Quoting the definition provided in the CFP reform proposal (EC, 2011) it implies ensuring that benefits from living aquatic resources are high while the direct and indirect impacts of fishing operations on marine ecosystems are low and not detrimental to the future functioning, diversity and integrity of those ecosystems.

For many ecosystems, fishing a wide range of species at harvest rates related to the MSY results in depletion of predators through the combination of both fishing and loss of prey (Walters et al., 2005). Other simulations have found that many species were depleted and some even collapsed when a multispecies MSY was taken from an ecosystem (Worm et al., 2009). The question raised here is whether fishing top predatory species (cod and saithe) at current single species estimate of F_{MSY} will allow prey stocks above precautionary biomass reference points. In an ecosystem as the one in the North Sea, studies on the impact of fishing mortalities of some predatory species on the rest of commercial species has been carried out (ICES, 2012a).

Predator and prey stocks relationships can be simulated. In the case of the North Sea, there is abundant data on abundance and relationships among predators and prey (cod, whiting, haddock), prey only (herring, sandeel), predator only (saithe) (ICES, 2012a).

Different combinations of target fishing mortalities (F), where cod and saithe are fished at even moderately low F's, resulted in cascading effects through the rest of the species Cod and saithe biomass increases resulting in increased natural mortality of haddock and whiting and subsequent lower biomass and yield of these species. Their prey species (herring, sprat sandeel, Norway pout) were then prevented from predation and increase in abundance substantially (ICES, 2012a).

In the case of an increasing in fishing pressure on cod and saithe lead to the opposite situation. As cod and saithe biomass is decreased, haddock and whiting biomass increases and yield of herring, sandeel, Norway pout and sprat decrease. Because of these large effects of predation on haddock and whiting, it might not possible to maintain their stocks above B_{lim} when reducing fishing pressure on cod and saithe to their single species F_{MSY}. (ICES, 2012a)

For the same ecosystem (North Sea), species yields which are greatly influenced by fishing mortality on other species were identified. The yield of mostly all species is strongly affected by the target fishing mortality on cod and saithe. The effect of changes in predation on yield is much as large, or larger as the effect of target F on all species. All species had at least two strong interactions, and whiting and sandeel yield were strongly affected by fishing mortalities on three other species (saithe-cod and sandeel-saithe and cod-haddock, respectively).

Even before the “Rio Declaration” of 1992 (UN, 1992) the dangers in applying the concept of MSY to ecosystems were known (May et al., 1979). There were some other works (for example (Walters et al., 2005)) that explicitly mentioned that there is a risk that some species may become extinct if MSY is applied to ecosystems carelessly.

Balguerias et al. (2000) studied possible multispecies interaction in the Sahara Bank as octopus appeared to increase abundances highly when sparids disappeared around year 1960. The years from 1962 to 1980 were characterized by the massive presence of trawlers from many different countries, which were attracted by the new cephalopod fishery. The explanation appears to be, apart from oceanographic factors, just a regular ecological relationship between a decrease in prey species and an increase in predator as results of overexploitation of Sparidae, with apparent changes in faunistic assemblages occurring in the area, but this hypothesis needs to be quantitatively confirmed. Caddy and Rodhouse (1998) in particular deal with the transition from finfish-targeted fisheries to cephalopod-targeted fisheries at different geographical scales and from the perspective of oceanic, neritic, and benthic cephalopods. The case of the Saharan Bank fishery represents an example in these studies where the main cause alluded to the species substitution is overfishing of the Sparidae stocks in the area.

The question raised again is, once an ecosystem has reached equilibrium under certain exploitation rates (sustainable), what would happen to that same ecosystem if exploitation rates are again altered? Are we able to predict that the situation to be reached will be “better” that the previously existing one? Would that “new” ecosystem be able to provide equal or better human services (fishing, in our case) than before? In an EBFM implementation, there have to be considered the existing relationships within all the ecosystem components. MSY does not, and it may mislead the advice provided (Pauly et al., 1998).

On the contrary it has also been shown how EBFM can be achieved by improving current single-species management (Mace, 2001; Froese et al., 2008).
Several studies suggest that substantial reductions on fishing mortality should be considered in order to meet all the EBFM requirements such as multispecies interactions, maintenance of genetic diversity and reduction of waste and discards. Single species models may provide the same advice (reductions on F) even if they can be due to different reasons.

If both advices are valid the change from considering ecosystems as a “black box” to a holistic approach as if the ecosystem were the starting point for any consideration looks like a too drastic solution. As pointed out by Mace (2001) this is a continuum representing both extremes. But even if it is like that intermediate solutions have to be treated with caution.

It also has to be remained that definition of overexploitation could vary if EBFM is considered (Murawski, 2000). Somewhere in the middle between single species MSY and EBFM, Total MSY (T_{MSY}) is found (Legović and Geček, 2012). In this MSY interpretation, results also vary depending on the ecosystem treated. Looking at the results from Legović and Geček (2012) it can be seen how if species are independent, applying one harvesting effort to many will inevitably lead to extinction of species with small biotic potential.

4.2.2 Biological Reference Points

Biological reference points (BRP) are benchmark against which the abundance of the stock or the fishing mortality rate can be measured in order to determine its status. There are different approaches to the concept of MSY with alternative reference points. F_{MSY} (whatever is defined), is the fishing mortality rate at which, if applied constantly, would result in MSY. Used as a biological reference point, F_{MSY} is the implicit target harvest rate of EU Common Fishery Policy.

In the Table 4 and Table 5 stock status in the Mediterranean and ICES waters are analysed respectively against the MSY target point defined by stock (STECF, 2013a). A traffic light system is used to categorise each status. Thus, when the stock status is far from MSY target, a red colour is assigned, orange for a status getting close to MSY target and green colour when the stock is being exploited under MSY.

A further analysis is carried out calculating the percentage of number of stocks overexploited or no overexploited in the Mediterranean and ICES area. The number of stocks over exploited in ICES area accounted for 40% while in the Mediterranean 92% of stocks are overexploited. When volume of catches is reviewed, percentages reversed as in the Mediterranean just 33 % of the catches come from overexploited stocks whereas in ICES area, 78% of catches come from overexploited ones.

Table 4 : Mediterranean stocks status related to MSY.

Mediterranean stocks	Status MSY	Mediterranean stocks	Status MSY
Anchovy-GSA17		Picarel-GSA25	
Anchovy-GSA22		Sardine-GSA01	
Deep water rose shrimp-GSA09		Sardine-GSA16	
Anchovy-GSA01		European hake-GSA18	
Anchovy-GSA06		European hake-GSA19	
Anchovy-GSA09		Giant red shrimp-GSA09	
Anchovy-GSA16		Giant red shrimp-GSA10	
Anchovy-GSA20		Giant red shrimp-GSA11	
Black bellied angler-GSA05		Giant red shrimp-GSA15-16	
Black bellied angler-GSA06		Giant red shrimp-GSA18	

Mediterranean stocks	Status MSY	Mediterranean stocks	Status MSY
Black bellied angler-GSA07		Greater forkbeard-GSA09	
Black bellied angler-GSA15-16		Norway lobster-GSA01	
Blackmouth catshark-GSA06		Norway lobster-GSA05	
Blackmouth catshark-GSA09		Norway lobster-GSA06	
Blue and red shrimp-GSA01		Norway lobster-GSA09	
Blue and red shrimp-GSA06		Norway lobster-GSA18	
Blue and red shrimp-GSA09		Poor cod-GSA09	
Blue and red shrimp-GSA10		Red mullet -GSA10	
Blue whiting-GSA01		Red mullet-GSA01	
Blue whiting-GSA06		Red mullet-GSA05	
Blue whiting-GSA09		Red mullet-GSA06	
Common octopus-GSA05		Red mullet-GSA07	
Common pandora-GSA09		Red mullet-GSA09	
Common pandora-GSA15-16		Red mullet-GSA11	
Common sole-GSA17		Red mullet-GSA15-16	
Deep water rose shrimp-GSA05		Red mullet-GSA17	
Deep water rose shrimp-GSA06		Red mullet-GSA18	
Deep water rose shrimp-GSA10		Red mullet-GSA19	
Deep water rose shrimp-GSA11		Red mullet-GSA25	
Deep water rose shrimp-GSA15-16		Sardine-GSA06	
Deep water rose shrimp-GSA18		Sardine-GSA09	
European hake-GSA01		Sardine-GSA17	
European hake-GSA05		Sardine-GSA20	
European hake-GSA06		Sardine-GSA22	
European hake-GSA07		Spottail mantis squillids-GSA09	
European hake-GSA09		Spottail mantis squillids-GSA10	
European hake-GSA10		Spottail mantis squillids-GSA17	
European hake-GSA11		Spottail mantis squillids-GSA18	
European hake-GSA15-16		Striped red mullet-GSA05	
European hake-GSA17		Striped red mullet-GSA09	

Source: AZTI Tecnalia

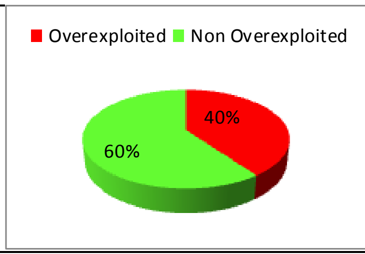
Table 5: ICES stocks status related to MSY.

ICES stocks	Status MSY	ICES stocks	Status MSY
North-East Arctic cod (Sub-areas I and II)		Icelandic summer-spawning herring (Division Va)	
Haddock in Sub-area IV (North Sea) and Division IIIa		Irish Sea herring (Division VIIa)	
Hake -Northern stock (IIIa, IV, VI, VII, VIIIa,b)		Megrim (L. boscii) in Divisions VIIIc and Ixa	
Herring Celtic Sea and Division VIIj		Plaice Sub-area IV (North Sea)	
Herring in Division VIa (North)		Southern horse mackerel (Divisions Ixa)	
Icelandic saithe (Division Va)		Whiting in Divisions VIIe-k (Celtic Sea)	
Herring in Sub-divisions 25 to 29 and 32 Gulf of Riga		Sole in Division VIIe (Western Channel)	
Haddock in Division VIa (West of Scotland)		Sprat in Sub-divisions 22 to 32	
Haddock in Division VIb (Rockall)		Megrim (L. whiffiagonis) in Divisions VIIIc and Ixa	
Cod in Division VIa (West of Scotland)		North-East Arctic haddock (Sub-areas I and II)	
Cod in Divisions VIIe-k (Celtic Sea)		Plaice in Division VIIe (Western Channel)	
Cod in Sub-area IV, Divison VIId & Division IIIa (Skagerrak)		Saithe in Sub-area IV, Division IIIa (Skagerrak) & Sub-area VI	
Faroe haddock (Division Vb)		Sole in Division VIIa (Irish Sea)	
Faroe Plateau cod (Sub-division Vb1)		Sole in Division VIId (Eastern Channel)	
Faroe saithe (Division Vb)		Sole in Divisions VIIf and g (Celtic Sea)	
Hake - Southern stock (Divisions VIIIc and IXa)		Sole in Divisions VIIIa,b (Bay of Biscay)	
Herring in the Gulf of Riga		Sole in Sub-area IV (North Sea)	
Herring in Sub-divisions 22-24 and Division IIIa (spring-spawners)			

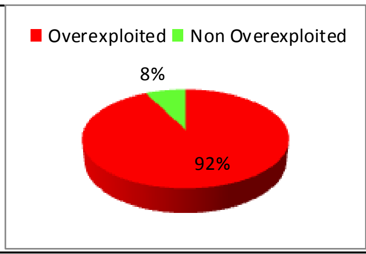
Source: AZTI Tecnalia

Figure 6: Percentages of stocks and catches in relation to MSY.

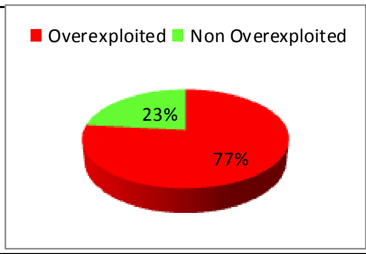
ICES Number Stocks	Overexploited	14
	Non Overexploited	21



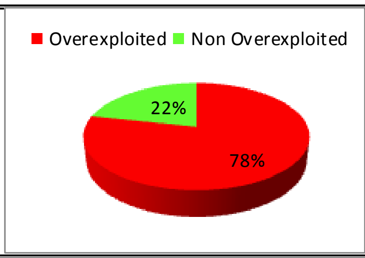
Mediterranean Number Stocks	Overexploited	74
	Non Overexploited	6



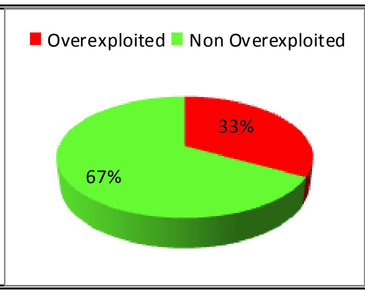
Total Number Stocks	Overexploited	88
	Non Overexploited	27



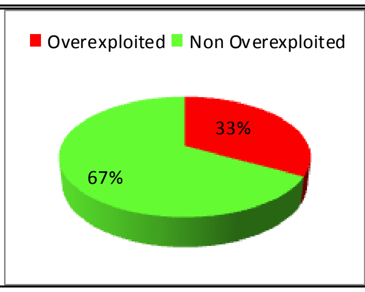
ICES Catches	Overexploited	78
	Non Overexploited	22



Mediterranean Catches	Overexploited	33
	Non Overexploited	67



Total Catches	Overexploited	111
	Non Overexploited	89



Source: AZTI Tecnalia

Area specificities: The Mediterranean Sea

In Caddy (1983) the Mediterranean stocks have been advocated as higher resilience compared to Atlantic stocks.

In Mediterranean European countries, 85% of the assessed stocks are currently overfished compared to a maximum sustainable yield reference value (MSY) (Colloca et al., 2013).

Thirty-two out of 38 stocks assessed in Mediterranean European countries are overfished (about 84%), while only 4 stocks are considered sustainably exploited compared to the fishing mortality (F) level able to provide MSY. In particular, all assessed demersal fish stocks (100% of 18 stocks) were found over-exploited, while among the 9 crustacean stocks assessed, 7 were over-exploited while the status of two stocks was unknown. The highest rate of sustainable exploited stocks (27%) was found among the small pelagics as anchovy and sardine (i.e. three of 11 stocks) (STECF, 2010).

4.3 Are we able to manage fisheries under the MSY accomplishing with the socio-economic and ecological objectives set under new CFP?

The concept of Maximum Sustainable Yield (MSY) for managing fisheries gained popularity in the 1930s as an apparent simple and logical management goal. It can be easily explained to managers and consequently it is easily understood. That is the reason why MSY was adopted as the primary fisheries management goal by several international organizations and countries. However, simplicity is precisely its weakness. In the 1960s and 1970s fisheries researchers started challenging the capability of MSY dealing with real world complexities such as its inability to account for: i) variability in population productivity; ii) species other than the target species, iii) food chain interactions and/or changing ocean environments and iv) considering just only the income, not the costs of harvest.

The challenge to use MSY as management has gained some detraction nowadays by the difficulty of its application in the real word, especially when, as in the new CFP, there is a need of reconciling three different objectives (biological, environmental and socio-economic objectives).

In relation to the socio-economic objectives of the CFP: Professor Sidney Holt[3] in a conference at Fishmongers' Hall in London on the theme "*Why, or why not, maximum sustainable yield (MSY)? Contemporary thoughts on the rational management of fisheries*", commented that fisheries should be managed so that they are profitable, otherwise fishermen won't go out to fish. In fact, this is also, one of the CFP objectives for managing fisheries.

The revenue obtained from the catch has to be more than the cost of catching it. In that sense it seems more useful to manage the input (effort placed on a fishery) not the output (the catch), which highly depends on environmental and biological variables, such as recruitment. Thus, maximizing yields using simple surplus production models seems to be a too simplistic method of managing fish populations which does not take into account selectivity, and maybe too many young fish are caught. MSY can be also calculated with

[3] Professor Sidney Holt is considered as the "father" of modern fisheries management, and best known for the book On the Dynamics of Exploited Fish Populations published with Ray Beverton in 1957 what has become the most cited book on fisheries.

more complex models in which overall stock selectivity is taken into account. But even with those ones, the selectivity of individual fleets is not considered. Thus, the main issue for MSY should be to look at the relationship between population growth and mortality and specifically, how much mortality is caused by fishing than by nature and not just for target species but for the whole fish community and taking into account the heterogeneity in the fleets that harvest the species.

In relation to the ecosystem objectives of the CFP: fishing for MSY also ignores fundamental aspects of the ecosystem such as the need to leave enough fish in the sea for other parts of the food chain including mammals and seabirds. This will mean, reducing the harvest of the fish stocks. In this sense, to achieve profitable fisheries, would mean, in the case of some European fleets, reducing fishing effort by up to a massive very high percent (> 60%). In that scenario, less fishing effort would mean more profit for those fleets left in the fishery, providing a better balance between the components of the food chain harvested by humans, birds and marine mammals.

The reality is that the actual European scientific advice in the framework of MSY (as defined by ICES) for European stocks is now aiming to establish fishing rates targets rather than stock biomass targets. In the last four years of this ICES MSY framework approach application, fishing rates are now falling in the most critical fisheries, and are closer to MSY, which even though, it is not the ideal in the strict application of MSY, is on the trajectory to match the socio-economic objectives (profitability) and the ecosystem objectives (reduction of discards and affection to other species) contemplated in the CFP. The proposal could be, if MSY has to be used as the policy accepted by the EU, then it should be make as a limit and not a target.

Managing at or above BMSY, seems to be possible. The approach could be to use the concept of MSY not in its original definition or format; on the contrary tuned or adjusted to the socio-economic and ecosystem reality of the European fisheries.

There is a possibility for managers to define as what is known as "Pretty good yield" region (e.g. where yield >0.95 maximum yield) (Hilborn, 2010). The idea will be to define fishing mortality or biomass ranges that can be used when advising on fisheries options in a multispecific and mixed fisheries context and in which the biological sustainability is assured.

ICES is working under these premises regarding multispecies and mixed fisheries advices for providing with F limits in relation to MSY (ICES, 2013a)

Distribution of different references points can be inspected: F_{max}[4], $F_{0.1}$[5], $F_{\%SPR}$[6], $F_{50\%}$[7], in this way, appropriate proxies could be defined. Fs should be below a rate that implies a low probability than the spawning stock biomass fall below the biomass limit below which the dynamics of the stock are unknown (B_{lim}). Thus, values of proposed Fs should be examined for consistency with B_{lim} in the long-term. In the F defined range, F target could be

4 F_{max}: the fishing mortality rate that maximizes equilibrium yield per recruit. It is often used to define growth overfishing.

5 $F_{0.1}$, the fishing mortality at which the yield per recruit of a fishery increases only 10% of the yield per recruit of the unexploited stock.

6 $F_{50\%}$, the fishing mortality that will reduce the equilibrium spawning potential per recruit to 50% of what it would be without any fishing.

7 $F_{\%SPR}$, the fishing mortality that will reduce the equilibrium spawning potential per recruit to X% of what it would be without any fishing.

weighted depending on the dimension to be prioritized (economic, social or ecological priority) but always maintaining it within the defined range.

When defining F ranges for mixed fisheries some considerations could be taken into account. For instance, for stocks fished together at Fs that are at different distances from stock specific Fmsy, manager could decide on "pretty good yield" interval using $F>F_{MSY}$ to allow some further "space" to reconcile these differences, if this "space" is insufficient and Fs of some stock are higher than the lowest limit of interval, managers could look some further flexibility above F_{MSY} (ICES, 2013a). Thus, as far as all stocks are fished "precautious" (under levels of "pretty good yields), the mixed fishery could be considered as fished at MSY. As no information could be available for all species, "choke" species, understood as the most valuable or more ecosystem important ones, would be used as sentinels of the species assemblage or ecosystem health status. Maybe the idea could be to move from the traditional concept of MSY towards a precautions "pretty good multiyield" concept applicable to multispecific and mixed fisheries within the CFP objectives.

Also, when multispecies considerations (predator-prey relationships, cannibalism, and density-dependent growth) are to be taken into account, there is a need on defining MSY limits providing targets for ecosystem health indicators. This is, taking into account the Marine Strategy Framework Directive descriptors rightly directed to ecosystem health (ICES, 2013a).

Summarizing, the ideals of fisheries management are relatively simple but in practice, reconciling the three mentioned objectives, is currently very difficult. The applicability of MSY and to offer robust alternatives to MSY seems to be vague and challenging under the actual CFP. Thus, maximum sustainable yield is a weak statement in the context of other CFP objectives: the economic and the environmental.

5. CONCLUSIONS

Ecosystem capacity to respond to fishing is limited; and there should be an optimum balance between the amount of fish removed by fishing and the amount of fish remaining in the ecosystem. In fisheries management, other dimensions such as, economy or social sciences, also look to sustainability but they propose different ways of reaching it. These other ways should be taken into account to address management problems such as the issue of discards and its potential solutions.

The European fisheries are characterised by a great diversity of exploited species (fish, crustaceans and molluscs) and by a variety of fishing gears. European fisheries are multi-gear and multi-species. This highly complex nature has been a major contributing factor to the limited success of certain management strategies (e.g. TAC). Different catch limits for the various stocks may lead to imperfect implementation of the single-species TAC through incentives for misreporting or discarding.

The ecological and biological aim of the landing obligation is clear but it bumps against its practical implementation. In the short term, profitability of the multi specific and mixed fisheries is clearly reduced and even in the long term, the loss of fishing opportunities could appear. There may be an increase of costs in monitoring and surveillance programs unless incentives are provided to create commitment between managers and fishers.

Hopefully, there is still room to improve selectivity on by-catch; encourage fisheries behavioural changes in relation to areas and seasons of high by-catch and finally, encourage research on new marine products.

Some species appear to have low mortalities when discarded (flatfish, large pelagics and anglerfish). However, discard survival is species-gear-regional specific and consequently these results cannot be extrapolated. There are not defined fixed levels from where (above or below) survival rate could be considered as high or low.

Fishing under precautionary limits means setting conservative limits to catch, so that in case of unpredictable events affects fish stocks, they will still be under safe biological limits. The MSY is understood as the largest yield (or catch) that can be taken from a species' stock over an indefinite period. Precautionary limits could include other approaches to MSY apart from the traditional simplistic concept.

In a multispecies fishery with more than one species caught at the same time, fish stocks MSYs targets are calculated separately. However, in multispecies fisheries is not possible to apply different levels of fishing effort to the species inhabiting a single habitat and that are vulnerable to the same fishing gear. In other words, what may be "safe" for one stock may be "dangerous" for another stock caught together with it.

In multispecies and mixed fisheries, the idea will be to define fishing mortality or biomass ranges, which assure sustainability that can be used when advising on catch options ("pretty good yield concept"). The concept will be to move from the traditional MSY towards a "pretty good multiyield" concept applicable to multispecific and mixed fisheries.

In multispecific and mixed fisheries, MSY simple concept is weak in relation to its own definition and implementation. MSY is not able to cope with real world complexities i.e. i) variability in population productivity; ii) species other than the target species, iii) food chain interactions and/or changing ocean environments and iv) considers just only the income, not the costs of harvest.

In multispecific and mixed fisheries, if the overall level of exploitation is fixed at the lowest level required by the species with the lowest resilience, this will reduce drastically the utility of the resource.

In an Ecosystem Based Fisheries Management (EBFM), the existing relationships within all the ecosystem components have to be considered and it is also well known that EBFM could be closer by improving current single-species management. But MSY do not take this into account, and it may mislead the advice provided.

For some ecosystems, species yields are greatly influenced by fishing mortality of other species, especially large predators (i.e. cod and saithe). The effect of predation on yields is as much as large of the effect of fishing mortality.

6. GENERAL RECOMMENDATIONS

Landing obligation will be first in place on the1st January 2015, at the latest, for small and large pelagic fisheries, industrial fisheries and salmon fisheries.

For most fisheries described under the Case Studies, this term (2015) appears too short to accomplish all the technical, handling and storing changes. Control and surveillance had also to be ready to be implemented by that date. Assessment and management systems should be also clear. Under these complex facts, it is recommended that an extension or larger flexibility of these time-frames should be considered.

It is recommended a constant dialogue between scientist and managers, to define implicit management objectives or the selection of preferred options through discussions within a governance process

The following general recommendations in relation to landing obligation are extracted from the case studies:

- ✓ Selectivity solutions: there is still a chance to improve it. The eligibility of fishing fleets for the de minimis exemption has to be scientifically assessed.

- ✓ Improvement of selectivity implies a short term cost for the fishermen. This cost has to be quantified and incentives (not just economic) should be provided to compensate for extra costs and loss of fishing opportunities.

- ✓ The monitoring, control and surveillance system has to be reinforced to guarantee the accomplishment of the landing obligation.

- ✓ An assessment of the likely costs of landing, handling, storing and transport of extra biomass has to be carried out. Also the cost of the landing obligation implementation should be quantified. The recommendation is to determine the economic feasibility of the landing obligation as a framework to define the incentives to be created.

- ✓ TAC and quotas new management scenarios testing are strongly recommended to be simulated as, up to now, just preliminary studies on how to, first, calculate new TACs (including discards) and second, how to share the new resulting quotas are available.

- ✓ Flexible quota-swap mechanisms among fleets of different Member States should be deployed to compensate vessels' quota overshooting.

- ✓ As presently MLS regulations prohibit the landing of catches below the minimum size, there is a need to abolish it as they would conflict with the requirement to land all catches. MLS are suggested to be replaced by Minimum Conservation Reference Sizes (MCRS).

- ✓ New products and markets could be explored for fishermen to trade new species and sizes landed but avoiding the creation of incentives that could shift fishing effort to other ecosystem components.

- ✓ Fishermen institutions know the technical aspects of the fishing activity being able to facilitate the accomplishment of the landing obligation. Therefore, they should be given a key role in the process of implementing the landing obligation.

- ✓ Landing of large quantities of fish for industrial purposes e.g. production of fishmeal will require investments in storing capacity and transportation. In relation to these issues, the fishmeal transformation chain and other unidentified actors will take more relevance and should be also taken into account.

- ✓ Some regional workshops could be organized to exchange information among fishermen concerning good practices on the landing obligation.

In relation to MSY application:

- ✓ The ICES mixed-fisheries advice is currently implemented only in the North Sea stocks. This work is taken into account to give the first catch advice.

- ✓ Important inconsistencies in TAC of different species being caught by the same fleets are identified in the Iberian waters. The conclusion is that all MSY targets cannot be achieved simultaneously.

- ✓ Multispecies considerations have only been deeply analysed and included for advice for some North Sea stocks.

- ✓ It is recommended that other ICES ecoregions (Celtic Sea & Bay of Biscay and Iberian waters) continue and/or start working on assessment of multispecies in mixed fisheries.

- ✓ MSY references ranges of the main European commercial species should be defined in a multispecific context.

- ✓ On average, fishing mortality used under the precautionary approach (Fpa) is 1.6 times that fishing mortality used under the maximum sustainable yield approach (Fmsy) (WKFRAME-2, 2011). Meaning that, the Fmsy is, in general much more conservative. So when establishing multispecies MSY reference ranges, it is recommended to overview the total catch profile by fleet, and avoid to simplify the complex ecosystem to single catch advice.

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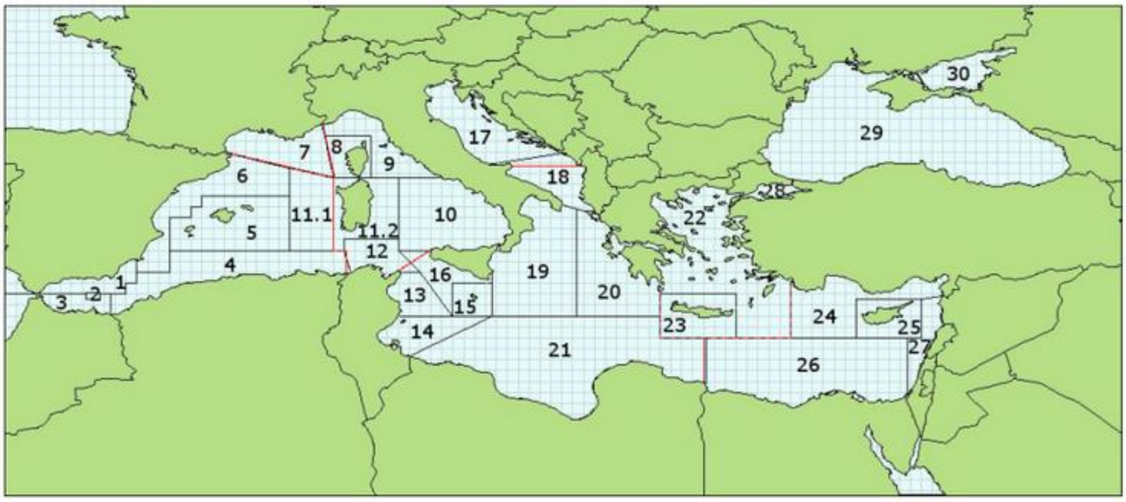
ANNEX I: MAPS

Map 1: FAO Statistical Divisions and GFCM/ Geographical Sub-areas.



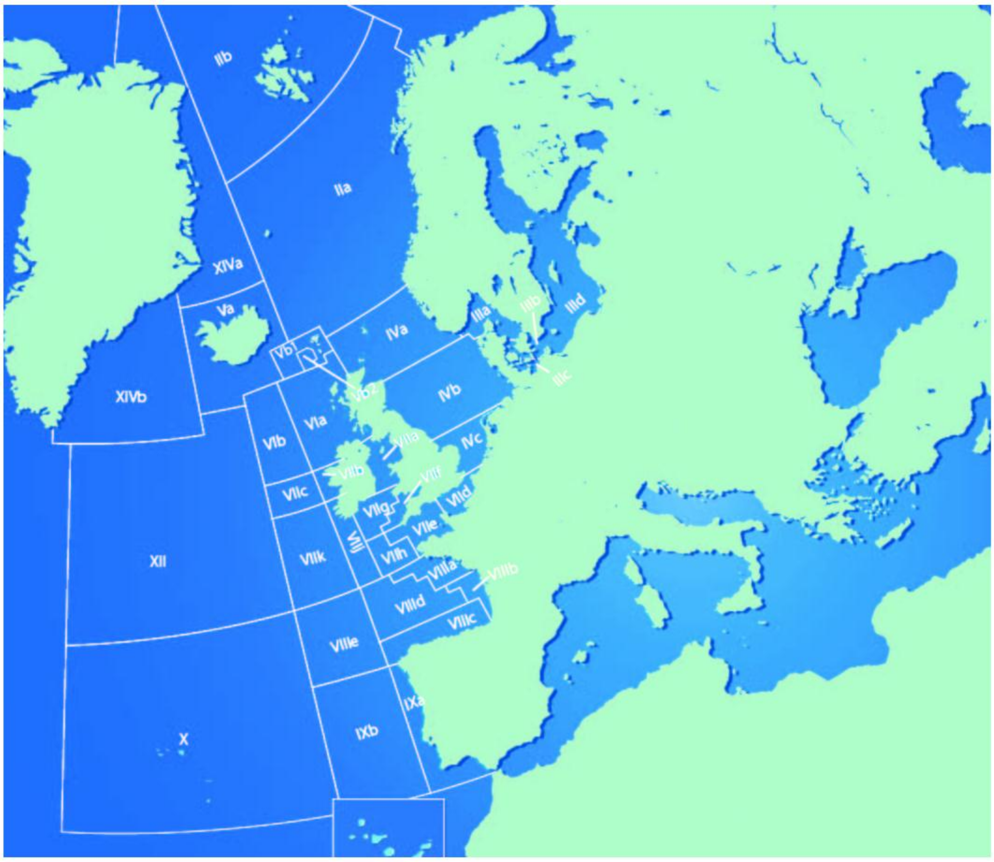
— FAO Statistical Divisions (red) *— GFCM Geographical Sub-Areas (black)*

01 - Northern Alboran Sea	07 - Gulf of Lions	13 - Gulf of Hammamet	19 - Western Ionian Sea	25 - Cyprus Island
02 - Alboran Island	08 - Corsica Island	14 - Gulf of Gabes	20 - Eastern Ionian Sea	26 - South Levant
03 - Southern Alboran Sea	09 - Ligurian and North Tyrrhenian Sea	15 - Malta Island	21 - Southern Ionian Sea	27 - Levant
04 - Algeria	10 - South and Central Tyrrhenian Sea	16 - South of Sicily	22 - Aegean Sea	28 - Marmara Sea
05 - Balearic Island	11.1 - Sardinia (west) 11.2 - Sardinia (east)	17 - Northern Adriatic	23 - Crete Island	29 - Black Sea
06 - Northern Spain	12 - Northern Tunisia	18 - Southern Adriatic Sea	24 - North Levant	30 - Azov Sea

Source: GFCM

Map 2: ICES Fishing areas

ICES FISHING AREAS

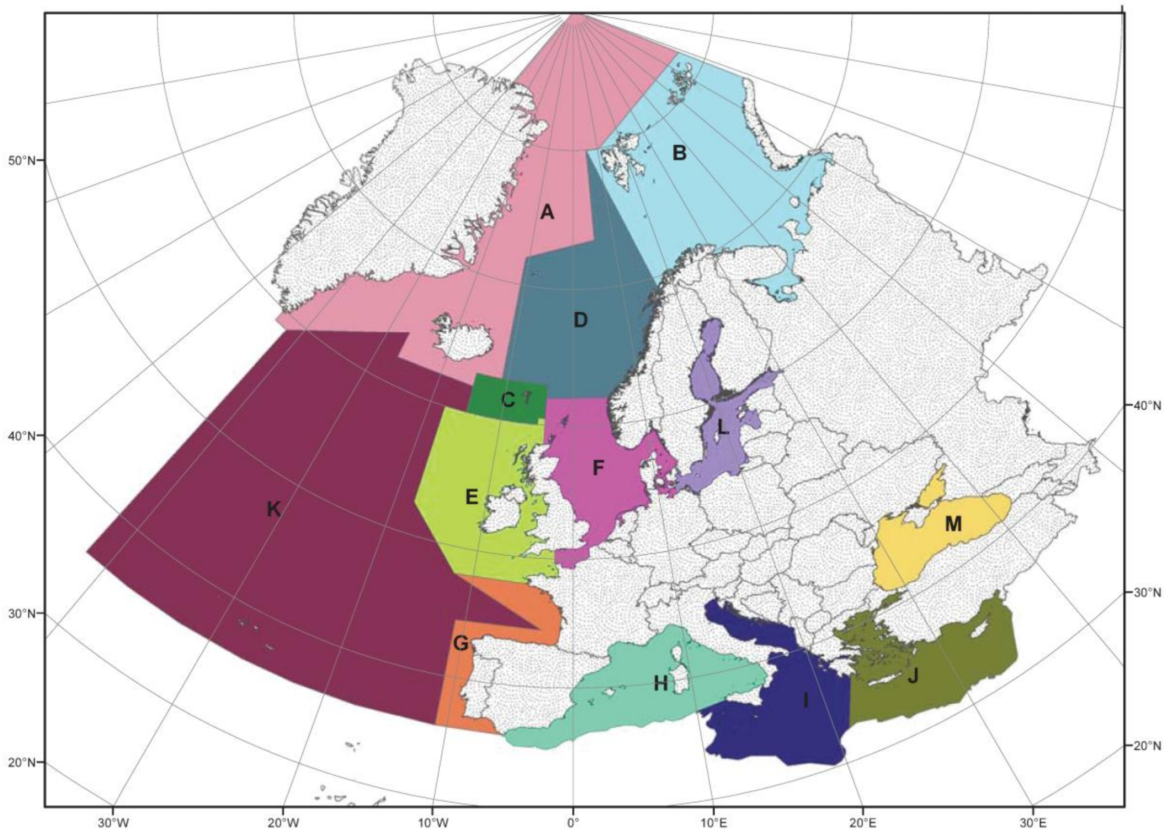


I	Barents Sea
IIa	Norwegian Sea
IIb	Spitzbergen and Bear Island
IIIa	Skagerrak and Kattegat
IIIb	Sound
IIIc	Belt
IIId	Baltic Sea
IVa	Northern North Sea
IVb	Central North Sea
IVc	Southern North Sea
Va	Iceland
Vb	Faroes
VIa	West Scotland (Clyde stock)
VIb	Rockall
VIIa	Irish Sea
VIIb	West Ireland
VIIc	Porcupine Bank
VIId	Eastern English Channel
VIIe	Western English Channel
VIIf	Bristol Channel
VIIg	South-east Ireland
VIIh	Little Sole
VIIj	Great Sole
VIIk	West Great Sole
VIIIa	South Brittany
VIIIb	South Biscay
VIIIc	North and North-west Spain
VIIId	Central Biscay
VIIIe	West Biscay
IXa	Portuguese coast
IXb	West Portugal
X	Azores
XII	North Azores
XIVa	East Greenland
XIVb	South-east Greenland

EN

Source: www.docstoc.com

Map 3: Ecoregions based on ICES Advice ACFM



A: Greenland and Iceland Seas
B: Barents Sea
C: Faroes
D: Norwegian Sea
E: Celtic Sea
F: North Sea
G: South European Atlantic Shelf
H: Western Mediterranean Sea
I: Adriatic-Ionian Seas
J: Aegean-Levantine Seas
K: Oceanic northeast Atlantic
L: Baltic Sea
M: Black Sea

Source: ICES

Note: ICES Convention area (FAO area 27) includes regions A-G, L . Zones H-J, M are outside the ICES area

ANNEX II: CASE STUDIES

1. Cod mixed fisheries in the North Sea

KEY FINDINGS

- Large-scale discarding is known to occur in the mixed demersal trawl fisheries in the North Sea. Discards are mainly composed of small and juvenile fish below or close to the minimum landing size and of larger individuals of species without a reliable market.
- Single stock management is one of the reasons of discarding in mixed fisheries in the North Sea.
- Beam trawl and otter trawl fleets are the most important fleets affected by landing obligation. The accomplishment of landing obligation might be feasible as the main reason for discard can be addressed by improving selectivity through the use of larger mesh size in the cod end.
- Improvement of selectivity implies a cost for the fishermen. This cost has to be quantified and incentives should be provided to compensate for these extra expenses.
- Cod interacts with a range of species in the ecosystem. It is obvious that all MSY targets cannot be achieved simultaneously. A new management system based on a multispecies approach has been proved for the North Sea, suggesting changes in single-species MSY values in order to maintain all stock within precautionary limits.
- Around 75% of the fleets targeting cod in the North Sea and 85% targeting plaice and sole will be significantly affected by the landing obligation.

1.1. Landing obligation

Due to the technical differences between otter trawl and beam trawl fishing it has been considered necessary to focus on two representative fisheries exploited with such technologies: otter trawl cod mixed fisheries, and beam trawl targeting plaice and sole fisheries, respectively.

1.1.1. OTTER TRAWL COD MIX-FISHERIES IN THE NORTH SEA

Fleets affected

In the North Sea, cod is either targeted as part of mixed fisheries together with haddock, whiting, nephrops, plaice and sole. Cod is caught by fleets using otter trawl, beam trawls, seine nets, gill nets and lines. According to ICES (2013a), discards of cod are around 25% of the cod catch, having diminished in the last years. Reasons for discarding are undersized cod, over quota catches and high grading. According to Article 15 of the recently approved text of the basic CFP regulation the landing obligation shall be accomplished for this species by January 2016. Member states involved in the fishery are Danish, British, Dutch and German fleets.

Single stock management is one of the reasons of discarding in mixed fisheries in the North Sea (ICES, 2013a). This produces inconsistencies among the management objectives of the species concerned. TAC for one species can be fished up before the TAC of the other is not yet exhausted. Some measures have been adopted in Scotland, where a voluntary scheme aimed at counteracting discards provides incentives to fishermen (i.e. extra days at sea) for time closures and adoption of technical measures. These measures have proven to be effective in minimizing discards. The closure of areas seems effective to avoid unwanted cod. The implementation of such measures to all fleets concerned will imply a process of negotiation with the fishing sectors.

In the context of the obligation to land all fish underreporting of cod may arise as a problem. Flexible quota swaps among fleets can counteract quota exhaustion. This seems a useful mechanism to compensate quota overshooting of marketable fish. Otherwise, it may be less useful when the catch is made up of undersized fish.

The landing obligation of all catches may produce a problem of storage and handling. This problem is especially hard if the catch is made up of fish with low economic value (e.g. undersize specimens).

Problems at sea

The improvement of the selectivity patterns will likely reduce the presence of juvenile cod in the catch. Within the framework of Scottish cod avoidance program, for example, technological measures to improve selectivity have been tested such as cod avoidance panels and square mesh panels (STECF, 2013c). Article 15 of the CFP text states that fisheries based on species with a high survival rate will be exempted from the landing obligation. In this regards, studies have shown that cods and other finfish are severely damaged after being hauled and brought on board, especially because of the effects of the change of pressure in the bladder, thus this exemption will not apply for cod (see section 3.4). According to the new text of the CFP de minimis exemption will apply for fisheries where it is scientifically proved that improvements on selectivity are not feasible. Selectivity improvement appears to be achievable at least from the technical point of view. However, scientific evaluation of selectivity measures shall be carried out to back up any decision.

The improvement of selectivity seems to counteract the discard problem. Lack of effective measures to reduce unwanted cod may cause many difficulties to storage it. Low prices of undersize fish may not worth the costs associated to landing all catches. This may motivate fishermen to keep discarding. All landed fish will count against quotas which may encourage underreporting.

Problems on landing site

If cod avoidance measures fail, market alternatives should be explored to the commercialization of otherwise discarded fish. Most of the by-catch is made up of juveniles, which have a lower market value and that may only be destined to processing of non-human consumption products. The alternative of fishmeal seems accurate since finfish is raw material for the reduction industry. But fishmeal production requires large quantities of raw material. In any case the price paid for undersized cod is expected to be low provided that these catch is treated as raw material together with other species. Once discarded fish is landed, costs of handling, storing, refrigerating, and transporting fish destined either for human or non-human consumption will likely be high. Low prices at markets may discourage full compliance of the landing obligation. In general, the price of a ton of raw material for production of fishmeal may not exceed 200 €/ton, which may not be attractive for the fishermen. According to Cefas (2012) investments in infrastructure may be needed to deal with the large amounts of fish to be brought ashore for production of fishmeal.

Management approach

The obligation to improve selectivity trough gear improvements will require comprehensive inspection. The landing obligation of all by-catch will require a comprehensive observer program or any other mechanism that ensures performance of rules (e.g. CCTV systems). If these measures are combined with spatial management, it will also require a VMS system. Fully documented fisheries are in place in UK, Denmark and Germany. There is evidence that these systems have contributed to reduce high grading (ICES, 2013b).

Incentives have to be deployed to motivate fishermen to adopt measures to avoid unwanted cod. The example of the voluntary Scottish Conservation Credit Scheme shows how incentives contribute to the adoption of measures as improvement of selectivity implies a cost for the fishermen. This cost has to be quantified and incentives should be negotiated with fishermen to compensate for these extra expenses. The implementation process is likely to be long since it requires negotiation and agreement with fishermen.

1.1.2. BEAM TRAWL FLATFISH FISHERIES IN THE NORTH SEA

Fleets affected

The beam trawling fishery in the North Sea is oriented to flatfish i.e. sole and plaice. There is a substantial discard rate in the beam trawl fishery of around 50% (MRAG & IEEP, 2011). This is basically made up of dab, whiting, undersized sole, gurnard and sea bottom invertebrates. According to Article 15 of the basic text of the CFP the landing obligation shall be accomplished by January 2016. Fleets involved in the fishery are Dutch, Belgian, British, German and Danish.

At least from the technical point of view accomplishment of the discard ban might be feasible provided that the main reason for discarding (i.e. the by-catch problem) can be addressed by improving selectivity through the use of larger mesh size in the cod end. However, the mandatory change of the cod end may imply provisions of incentives for fishermen to compensate for the extra costs of gear modifications. More sophisticated techniques to improve selectivity such as the use of panels may require longer time since they require gear modification, trials, and scientific evaluation. In addition, agreement with fishermen and tuning of technical solutions may require considerable time.

Quota exhaustion does not seem to incentivize discards. These are basically produced due to the large amounts of unmarketable by-catch. If the selectivity problem is not solved and by-catch species landed, a quota exhaustion problem may arise because some of these species are managed through quotas and hence landings have to be counted against quotas. Store capacity and handling are major issues to be addressed to enforce the landing obligation. Currently, these issues do not seem a problem for the fleet.

Problems at sea

It seems possible to counteract the selectivity problem trough increase in the cod end mesh size. For example, benthic drop out panels and larger mesh sizes are being tested (MRAG and IEEP, 2007). It seems that an increase in mesh size (> 80 mm) reduces unwanted plaice but there is a trade-off with loss of marketable sole (ICES, 2013b). In spite of this, an increase of the MLS of sole may provide incentives for fishermen to increase mesh size, hence reducing unwanted plaice (ICES, 2013b).

According to stakeholders, days at sea restrictions in connection with the cod recovery plan, encourage fishermen to fish close to shore, which increase discards rates. The alternative to implement spatial management seems to be effective but requires the deployment of a VMS system (MRAG and IEEP, 2007).

The improvement of selectivity, as discussed before, seems to counteract the discard problem. On the contrary, if the selectivity problem is not (or poorly) addressed all fish have to be landed. This may cause many difficulties to sort out the catch and storage it. Low prices or no market value may not be worth the costs associated to landing all catches. This may motivate fishermen to keep discarding.

The use of spatial management seems feasible but requires an effective monitoring system. The VMS system arises as a good choice since it is cheaper than an observer program. This measure can be combined with measures to improve selectivity.

Problems on landing site

Most of the by-catch is made of dab, dragonets and gurnards which is fish that have very low or no market value. Moreover, the catch has to be sorted out and unmarketable benthos organisms separated from the catch.

Currently, there is little or no demand for most of the by-catch species. Exploration of new markets for these fish or new products will be required.

The alternative of fishmeal production may not be feasible since production requires large quantities of finfish. Provision of finfish to fishmeal plants has to solve also the problem of sorting out finfish from other organisms.

Management approach

The obligation to improve selectivity trough mesh sizes, MLS or panels will require strict control. If these measures are combined with spatial management it will also require a VMS system.

Producer Organizations (POs) are already engaged in exploring alternatives to reduce discards since it allows improving the quality of the catch and reduces the time devoted to sort fish out. In addition, it improves sector´s public image. So the experience of POs has to be taken into account. They can facilitate the implementation of the landing obligation.

Improvement of selectivity implies a cost for the fishermen. This cost has to be quantified and incentives (or reimbursement) should be discussed with fishermen to compensate for these extra expenses.

In spite of the basic selectivity improvement (i.e. increased mesh size) that could be implemented in relative short time, the implementation process may take longer time since it needs the agreement of fishermen. More sophisticated tools will require a longer time for development and achievement of consensus.

1.2. MSY APPLICATION

Effort or technological limitations of mixed fisheries MSY

Recent exercises show that the effort needed to reach MSY for each of the stocks is very different. Consequently, MSY targets are not achievable for all species simultaneously. Since 2012, mixed fisheries advice has been provided by ICES for North Sea area, based on a single stock assessment for the main species (cod, haddock, whiting, saithe, plaice, sole and nephrops) but combined with knowledge on the species composition in catches. The group uses the Fcube approach (Ulrich et al., 2008, 2009), presenting different scenarios for advice.

Mixed-fisheries catch options can take specific management priorities into account. Scenario results confirm that it is often not possible to achieve all management objectives simultaneously. For instance, if rebuilding of the cod stock is the major objective, this could mean that the TAC for other species in the mixed fisheries cannot be fully utilized. In contrast to single-stock advice there is therefore no single recommendation, but a range of plausible options (ICES, 2013a).

Multispecies considerations of MSY

Most species in the North Sea have historically been assessed from a single-species perspective, establishing target levels for both the precautionary and the MSY approach, if possible. Although models that include several species and their interactions have existed for quite some time (e.g. Lotka-Volterra two species model in 1925), first true applications of multispecies models of marine ecosystems were seen closer to the end of the twentieth century (e.g. ICES, 1989). But it has not been until 2013 when these considerations have been included into the advice (ICES, 2013b), where the SMS model (Lewy and Vinther, 2004) has been used to investigate how the dynamics of the modelled species, and so, the dynamics of the fleet, could be affected by the existing trophic relationships. This study shows for example that, for almost all the prey species, the historical development in recruitment differs greatly between multispecies and single species assessments. And that fishing mortality on cod and other predators such as saithe should be higher than single-species FMSY in order to maintain all stock within precautionary limits (ICES, 2013b).

2. MIXED DEMERSAL FISHERIES IN THE CELTIC SEA

KEY FINDINGS

- Large-scale discarding is known to occur in the demersal fisheries in the Celtic Sea.
- While juvenile hake is discarded in otter trawler fisheries, a variety of finfish species are discarded in the nephrops fishery. Discards are mainly composed of undersized fish.
- Improvement of selectivity arises as a need to counteract high levels of discarding. The accomplishment of landing obligation might be feasible since selectivity improvements are currently being developed.
- Restrictions on fishing effort may induce high-grading since fishermen might prioritize landing of fish with a higher value.
- Landing obligation appears to be difficult to implement when some species are perceived by fishermen as very abundant but quota system limit its landing.
- Around 60 % of the fleets in the Celtic Sea targeting Northern hake and around 100 % of the fleets targeting nephrops will be significantly affected by the landing obligation.
- There is a need of TAC reconciliation of different choke species for improving both assessment and management and in this way assure success on landing obligation.
- Only cod, whiting, sole and herring are being exploited at individual MSY levels.

2.1. LANDING OBLIGATION

Due to the technical differences between otter trawl for finfish and nephrops trawling, it has been considered necessary to split the landing obligation analysis in two representative fisheries exploited with such technologies: hake fisheries and nephrops fisheries, respectively.

2.1.1. HAKE FISHERIES IN THE CELTIC SEA

Fleets affected

The hake fisheries in the Celtic sea and Bay of Biscay are composed of gillnetters targeting hake and sole, long-liners targeting hake and trawlers targeting hake, megrim and anglerfish (EC, 2008b) and also nephrops. Discard of juvenile hake is particularly relevant. According to Article 15 of the recently approved CFP text the landing obligation shall be accomplished for this species by January 2016. Fleets involved in the fishery are Spanish, French, British and Irish.

The discard problem for hake is basically related to presence of undersize hake in the catches. Hence, the introduction of technical measures to protect juvenile hake may reduce discards while contributing to the sustainability of the stock. Reduction of fishing effort may also reduce by-catch of small hake and other species, hence discouraging discards. Implementation of technical measures to reduce discards seems achievable within the period proposed by the new CFP. However, implementation of the measures will require achieving consensus with the fishing sector.

In spite catches of hake usually surpass the TAC (ICES, 2013b) this does not seem to be the problem for discarding of juvenile hake. The rationale of discarding is the impossibility to bring juvenile hake to shore due to MLS and low market value. A reduction of the hake TAC may encourage high-grading thus ensuring that the fewer fish brought to harbor has sufficient market value. This fact may produce increase of discards.

This will be a problem if selectivity is not improved and by-catch have to be store on board and landed.

Problemas at sea

The main reason for discarding of hake is the by-catch of juvenile hake. Quota exhaustion seems not to play a significant role in this problem for hake. The improvement of the selectivity patterns will likely counteract the presence of juveniles in the catch. Within the framework of the recovery plan some measures have been implemented in these fisheries including square mesh panels and increased mesh sizes (ICES, 2013b). In addition, hake is usually caught together with megrim and anglerfish in an otter trawl mix fisheries. In these fisheries once one of these species run out of quota it induces fishermen to discard in order to continue fishing. This is especially relevant for fleets holding a smaller quota of one of these target species. Hence, a misbalance in the allocation of quotas in Celtic Seas’ mix fisheries may produce an incentive to discard. This situation can be seen in the case of the Spanish fleet targeting megrim, hake and anglerfish. In this case, the quota of anglerfish is far smaller than the quotas for the other two species (ARVI and CLUPESCA, 2013). It is also worth pointing out that hake can also be considered by catch for the Vigo trawling fleet, which targets megrim. Quota exhaustion for hake in this case may induce discarding.

Effort restrictions may reduce discards in hake fisheries. However, it does not discourage discarding practices. Reduced fishing effort may motivate fishermen to high-grade to obtain a better profit. Exchange of quotas within a given fleet is a practice that is being used in different countries. It will be necessary to discuss with the fishing sector how to use this mechanism to cope the problem of juvenile fish. The low economic value of undersized fish may discourage quota transfers among operators. In spite the reform of the CFP did not take into account the alternative of a pan European market for quotas a mechanism should be devised to facilitate quotas transfers amongst EU fleets[8]. This mechanism may facilitate exchange of quotas in mix fisheries. This, for example, may help solving the problem of quota exhaustion of a given species, which is a fact that may either stop the fishing activity or induce discards. The improvement of selectivity, as discussed before, seems to counteract the discard problem. On the contrary, if the selectivity problem is not (or poorly) addressed all fish have to be landed. This may cause many difficulties to sort out the catch and to storage it. Low prices of undersize fish may not worth the costs associated to landing all catches. This may motivate fishermen to keep discarding.

Problems on landing site

Most of the by-catch is made up of juveniles which is fish that have very low or no market value. Moreover, the catch has to be sorted out and other unmarketable fish separated from the catch. Exploration of new markets for these fish or new products will be required. In general, the costs of bringing all catches ashore will mean an increase of the costs of handling, storage and refrigeration, and transportation. Fishmeal and oil production is an alternative to finfish by-catch because fishmeal is basically made up of finfish. But, as pointed out before in this report, fishmeal production requires handling and storing and in

[8] It is worth recalling that quota swaps among Member States are being used, and will continue being used. However, direct quota swaps among fishing fleets is not possible in the framework of the CFP.

some cases may require investing in expensive facilitates to store large amounts of raw material before processing.

Management approach

The obligation to improve selectivity trough a mandatory increase of mesh sizes and square panels will require strict control. The obligation to land all by-catch will require a comprehensive observer program or any other mechanism that ensures performance of rules (e.g. CCTV systems.). If these measures are combined with spatial management it will also require a VMS system.

POs can facilitate the implementation of the discard ban. These institutions facilitate quota exchange amongst their associates and can propose management measures on behalf of them. Moreover, they can speed up the process of changing gear configurations. These institutions are found out in France, Spain and UK.

Improvement of selectivity implies a cost for the fishermen. This cost has to be quantified and incentives (or reimbursement) should be provided to compensate for these extra expenses.

In spite the basic selectivity improvement (i.e. increased mesh size) could be implemented in relative short time the implementation process may take a long time since it needs the agreement of fishermen.

2.1.2. NEPHROPS FISHERIES IN THE CELTIC SEA

Fleets affected

There is a substantial discard rate in the nephrops fishery in the Celtic sea, around 50% (MRAG, 2011,). This is basically made of finfish (cod, hake, whiting, haddock) and small nephrops discarded due to high grading (ICES, 2012b). According to Article 15 of the new CFP text the discard ban shall be accomplished by January 2016.

From the technical point of view, accomplishment may be possible due to the variety of technical solutions currently available. Due to the characteristics of nephrops trawling the problem of discarding of finfish by-catch could be diminished by modifying the fishing net in various ways. Utilizing FEDs, for example, is feasible since there are grids developed for that purpose (Seafish, 2011). The same applies for inclined separated panels. The prompt and wide implementation of FEDs utilization may depend on the availability of such devices. Previous studies have shown that the use of grids in nephrops trawls diminish the unwanted finfish catches. A thorough review of previous experiences will be required to select the FED with the better performance. FEDs will require gear modification, trials, and scientific evaluation. Changes in fishing gear configuration and mesh sizes and shapes can also be explored. Square mesh panels and coverless nets have also been tested. Changes of mesh sizes may take less time than installation of FEDs or changes in gear configuration. But its efficiency will need to be compared in relation to other solutions. According to ICES (2012c) small nephrops is also discarded in the nephrops fishery. This problem requires fishing gear that, while allowing escapement of by-catch of fish, will also allow escapement of small nephrops. On the other hand it is worth to say that there are some experiments carried out on nephrops survival after discarding with promising survival rates (Mehault et al., 2011).

In spite selectivity improvement appears as the primary solution for finfish by-catch, total efficiency of these technical solutions is hard to obtain; thus the landing obligation will apply if catches do not match the de minimis exemption. In spite of this, species such as cod, hake and even whitting can be marketed. This fact may reduce the incentive for the fishermen to discard. However, landings of these fish will be counted against quotas. Currently, lack of quota for cod, for example, is reported as a reason for discarding of by-catch cod in nephrops trawl.

In the absence of an accurate plan to improve selectivity the landing obligation will imply carrying and landing otherwise discarded fish. Store capacity and handling on board effort will arise as a problem in such scenario. In spite of this most of the by-catch is made of marketable fish so there shall not be an incentive of discarding low value fish but to high-grade among the marketable catch.

Problems at sea

Currently, lack of quota for cod, for example, is reported as a reason for discarding of by-catch cod in nephrops trawl. To counteract this and other causes of discarding the obligation to install FEDs in the nets or changes in the configuration of the fishing nets will be required. Provision of incentives to compensate fishermen for the extra costs of grids and gear modifications shall be considered.

Selectivity improvement may mean less fish to land. Hence, handling and storage on board shall not arise as a meaningful problem for fishermen.

Problems on landing site

Most of by-catch fish in this fishery has a market value. Commercialization of undersized fish (below MLS and lower market value) may arise as a problem.

Undersize fish may not find out a place in the market, hence alternative solutions to use it as raw material for industrial uses should be explored.

Management approach

The success of the landing obligation in this fishery may require the mandatory change in the selectivity patterns by the use of the above mentioned technical solutions. Deployment of incentives to compensate the fishermen for the extra costs will be required. The enforcement of the landing obligation will require control but is expected that most of fish will be landed because it has a market value. In any case, the quota mechanisms devised to record landings of otherwise discarded fish will require effective controls to discourage underreporting.

Institutional structures such as POs would help in speeding up the technical improvements of the gear of their associates. In fact, the nephrops fleets are based on countries where POs play a key institutional role: France, Netherlands and UK. The role of POs is especially relevant as they represent fishermen. They will play a key role in decision-making in an eventual co-management scenario. It is worth pointing out that the mandatory change in net configuration and subsequent selectivity may face resistance from the side of the fishing industry since some marketable specimens will escape.

Improvement of selectivity implies a cost for the fishermen. This cost has to be quantified and incentives (or reimbursement) should be provided to compensate for these extra expenses.

In spite the basic selectivity improvement (e.g. mesh size) could be implemented in relative short time the implementation process may take a long time since it needs the agreement of fishermen. More sophisticated tools (e.g. selectivity panels) will require a longer time for development and achievement of consensus.

2.2. MSY APPLICATION

Effort or technological limitations of mixed fisheries MSY

Demersal fisheries in the Celtic Sea can be characterized as being biologically and technically diverse with discarding of juveniles and over quota of many demersal species. Under the current management approach with single species TAC's, the TAC's of other species are exceeded in trying to maximize the TAC of one species. This TAC's are set without any technical consideration, and tactical and technical adaptations should be considered to get single-stock MSY level and maximize potential yield simultaneously. Also, a change in the exploitation pattern should be included in the context of setting fishing opportunities (Gepeto, 2013).

Based on the information provided in the NWWRAC May 2013 meeting (NWWRAC, 2013) in the Celtic Sea ICES are looking at mixed fisheries advice using Fcube matrix methodology (Ulrich et al., 2008, 2009). Fcube matrix approach highlights conflicts within single species advice and it is a broader multi-species MSY approach assessing how to manage stocks together. There is not yet any published report in relation to this topic.

Depending on the target species and market values, it is supposed that fishermen change the target species going to a different fishing ground or changing the mesh size. They keep fishing since the latest quota is reached and no overpassing the limited days that they can be at sea.

Multispecies considerations of MSY

The following considerations should be taken into account in developing ecosystem based advice for Celtic Sea fisheries (ICES, 2007):

- ✓ Fishing has impacted a number of commercial species, with some commercial species such as Cod, Plaice and Herring now severely depleted.
- ✓ A reduction in the abundance of large piscivorous fishes such as cod and hake, and an increase in smaller pelagic species and nephrops, which feed at a lower trophic level has resulted in a marked decline in mean trophic level of the fish community over time.
- ✓ There has been a change in the size structure of the fish community over time with an increase in smaller fish and a reduction in larger fish. Temporal analyses of the effects of fishing and climate variation suggest that fishing has had a stronger effect on size-structure than changes in temperature. The inshore areas of the Celtic Sea contain some important spawning grounds for herring. Aggregate extraction and dumping of dredge spoil are likely to have negative effects on herring recruitment due to perturbation of the spawning beds and an increase in turbidity.

As said before, in the Celtic Sea some trials are being done where the most important target species are considered. Also a long term management plan is being analyzed and the alignment of this LTMP to "landing obligation", MSY and regionalization is followed. Despite, no trophic relationship has been considered for assessment and there is not yet an MMSY approach in the Celtic Sea.

In the Celtic Sea mixed demersal fisheries many stocks are target species: whiting, cod, haddock, Norway lobster, etc. Based on the results showed in the report (Gepeto, 2013) those are the species that are exploited under MSY levels: cod, whiting, sole and herring. Some other target species like anglerfish, megrim or nephrops do not have the MSY threshold defined.

3. DEMERSAL MULTISPECIES AND MIXED FISHERIES IN THE IBERIAN WATERS

KEY FINDINGS

- The Iberian stocks are managed by applying single-species management measures. This is recognized as one of the main causes of discarding because individual management objectives are not consistent with each other.
- Otter and Pair trawls targeting hake, horse mackerel, monkfish and megrim are reported to have discards. Discards reach 30-60% in weight of the total catch.
- Selectivity devices would reduce discard, yet these would also reduce the catch of accessory marketable species. Despites this, there is margin of improvement in gear selectivity.
- Store capacity and handling on board effort (time) could be a limiting issue for some specific vessels.
- Iberian fisheries benefits are expected to decrease in the short term and consequently, industry commitment with landing obligation implementation would be low.
- There are possibilities of creating new markets for new species. However, managers should be able to regulate the probable competency to be generated between fleets for the market.
- Significant inconsistencies in TAC of different species being caught by the same fleets are identified in the Iberian waters. In the mixed fisheries context, the conclusion is that all MSY targets cannot be achieved simultaneously
- Multispecies/ecosystem considerations have not being taken into account when estimating MSY values.
- Mostly all the Iberian waters industrial fisheries will be affected be landing obligation by 2016. There is no estimation of the exact number of vessels but it is believed that new obligation will highly impact on Iberian waters fisheries activity.

3.1. LANDING OBLIGATION

Fleets affected

Main fleets producing discards are:

- ✓ Otter bottom trawl targeting demersal fish using a minimum mesh size of 55 mm.
- ✓ Pair bottom trawl targeting demersal fish (blue whiting, hake) using a minimum mesh size of 55 mm.
- ✓ Otter bottom trawl targeting crustacean species using a minimum mesh size of 55 mm.

Finfish bottom trawls targeting hake, horse mackerel, monkfish and megrim in the Iberian Peninsula are reported to have discards. In the **hake fishery, high-grading** is particularly high at the beginning of the fishing season due to **individual vessel quota allocation** and can reach **90% of catch**. For the rest of the target species, main discard reason is the undersize individuals followed by discards of some non-commercial by-catch. There is a particular case, blue whiting, in which reasons for discarding are both market value and fish condition as this species gets easily damage by the fishing gear; hence it is discarded in large quantities. In general, for all species together, discards rates reach around 30-60% in weight of the total catch.

According to Article 15 from the CFP the landing obligation shall be achieved by accomplished by January 2015 for fisheries targeting pelagic species while for fisheries targeting demersal species should be implemented by 2016. Thus, in 2016, fisheries targeting cod, hake, sole and other demersal species will be affected by the ban.

Problems at sea

First approach is to analyze any feasible improvement of the selectivity of the fleets. Most of selectivity experiences in the area have been focused on the hake species. In 2011, STECF deployed selectivity modeling experiences (Campos and Fonseca, 2003 in STECF, 2011) with 3 different mesh sizes for evaluating the impact on Southern hake stock status. Results show that the change in mesh from the actual 55 mm to square 65 mm mesh would result on a strong reduction in discards.

Improvement on the selectivity on smaller sizes (lower ages) would positively impact on reduction of biomass to be landed. However, most of those trawlers, target hake together with pelagic species (such as mackerel, horse mackerel, blue whiting) which limits the possibility of mesh increase in trawls.

Metiers targeting finfish, which also target crustaceans, are unlikely to adopt selectivity measures due to the expected reduction of this commercial by-catch. This would lead to an important loss of marketable catch, and hence, unlikely to be implemented. Just métiers targeting finfish assemblages would welcome selectivity measures as they also work towards improving the overall fish condition increasing the quality of the catch.

Area closures are another management measure to be analyzed. In case of southern hake, there is a need of determine if hake juveniles are aggregated and the amount of overlapping of hake juvenile's concentrated areas and other trawl target species distribution (STECF, 2011). There is a general concern about the impact on the small fish fishing mortality when extending closures as these ones would not be effective if the fishing effort transferred to other areas.

Temporal closures are already in practice in Iberian waters. However, results are questionable (MRAC & IEEPA, 2007). These closures lead fleets to overexploit certain areas upon its reopening to the fishery. Long term closures of nursery areas would be a possible solution.

Other problem at sea is how to manage the extra biomass taken on board. A first step is to know the mean kilograms by trip of commercial species under landing obligation to be handle and stored on board.

Table 6: Mean extra kilos (coming from previously discarded species) in trawling metiers operating in the Iberian waters by trip.

Metier	Species groups	kg/to be landed by trip
Otter trawl Demersal and Pelagic species	Pelagics	372.6
	Demersal & others	142.8
	Total in metier	**515.4**
Otter trawl Horse mackerel	Pelagics	360.5
	Demersal & others	78.0
	Total in metier	**438.5**
Otter trawl Mackerel	Pelagics	329.9
	Demersal & others	19.1
	Total in metier	**349.0**
Pair trawl Blue whiting	Pelagics	663.2
	Demersal & others	173.0
	Total in metier	**836.2**

Source: SWWRAC presentation, AMDES report (2004-2008).

In a second step it will be necessary to know the handling and storing capacity of the fleet. Expert mix fisheries scientist working on Iberian waters fleets (J. Castro, pers. comm), provided the number of trawlers for Spain and Portugal in each of the length sections. These ones are supposed to be affected by landing regulation. Data is for the most recent period 2010-2012.

Table 7: Number of vessels by vessel length segment in the Iberian waters.

Fleet segment	00-10 m	12-18m	18-24m	24-40m	TOTAL
Nº vessels	0	65	106	140	**311**

Source: Dr. Jose Castro, *pers. comments* from ICES 2013d.

Considering the amount of fish to be retained on board and the length of the vessels which can be related to the storing capacity, it seems that the largest trawlers operating in Iberian waters could be able to handle and store this extra catch. However, this exercise should be done for each of the fleets segments as it is know that the smaller vessels will have problems managing the additional biomass taken on board. Also, the storage should be carried out by species, separately, in big bins or plastic bags. Besides the volume of catches, the time and the way that the storage has to be carried out appear to be more limiting for some vessels than others. This aspect could largely prolong the average time needed for the maneuver of the haul.

Taking this fact to the extreme situation, it would make vessels return to port earlier due to lack of room in the cold store and it could be expected that the number of hauls by fishing trips will be reduced resulting in a lower benefit for fishermen. This will mean an important change in the activity as the work load will increase while wages could be decreased.

The introducing classification machines on board to help fishermen in this task while packing this species could be also automatized by diverting species previously discarded into bins/bags for their storage. The introduction of these new devices is an added cost to the activity and should be assessed on métier basis.

Problems on landing site

Up to now, the only improvement detected by the industry in relation to mitigating the volume of discards has been the opening of new market opportunities for species previously not traded (MARAC & IEEP, 2007). This has occurred for Blue whiting (*Micromesistus poutassou*), Blackmouth (*Galeus melastomus*), Small-spotted catshark (*Scyliorhinus canicula*), Red gurnard (*Aspitrigla cuculus*), Bluefish (*Pomatomus saltatrix*), Black scabbardfish (*Aphanopus carbo*) and Bluemouth rockfish (*Helicolenus dactylopterus*) in Portuguese markets.

On the other hand, under landing obligation, new catches brought to port, containing species and sizes that previously were discarded, could generate competency between fleets for the market. It is expected that the final markets and its marketing via should by regulated for preventing the creation of new incentives from targeting "previously discarded species and sizes" which, at the same time could affect the marine ecosystem.

Management problems

The Iberian stocks are managed by applying of single-species management measures. This is recognized as one of the main causes of discarding in these mixed fisheries, because individual management objectives may not be consistent with each other. It appears that the current quota system (quota established per vessel) in this fisheries could have worsening the discards problem as this system incentivizes each vessel to high-grade its catch for the purpose of not meeting the quota with low value fish.

In general, monitoring, control and surveillance are basic steps for any plan to success. This is a pre-requirement for the introduction of the landing obligation. Thus, before implementing landing obligation regulations it is important ensure that logbook information, regarding the location and the amount of the catches, are more accurate. A surveillance program is needed to identify the areas where discarding occurs as well as which are the main discarded species.

For the landing obligation to success, it is believed that the only measure that would compensate for a landing obligation would be the implementation of financial incentives that would cover all additional operational costs resulting from catching, handling storing and landing low-value or non-commercial species. Also, measures such as more quota adjusted to the reality of métiers could act as positive incentives.

3.2. MSY APPLICATION

Effort or technological limitations of mixed fisheries MSY

In 2013, ICES deployed an analysis of the technical interaction between the fleets and some of the most important stocks caught in the mix-multispecies fleets deployed in the Iberian waters (ICES, 2013c). The stocks considered were southern Hake, Horse mackerel, both Megrim species and White Anglerfish. The first quota to be exhausted is the hake quota, and the latest quota to be exhausted is the horse mackerel one. Results show low consistency between the single-stock forecasts and the actual effort especially between hake and white angelfish stocks. The actual Hake quota is taken with the minimum effort deployed, which mean that hake is the limiting specie and losses of catch opportunities appear for the rest of the stocks. On the other hand when the highest quota is to be caught, the catch of hake is overpassed by more than 100% of the quota. It is supposed that fishermen keep fishing until the latest quota is reached and no overpassing the limited days at sea. Thus, it is expected that all hake caught after the minimum effort level deployed is discarded. Consequently, MSY targets are not achievable for all species simultaneously.

Multispecies considerations of MSY

Multispecies/ecosystem considerations have not being taken into account when estimating MSY values of commercial species in Iberian waters. No main trophic interactions for the stocks are taken into account. None of the stocks considered in this Case Study are at MSY. Just horse mackerel is believed to be under F below MSY.

In general, since hake is one of the main predators on these ecosystems, feeding mainly upon pelagic fish but also upon some other demersal species (Mahe et al., 2007; Velasco, 2007; Preciado et al., 2008; López-López et al., 2012), it is easily understandable that the higher the hake fishing pressure is, the better stock condition would be for its prey species. On the other hand, if selectivity is improved for hake, and maybe some closures are deployed for protecting juveniles, the unwanted by-catch and consequently, discards would be reduced. This is more alive fish will be placed in the ecosystem (STECF, 2011) consequently as these species are top predators in the ecosystem, the mortality of their prey could be expected to increase.

On the other hand, hake is also a target prey. Hake plays an important role as preferred prey species for common dolphins, stripped dolphins, harbour porpoises and bottlenose dolphins (Santos et al., 2013). It has been estimated that, for example, for the southern hake stock, estimated average removal by cetaceans often exceeds hake natural mortality (Santos et al., In press).

At the same time, Hake is a cannibal species and predation could represent an important part of the diet of adult individuals (Mahe et al., 2007). Hake in this case could be somehow compared to cod in the North Sea: both are important predators with a similar trophic level in their systems. In this last case, it has been shown that keeping the fishing mortality a bit higher than the one established in the single-species approach, would help to avoid cannibalism problems, and hence, it would also help to avoid too much loss in yield caused by it (ICES, 2011, 2013a).

Further research would be needed in this field in order to better understand the foodweb dynamics and be able to provide a more appropriate advice.

4. TRAWL DEMERSAL MULTISPECIES FISHERIES IN THE MEDITERRANEAN SEA

KEY FINDINGS

- Mediterranean demersal fisheries are not regulated through quotas but through restrictions on the number and horsepower of vessels, gears, size of landed fish and time of activity.
- The overall state of Mediterranean demersal resources is "overexploited" according the most recent stock assessments.
- The main causes of discarding in Mediterranean fisheries are the lack of commercial interest of a significant fraction of catches, and price control in high landing periods (recruitment season).
- Almost 100% of the trawl demersal fleets in the Mediterranean Sea will be affected by the landing obligation.
- Restrictions on the size of fish to be landed exist but are poorly enforced.
- Overall fishing effort reductions accompanied with selectivity measures towards increasing the size of landed fish would improve the performance of these fisheries.

4.1. LANDING OBLIGATION

Fleets affected

Mediterranean fisheries account for 22% of the tonnage of the European Community fleet, 34% of its engine power and 46% of the total fleet. Over 80% of the fleet comprises vessels under 12 meters in length. Landings account for only 12% of the Community total but their market value is high.

Target species are mainly hake, red mullets, nephrops, shrimps, whiting, anchovies, sardines, bluefin tuna and swordfish. The demersal trawling targets mostly young fish of many overexploited stocks, while longliners mostly target adults. Some fisheries are essentially based on targeted catches of juveniles of some species. Landings have increased by 50% during the last 25 years. Catch rates per vessel are still low compared with other EU regions although the market value of catches is generally high. Main fishing gears involved are bottom otter trawls, purse seines, and other coastal gears such as gillnets, trammel nets, longlines, hand-lines with hooks, traps and pots.

Mediterranean multi-species bottom trawl fisheries target a wide range of demersal species with a high discarded fraction. Approximately 34-46% (De Juan, 2007) of catches are discarded because they don't have any commercial interest, an undetermined fraction are discarded in order to increase their market value and another fraction is discarded because it does not reach the legal size for commercialization.

Problems at sea

There is no quota limitation in Mediterranean fisheries. The causes of the discards in Mediterranean fisheries are commercial interest and theoretically size restrictions. However, in reality fish is discarded because it has no commercial value or in recruitment seasons to buffer price drops of too many landings.

Changing fishing tactics is important in the sense of avoiding recruitment seasons and grounds, but the solution as commented above should go in terms of the selectivity of the gears and the enforcement of it.

Problems on landing site

A fraction of undersized fish is probably unavoidable, especially for bottom-trawl fleets. With current marketing conditions and with no enforcement of the size restrictions, fishermen will discard small fish to keep their price at profitable levels. Any commercialization of this fish would only be acceptable if it represents a small fraction of total catch. A bulk of the discards is composed by species that are not commercialized for human consumption but their alternative use has seldom been explored.

One of the problems encountered in the Mediterranean is the large number of landing sites, in comparison with some other EU areas which prevents from an efficient enforcement in port.

Management problems

Changes in selectivity will be necessary to restore fish stocks in the Mediterranean but additional fishing mortality reductions are recommended for the bottom trawl fleets. In the recent years, the fishing effort reduction due to the reduction of the number of fishing units in the Mediterranean has been compensated with investments in larger, more powerful vessels which have buffered the fishing mortality reductions sought by vessels dismissal plans from European fishing funds.

Therefore, the reductions of by-catch will be conditioned to the reduction of the size and fishing power of fleets, increase of mesh size and enforcement of fish size limits. Effort reduction and selectivity change will reduce the catch of non-commercial species and of undersized fish. The enforcement of fish size limit will encourage fishermen to accept selectivity changes that will, following predictions (Merino, 2007a,b), contribute to stocks recovery and catch of larger and more valued individuals. Closures at recruitment season could also be contemplated.

Currently, the restrictions on the size of fish are poorly enforced in the Mediterranean and efforts to achieve larger landing sizes could represent a first step to reduce by-catch.

4.2. MSY APPLICATION

Two types of interactions should be considered in fisheries management as a first step to incorporate knowledge about the interactions between the various fish populations, for which advice is given (ICES, 2013c). One type of interaction results from the non-selective nature of many fishing operation (technical interactions–mixed fisheries) whereas the other one results from the inter and intra–specific relationships of the species (also called multispecific) biological interactions between species.

Effort or technological limitations of mixed fisheries MSY

85% of the stocks assessed by the Scientific, Technical and Economic Committee for Fisheries (STECF, 2013b) are overexploited. In particular, all (100% of 18 stocks) assessed are overexploited. Many studies (Colloca, 2011) recommend a generalized reduction of fishing effort for Mediterranean fleets, in particular for bottom trawl fleets. Hake is the species that has been assessed in the poorest state of exploitation, but red mullet and other demersal fish are overexploited too. All demersal species would benefit from a drastic reduction of fishing effort but seeking for an overall multispecies MSY would still maintain hake overexploited (Merino, submitted). Due to the high number of species captured with bottom trawl gears, achieving MSY for all stocks seems unrealistic. However, effort reductions should be accompanied with technical measures to increase the size of first capture and this would increase the productivity of Mediterranean demersal fisheries.

Multispecies considerations of MSY

The 18 demersal stocks assessed in the Mediterranean (100%) by the STECF are overexploited. However, many studies indicated that some stocks not necessarily assessed by the STECF are nearby MSY levels (Quetglas, 2012, 2013).

Emblematic species such as hake have remained overexploited since long time but haven't collapsed. The reason for this is that small cod-ends have incidentally provided some protection for older individuals that have migrated to deeper waters and allowed for a sustained recruitment despite the conditions of high fishing mortality on the immature age groups (Caddy, 1983).

There are very few studies with ecosystem models that have investigated this (Coll, 2010) and they have recommended overall reductions of fishing mortality. However, it is likely that any change on some species fishing mortality will have an impact on their prey and predators.

ANNEX III: DETAILED ROAD MAP FOR LANDING OBLIGATION AND MSY APPROACH

DESIGN OF THE ROADMAP FOR LANDING OBLIGATION

- What is the context of the Case Study in relation with article 15 of the CFP? (*Definition of the timing of each each fishery for landing obligation and species concerned).*

- Is feasible the accomplishment of the landing obligation in the specified time for this Case Study?

(*Identify gears/métiers where it is possible & where it is not).*

- Where accomplishment is not possible in spite of caveats or exemptions defined by CFP (de *minimis*, high survival rate discard) have been applied:
    - Identify the main reasons for that: *Quota exhaustion, Vessel store capacity and handling efficiency, etc.*

- **Sea approach**

A) When quota exhaustion is the reason that makes impossible the accomplishment of landing obligation: *(It is supposed that if all the quota of any of the species is finished the vessel should stop activity).*

1. Is the improvement of selectivity the solution?
    If YES (end of the problem)
    If NO (Looking for solutions)
2. Is the change of fishing tactics the solution?
    If YES (end of the problem)
    If NO (Looking for solutions)

B) When handling and storage is the reason that makes it impossible the accomplishment of landing obligation: (*Work load and limitation of space on board increase costs and reduces catches, so there is a reduction in profitability*).

1. Is the improvement of selectivity the solution?
    - If YES (end of the problem)
    - If NO (Looking for solutions)
2. Is the change of fishing tactics the solution?
    - If YES (end of the problem)
    - If NO (Looking for solutions)

- **Landing approach (Once catch arrives to port)**
    - Human consumption: *Find a "differentiated" market for new landed species without affecting negatively the actual market (sub-products, transformations, etc)*
    - No-human consumption: *Find market for other marine products (pharmacy, fish meal, cosmetics, etc)*

- **Management approach**
    - Control: measurement and monitoring of the actual compliance with other regulations, gives an idea of the actual commitment level. If this compliance could be low, there are two alternatives:
        - ✓ Incentives: for the industry to accomplish landing obligation.
        - ✓ Control: Enforcement effort:
            -Fully documented fisheries: Observers; Technological methods CCTV
            -Lower documented fisheries: Coast guards; Control at landing port
    - Cost of implementation of measures to adapt to landing obligation
    - Time needed for implementation of landing obligation

APPLICATION OF MSY

- **Technological aspects of mixed-fisheries MSY:**
  - Is the effort variation needed to achieved stock specific MSY very different among stocks? Is it feasible to achieve all MSY targets simultaneously? (*Meaning: In relation to the technical possibilities or limitations to reach the MSY target for all species*).
  - What does the fleet do once the more restrictive TAC or effort quota is reached? (*Meaning: how the fleet dynamics changes: fleets stop or keeps fishing to reach the next TAC?).*
  - If the fleet continues fishing, what happens with the catches of the stocks once each TAC quota is reached? (*Meaning: discards, unreported landings).*
- **Multispecies aspects of MSY:**
  - Are MSY limits correctly established? Have multispecies/ecosystem considerations been taking into account when estimating values? (*Meaning: If multispecies/ecosystem considerations are taken into account we consider them multispecies MSY (MMSY). If not, we consider having single stock MSY approach (most of the cases).*
  - If there is MMSY:
    - Are main trophic relationships considered? (*Meaning: review whether just target commercial species of the fisheries are taken into account or a broader number of species are considered to avoid larger impact on the ecosystem).*
    - How environmental variations are or are not affecting the targets established? (*Meaning: in the Northern Pacific, raising sea water temperatures have led to an important increase of capelin being this, an important prey for seagulls. The abundance of preys for sea birds has led to an increase of birds productivity in the area. Are there examples of environmental variables affecting European marine ecosystems key species abundances?*).
  - If there is not MMSY:
    - Is MSY reached for any species in the fishery? *(Meaning: are the MSY target respected for any of the commercial species?).*
    - Is there high probability of collapsing the stock for which the MSY limit has been defined? (*Meaning: in the case that MSY target are not respected)*
  - Is there any species in the ecosystem that will be affected directly by not reaching the targets? If so, how would they be affected? (*Meaning: when fishing rate is changed how this could impact on other species and vice versa?).*
  - Would there be any population density problem? I.e. niche-habitat problems (*Meaning: could this impact on ecosystem niches, change of body condition of some species, etc).*
  - Would there be any equilibrium problems in the ecosystem? Changes in top-down, wast-waisp or bottom-up controls? Would there be any trophic cascade effect? *(Meaning: the "equilibrium" of an already under pressure system, could be changed when fishing pressure on a predator is released).*

ANNEX IV: LANDING OBLIGATION TIME-FRAMES

Based on Article 15 of Regulation **(EU) No 1380/2013** the following time-frames are defined for the implementation of the landing obligation:

(a) From **1 January 2015** at the latest:

- small pelagic fisheries (i.e. fisheries for mackerel, herring, horse mackerel, blue whiting, boarfish, anchovy, argentine, sardine, sprat);
- large pelagic fisheries (i.e. fisheries for bluefin tuna, swordfish, albacore tuna, bigeye tuna, blue and white marlin);
- fisheries for industrial purposes (inter alia, fisheries for capelin, sandeel and Norwegian pout);
- fisheries for salmon in the Baltic Sea

(b) From **1 January 2016** at the latest for the species which define the fisheries and from 1 January 2019 at the latest for all other species in:

(i)the North Sea
- fisheries for cod, haddock, whiting, saithe;
- fisheries for Norway lobster;
- fisheries for common sole and plaice;
- fisheries for hake;
- fisheries for Northern prawn;

(ii) North Western waters
- fisheries for cod, haddock, whiting, saithe;
- fisheries for Norway lobster;
- fisheries for common sole and plaice;
- fisheries for hake;

(iii)South Western waters
- fisheries for Norway lobster;
- fisheries for common sole and plaice;
- fisheries for hake;

(iv) other fisheries for species subject to catch limits.

(c) From **1 January 2017** at the latest for species which define the fisheries and from 1 January 2019 at the latest for all other species in fisheries not covered by point (a) in the Mediterranean, in the Black Sea and in all other Union waters and in non-Union waters not subject to third countries' sovereignty or jurisdiction.

Table 8. Landing obligation time-frames applied to case studies.

Case studies	Landing obligation time-frame		
	1 January 2015	**1 January 2016**	**1 January 2017**
Cod mixed fisheries in the North Sea			
• Otter trawl:			
✓ a directed roundfish fishery by UK, Danish and German vessels.		✓	
✓ French whiting trawl fishery and UK Nephrops fishery		✓	
✓ a Danish and Swedish mixed demersal fishery.		✓	
• Beam trawl, a directed Dutch and Belgian flatfish fishery.		✓	
• Gillnets, a targeted cod and plaice fishery.		✓	
Demersal multispecies and mixed fisheries in the Iberian Waters			
• Otter bottom trawl targeting demersal fish using mesh size >=55 mm		✓	
• Pair bottom trawl targeting demersal fish (blue whiting, hake) using a minimum mesh size of 55		✓	
• Otter bottom trawl targeting crustacean species mesh size >=55 mm		✓	
• Set gillnet targeting demersal fish using mesh size of 60-79 mm		✓	
• Set gillnet targeting demersal fish using mesh size of 80-99 mm		✓	
• Set gillnet targeting demersal fish using mesh size >=100 mm		✓	
• Set longline targeting demersal fish		✓	
• Set trammel net targeting demersal fish using mesh size of 80-99 mm		✓	
• Set trammel net targeting demersal fish using mesh size >=100 mm		✓	
• Mixed: Using more than one type of gear		✓	

Table 8(cont). Landing obligation time-frames applied to case studies.

	Landing obligation time-frame		
Case studies	**1 January 2015**	**1 January 2016**	**1 January 2017**
Mixed demersal fisheries in the Celtic Sea			
• Long-line in medium to deep-water		✓	
• Long-line in shallow water		✓	
• Gill nets		✓	
• Non-nephrops trawling in medium to deep water		✓	
• Non-nephrops trawling in shallow water		✓	
• Beam trawling in shallow waters		✓	
• Nephrops trawling in medium to deep water		✓	
Trawl demersal multispecies fisheries in the Mediterranean Sea			
• Polyvalent small-scale vessels without engine.			✓
• Polyvalent small-scale vessels with engine less than 6 m.			✓
• Polyvalent small-scale vessels with engine between 6 and 12 m.			✓
• Polyvalent vessel longer than 12 m.			✓
• Trawlers less than 12 m.			✓
• Trawlers between 12 and 24 m.			✓
• Trawlers longer than 24 m			✓
• Purse Seiners between 6 and 12 m. • Purse Seiners longer than 12 m.	✓		
• Long liners longer than 6 m.			✓
• Pelagic Trawlers longer than 6 m.	✓		
• Tuna Seiners.	✓		
• Dredgers longer than 6 m.			

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ISBN 978-92-823-5602-9
doi: 10.2861/59233

Publications Office