Costs of Illegal, Unreported and Unregulated (IUU) Fishing in EU Fisheries

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Executive summary

Illegal, Unreported and Unregulated (IUU) fishing is a serious threat to fisheries sustainability in EU fisheries, and worldwide. The European Council recently adopted a regulation to prevent, deter and eliminate IUU fishing[1] and the European Commission proposes a reform to the EU's Control and Enforcement regime. Inevitably, a number of measures to combat IUU fishing will have costs. It is important, therefore, to recognise the main costs that are caused by IUU activity today and which will affect the future of European fish stocks and fishing industries. This report makes a preliminary investigation into the level of the economic, social and environmental costs of IUU fishing at the wide scale of EU fisheries and Member States.

After a general introduction to the threat, in Chapter 2 we describe the existing evidence and knowledge about IUU activity, its drivers, levels and costs. IUU fishing is reasonably well understood on a theoretical level but hard data are generally lacking. However, in some specific cases – notably for cod and tuna stocks – good estimates of IUU fishing rates exist. More generally, it is possible to infer that IUU activity is a widespread phenomenon. Indeed, IUU fishing levels of 30–40% of total catch, and sometimes more, appear to be commonplace.

Chapter 2 also assesses the stocks most likely to be at risk of incurring high costs resulting from IUU fishing. This cost breaks down into three separate considerations:

1. The total economic value of the stock: the highest costs can be expected in the most important fisheries overall;
2. The value per tonne of the stock, and the tightness of its control regime: these determine the incentives for fishers to engage in IUU activities;
3. The ecological vulnerability of the stock to overexploitation: this determines the risk of serious stock failures or extinctions from IUU activities.

These assessments led us to derive a short-list (see section 2.5) of commercial groups and key stocks for the modelling phase of the research.

Chapter 3 describes what we know about the different types of cost of IUU fishing and how these might be assessed. Several different costs can be identified (see Table 5), though some are much more significant than others. We have identified what we consider to be the main costs and the best approaches to modelling them at the European scale (see section 3.5).

In order to make some broad-scale estimations, in Chapter 4 we explain a modelling and simulation approach in which we first used stock and landings data to model stock growth rates, then transferred the estimated parameters to models of whole commercial groups of fish at the scale of Large Marine Ecosystems (LMEs). Five of these – the Baltic Sea, North Sea, Celtic-Biscay Shelf, Iberian Coastal and Mediterranean Sea – are responsible for the large majority of EU fishing value and are primarily fished by EU Member States. Various data constraints made it impossible to model all the different groups in each region, but we derived simulation models for 14 of the most important groups, representing 46% of EU fisheries value.

Chapter 4 also briefly explores the different options for modelling stock growth rates and for simulating fisheries, explaining our decision to focus on single-species surplus-production models, estimated for individual stocks, then used as representing commercial groups within each LME. The results of the single-species models for estimating growth rates are then presented and discussed. Although data are generally inadequate for estimating models with precision, we derived appropriate models allowing us to represent some key commercial groups: perch-likes, cod-likes, herring-likes and flatfishes. We were

[1] Council Regulation 12083/08.

not able to develop a model for crustaceans. For tuna and billfishes, data were not available for estimating a model, but we were able to rely on some limited published estimates of stock growth rates.

Using the stock growth rates estimated in these models, we developed a method for simulating the impacts of IUU activities in fisheries. In Chapter 5, we describe this model and present two detailed worked examples of applying the simulation method to two key case studies – cod from the Baltic LME, and tuna and billfishes from the Mediterranean LME.

The results of the simulations show that IUU fishing can have very substantial costs and also that this is dependent on the underlying management structure. Where a fisheries management rule is ill-adapted to the fishery, IUU fishing costs appear minor – simply making an already bad situation worse. Conversely, the highest costs of IUU activity arise when it prevents good management measures from renewing or safeguarding a fishery. This means that it is not possible to estimate the costs of IUU fishing independently from a real or assumed management structure or catch-setting rule.

We examine a number of such possible rules and present results from simulations. In the light of this, we argue for a particular rule as a conservative background against which to gauge the costs of IUU fishing. The rule is conservative in that it sets zero legal catches when the stock falls below a low precautionary limit, and restricts changes in legal catches to +/-25% per year. It is a reasonable shorthand representation of the current regime of setting catch limits. Using this rule to modify target catches, we simulated the costs of different levels of IUU fishing for the 14 commercial groups in the five LMEs. Across the simulations, we reached the following cost estimates:

- A total cost to EU Member States of lost catches from 2008 to 2020 of €10.7 billion – this is an average cost in lost catches of €825 million per year which equates to about 15% of total fishery value and more than 30% of the value of the fisheries considered.
- Over 27,800 lost job opportunities in fishing and processing industries: around 13% of total fisheries employment.
- Significant stock depletion across most of the fisheries assessed: the models suggest that IUU fishing is preventing stock recovery and keeping fisheries locked in low-value states. It is difficult to put a number on this, but valuing lost stocks at the same value per tonne as landings suggests a total cost of almost €9 billion.

These costs, though substantial, do not represent the full costs of IUU activity for several reasons:

- We have not modelled all stocks;
- We have modelled only three of the main costs;
- We have interpreted stock models, parameters, data and estimates of IUU fishing levels conservatively; and
- We looked at a short-time horizon (2020).

Therefore, we conclude that the cost figures presented here can fairly be interpreted as a lower bound on the possible costs of IUU activity in EU fisheries. The true costs may be substantially higher, and strong action to combat IUU fishing is very likely to be warranted.

1. Introduction

Marine fishing and associated processing and commerce are important industries for a number of coastal communities in the European Union (EU). Illegal, Unreported and Unregulated (IUU) fishing, in various forms, is a significant threat to achieving biologically sustainable fisheries and a serious management problem for a large number of the fisheries on which these industries and coastal communities depend. Common forms of IUU fishing include fishing without permission, catching protected species, breaches of gear restrictions, disregarding catch quotas, high-grading catches, and deliberate under-reporting or mis-reporting.

In 2008 the EU agreed a definition of IUU fishing based on the only internationally agreed[2] definition found in the Food and Agriculture Organisation's (FAO) International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing[3]. The Plan of Action reflects consensus among the international community that all appropriate means should be devoted to fighting IUU fishing. This has also been widely recognised in all international and regional bodies in charge of fisheries management and conservation, including the United Nations General Assembly, Organisation for Economic Co-operation and Development (OECD), and Regional Fisheries Management Organisations (RFMOs). The most recent European Commission publication, the Proposal for a Council Regulation Establishing a Community System to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (COM[2007] 602 final), gives more detail on exactly what is considered to be IUU fishing (see Box 1).

This level of concern is justified because IUU fishing is a major threat worldwide to the sustainability of fish stocks and marine biodiversity. It is directly harmful to fish stocks, either through catching too many fish or simply the wrong ones, and frustrates efforts to achieve rational management: IUU activity has significant social impacts on legitimate fishing communities that face unfair cost competition or depressed prices, and sometimes on workers who, when employed in IUU activities, may experience lower employment standards (Schmidt, 2004). Some forms of IUU fishing have higher ecological impact on non-target species than legal fishing, either through greater by-catch, or habitat destruction. IUU fishing has additional indirect impacts on fisheries management because it biases fisheries data, making modelling and policy setting less accurate.

IUU fishing is a major problem for the sustainability of the marine environment and the fisheries sector, but also for the credibility of the EU's Common Fisheries Policy (CFP). The European Council has therefore recently adopted a regulation to address IUU fishing, while the European Commission proposed to strengthen the control and enforcement regime through stronger regulation. This report aims to contribute to the debates surrounding these policy initiatives by assessing the economic, social and environmental costs of IUU fishing.

[2] http://ec.europa.eu/fisheries/press_corner/press_releases/archives/com07/com07_69_en.htm.
[3] http://www.fao.org/DOCREP/003/y1224e/y1224e00.HTM.

Box 1: Definition of IUU fishing

The European Commission's definition of IUU fishing is essentially based on the internationally agreed FAO's International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU), which was adopted in 2001.

The recently adopted Council Regulation on IUU gives, in Article 3, the most detailed definition of what counts as IUU. The text of the Article reads as follows:

"A fishing vessel shall be presumed to be engaged in IUU fishing if it is shown that, contrary to the conservation and management measures applicable in the fishing area concerned, it has:
(a) Fished without a valid licence, authorisation or permit issued by the flag State or the relevant coastal State, or
(b) Not fulfilled its obligations to record and report catch or catch-related data, including data to be transmitted by satellite vessel monitoring system, or prior notices under Article 6, or
(c) Fished in a closed area, during a closed season, without or after attainment of a quota or beyond a closed depth, or
(d) Engaged in directed fishing for a stock which is subject to a moratorium or for which fishing is prohibited, or
(e) Used prohibited or non-compliant fishing gear, or
(f) Falsified or concealed its markings, identity or registration, or
(g) Concealed, tampered with or disposed of evidence relating to an investigation, or
(h) Obstructed the work of officials in the exercise of their duties in inspecting for compliance with the applicable conservation and management measures, or the work of observers in the exercise of their duties of observing compliance with the applicable Community rules, or
(i) Taken on board, transhipped or landed undersized fish in contravention of the legislation in force, or
(j) Transhipped or participated in joint fishing operations with, supported or re-supplied other fishing vessels identified as having engaged in IUU fishing under this Regulation, in particular those included in the Community IUU vessel list or in the IUU vessel list of a regional fisheries management organisation; or
(k) Carried out fishing activities in the area of a regional fisheries management organisation in a manner inconsistent with or in contravention of the conservation and management measures of that organisation and is flagged to a State not party to that organisation, or not cooperating with that organisation as established by that organisation, or
(l) No nationality and is therefore a stateless vessel, in accordance with international law."

2. Assessing IUU activity in EU fisheries

IUU fishing is a global problem. The extent, impacts and seriousness of IUU fishing vary with economic and social factors, and with the ecological characteristics of the harvested stocks. This chapter considers current levels of IUU fishing in the EU[4]. It examines where IUU fishing takes place, who carries it out, its causes and impacts, and levels of IUU activity. This information provides the context and assumptions required to construct appropriate models of IUU fishing.

There is limited evidence of IUU fishing details. However, by combining what we know about it with an assessment of the relative economic values and ecological vulnerabilities of European stocks, we can derive an overall assessment of the broad scale of costs of IUU fishing to different EU Member States.

2.1 Scope of analysis

IUU fishing is a problem at all geographical scales, and the details of its costs and the scope for controlling it vary according to a number of factors. Particularly important elements include:

- The status of the waters – are they within an Exclusive Economic Zone (EEZ), or High Seas?;
- The spatial behaviour of the stocks under consideration – whether they remain in one 'legal' area, or migrate between different EEZs, or between EEZs and High Seas;
- The management and control regime and capabilities within the area.

Different studies of IUU fishing focus on different levels. For example, MRAG (2005) treats the special problems associated with High Seas IUU fishing. This report focuses on IUU fishing by the EU fleet, primarily within the EU EEZs where EU and Member State policies have, in principle, full control. But in fact it is not practical to focus purely on EEZs, partly because these are not defined in the Mediterranean, and partly because it is generally more appropriate to model fish stocks within ecosystem boundaries rather than within jurisdictional boundaries. The reasons for this, and the details of the who, where, what and how of the analysis, are set out briefly below.

The geographical and political scope of our analysis

IUU fishing by EU vessels is the primary focus of this report. The CFP regulates the EU fleet both inside and outside EU waters and EEZs, while EU Member States have responsibility for controlling IUU fishing by their vessels and nationals in all areas. Any fishes caught by EU flag vessels in non-EU waters legally become 'EU product', and a significant amount of catches by EU fleet operating outside the EU EEZs are landed at EU ports.

IUU fishing by distant EU fleet operating beyond EU EEZs is within the scope of our interest, and will have costs for EU Member States. However, the costs of IUU fishing by EU vessels outside the EU EEZs can be difficult to apportion, because the costs of activity are shared among all states fishing in the area. Although reduced IUU fishing by EU vessels in these areas would likely bring benefits to Member States, at least in terms of stronger bargaining position in respect of resource sharing agreements, it is possible that any potential improvements in stock status would result in greater fishing effort from other nations. This interaction with other fleets makes the effects of IUU activities by EU vessels in these locations almost impossible to model. So it is more conservative to consider only the EU EEZ, where we can make clearer assessment of the distribution and extent of costs.

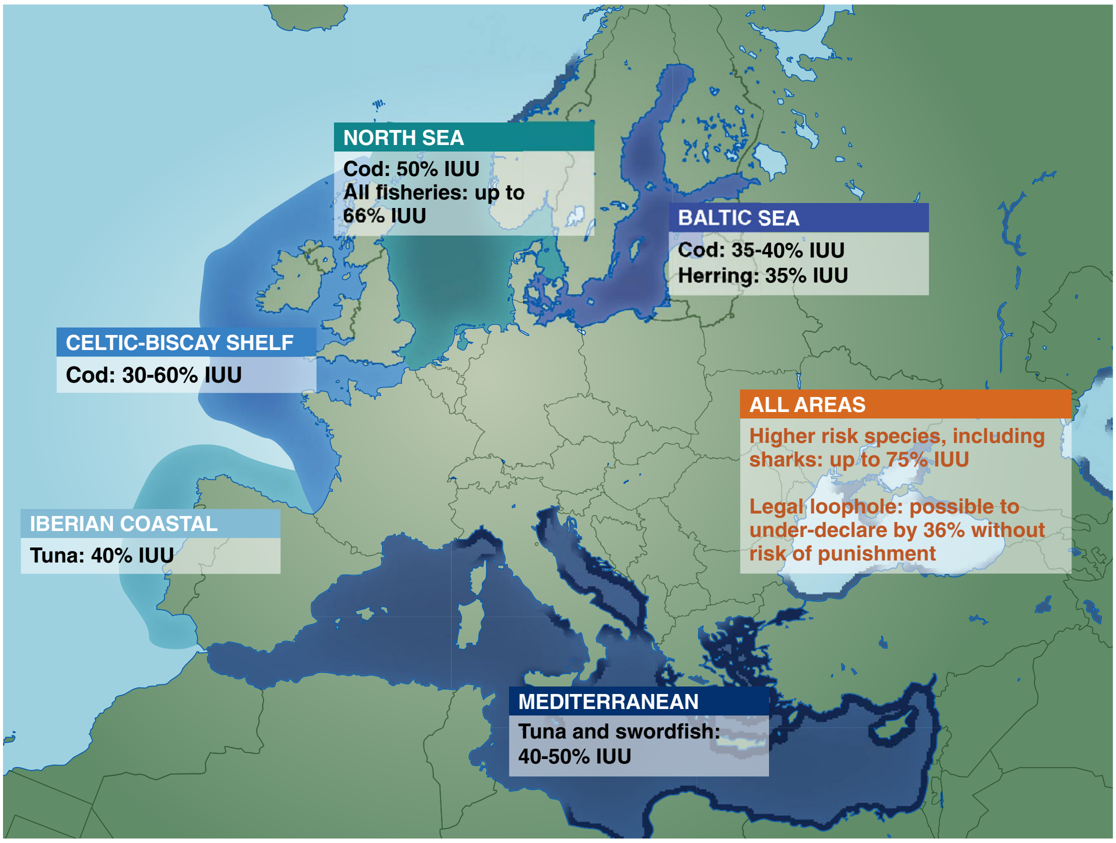
On the other hand, fish stocks do not respect jurisdictional boundaries. Many of the important stocks for the European fishing industry can be best defined at a scale covering

[4] IUU data is sometimes reported in different ways – either as a percentage of legitimate fish catch, or as a percentage of total (i.e. legitimate and IUU) catch. Throughout this report, IUU rates are expressed as a percentage of a fishery's total catch.

more than one EEZ, and often crossing from an EU Member State to a non-EU state EEZ. This is the case especially for stocks in the North Sea (shared with Norway), the Mediterranean and the Black Seas. The Iberian coastal area, the Celtic-Biscay shelf, and the Baltic Sea are entirely or predominantly within EU waters, but even here it is often difficult to define stocks within a specific Member State's EEZ.

The compromise position we adopt for the purpose of this study is to consider the Large Marine Ecosystems (LMEs) adjacent to the coastlines of EU Member States (see Figure 1). LMEs: "Are regions of ocean and coastal space that encompass river basins and estuaries and extend out to the seaward boundary of continental shelves and the seaward margins of coastal current systems"[5]. The six identified in Figure 1 cover most of the EU EEZ area, including the most productive parts, but not all – for example, the UK EEZ extends further north-west towards the Faroe Plateau, and the French and Spanish EEZs fill the gap between the Celtic-Biscay and Iberian Coastal LMEs. Because of this, and because we only consider the EU share of fisheries in these areas, it remains conservative to focus at the LME level, while also being ecologically appropriate[6].

Figure 1: Large Marine Ecosystems around the EU[7]



In addition, there could be some IUU fishing by third countries within EU waters, either by vessels flying flags of convenience, or IUU activities by third-country vessels authorised to fish. The costs of these IUU activities are borne by EU fleets and Member States. However data on the precise extent of the problem are lacking. We will implicitly include these

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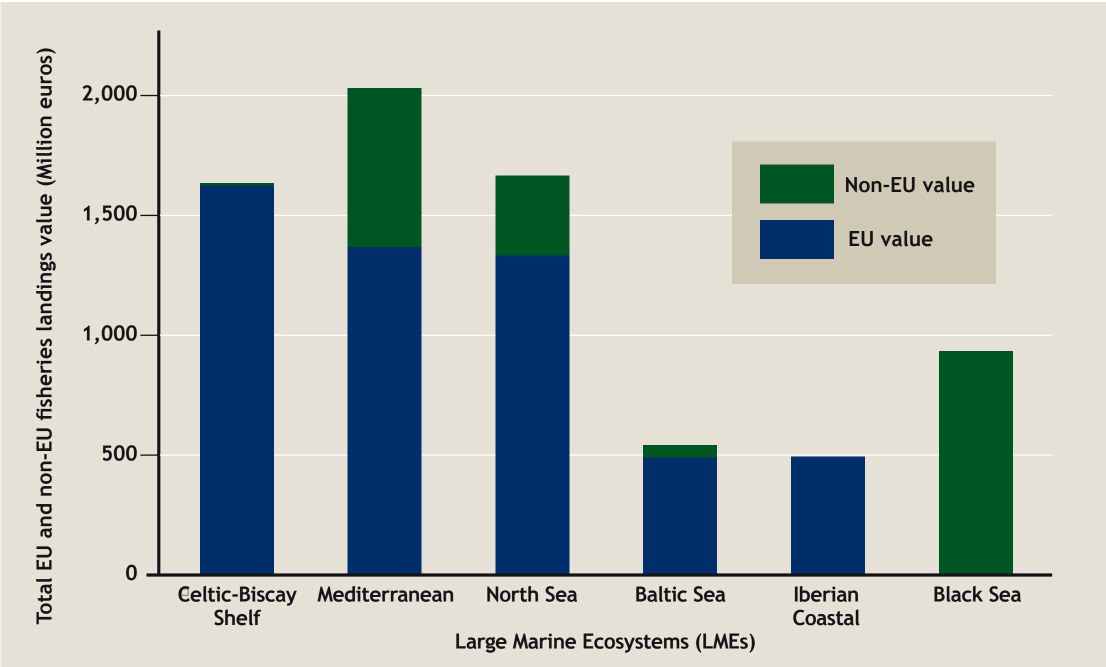
[5] http://www.oceansatlas.org/servlet/CDSServlet?status=ND0xMjcyNyY2PWVuJjMzPSomMzc9a29z.
[6] Even greater ecological realism could be achieved by modelling stocks at the more explicit scale of ICES areas (www.ices.dk), sub-dividing all the Atlantic areas under consideration. But there are too many such areas for this to be practical, and the data available do not allow us to determine exactly which countries are fishing there, whereas we do have reasonable country data on fishing within LMEs.
[7] Map adapted from European Environment Agency: http://www.eea.europa.eu/themes/water/european-waters/europes-seas-and-coasts. See Table 1 for IUU rates and sources.

activities, because our models consider the total level of IUU fishing within EU fisheries, but we can not model it separately from IUU fishing by EU vessels.

IUU fishing by non-EU vessels outside the EU EEZ is entirely outside the scope of this research.

Figure 2 shows the total landings value from the LMEs adjacent to the EU coast. The figure illustrates the very small value to European Member States of fishing in the Black Sea – about one-fifth of 1%. Fishing in the Black Sea is dominated by other states, in particular Turkey, and Romania and Bulgaria have a very small share. Fisheries in the Outermost Regions, not shown here, similarly represent a small fraction of EU fishing value: about 1.6%. This suggests that the costs of IUU activities in these fisheries do not form a significant part of the total costs of IUU fishing to Member States, justifying a decision to exclude the Black Sea and Outermost Regions from the modelling efforts. The very different ecological conditions in the Outermost Regions' fisheries also suggest that it is not possible to extrapolate results directly from the modelling carried out in this study.

Figure 2: Total EU and non-EU fisheries landings value (five-year average; 2000-2004; in million euros)[8]



How we assess the costs of IUU activities

We are interested in the costs of IUU activities for EU fishing in the LMEs identified above, taking into account, insofar as the data allow, the different levels of IUU fishing in different fisheries and the different economic, social and ecological costs. We can not hope to assess all of these costs in detail, not least because the data available are very limited (see Chapter 3). As explained below, we restrict the assessment to consideration of the direct costs in terms of the value of reduced fish harvest (economic cost), the impacts on employment (social cost) and the impacts on stock status (ecological costs), while recognising the overlaps between these measures, and the existence of wider costs which we are unable to assess. In assessing only a proportion of the full costs, we ensure that the results are conservative.

[8] Calculated from data available at www.seaaroundus.org. Values have been converted from US$ (2000) to euros (2008) using the average exchange rate from 2000, and the euro Consumer Price Index (CPI) from July 2000–July 2008: overall, multiplying by 1.31355. Source for CPI data: http://sdw.ecb.europa.eu/browseSelection.do?DATASET=0&FREQ=&REF_AREA=376&node=2120778.

Where the stock under consideration is wholly or largely within EU waters, there is no problem in assuming that the costs of IUU fishing impact on EU states. However, some of the stocks of interest do not remain wholly within EU waters, instead straddling or migrating between there and the EEZs of other states, or the High Seas. This could lead to problems apportioning the costs of EU IUU fishing, which could have impacts throughout the fishery. Although it is possible that stock improvements arising from fewer IUU activities in EU fisheries could be wholly lost when the stocks are subject to harvesting elsewhere, this is rather unlikely. In most cases, all or most of the areas in which the main stocks reside lies within EU waters and/or resource sharing agreements exist with the other countries involved. Thus it remains reasonably conservative to assume that the costs of IUU fishing in each LME impact on EU Member States in proportion to their current share of the values of these fisheries (see Figure 3).

The basic approach to evaluating the costs, described in more detail below, is firstly to assess – combining data and theoretical arguments – the likely extent of IUU activities for different fisheries in the LMEs. Then we assess the different likely implications of this activity, in particular regarding the impacts on stocks. Using published data, we construct a number of simple fisheries models to assess quantitatively how different types of fish stock might respond to IUU fishing. We then combine the results of these analyses to derive approximate estimates of the costs of IUU activity to fisheries in the LMEs, broken down by Member State fishing.

2.2 What drives IUU fishing?

An important step in understanding which stocks are most likely to be subject to IUU fishing is to consider the drivers of this activity. The key drivers considered here are the expected economic benefits for fishers, overcapacity in the fishing fleet relative to stocks available, and the lack of effective management regulations and enforcement.

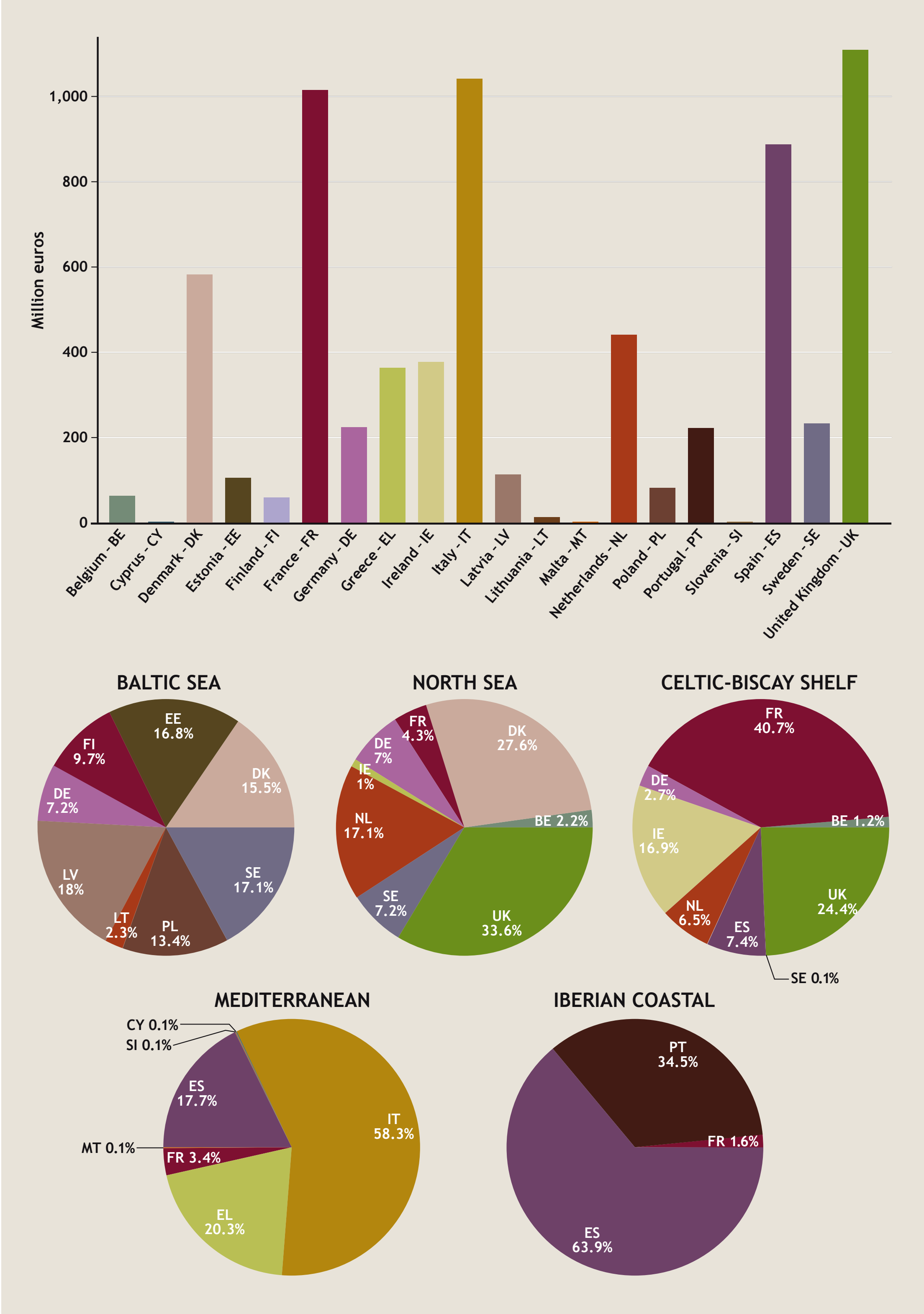
Economic payoffs for individual fishers

Ultimately, the key element driving IUU activity is fishing opportunities where fishers' expected benefits from breaching regulations – additional catch and/or lower harvesting costs – outweigh the downside, in particular the risk of being detected and suffering any sanction that might follow. IUU fishing can be highly lucrative and the only viable solution is to make it unprofitable through stronger governance measures[9].

Although many fishers generally respect fisheries regulations, some do not. Any given population of fishers can be classified into (i) chronic violators, (ii) moderate violators, and (iii) non-violators; although chronic and non-violators generally make up a small portion of the population (Kuperan and Sutinen, 1998). The bulk of moderate violators – perhaps around 90% of the total (Sumaila et al., 2006) – will occasionally engage in IUU fishing, based on economic considerations; secondary influences, including the perceived legitimacy of the regulations and the scientific assessments underpinning them; the administrative burdens involved; norms of behaviour; and the moral code of the individual fisher. This is quite similar to speeding among a population of drivers – some never speed, some speed chronically, but most speed sometimes, under certain conditions.

[9] For instance MRAG (2003) studies the economics of IUU fishing from the perspective of incentives and disincentives for IUU fishers.

Figure 3: Total EU value from fishing, by country fishing, from five LMEs in total, and individually.[10]



[10] Figure 3 shows share of five-year average landings values (2000-2004) calculated from data at www.seaaroundus.org.

The economic argument suggests that any factor that either increases fishers' benefits from IUU fishing or reduces their costs, will tend to increase IUU activity. Such factors include the following:

- A high value of fish: since restricted supply leads to increased price, this also means that when stocks and catches are low, or regulators try to restrict catches, incentives for IUU fishing can rise;
- A low chance of detection: e.g. inadequate vessel inspections, poor port controls, ease of concealing IUU fishing, advance knowledge of inspections;
- A low risk of prosecution following detection, or low fines relative to value of IUU fishing;
- Low peer pressure for compliance; and
- 'Limbo' situations not effectively addressed by regulation: rules of origin and transfer of catch at sea between vessels.

Fleet capacity in relation to available fishing opportunities

A key driver of IUU activity is overcapacity in fishing fleets. The latest estimates of EU overcapacity come from 1996 and suggest an overcapacity of 40% in the European fleet[11]. Although more recent data are not available, the European Commission and the European Court of Auditors (ECA) recognise that the 2002 reform of the CFP has not succeeded in addressing persistent overcapacity in the fishing fleets of the Member States (ECA, 2007).

Fishing capacity includes significant sunk-capital costs in the value of vessels, gear and technology, often involving fishers in high overheads for servicing credit. Overcapacity means there is significant under-deployed capital, with its owners seeking returns to meet fixed overhead costs, but often having relatively low short-term marginal or variable costs. Relatively low variable costs, and the economic imperative to meet credit payments, increases the attractiveness of engaging in IUU fishing (Schmidt, 2004). In addition, through its effects on stocks: "Overcapacity detracts from the profitability of the fishing industry and in a context of decreasing authorised catches is an incitement to non-compliance with these restrictions" (ECA, 2007).

The problems associated with fishing overcapacity have been known for years, but the policy of compulsory capacity reduction in the EU was abandoned in the reform of the CFP in 2002. While fisheries subsidies for the construction of new vessels were phased out, incentives for capacity enhancement, for example subsidies for modernisation, remain a significant problem, resulting in productivity gains associated with advanced technology that may be between 1 and 3% per year, or even more in some fisheries (COM[2007] 39 final). This in turn exacerbates overcapacity and ultimately IUU fishing (ECA, 2007). There is also a control and enforcement problem, since for instance actual engine power is often much higher than reported to authorities.

Overcapacity and IUU activities create a vicious circle in which depleted stocks worsen the problem of overcapacity and the drive to engage in IUU fishing. It is widely recognised that dealing effectively with overcapacity is a prerequisite for effective fisheries management in Europe. Nevertheless, this remains a difficult social and political task.

Political will and inadequate enforcement of regulations

Several authors (e.g. Cochrane and Doulman, 2005; Hilborn et al., 2005) have reviewed fisheries policies and institutions, identifying a lack of the political will or the political ability to address shortcomings effectively as a key problem. One consequence is that agencies charged with fisheries management are not provided with adequate technical and financial capacity to implement the instruments in most, if not all, countries. Another is that in some cases management bodies turn a blind eye to, or even encourage, certain forms of IUU fishing.

[11] Estimate based on the so-called Lassen Report: Report of the Group of Independent Experts to Advise the European Commission on the Fourth Generation of Multi-Annual Guidance Programmes, 1996.

Both underfunding and collusion can be understood as what Froese (2004) refers to as "convenience overfishing" – deliberate overfishing effectively accepted by official bodies who find it more convenient to risk eventual collapse of fish stocks than to risk social and political conflicts.

Both underfunding and collusion arise in the EU. In many European countries, the number of inspectors available is wholly inadequate for proper control of fishing and landings. The European Court of Auditors (ECA, 2007) notes that inspection systems are inadequate for the purpose of detecting IUU fishing, and that infringements are not adequately followed up or penalised. These inadequacies relate to both the Commission and Member States. Within the Commission, the Directorate-General for Maritime Affairs and Fisheries (DG Mare) is not cross-checking reported catches against Eurostat data (which can be significantly different) nor requesting original data files from Member States, which it blames on lack of staff resources and skills. At the Member State level, the ECA identified inadequate numbers of inspectors among several failings in the overall inspection system. Tellingly, the direct Community support for control and enforcement is only €46 million – this is much less aid than is provided for structural assistance (€837 million) and international fisheries agreements (€156 million) (ECA, 2007).

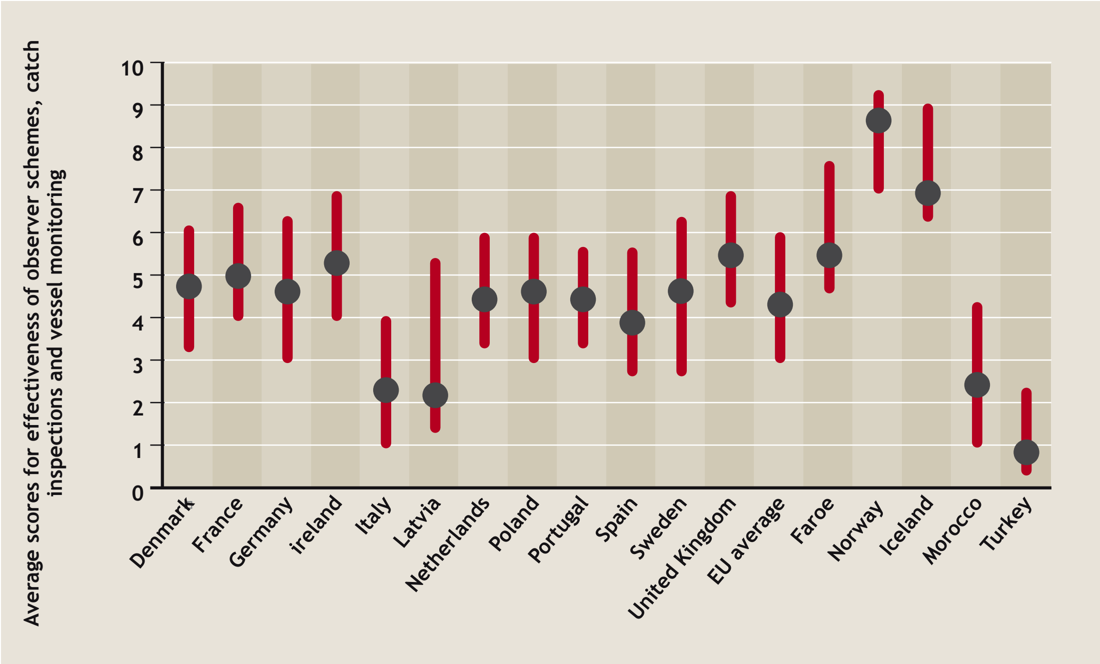
Even when wrongdoing is detected, adequate follow up is not guaranteed and sanctions applied are generally too low to be a deterrent. Across the Community the amounts paid in penalties in 2003 and 2004 averaged 0.4% and 0.2% of the value of fish landings in 2002 and 2003 respectively, with great variances among Member States[12]. If IUU fishing is assumed to account for 10–30% of total catches, this means that fines will amount to approximately 1–2.5% of the value of IUU landings. This suggests that fishers could consider penalties imposed for infringements of the CFP rules as an ordinary running cost of the enterprise, seeing no real incentive to be compliant (COM[2006] 387 final).

Pitcher et al. (2008) present a wide range of evidence on various aspects of fisheries management for a number of countries. Several of the criteria on which they report are relevant to IUU activity and the European context. For instance, Member States' scores for the effectiveness of observer schemes, catch inspections, and vessel monitoring are 5.8, 4.5 and 4.8 respectively out of 10. See Figure 4 – the box on the figure represents the median score for each country, and the bars represent the ranges, across the experts involved in making the assessments. These scores are 2.3 to 2.9 points lower than the average for Norway, the Faroes and Iceland. They reflect a significantly poorer standard of enforcement within the EU compared to these neighbouring fishing countries. However, scores for neighbouring Mediterranean countries (e.g. Turkey and Morocco) are lower than for the EU.

The variability between Member States in relation to the enforcement of CFP regulations, risks of detection, follow-up, and sanctions, creates different conditions for different fishers and contributes to explaining the variety of IUU levels in different fisheries. The EU's low to moderate standards of enforcement and follow-up influence the risk of detection of IUU activity and the expected penalties, which in turn lower the expected costs of engaging in IUU fishing.

[12] Source: Report from the Commission to the Council and the European Parliament on the Monitoring of the Member States' Implementation of the Common Fisheries Policy 2003–2005, COM(2007) 167 final, p9.

Figure 4: Average scores for effectiveness of observer schemes, catch inspections and vessel monitoring[13]



2.3 How much IUU fishing occurs?

Various methods exist for assessing levels of IUU activities, including direct observation, interviews, and indirect techniques such as inference from other data. Overall, however, there is very limited evidence on the extent of IUU fishing and there are numerous severe problems of data reliability. Clearly, fishers engaging in IUU activities can be expected to take steps to avoid discovery, and some management bodies and governments may collude in this.

The extent of IUU fishing is therefore difficult to establish. Estimates of the relative size of IUU activity vary substantially across fisheries, as we would expect from the discussion of drivers, which apply differently in different areas. The European Commission estimates that 15-20% of global catches are IUU[14]. The FAO estimates that illegal fishing represents up to 30% of total catches in certain major fisheries and states that catches of certain species could in fact amount to three times the authorised volume[15]. Clarke et al. (2006) state that trade statistics imply three to four times more sharks are traded than are represented in FAO catch statistics.

The global value of IUU fishing has been estimated as US$5–11 billion[16], while the Commission's 15-20% catch estimate could imply a value of more than US$30 billion per year. However, the value of fish caught by IUU activity is much smaller than the economic, social and environmental costs of IUU fishing (see Chapter 3).

Estimates of IUU rates for EU fisheries

Some individual studies of IUU fishing provide quite detailed evidence about particular problems. The evidence relevant for the EU is summarised in Table 1 (see also Figure 1). Except where stated, these estimates are for fisheries, and we do not know in detail how this IUU fishing breaks down across Member States' fleets.

[13] Source: Pitcher et al. (2008).
[14] http://ec.europa.eu/maritimeaffairs/pdf/thematic_factsheets/fisheries_en.pdf.
[15] http://ec.europa.eu/fisheries/cfp/external_relations/illegal_fishing/facts_and_figures_en.htm.
[16] MRAG, 2008.

Table 1. Estimates of IUU fishing rates (expressed as % of total catch)

Area	Fishery	IUU %	Comments	Source
Inter-national	All catches	15-20%	Global figure.	European Commission[17]
	Higher risk species	Up to 75%	Reporting FAO estimate: up to 75% for some species.	European Commission[18]
	Sharks	66-75%	From comparison of trade data with reported catch data.	Clarke et al. (2006)
	Redfish	20%	North East Atlantic Fish Commission estimates for 2001	Schmidt (2004)
High Seas in N.E. Atlantic	All	9% (6–13%)		MRAG and UBC (2008)
Atlantic	Tuna	10%		ICCAT (2007)
		18%		Schmidt (2004)
	East Atlantic bluefin Tuna	36%	Based on estimate of volume of actual catches compared to quota.	WWF (2006)
Europe	All	Up to 49%	Based on difference in declared landings with and without inspections.	ECA (2007)
Mediterranean; E. Atlantic	Bluefin tuna	40%	Catches under-reported to ICCAT.	ICCAT (2007)
Greece	All	35% (10–65%)	Based on reconstructed landings data and comparison with official statistics. Large variations across stocks. Suggest that under-reporting is most serious for the more valuable, and harder fished and controlled, stocks, as might be expected.	Tsikliras et al. (2007) – estimates made in early 1990s
	Swordfish, bluefin tuna & other tuna-like fishes	50%		
Spain	Galician monkfish trawl fishery	10%	Port-based analysis of the difference between total catches estimated in the model and official figures from 1999.	Rocha et al. (2004)
Spain	Artisanal octopus and squid	40%		
Baltic	Cod	35-40%	ICES Baltic Fisheries Assessment Working Group estimates.	ICES (2004)
Baltic	Herring	35%		
Baltic	Cod	Up to 45%	Cod caught and landed illegally.	Regeringkansliet (2006)
North Sea	North Sea	Up to 66%	ICES has suggested that as much as two-thirds of total catches are unreported.	*New Scientist* (2004)
UK	Scottish purse seiners	Up to 100%		

[17] http://ec.europa.eu/maritimeaffairs/pdf/thematic_factsheets/fisheries_en.pdf.
[18] http://ec.europa.eu/fisheries/cfp/external_relations/illegal_fishing/facts_and_figures_en.htm.

Table 1. Estimates of IUU fishing rates (expressed as % of total catch)				
Area	Fishery	IUU %	Comments	Source
UK	West Scotland Cod	30-60%	Under-reporting, 1991–1998.	
UK	Humberside fisheries	50%	Unreported catch may equal reported catch.	
UK	Cod	50%	One-half of all cod landed in the UK is misreported.	

Under current EU rules it is also possible to 'get away with' an under-declaration of 36% of landings with no risk of penalty[19]. This legal loophole accords with evidence from which it can be inferred that there must be substantial under-reporting generally in EU fisheries, since, all things being equal, the quantities declared are higher if there is a landing inspection (ECA, 2007). This difference reached 48.7% in the case of landings of cod in Poland[20].

Reported infringements

Additional evidence of levels of IUU activity is provided by official reports of infringements. In the EU 'serious infringements' of the CFP – relating to important obligations on stock conservation, monitoring, and marketing – are annually reported by Member States. In 2006, 9,600 serious infringements were recorded, about 22% of which related to unauthorised fishing (COM [2006] 387 final). However, this data is partial, and unreliable for comparisons. For example, the level of inspections is not supplied accurately by all Member States, and what there is has big variations. The result is that the reported rate of infringement varies: from 2% (Poland) to 65% (Greece)[21].

Data from inspections coordinated by the Community Fisheries Control Agency in 2007 and 2008[22] indicate that the percentages of inspections detecting infringements ranges from 0% to 24%, but is generally between 5 and 10% and averages 6%. This does not imply that IUU fishing constitutes 6% of fish catch in these areas, as the volume of IUU catch is not solely determined by the number of vessels infringing, but suggests that at least one in 17 EU vessels may be infringing regulations at any time, and probably more, since it may be possible to conceal certain infringements and inspections may detect only certain kinds of infringements.

Country reports

Some more indications on the levels of IUU fishing are provided by the aforementioned country reports (Pitcher et al., 2008). The reports generally reveal a high proportion of IUU activities in EU Member States (see Figure 5). This goes along with a relatively poor score by EU Member States for their ability to control IUU fishing (Figure 6), substantially worse than the scores for Iceland, Norway and the Faroe Islands, and similar or little better than for Morocco and Turkey.

Conclusions on the extent of IUU fishing in Europe

Although the evidence is patchy, it is clear that IUU fishing is prevalent across a wide range of European stocks, at quite high levels: estimates reach as high as 100% of total catch in some cases. More generally, IUU activity in many of the higher value, and more depleted,

[19] If there is a landing inspection, an actual catch and logbook declaration differential of 20% is tolerated. If there is no inspection, a further difference of 20% from the logbook to the landing declaration is allowed. Since the landing declaration can be made up to two days after the landing, the fishers know whether or not there has been an inspection when the declaration is made. In the majority of cases it is possible to make a total under-declaration of 36% with no risk of penalty (though where a recovery plan exists, tolerances are only 8%, so 'only' 15% under-reporting is 'safe') (ECA, 2007).

[20] DG Fish (now DG Mare), Evaluation Report of Catch Registration Baltic Sea 2005 to 2006.

[21] The rate is the number of serious infringements detected divided by the number of vessels listed in the Fishing Vessel Register for each Member State. Therefore the figure varies according to, inter alia, the intensity of the inspection regime.

[22] See www.cfca.europa.eu/reports_en.htm.

fisheries, is widely reported to be in the 40-50% range or higher. We draw on these figures in the simulation phase of the research to develop conservative estimates of the extent and cost of IUU activity in EU fisheries.

Figure 5: Country scores on "Are vessels fishing illegally in the fisheries?"[23]

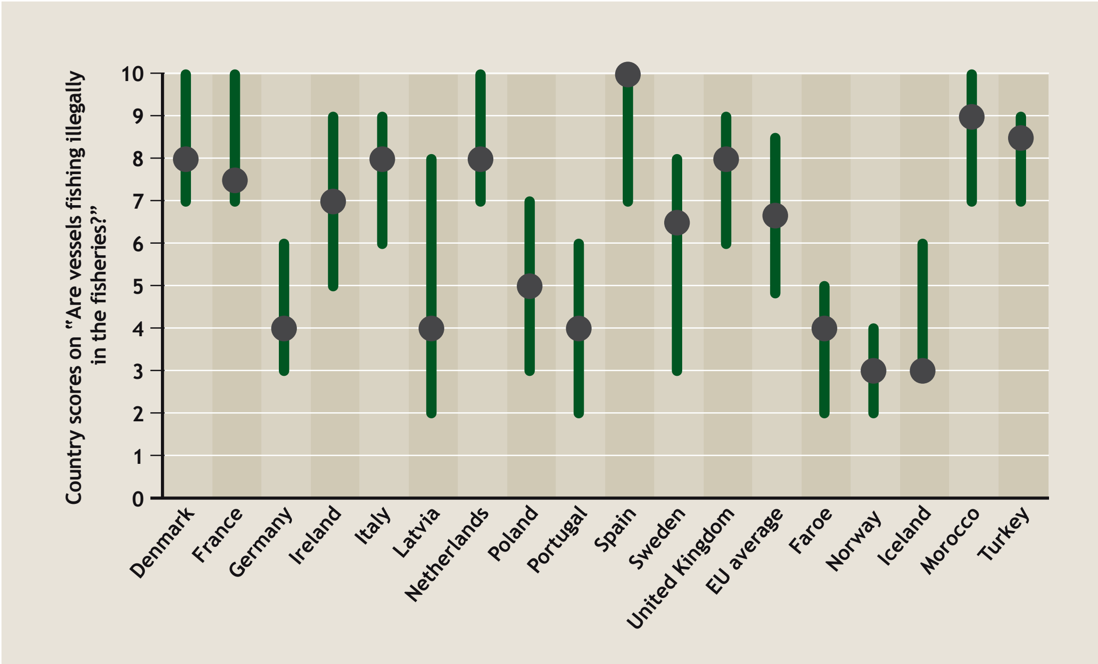
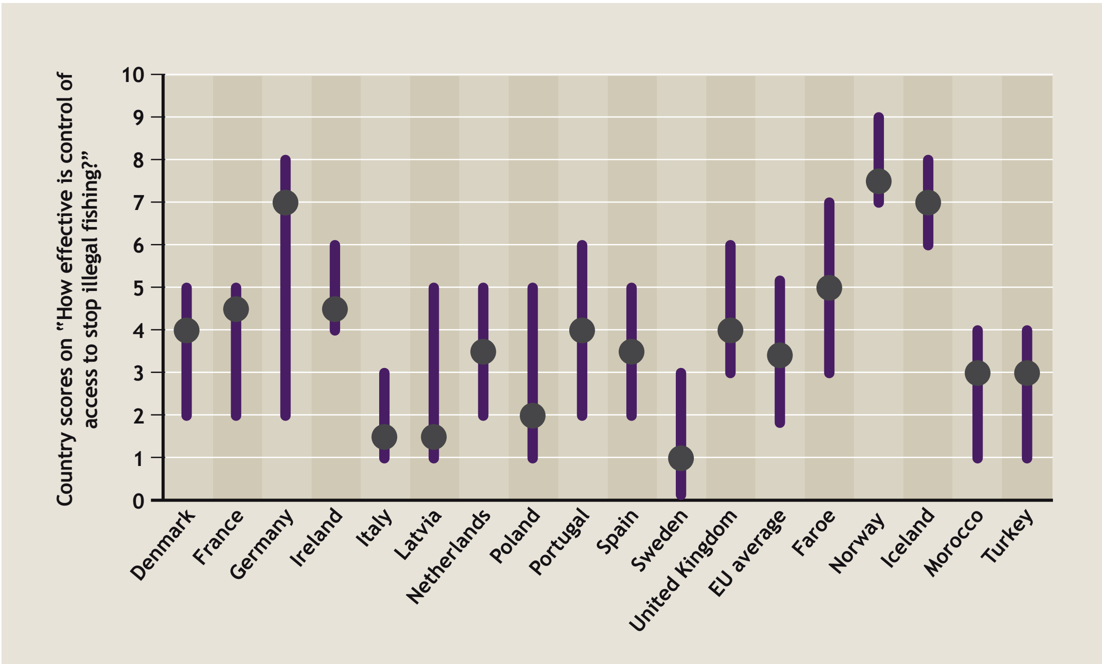


Figure 6: Country scores on "How effective is control of access to stop illegal fishing?"[24]



[23] Source: Pitcher et al. (2008), higher score reflects more infringements.
[24] Source: Pitcher et al. (2008), higher score reflects better control.

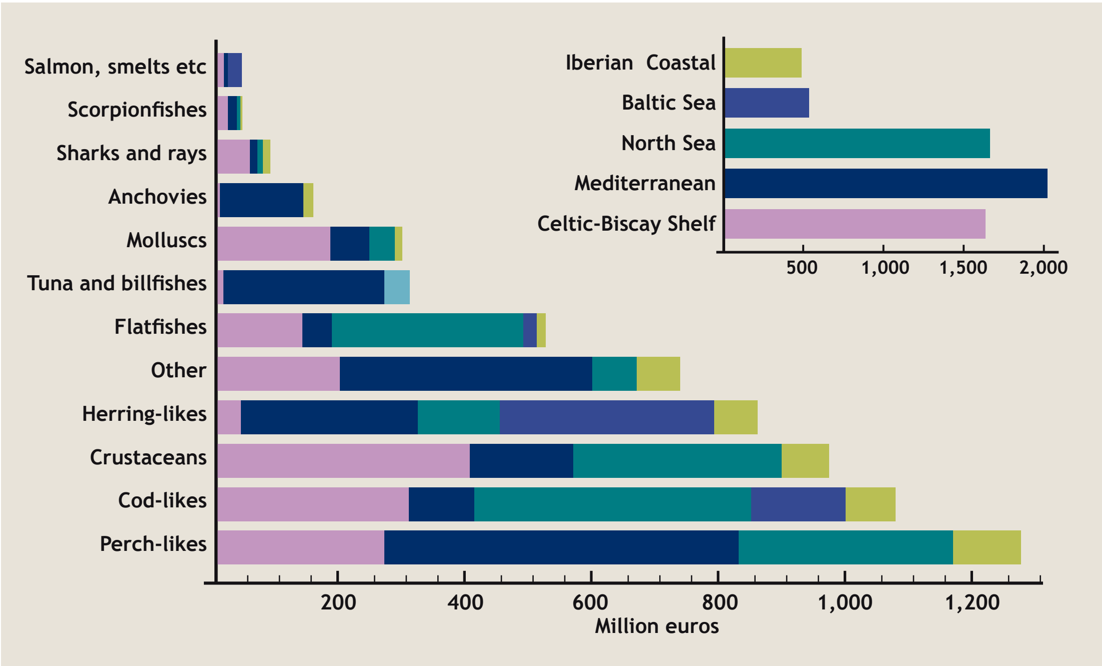
2.4 Key stocks

One aspect of the modelling strategy for the project is to examine how the costs of IUU fishing might vary across different types of fisheries. This section explores the stocks of economic importance, the stocks at ecological risk, and the stocks susceptible to IUU activity in EU fisheries, in order to guide the choice of stocks for modelling and assessment. The assessment in this section is focused primarily on identifying key stocks and species within each category.

Commercially important stocks

Although there are a large number of stocks exploited in EU fisheries, only a relatively small number of commercial groups dominate the economic value of landings (see Figure 7; Figure 8). Perch-likes, cod-likes, crustaceans and herring-likes account for two-thirds of fisheries value.

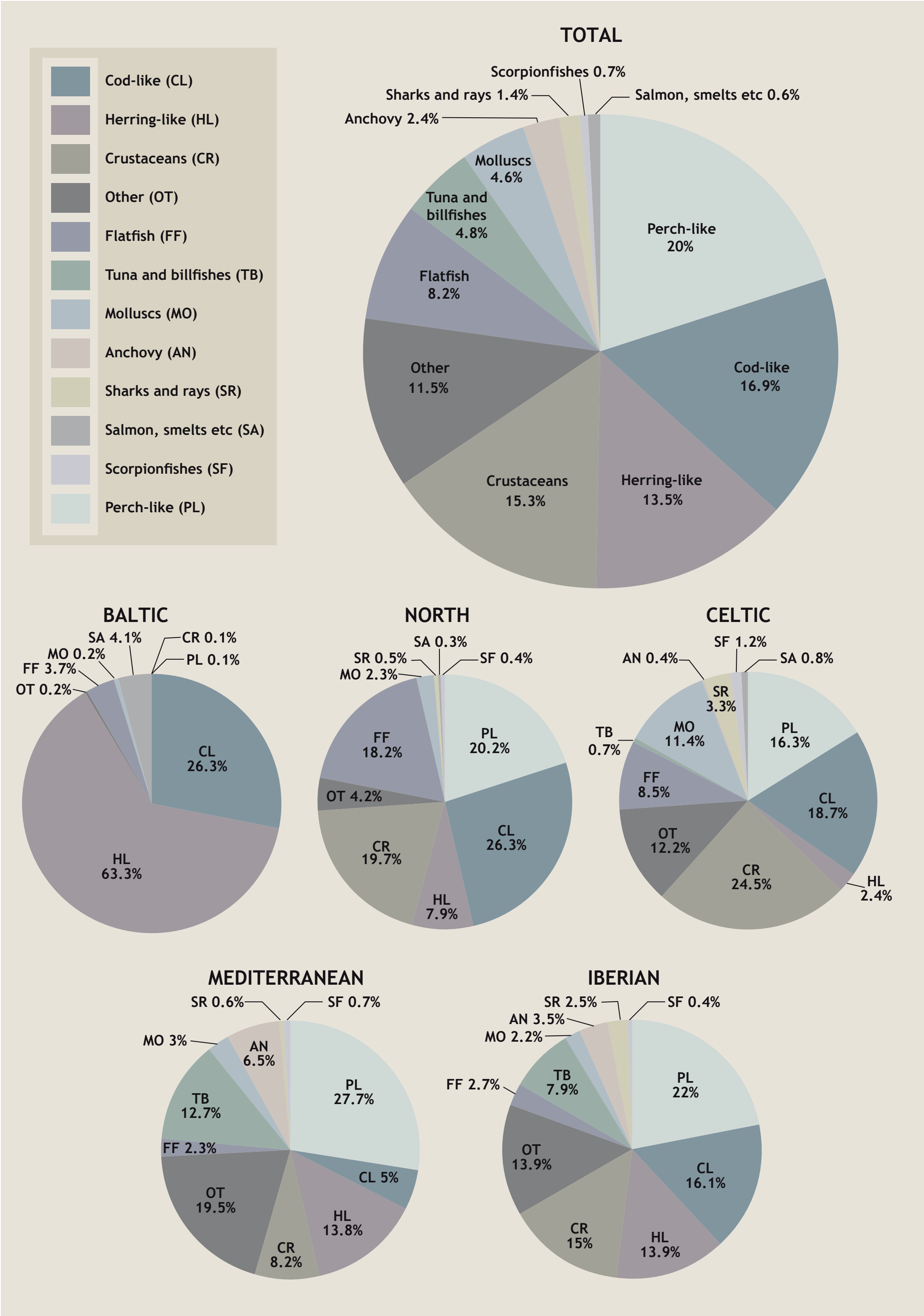
Figure 7: Average value of EU landings (2000-2004) from five main LMEs, by commercial group in million euros[25]



Within most commercial groups, a small number of stocks dominates in each sea area. In some areas, this means that almost the whole value of fishing hangs on a handful of stocks. In the Baltic, for example, almost all the fishery value comes from just three species: cod and two herring-like species, herring and sprat. In other areas, a wider range of groups is important (see Figure 8), with more species in each group, but generally 40-50% of the value is attributable to the top six or fewer species (see Table 2). It is also noteworthy that some species are important in two or more LMEs, including mackerel, horse mackerel, cod, blue whiting, herring and nephrops.

[25] 2008 values. Source: adapted from data at www.seaaroundus.org.

Figure 8: Shares of different commercial groups in total landing values, in total and by LME[26]



[26] SF = Scorpionfish, SA = Salmon. Figures are for five-year-average value of landings (2000-2004) for the five LMEs cited, based on data from www.seaaroundus.org.

Table 2: The most important commercial stocks in European LMEs[27]

Area	% Value	Stocks
Baltic	91	Sprat, cod, herring
North Sea	51	Mackerel, plaice, nephrops, cod, herring, crab
Celtic-Biscay	42	Nephrops, mackerel, crab, blue whiting, horse mackerel, whiting
Iberian Coastal	50	Pilchard, blue whiting, octopoidae, mackerel, albacore tuna, horse mackerels
Mediterranean	31	Pilchard, anchovy, mussels, swordfish, bluefin tuna, horse mackerel

Knowledge of the most commercially important stocks gives a clear steer as to where to model the economic and social impacts of IUU fishing. But, not all of these stocks may be subject to IUU activity or vulnerable to its effects. To take this into account, other parameters beyond simple fisheries value must also be considered.

Susceptibility to IUU fishing of key stocks

Susceptibility to IUU activities varies according to the drivers of IUU fishing, including the value of fish (at different sizes) and the costs of catching them, and aspects relating to the current efficiency of control and enforcement measures. In some cases, we have existing estimates of fishing levels, as reported above. For most stocks, however, no clear data are available. For these stocks, we have to rely on indirect assessment of the likelihood of IUU activity taking place. We can draw on evidence on fish price and also on the existence of TACs (see Table 3). TACs are a prerequisite for certain forms of IUU fishing (it is not possible to be over quota if there is no quota) and also indicate stocks which have had to be regulated due to heavy fishing pressure. However, not all TACs limit fishing pressure: in some cases TACs are set at levels similar to recent landings and in others not enough fishes are landed to exhaust the TAC. Generally speaking, however, the existence of a TAC (or alternative management measure) is a clear indication that a stock is commercial, important and at risk of over-exploitation without a policy to control fishing; and it is these stocks for which IUU fishing is a risk.

Of course, there remains the impact of 'indirect' IUU activities in multispecies fisheries – that is, a fish from a stock that is not the target of IUU activity may nonetheless be taken as by-catch through IUU activity targeting another stock. In addition, the absence of TACs does not mean that a stock is not being overfished – as noted above, in many cases scientific advice does not translate into catch limits, or available data do not allow the status of stocks to be determined and a precautionary approach should be applied. So although the susceptibility characteristics outlined here may determine a significant part of IUU activity, stocks without these characteristics may also be vulnerable to IUU fishing.

[27] Source: calculated from data at www.seaaroundus.org.

Box 2: Deep-sea stocks and IUU fishing

Deep-water fisheries are especially vulnerable to IUU activity. ICES (2003) describes the deep-water fish of the North Atlantic – with a few exceptions – as: "Adapted to a life with very little food and at a very slow pace... the fish grow extremely slowly and reproduce at a very slow rate". Some fish can be very long-lived (100 years or more) and reach sexual maturity late (15–30 years). These stocks need careful handling, especially since our knowledge of their biology is generally poor, and rapid decline in catches is a clear warning sign. Sensible management of these stocks may require very low mortality rates, "pulse" fishing, and/or substantial Marine Protected Areas or no-take zones.

Good management of deep sea stocks is increasingly important because catches are coming from deeper and deeper average depths (Morato et al., 2006). The mean longevity of the catch has increased during the past 50 years, but most dramatically since the early 1990s. Catch from shallow waters has a lower mean longevity (about 15 years) compared with intermediate water (about 40 years) or deeper waters (more than 100 years). Hence, fishing deeper means fishing for increasingly longer lived and thus more vulnerable species – their life-history characteristics (Merrett and Haedrich, 1997; Morato et al., in press) suggest that decline will be much faster than for shallow stocks, with a smaller likelihood of recovery after collapse.

Table 3: European stocks controlled by TACs (including some migratory stocks)				
Group	**Latin name**	**Common name**	**Price (euro 2008/tonne)[28]**	**EU TAC?[29]**
Anchovy	Engraulis encrasicolus	European anchovy	1,353-Mediterranean	Y
Cod-likes	Brosme brosme	Tusk		Y
	Gadus morhua	Atlantic cod	1,988-Baltic; 2,506-North; 2,980-Celtic	Y
	Melanogrammus aeglefinus	Haddock	2,004-North	Y
	Merlangius merlangus	Whiting	1,442-North; 1,618-Celtic	Y
	Merluccius merluccius	European hake	2,105-Celtic;1,982-Iberian	Y
	Micromesistius poutassou	Blue whiting	515-Celtic; 1,437-Iberian	Y
	Molva dypterigia	Blue ling		Y
	Molva molva	Ling		Y
	Pollachius pollachius	Pollack		Y
	Pollachius virens	Saithe	901-North	Y
	Trisopterus esmarkii	Norway pout		Y
Crustaceans	Nephrops norvegicus	Norway lobster	5,956-Celtic	Y
	Pandalus borealis	Northern prawn		Y
	Penaeus spp.s	Shrimps (in French Guiana)		Y
Flatfishes	Lepidorhombus spp.	Megrims		Y
	Pleuronectes platessus	European plaice	2,215-North	Y
	Scophthalmus rhombus	Brill		Y (with turbot)
	Psetta maxima (Scophthalmus maximus)	Turbot		Y (with brill)
	Glyptocephalus cynoglossus	Witch		Y (with lemon sole)
	Microstomus kitt	Lemon sole		Y (with witch)
	Platichthys flesus	Flounder	1,147-Baltic	Y (with dab)
	Limanda limanda	Dab		Y (with flounder)
	Reinhardtius hippoglossoides	Greenland halibut		Y
	Solea solea	Common sole		Y
Goosefishes	Lophiidae	Anglerfish		Y
Herring-likes	Argentina silus	Greater silver smelt		Y
	Clupea harengus	Atlantic herring	549-Baltic; 278-North; 301-Celtic	Y
	Sprattus sprattus	European sprat	589-Baltic	Y

[28] Source: own calculations, based on data for catch by species and value by species for different LMEs, from www.seaaroundus.org.
[29] Source: Council Regulation EC No.40/2008.

Table 3: European stocks controlled by TACs (including some migratory stocks)				
Group	**Latin name**	**Common name**	**Price (euro 2008/tonne)[28]**	**EU TAC?[29]**
Perch-likes	Ammodytidae	Sandlances/sandeels		Y
	Scomber scombrus	Atlantic mackerel	771–North; 816–Celtic; 1,247–Iberian	Y
	Trachurus trachurus	Atlantic horse mackerel	507–Celtic; 820-1423–Iberian; 1,999–Mediterranean	Y
Sharks/rays	Lamna nasus	Porbeagle	Low-value meat; very high-value fins	Y
	Rajidae	Skates and rays		Collective
	Squalus acanthias	Spurdog		Y
Tuna/billfishes	Makaira nigricans	Blue marlin		Y
	Tetrapturus albidus	White marlin		Y
	Thunnus alalunga/Germo alalunga	Albacore		Y
	Thunnus obesus	Bigeye tuna		Y
	Thunnus thynnus	Bluefin tuna	3,879–Mediterranean	Y
	Xiphias gladius	Swordfish		Y

Vulnerability of key stocks

The most commercial stocks are often those most subjected to IUU activity. However, they are not always those most vulnerable to its effects. Several species of fish are at serious risk of disappearing altogether from European waters and, in some cases, of global extinction (see Table 4). These stocks are not necessarily commercial, though they can be. They tend to be of long-lived, slow-growing and slow-reproducing animals unable to resist high levels of exploitation, whether through targeting or by-catch.

Ecological vulnerability to overfishing varies, with biological parameters relating in particular to growth and reproduction. Cheung et al. (2005) constructed an expert system for assessing stock vulnerability to overfishing based on a number of such factors[30]. The assessments do not consider economic or fisheries factors, and so give a pure ecological measure of vulnerability to depletion.

Alongside the vulnerability index, we consider the World Conservation Union (IUCN) assessments of stock status, including the reasons for depletion. Several species of fish present in European waters are assessed as Vulnerable, Endangered or Critically Endangered; of these, almost all cite exploitation as one of the causes. Some species are assessed as Data Deficient or are not assessed at all and it is likely that at least some of these may also be in bad shape. In addition to species listed in Table 4, several species of sturgeon are endangered – these are primarily freshwater fish, and we do not consider them further here, although many sturgeon do migrate into estuaries and coastal waters, and some will be taken as by-catch in certain coastal fisheries. There are also many species assessed as Endangered in waters around the Outermost Regions, which for reasons of space we do not list in Table 4.

Several species of rays and sharks are especially threatened. Some are targeted commercially despite scientific advice that fishing should be stopped, or in the absence of any scientific advice. Others comprise a significant portion of by-catch in many fisheries.

The laxity of European regulation on the removal of fins of sharks on board vessels (Council Regulation [EC] No. 1185/2003) increases the risk of this form of IUU activity. Shark finning is the illegal practice of slicing off shark fins and discarding the remaining carcass at sea. The European regulation allows fins adding up to 5% of a shark's whole weight to be landed as long as the carcass is kept as well, but since for most species the fins weigh much less than 5% of the whole carcass, this creates opportunities for IUU activity: many more sharks can be finned without fear of prosecution. The regulation also allows vessels to land and/or transship fins separately from the carcasses, making effective monitoring all but impossible. This major loophole is not part of any other finning ban in the world[31]. Hence, while there is no direct evidence on the extent of shark finning in the EU, IUU fishing on sharks could potentially be a major problem in EU fisheries.

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[30] Maximum body length, age at first maturity, von Bertalanffy growth parameter K, natural mortality rate, maximum age, geographic range, annual fecundity, and strength of aggregation behaviour. The assessments here range from very low vulnerability (10) to very high (90) – the vulnerability does not correlate perfectly with IUCN assessments because it considers only ecological factors, whereas the IUCN assessments are concerned with actual and projected status of stocks, which also depend on pressures such as fishing and habitat loss.

[31] http://www.sharkalliance.org/content.asp?did=950.

Table 4: Globally threatened species occurring in European waters[32]					
Group	Latin name	Common name	Vulner-ability [33]	Red List category[34]	Exploitation cited as reason?
Sharks/rays	Pristis pristis	Common sawfish	83	CR	Yes
Sharks/rays	Squatina squatina	Angelshark	83	CR	Yes
Sharks/rays	Squatina aculeata	Sawback angelshark	81	CR	Yes
Sharks/rays	Squatina oculata	Smoothback angelshark	80	CR	Yes
Sharks/rays	Dipturus batis	Blue skate	60	CR	Yes
Sharks/rays	Leucoraja melitensis	Maltese ray	48	CR	Yes
Perch-likes	Epinephelus marginatus	Dusky grouper	86	EN	Yes
Sharks/rays	Sphyrna mokarran	Great hammerhead	85	EN	Yes
Sharks/rays	Rostroraja alba	Bottlenosed skate	84	EN	Yes
Sharks/rays	Rhinobatos cemiculus	Blackchin guitarfish	79	EN	Yes
Flatfishes	Hippoglossus hippoglossus	Atlantic halibut	77	EN	Yes
Sharks/rays	Mobula mobular	Devil fish	72	EN	Yes
Sharks/rays	Rhinobatos rhinobatos	Common guitarfish	56	EN	Yes
Perch-likes	Pagrus pagrus	Common seabream	41	EN	Yes
Sharks/rays	Oxynotus centrina	Angular roughshark	90	VU	Yes
Sharks/rays	Centrophorus squamosus	Leafscale gulper shark	87	VU	Yes
Sharks/rays	Squalus acanthias	Spurdog	86	VU (EN in N-E Atlantic & Med. Sea)	Yes
Sharks/rays	Centrophorus granulosus	Gulper shark	86	VU	Yes
Sharks/rays	Carcharodon carcharias	Great white shark	84	VU	Yes
Sharks/rays	Galeorhinus galeus	Tope shark	80	VU	Yes
Sharks/rays	Lamna nasus	Porbeagle	78	VU (CR in N-E Atlantic & Med. Sea)	Yes
Sharks/rays	Carcharhinus longimanus	Oceanic whitetip shark	74	VU	Yes
Sharks/rays	Sphyrna tudes	Smalleye hammerhead	74	VU	Yes
Cod-likes	Gadus morhua	Atlantic cod	61	VU	Yes
Sharks/rays	Cetorhinus maximus	Basking shark	61	VU (EN in N-E Atlantic)	Yes
Tuna/billfishes	Thunnus obesus	Bigeye tuna	59	VU	Yes
Sharks/rays	Carcharias taurus	Sand tiger shark	52	VU	Yes
Sharks/rays	Gymnura altavela	Spiny butterfly ray	51	VU	Yes
Cod-likes	Melanogrammus aeglefinus	Haddock	50	VU	Yes
Sharks/rays	Isurus oxyrinchus	Shortfin mako	78	VU	Yes
Tuna/billfishes	Thunnus thynnus	Northern bluefin tuna	65	DD (EN in E. Atlantic)	
Tuna/billfishes	Thunnus alalunga	Albacore	55	DD (VU in N. Atlantic)	
Tuna/billfishes	Xiphias gladius	Swordfish	55	DD (EN in N. Atlantic)	

[32] Ordered by IUCN Red List status, then vulnerability estimate.
[33] Source: individual species pages from www.fishbase.org and mirror sites.
[34] CR = Critically Endangered; EN = Endangered; VU = Vulnerable; DD = Data Deficient. For details on IUCN Red List criteria, go to www.iucnredlist.org. The Red List is due to be updated in October 2008, so categories in this table might change, and other European species may be added; the category in the table for shortfin mako is the anticipated 2008 category.

Data availability and stock selection

Ideally, our selection of stocks on which to model costs could now be guided entirely on the evidence available on economic importance, susceptibility to IUU activity and ecological vulnerability. However data availability is a serious problem. For example, it is clear that certain species of shark are at particular risk from IUU fishing, but, as the ICCAT (2005) shark stock assessment notes: "Little is known of the elasmobranchs taken in European fisheries". In the absence of data linking exploitation to stock impacts, it is not possible to be quantitatively specific about the possible impacts of IUU fishing on shark populations. However it is certain that many stocks are at serious risk of extinction, and that IUU fishing is increasing this risk, perhaps substantially.

In determining how to progress with the stock-modelling phase of the research, we need to take into account:

- The data requirements of modelling, notably landings and biomass or effort data from reasonably long time series;
- The data available, in particular from ICES and ICCAT sources;
- The assessments of fisheries values, susceptibility to IUU fishing, and vulnerability to overexploitation;
- Evidence available on IUU fishing rates; and
- The strategy for extrapolating results from stocks to commercial groups.

The most important groups, commercially, are perch-likes, cod-likes, crustaceans and herring-likes. Flatfishes, tuna/billfishes, and sharks/rays are all less important in terms of total economic value across Europe, though this is uneven (for example, flatfishes have 8% of value overall but 18% in the North Sea; tuna/billfishes have 5% overall but 13% in the Mediterranean; see Figure 8).

The most important species, commercially, also vary across LMEs. But it is clear (see Table 2) that cod, blue whiting, herring, mackerel, and nephrops make a particularly significant contribution to overall fisheries value.

The key species susceptible to IUU fishing are those controlled by TACs, in particular when stocks are depleted and the fish are high-value. Stocks such as cod, haddock, hake, nephrops, plaice, bluefin tuna and swordfish may be particularly susceptible. Many species of shark are also especially susceptible due to the high value of shark fins and the lax EU shark finning regulations.

In terms of vulnerability, the key species at risk are slow-growing and late-maturing, and ill-adapted to withstanding heavy exploitation. Many sharks and rays targeted or taken as by-catch in EU fisheries fall into this category. Some other species may also be at risk, including cod and haddock, and various tuna species and swordfish, for which data are not sufficient to permit a clear classification of status.

On the data side, we have reasonable stock and landings data for many ICES stocks, including various cod-like stocks, herring-like stocks, flatfish and mackerel. We have limited data for other species, but a published model for swordfish is available (ICCAT, 2007b). Although substantial data are available for bluefin tuna, they are not in a form suitable for estimating a surplus-production model. Despite an extensive search we have not found any suitable model for the bluefin tuna. Although there are several papers dealing with general discussion of the stock and its status (e.g. Fromentin and Kell, 2007; Fromentin and Powers, 2005), these are inconclusive regarding key stock parameters, partly because the stock appears to be inherently complex and partly because available data are poor.

Estimates of IUU fishing rates (see Table 1) are available for several stocks, in particular Mediterranean bluefin tuna and swordfish, Baltic cod and herring, and North Sea stocks collectively. Clearly, models of these stocks are a priority, but we can also fill the gaps by conservative extrapolation from available estimates.

Taking the above into account, the most promising species for modelling, and subsequent use in estimating IUU fishing costs at the scale of commercial groups in LMEs, are the following:

- Cod: highly commercial, high-value species; low stocks; vulnerable; estimates of IUU fishing rates; reasonable stock data. To represent cod-like species.
- Haddock: high-value species; low stocks; vulnerable; some estimates of IUU fishing rates; reasonable stock data. To represent cod-like species.
- Herring: highly commercial; very variable stocks; reasonable stock data; some estimates of IUU fishing rates. To represent herring-like species.
- Mackerel: highly commercial species, in several LMEs; reasonable stock data; only indirect estimates of IUU fishing. To represent perch-like species.
- Sole and plaice: commercial species; reasonable stock data; higher vulnerability; only indirect IUU fishing estimates. To represent flatfishes. Halibut is assessed as Vulnerable by the Red List, but data are not sufficient.
- Swordfish: commercially important; high-value; vulnerable; published model available; estimates of IUU fishing rates. To represent tuna and billfishes.

Species which we would like to model, but can not, include the following:

- Nephrops: although present in the ICES database, there is no stock data. There are no estimates of IUU fishing levels, and the available advice from ICES does not include model data or results. We do not have a solution for representing crustaceans in the modelling.
- Bluefin tuna: available data do not allow estimation of a simple model. In simulations we model tuna along with swordfish. Estimates of IUU fishing level available.
- Species of sharks and rays: although some estimates of growth rates are available, we do not have good data for estimating carrying capacities or stock status.

We do not attempt to model stocks from the other less commercially important groups (see Figure 8), partly because of the lower value, and partly because of lack of data. However there are some species in these groups which may be quite sensitive to overfishing, for example anglerfishes. The approach to be taken, discussed further below, is not to model a single stock of each species, but rather to construct similar models for data from a number of stocks (of cod, for example) in order to compare results and ensure that projections are robust and conservative. Results from projections using these 'representative' models can then be used for extrapolation to the scale of commercial groups of fish within the LMEs, and to the fishing value extracted from these areas by European Member States.

2.5 Conclusions for Chapter 2

The analysis above suggests that a strategy of modelling the main commercial groups for each LME would cover the most important areas of IUU activity for EU fisheries.

The Outermost Regions will not be included in the quantitative projections, partly because the value of the fisheries is very low compared with the main EU fisheries, and partly because the fisheries are very different from those in continental European waters, involving different species and conditions. We would not be justified in extrapolating from temperate stock models to tropical fisheries. We do not attempt to model stocks in the Black Sea, where European Member States claim only a tiny share of the fisheries. And we do not attempt to model the least commercially important groups.

Information on the extent of IUU fishing is, unsurprisingly, thin on the ground. But such evidence as is available suggests that it is a serious problem in the EU. Various studies have produced estimates of IUU fishing rates for certain EU fisheries, many of them suggesting rather high rates in the 35–50% range, and over.

We have selected a set of representative species for modelling based on an overall consideration of evidence, data availability, stock characteristics and cost-estimating strategy. The methods for modelling are set out in more detail in Chapter 4. First, however, we consider the various costs of IUU fishing that can arise.

3. Types of costs of IUU fishing

The primary objective of this report is to assess the costs of IUU fishing. The qualitative costs of this activity can be described clearly, but quantitative estimates are challenging, not least because the actual amount of IUU fishing is so uncertain. This chapter discusses what we know about the various types of costs of IUU fishing, and how we can hope to derive estimates for some of them through modelling.

The various costs of IUU activity, discussed below, cover a range of economic, social and environmental impacts. But the boundaries between the different types of impacts can be vague and there are feedbacks between them, so in some cases the classifications below are somewhat arbitrary. For example, reductions in ecological resilience or stock status (environmental impacts) reduce the reliability and value of the economic resource base. In turn economic losses from sub-optimal stock levels have social impacts in terms of employment and population retention in fishing communities. Below, we treat environmental costs first, as the economic and social costs largely depend on that part of the environmental impact relating to fish-stock depletion.

3.1 Environmental costs

Depleted stocks. The most obvious cost of IUU fishing, and probably the most important overall, is the impact of increased fish mortality on stock levels, leading to reduced rates of stock growth, reduced recruitment, and corresponding losses in fishing opportunities in future years. The European Commission (COM[2008] 331 final) notes that in 88% of European stocks, overfishing is so serious that more fish would be caught if there was less fishing (outside the EU, the comparable figure is only 25%). Almost one-fifth of European stocks are in such a bad state that scientific advice is for zero fishing. The role IUU fishing plays in this problem is complex because the impact of greater mortality need not be linear. With fisheries under great pressure anyway, and with a tendency for the EU Council to set TACs well above scientific advice[35], there is a risk of serious overfishing or stock collapse, and this risk will likely be highly non-linear in catches. Therefore the marginal expected costs of IUU activities are much higher than the average expected costs over the whole catch.

Size-related impacts. Slightly more complex effects, potentially of great value for certain stocks, may occur if IUU fishing disproportionately targets smaller or undersize fish, compared with legal fishing. Reducing IUU activity can enhance the stock both by leaving younger individuals to grow and allowing them to reproduce before capture, with an impact on recruitment. Increased fishing mortality on smaller fish may result in evolutionary pressure towards earlier (smaller) sexual maturity, with significant long-term impact on the value of stocks. Costs could also arise where IUU activities target larger specimens, such as pregnant shark females, or large individuals contributing disproportionately to spawning output in other species. These effects exist for legal fishing, but may be highly non-linear, so could form a significant cost of IUU fishing for certain stocks.

Ecological impacts. By removing more of a stock, IUU activity will have knock-on effects on the stock's prey, predators and competitors. Again, this could be quantitatively different from the effect of legal fishing if the IUU activity is qualitatively different in size, selectivity, time or location. There may be impacts on stocks of other commercial fish, or on other marine species (including birds and mammals) caught incidentally in the fishery, or on habitats, especially if the IUU activity relates to non-respect of gear restrictions. Because IUU fishing is likely to focus on higher value fish, it worsens the trend towards 'fishing down the foodweb' (exhausting stocks of larger species and fishing on the smaller species that replace them). These impacts can result in losses of ecosystem services – food provision obviously, but also other services such as nutrient cycling, and tourism services (see Box 3 below).

[35] On average, over the last five years TACs decided by Council have been 48% higher than scientific advice (considering a TAC set when scientific advice is for a zero catch as a 100% excess). COM(2008) 331 final.

Extinctions. Extreme overfishing can lead to extinction or extirpations (localised extinctions) of certain species. While extirpations through direct targeting are rare (because it becomes uneconomic to chase the last specimens) ongoing by-catch of susceptible organisms in other fisheries can and does lead to extirpation and perhaps global extinction. It is difficult to distinguish clearly between IUU and legal fishing in their impacts on extinction risks. What is clear is that several species of fish in European waters are listed by the IUCN as Critically Endangered, Endangered or Vulnerable, while others may be endangered but have not been assessed or are listed as Data Deficient (see Table 4). Many sharks and rays in particular are under severe pressure from a combination of direct fishing and by-catch. The fundamental problem in most cases is harvesting, and IUU fishing is increasing the risks of extinction for these species.

Location- or time-specific environmental impacts. Some effects will be spatially/ temporally explicit, where the IUU activity relates to non-respect of seasonal, temporary and/or localised fishery closures, whether for protecting spawning aggregations, in the context of marine reserves, or for allowing depleted stocks to recover. The value of impacts here may be much greater than simple consideration of mass extracted would suggest, but the data to assess this quantitatively are lacking.

3.2 Economic costs

Reduced profits. IUU fishing has economic impacts for fishers and consumers. The short-term impacts may be positive, since the caught fish bring returns to fishers, and more/cheaper fish to consumers. However, the medium- and long-term impacts include fewer and lower quality fish, higher costs of fishing, and higher prices. More sustainable fisheries with healthier stocks could support substantially higher harvests, lower costs and lower prices, and both consumers and fishers could be substantially better off. This is the main economic cost we have modelled. We have modelled the value of fish caught, using models of stock response to fishing effort, and data on fish prices. We do not possess data to make a quantitative estimation of impacts on fishing costs.

Data quality. Absence of IUU fishing would have a further impact on fisheries through improving the quality of data. At present, the fact that IUU activity is largely an unknown quantity makes interpreting fisheries data difficult: the EU Commission has noted (COM(2008) 331 final) that: "Largely because of inaccurate catch reports, the state of some 57% of stocks is unknown". This reduces the quality of scientific advice to managers, and the ability of authorities to undertake optimal management of the environment and natural resources. In turn this can have a potentially large impact on the expected value of the fishery: the value of improving data quality could be significant.

Distorted markets. EU fishermen operating legally, and aquaculture producers, are competing with the unfair practices of IUU operators. This results in loss of market share for legitimate EU operations and trade distortions due to the different cost structures of legal and illegal operators[36]. Some IUU fishing is associated with poorer employment practices and may be more likely to be associated with employment in the informal economy, where costs, such as employment taxes or social security contributions, are not paid, which leads to a revenue loss to governments.

Reduced access to fisheries markets. The presence of significant levels of IUU fishing undermines the ability of fishery managers to ensure sustainable management of stocks, and this can make the product less attractive to corporate buyers. The Chair of the Food and Drink Federation's Seafood Group told the UK House of Lords (2008) about the pressures on companies to ensure their supplies are sustainable, citing the Baltic, where the estimates of 40% illegal fishing have created a "huge debate" within "major companies, as to whether they should stay in the Baltic or whether they should pull away totally from an EU fishery". Costs can also arise where IUU fishing contributes to non-sustainable stock management, preventing fisheries qualifying for Marine Stewardship Council (MSC) certification (which can create a premium for fisheries products, and more secure access to markets, and is experiencing growing levels of consumer demand).

[36] http://ec.europa.eu/fisheries/press_corner/press_releases/archives/com07/com07_69_en.htm.

Tourism impacts. Four types of potential tourism impact can be identified. Firstly, IUU fishing can contribute to stock reductions that cause imbalances in ecological systems, for example promoting increased jellyfish abundance, with a negative impact on the attractiveness of coastal bathing waters in some parts of the EU (see Box 3). Secondly, the availability of certain locally caught fish species may be part of the tourism 'product' of an area and so could be compromised if IUU activities contribute to the reduction of the availability of those species (e.g. diving to see sharks). Thirdly, IUU fishing impacts on wider marine ecosystems may reduce the abundance of other marine species that are an attraction to tourists (e.g. cetaceans, seabirds). Fourthly, and similarly, many target and by-catch species, including in particular larger species threatened by overfishing and IUU activity, are important game fish. These impacts represent direct costs to tourists, and if these are significant enough to influence patterns of tourism activity, these impacts will result in economic costs to coastal communities that see reductions in tourism activity.

International negotiations. For several straddling or migratory stocks, the European Commission, on behalf of the EU, undertakes negotiations with third countries regarding management and allocation of quotas. The EU is a contracting party to 11 RFMOs and will shortly be joining two more.[37] High levels of IUU fishing in Community waters or by the EU fleet can weaken the bargaining position of the Commission, because its partners may not believe that it can enforce any agreement it enters into. In some cases this could cause an agreement to break down, or prevent an agreement from being reached in the first place. Hence, IUU fishing by Member States reduces the Commission's assets in international negotiations.

Box 3: Tourism impacts from overfishing and IUU activities

Overfishing, exacerbated by IUU, can result in long-term or irreversible ecosystem damage, and serious losses beyond the particular fishery. Cury (2004) notes that shifts from demersal fish dominated to pelagic-fish-dominated ecosystems, and shifts towards short-lived species such as shrimps, crabs or octopus, have been documented in the Atlantic and the Baltic (Worm and Myers, 2003). Shifts from fish-dominated to jellyfish-dominated ecosystems have been observed in the Bering Sea, the Black Sea, the Gulf of Mexico, the western Mediterranean Sea, Tokyo Bay and off Namibia (Parsons and Lalli, 2002).

When predators such as tuna, sharks, and turtles are overfished, fewer jellyfish are eaten, and they have less competition for food. This may result in a regime shift which is practically irreversible. Brierly (2008) stated that: "Jellyfish both compete with fish for plankton food, and predate directly on fish. It is hard, therefore, to see a way back for fish once jellyfish have become established, even if commercial fishing is reduced."

This is bad news for the fisheries, but also more generally for coastal tourism. Tourism accounts for about 4% of the EU's GDP and is concentrated in particular areas, including coastal communities.

3.3 Social costs

Reduced employment: Although, in the short term, IUU fishing may help to maintain employment in fisheries, a clear corollary to the resulting stock depletion and catch reduction is loss of employment opportunities in fishing and related industries. This impact will be felt most in communities that are heavily dependent on fishing.

We have estimated this social cost in the modelling, however it is important to realise that the margin of error is substantial, for the simple reason that there is a choice regarding how fishing opportunities are divided among fishers and vessels, in effect between a more employment-intensive fishing fleet or a more capital-intensive fleet. In fact, the number of jobs per million euros of landings value appears to vary enormously across the EU, as

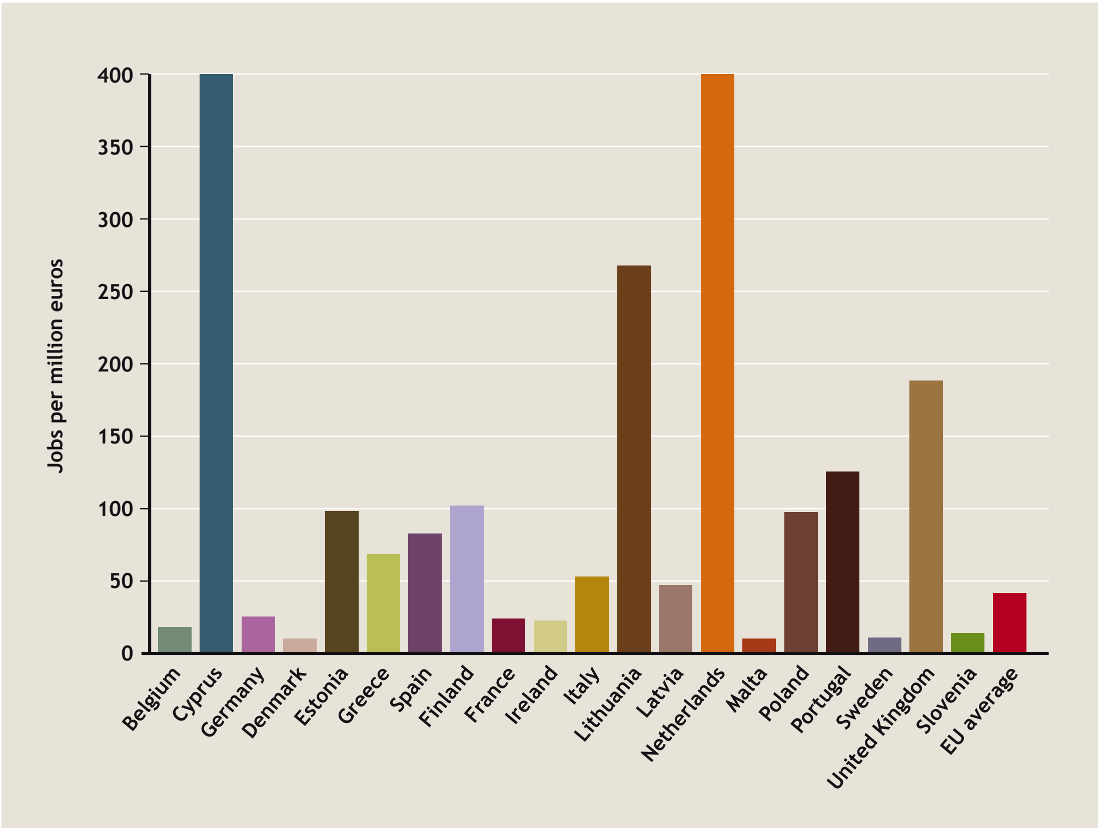
[37] http://ec.europa.eu/fisheries/faq/external_relations_en.htm.

illustrated in Figure 9. This reflects different technical and economic characteristics of fisheries, but may also be partly due to inconsistent reporting protocols.

It is also worth noting that the structure of the fleet may in turn have implications for IUU activities: a smaller, more profitable fleet may have a higher stake in the long-term status of the stocks than a large fleet operating essentially in open access.

Community impacts: Fishing communities will suffer from IUU activity through unfair competition in the industry. This may also force more fishers to engage in IUU fishing in order to compete and thereby suffer reduced security through the risks of detection and punishment. These problems could be divisive in traditionally close-knit communities, and can kindle great resentment against fishers from other areas or nations who are perceived to be playing by different rules. The long-term impact of IUU activity on fishing employment and communities will be negative, since IUU fishing hinders stock maintenance and/or recovery, leading to fisheries that can not support so many fishers.

Figure 9: Jobs per million euros landed value[38]



3.4 Modelling options

The key element in modelling the costs of IUU fishing is to consider the increases in fishing mortality arising from IUU activities and the impacts this has on stock depletion. Most of the other costs follow from this, although in more or less complex ways. For example, it would not be possible to model size-specific impacts without using a size (or age) structured model. But some costs also depend heavily on other factors, such as the social and economic structure of the communities engaged in fishing. The data requirements for assessing the costs vary, and data- and modelling-intensive approaches, which would be feasible in a detailed study of a particular IUU problem in a given fishery, are infeasible in a broad-brush study of IUU activity in all EU fisheries. Table 5 summarises the ways in which

[38] Landings data five-year-average values (2000–2004) converted to euro (2008), from www.seaaroundus.org. Employment data from Eurostat, most recent years available for each country. Outlying full values not shown for Malta (2,025) and Cyprus (711). EU average is calculated from total value and total employment, so these outliers do not influence it unduly.

the different costs might be modelled, commenting on data availability and modelling feasibility within the context of this study, and starting with those costs that we aim to assess for IUU activity in EU fisheries.

Ideally we would also like to consider the impact of IUU activity on the costs of fishing. However this is not feasible, partly because data are lacking, but also because costs are highly dependent on fuel prices, and in particular because the costs depend on the way in which policy is implemented. For example, it is cheaper to have a small number of big boats in a relatively capital-intensive fishery, but for social reasons it may be preferable to have a less capital-intensive, higher-employment fishery. It is not the aim of this report to delve into these issues. But we know that costs per unit of catch will fall for higher stock densities, so since IUU fishing reduces stock densities, we can be confident that IUU fishing has the effect of increasing costs for legitimate fishers.

Similar arguments suggest that the specific social impacts of reducing IUU activities are difficult to estimate because they too are policy dependent. The best we can do in the circumstances is to take data on fisheries and processing employment and assume that these are linearly, or at least monotonically, related to catch sizes, enabling us to derive an index of social 'value' for the fisheries. More complex approaches are possible – for example taking into account the distribution of returns across different gear types – but we have not modelled this explicitly.

Our models give estimates for the impact of IUU fishing on stock size in the modelled commercial groups. This covers only part of the environmental costs of IUU activities. In particular, it does not touch on the problem of by-catch and how this might influence survival probabilities for threatened species.

3.5 Conclusions for Chapter 3

IUU fishing results in a range of inter-related environmental, social and economic costs. Several of these costs depend quite heavily on the status quo ante, including the state of the stock, the capacity of the fleet exploiting it, the history of catches and the number of jobs in the fishing and processing of the catch. When modelling costs, we have considered the current state of the fisheries, and assessed what would happen if IUU activity were to be removed. This gives a measure of the costs of IUU fishing: not what IUU activities have cost in the past, but what we stand to lose now and in the near future through continued failure to control IUU fishing.

However, many of the costs listed above can not be identified quantitatively without detailed data and modelling, beyond the scope or resources available for this project. From our review of existing evidence, we have concluded that the most important cost is the environmental cost of depletion of target stocks. Most other costs follow from this, including the key economic costs of lost fishing revenues and social costs of lost employment opportunities. In addition, there are costs arising through the by-catch associated with IUU fishing, which depresses other stocks and creates risks of extinctions for vulnerable species.

The scope for assessing these costs depends on data availability and modelling feasibility, at the scale of analysis under consideration. In this report, focusing on IUU activities in EU fisheries, data availability is a major challenge which we have overcome by extrapolation to the EU scale from those cases in which sufficient data are available.

Taking this into account, the three main costs we have assessed in this report are:

- Impact of IUU fishing on stocks of target species;
- Costs of IUU fishing in terms of reduced value of fish landed; and
- Costs of IUU fishing in terms of reduced employment in the fishing and processing industries.

The next chapter discusses in more detail the modelling approach we have adopted in order to estimate these costs.

Table 5: Modelling options for different IUU fishing costs

Cost of IUU fishing	Modelling options	Likely significance	In estimates?
Ecological costs			
Depleted stocks	Model IUU fishing as extra effort; catch or fishing mortality in same unit as legal fishing within a dynamic fishery model. Many options, of which the simplest is surplus-production modelling. For some fisheries, necessary data are available and modelling is feasible with the resources available. Extrapolate from results, taking account of different fishery characteristics and assuming rules for TAC setting. Feasible for this project.	Highest. We use simple surplus-production models and TAC-setting strategies to give quantitative estimates of stock depletion.	Yes
Size-related impacts	Increased fishing mortality or catchability for specific age/size classes in age-structured model. Could model different size selectivity of IUU activities as a separate fishing gear. But data on selectivity not available, modelling becomes complex, and results not generalisable.	High in certain specific cases; more generally low or zero.	No
Ecological impacts	Multi-species or whole-ecosystem models. Very data- and resource- intensive: not feasible in this project. Alternative approach is extrapolation from existing evidence on impacts of overfishing.	Probably high.	No
Extinctions	Of target stock – covered by depletion models. Of by-catch stocks – requires additional model for dynamics of vulnerable stock. Alternatively, extrapolation from evidence on impacts of overfishing.	High in certain cases, and highly non-linear.	No
Location/time specific impacts	Spatial models, with IUU effort inside protected zone, or models with closed periods. Requires detailed data on specific fisheries; not possible to generalise. Not feasible in a general project.	May be high in specific cases; more generally low or zero.	No
Economic costs			
Reduced profits	Derives from depleted stocks: use same models. Quantity covered by harvest impacts, valued using available data on fish price. Feasible. Full price-quantity requires modelling demand for fish, or for specific market types (e.g. MSC certified): data not available, and too resource-intensive for this project. Accounting for costs requires stock-dependent cost or catchability function. Requires detailed data, mostly lacking. Costs highly variable with fuel prices and with decisions about fleet size/quota allocation. Not feasible within the scope of this project.	Highest. We use the same models to estimate the costs of IUU fishing in terms of reduced catches, valued at existing prices.	Yes, partly
Data quality impacts	Explicit modelling of the management algorithm, e.g. TAC setting, based on data from fishery with/without IUU activity. Requires multiple simulations using detailed data on specific fisheries, ideally taking account of randomness.	May be high. Dependent on management regime.	No

Table 5: Modelling options for different IUU fishing costs			
Cost of IUU fishing	**Modelling options**	**Likely significance**	**In estimates?**
Distorted markets	Requires modelling profits of IUU and non-IUU operators. Would require primary data collection.	Could be high.	No
Reduced access to markets	Requires detailed data collection; difficult because strategically sensitive. Not feasible.	Historically low, may become high in certain cases.	No
Tourism impacts	Anecdotal evidence. Modelling would require collection of primary data on tourist preferences.	Probably minor in most cases; locally high.	No
International negotiations	Incorporate IUU fishing in pay-off functions for game-theoretic models for key fisheries. But results are case specific, and no quantitative information on which to base assumptions.	Could be high in some cases; generally low or zero.	No
Social costs			
Employment	Modelling the income shares of 'legal' and 'illegal' fishers or the employment impacts of catch changes requires detailed assessment of individual fisheries, including determination of choice between fleet size and profitability. Data intensive, and data largely lacking. A feasible simplified alternative: relating future catches to future jobs in fishing and processing based on current catch/employment ratios.	Highest. We adopt the simplified approach to give approximate quantitative measures based on modelling as described above.	Yes, simplified
Community impacts	Qualitative measures. Not possible to assess without intensive primary data collection from affected communities.	May be significant in some cases; could change rapidly.	No

4. Description and assessment of suitable models and simulation approaches

The preceding chapters give some indication of the stocks most susceptible and vulnerable to IUU fishing, and of the qualitative nature of the costs involved. In this chapter, we draw on that information to determine the appropriate modelling and simulation strategy, taking into account the practical constraints of time and data availability, and the overall objectives of the project, in order to assess the costs of IUU fishing.

4.1 Sketch of our approach

The task for this study was to develop simulation models for key commercial groups of fish within LMEs. In order to do this, we have estimated how quickly stocks within each group tend to grow from year to year. We have first estimated growth models for several individual stocks, considered to be representatives of their commercial groups. Using the results of these growth models, and additional data and assumptions, we have developed simulation models for the commercial groups, and modelled the catches and stocks of the group under different management regimes and different levels of IUU fishing. Using our best estimate of the actual level of IUU fishing, and of the management regime thought most similar to real EU TAC setting, we have developed conservative estimates of the environmental, economic and social costs of IUU fishing within each commercial group modelled. With the data available, we were able to model 14 commercial groups, representing 46% of fishing value in the five LMEs. We extrapolated the cost estimates resulting from catches across commercial groups within each LME, and then broke these results down by Member State fishing.

The following process has been used:

- Collect datasets for key stocks (this chapter).
- Estimate simple stock-growth models for these stocks (this chapter).
- Analyse the model fits and parameters for stocks modelled within each commercial group, to derive representative growth rates for these groups (this chapter).
- For two case studies, cod-likes in the Baltic and tuna/billfishes in the Mediterranean, simulate the costs of IUU fishing under a range of different levels of IUU activity and with different TAC-setting rules, using the results to illustrate how the costs of IUU fishing vary with these characteristics and demonstrate the method underlying the estimation of IUU activities costs and extrapolation to Member State fishing (see Chapter 5).
- Drawing on IUU activities data, fisheries data and the model results, derive a 'representative' model for each commercial group in each LME, and simulate the costs of IUU fishing (see Chapter 6).
- Disaggregate these costs for Member States, by assuming that those states exploiting the stock legitimately share the costs of IUU fishing in proportion to their share of fishing value within each LME (see Chapter 6).

To maintain a conservative approach, we have restricted attention to a relatively short time period (up to 2020), and cross-checked with historical data to ensure that our projections remain within the bounds of historically feasible catches within and between commercial groups, in order to control for the possibility of any substitution or regime shift effects.

The approach adopted here is simplified, but has allowed us to derive models which can be generalised to the level of EU fisheries, resulting in conservative estimates of some of the environmental, economic and social costs of IUU fishing in EU fisheries.

4.2 Options for modelling fish stock growth rates

There are many different options for modelling fish stocks. Mass-balance models of whole ecosystems can be constructed, but this requires large quantities of data and considerable time and skill. Detailed statistical models of individual stocks and fisheries are widely used, for example by ICES for generating advice on TAC setting. At the other extreme there are theoretical models of fisheries demonstrating mathematical results under specific assumptions, relating to economic and ecological conditions in fisheries. Some of these models incorporate random environmental effects, predator-prey or competitive interactions, fleet dynamics, fisher decision making, and so on. Most fisheries science and management advice uses relatively simple single-species models, in particular:

- Surplus-production models of stocks based on catch and effort or abundance data;
- Yield-per-recruit analysis and other modelling based on key biological parameters of individual stocks; and
- Virtual population analysis aiming to estimate fish numbers in each age group, based on estimates of fishing and natural mortality.

The key objective of this project is to create initial estimates of costs of IUU fishing to EU Member States, across a wide range of stocks and circumstances. This requires a fairly simple modelling approach, making use of existing data sources, to derive models that fit the past data well enough to support projections over the short to medium term. There is strong evidence linking reductions in fishing effort (F) with increases in biomass (see e.g. Mace, 2004) and this gives a good base on which to assess likely impacts of reducing IUU fishing. Models of fleet dynamics or fisher behaviour, or models requiring detailed data and analysis to study age structure, while clearly relevant to IUU activities, are too complex, and not sufficiently generalisable. The constraints of data availability, modelling time and objectives, suggested simple surplus-production modelling as the best approach; results have been supplemented by arguments about how the cost estimates could change with the introduction of various more complex considerations.

The general idea of surplus-production modelling is to assume some general functional form for the dynamics of the fish population and to estimate the parameters for particular stocks of fish with real-world data. In turn, once the dynamics of a given stock have been estimated from the data, we can use the model to simulate the dynamics of the fish population under various scenarios.

The models assume that the fish population can be seen as an undifferentiated biomass whose rate of increase or decrease over time can be explained by a simple growth function. For example:

$$X = Y + rY(1-Y/K)$$

In this formula X is the population biomass, Y is the escapement (stock minus harvest)[39] and r and K are the parameters of interest, respectively the intrinsic growth rate of the stock and the carrying capacity. This is the logistic or Schaefer model (Schaefer, 1954) and is one of the simplest but most robust and widely used fisheries models. It gives a symmetrical growth function, with maximum sustainable yield (MSY) equal to rK/4 at a stock level of K/2.

An alternative is the Fox model (Fox, 1970):

$$X = Y + rY(\mathrm{Log}(K)-\mathrm{Log}(Y))$$

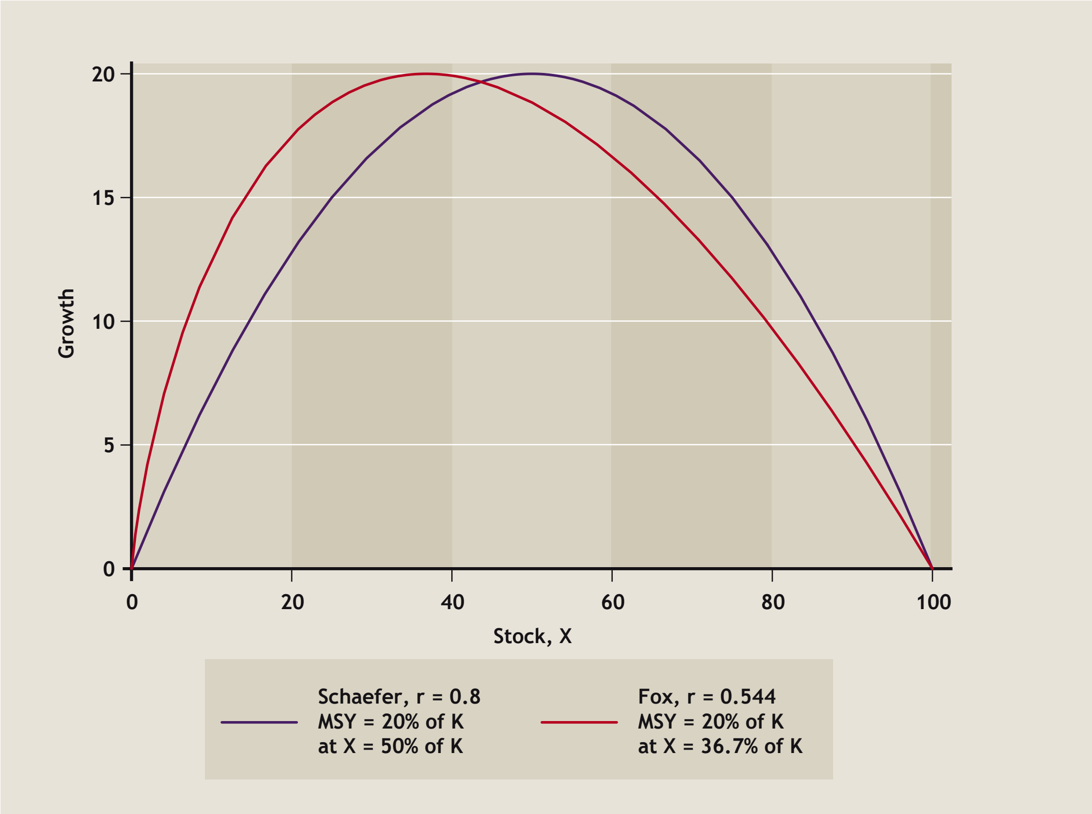
This model gives a growth curve similar to Schaefer's, but skewed slightly, giving a MSY of rKe^{-1} at a stock size of Ke^{-1}. The models are sketched in Figure 10, which shows stocks with the same K and MSY, which require a lower value of r in the Fox model than in Schaefer's. Conversely, for given values of r and MSY, the Fox has a larger K. This is relevant in the estimation, since it implies we can not take r values from one model and directly compare

[39] One slightly unrealistic aspect of stock modelling is the need to separate harvesting and growth in time. In fact, both processes are more or less continuous, but for modelling purposes we must assume that the starting stock is first harvested, then the escapement grows, then the new stock is harvested, then its escapement grows... and so on.

with the other, and because the data available generally allow better estimation of r than of K, as discussed in section 4.4.

A generalised model encompassing both forms is also available, but is more sensitive to outliers (Prager, 2002); unless there is strong evidence to the contrary, the logistic model is generally more robust.

Figure 10: The Schaefer and Fox surplus-production models (stock as % of carrying capacity)



Surplus-production models have the great merit of being relatively simple and tractable, making it feasible to work with them for several different groups in different areas. The downside to this advantage is that they also have weaknesses relating to oversimplification. While recognising the weaknesses of single-species modelling, our objective has not been to derive detailed prescriptions for the management of particular stocks, but rather to derive growth parameters for use in simulation models of the costs of IUU fishing, at a continental scale. For that purpose, these simple models are the most appropriate choice. Therefore, for a number of stocks, we have estimated the single-species Schaefer and Fox surplus-production models using data for abundance and catches, using linear and non-linear regressions.

Box 4: Risk of double-counting when combining single-species models

The main problems which can arise with a focus on single-species management are that it takes no account of the problem of 'fishing down the foodweb' (Lotze, 2004), nor of the potential for regime shifts or competitive impacts within groups. This could lead to double-counting, which is when we assess several stocks in the same ecosystem. For example, if we model fisheries from different groups such as "cod-like" and "herring-like", there may be a risk of double-counting where (for example) a restored Baltic cod fishery could result in a less productive sprat fishery, or where a sardine-anchovy pair alternate in dominance of an upwelling system.

There are potentially three options here: one is to review data and comment on the risks of double-counting; a second is to focus just on the most important stock in each fishery; and the third is to construct models for composite fisheries – that is, rather than modelling 'cod' in the North Sea, we model 'cod-likes' – cod, whiting, haddock, saithe (coley) – in a surplus-production model for the 'stock' of this whole group in the area. This last approach has several attractions, though data availability is a problem, and we have carried this out in this study.

However, EU fisheries are generally heavily overfished, as reflected in poor stock status for most stocks. Therefore, it seems quite likely that it would be possible to restore stocks across the board, and to increase stocks and catches over current levels from all commercial groups, with any trade-offs kicking in only later on within restored fisheries systems; so provided our projections are kept short- to medium-term, double-counting of costs is very unlikely.

4.3 Estimation methods for stock-growth models

We have tested the Schaefer and Fox surplus-production models for 41 stocks for which we could find potentially suitable data. Although for many stocks the fits were not very good, we did manage to find suitable fits for three cod-like stocks, two flatfish, two herring and one perch-like. The stocks are not all from the European EEZ, though all are nearby. In particular, the longest ICES data series are for Arctic stocks, and since the length of the data series is very important in determining the quality of the fit, some Arctic cod-like stocks have given the best results in that group.

We estimated r and K directly from linear or non-linear regression methods. The simplest way to do this involves regressing fish stock on a function of lagged (previous year's) fish stock, but then there is a potential problem that the errors in the model are correlated with the explanatory variables, leading to biased estimates. To avoid this, we have used an instrumental variable (IV) approach. This means using an 'instrument' or substitute for escapement in place of actual escapement; the instrument must be highly correlated with actual escapement, but will not be correlated with the error terms. The obvious candidate, which we used, is the escapement from the previous period. That is, we have estimated stock for year t+2 as a function of escapement in year t, instead of year t+1. Tests of correlation show that the errors (residuals) are indeed correlated with the independent variable in the standard regressions, sometimes very strongly, and that the correlations were successfully entirely removed using the instrumental variable approach. But in fact the parameter estimates are in general not significantly different between different forms of a single model. The estimates are a little different for the Fox and Schaefer forms, but the estimated values of MSY are generally very similar across all models for most stocks.

4.4 Results of stock-growth models

Figure 11 and Figure 12 show two examples of the full output of the regression analyses. The stocks shown here, Celtic Sea sole and Arctic cod, represent the better-fitting models. Each figure shows the six estimated curves, and the raw data points, relating escapement on the x-axis to stock growth on the y-axis. In each case, the two curves slightly skewed left are the Fox models (non-linear models, with and without IV approach) and the remaining four are the Schaefer models (linear and non-linear, with and without IV).

The data here show sufficient spread to allow all the models to give similar parameter estimates, however there remains substantial unexplained noise in the data. This is a general phenomenon and few of the models achieve R-squared values much over 0.2, though for this kind of work a value over 0.2 can be considered reasonable.

The main problem in fitting arises in two ways. The fact that the overall explanatory power of the models is generally limited is a reflection on the large amount of variation in the data, perhaps due to environmental factors, interactions with other species, or other aspects not controlled for in the models; and perhaps also due to data quality issues. Additionally, the models are mostly poor at determining the theoretical maximum population size (K). This is for two reasons, both connected with fishing: because the stock sizes are generally low, there is little data from stock sizes near K; while, for many stocks, the general trend in stock has been downwards, whereas good quality data for estimating the relationship need to show both sustained increases and decreases in stock size.

Although they do not explain all the factors influencing stock growth, this does not mean that models can not be used. The error terms in the IV models appear normally distributed, suggesting that the parameter estimates are unbiased. The models, when applied to the real data, track stock movements very well. In fact, the low R-squared values simply mean that while we can expect substantial interannual variability in growth rates, based on factors not included in the model, *on average* the predictions will be close to reality.

The figures illustrate the variability in the estimates of K, seen as the point at which a curve cuts the x-axis to the right. The estimates of the intrinsic growth rate, r, seen as the slope of a curve at the origin, are much more similar within each model type (Fox or Schaefer). Selected results are presented in Table 6 – these primarily include examples with good fits, and a few with rather poor fits. In this table, and in the rest of the report, we refer only to the output of the linear Schaefer models using instrumental variables. These are preferred because of the possible bias noted above (though as also noted the estimates are similar), and because there is no clear evidence favouring the Fox over the Schaefer form.

Although each regression model estimates both growth rate r and carrying capacity K, our primary interest has been in growth rates of different kinds of stock. These are the estimates one can transfer to commercial groups. The estimates of K, on the other hand, are stock-specific, so we have derived these separately for the commercial groups by a combination of examining past data and assumption about the ratio of stock to carrying capacity, taking into account evidence from ICES assessments and advice[40]. Therefore the high variability in the estimates of K is not a major concern.

[40] In each case using the most recent advice available (either 2007 or 2008) from the ICES website: http://www.ices.dk/advice/icesadvice.asp.

Figure 11: Estimated surplus-production models for the Celtic Sea sole stock

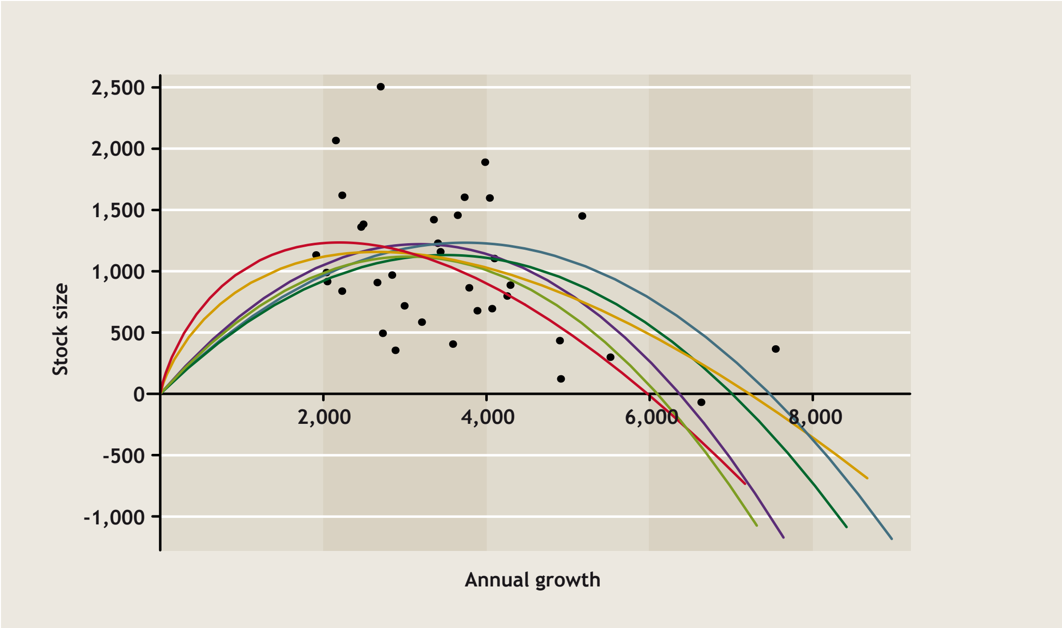
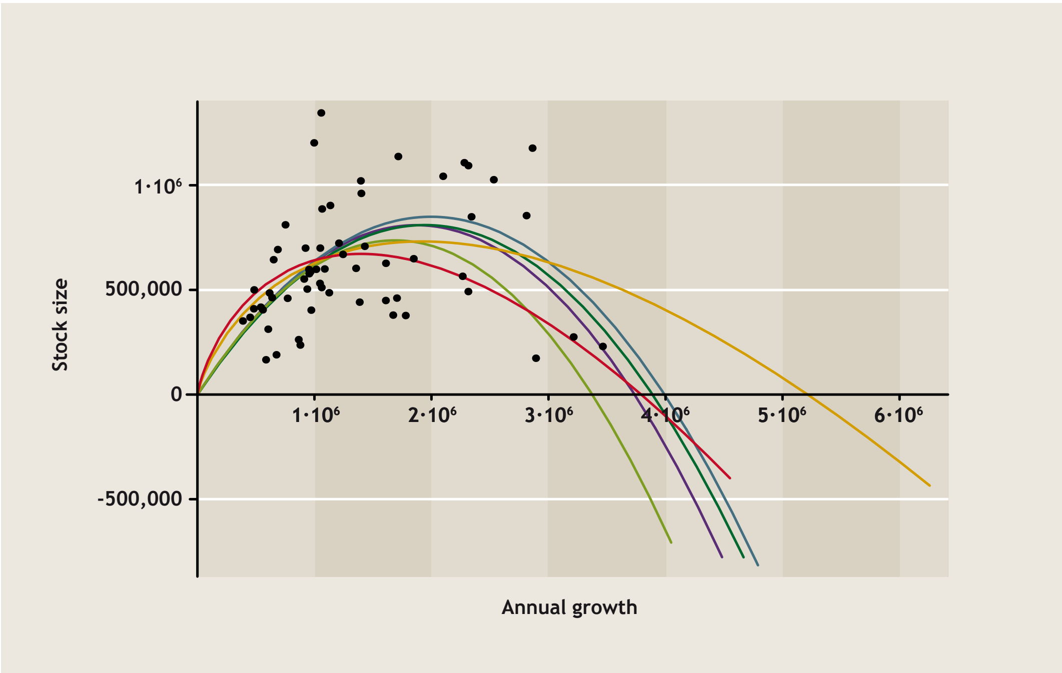


Figure 12: Estimated surplus-production models for the Arctic cod stock



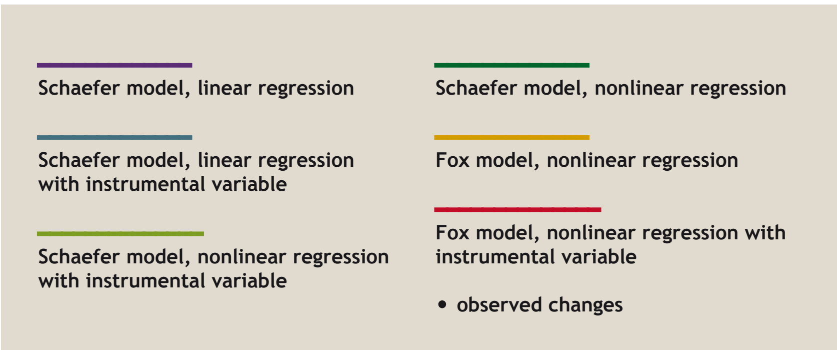


Table 6 summarises results for selected stock-growth regression models. Within each group (cod-like, flatfish and herring-like) the estimated intrinsic growth rates are broadly consistent. The estimates for K are generally less well-defined, and (though the table does not show this) the K estimates often vary substantially across the six different model estimation methods used and often have quite wide confidence intervals. There is a suspicion that the K estimates may be a little on the low side because some of the data sets include stocks higher than the estimated K – in fact, the most recent biomass estimates for some stocks[41] modelled exceed the estimate value of K. On the other hand, the K estimates presented do seem broadly consistent with ICES advice on Bpa (the precautionary biomass level that management aims to stay above).

Table 6: Results for selected models, and comparison with data

Stock	r	K (000t)	R-sq	MSY (000t)	Recent catch/MSY	Recent biomass/K	ICES advice	Bpa/K
Cod (Arctic)	0.85 (0.73–.97)	4,000	0.34	849	0.70	0.37	Bpa=460; sustainable	0.115
Cod (Faroes)	0.80 (0.60-0.99)	130	0.32	26	0.41	0.20	Bpa=40; zero	0.310
Haddock (34)	0.83 (0.31–1.35)	3,500	0.06	736	0.07	0.32	Bpa=140; sustainable	0.040
Haddock (Faroes)	0.74 (0.40–1.09)	120	0.14	22	0.75	0.68	Bpa=35; zero	0.290
Haddock (W. Scotland)	1.33 (0.77–1.89)	100	0.19	34	0.48	0.44	Bpa=30; zero	0.300
Saithe (Arctic)	0.82 (0.70-0.94)	1,100	0.52	227	0.93	1.18	Bpa=220; sustainable	0.2 (and K<max. stock!)
Saithe (Faroes)	0.52 (0.36-0.68)	320	0.20	41	1.52	0.75	Bpa=85; unknown status	0.27
Herring (2532)	0.30 (0.20-0.41)	2,900	0.22	223	0.49	0.44	<147; underfished	
Herring (30)	0.27 (0.13-0.40)	735	0.06	49	1.41	0.58	<67; TACs not limiting	
Herring (47d3)	0.53 (0.39-0.66)	4,400	0.27	582	0.87	0.88	unknown	
Mackerel (N-E. Atlantic)	0.82 (0.65-1.00)	3,600	0.45	743	0.64	0.62	Bpa=2300	0.64 (but K < max. stock!)
Plaice (English Channel W.)	0.72 (0.41-1.03)	10	0.03	1.89	0.67	0.34	Bpa=2.0; Blim=1.3; major cut	0.200
Sole (Celtic Sea)	0.66 (0.45-0.87)	7.4	0.22	1.23	0.77	0.53	Bpa=2.2; <1.0	0.300
Sole (Irish Sea)	0.61 (0.33-0.88)	9.3	0.06	1.42	0.40	0.23	Bpa=3.1 Blim=2.2; overfished	0.330
Sole (Kattegat/ Skaggerak)	0.64 (0.38-0.90)	6.3	0.21	1.01	0.72	0.75	Bpa=1.06; sustainable	0.170

Table 6 illustrates that although the results are not ideal they give a broad basis of support for some assumptions about the growth rates of commercial stocks in EU fisheries.

This has been supplemented with information from published models. It is generally the case that longer-lived species exhibit slower stock growth, and Punt and Hilborn (1996) recommend r estimates in the range 0.1–0.4 for longer-lived species such as anglerfish. For some vulnerable species, rates can be much lower – for example, Gedamke et al. (2007)

[41] For example, Saithe (Arctic) in Table 6.

estimate 0.03–0.06 per year for lemon sharks. They also note that some elasmobranchs can exhibit much faster population growth, citing the barndoor skate growth rates of 0.36-0.4, which nevertheless remain below the estimates for other species presented here.

Within ICCAT, the 2007 Mediterranean swordfish stock assessment uses estimates of 0.67 for r and 90,547t for K. The 2006 billfish assessment meeting presents estimates for blue and white marlin in the range of 0.1–0.4. As noted previously, the jury is out on the bluefin tuna and we are not aware of any existing parameter estimates for the simple models considered here.

4.5 Conclusions for Chapter 4

Based on the modelling exercise, and limited results from literature searching, we can move forward to the simulation stages with a set of growth parameters for application to the different commercial groups. It is appropriate to err on the side of conservatism in assessing the parameters, and this consideration gives the following list of central estimates and confidence ranges for intrinsic growth rates:

- Cod-like species: 0.75 (0.6–0.9).
- Perch-like species: 0.75 (0.6–0.9).
- Flatfish species: 0.6 (0.45–0.75).
- Herring-like species: 0.3 (0.2–0.4).
- Tuna and billfishes: 0.5 (0.4–0.6).
- Sharks and rays: 0.15 (0.05–0.25).

These estimates are working assumptions, based on the models, and aim to represent the groups. But we make no claim that these values are 'right'. By modelling different commercial groups with different assumed growth rates, the simulations will test how sensitive the cost estimates are to variations in these parameter estimates.

5. Demonstrating the simulation method: two case studies of commercial groups

To simulate the costs of IUU fishing, we have defined a simple model of the combined fishery for each commercial group in each sea area. The model combines a surplus-production model of stock dynamics with a model of harvest strategy. For the stock dynamic part, we have transferred the estimates of stock growth rates for stocks representing the commercial group (see Conclusions to Chapter 4) and have determined the carrying capacity separately. The management strategy was specified through one or more rules for determining TACs; some such rules required defining an additional parameter, such as the precautionary threshold for biomass, Bpa. Finally, we have initialised the simulations by deciding on the starting stock and starting TAC.

In this chapter we produce two fully worked examples to demonstrate the methodology, and explain the approach to the simulations, aiming to establish estimates of the costs of IUU fishing for each of the LMEs considered.

The full examples are cod-like stocks in the Baltic and tuna/billfish stocks in the Mediterranean. We chose these stocks because:

- They have different characteristics;
- They are important fisheries within their areas;
- We have good estimates of IUU fishing rates; and
- There is some data on stock status.

5.1 Modelling IUU fishing, carrying capacity and TAC-setting rules

Once the parameters of the surplus-production model for the commercial group have been estimated, it is possible to simulate the time path of the stock biomass according to the level of catch in the years of interest, or equivalently, according to the fishing mortality. Doing this while including and excluding IUU fishing allows the costs of IUU activity to be calculated by comparing the outputs of the models. But in order to do this we have had to specify rules to determine (a) the level of IUU fishing and (b) the level of TACs.

Rule for setting the level of IUU fishing

The IUU activity is modelled using an assumed percentage rate of IUU fishing (see Table 1). The percentages are expressed in terms of total catch. Since:

- Total catch is IUU + legal catch, and
- IUU fishing is defined as a fraction "u" of total, and
- Legal catch is the TAC, therefore
- The total catch is TAC/(1-u), and
- The IUU catch is u*TAC/(1-u).

The IUU parameter 'u' is based on the evidence available (see Table 7), with conservative estimates used where direct data are not available. The main cost results discussed below make use of these IUU fishing rates, though we have carried out simulations for a range of IUU rates (from 0 to 90%) in order to test the full range of possibilities, and to check for thresholds.

Table 7: Best estimates of IUU fishing rates for commercial groups modelled		
Commercial group	IUU fishing estimate	Rationale (c.f. Table 1)
Baltic cod-likes	40%	Average of 35–40%, 45%.
Baltic herring-likes	35%	35% estimate.
Celtic cod-likes	45%	Average of 30–60%.
Celtic flatfishes	35%	No direct data – by analogy with other areas, and European-level arguments, 35% is minimum expected.
Celtic herring-likes	35%	
Celtic perch-likes	35%	
Iberian cod-likes	40%	As above, but 40% by analogy with other cod groups – cod higher risk for IUU activity.
Iberian perch-likes	35%	See Celtic perch-likes.
Iberian tuna/billfishes	36%	36% estimate.
Mediterranean tuna/billfishes	45%	Average of 40%, 50%.
North Sea cod-likes	50%	"Up to 66%" and other figures suggest 50% as safe estimate for North Sea
North Sea flatfishes	50%	
North Sea herring-likes	50%	
North Sea perch-likes	50%	

This method fits well with the data we have, which express IUU fishing as a percentage of total catch. However, there is a particular problem: when TACs are low or zero, IUU fishing will also be calculated low or zero, since we are defining IUU catch as a proportion of total catch. It is however unrealistic to assume that IUU fishing stops if TACs are set to zero. So in some of the simulations, we have assumed a minimum level of IUU activity.

Unfortunately we have no data which tell us what such a minimum level might be. All we have to go on are estimates of recent IUU fishing rates and data for recent catches. So we have defined a parameter equal to 75% of the average annual catch from 2000–2004. For all the groups modelled, this parameter is less than the expected stock growth at 20% of the carrying capacity. We have estimated the minimum IUU fishing level as being the IUU percentage 'u' multiplied by this parameter.

In effect, this assumes that the minimum level of IUU fishing is 75% of recent levels of IUU activity. Given that the majority of EU fisheries are currently heavily overexploited, and that catches are depressed from what they could be in healthy fisheries, this seems a reasonably conservative approach to take.

Estimating carrying capacity for groups

As noted above, unlike the intrinsic growth rate, the carrying capacity can not be transferred directly from the individual stock models. Each commercial group is made up of a number of stocks, and the composite carrying capacity can not be estimated by modelling any single stock. Consequently we have determined a carrying capacity and starting stock for each commercial group modelled.

To do this, we have made a judgement based on recent and historic catch levels for the group (including assessment of any period in which the catches appeared to be sustained at similar levels over many years, and of any period in which catches at a given level were followed by sharp declines in catches), current advice regarding biomass of key stocks in the group and where they lie with respect to the precautionary thresholds, and our estimate of r. This was a difficult judgement to make, and we sought to make it conservatively, erring on the low side in setting the carrying capacity.

Given our estimates of K and r, knowledge of recent catches and, where possible, stock assessments and advice, we also had to assess starting stocks for each group. As discussed in section 3.1, we know that 88% of European stocks are considered to be overfished, meaning that they would produce higher catches if they were allowed to recover, so we should expect estimates of starting stocks to be rather less than one-half of the carrying capacity.

The full procedure for estimating carrying capacity and starting stock is best explained through examples, and is illustrated in the case studies, below.

Rules for setting TACs

To run the simulations, it is necessary to specify the way in which TACs are set, in relation to observed stocks or landings. Actual TAC setting is a complex process, relying partly on scientific advice and partly on political negotiation. We have not attempted to model this process, and in determining how to establish TACs for the scenarios, we have taken account, insofar as it is practical, of the most recent guidance from the European Commission (COM(2008) 331 (final)) on their rules for TAC setting and maximum inter-annual changes in TACs. But the costs of IUU fishing may depend on the specific rule used. There are endless possibilities. We have tested several, and have retained six for illustrating a range of interesting features.

Rule 1: MSY TARGET. Our models do not take account of costs, and do not include a discount rate. Under these conditions, the optimal policy in a simple surplus-production model is a policy of constant escapement at the stock level supporting MSY. This is one rule that can be simulated easily. TAC is set at zero if the stock is less than K/2, and at whatever it takes to reduce the stock to K/2 otherwise. This yields excellent results in terms of total catch and stock levels. But there is a particular problem which makes this rule quite unrealistic: TACs can vary considerably, and may often be zero.

Rule 2: MSY TARGET + MIN IUU. As noted above, it is (very) unrealistic to assume that IUU activity stops if TACs are set to zero. So in this rule variant, we have assumed a minimum level of IUU fishing, as explained above.

Rule 3: TAC+/-15%. This rule also aims for an MSY fishery, but with the important constraint that TACs can not rise or fall by more than 15% per year. This reflects a main plank of current European policy, though in that there is more flexibility when stocks are very low or around MSY levels (see Rules 5 and 6). The result of this rule is that catches are more stable, but can also be much lower: the inability to cut TACs quickly to protect falling stocks can mean that the fishery is locked into collapse; this problem is made much worse by IUU fishing.

Rule 4: TAC+/-15% + MIN IUU. This is as Rule 3, with the addition of the minimum IUU fishing rate. This minimum IUU rate will feature less than in Rule 2, because TACs can not fall so low so quickly in Rules 3 and 4. But when it does occur, it can exert a powerful additional block on stock recovery.

Rule 5: Bpa, +/-25%. This is a more complex rule, attempting to approach closer to real TAC setting. The overall objective remains MSY fishing (as in Rule 1) with a constraint of +/-25% per year in the TAC (as Rule 3, but with more flexibility). Additionally, a precautionary threshold Bpa is defined as 20% of the carrying capacity. If the group stock falls below this level, TAC is set to zero. But since this is not supposed to be a model of zero fishing below MSY (Rule 1 does that) we have had to reset the TAC when the group recovers above Bpa. We set this recovery TAC at 67% of the stock growth expected at the Bpa level. This is intended to reflect a tendency to aim for stock protection if stocks are very low, but to favour somewhat short-term fishing opportunities when stocks are within precautionary limits.

Rule 6: Bpa, +/-25% + MIN IUU. As for the previous Rules 1 and 3, Rule 5 is unrealistic in assuming that IUU fishing drops to zero when the fishery is closed (TAC is zero). Rule 6 corrects this by adding in the minimum IUU assumption.

Completing the simulation model

One additional feature added to the model is a minimum escapement (i.e. stock minus harvest) level equal to 1% of the carrying capacity. This is a conservative feature which aims to reflect the difficulty of fishing out every last fish, preventing scenarios from descending to zero stock levels. We kept check in the simulations of the number of years in which the stock lies below the assumed precautionary biomass threshold, as a way of measuring the level of risk of stock collapse within the scenarios.

We added randomness to the model by allowing the estimated growth rates to vary according to a normal distribution based on the confidence intervals for the parameters (see list in Section 4.5). This has the effect of allowing for the uncertainty in our stock-growth models, and makes the simulations more realistic through the inclusion of natural variability and the fact that this prevents perfect foresight within the TAC rules. However, although based on the estimated confidence intervals, the randomness assumptions are essentially arbitrary.

For each scenario, we used 750 simulation runs. To make sure that the results are strictly comparable, we used the same table of random values for each of the scenarios applied within a given model (but then changed the random values prior to running the next model).

Each scenario was run over the period 2008 to 2020, with results showing the (undiscounted) total catches from 2008 to 2020 (split into legal and IUU), the final stock, and the number of years in which the stock has fallen below the Bpa threshold.

The cost estimates were made by comparing these values for a scenario with zero IUU with the values for a scenario with IUU at the best estimate level for the group (see Table 7). That is, the models show how much will be lost between now and 2020 – in terms of stock, catches, and periods during which the stock is at risk of collapse or actually collapsed – due to the presence of IUU activities in the fishery.

The physical costs can be valued according to the estimated values per tonne for the different commercial groups (see Table 8). It is noteworthy that the values vary substantially across LMEs for the same groups. This reflects a number of factors, including the following:

- The groups are made up of different species or proportions of species in each LME.
- The average size of fish from each species may vary substantially across LMEs.
- The markets, and processing methods, may be very different.
- The data quality may be variable.

It seemed most appropriate to assess costs within an area using the values estimated for each area and not the EU average.

Table 8: Values per tonne of catch (euros 2008) by commercial group and LME[42]								
Group	**CL**	**C**	**FF**	**HL**	**PL**	**TB**	**SR**	**Mean (all groups)**
Baltic	1,976	3,619	1,164	571	614	967	1,208	753
North Sea	866	4,337	2,542	223	349	900	1,500	696
Celtic-Biscay	1,010	6,369	2,937	327	745	2,770	1,298	1,451
Iberian Coastal	1,687	17,440	2,833	1,122	1,095	2,761	1,121	1,741
Mediterranean	2,821	4,180	7,448	1,129	2,670	4,707	1,391	2,276

The final step of calculating the costs for each Member State involved the straightforward process of breaking up the estimated total costs of IUU activity for each LME according to each Member State's share of fishing value in the area. Ideally we would have liked to take account of differences in value shares at the commercial group level, however we do not have the necessary data. By taking account of the different harvest/employment ratios in different Member States (see Figure 9), averaged across LMEs according to each Member State's share of fishing, we drew conclusions on IUU fishing impacts on employment (jobs) in the catching and processing sectors.

The results of the simulations for LME commercial groups, and the breakdown by Member State fishing, are presented in Chapter 6. The remainder of this chapter focuses on two detailed case studies.

5.2 Modelling IUU fishing and costs for Baltic cod-like stocks

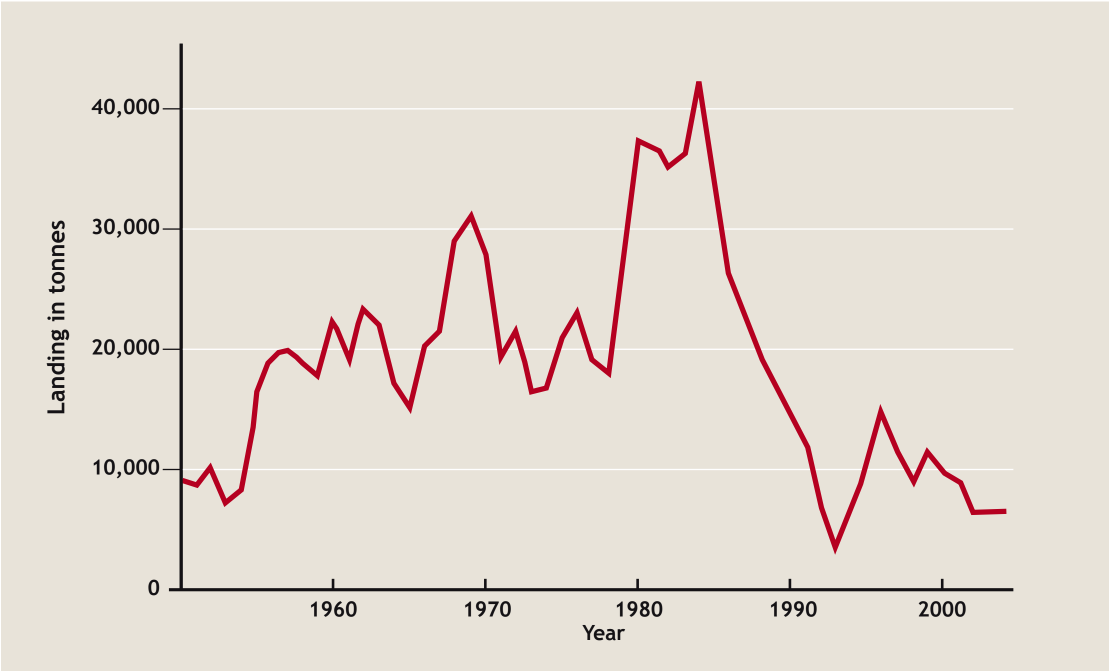
In modelling harvesting from a commercial group, such as cod-like stocks in the Baltic[43], the first step is to derive estimates for carrying capacity and intrinsic growth rate. As explained in section 4.5, we assume that a growth rate of 0.75, in a range 0.6–0.9, is suitable for cod-like stocks. To determine carrying capacity, we need to examine available data and evidence.

The graph of landings (see Figure 13) shows a gradual increase, with a reasonably stable period of landings around 200,000 tonnes (t), then a sharp rise to 400,000t in the early 1980s followed by collapse, with subsequent stabilisation below 100,000t. This suggests that MSY may be in the region of 200,000t. Given the assumed r of 0.75, this would correspond to a K of approximately 1 million tonnes. Current harvests of 100,000t would correspond to a current escapement level of 160,000t, in equilibrium, but since the stocks are not currently harvested sustainably, the escapement may be assumed to be somewhat lower.

We also estimated the precautionary biomass threshold level. The evidence from the last column in Table 6, which compares ICES Bpa levels with our carrying capacity estimates, suggests that this varies from stock to stock – though we also know that our estimates of carrying capacities from the regression models are quite uncertain. Based on the evidence in the table, and in the absence of better data, we made the working assumption that the precautionary level is 20% of the carrying capacity (which is equivalent to 40% of the stock supporting MSY). This precautionary level is defined for the purposes of our TAC-setting Rules 5 and 6, and for determining the number of years in which stocks are deemed to be low. It is not supposed to be a summation of actual Bpa estimates for the component stocks of a commercial group (these are known in some cases, but in many are not defined).

[42] Calculated from data on catch by group and value by group for LMEs, taken from www.seaaroundus.org. Groups shown are: CL = cod-likes; C = crustaceans; FF = flatfishes; HL = herring-likes; PL = perch-likes; TB=tuna and billfishes; SR = sharks and rays.
[43] Which essentially means cod stocks, but the approach is still modelling at the 'group in LME' level, in contrast to the stock level, which in the Baltic involves distinguishing between east and west cod stocks.

Figure 13: Landings of Baltic cod-like stocks, 1950-2004[44]



These estimates correspond reasonably well to ICES advice for the Baltic, which suggests that stocks are at very low levels, around Bpa, and that landings should not exceed 62,300t.

So for simulations of Baltic cod-likes we assumed that:

- The intrinsic growth rate r is normally distributed with mean 0.75 and 95% confidence bounds 0.6–0.9;
- The carrying capacity is 1 million tonnes;
- Current TAC is set at 80,000t, a compromise between recent catches and scientific advice;
- Current escapement is 140,000t;
- Current stock (escapement plus growth) is 220,000; and
- Bpa is 200,000t, equal to 20% of carrying capacity.

These are working assumptions for the purposes of estimating what the costs of IUU activity might be in this fishery. The assumptions, and the model, would not be adequate for setting policy for the fishery - they are overly simple and too approximate for that purpose. However, for the objective of this study the simple nature of the models is very acceptable.

The results of the simulations using these parameters are presented in Figure 14, which shows the following:

1. The total catches taken between now and 2020. Each curve shows a different TAC-setting rule (see the chart legend and Section 5.1). The x-axis shows IUU level. So the curves illustrate how total catch projection falls as the assumed IUU level increases.

2. The end stocks in 2020, after harvest and regrowth. These are the stocks available for exploitation in 2021, and represent the value or health of the fishery at the end of the simulation time horizon.

3. The number of years of low stocks between now and 2020. This shows the average number of years during which the stock is below the Bpa level, and therefore considered at risk of collapse (or, in many cases, actually collapsed).

[44] Data from www.seaaroundus.org.

Figure 14: Simulation results for Baltic cod-like stocks: total catches; end stocks in 2020; years with low stocks

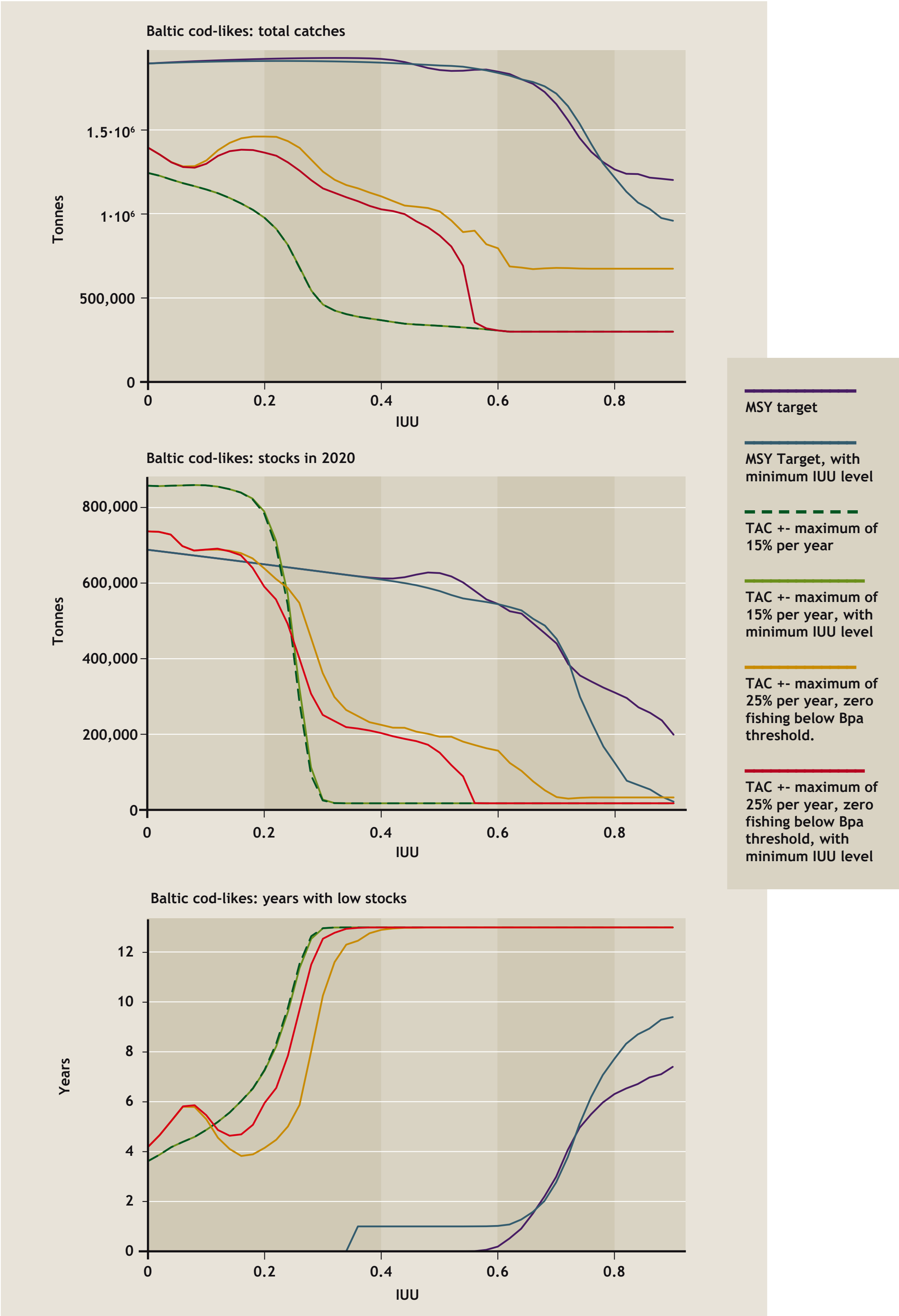


Figure 14 illustrates many interesting features common to many of the simulations:

- The MSY rules (Rules 1 and 2) appear to show very low catch losses from IUU fishing over a broad range of IUU levels, though this is paid for in lower end stocks. This is simple to explain: the TACs under these rules are extremely flexible. If there is IUU activity this year, resulting in lower escapement and therefore lower stock growth, the management response is to reduce the TAC. The TAC is always set at the level required to reach the MSY escapement. So the impact of IUU fishing is simply to move catch forward a year, resulting in less catch the next year. In fact, over a long enough period, this would result in lower total and average catches, however with the short time-horizon here, the dominating effect is that in the last period (2020) the IUU fishing scenarios take more catch[45]. Costs of catch losses set in at higher IUU fishing levels, especially when there are some years in which the heavy IUU activity, coupled with a poorer growth year, prevents the stock from recovering above K/2 and leads to a zero TAC.

- Any apparent benefit from fractionally higher catches with moderate IUU fishing levels under the MSY scenarios is therefore an 'illusion', in the sense that the gain is more than paid for in terms of reduced stocks; this can be seen by comparing the top two figures.
- Under the MSY + Min IUU rule (Rule 2), the costs of higher IUU activity set in much faster. This occurs where the TAC is set to zero, and the minimum level of IUU activity is sufficient to stop the stock recovering above the MSY level.
- In certain cases, small levels of IUU fishing appear to bring higher catches, over the short time-horizon considered. This can occur where the TAC rule is a little conservative, not taking full advantage of fishing opportunities, and it can occur where IUU fishing leads to higher catches in the short term while stocks are depleted. These higher catches are a short-term phenomenon, and the longer-term effect is reduced catches, through smaller stock sizes.
- The TAC+/-15% rule (Rule 3) is, in this simulation, indistinguishable from Rule 4 (TAC+/-15%+ Min IUU). This is because the TAC+/-15% rule never reaches low enough TAC levels for the minimum IUU to be triggered.
- The TAC+/-15% rule generally performs badly, in total catch terms, compared to MSY rules. It tends to overshoot the MSY level, because the TAC can only increase by 15% per year. This can result in lower catches, and higher end stocks, at least over a short-term simulation. In other cases, this rule gets stuck at low stock levels, simply because when the TAC can not fall by more than 15% each year, the rule is not able to reduce TAC quickly enough to let stocks recover. Thus the performance is quite dependent on the initial TAC and stock levels.
- The IUU fishing rate has a big influence on TAC+/-15%, as is clear from the figures: over a very small range of IUU rates, between about 20% and 30% IUU, the TAC+/-15% rule moves from the rising stock profile to a falling stock profile, simply because of the impact of IUU added to the inability to vary TAC quickly.
- The Bpa rules (Rules 5 and 6) can suffer from the same problem, but generally to a lesser extent, because they allow for +/-25% per year. The decline in catches and end-stocks under higher IUU levels is therefore more gradual than in TAC+/-15%.
- However another effect exists for the Bpa rules, related to setting a zero TAC under the Bpa threshold. This makes them much less prone to getting stuck at low stocks, but it also creates a somewhat artificial threshold effect, due to the discontinuity in the TAC-setting rule. At some level of IUU activity, the initial harvest drives the stock below the Bpa level, resulting in zero TAC in the following period, and the TAC is then reset to the minimum TAC when the stock recovers. Levels of IUU fishing that are a little less than required to drive the stock below Bpa do not cause this, and the TAC is not reset. Paradoxically, this can result in lower costs for the higher IUU fishing level, if the setting of TAC to zero followed by resetting the TAC results in faster stock recovery. For this simulation, the threshold IUU level at which the stock is driven below Bpa in the first period is a little under 0.2, and this threshold effect

[45] Specifically, assuming stock is greater than K/2, they take (stockIUU-K/2)/(1-u) instead of (stock0-K/2); though the stockIUU (with IUU) is less than stock0 (without IUU), the overall effect can be to keep catches up, at the expense of reduced stock next year.

explains the 'wavy' behaviour of the total catch curve for these rules at IUU rates around this level.

- At exactly the level where this threshold exists, the Bpa rules without (Rule 5) and with (Rule 6) a minimum IUU level starts to diverge. Under Rule 5, stock falls below IUU, TAC is set to zero, and there is no IUU, so the stock recovers quickly. Under Rule 6, TAC is also set to zero, but IUU continues at the minimum level and so the stock recovers more slowly. This can be seen in the lower catches, lower-end stocks and greater number of years under the precautionary threshold for Rule 6 compared to Rule 5. For higher levels of IUU, around 50%, the minimum IUU effect is strong enough to prevent the stock from ever recovering above Bpa, and the stock is locked into a low-stock, low-harvest equilibrium.

The evidence in Table 1 suggests that IUU fishing rates in Baltic cod are in the range 35–45%. Assuming 40% leads to physical cost estimates as described in Table 9.

Table 9: Costs of 40% IUU activity in Baltic cod fisheries (negative number implies benefits; catches and stocks in thousand tonnes)

TAC-setting rule	Total loss in catches, 2008–2020	Loss in end stock, 2020	Additional years with low stocks
1: MSY target	-24.4	72.7	0
2: MSY and Min IUU	-2.3	75.8	1.0
3: TAC +/-15%	872.0	841.0	9.4
4: TAC +/-15% + Min IUU	872.0	841.0	9.4
5: Bpa, TAC+/-25%	276.0	514.0	8.6
6: Bpa, +/-25% + Min IUU	358.0	535.0	8.7

The cost estimates show some interesting features. The importance of the assumption regarding minimum IUU level is particularly clear for the Bpa rules (Rules 5 and 6). For them, the 40% rate is above the point at which they split (see Figure 14) and the costs rise rapidly due to the ongoing IUU activity when the fishery is closed due to low stock levels.

In particular, the costs are heavily dependent on the TAC-setting rule. This is a feature of all the simulations and is unavoidable: the overall value of the fishery depends crucially on how it is managed, and so the estimates of costs must be similarly dependent.

The fundamental issue is that we can not simulate any fishery without assuming some rule for setting catches – whether that be through TACs or by controlling fishing effort. And whatever TAC or other rule we establish will, along with IUU fishing levels, determine the performance of the fishery, against which costs are measured. Further, it is always possible to find situations in which the rule is too precautionary, relative to the fishing opportunities available; then the simulations are likely to show that some level of IUU activity brings benefits, in effect by making an overly conservative catch rule make better use of opportunities. In short, the costs of IUU fishing are inextricably linked to the details of stock management, as well as to the biological parameters of the stock.

As a particular example of this, the IUU fishing costs under MSY appear to be very limited. As explained above, this is simply because of the flexibility in the TAC rule. In effect, the regulator's response to IUU fishing is just to set lower TACs.

Indeed, one possible response to IUU fishing is for fisheries managers to set TACs lower. In the MSY scenarios here, it is done retrospectively – the TAC rule is based on current stock, and last year's IUU activity makes this year's stock, and therefore this year's TAC, lower. It could also be done prospectively – that is, if we know there will be 40% IUU activity, we could simply curb TACs sufficiently to take this into account.

In fact, what is depicted in the MSY scenarios is quite similar to the idea of reducing discarding by allowing fishers to land catches above TAC in return for reduced TAC the following year. More generally, however, where there is no such direct exchange for the same fishers, it can be argued that it would not be a fair response to IUU fishing to accept it and react by reducing TAC for legal fishers. So this would not be a particularly satisfactory response, in terms of its social impacts, however it could help keep total harvests to sustainable levels. Or in any event, this is how it would appear in simple models such as those presented here.

The only real answer to the problem of IUU fishing costs being dependent on the TAC-setting rule is to get as close as possible to how TACs are set in reality. But it must be stressed that the cost estimates are conditional on that rule (not just in the models but also in the real world), so the results must be interpreted in that light. In the simulations, we have examined a number of TAC-setting rules, including the six presented above. In the end, we picked the most appropriate one for deriving cost estimates. The most realistic choice, and also a reasonably conservative one, is to focus on Rule 6 – allowing TAC to change b +/-25%, aiming for MSY, but taking zero TAC below a precautionary threshold, while recognising that IUU activity will continue in a closed fishery. So it is on this rule that we have based the main cost estimates in the next chapter.

5.3 Modelling IUU fishing for Mediterranean tuna and billfish stocks

In deriving a model for Mediterranean tuna and billfish stocks, we applied essentially the same procedure as above. The growth rate assumed is 0.5, based on the ICCAT models noted in section 5.2.

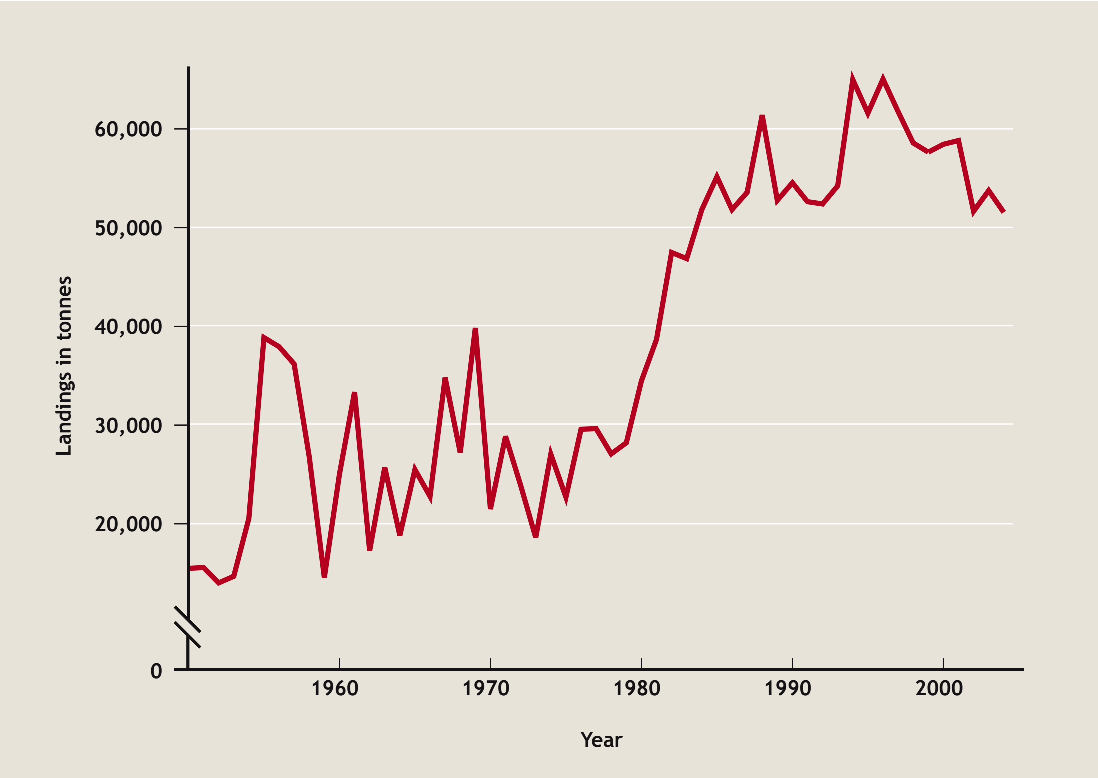
Evidence for stock status is limited. ICCAT stock assessments (ICCAT, 2007) are available for bluefin tuna and swordfish, but not for albacore or other species. For the bluefin, reported harvest in 2006 was 32,665t, though actual catches are estimated at 50,000t. The long-run potential MSY is thought to be around 45,000t. The ratio of current spawning biomass to that in the early 1970s is 0.48. TAC is 32,000t.

For swordfish, MSY is estimated around 15,000t, while current yield is 14,600t. The biomass is thought to be between 0.26 and 0.87 of the stock, corresponding to MSY.

Figure 15 shows the evolution of landings from the fishery, which is largely made up of bluefin tuna, swordfish, albacore and smaller tuna species. A period of steady increase has led up to a plateau a little under 60,000t, with perhaps the start of a decline – though we know that actual landings are likely to be higher, since there is evidence of under-reporting.

The ICCAT assessments (ICCAT, 2006; 2007) suggest MSY for bluefin tuna and swordfish combined may be 60,000t. Making a conservative allowance for the other species, we assumed MSY is 80,000t. With an assumed growth rate of 0.5, this corresponds to a carrying capacity of 640,000t. The stock corresponding to MSY would then be 320,000t, and if we assume that current stocks are around half that level, based on the figures above, we estimate escapement to be 160,000t. The expected growth at that level is 60,000t, which equals current catches. We set the starting TAC at this level.

Figure 15: Landings of tuna and billfishes in the Mediterranean, 1950-2004[46]



As explained in Table 7, our estimate for IUU activity in this fishery is 45%, based on estimates from ICCAT (2007) and from Greece (Tsikliras, 2007) suggesting Mediterranean tuna and billfish IUU fishing rates are in the range 40-50%. This leads to physical cost estimates as described in Table 10.

Table 10: Costs of 45% IUU activity in Mediterranean tuna and billfish fisheries (negative number implies benefits; catches and stocks in thousand tonnes)

TAC-setting rule	Total loss in catches, 2008-2020	Loss in end stock, 2020	Additional years with low stocks
1: MSY target	-25.5	38.0	0
2: MSY and Min IUU	-17.4	35.5	0
3: TAC +/-15%	411.0	409.0	13
4: TAC +_15% + Min IUU	411.0	409.0	13
5: Bpa, TAC +/-25%	157.0	263.0	13
6: Bpa, +/-25% + Min IUU	185.0	275.0	13

The results presented in Figure 16 and Table 10 are quite similar to those for the Baltic cod stocks, although the precise levels of IUU activity at which costs and thresholds occur are different. In this example, threshold effects with stocks around the BPA level, and assumed minimum level of IUU, influence the results for Rule 6 quite strongly around the 50–55% IUU level. Other than this the pattern is a straightforward decline of catches and end stocks with rising IUU activity for all the scenarios, although to different degrees.

Again the MSY rules are quite resistant to IUU fishing, but the losses in end stocks exceed catch gains. This again demonstrates that, if TACs can take full account of IUU activity, major costs can be avoided, at the expense of high TAC variability and denying fishing opportunities to legal fishers. But the end stocks are lower with IUU fishing, and over a longer time horizon, the costs of IUU activity would increase.

[46] Source: www.seaaroundus.org.

However, the picture is again very different under the other scenarios. Here, serious costs of IUU fishing set in at levels around 20%. Again, the TAC+/-15% scenario performs extremely badly under IUU activity. The Bpa scenarios fare a little better, but again show the important impact of the assumptions about IUU levels when the TAC is set to zero: with a minimum level of IUU activity continuing in a closed fishery, costs rise faster, and total fishery collapse occurs at lower IUU rates.

5.4 Conclusions for Chapter 5

As is clear from Table 8, Table 9, Figure 14 and Figure 16, the costs of IUU fishing are highly variable depending on the level of IUU activity and the details of the TAC rule (or other management rule) used. These are unavoidable issues: it is not possible to simulate a fishery without making some set of assumptions about how policy is set[47]. Unfortunately, this makes it difficult to describe costs of IUU fishing 'cleanly' without becoming embroiled in the advantages and disadvantages of different management strategies.

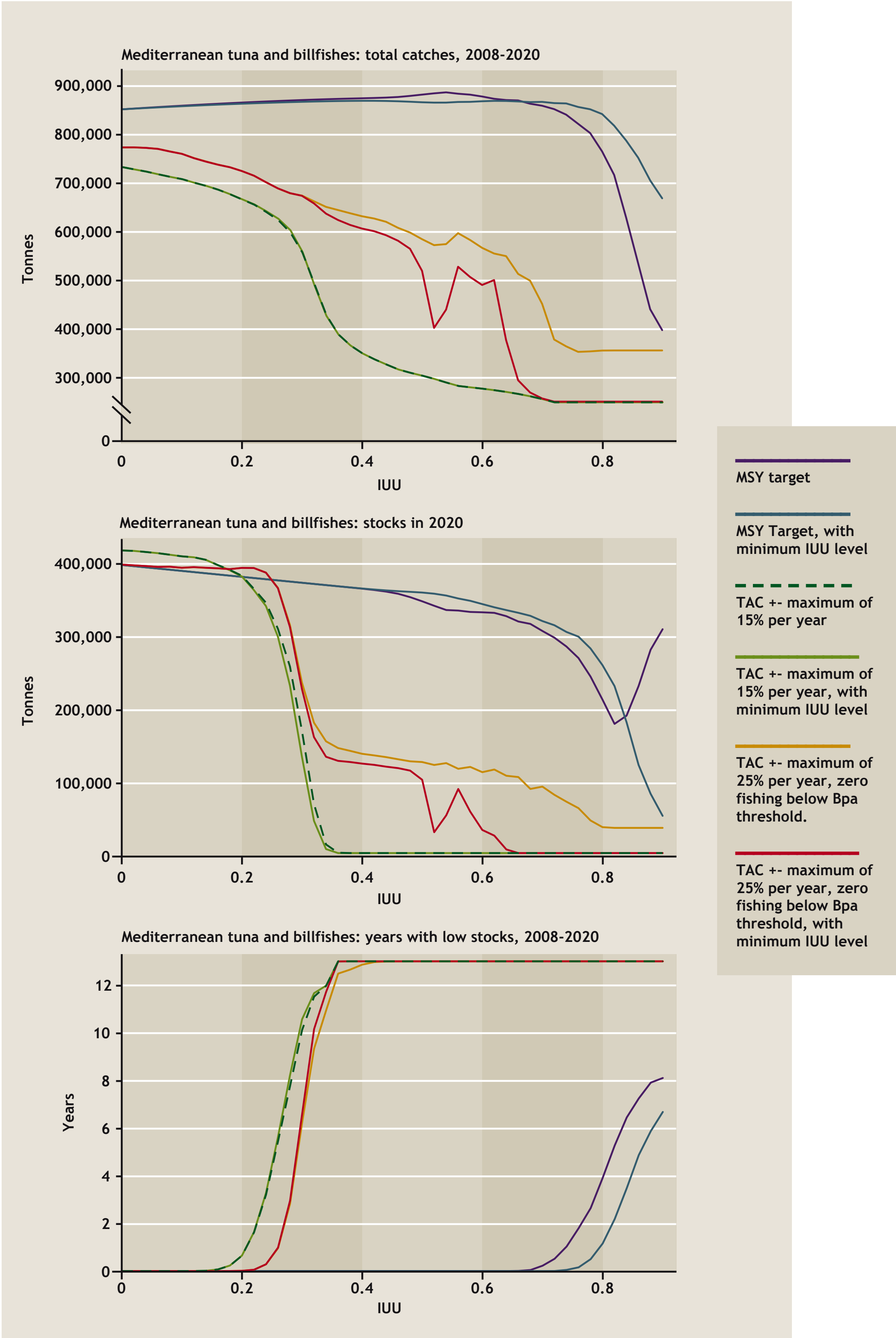
The MSY scenario gives easily the best fisheries performance, at least in terms of total catch and final stock. Indeed, it is less attractive from the perspective of continuous fishing, since it can feature regular fisheries closures to allow stocks to rise above the MSY level. It is unrealistic in this respect, and in assuming IUU activity is zero when the fishery is closed. It often shows fairly steady performance under low levels of IUU activity because of the very flexible TAC-setting rule – IUU fishing this year means less growth the next, and so a smaller TAC (and less IUU activity). Although, provided the IUU level is not high enough to drive escapement down below a level that can grow back to above one-half of the carrying capacity, this basically involves shifting catches from one year to another.

The TAC+/-15% scenario is very sensitive to IUU fishing. If IUU activity is high enough, it can completely prevent this TAC rule from adapting to stock changes, and lock the stock into a low-value equilibrium. Consequently, estimates of the costs of IUU fishing tend to be very high with this rule.

The Bpa rules tend to give more modest costs, principally because they incur costs from increasing levels of IUU fishing in a more gradual fashion. But these models are also perhaps the most realistic as regards the current situation in most EU fisheries, which is essentially one of trying to balance out the need to help severely overfished stocks to recover, while still maintaining a reasonable level of fishing activity. We conclude, therefore, that this is the most appropriate scenario to consider, and a suitably conservative choice. We also believe that it is important to consider Rule 6, including some minimum level of IUU activity when the fishery is closed – this report aims to assess the costs of IUU fishing, and some of the most important costs can arise when it impacts on a fishery at risk of collapse. Although the IUU fishing estimates we have are for percentage of total catch, it would be unrealistic to assume that IUU activity falls to zero when TAC is zero. The conservative assumptions we have made regarding setting a minimum IUU setting level (see section 5.1) seem appropriate for the task at hand.

[47] The 'opt-out' position of assuming TACs do not change does not avoid the problem, because it is still an assumption about how TACs are set.

Figure 16: Simulation results for Mediterranean tuna and billfishes: total catches; end stocks in 2020; years with low stocks



6. Simulation results for all LMEs

In this chapter, we have presented tables representing simple models and their results for specified rates of IUU fishing for a range of commercial groups in the LMEs under study. These models have been derived in exactly the same way as illustrated for the two case study groups in the previous chapter. The assumed IUU fishing rates are either those presented in Table 1, or conservative extrapolations from them. We were unable to derive a model for several groups, due to the lack of one or more key elements of data. In other cases, we did not attempt to derive a model because TACs are not defined, and hence IUU fishing was difficult to assess. These results represent models of those more valuable fisheries for which appropriate data are available.

For each LME, and in total, we have demonstrated how the figures can be broken down across Member States, giving indicative figures of the costs of IUU activity in these fisheries to the Member States fishing. It is important to note that these estimates are likely to be considerably lower than the total costs of IUU fishing. We:

- Have modelled only some commercial groups (see Chapter 2.4);
- Have modelled a smaller number of types of cost (see Chapter 3);
- Have made no distinction between legal and illegal catch, assuming them to be equally valuable;
- Have made a conservative estimate of the ongoing IUU activity level if a fishery is closed;
- Have assumed that it is not possible to fish a stock completely to extinction;
- Have erred on the side of conservatism in determining key parameters, including in particular the estimated rates of IUU fishing; and
- Are looking only at a 2020 time horizon.

That said, it must also be kept in mind that the costs are dependent on the management strategy: this is not a flaw in the model, but rather a feature of the real world. At the same time, it is possible that the management strategy modelled is not a good reflection of real TAC setting. All we can say to that is that we have tested several different approaches (see Chapter 6) and have been deliberately conservative in selecting a rule that seeks to protect stocks by setting zero TAC at low levels.

In the tables that follow, we have calculated the value of lost catches between 2008 and 2020, the value of lost end stocks, and the number of sustainable jobs lost. The calculation of values is based on the estimated values per tonne of the commercial groups (see Table 6).

Note also that the lost stock is expressed in value terms – although this is intended as a physical measure of environmental cost for each commercial group, when aggregating across groups for the LMEs we can not really add, for example, "tonnes of flatfish" to "tonnes of tuna"; weighting by price is an obvious way to make the figures comparable. It is not strictly accurate however to state that a tonne of fish in the sea has the same value as a tonne of fish landed[48]. So we do not directly add the "lost stock value" to the "lost catches value", but discuss the values separately in the text.

The lost jobs were calculated based on an estimate of jobs per million euros in each LME. Fisheries employment varies substantially across Europe, and the ratio of jobs to value also varies greatly. To obtain the best possible estimates of employment costs of IUU fishing, we have calculated a weighted average employment per million euros figure for each LME[49],

[48] On the one hand the fish are less valuable because it costs something to land them; on the other hand, they are more valuable because they can grow and make more fish. Questions also arise about discounting: overall it is not clear what the relationship is, except that it will depend on the stock.
[49] Raw data from the European Commission's "Facts and Figures on the CFP, 2006", supplemented with data from www.seaaroundus.org and Eurostat.

weighting the employment intensities of each Member State by its share in the value of fishing in that LME.

6.1 Baltic

The Baltic LME is the 'simplest' ecosystem included in our research. The fishery value is dominated by cod and two herring-like species, sprat and herring. These are the groups we have modelled, and they represent 91% of the fisheries value in the Baltic. The data available is reasonably good, in comparison to other LMEs, and in particular we have estimates of IUU rates for cod and for herring (see Table 7). The model development, parameters and results are briefly summarised in Table 11, below.

Table 11: Commercial group models and IUU fishing costs for the Baltic LME

(t=tonnes)	Cod-likes	Herring-likes
Average landings (t)	184,000	469,000
Maximum landings(t)	424,000	815,000
Recent landings (t)	65,000	570,000
Landings trend	Increase; stable below 200,000; rise to 400,000; collapse	Rise to peak; appear stable below 600,000
Evidence on stock size/TAC (ICES advice)	Around Bpa; keep TAC below 62,300	Some sustainable, some overfished; keep TAC below 540,000
MSY estimate (t)	185,000	550,000
R estimate	0.75	0.3
Implied K (t)	1,000,000	7,330,000
Bpa estimate (t)	200,000	1,470,000
Recent escapement estimate (t)	160,000	3,200,000
TAC estimate (t)	80,000	540,000
Starting stock estimate (t)	220,000	3,750,000
IUU estimate	40%	35%
Value (euros per tonne)	1976	571
Jobs per million euros	81	81
Lost end stock (t)	**535,000**	**196,000**
Lost catches (t)	358,000	-51,600
Extra low stock years	8.7	0
Value lost stock (million euros)	1,057	112
Value lost catch (million euros)	**707**	**-29**
Annual average value lost catch (million euros)	54	-2
Lost jobs (number)	**4,397**	**-183**

The results in this table illustrate the rather different cost estimates arising from different fisheries. The Baltic cod fishery, already in bad shape, is highly sensitive to IUU fishing. In the absence of IUU activities the fishery could recover well (according to our model - see Figure 14) but IUU activity at the current 40% rate is keeping the stock at low levels. The costs are substantial.

The herring-like stocks, in contrast, are in quite healthy shape, producing catches near MSY level; though some sub-stocks are overfished, others are sustainable. This situation leads to rather lower cost estimates for IUU fishing, though the effect on pushing down stocks remains clear. This conclusion is heavily dependent on the assumption that TACs are flexible enough to adapt to IUU fishing rates. That is the case here, because of the IUU fishing rate (35%), and the +/-25% rule in TAC setting. In the scenarios with +/-15% limits, the costs of IUU fishing at a rate of 35% are more substantial.

Table 12: Costs of IUU activity in the Baltic, by country fishing (values in million euros)				
	Share (%)	Stock value lost	Catch value lost	Jobs lost
Denmark	13.9	163	94	586
Estonia	15.1	177	102	636
Finland	8.7	102	59	367
Germany	6.5	76	44	274
Latvia	16.2	189	110	683
Lithuania	2.1	25	14	88
Poland	12.0	140	81	506
Sweden	15.3	179	104	645
EU	89.8	1,050	609	3,784
non-EU	10.2	119	69	430
TOTAL	**100**	**1,169**	**678**	**4,214**

Taken together, the costs to EU Member States fishing in the Baltic amount to an annual lost catch value of €47 million[50], and almost 3,800 lost jobs. That is approximately 10% of the EU fisheries value from Baltic, and is worth more than Finland's total fishing.

But in this LME the biggest cost is in ongoing damage to the cod stocks. The difference is between a recovered, productive fishery supporting MSY of around 180,000t per year, and a collapsed fishery outside biological limits and producing a yield of only 80,000t per year. Maintained at that level, this represents an ongoing loss of 100,000t of fish, or about 90,000t lost to the EU states, worth in the region of €180 million per year.

Valuing this loss of stock only at €1.2 billion, as in the table, is perhaps conservative, but on the other hand we have not applied any discounting, and the inheritors of the collapsed stock in 2020 could decide to allow it to recover to a productive state – which in principle, given the parameters of the model, would require four or five years of zero catches (and zero IUU activity). So this form of valuation is approximately right.

The difference between the estimate of €47 million for annual average lost catch from the simulations, and the €180 million described here, is easily explained: €180 million is the value achievable once the stock has recovered. To get there, we need to continue with low TACs for several years until the stock recovers. By contrast, in the IUU fishing scenario, the catches continue at a higher rate, because of the IUU catch added to the legal catch. So in the early years of the simulations, the IUU fishing scenarios tend to give higher total catches, and the no-IUU scenario only catches up once the stocks have recovered.

This also means that, if we were to continue the simulations further beyond 2020, we would find most of the continuing costs of IUU fishing would be in the form of lost catches and jobs; the difference in stocks is already about as bad as it can get, between an MSY and a collapsed fishery.

One further comment to this is that our estimate of jobs lost is based on the annual average. If instead we were to consider the employment position in 2020, and go forward from then, we would find much higher differences between the IUU and no-IUU case. This could be as much as 14,500 sustainable jobs – a similar level to current Latvian, Lithuanian and Estonian fisheries industry employment combined.

These sums may seem large; indeed they are large, but we are dealing with a fishery which, even in its current depressed state, accounts for over one-quarter of fisheries value in the Baltic LME. The overall costs of IUU fishing in the Baltic might be summarised as: "Preventing the cod fishery from recovering to a highly productive and valuable state".

[50] From €609 million total loss in Table 12, divided by 13 years from 2008–2020. This gives a figure for annual cost to EU Member States, and therefore differs from the €52 million net figure in Table 11, which is for total costs across all fishing nations.

6.2 North Sea

The North Sea supports a very mixed fishery with high values from a number of commercial groups. Data availability is reasonable, most of the key stocks are controlled by TACs, and there are estimates, albeit rather broad-brush, of rather high IUU fishing rates in the area. Based on these estimates (see Table 1; Table 7) we have assumed 50% IUU for all the groups in the North Sea. We have derived models for four main commercial groups, representing 73% of the total fishery value.

Table 13: Commercial group models and IUU fishing costs for the North Sea LME

(t = tonnes)	Cod-likes	Flatfishes	Herring-likes	Perch-likes
Average landings (t)	856,000	159,000	885,000	721,000
Maximum landings (t)	1,750,000	424,000 (outlier)	1,650,000	1,400,000
Recent landings (t)	425,000	110,000	600,000	700,000
Landings trend	Sharp rise; peak; strong fall	Rise; steady at 175,000; fall	Strongly down	Steady rise; plateau; possible fall
Evidence on stock size/TAC (ICES advice)	Mostly overfished. Cod – zero; haddock <450,000; pout <148,000; whiting <11,000; saithe 139,000	Overfished. Plaice <55,000; sole<14,000	Herring – badly overfished. Zero catch. Sprat <170k; Bpa herring=1.3m	Unknown
MSY estimate (t)	1,000,000	150,000	800,000	800,000
R estimate	0.75	0.6	0.3	0.75
Implied K (t)	5,340,000	500,000	10,000,000	4,300,000
Bpa estimate (t)	1,000,000	110,000	2,000,000	860,000
Recent escapement estimate (t)	650,000	240,000	2,000,000	1,300,000
TAC estimate (t)	350,000	110,000	500,000	700,000
Starting stock estimate (t)	1,000,000	350,000	2,500,000	2,000,000
IUU estimate	50%	50%	50%	50%
Value (euros per tonne)	866	2542	223	349
Jobs per million euros	17	17	17	17
Lost end stock (t)	**3,180,000**	**318,000**	**3,400,000**	**2,880,000**
Lost catches (t)	3,420,000	554,000	-652,000	6,460,000
Extra low stock years	9	12	12.8	13
Value lost stock (million euros)	2,754	808	758	1,005
Value lost catch (million euros)	**2,962**	**1,408**	**-145**	**2,255**
Annual average value lost catch (million euros)	228	108	-11	173
Lost jobs	**3,800**	**1807**	**-187**	**2,893**

The observations we can make here are very similar to those for other LMEs. The presence of IUU fishing levels at 50%, a bit higher than for the other LMEs, imposes huge costs on North Sea stocks. Again the straightforward story is that IUU fishing is holding the stocks at low levels; without IUU activity, fisheries could recover and produce higher yields.

Table 14: Costs of IUU activity in North Sea, by country fishing (values in million euros)

	Share (%)	Stock value lost	Catch value lost	Jobs lost
Belgium	1.2	64	78	100
Denmark	22.0	1,172	1,425	1,829
France	3.4	181	220	283
Germany	5.6	298	363	466
Ireland	0.8	43	52	67
Netherlands	13.6	724	881	1,131
Sweden	5.7	304	369	474
UK	26.8	1,427	1,736	2,228
EU	79.1	4,213	5,125	6,577
non-EU	20.9	1,113	1,354	1,737
TOTAL	**100**	**5,326**	**6,479**	**8,314**

The total medium-term costs of catch loss identified for EU Member States are just over €5 billion, an annual average of €385 million, representing more than 6,500 jobs. Taking 73% of the average annual value of fishing, to account for the proportion of value we modelled, and 79.1% for the EU share, gives €923 million. Thus the bottom line result from the North Sea simulations is that, over the period 2008–2020, the cost of IUU fishing is equal to about 41% of the value of fishing in the North Sea. This does not take into account the additional costs of depleted closing stocks.

6.3 Celtic-Biscay

The key fisheries in this area are for perch-likes, cod-likes and crustaceans. As noted previously, we do not have suitable models or IUU activity estimates for crustacean fisheries. However we do have some suitable data for the other groups and for herring-likes. The four groups modelled represent 46% of the fisheries value in the LME.

Direct data on IUU fishing rates are lacking, except for the cod-like group, where we have an estimate of 30–60% from the west of Scotland. We have assumed the midpoint, 45%, for cod-likes, also supported by higher estimates for the adjacent North Sea. For the other groups, we have assumed 35%, by analogy with the adjacent North Sea fisheries for which we do have some data, and as a conservative estimate of the minimum level of IUU activity in highly commercial and regulated EU fisheries (see also Table 7).

Table 15: Commercial group models and IUU fishing costs for the Celtic-Biscay LME				
(t=tonnes)	Cod-likes	Flatfishes	Herring-likes	Perch-likes
Average landings (t)	267,000	43,000	173,000	299,000
Maximum landings (t)	482,000	62,000	330,000	636,000
Recent landings (t)	300,000	43,000	120,000	310,000
Landings trend	Increase; now stable	Peak; trough; peak; trough or stable?	Rise to peak; collapse; low stable	Increase; plateau; decline
Evidence on stock size/TAC (ICES advice)	Mostly overfished, some seriously. Reduce catches, some to zero.	Mixed – many poorly known, some sustainable, others overfished. Generally low. Reduce catches	Mixed – little data on sprat. Herring generally low. Cut catches.	No clear information.
MSY estimate (t)	300,000	40,000	180,000	350,000
R estimate	0.75	0.6	0.3	0.75
Implied K (t)	1,600,000	270,000	2,400,000	1,870,000
Bpa estimate (t)	320,000	54,000	480,000	374,000
Recent escapement estimate (t)	400,000	80,000	500,000	500,000
TAC estimate (t)	200,000	30,000	100,000	300,000
Starting stock estimate (t)	600,000	110,000	600,000	800,000
IUU rate estimate	45%	35%	35%	35%
Value (euros per tonne)	1,010	2,937	327	745
Jobs per million euros	25	25	25	25
Lost end stock (t)	**1,070,000**	**11,600**	**833,000**	**1,040,000**
Lost catches (t)	2,090,000	95,200	-231,000	1,680,000
Extra low stock years	13	8.3	12	13
Value lost stock (million euros)	1,081	34	272	775
Value lost catch (million euros)	**2,111**	**280**	**-76**	**1,252**
Annual average value lost catch (million euros)	162	22	-6	96
Lost jobs	**3,652**	**484**	**-131**	**2,165**

The results here again show the high cost of IUU fishing in terms of stock status. For both the cod-likes and the perch-likes, the end-stock is around the MSY level in the zero IUU case but crashed with IUU activity at the levels simulated (45% and 35% respectively).

The herring-like case is again interesting. The catches remain quite stable under IUU scenarios, over the short-time horizon we are considering. In fact, because of the extra catch from IUU activity, total catches increase slightly over a fair range of IUU fishing rates in all the scenarios. But this does not mean that IUU activity is beneficial! There is a big cost to pay in stock depletion, as the full simulation results illustrate (Figure 17). One corollary of this is that the small advantage in terms of catches is clearly a short-term phenomenon – the IUU activity is keeping the stock depressed, while without IUU activity the stock in 2020 will be capable of supporting MSY fishing.

Figure 17: Celtic-Biscay herring-like group: projected stocks in 2020

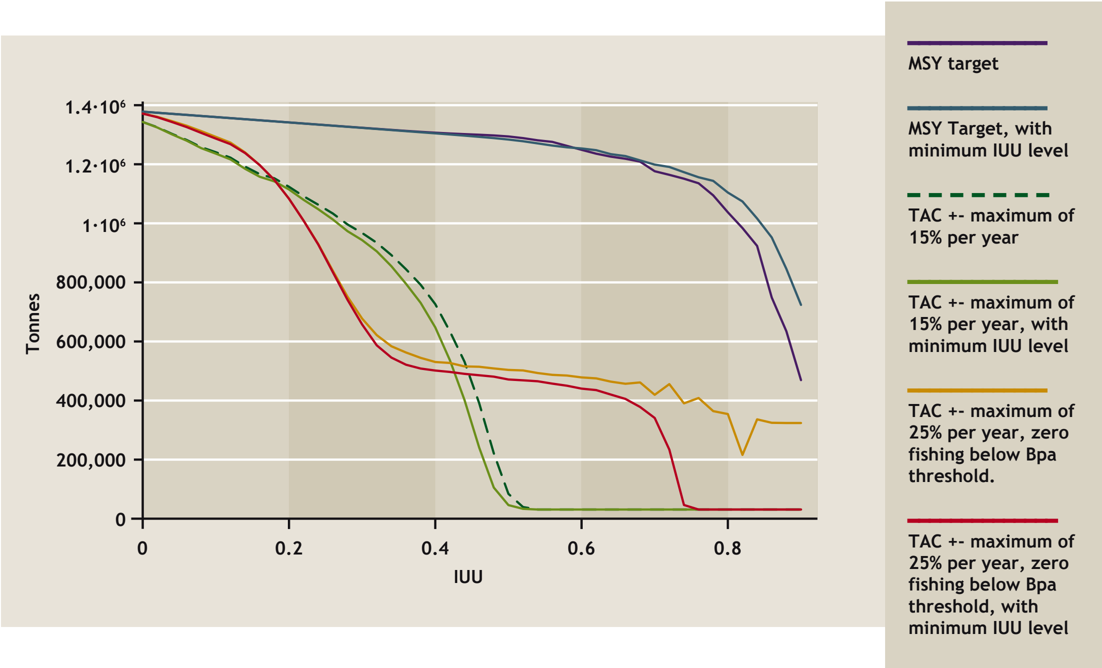


Table 16: Costs of IUU activity in Celtic-Biscay, by country fishing (values in million euros)				
	Share (%)	Stock value lost	Catch value lost	Jobs lost
Belgium	1.2	26	43	74
France	40.3	871	1,437	2,487
Germany	2.6	56	93	160
Ireland	16.7	361	596	1,030
Netherlands	6.4	138	228	395
Spain	7.3	158	260	450
UK	24.1	521	860	1,487
EU	98.6	2,132	3,517	6,084
non-EU	1.4	30	50	86
TOTAL	**100**	**2,162**	**3,567**	**6,170**

The estimates presented here suggest that the total value of lost catches to EU Member States from 2008–2020 could reach €3.5 billion, an annual average of €270 million, representing over 6,000 jobs in the fishing and processing industries. This is approximately the equivalent of fishing value and employment in Ireland.

Considering that these estimates relate to only 46% of the fishery value suggests that the true costs across all groups could be much higher. Again, the figures relate to the annual average; costs are higher in 2020, when (as the stock value figure shows) the contrast between flourishing fisheries in the no-IUU case and crashed fisheries with IUU activity is stark.

6.4 Iberian Coastal

The fishing value in the Iberian Coastal LME is spread over several groups. However in some cases there are no TACs defined (for example the important pilchard and sardine fisheries, forming most of the herring-like species), while in other cases we lack the data to make a proper assessment of costs (for example, anchovy). Therefore groups we modelled in this LME are cod-likes, perch-likes and tuna/billfishes. These groups again represent 46% of the value of fisheries in the LME. The IUU fishing rate estimates are as described in Table 7: 36% for the tuna, based on WWF (2006), 40% for the cod-likes, by conservative analogy with the cods in other regions for which estimates are available, and 35% for the perch-likes, as the default minimum level.

Table 17: Commercial group models and IUU activity costs for the Iberian Coastal LME			
	Cod-likes	Perch-likes	Tuna and billfishes
Average landings (t)	43,300	95,000	8,700
Maximum landings (t)	60,600	195,000	28,000
Recent landings (t)	43,000	92,000	8,000
Landings trend	Very variable; recently high with signs of falling.	Strong peak followed by major crash early 1980s; recovery, but perhaps too fast.	Often been around 8,000; recent rapid rise and rapid fall.
Evidence on stock size/TAC (ICES advice, ICCAT)	For hake (the main stock) – heavily overexploited, unsustainable. TAC suggested 7,100 but not enough to put stock above Bpa, est. 35,000 (for hake alone).	For horse mackerel (important group member) unknown, but suggest recent catches probably sustainable.	Tuna biomass thought to be around half values in 1970s.
MSY estimate (t)	40,000	100,000	8,000
R estimate	0.75	0.75	0.5
Implied K (t)	210,000	534,000	64,000
Bpa estimate (t)	42,000	96,000	12,000
Recent escapement estimate (t)	40,000	180,000	26,000
TAC estimate (t)	10,000	90,000	6,000
Starting stock estimate (t)	50,000	270,000	32,000
IUU rate estimate	40%	35%	36%
Value (euros per tonne)	1,687	1,095	2,761
Jobs per million euros	133	133	133
Lost end stock (t)	140,000	269,000	24,600
Lost catches (t)	268,000	409,000	5,730
Extra low stock years	11.8	11.2	4.4
Value lost stock (million euros)	236	295	68
Value lost catch (million euros)	452	448	16
Annual average value lost catch (million euros)	35	34	1
Lost jobs	4,633	4,590	162

These three groups all show strong costs arising from IUU fishing. The pattern for the cod-like and perch-like groups is as in the other LMEs, with IUU activity making the difference between a healthy fishery near MSY, and a collapsed fishery near precautionary levels.

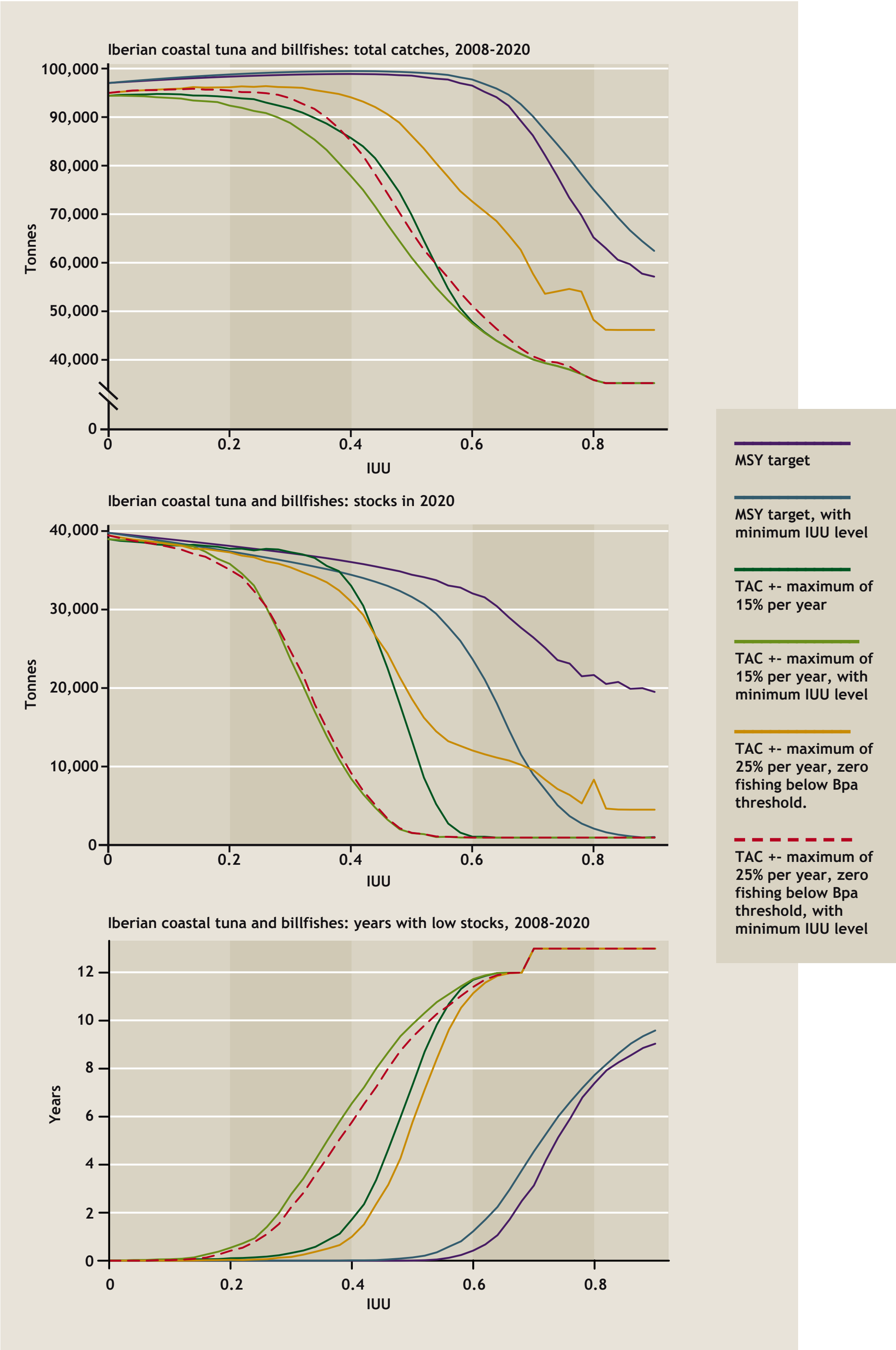
The tuna and billfish group appears slightly different in having a much smaller number of additional years at low stock levels. The full results for this group (see Figure 18) show that with no IUU activity, this group achieves MSY levels for all scenarios. As IUU fishing rates increase, decline sets in, with the IUU threshold and steepness of the fall depending on the scenario. The key importance of the minimum IUU fishing level can be seen clearly in this group: the two scenarios with the earliest, fastest declines are ones in which there is a minimum level of IUU activity when the TAC is low or zero. The minimum IUU fishing level is preventing changes in the TAC from saving the stock from decline.

Table 18: Costs of IUU activity in Iberian Coastal LME, by country fishing (values in million euros)

	Share (%)	Stock value lost	Catch value lost	Jobs lost
France	1.6	10	15	150
Portugal	34.5	207	316	3,238
Spain	63.9	383	585	5,997
EU, TOTAL	**100**	**600**	**916**	**9,385**

The lost catch values presented in the table for EU Member States represent an annual average over the simulation of €70 million. This compares with actual value of around €500 million for the whole LME, or €230 million for the groups we modelled. So the cost estimate represents about 30% of the value of fishing from these groups. But, as noted previously, this remains a very conservative estimate, because the state of the stocks in 2020 represents a major additional cost.

Figure 18: Simulation results for Iberian tuna and billfishes: total catches; end stocks in 2020; and years with low stocks



6.5 Mediterranean Sea

Fisheries in the Mediterranean are much more loosely managed than those in the other LMEs considered. The only TACs currently defined are for bluefin tuna, though there are numerous other restrictions in place regarding gear, closed seasons and so on. In addition, there is very limited data on the status of different stocks, and little information about IUU fishing levels. The main exception to this is the tuna and swordfish case, discussed in section 5.3 above. This is the only group we feel comfortable modelling in this LME. It represents 13% of the fishery value of the Mediterranean. The IUU fishing level estimate of 45% is based on the average of ICCAT and Greek estimates (see Table 1, Table 7).

Table 19: Tuna and billfishes model and IUU fishing costs for the Mediterranean

	Tuna and billfishes
Average landings (t)	
Maximum landings (t)	
Recent landings (t)	60,000 – under-reported
Landings trend	Plateau; possible decline
Evidence on stock size/TAC (ICCAT advice)	MSY perhaps 15,000 for swordfish, 45,000 for Bluefin; current stocks perhaps around 25% of virgin levels/half of MSY levels
MSY estimate (t)	80,000
R estimate	0.5
Implied K (t)	640,000
Bpa estimate (t)	128,000
Recent escapement estimate (t)	160,000
TAC estimate (t)	60,000
Starting stock estimate (t)	220,000
IUU rate estimate	45%
Value (euros per tonne)	4,707
Jobs per million euros	45
Lost end stock (t)	275,000
Lost catches (t)	185,000
Extra low stock years	13
Value lost stock (million euros)	1,294
Value lost catch (million euros)	871
Annual average value lost catch (million euros)	67
Lost jobs	2,987

Table 20: Costs of IUU activity for Mediterranean tuna/billfishes, by country fishing (values in million euros)

Country[51]	Share (%)	Stock value lost	Catch value lost	Jobs lost
France	2.3	30	20	69
Greece	13.5	175	118	403
Italy	38.9	504	339	1,162
Slovenia	0.1	1.3	0.9	3.0
Spain	11.8	153	103	352
EU	66.6	862	580	1,989
non-EU	33.4	432	291	998
TOTAL	**100**	**1,294**	**871**	**2,987**

This is another group for which the main impact is in terms of prevented stock recovery. The stocks are presently around 25% of virgin levels, near to our assumed Bpa. Action is

[51] As in other tables, Member States with less than 0.1% of the fishing value are omitted from the table – here, that includes Cyprus and Malta.

needed to protect them and allow them to recover. In the model, with no IUU activity, recovery is successful; with IUU activity around current levels, the stock is locked into a depleted state.

6.6 Conclusions for Chapter 6

The total cost estimates are summarised for the five LMEs in Table 21. However, the estimates are not truly comparable, because we have not modelled all commercial groups for each area; the last row in the table shows what proportion of the value of the fishery is modelled in our simulations.

Table 21 : Summary of costs of IUU fishing for commercial groups covered (million euros, jobs)

	Baltic	North	Celtic	Iberian	Mediterranean	All
Current value p.a.	537	1,670	1,640	491	2,040	6,370
Lost stock value	1,169	5,326	2,162	599	1,294	10,550
Lost catch value	678	6,479	3,567	916	871	12,510
Lost jobs	4,214	8,314	6,170	9,385	2,987	31,070
Fishery value modelled	91%	73%	46%	46%	13%	46%

The table shows that the lost catches in the years 2008 to 2020 are substantial. Taking into account that we have modelled only 46% of the groups, we can say that, across the groups modelled, the costs of IUU fishing include lost catches that are on average over 2008 to 2020 equal to approximately one-third of current actual catches.

Associated with this is a cost in terms of lost employment in fishing and processing. As noted previously, the data we have for employment are not fully reliable, so these results must be considered indicative. The number of jobs lost in EU Member States is estimated as 27,800, approximately 13% of total fisheries employment[52] of 216,000 (and again, this is based on only 46% of fisheries value).

The cost estimates may also be disaggregated according to Member States' shares of the value of fisheries in each LME, as shown in Table 22, though again these figures are not fully comparable. In particular, the percentage figures should not be compared across countries because we have modelled different proportions of fishery value in different areas.

To put these figures in overall context: we have constructed simple models representing a little less than one-half of European marine fisheries, by value. The results suggest that the costs of IUU activity in these fisheries are at least as great as indicated in Table 21. The estimated costs per year are 15% of the annual value of all landings from the LMEs, including the ones not modelled here, and the estimated cost in jobs is 13% of total employment in fisheries and processing.

It is not really possible to scale up to the level of the entire European fishing industry, because it is not all managed in the same fashion, and we have focused on commercial groups for which IUU fishing is likely to be a problem. But we have not examined all such groups – in particular, we did not consider nephrops, anchovy, or sharks and rays – and our cost estimates certainly do not exhaust the total costs of IUU fishing in Europe. We can extrapolate in this way: for groups like the ones we have modelled, likely to be subject to IUU fishing, the costs of IUU activity may be approximately 30% of catches and jobs. IUU fishing has additional impacts on stocks not included in these figures. Significant as these

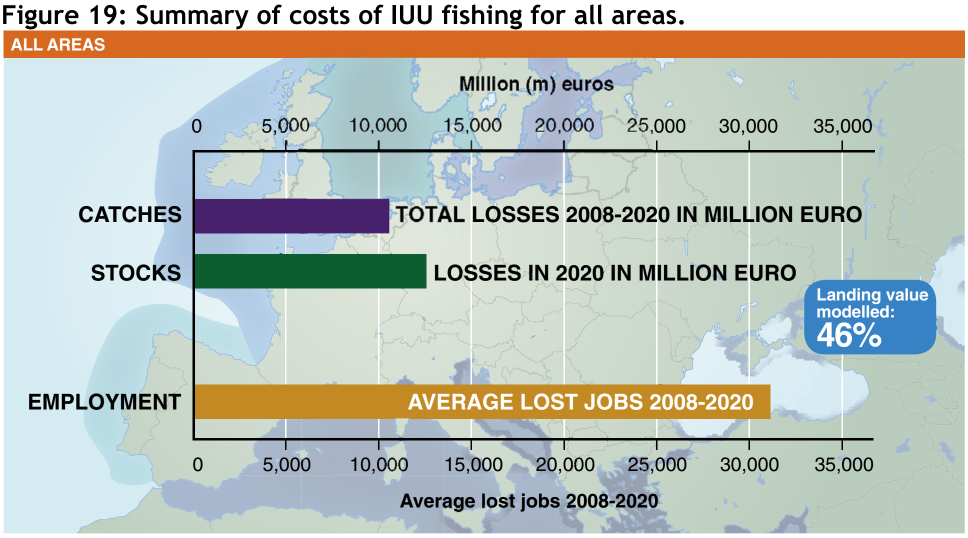
[52] Only in the EU Member States fishing in the LMEs we have considered. Total EU fisheries employment is a little higher, due to Romania, Bulgaria, and Member States with only inland fisheries.

estimates are, for the various reasons set out at the start of this chapter, they should be considered as a conservative minimum bound on the costs, which may in fact be substantially higher.

Table 22: Costs of IUU activity until 2020, broken down by country fishing

Member State	Landing value modelled	Stock value in mill. €	Annual value of landings		Employment 2008-2020	
			In mill. €	%	In real terms	%
Belgium	62%	90	9	23%	174	20%
Denmark	76%	1334	117	26%	2,415	54%
Estonia	91%	177	8	10%	636	8%
Finland	91%	102	5	10%	367	8%
France	46%	1092	130	17%	2,988	16%
Germany	70%	430	38	22%	900	21%
Greece	13%	175	9	3%	403	2%
Ireland	47%	404	50	17%	1,097	17%
Italy	13%	504	26	3%	1,162	3%
Latvia	91%	189	8	10%	683	17%
Lithuania	90%	25	1	10%	88	3%
Netherlands	64%	863	85	26%	1,526	44%
Poland	91%	140	6	10%	506	8%
Portugal	46%	207	24	14%	3,238	15%
Slovenia	13%	1	0	3%	3	1%
Spain	34%	693	73	11%	6,800	12%
Sweden	81%	482	36	21%	1,119	58%
UK	60%	1,948	200	24%	3,715	32%
EU	46%	8,855	827	16%	27,818	13%

Figure 19: Summary of costs of IUU fishing for all areas.



7. Conclusions

This report describes a preliminary investigation into the level of the economic, social and environmental costs of IUU fishing at the wide scale of EU fisheries and concerning impacts on EU Member States. The arguments and evidence set out in the preceding chapters illustrate the very substantial costs of IUU fishing to EU Member States, under certain assumptions and using modelling as described in the previous chapters.

- Lost catches from 2008 to 2020: total cost of €10.7 billion, equivalent annual average to about 30% of fishery value in those fisheries modelled.
- Lost jobs: over 27,800 lost job opportunities in fishing and processing industries, around 13% of total fisheries employment
- Lost stocks: valuing lost stocks at the same value per tonne as landings suggests a total cost of almost €9 billion.

These costs, though substantial, do not represent the full costs of IUU fishing, for several reasons. For one, we have not modelled all stocks; our models for commercial groups cover approximately 46% of EU fisheries value. Also, we have modelled only three key costs of IUU fishing – several others that we identified in Chapter 3 have not been estimated. We have aimed to be realistic but conservative in our estimates of key parameters. And we have restricted attention to a short-time horizon (2020).

Therefore we conclude that the cost figures presented here can fairly be interpreted as a lower bound on the possible costs of IUU activity in EU fisheries; the true costs may be substantially higher.

Several other interesting points warrant consideration. Firstly, the costs of IUU fishing are very heavily dependent on the management strategy in the fishery. The different scenarios we tested gave very different results at the same levels of IUU activity. This is not a problem with the models, but rather a feature of the real world.

Much of the question turns on how flexible the TAC-setting rules are: those which are highly flexible, and are able to react to IUU activity and counter any stock depleting effect, will tend to show low costs for IUU fishing over a range of low to moderate levels.

But what underlies this result is simple shifting of catch from 'legal' to 'illegal' categories. In effect the management response to IUU activity is to reduce legal quotas, so that the total catch stays within targets (to a greater or lesser extent, depending on the precise rule). And of course such a policy could help keep total harvests to sustainable levels. Or in any event, this is how it would appear in simple models such as those presented here. But the social impacts of this could be very negative, penalising legal fishers for the illegal activities of others. In a way, of course, such unfairness is unavoidable – either the legal fishers are penalised through reduced quotas, or they're penalised through reduced stocks; but if there is IUU fishing, someone, somewhere, has to bear the costs.

At the other end of the scale, seriously inflexible or badly adapted rules will often also show low costs under IUU scenarios. Where the TAC-setting rule is inflexible, the costs of IUU fishing may appear limited, because the TAC rule itself can be the main cause of stock failures or of preventing stock recovery. The point here is that if the management regime is already destroying a fishery, IUU fishing isn't going to make it much worse.

In between these extremes lie a great many possible rules for managing fisheries, and IUU fishing will interact differently with each one. Our simulations suggest that the costs of IUU fishing will usually be quite non-linear. That is, at low levels of IUU activity, costs will usually rise quite slowly, but at some threshold level of IUU fishing, costs will start to rise quickly. Sometimes this rise is quite gradual and sustained over a wide range of IUU fishing rates, but more generally the costs will rise rapidly over a fairly short range of IUU fishing rates, reaching at some IUU activity level a maximum cost, where the fishery is in a collapsed state.

The precise details of where the rapid-cost increases occur varies according to the specific details of model parameters. An important problem with IUU fishing is that we don't really know how much there is; these models suggest that this is rather important information, because the difference between rates of 20% and 40% IUU activity is unlikely to be a simple doubling of costs – it is more likely to be the difference between a reasonably healthy fishery and a collapsed stock.

Another key element determining costs is the time horizon. Essentially, we have modelled IUU activity as taking more catch in a given year than is permitted. The *initial* effect of IUU fishing is therefore to increase catches. Of course the pay-back to this is that future stocks will be reduced, and eventually that will lead to higher catches in the no-IUU case. But the amount of time it takes the no-IUU scenario to move into the lead varies with the parameters of the fishery, in particular the starting stock and growth rate, and the rule for setting TACs. With the relatively short-time horizon we consider, we found that most groups did move to a positive balance within the simulation period, but this was not the case for the slowest growing groups. These groups nonetheless showed heavy depletion of stocks. Had the simulations been conducted over a longer time period, we would have seen a much greater proportion of costs arising under 'lost catches' rather than 'lost stock'. Since the carrying capacity of the fisheries is limited, there is only so much stock it is possible to lose. Beyond that point, the difference in stocks remains the same, and the ongoing cost is in the very different catches that different stock sizes can support.

Overall the results of simulations suggest that the costs of IUU fishing can be very high for stocks that are overexploited. Where the stock is in good shape, and TACs are not excessive, the costs of lower IUU fishing levels (up to 20%) may be reasonably small. However, significant costs arise for higher levels of IUU fishing (40% and above).

The level of IUU fishing when TAC is low, or the fishery is closed, can be especially important. These are the times that the stock is most vulnerable to overexploitation, and most in need of respite. Ongoing IUU fishing can destroy the effectiveness of stock conservation measures such as fisheries closures.

So far as determining estimates of costs of IUU fishing is concerned, the only satisfactory answer to the problem of these costs being dependent on the TAC-setting rule is to attempt to get as close as possible to how TACs are set in reality. The rule we chose for this purpose is a reasonably conservative one: it allows TAC to change by +/-25%, aiming for MSY, but taking zero TAC below a precautionary threshold, while recognising that IUU activity will continue in a closed fishery. This is quite close to the actual principle used in European TAC setting and would allow all commercial groups modelled to recover to around MSY levels by 2020 if IUU fishing were eliminated.

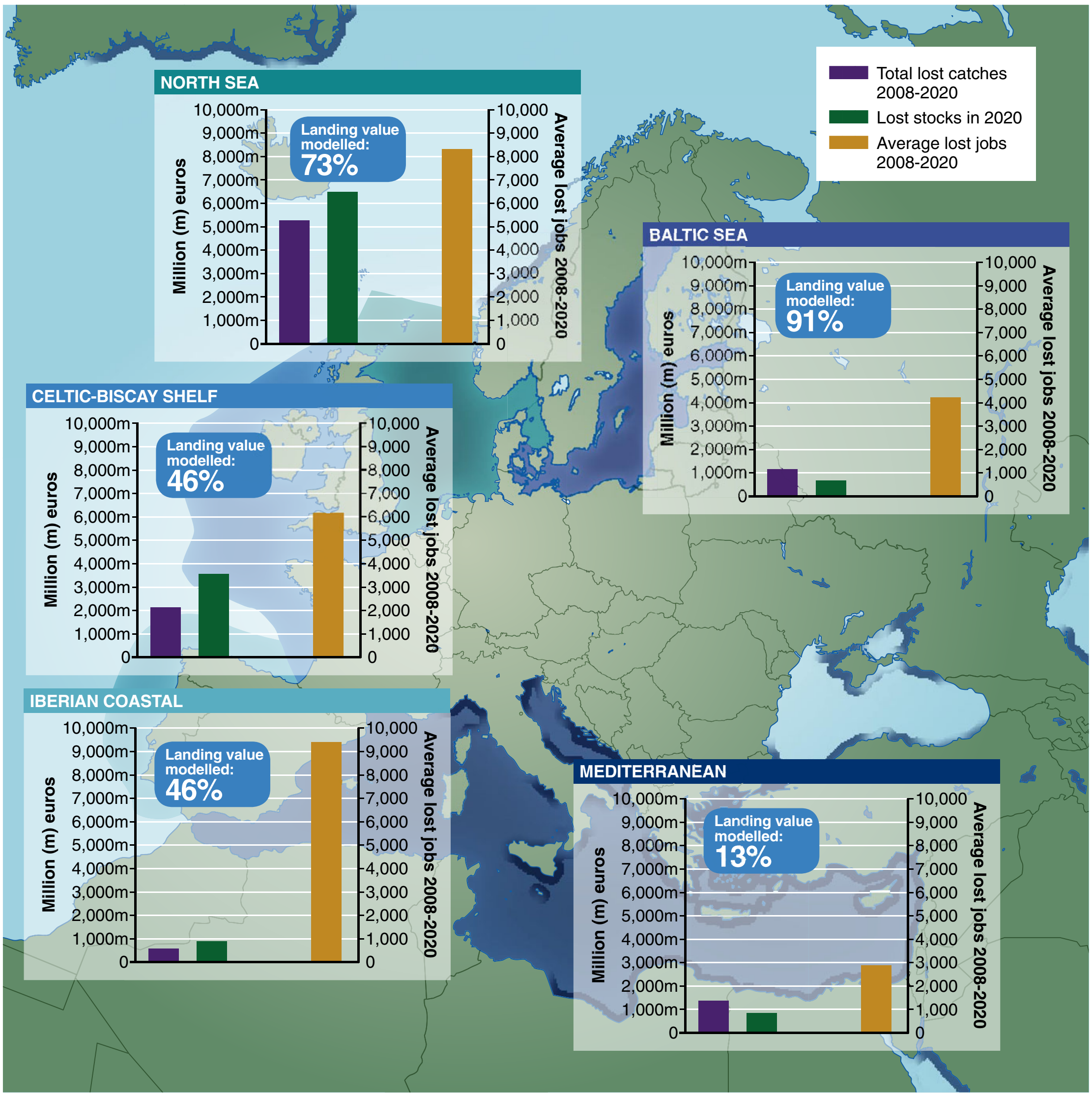
Our costs estimates are also conservative in focusing only on three main cost categories: the cost of lost catches; the cost of reduced stock size; and the cost of lost jobs in the fishing industry. Many additional costs exist (see Chapter 3).

Because of the limited time horizon, the conservative TAC-setting rule, the reduced set of cost categories, and the focus on a subset of EU fisheries, our cost estimates are likely to be significant underestimates of the true costs of IUU activity in EU fisheries. Nevertheless, our cost estimates are substantial, as summarised in Table 21. As mentioned above, and shown in figure 20, across the five LMEs, the cost estimates for European Member States sum to:

- over €10 billion of lost catches until 2020;
- over €8 billion of lost stock value in 2020; and
- over 27,000 lost jobs in fishing and processing industries.

These costs are substantial. For comparison, EU Member State fishing in the LMEs under assessment is valued in the region of €6 billion per annum. Still, these costs, large as they are, do not represent the full costs of IUU fishing, because we have not modelled all stocks, nor all costs, and our methods have been conservative. Thus we conclude that the true costs of IUU fishing are likely to be substantially higher than the estimates set out here.

Figure 20: Summary of costs of IUU fishing for five LMEs.



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