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Deliverable 2.2

Economic performance of selected European and Canadian fisheries

31. August 2016

Executive Summary

This deliverable analyses recent productivity developments in some of the most important capture fisheries in Europe. Using data on specific fleet segments, productivity growth has been compared between the demersal fisheries in UK, Spain, Norway, Iceland and the Faroe Islands, as well as the pelagic fisheries in the UK, Denmark, Norway, Iceland and the Faroe Islands.

In this study, output is measured as total landings of the sum of the most important demersal or pelagic species and an aggregate stock is compiled from stock assessments of the corresponding stocks. Capital is measured as a three-dimensional capacity index, where allowance is made for the number of vessels in each fleet segment, as well as average length and engine size. Labour is measured as the number of employed. The period spanned by the data differs, and is in some cases quite short.

Two measures of multifactor productivity have been compiled; 2-factor productivity (2-FP) which analyses the interplay between landings on the one hand and capital and labour on the other hand, and 3-factor productivity (3-FP), which also takes into consideration the impact that changes in stock size have on productivity.

In the demersal fisheries, productivity grew on average by 1.5% in the Faroese fisheries over the period 1994-2014. The second highest growth was observed for the UK fleet, 1.2%, but the time period is much shorter or only 2009-2014. Productivity was stagnant in Iceland but declined on average by 0.5% in the Norwegian fisheries during 2003-2014. The Spanish NAFO fleet experienced an average productivity decline of 8.1% during 2007-2014. Smaller fleet capacity and lower employment have had a positive effect on the productivity growth in the demersal fisheries, but growing stocks have led to deteriorating productivity.

The UK pelagic fisheries outperformed the corresponding fisheries in Denmark, Norway, Iceland and the Faroe Islands. The UK productivity growth amounted on average to 15% during 2009-2014, but was 7.3% in Denmark in 2010-2014. Productivity in the Norwegian pelagic fisheries declined on average during 2002-2014 by 2.5% and by 5% in the Faroese fisheries over the same period. In Iceland, productivity in the pelagic fisheries declined on average by 10.4% during 2003-2014. Changes in productivity in the pelagic fisheries can mostly be attributed to changes in landings and changes in capital and labour, with changes in stock only having a small effect.

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Introduction

In 2014, European catches of marine fishes totalled 12.2 million tons (FAO, 2016). Landings of demersal species amounted to 5.9 million tons, whereof catches of cods, hakes and haddocks totalled 5.1 million tons. This FAO category contains the most important demersal species, i.e. Atlantic cod, haddock, hake, saithe and whiting. Pelagic catches in that same year totalled 4.9 million tons, whereof catches of herrings, sardines and anchovies totalled 2.7 million tons. Other important pelagic species, such as mackerel and capelin are included in the FAO category miscellaneous pelagic fishes.

Table 1 European marine catches in 2014. Thousand tons.

FAO category	000 tonnes
Demersal species	
Cods, hakes, haddocks	5,091
Flounders, halibuts, soles	374
Miscellaneous demersal fishes	418
Pelagic species	
Herrings, sardines, anchovies	2,718
Miscellaneous pelagic fishes	2,196
Sharks, rays, chimaeras	138
Other species	
Tunas, bonitos, billfishes	540
Miscellaneous coastal fishes	650
Marine fishes not identified	113
Total	12,238

Source: FAO.

Most of the European demersal catches were registered by vessels from non-EU countries. Thus Russian catches of cods, hakes and haddocks amounted to 2.3 million tons, Norwegian to 1.2 million tons and Faroese and Icelandic catches totalled 830 thousand tons. Within the EU, the main demersal fishing nations are Spain, the UK, France and Denmark.

Table 2 European catches of cods, hakes and haddocks in 2014. Thousand tons.

Country	000 tonnes
Denmark	98
France	112
United Kingdom	140
Spain	179
Faroe Islands	308
Iceland	523
Norway	1.179
Russia	2.347
Other countries	206
Total	5.091

Source: FAO.

The most important pelagic nations within EU include Germany, Spain and the Netherlands, and especially Denmark and the UK, but much of the European pelagic catches are also registered by vessels from non-EU countries. Thus, in 2014, landings of the pelagic fleets in the Faroe Islands, Iceland, Norway and Russia totalled 2.3 million tons, or 47% of all European catches. In what follows the economic performance of the pelagic fleets in Denmark, Germany and the UK is compared with the performance of the corresponding fleets in the Faroe Islands, Iceland and Norway

Table 3 European pelagic catches in 2014. Thousand tons.

Country	000 tonnes
Germany	132
Faroe Islands	202
Spain	212
Netherlands	246
Denmark	385
UK	408
Iceland	440
Norway	787
Russia	895
Other countries	1,206
Total	4,782

Source: FAO.

The aim of this deliverable is to use sector-level data to analyse and decompose productivity growth in selected capture fisheries. The deliverable is the outcome of two tasks within work package (WP) 2 in PrimeFish; Task 2.1.1 Demersal (cod) fisheries, and Task 2.1.2 North Atlantic pelagics (herring). The former task consists of comparing the economic performance, measured as productivity growth, of the industrial demersal fisheries in Iceland, Norway, Spain, the UK and Newfoundland. However, finding suitable data for Newfoundland has proved extremely difficult. No public data at fleet segment level was available, and data from the Canadian fisheries departments was not ready for release at the time of delivery of this deliverable. To compensate for that it was decided to include data on the Faroese demersal fisheries. The second task consists of comparing the economic performance of the industrial pelagic fleets in Denmark, Iceland, the Faroe Islands, Norway, Germany and the UK. German data was, however, not available for the specific fleet segment. The study therefore includes most of the major demersal and pelagic fishing nations in Europe.

The PrimeFish grant agreement explicitly states that the analysis will be undertaken using microeconomic models which make it possible to decompose changes in productivity into technical change and scale effects. However, such an approach demands far longer time-series than proved to be available. Although good aggregate data can be found on the fisheries sectors in most countries, finding more disaggregated data, as is needed for this kind of analysis, proved to be more troublesome. The data employed in tasks 2.1.1 and 2.1.2 and this deliverable often only covers 10 years or so, and it was therefore decided to abandon the idea of using parametric microeconomic models. Instead, the analysis is based on growth-accounting methods which are well routed in microeconomic theory and have been used in earlier studies on productivity growth in fisheries. This approach is described in considerable detail in the section on methods.

Methods

In the simple production process when one input is used to produce one output, output produced per unit of input yields a comprehensive measure of productivity. However, matters become a bit more complicated when several inputs are used to produce several outputs. Focusing on the productivity on one input will then only yield partial productivity measures, such as for instance output per worker per hour worked or output per unit of capital or machine hour. Although commonly used, such measures provide an incomplete picture and may even "mislead and misrepresent the performance of a firm" (Coelli, Rao, O'Donnell, & Battese, 2005, p. 62). Labour productivity can, for instance, improve because of more skilled labour or because of the additional usage of other inputs, such as capital.

To counter this, measures of multifactor or total factor productivity (MFP or TFP) have been developed and applied to cases where a multitude of inputs are employed to produce several outputs. By thus taking into account the changes that utilisation of all inputs has on production, these measures provide a more accurate picture of productivity. Total factor productivity may then be defined as the ratio of aggregate output produced relative to aggregate input used.

Following Solow (1957), the production function may be written as

(1) $y_t = A(t) f(X_t)$

where *y* is a single output, *X* is a vector of inputs, *A(t)* represents Hicks neutral technical change, i.e. technical change that does not impact on the relative use of inputs and thus leaves the mix of inputs used the same, and *t* denotes time. Assume further that $f(X_t)$ exhibits constant-returns-to-scale, i.e. that a 1% increase in the use of all inputs will result in 1% increase in output, and that inputs are paid the value of their marginal products, i.e.

(2) $$\frac{\delta f(y_t)}{\delta x_{nt}} = \frac{w_{nt}}{p_t}$$

where *n* denotes input *n*, *w* the price of input *n* and *p* the price of output. The left hand side of (2) thus represents the marginal product of input *n*, and the right hand side the share of the value of input *n* in the price of output *y*. This assumption presumes that producers maximise profits, and the absence of any technical or allocative efficiencies. Total differentiation of (1) then yields

(3) $$\frac{\dot{y}}{y} = \frac{\dot{A}}{A} + \sum_{n=1}^{N} \left(\frac{\delta f(X_t)}{\delta x_{nt}}\right)\left(\frac{x_{nt}}{f(X_t)}\right)\left(\frac{\dot{x_{nt}}}{x_{nt}}\right)$$

where dots indicate time derivatives, i.e. $\dot{y} = \frac{dy}{dt}$, and $\frac{\dot{y}}{y}$ represents relative changes in output.

From (2) it follows that that the share of input *n* in total input usage may be written as

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$$(4) \qquad S_{nt} = \left(\frac{\delta f(X_t)}{\delta x_{nt}}\right)\left(\frac{x_{nt}}{f(X_t)}\right)$$

$$= \left(\frac{\delta y_t}{\delta x_{nt}}\right)\left(\frac{x_{nt}}{y_t}\right)$$

$$= \left(\frac{w_{nt}}{p_t}\right)\left(\frac{x_{nt}}{y_t}\right)$$

$$= \frac{w_{nt}\, x_{nt}}{\sum_{n=1}^{N} w_{nt}\, x_{nt}}.$$

Consequently, (2) may be expressed as

$$(5) \qquad \frac{\dot{y}}{y} = \frac{\dot{A}}{A} + \sum_{n=1}^{N} S_{nt}\left(\frac{\dot{x}_{nt}}{x_{nt}}\right)$$

or

$$(6) \qquad \frac{\dot{A}}{A} = \frac{\dot{y}}{y} - \sum_{n=1}^{N} S_{nt}\left(\frac{\dot{x}_{nt}}{x_{nt}}\right)$$

Here, the component that represents neutral technical change in the production function, $\frac{\dot{A}}{A}$, may be viewed as a residual growth in output that is not accounted for by growth in inputs. This growth accounting representation was introduced into the literature by Solow (1957) and later employed in empirical analysis of productivity growth by several authors (Kendrick, 1961), (Jorgenson & Griliches, 1967) and (Denison, 1972).

As shown by Solow (1957), productivity can now be calculated provided the time derivatives in (6) can be approximated by discrete changes. Grosskopf (1993) notes that this results in a non-parametric index of productivity growth which in its continuous time formulation is equivalent to a Dvisia index of productivity growth. Taking log-differences and calculating input shares as arithmetic means yields results equivalent to the Törnqvist (1936) index of total factor productivity growth.

$$(7) \qquad TFP = (ln\, y_t - ln\, y_{t-1}) - \sum_{n=1}^{N} \frac{1}{2}(s_{nt} + s_{nt-1})(ln\, x_{nt} - ln\, x_{nt-1})$$

If the production technology in (1) is of translog form, then the Törnqvist index has been shown to be an exact and superlative index (Diewert, 1976).

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Provided data on output, inputs and input shares are available, productivity growth can easily be calculated using (7), but the underlying technology as expressed by (1) can also be estimated using parametric and non-parametric techniques.

As noted by Hannesson (1983) the fisheries production function may be stated as

(8) $$Y_{it} = F(K_{it}, L_{it}, t)S_{it}^{\alpha_i}$$

where Y_{it} denotes catches of species i at time t (or values of catches in fixed prices), K_{it} and L_{it} the amount of capital and labour used in the harvesting of species i at time t, and S$_{it}$ the stock of species i at time t, while α_i represents the elasticity of output with respect to the stock of species i. This representation of the fisheries production function assumed separability between stock input and the other factor of inputs, capital and labour. Eggert and Tveterås (2013) refer to capital and labour in the production function as control inputs, as operators are able to change their usage in the production process, whereas stocks are outside the realm of individual harvesters.

The elasticity of output with respect to stock refers to the catchability of individual stocks which may differ substantially between pelagic and demersal species, reflecting different distribution patterns of stocks. Thus, while pelagic species tend to form schools, many demersal species tend to be more evenly distributed. In the case of pelagic species the stock elasticity of output will therefore take a value close to zero, indicating that even if stocks are large the schooling behaviour of the specie in question may reduce its catchability, while in the case of demersal species the elasticity may take a value close to unity. Empirical studies (Bjørndal, 1987; Sandberg, 2006), have revealed a weak stock effect for pelagic species such as herring, implying a value of close to zero for the stock elasticity, but a value close to unity for demersal species (Hannesson, 1983; Hannesson, 2007; Sandberg, 2006).

Although the first study on productivity in the fisheries were undertaken in the 1960s (Comitini & Huang, 1967), it was not really until the 1990s that serious attempts were made to examine the economic performance of fisheries (Walden, Fissel, Squires, & Vestergaard, 2015). Since then numerous studies have been undertaken of productivity of selected fisheries. Typically, these have been based on data on individual vessels which make it possible to employ either stochastic frontier analysis (SFA) or data envelopment analysis (DEA) to decompose productivity changes into changes in efficiency, economies of scale and technology. However, several studies have also been undertaken at a more aggregate level.

This study follows the approach set out be Arnason (2003) and later used by Eggert and Tveterås (2013) to compare productivity of the Icelandic, Norwegian and Swedish fisheries. Using eq. (8), the Törnqvist approximation of total factor productivity change in fisheries in discrete time may be defined as

(9) $$TFP = (ln\,Y_t - ln\,Y_{t-1}) - \gamma\delta\frac{1}{2}(s_{kt} + s_{kt-1})(\ln K_t - ln\,K_{t-1})$$

$$-\gamma_t\delta_t\frac{1}{2}(s_{lt} + s_{lt-1})(\ln L_t - ln\,L_{t-1}) - \frac{1}{2}(s_{at} + s_{at-1})(\ln S_t - ln\,S_{t-1}).$$

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Here, Y represents landings which are measured in tons. Although fishermen may target one specific species, there is also some bycatch of other species, which in many cases may be considerable. In fisheries analysed in this deliverable, Y is therefore always defined as aggregate of the most important species targeted by fleet segment in question. In the case of demersal fisheries, Y may therefore represent the combined catches of cod, haddock and saithe, and in the pelagic cases Y may represent the combined catches of herring, mackerel and capelin. The precise definition of Y does, however, differ between cases. K is defined as a capacity index that is usually measured as the product of average vessel length, average engine size (in kW) and number of vessels. This measured does therefore both take into account changes in the number of vessels and harvesting capacity of the vessels. L is defined as the number of employed fishermen or full-time equivalents. The value of the share of labour (s_l) and capital (s_k) is taken from the economic accounts of the fishery.

As explained above, Y represents the total catches of the most important species of the relevant fleet segment. In the Icelandic case, for instance, catches of cod, haddock, saithe, redfish, wolffish and ling made on average up 89% of the total catches of the demersal fleet during the period 2002-2014. If it can be assumed that harvesting of all species is equally capital- and labour-intensive, which is a questionable assumption, it follows that capital and labour was only utilised 89% of the time on the harvesting of these six species. In the productivity analysis, this can be "corrected" by multiplying K and L by the parameter γ which takes on a value of unity if Y includes catches of all the species harvested by the relevant fleet, but a value below unity if catches of some species are excluded. In the Icelandic case, γ would therefore on average take a value of 0.89.

In some of the cases included in this deliverable, information exists on the number of days-at-sea, i.e. the number of days spent searching for fishable quantities of the target species and time spent on fishing. Where such information is available, it may be used to adjust the utilisation of capital and labour, by multiplying K and L by the ratio of actual number of days-at-sea divided by 300, i.e.

$$\delta = \frac{number\ of\ days\ at\ sea}{300}.$$

The denominator is set at 300 rather than 365 (the number of days in a year) to take into account the fact that vessels may spend some day in harbour between fishing trips and to allow for time for necessary refurbishment and maintenance. Both γ and δ will in general vary between years, i.e. not take on fixed values.

Finally, in eq. (9) S represents an aggregate measure of the same stocks as included in Y. For the Icelandic case, mentioned above, S would therefore be defined as the sum of the stocks of cod, haddock, saithe, redfish, wolffish and ling. Stocks are usually defined as spawning stock biomass (SSB) or fishable biomass if information on SSB is unavailable. The output elasticity, s_a, is set at 0.85 for all demersal species and 0.1 for all pelagic species.

Provided data are available on landings, capital, labour and stocks, as well as the share of capital and labour, eq. (9) can then be used to calculate annual changes in total factor productivity for the fishery in question. As stated in eq. (9), productivity growth will depend on changes in landings, changes in the capital and labour, and changes in stocks. While increased landings have a positive effect on productivity growth, decreased landings will retard productivity growth. Increases in capital and labour will, *ceteris paribus*, decrease productivity growth, but decreases in these control inputs will have a

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positive effect. It should be remembered that in the studies included in this deliverable, K is defined as a three dimensional capacity index that allows for changes in the number of vessels, average length and average engine size. Thus, scrapping programs that are aimed at reducing the number of vessels will encourage productivity growth. However, the harvesting capacity of the vessels remaining in the fleet may increase enough to compensate for the fall in vessel number. The end result could thus be an increase in K. In eq. (9), stocks are treated just like a traditional input. Increases in stock size will then, ceteris paribus, decrease productivity growth, while decreases in stocks enhance productivity growth. In this analysis, fishing stocks is therefore considered a viable way to promote productivity. This counterintuitive argument does though only hold in the short run, i.e. in the same year. In the long-run fishing down stocks will decrease catches and may of course jeopardize the existence of the fish species in question.

The next sections will describe each of the cases included in this deliverable, discuss the data used and present the productivity growth calculations. For each case, a table is presented that shows how average productivity growth may be decomposed into changes in landings, changes in capital and labour (the control inputs capital and labour are together regarded as one component), and changes in stocks. This is followed by a figure that shows how productivity growth and its three components have developed over the period under observation.

This may be illustrated using Figure 1 below which shows the development of productivity in the Faroese demersal fisheries 1994-2014. Here, the black line shows productivity developments, and the columns show changes in landings (red), capital and labour (dark blue) and stocks (light blue). Columns stretching up (above the zero line) represent changes that have a positive effect on productivity, while columns stretching downwards represent changes that have a negative effect on productivity. To take an example, increased landings in 1994-1997 led to productivity increases but decreased landings in 2006-2011 led to declining productivity. In 2005, decreases in capital and labour had a positive impact on productivity growth, but increases in capital and labour in 2003 retarded productivity growth. The figure also clearly illustrates the importance that changes in stocks can have on productivity. The productivity growth decline in 1996 can thus be explained by increases in the aggregate demersal stock that far outweighed the positive effect that increased landings and smaller capital and labour had on productivity growth.
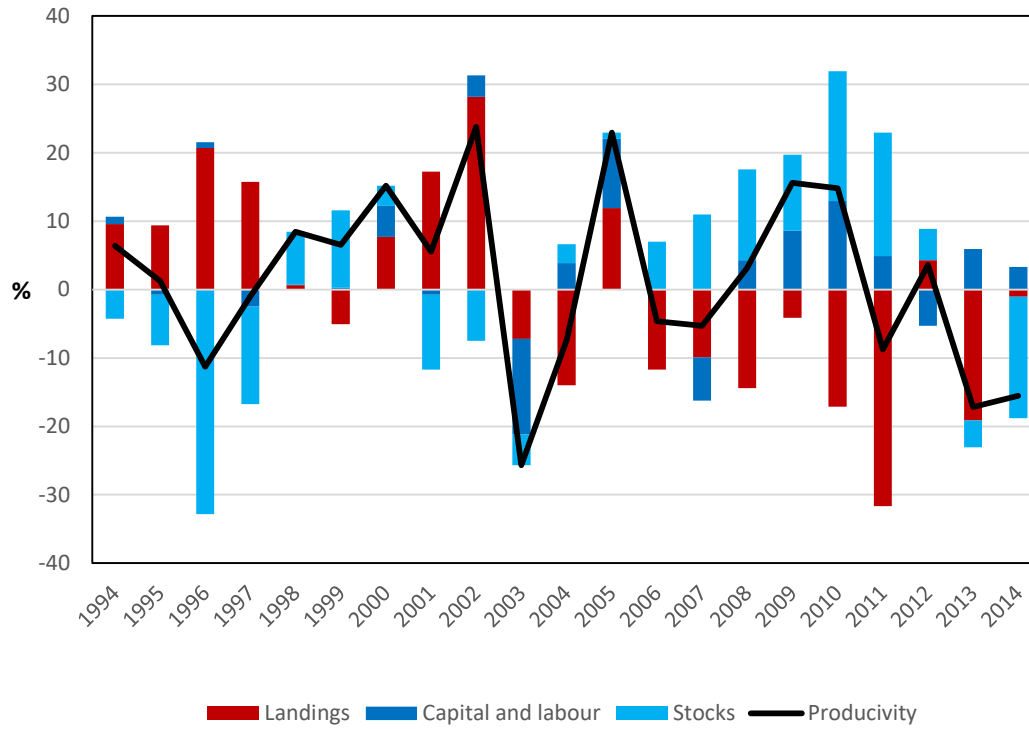
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Figure 1 Decomposition of changes in the productivity of the Faroese demersal fisheries 1994-2014.

![PrimeFish logo]

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Results

Demersal fisheries in the UK

Introduction

Systematic records of fish landings in the UK began in 1889 (Thurstan et al., 2010). A rapid increase in total landings from the late 19th century to the mid-twentieth century corresponding to growth of the fleet, technological progress and expansion to new grounds, could be seen in the left panel of Figure 2. The increase was punctuated by abrupt declines during the two world wars when fishing became too dangerous and vessels were put to other uses. After World War II, landings went into long-term decline, despite heavy investment in the fleet. The right panel of Figure 2 shows the changing composition of the fleet over time. The sail trawling fleet began with around 2.5 times the overall fishing power of steam trawlers in 1889, but the latter had eclipsed the sail fleet by the beginning of the 20th century. Steam power peaked in the inter-war period, but declined after World War II as diesel engines were adopted. Figure 2 shows that total fishing power continued to increase after World War II and peaked in 1972, well after landings began to fall (Thurstan et al., 2010).

Throughout the 118-year time series, trawl vessels were responsible for the majority of demersal landings. In 1935, large trawlers landed 96 % of the demersal fish caught by large British fishing vessels using demersal gear, and in 1955 landed 91%. Throughout the 1950s, the Danish seine increased in importance as a demersal gear, but by 1982, large trawlers still landed 74 % of the total demersal catch by large vessels.
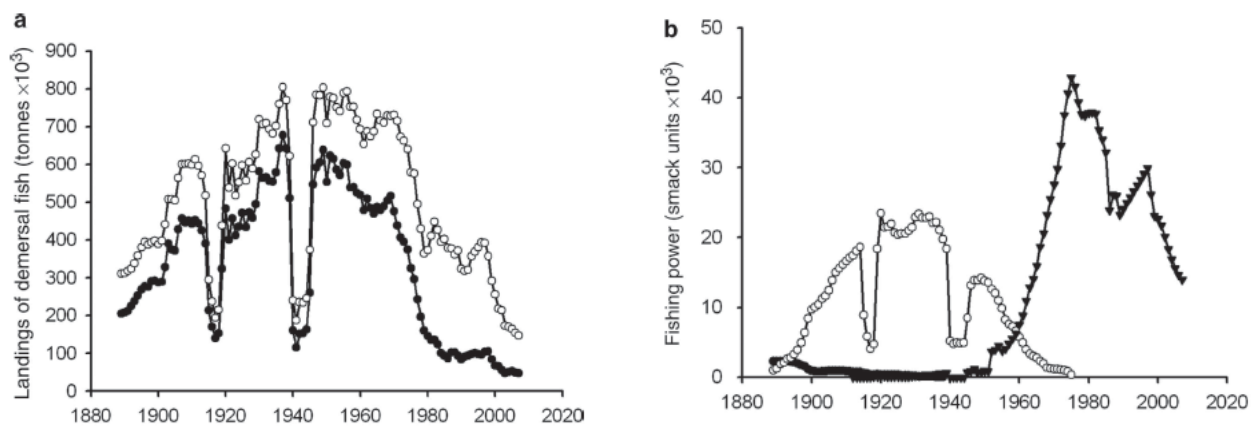
Figure 2 Changes in landings and fishing power of demersal fish from 1889 to 2007. Total landings of demersal fish speciesinto England and Wales (closed circles) and United Kingdon (open circles) by British vessels (left). Estimatd total fishing power of lage british vessels registered in England and Wales. Closed circles indicate sail trawlers, open circles –steam trawlers and closed triangles- motor trawler (right). Source: (Thurstan et al., 2010).

Catch rate

A simple measure of the productivity of fishing could be obtained by dividing landings by fishing power (see Figure 3). Although not a direct measure of stock size, this index of 'landings per unit of fishing power' (LPUP) (closed circles) offers insight into the availability of commercially valuable fish to the fleet. The picture is complicated slightly from the mid-1970s when landing limits for some species began to be introduced. In 1983, the European Common Fisheries Policy was formally enacted,

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introducing a system for setting total allowable catches among member states. However, by this time, most of the decline in fisheries had already occurred (corrected for landings abroad) (Thurstan et al., 2010). According to the same authors, four phases in the development of productivity of fisheries in the UK could be distinguished. Phase 1, from 1889 to the onset of World War I, corresponds to the rapid industrialization and intensification of fishing in home waters. During this period, the fleet was converted from sail to steam power. Landings increased, but new technology, more boats and expanded grounds masked a steep decline in fish stocks. Phase 2 covers the inter-war years of 1919 – 1939 and saw a second wave of expansion as fishing vessels sought new grounds in the Arctic and West Africa. The exploitation of these unexploited grounds brought an increase in LPUP that lasted until the late 1950s. Phase 3 covers the precipitous collapse in catches between 1956 and 1982 as distant-water stocks became fully exploited. Towards the end of this period, there was a sharp contraction in distant-water fishing opportunities, as Iceland and other nations declared first 50, then 200 nautical mile Exclusive Economic Zones. However, the timing of these moves (late 1960s to late 1970s) indicates that they were a response to declines in fish stocks rather than a cause of the collapse in fish landings experienced by the English and Welsh fleets. Phase 4 began in 1983 with the formal creation of the Common Fisheries Policy. Comparison of Figures 3-1a and 3-1b shows that landings into England and Wales were only maintained throughout the 1960s because of an increase in fishing power. A sharp decline in LPUP began in 1957, a decade before the collapse in landings began.
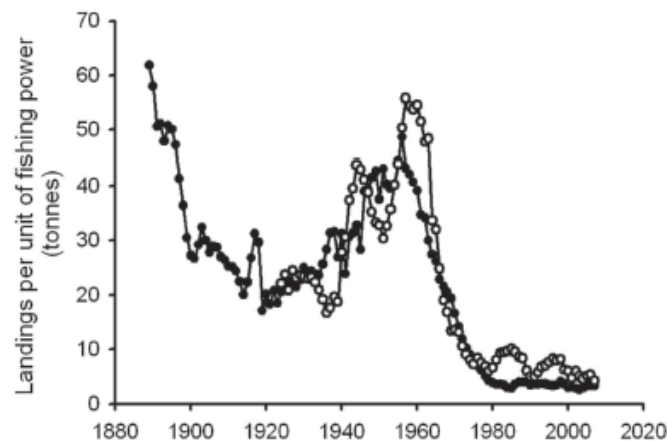
Figure 3 Trends in the productivity of bottom fi sheries (trawls).Landings of bottom-living fi sh per unit of fi shing power of large British trawlers from England, Wales and Scotland. Closed circles show LPUP into England and Wales, open circles show LPUP into Scotland. Source: (Thurstan et al., 2010)*.*

Stock biomass

As mentioned before, regulation of landings under the Common Fisheries Policy from 1983 makes it difficult to discern trends in underlying fish stocks from LPUP data. However, direct estimates of spawning stock biomass are available after 1982 for seven principal demersal species that together made up over half of the total landings, and show that during the period up to 2007, combined stocks around the United Kingdom declined by 42.6 % (see Figure 4) whereas LPUP for the same period declined by only 5.0 % Figure 2.
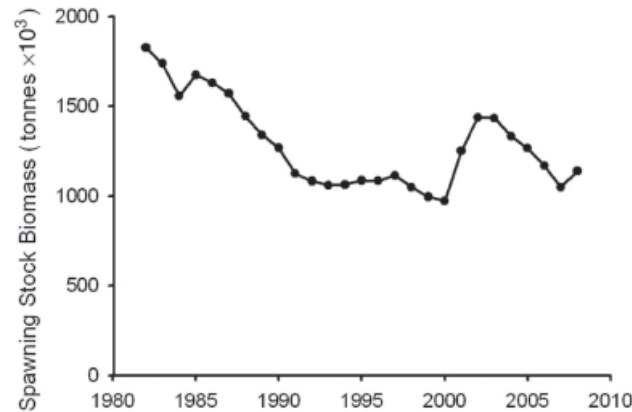
Figure 4 Summed spawning stock biomass of species in waters around the United Kingdom, where assessments are available (species included were cod, haddock, plaice, sole, whiting, saithe and hake). Spawning stock estimates were taken from ICES sub-areas appropriate to these species and in proximity to the United Kingdom, including IIIa (Skagerrak), IV (North Sea), VIa (West of Scotland), VIb (Rockall), VIIa (Irish Sea), VIId-e (English Channel) and VIIf-k (Celtic Sea). The hake stock from sub-areas VIIIa, b was also included. Sourc: (Thurstan et al., 2010).

When looking at the species composition of demersal catch since the 1950s (see Figure 5 and Figure 6) it can be noticed that cod predominated landings by UK vessels until 1980s, when it was overtaken by haddock as a top landed species by volume. Cod landings declined from a peak of more than 500,000 tonnes in the '50s to less than 30,000 tonnes in 2014. However, cod still remained one of the most important demersal fin-fish species for the UK fishing fleet.
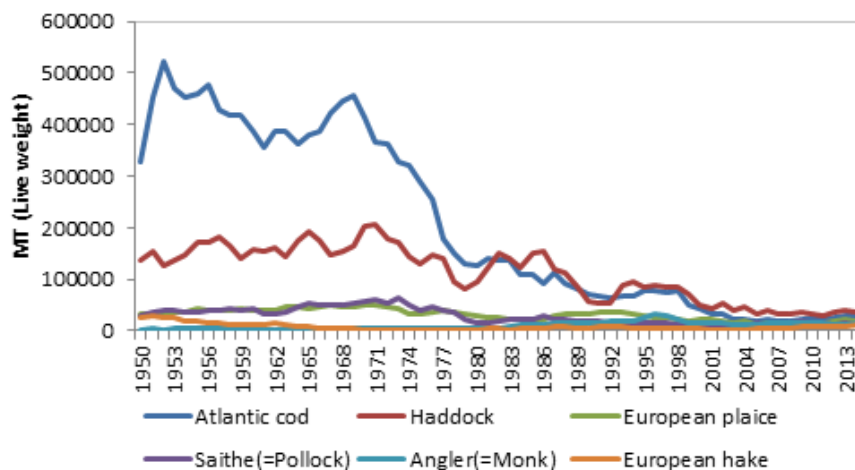
Figure 5 Landings of key demersal species by UK vessels into the UK and abroad (1950-2014). Tonnes. Source: FAOSTAT.
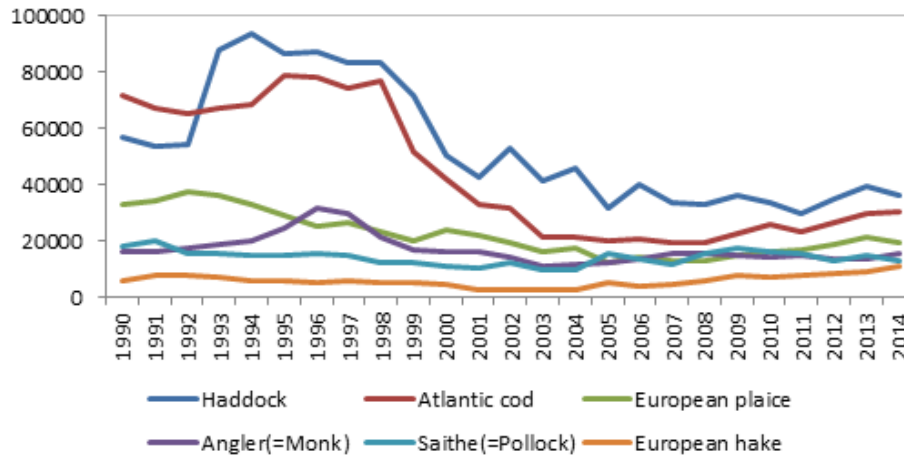
Figure 6 Landings of key demersal species by UK vessels into the UK and abroad (1990-2014). Tonnes. Source: FAOSTAT.

In 2014, the large majority of the three most important demersal fin-fish species was caught in the North sea (see Figure 7).
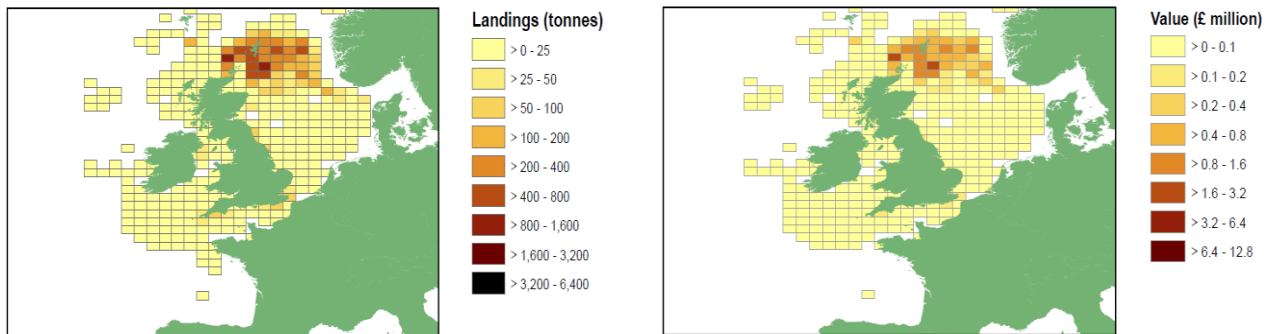
(a) Atlantic cod
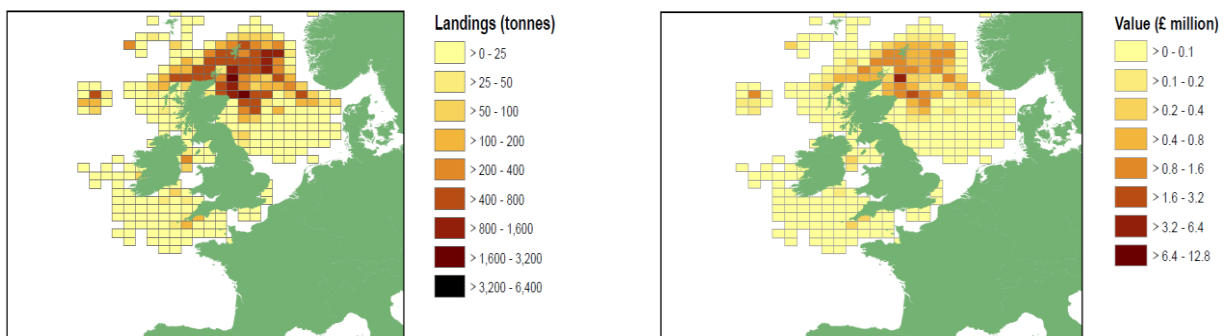
(b) Haddock
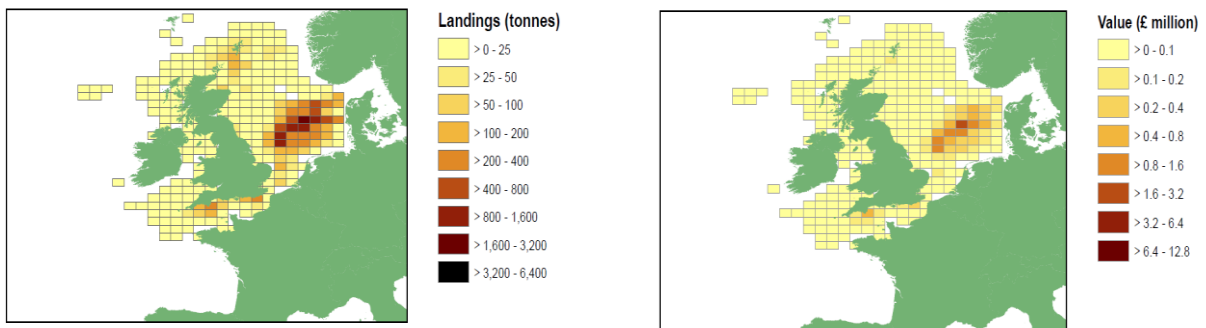
(c) European plaice

Figure 7 Landing of the three most important demersal fin fish species (in terms of volume of landings) by ICES rectangle. Source: Dixon (2015).

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Stock development by species

In this section the North Sea stocks of cod, haddock and plaice will be examined.

North Sea cod in ICES Sub-area IV (North Sea), ICES Division VIId (Eastern Channel) and ICES Division IIIa (Skagerrak)

The cod stock remains seriously depleted. It has been assessed as suffering reduced reproductive capacity by ICES since 2004. The spawning stock biomass has increased from the historic low in 2006 and is now in the vicinity of Blim, Fig 8. The international fishing rate has been high since the 1980s, and has shown a decline since 2000. The number of young cod (recruitment) has been low since 1987, and even lower since 1998, causing serious concern. The 2014 ICES assessment indicates that the 2005 year-class is estimated to be one of the most abundant amongst the recent poor year-classes. Agreement was reached in 2004 within the EU on a formal recovery plan that was operational during the TAC and management decision processes of 2004, effectively rendering the plan operational in 2005. Subsequently, this was repealed and replaced by Council Regulation (EC) No 1342/2008 to establish a long-term plan for cod stocks. The TAC for 2015 was 29,189 tonnes, compared with 27,799 tonnes in 2014 and 26,475 tonnes in both 2013 and 2012 (Dixon, 2014).
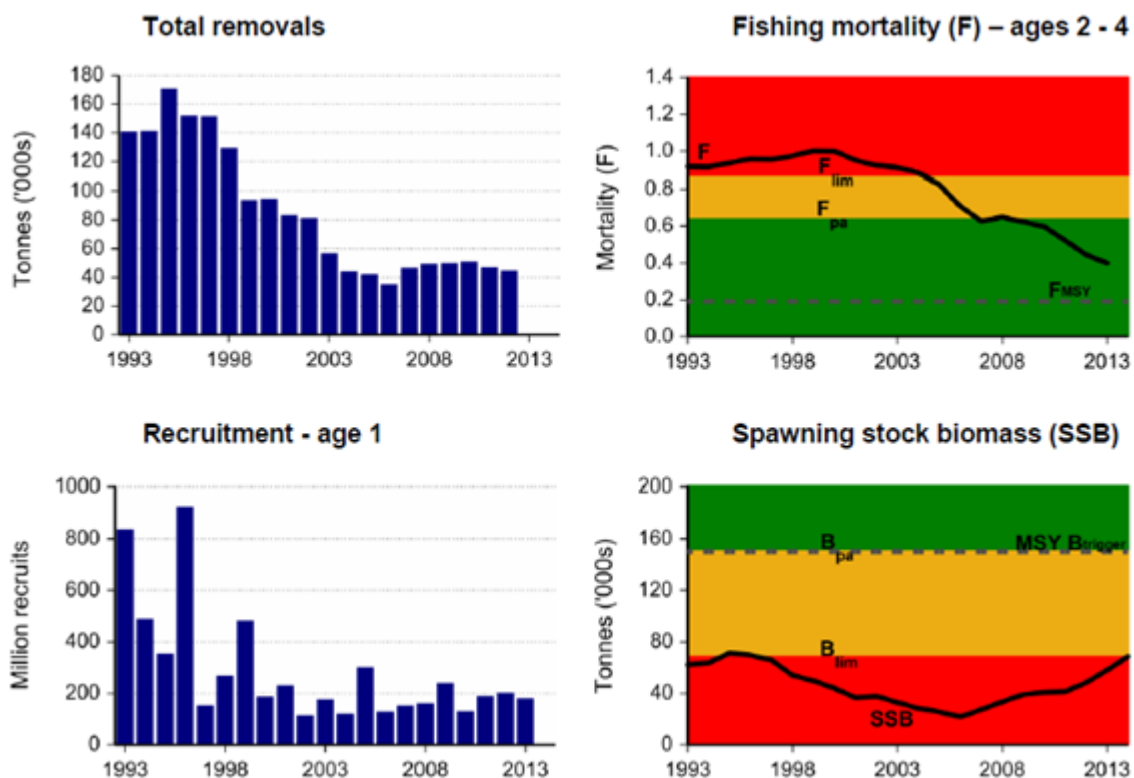

Figure 8 North sea cod stock development. Source: (Dixon, 2014)

North Sea, Skagerrak and West of Scotland Haddock – in ICES Sub-area IV (North Sea) and ICES Divisions IIIa (Skagerrak – Kattegat) and VIa (West of Scotland)

The haddock stock in the North Sea and Skagerrak is managed under an EU-Norway long-term management plan which is intended to constrain harvesting within safe biological limits and to provide for sustainable fisheries. In 2014, ICES has assessed the new combined area haddock stock as being at

full reproductive capacity and being harvested sustainably. Recruitment has been characterized by occasional large year classes, the last of which was the strong 1999 year-class. In the 2014 assessment, this haddock stock was combined with haddock in the Northern Shelf and assessed as a single stock. The 2014 assessment shows that the fishing mortality rate has been below FMSY since 2008 and is estimated to be below the target of 0.3 specified in the EU-Norway management plan (Subarea IV); and that apart from the relatively strong 2005 and 2009 year classes recent recruitment has been poor. In the North Sea, the haddock TAC was set at 45,040 tonnes for 2013, 38,284 tonnes for 2014 and 40,711 tonnes for 2015. In the West of Scotland, the TAC for 2015 is 4,536 tonnes, compared with 3,988 in 2014 and 4,211 tonnes in 2013 (Dixon, 2014)
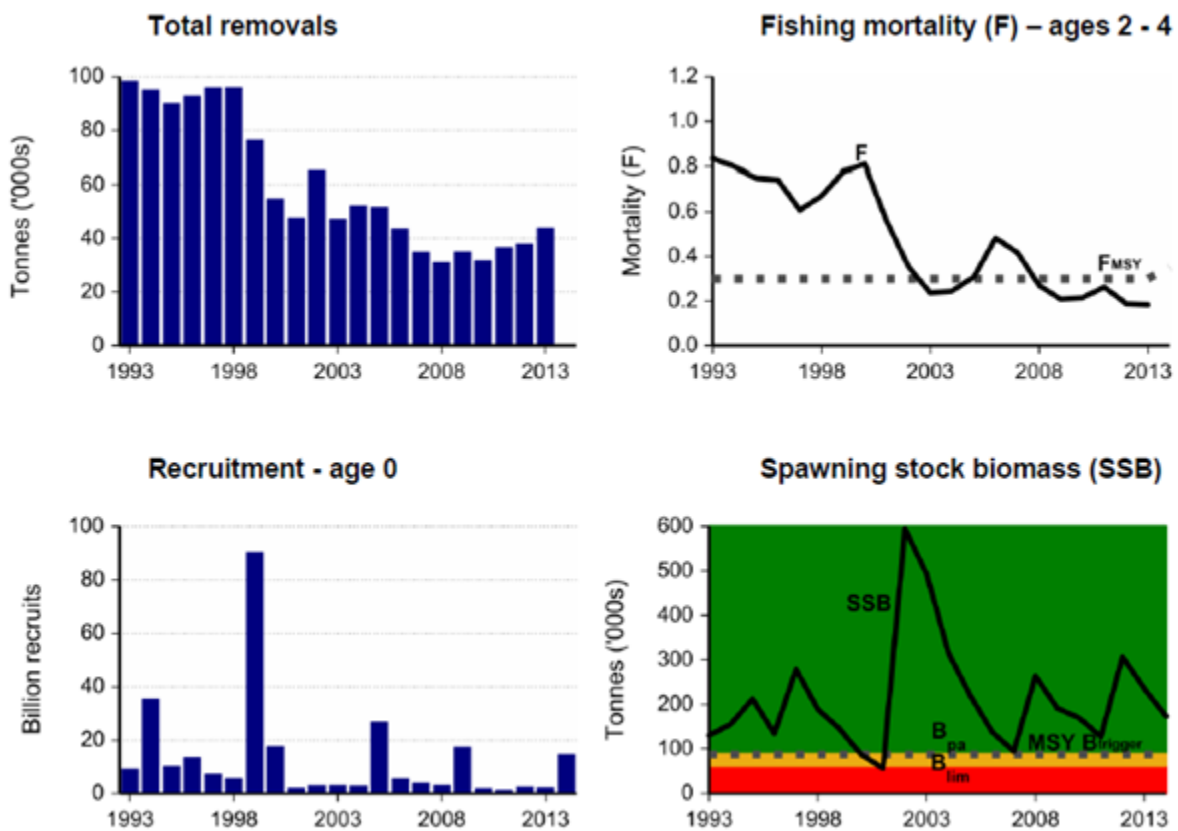
Figure 9 North Sea and West of Scotland haddock stock development. Source (Dixon, 2014)*.*

North Sea Plaice – in ICES Sub-area IV (North Sea)

Since 2004, the plaice assessments have included estimates of discards and now the stock is assessed to be at full reproductive capacity and being harvested sustainably while in 2002 and 2003 assessments showed stocks were suffering reduced reproductive capacity. Discarding of small plaice continues to be a problem. A long-term management plan for North Sea plaice and sole has been under development within the European Commission –final details are contained within Council Regulation (EC) No 676/2007 of 11 June 2007. The TAC for 2015 was 128,376 tonnes, compared with 111,631 tonnes in 2014 and 97,070 tonnes in 2013.
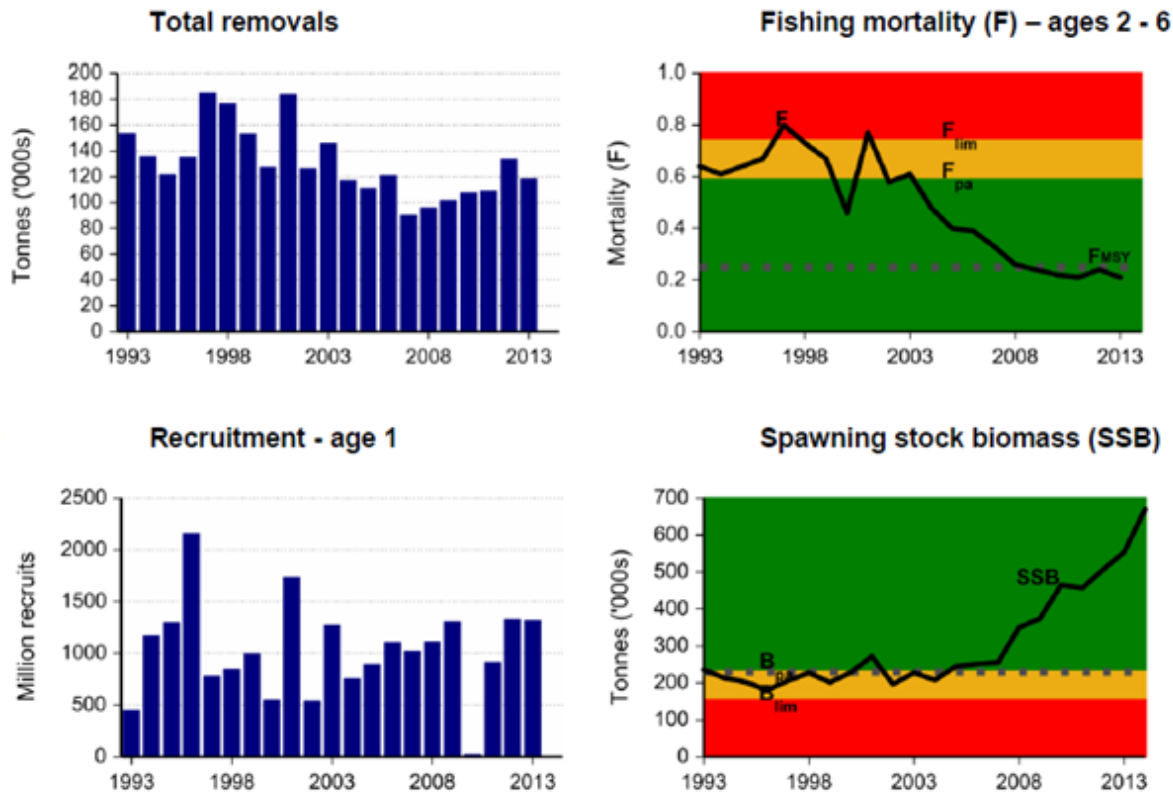
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This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 635761

Figure 10 North Sea plaice stock development. (Dixon, 2014).

While haddock and plaice stocks in the North Sea have been said to have been sustainably exploited during the past decade, it is worth noting that, compared to late 19th / early 20th century, catch rates for all commercially important demersal species are more than 80% lower, in some cases more than 99%. This implies a massive loss of biomass of commercially fished bottom-living fish from seas exploited by the UK fleet. In absolute terms, the landings of haddock per unit power, for example, have declined over 100 times, and of halibut - by 500 times since records began. However, it should be kept in mind that the year 1889 does not represent the onset of fisheries intensification in England and Wales; it simply picks it up from the point when catch statistics become available. These declines are much greater than those suggested by the shorter time series of data used to underpin fisheries management in Europe, and show that in many cases today's fisheries are sustained by populations of species that should be considered commercially extinct (Thurstan et al., 2010).

Table 4 Single species landings per unit of fishig power (LPUP) by the English and Welsh trawl fleet.

Species	Early averaged LPUP (t) (s.d.)	Early LPUP timescale	Latest averaged LPUP (t) (s.d.)	Latest LPUP timescale	Percent decline
Cod	4.27 (0.350)	1889–1893	0.58 (0.074)	2003–2007	86.6
Brill	0.20 (0.010)	1890–1894	0.03 (0.005)	2003–2007	85.7
Plaice	8.18 (0.344)	1889–1893	0.23 (0.024)	2003–2007	97.2
Skates and rays	1.34 (0.092)	1902–1906	0.22 (0.008)	2003–2007	83.4
Turbot	0.21 (0.040)	1903–1907	0.03 (0.003)	2003–2007	84.8
Wolffish	0.19 (0.026)	1903–1907	0.01 (0.002)	2001–2005	95.8
Conger eel	0.20 (0.021)	1902–1906	0.02 (0.003)	2002–2006	89.2
Haddock	20.72 (1.335)	1889–1893	0.19 (0.041)	2003–2007	99.1
Hake	1.63 (0.392)	1891–1895	0.07 (0.014)	2003–2007	95.2
Halibut	1.03 (0.154)	1890–1894	0.00 (0.000)	2002–2006	99.8
Ling	1.17 (0.146)	1889–1893	0.05 (0.009)	2003–2007	95.7

LPUP were averaged for the first and latest 5 years of the fishery (timescales shown). LPUP are based upon landings by British vessels (UK vessels after 1990) into England and Wales. LPUP were corrected to take account of vessels landing their catch into other countries.

Source: Thurstan et al. (2010).

Productivity analysis

Data

The UK fisheries fleet has many segments, all of which catch various species. The productivity analysis deals with vessels catching cod, haddock, plaice, saithe, hake and monk (angler), but only includes those fleet segments that fulfil two requirements. First, that catches of these demersal species constituted a substantial share of total catches of that fleet segment. Second, that catches of each fleet segment exceeded 1% of the total catches of each of those species. In all, there were 11 fleet segments that met these requirements. Of these, trawlers are included in the following fleet segments: area VIIBCDEFGHK 24-40m; North Sea beam trawl over 300kW; North Sea nephrops over 300 kW; North Sea/West of Scotland demersal over 24m; North Sea/West of Scotland demersal pair trawl seine; North Sea/West of Scotland demersal seiners; North Sea/West of Scotland demersal under 24m over 300 kW; and miscellaneous vessels. Two fleet categories contain netters - gill netters and South West beamers over 250kW – and longliners represent a separate segment. The period under consideration covers the years 2008-2014, but values for some of the variables are though available for earlier years and/or the year 2015.

Vessels and catches

Figure 11 depicts the number of active vessels by the groups mentioned above, netters, longliners and trawlers. Downward trend is evident in the number of active trawlers and netters. However, the number of demersal longliners is fairly stagnant throughout the period.
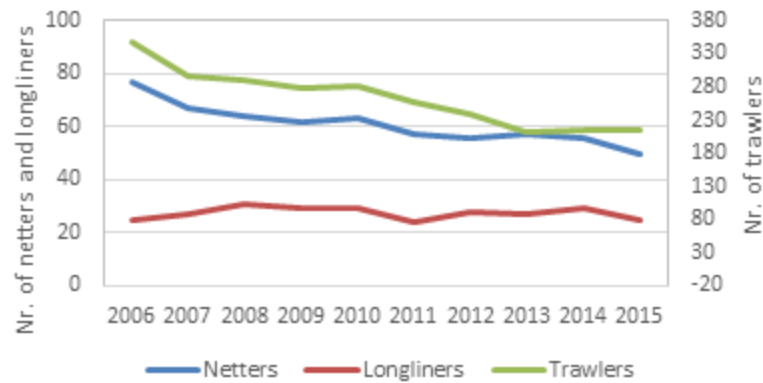
Figure 11 Number of boats in each fleet segment 2006-2015.

Catches of the six demersal species included in the study are plotted in Figure 12. All fleet segments have experienced a steady increase in catches of the main demersal species. In the period, longliners experienced the most increase thereafter the netters and finally the trawlers.

Although the relative share of trawlers of the total catches has decreased in recent years, they still catch more than 80% of all demersal catches. The share of netters has grown and was in 2015 13% of total catches. Longliners have also seen their share grow and they currently catch 5% of total demersal catches (see Figure 3-11).
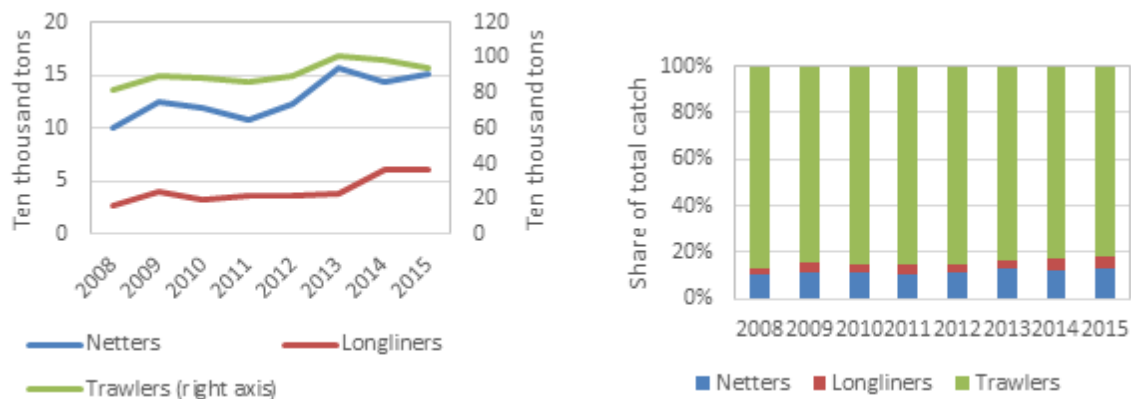
Figure 12 Landed weight by fleet segments (left) and share of total catch by fleet segments (right) 2008-2015.

In the last few years, the size and power of trawlers, netters and longliners has changed. Netters have been getting larger and on measured on average 23.3 meters long in 2015. Longliners, on the other hand, have been getting shorter; their average length was only 22.5 meters in 2015 as opposed to 28.5 meters in 2006. The size of trawlers has not changed much. The engine size – measured in kWh – of netters has also changed sustantially in recent years, and these vessels are now on average equipped with a 24% more powerful engines than in 2006. The engine size of trawlers has not changed much but longliners now have engines which are on average 27% less powerful than a decade ago.
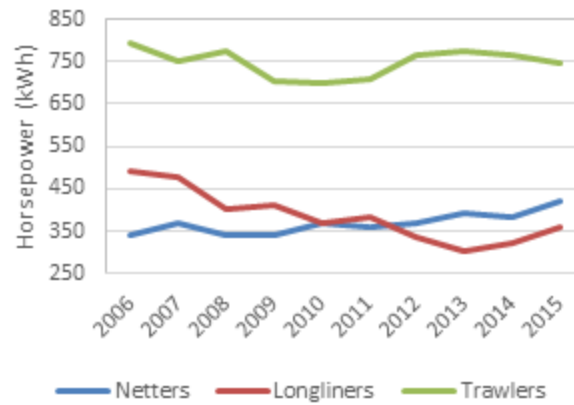
Figure 13 Average engine size (kWh) by fleet segment 2006-2015.

Figure 14shows the development of fleet capacity, measured as the product of average engine size, length and the number of vessels in each fleet segments. As can be seen, the capacity of longliners and trawlers has decreased, while the capacity of netters has remained rather constant. The decreased capacity of the trawler fleet can mostly be attributed to the fact that the fleet now contains fewer vessels than before, while in the case of longliners, the boats have both become smaller and less powerful, while the number of vessels has not changed much. Although the number of netters has also gone down, those that remain in the fleet are both larger and equipped with more powerful engines, resulting in an increased capacity of that fleet.
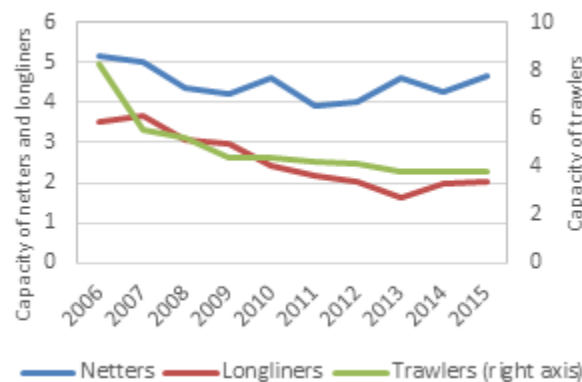
Figure 14 Capacity of fleet segments 2006-2015.

Employment

Figure 3-14 (left) depicts the number of seamen employed by those fleet segments along with the total number of vessels in UK's demersal fisheries. Both series show an apparent downward trend. As shown in the right panel of Figure 3-14, the number of fishermen employed on trawlers has decreased sharply in recent years, while the numbers employed on netters and longliners has fluctuated more.

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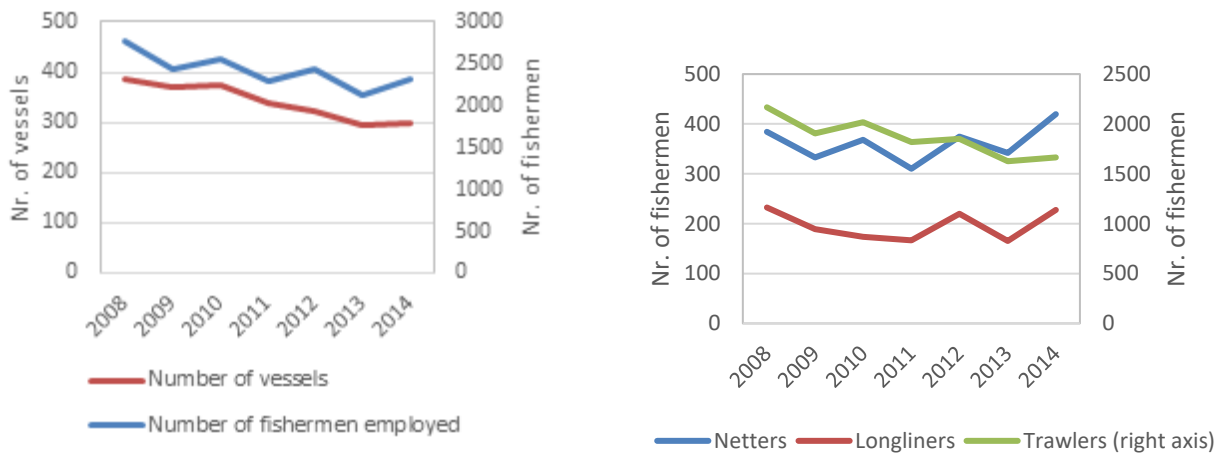
Figure 15 Number of fisherman employed and active vessels in demersal fisheries (left) & number of fishermen employed by fleet segments (right), 2008–2014.

Stocks

As mentioned above, this study takes into account catches of cod, haddock, plaice, saithe, hake and monk (angler). Information on the stock size of monk was unavailable, but as shown in Figure 16, the stocks of the other five demersal species have grown significantly during the study period, not least the spawning stock of plaice which has grown by 222% and the stock of hake which has increased by 685% since 2006. The right panel of Figure 16 depicts on the one hand the development of the aggregate spawning stock of these five species – the biological capital – which is measured as the sum of the stocks of the five demersal species, and on the other hand the sum of all catches of these same species as well as monk (angler).

25
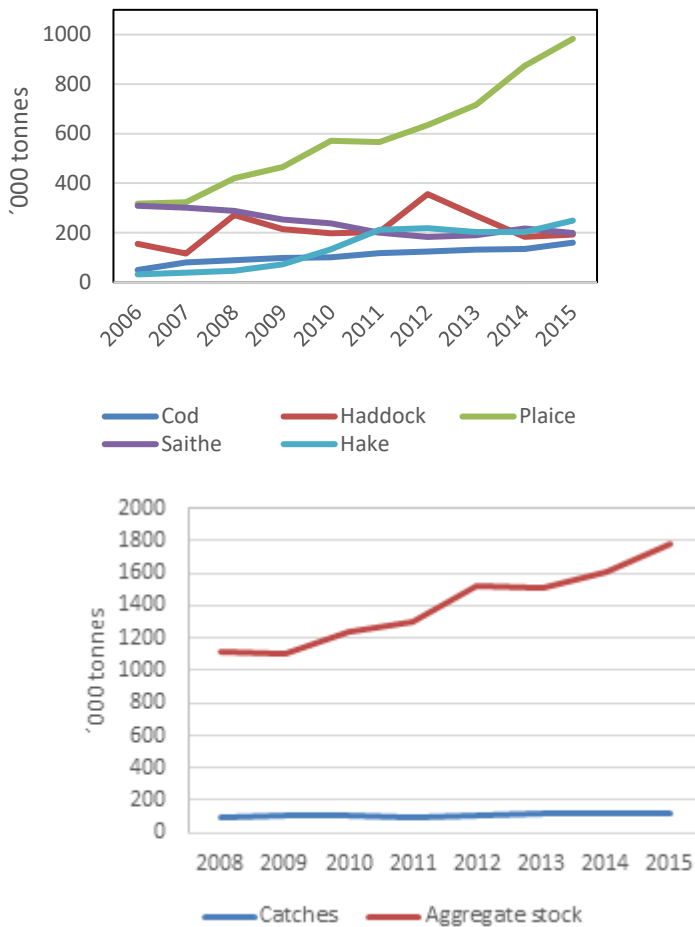
Figure 16 Assessment of the spawning stock of five demersal species 2006-2015 (left) and aggregate stock (biological capital) and total catches of the six demersal species 2008-2015 (right).

Productivity calculations

Although catches of cod, haddock, saithe, hake, plaice and monk (angler) make up most of the landings of the UK demersal fleet, the vessels also harvested other species. Catches of these six species constituted on average 67% of total catches with landings of other species making up almost one third of the total landings. In the calculations of productivity the use of the two control inputs – capital and labour – is therefore adjusted by the share of landings of these species in total landings each year, the variable γ is set at 0.67. Nor correction is, however, made for the number of days-at-sea. As discussed in the section on methods, the stock elasticity is set at 0.85.

Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 5. While landings and stocks grew on average by 3.8% and 6.2% respectively, capital and labour declined on average by 5.1% and 3.1%. The variability of landings, capital and the aggregate stock, as measured by standard deviation, is very similar or 6-7%, but labour shows far greater variability, or 10.7%.

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Table 5 Average growth rates and standard deviation of landings, capital, labour and stocks in the UK demersal fisheries 2009-2014. Percentages.

	Mean	Standard deviation
Landings	3.8	6.9
Capital	-5.1	6.1
Labour	-3.1	10.7
Stocks	6.2	6.6

In Figure 17 the development of the four components of productivity is examined in more detail. While the three input variables, labour, capital and stocks appear to move in sync, landings seem to follow a different path.
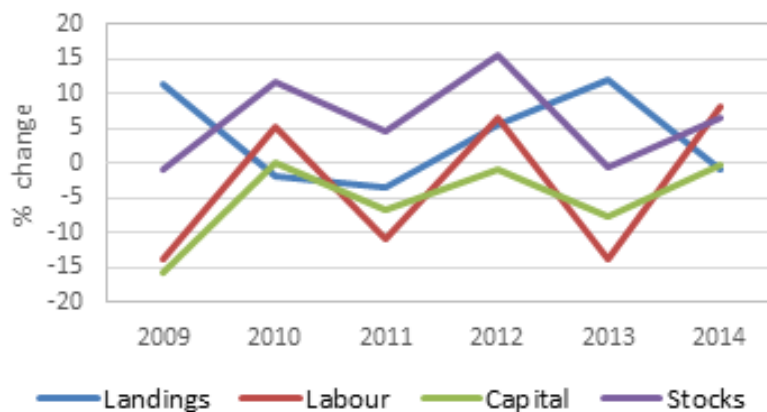
Figure 17 Percentage changes in the landings, labour, capital and stocks, 2009-2014.

On average, productivity grew by 1.2% in UK's demersal fisheries during 2009-2014. Increased landings contributed on average 3.8% to productivity growth and the contribution of smaller fleets and fewer seamen amounted on average on 2.6%. However, the fact that stocks grew on average faster than landings had a negative impact on productivity. As noted in the section on methods, productivity will decrease if increases in stocks are not translated into corresponding increases in landings.

Table 6 Decomposition of average productivity change in the UK demersal fisheries 2009-2014. Percentages.

	%
Landings	3.8
Capital and labour	2.6
Stocks	-5.2
Productivity	1.2

These averages though mask substantial swings, as revealed by Figure 18, which shows the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals that the role played by the different components in productivity development differs between years. Thus, in 2009, the 22% increase in productivity in 2009 can be attributed to an 11.5% increase in landings and 9.3% reduction in capital and labour. A similar story unfolds in 2013. The productivity decreases in 2010, 2012 and 2014 are by contrast driven by large increases in the level of aggregate stocks.
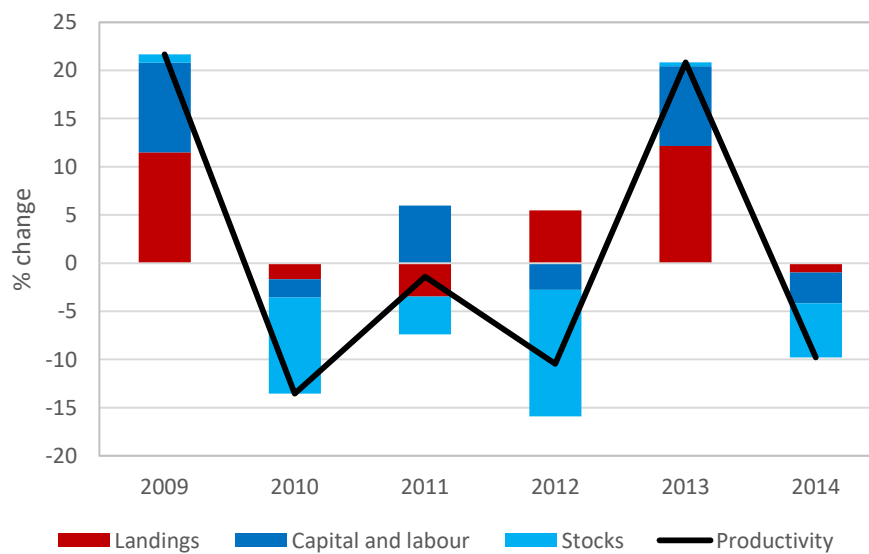
Figure 18 Decomposition of changes in the productivity of the UK demersal fisheries 2009-2014.

Spanish demersal fisheries in NAFO area 21

Introduction

The Northwest Atlantic has been an important fishing area for 500 years, especially for cod. This area, framed in the FAO Area 21 (see Figure 19) covers a total area of 6.26 million km^2 where 1.29 million km^2 are considered shelf areas. Ocean conditions are influenced by the cold Labrador Current, that flows southwards to the Grand Banks, and by the warm Gulf Stream, that flows north-eastwards and supplies warm water to the West coast of Greenland, as well as by the current of freshwater from the St. Lawrence River. FAO Area 21 lies inside national waters of The United States of America, Canada and Greenland.
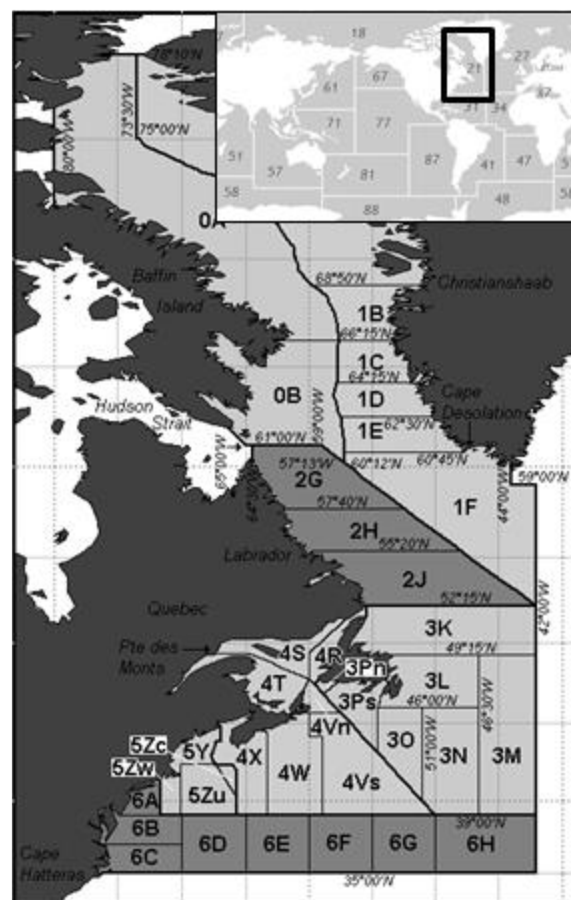
Figure 19 NAFO Division areas: Source: FAO.

The Spanish fleet is engaged in fishing activities in the North West Atlantic (FAO Statistical Area 21) which is managed by the Northwest Atlantic Fisheries Organization (NAFO), which is the regional fisheries management organization (RFMO). Fisheries advice is also based on recommendations of FAO about the Vulnerable Marine Ecosystems (VME). In this report, all the area notifications are addressed according to the limits stablished by them. Figure 19shows the different limits.

The analysis of catch-per-tow data over the last 50-year period indicated that the abundance and species composition of stocks in each statistical area have changed and that these changes have not been gradual but abrupt. Man of these changed occurred in the 1980s (Rothschild & Jiao, 2012). Various authors give differing views on the causes of variation in the Northwest Atlantic but it is possibly related to the combination of multiple and cumulative factors which impact on the stock abundance. In particular theses causes have been put forward; (i) fishing activity (e.g. technological progress that allow trawlers to operate over larger areas and at deeper depth, as well as the introduction of various electronic navigation and fishing systems); (ii) environmental variability (e.g. increased by strong flows from the Labrador Current, anoxia situations); (iii) biological factors (e.g. predator-prey interactions due to the lack of capelin (*Mallotus villosus*) or the increase of predation by marine mammals); (iv) fisheries management (e.g. lack of flexible TAC adaption and allocation, late moratorium adoption). Quite a significant amount of fisheries were still closed or operating under strict regulatory conditions in 2002. However, some stocks have started to slowly recover, e.g. the Georges Bank gadoid (cod (*Gadus morhua*) mostly) and yellowtail flounder (*Liamanda ferruginea*) stocks or the Newfoundland shrimp and snow crab stocks (Shotton, 2015).

The major activities of Spanish fleet are carried out in NAFO divisions 3L, 3NO and 3M (popular named Flemish cap). The fleet mostly focuses on plaice (*Reinhardius Hyppoglossoides)*, redfish (*Sebastes spp*), prawn (*Pandalus borealis*), cod (*Gadus morhua*), rays and sharks. The allowable fishing quota for each Member States is published by the EU Commission yearly (EU, 2013). Additionally, a few long-line vessels also operates in this area catching swordfish, tuna and a great quantity of blue shark, however this fishing segment is out of the scope of the study. Spanish fleet and EU quotas are shown in Table 7.

Table 7 Total EU and Spanish quota from NAFO areas by main species. Percentage of total quotas.

Specie	EU	Spain
Cod	57	14
Redfish	48	8
Skate	63	49
Greenland Halibut	59	37
Prawn	6	0

Description of the main commercial stocks

Cod (Gadus morhua)

The cod stock was heavily depleted by overfishing in the 1960s and again in the 1980s, with the latter period characterised by reduced stock productivity (Rose & Rowe, 2015). The largest decline of stock though occurred in the first years after 1990 during a very cold oceanographic period; other species suffered a similar fate, in particular capelin (Mallotus villosus), the cod's main prey, that declined 30-fold from 1990 to 1991 according to both Russian and Canadian surveys. In the last few years the stock appears to have recuperated somewhat, with stocks increasing from year-to-year in 2010-2015. This increase is being determined by the relatively strong year classes in 2005 and 2006 due to the small

fishing mortalities. New generations in Divisions 3NO do not seem to be as strong, fuelling worries of another decline (see Figure 20) in short term. (NAFO, 2015). Opposite to that, in the 3M Division, and due to the recovery of important preys, i.e. Redfish, Shrimp and smaller cod, and the strong recruitments in 2011 and 2012, populations show growing patterns (Figure 21) (NAFO, 2015). In fact, during the spring of 2015, large increases in cod abundance and size composition were identified for the first time since the moratorium in the more northerly spawning groups (Rose & Rowe, 2015).

Future recommendations by NAFO (2015) include the need of a precautionary approach with a small TAC for Division 3M. In the case of Divisions 3NO the recommendation includes a total closing of the direct fishery to allow stocks to rebuild. It also recommends an important effort to avoid or reduce by-catches of cod.
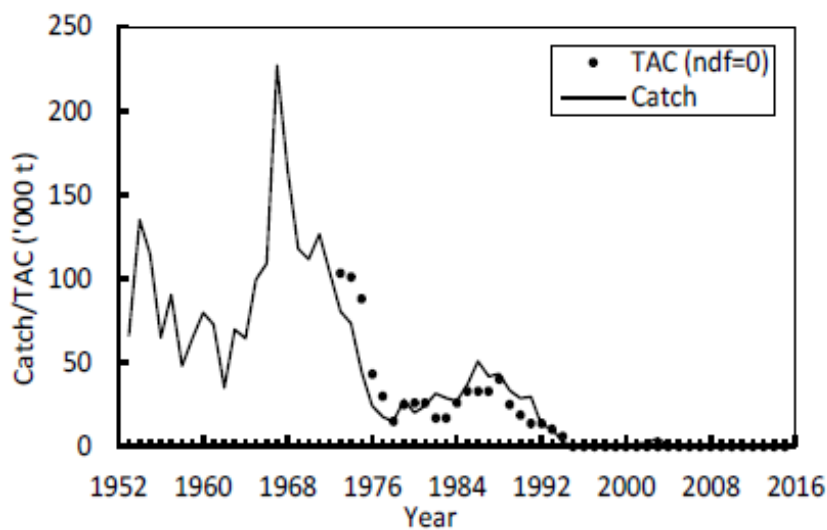
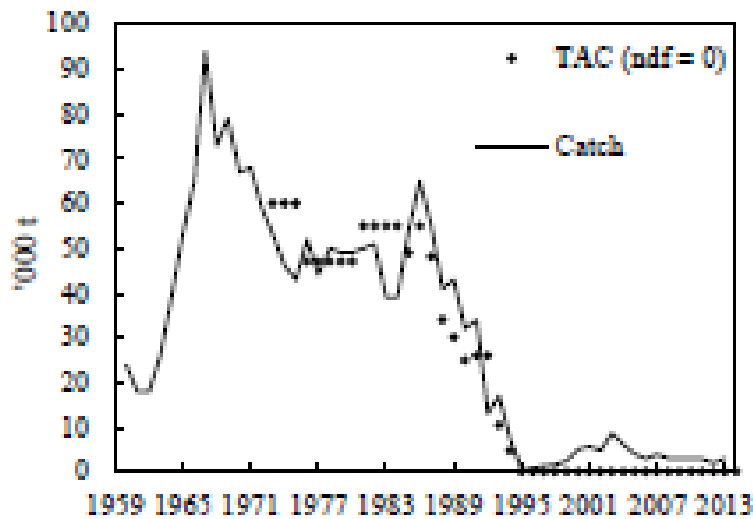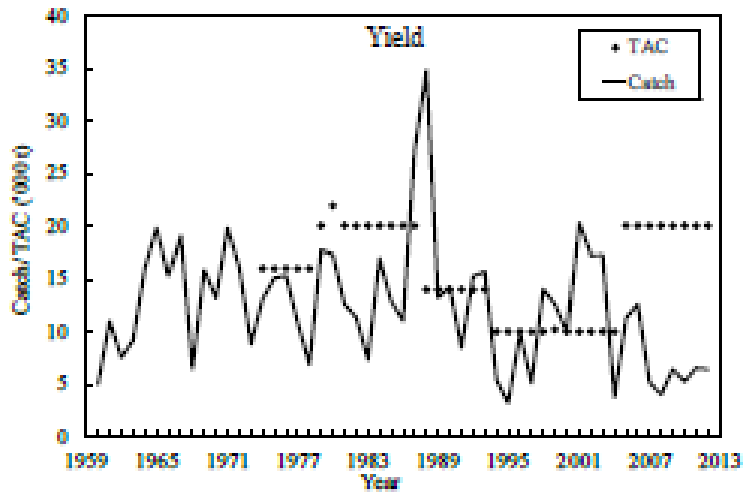*Figure 20 Historical cod catch/TAC data for the NAFO 3NO Divisions. Source: NAFO, 2015.*
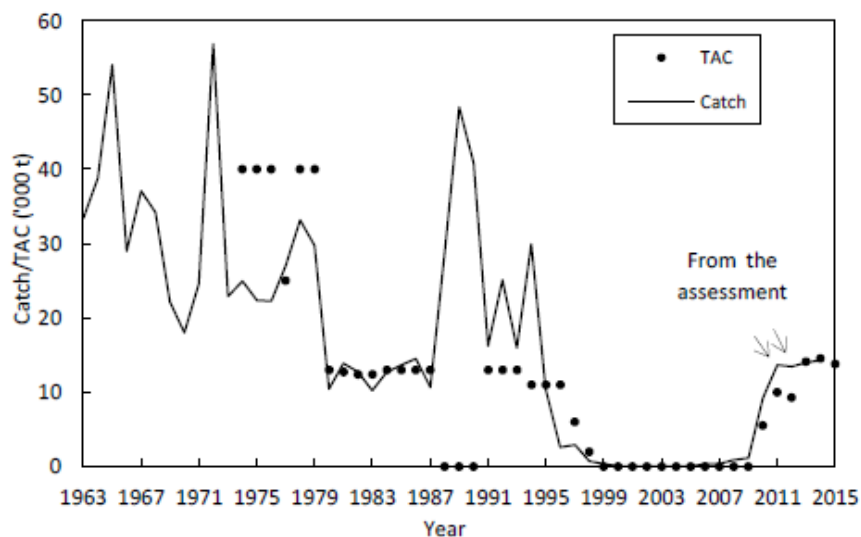
Figure 21 Historical cod catch/TAC data for the NAFO 3M Division. Source: NAFO, 2015.

American plaice (Hyppoglossoides platessoides)

Stocks started declining in the mid-1960s and this development continued almost unabated until the beginning of the 21. century. However, in recent years there have been signs of a stock rebound. Between 2001 and 2006 a small increase of the biomass was observed, mostly influenced by strong recruitments between 1999 and 2002. However, the stock declined in 2007 and 2013.

The American plaice stock is heavily influenced by the availability of prey. In the case of Divisions 3LNO (see Figure 21), there has been a 50% decrease of the maturity mostly due to fishing pressure and environmental changes. Reduced abundance of the traditional prey of the plaice, e.g. capelin and sandlance, have had a serious effect on stock size (NAFO, 2015). In the case of Division 3M stocks can be only located in depths shallower than 600m and there are not evidences of recovery in terms of biomass (see Figure 22. New spawning recruitments show poor conditions (NAFO, 2015). NAFO recommendations (2015) propose a total ban on direct fishing of this specie and a bigger effort to reduce by-catch mortality in all the areas.

Figure 22 Historical American plaice catch/TAC data for the NAFO 3LNO Divisions. Source: NAFO, 2015.
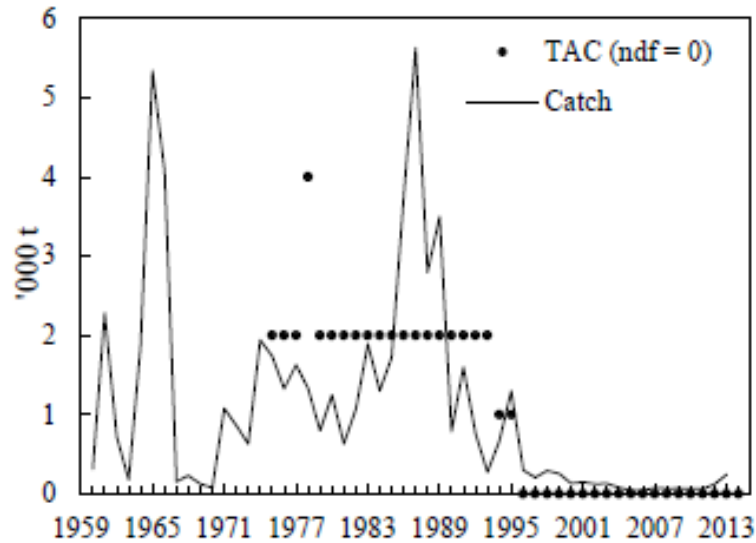
Figure 23 Historical American plaice catch/TAC data for the NAFO 3M Divisions. Source: NAFO, 2015.

Redfish (Sebastes mentella & Sebastes fasciatus)

The stock analysis of redfish shows major differences between the different divisions. In the case of Division 3O, stocks presented a big variability with a declining rate (Figure 24) until the early 2000s when the stock appears to have increased (NAFO, 2015). Changes in the zooplankton population allow favourable feeding conditions for new recruitments showing possible growing trends in the population. In this Division, catches seem to be sustainable. Division 3M shows stock increases since 1996 with a slow recruitment decline in the last 5 years (Figure 25Figure 24). However, future predictions tend to show declines in populations due to the increase of cod populations as young redfish represent an important prey for the cod. The assessment in Division 3M allows an small increase in TAC in the future without changing the exploitation rate (NAFO, 2015).Finally, in the case of Divisions 3LN slow recoveries can be observed since 2006 (Figure 26Figure 25) after the big collapse in 1996. Given the uncertainties in the area due to the prey status of redfish, assessment seems complicated in these divisions. A higher TAC could be stablished as an objective for future exploitations (NAFO, 2015).

![PrimeFish logo]

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 635761

Figure 24 Historical redfish catch/TAC data for the NAFO 3O Divisions. Source: NAFO, 2015.
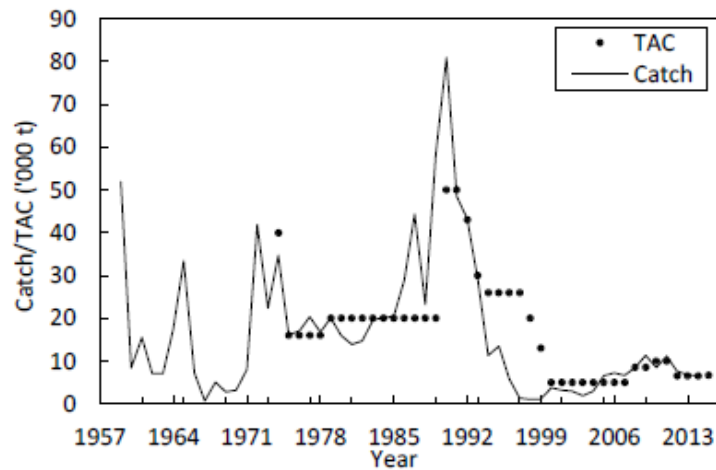

Figure 25 Historical redfish ctch/TAC data for the NAFO 3M Division. Source: NAFO, 2015.
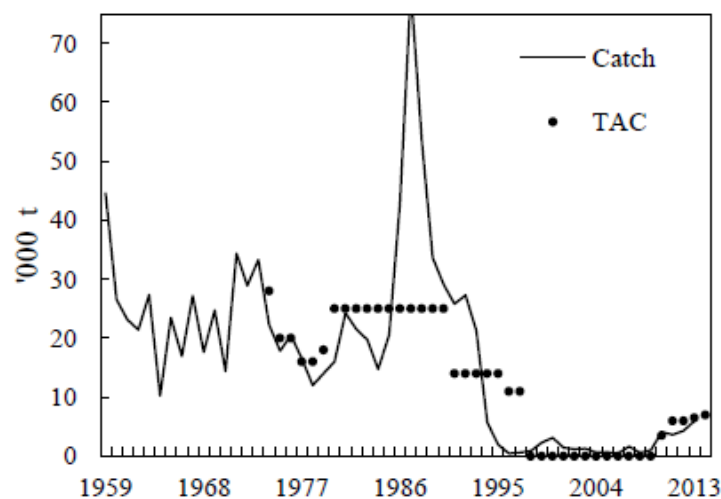

Figure 26 Historical redfish catch/TAC data for the NAFO 3LN Divisions. Source: NAFO, 2015.

Thorny skate (Amblyraja radiata)

Slow recoveries on the stock can be observed since the mid-1990s in the 3LNO Divisions (Figure 27). Between 2010 and 2013 recruitment show data above average. The future advice is based on this small improvements in catch levels. The recommendation is not to increase the catches (NAFO 2015).
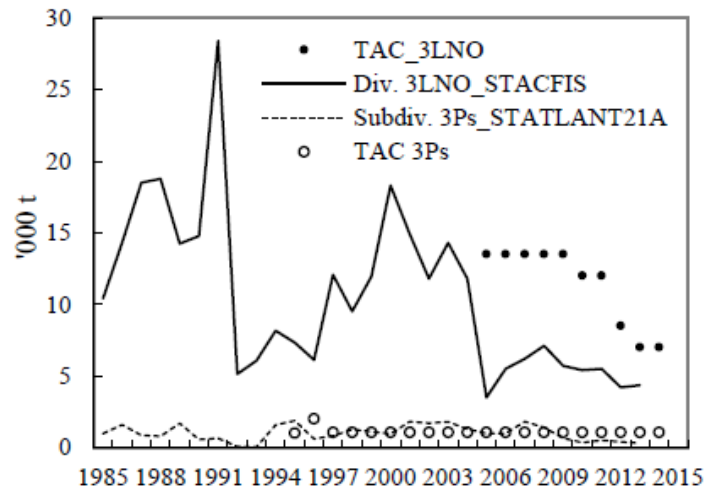
Figure 27 Historical thorny skate catch/TAC data for the NAFO 3LNO Divisions. Source: NAFO, 2015.

Witch flounder (Glyptocephalus cynoglossus)

Stock shows a steady increase since 1999 (Figure 28**Error! Reference source not found.**) with a below average increase of recruitment since 2005. This increase allows NAFO to recommend small increases in catch distribution with increasing TAC. Size limits should be stablished for the conservation of juveniles (<21 cm). In Divisions 2J3KL the stock remains below the Maximum Sustainable Biomass (MSB). The big historical decline, which in 1993 supposes an almost complete destruction of the population, have not shown increasing trends. Between 2011 and 2013 recruitment was below average and the actual spawning biomass in decreasing (**Error! Reference source not found.**).Future recommendations for these divisions contemplate fishing bands and reductions in by-catches (NAFO, 2015).
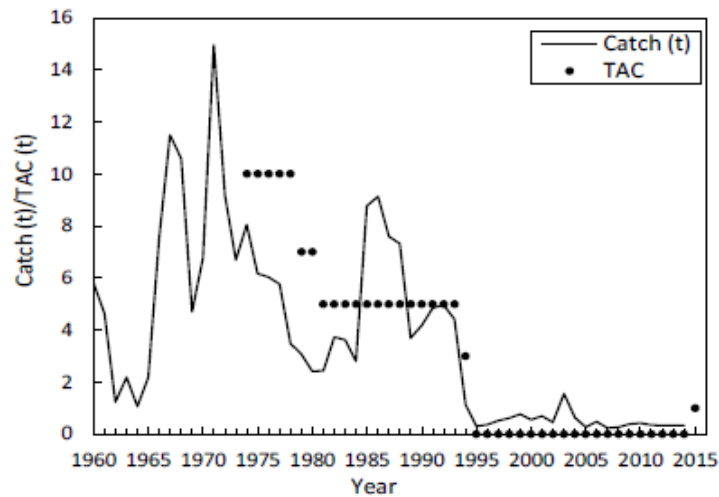
Figure 28 Historical witch flounder catch/TAC data for the NAFO 3NO Division. Source: NAFO, 2015.
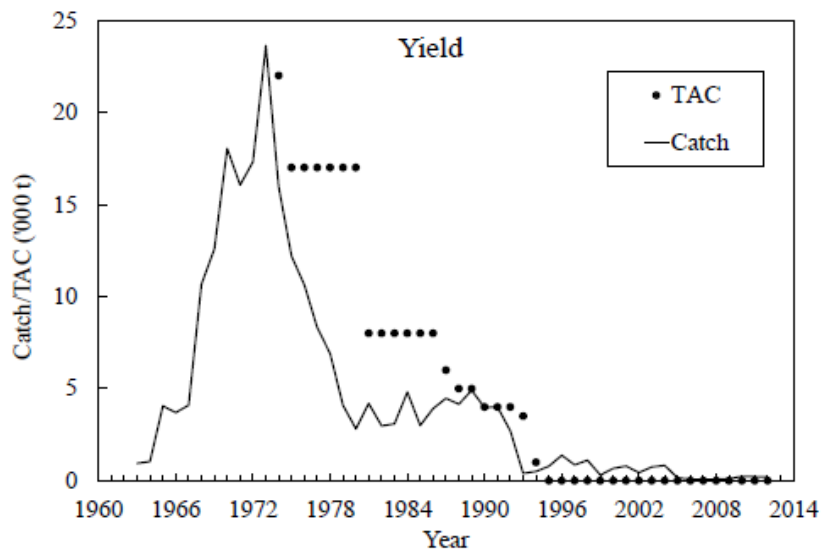

Figure 29 Historical witch flounder catch/TAC data for the NAFO2J 3KL Divisions. Source: NAFO, 2015.

Yellowtail flounder (Limanda ferruginea)

Yellowtail flounder stocks show a steady increase since 1994, with some occasional crashes, e.g. 2006, but with fast recoveries. Although there is very low risk recent recruitment tends to be lower than average (Figure 30). Increases in expansion to north have been observed which coincided with higher water temperatures. Despite the increase in stock the observed sizes since the mid-1990s have been lower. In addition, weight and length data since 1996 show steady decreases.

Recommendations for this species are based in a low risk situation and because of that small increases in catches could be supported by the stock (NAFO, 2015).
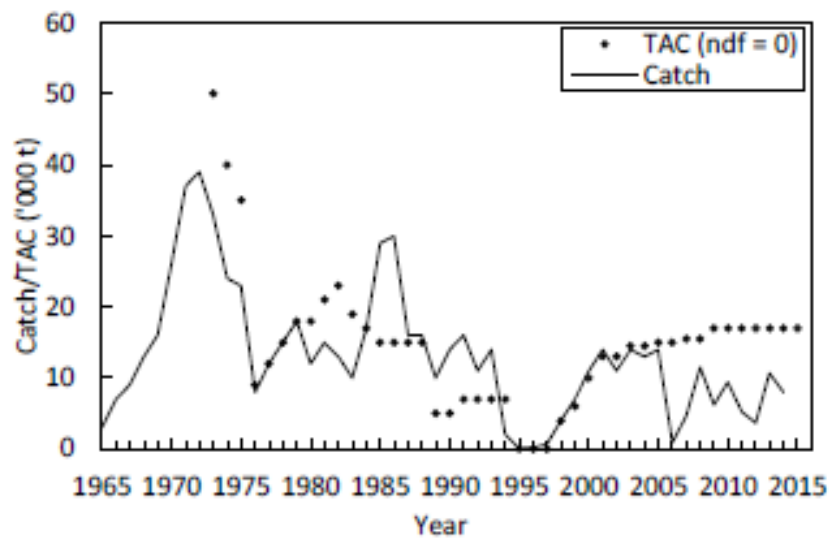
Figure 30 Historical Yellowtail Flounder Catch/TAC data for the NAFO2J 3LNO Division. Source: NAFO, 2015.

Greenland halibut (Reinhardtius hippoglossoides)

Stocks assessment show deficient data when it comes to Greenland halibut. This lack of information is related to changes in divisional and depth coverages. Nevertheless, the obtained data shows a trend of consistency in biomass between 1995 and 2003 with population declines since them. However, this decline cannot be assessed due to possible migratory behaviours of the population. NAFO (2015) recommends the continuation of the Management Strategy Evaluation (MSE) until 2017 before giving new recommendations to the future of the species. TACs levels should be maintained to levels prior to 1995 (Jørgensen, 2015).

Data

The data used in this case study comes from the Food and Agriculture Organisation of the United Nations (FAO) and from the Northwest Atlantic Fisheries Organisation (NAFO) and covers the ears 2006-2014, although information on some variables is available for earlier years. For the stock analysis and the description of the area, we used the information gather in the Review of the State of World Marine Fishery Resources from FAO (2015) and in the 2014 NAFO stock analysis compilation (NAFO, 2015). The information gather from NAFO was gather in two data sources. All the historical information until 2002 was gathered from the Scientific Council Reports. Catch data for the Spanish trawling fleet comes from the different scientific council meetings for the Spanish Research Report that F. González et al. compiled each year.

The socioeconomic data have been collected from the annual economic reports of Spanish fishing fleet compiled by the Spanish Minister of Food, Agriculture and Environment. The time series are taken from three different sources and minor differences on data homogeneity can therefore be found. The updated fisheries statistical framework is aligned with the Data Collection Framework (Council Regulation (EC) No 199/2008) through multi-annual plans. The data collected is related to the >40 meters trawlers which operates in North Atlantic, including NAFO (FAO 21) and FAO 27V, 27X, 27XII and 27 XIV.

Vessels and catches

The total number of vessels in Spain's demersal fisheries has been steadily decreasing from 2005, with the sharpest fall in 2008 when the fleet composition dropped from 42 vessels in 2005 to 14 vessels (Figure 31). Since then, the number of vessels has remained stable. Similar trends have been observed in all three segments in the Spanish demersal fleet, demersal bottom trawlers, pair trawlers and pelagic trawlers.
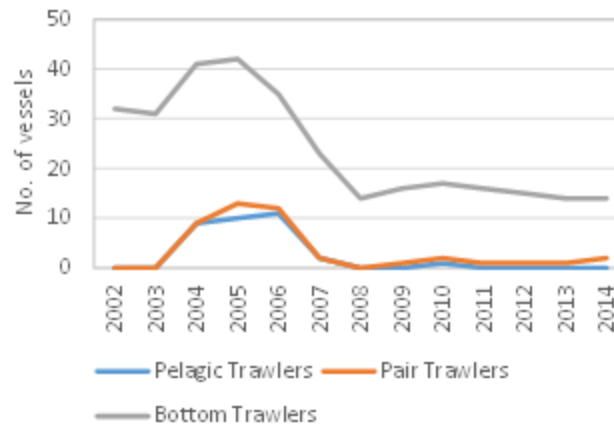

Figure 31 Number of Spanish vessels taking part in the NAFO demersal fisheries 2002-2014.

As mentioned above, demersal catches in the NAFO area are categorised into groups and not individual commercial species. Therefore, the group representing the Spanish demersal fisheries is the group containing subspecies of Greenland halibut (*Reinhardtius hippoglossoides*), thorny skate (*Amblyraja radiata*), cod (*Gadus morhua*), and redfish (*Sebastes mentella & Sebastes fasciatus*). Together catches of these four species represented in 2014 87% of total catches of this fleet segment, with the share of each species 29%, 26%, 16% and 16% respectively. These figures have remained stable since 2007, except cod, which has increased in share from the 2% in 2007 to the 16% in 2014 (Figure 32).
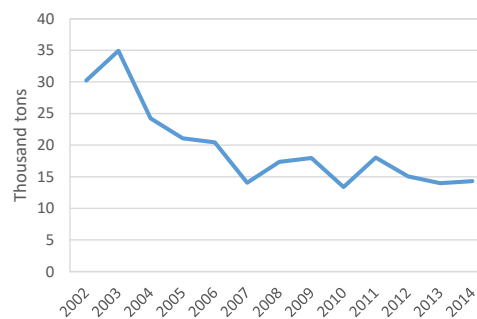

Figure 32 Total demersal catches of the Spanish NAFO fleet 2002-2014 Thousand tons.

As for the average length of the demersal trawlers, it is quite stable for the analysed period of time with 57.45 meters on average. Throughout the period vessels in the fleet have on average become one meter longer. As the fleet now counts fewer vessels, the total engine power has been declining, from 72 thousand kWh in 2006 to 42 thousand kWh in 2014.
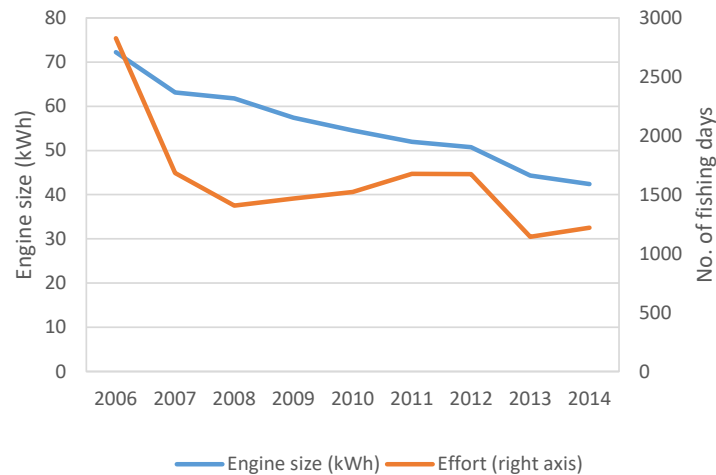

Figure 33 Fleet size (kWh) and effort (fishing days) of the Spanish NAFO fleet 2006-2014.

The development of the capacity of the Spanish NAFO fleet, measured as the product of the number of vessels, average length and average engine size in kW, is shown in Figure 34. While the number of vessels taking part in the NAFO fishery has dwindled from 23 in 2006 to 14 in 2014, the vessels have both become larger and more powerful. Thus, vessels had on average 2063 kW engines in 2006, but they measured 3029 kW in 2014. The vessel was even larger in 2008 when the 14 vessels had on average a 4500 kW engine. This development has resulted in the capacity index of the Spanish NAFO fleet declining.
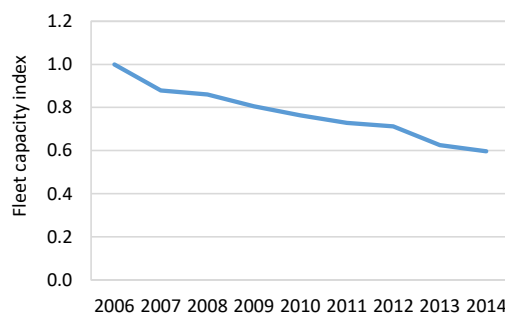

Figure 34 Capacity index of the Spanish NAFO fleet 2006-2014.

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Employment

Figure 35 depicts the development of employment in the Spanish demersal fisheries along with the number of vessels. The number of fishermen is based on survey data. The development of the two data-series shows an interesting difference, as the number of fishermen remained the same while the number of vessels declined, and then increased while the number of vessels remained unchanged.
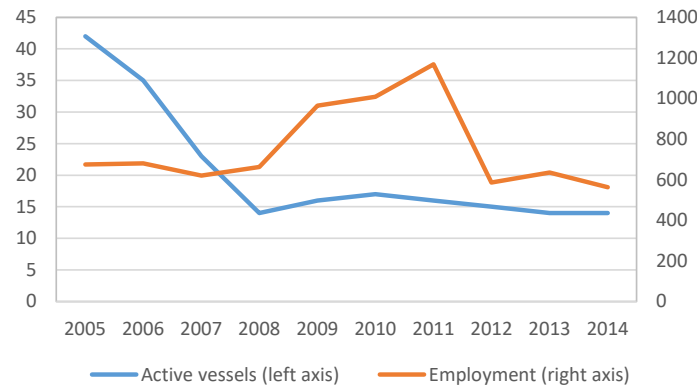

Figure 35 Number of fishermen and active vessels in the Spanish NAFO fishery 2006-2014.

Biological capital

Biological capital is defined here as the sum of the fishable biomass of the main stocks harvested by the Spanish demersal fleet in NAFO area 21. This aggregate measure of stock thus comprises Greenland halibut, American plaice, cod, yellowtail founder, redfish, witch flounder, thorny skate, black dogfish and roughhead grenadier. As shown in Figure 36 this aggregate stock measures shows a clear upward trend, mostly because of growing stocks of redfish and cod. The figure also clearly reveals that catches of these nine species have not followed the same trend as the aggregate stock. Thus, catches have remained at around 15 thousand tons while the aggregate stock grew from 900 thousand tons in 2006 to 1.5 million tons in 2013.
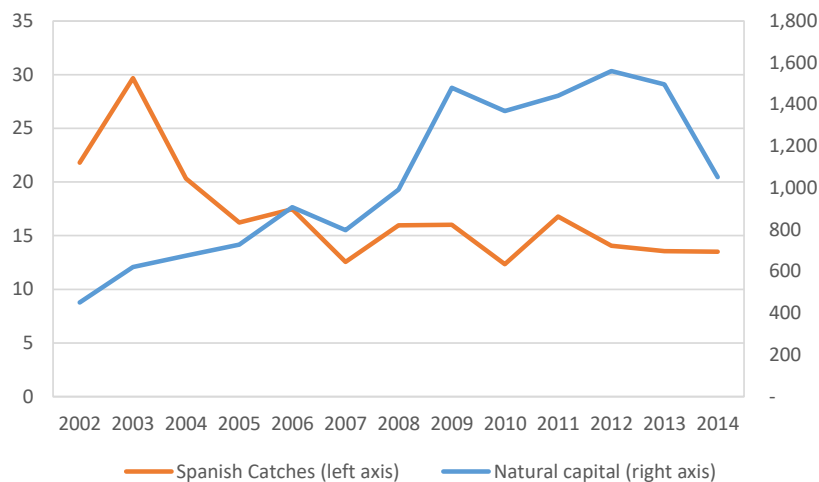

*Figure 36 Biological capital and demersal landings of the Spanish NAFO fleet 2002-2014.*

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Productivity calculations

Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 8. The negative relationship observed earlier between landings and catches is quite evident, as landings contracted on average by 3.2% while stocks grew by 9.0%. Capital and labour declined on average by 12.7% and 3.4%. The variability of labour, as measured by standard deviation, is very high or 31%, with landings and stocks showing a significantly lower level of variability.

Table 8 Average growth rates and standard deviation of landings, capital, labour and aggregate stocks in the Spanish NAFO fisheries 2007-2014. Percentages.

	Mean	Standard deviation
Landings	-3.2	22.5
Capital	-6.4	4.3
Labour	-2.4	31.0
Stocks	9.0	17.9

In Figure 37, the development of the four components of productivity is examined in more detail. The relatively smooth development of capital stands in stark contrast to rather large variations in the other three variables, especially labour.
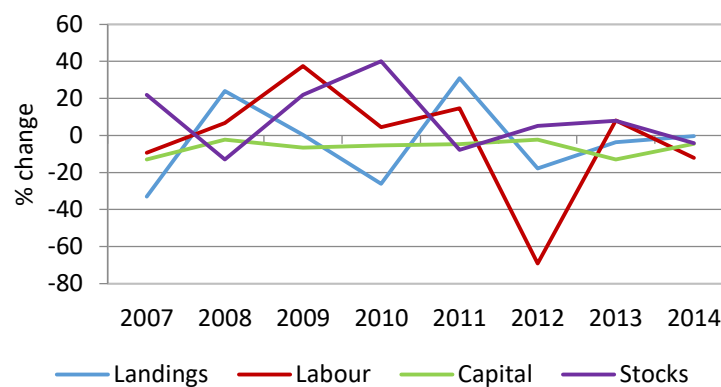
Figure 37 Percentage changes in landings, labour, capital and stocks in the Spanish NAFO fisheries 2007-2014.

During the period 2007-2009, catches of the nine demersal species discussed above represented on average 88% of the total catches of the Spanish NAFO fleet. In the calculations of productivity the use of the two control inputs – capital and labour – is therefore adjusted by the share of landings of these species in total landings. The γ parameter in eq. (9) stated in the section on methods, therefore takes

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on average a value of 0.88. As data also exists on the number of days-at-sea allowance is also made for this, as reflected by the δ in eq. (9).

On average, productivity declined by 8.2% in Spain's NAFO fisheries during 2007-2014 (Table 9). This performance is mostly due to the fact that while landings decreased, the aggregate stock of the main demersal species in the NAFO area grew substantially. As noted in Section 2, productivity will decrease if growth of stocks does not lead to a corresponding increase in landings. Declining use of capital, as measured by the fleet capacity index, and labour had a positive impact on productivity.

Table 9 Decomposition of average productivity change in the Spanish NAFO fisheries 2007-2014. Percentages.

Landings	-3.2
Capital and labour	2.8
Stocks	-7.6
Productivity	-8.1

These averages though mask substantial swings, as revealed by Figure 38, which shows the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals three very large spikes in productivity; huge declines in 2007 and 2010 and a large increase in 2011. However, the reasons for these changes are different. Thus, in 2007, the drop in productivity is mostly due to a decline in landings, while the decrease in 2010 can mostly be explained by a large increase in stocks, although declining landings also play an important part. The increase in productivity in 2011 can be mainly attributed to increased landings.
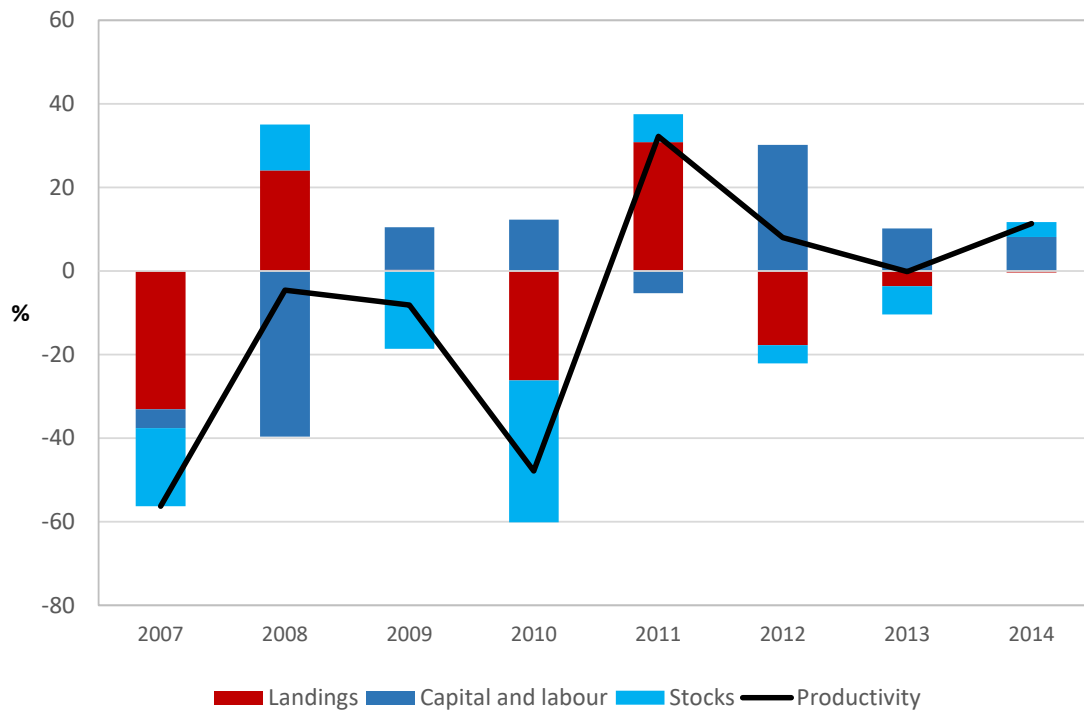
Figure 38 Decomposition of changes in the productivity of the Spanish NAFO fisheries 2007-2014. Percentages.

Demersal fisheries in Norway

The Norwegian fishing fleet can be broken down into a number of segments based on their fishing licenses, fishing gear and vessel size. License and associated quota share determines the annual fishing quotas along with the annual TAC for individual species. Roughly the fleet can be segmented as shown in Table 10. In the demersal fisheries, there are three main groups. There is a large number of smaller vessels generally operating close to the coast and employing a variety of fishing gears with the exception of trawl, as this requires a special license. The second main group are about 20 ocean-going primarily longliners and the third ocean-going trawlers. In addition to these vessels, there are a number of the coastal vessels combining demersal and pelagic fisheries.

For this study we have not included all vessel groups. From the coastal vessels, we have selected a sub-group of the coastal benthic fleet, namely netters between 11 and 15 m length. We have also included both the ocean-going longliners and trawlers. In 2015 these vessels accounted for 45%, 53% and 37% of the catches of respectively cod, haddock and saithe.

Table 10 Main vessel groups in Norwegian fisheries.

Demersal – coastal vessels, 0 – 500 cu. m cargo hold
Demersal – ocean-going longliners
Demersal – ocean-going trawl
Pelagic – coastal vessels, 0-500 cu cargo hold
Pelagic – ocean-going purse seine/trawl
Pelagic – ocean-going trawl
Combination demersal /pelagic – coastal vessels 0-500 cu cargo hold

Demersal stock development

The demersal fleets primarily target cod, saithe and haddock, with a number of other species as bycatch. There are several stocks for each species, but this study only looks at stocks in the Norwegian and Barents Sea which represent the majority of catches. The stocks of all three species are considered healthy, with the cod and haddock stocks in excellent standing. As shown in **Error! Reference source not found.**, the cod stock rose sharply until 2012, followed by an equally sharp decline. The haddock stock was relatively stable until 2010, since when it has more than doubled. The saithe stock saw a moderate rise in the first half of the period, followed by a sharp fall and has been relatively stable since 2010.
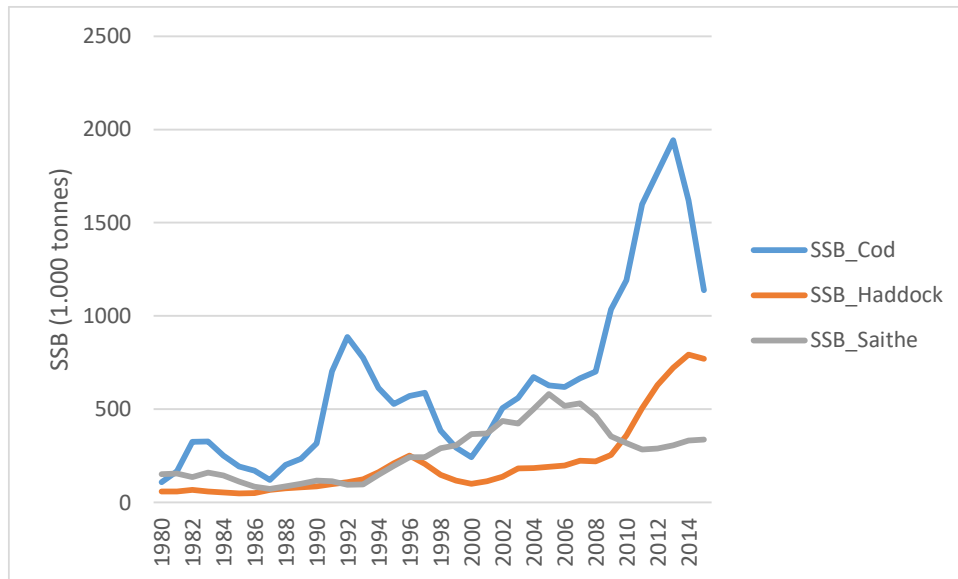
Figure 39 Spawning stocks of cod, haddock and saithe 1980-2015.

Demersal fleet catches

Since introduction of the EEZ's in 1977, most of the cod and haddock catches have been registered by Norway and Russia, while saithe is mostly harvested by Norwegian vessels. There have been strong variations in catches, particularly of cod, and catches have doubled in the 2008-2013 period (see Figure 40). Saithe catches were relatively stable in the period under study, while haddock catches have seen a gradual rise. Note that this is catch from all vessels from all nations, not only the ones selected for this study.
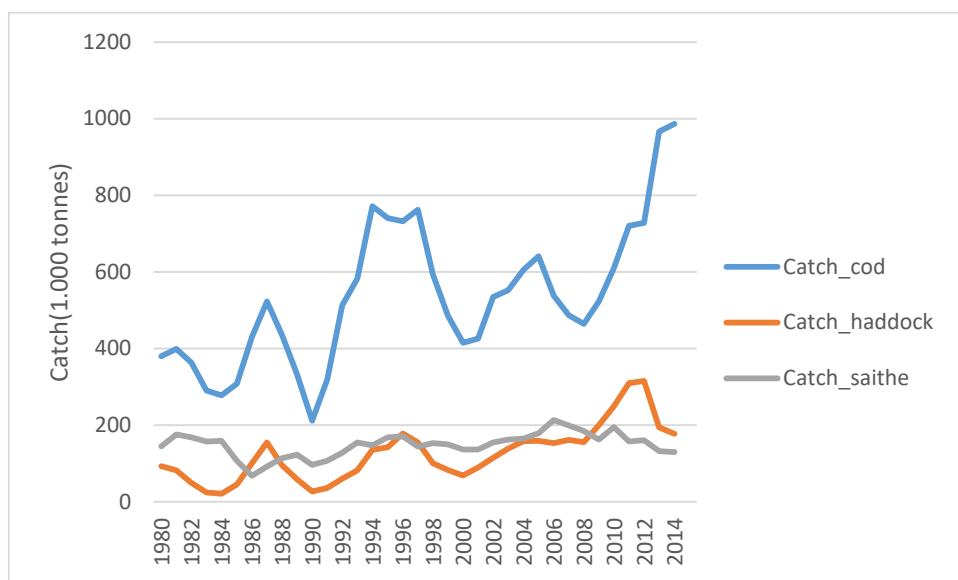

Figure 40 Catches of cod, haddock and saithe 1980-2014.

Turning to the fleet segments, although the described species are important for all segments, catch composition varies somewhat between vessel type and gear. As revealed Figure 41, cod constitutes

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about ¾ of the landed volume of 11-15 meters long netters, and haddock only a minor share for these vessels. Figure 42 describes catch for the ocean-going longliners. These vessels catch relatively smaller amounts of cod, with haddock, tusk and ling more important species. For trawlers, the picture is again slightly different. Saithe and cod make up most of their catches, as shown inFigure 43.
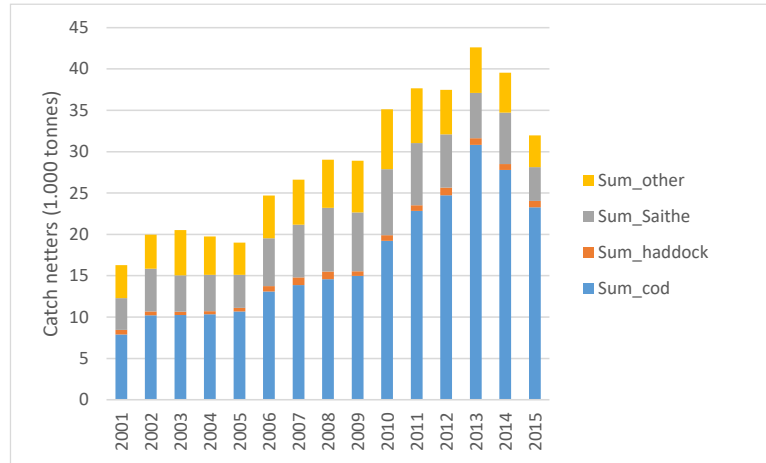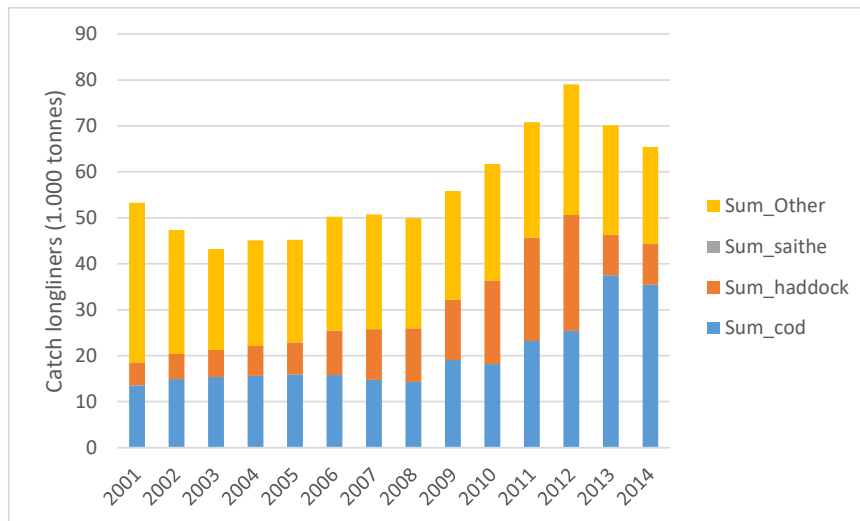

Figure 41 Catches of netters 11-15 m.

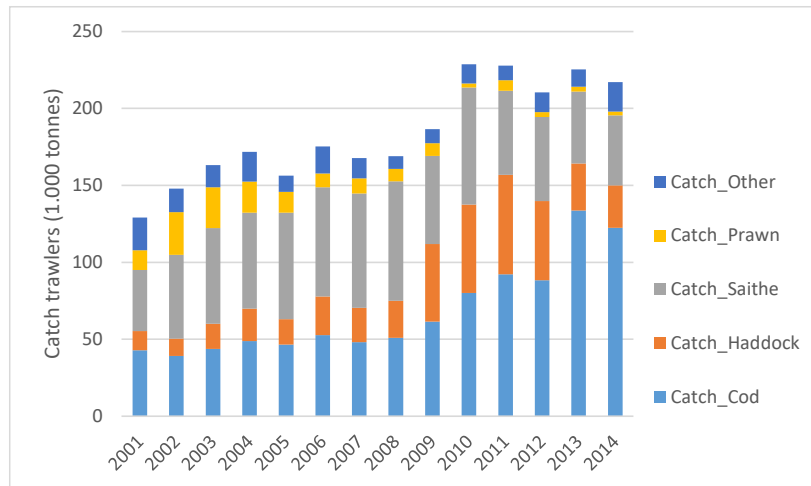

Figure 42 Catches of ocean-going longliners.

Figure 43 Catches of ocean-going trawlers.

Data

Data on both catch and technical vessel parameters were obtained from the Norwegian Directorate of Fisheries. The data cover each landing in Norway in 2002-2014 and include information on registration number, name of vessel, fishing gear, catch area, species caught and landed weight and value. Data on crew shares of value added and crew numbers are obtained from the annual fishing fleet profitability survey carried out by the aforementioned Directorate[4]. Stock development data are gathered from the latest relevant ICES reports.

Fleet and catches

The total number of vessels in the selected groups of Norwegian demersal fisheries increased between 2002 and 2008 when it peaked at 323 vessels, but since then the fleet has declined in numbers (seeFigure 44). The development is though different between fleet segments. While the fleet now contains more netters, the fleet counts fewer trawlers and longliners, as seen in Figure 8. The latter two vessel groups have had access to a slightly restricted ITQ-system since 1996 for trawl and 2000 for longline. This explains the gradual reduction of vessels in these groups. The vessel group containing the netters was only included in the ITQ-system from 2007. We can see that the number of netters grew up to 2008. Since then the number has been relatively stable with a drop in 2014. The increase of netters in the first part of the period is primarily due to other vessels switching from other gears to nets, particularly from hand-baited longlines. The cost of new nets has decreased whereas the cost of both bait and baiting has increased. Also nets catch a larger share of large cod that has a price premium. The stabilization and subsequent reduction in number of netters in the latter period is due to the ITQ-system.

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[4] .Directorate of Fisheries. Profitability survey in the Norwegian fishing fleet. Directorate of Fisheries,Bergen.
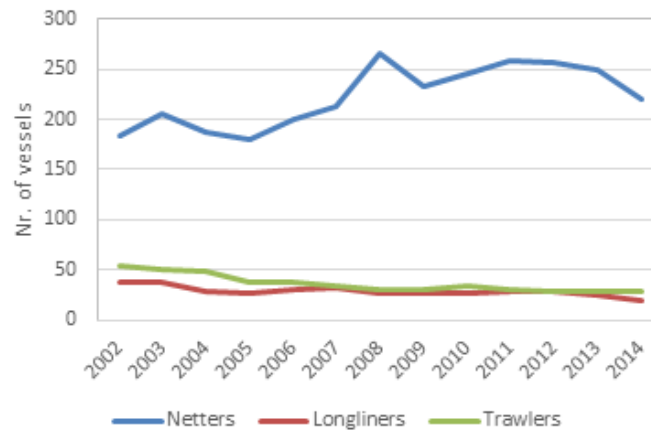
Figure 44 Number of boats in each fleet segment 2002-2014.

Total catches of cod, haddock and saithe have in doubled in the last 15 years. They were 141 thousand tonnes in 2002, but have been around 280 thousand tonnes in recent years. This increase is mostly due to tremendous increases in cod catches; from 70 to 200 thousand tonnes. The share of cod in the demersal fisheries has consequently been increasing, with smaller landings of saithe now registered than in previous years. In 2002, cod catches corresponded to 46% of all demersal catches, but that share has gone up to 68% in recent years. Saithe catches have on the other hand declined from 42% to 19%.
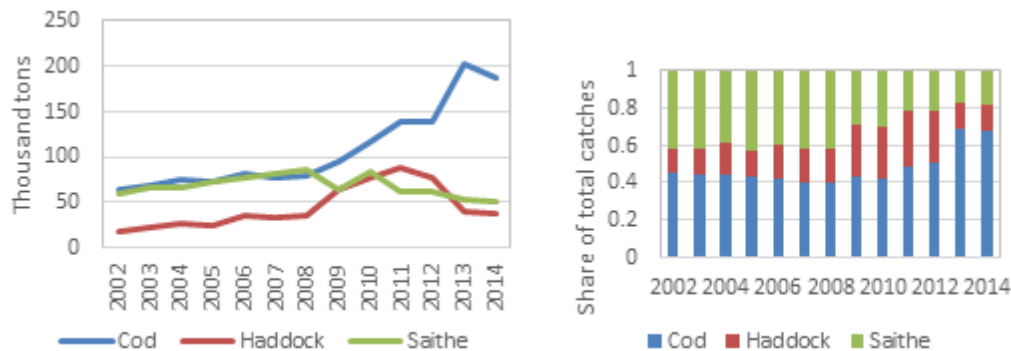

Figure 45 Landed weight by species (left) and share of each species in total catch of demersal species (right) 2002-2014.

Most of the cod, haddock and saithe catches are registered by trawlers. The total catches of that fleet segment have doubled from 100 to 200 thousand tonnes, while catches of longliners and netters have increased from 20 to 45 thousand tonnes and 15 to 35 thousand tonnes.
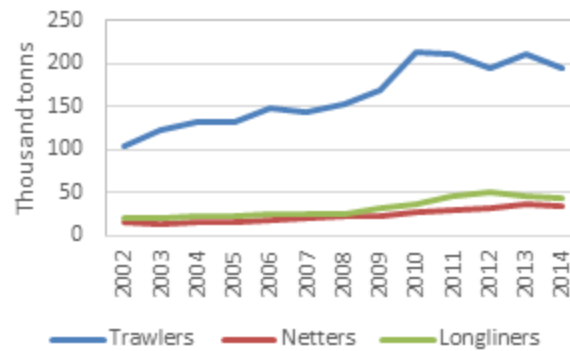
48

Figure 46 Landed weight by fleet segments 2002-2014.

In recent years, vessels in the Norwegian demersal fleet have both become larger and more powerful. Trawlers were on average 49 meters long in 2002, but measured on averaged 59 meters in 2014, while the average longliner measured 39 meters in 2002 and 45 meters in 2014. The typical netter measured 13 meters long and has not changed much in size. The engine size of trawlers has on average increased from 2600 kWh to 4800 kWh, and the engine size of longliners from 880 kWh to 1550 kWh. The average engine size of netters has increased from 220 kWh to 280 kWh.
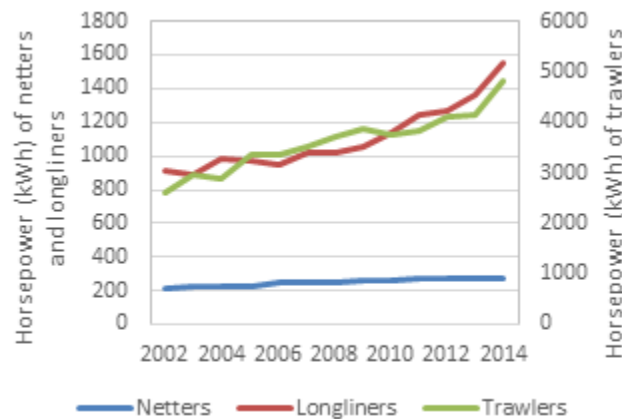

Figure 47 Average horsepower (kWh) by fleet segment 2002-2014.

The harvesting capacity of the Norwegian fleet, calculated as the product of average horsepower, average length and number of vessels, has increased in the last 15 years. This capacity index has though fluctuated a great deal, as Figure 48 clearly demonstrates. The behaviour of the capacity index for trawlers is especially interesting, as it declined as the number of vessels decreased from 55 in 2002 to below 40 in 2005. There followed a relatively stable period, where reduction in number of vessels was more or less offset by increasing size and engine power of the remaining fleet. From 2013 to 2014 the index grew by about 30% to record levels. This is due to several new long and powerful vessels entering the fishery, replacing older vessels. The capacity index for longliners shows more fluctuations, but in recent years the index has. The capacity index for the netters shows a clear upward trend, reflecting

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the fact that those boats have become more numerous. This is to an extent compensated by reduction of vessels using other gears.
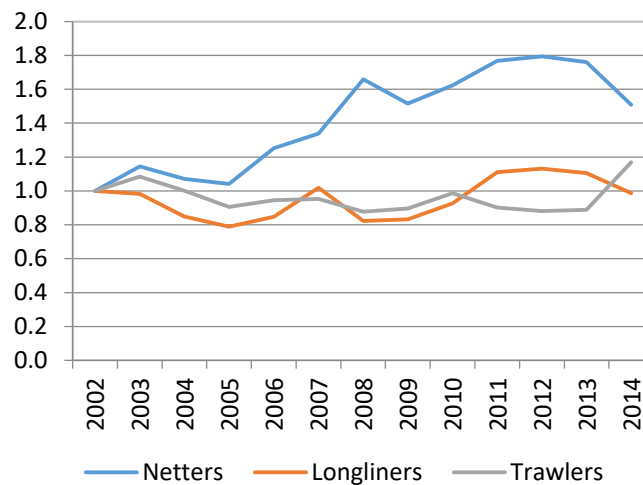

Figure 48 Capacity of the Norwegian demersal fleet 2002-2014.

Employment

Figure 49 (left) depicts the development of employment along with the total number of vessels taking in the Norwegian demersal fisheries. The number of fishermen shows a slightly downward trend. In 2003, the fleet employed 3000 individuals, but by 2014 the number had shrunk to 2300. Around half of the fishermen work aboard trawlers.

Estimations on manpower are based on an annual survey from the Fisheries Directorate in Norway. There is no determined development to be found in either series but a slight upward trend in the number of vessels and a downward trend in the number of fishermen employed.

In the right panel of Figure 49 the number of fishermen employed is disaggregated by fleet segments. For netters, the number of employed fishermen increased from 2002 resembling the increase in the number of netters. Meanwhile, a fall was experienced by fishermen employed on trawlers and likewise, in recent years, for fishermen employed on longliners.

Figure 49 Number of fisherman employed and active vessels in demersal fisheries (left) & number of fishermen employed by fleet segments (right), 2002 – 2014.

Stocks

The spawning stocks of the main demersal species have grown tremendously in the last 15 years. The spawning stock of cod has increased almost fourfold, peaking at close to 2.0 million tonnes in 2013 before declining slightly in the following year. The haddock increased almost sixfold, from 140 thousand tonnes to 800 thousand tonnes, but the saithe stock has fallen from 430 thousand tonnes to 250 thousand tonnes.

In what follows, the stocks of these three demersal species are added together to form an aggregate demersal stock that serves as a measure of the biological capital used in the fisheries. This aggregate is then used in the productivity calculations. As shown in the right hand panel of Figure 50, the aggregate stock has been growing in the last few years, mainly because of the growth of the cod stock.

That said, the biological capital which is calculated as the sum of estimated SSB for cod, haddock and saithe has been increasing throughout the period and closely followed by the increased weight of catches mentioned before (see figure 8).
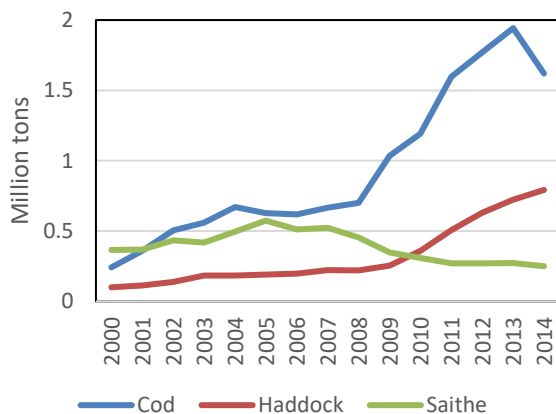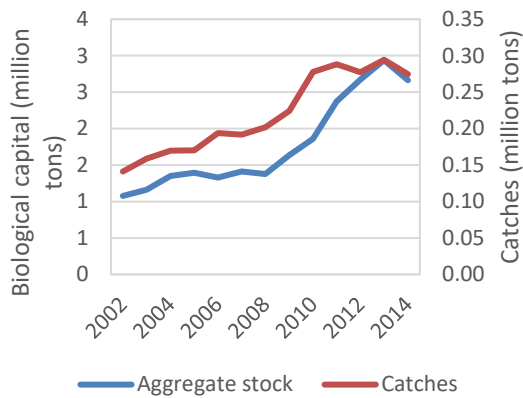
Figure 50 Stock assessment of three demersal species 2000-2014 (left) and the development of the aggregate stock and catches 2002-2014 (right).

Productivity calculations

Although catches of cod, haddock and saithe make up most of the landings of the Norwegian demersal fleet, the vessels also harvested other species. Catches of these three species constituted on average 79% of total catches. In the calculations of productivity the use of the two control inputs – capital and labour – is therefore adjusted by the share of landings of these species in total landings.

Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 11. While landings, capacity and stocks grew on average by 5.5%, 1.2% and 6.2% respectively, labour declined by 1.5%. The variability of all four variables, as measured by standard deviation, is quite similar at about 8-10%.

Table 11 Average growth rates and standard deviation of landings, capital, labour and stocks in the Norwegian demersal fisheries 2003-2015. Percentages.

	Mean	Standard deviation
Landings	5.5	7.9
Capital	1.2	8.0
Labour	-1.5	10.1
Stocks	7.5	9.9

In Figure 51 the development of the four components of productivity are examined in more detail. There is a strong positive relationship between landings and labour, as well as between landings and stocks, but the positive relationship between landings and capital is considerably weaker. Landings and capital are also positively correlated, as well as labour and stocks, but there exists a significant negative relationship between capital and stocks.
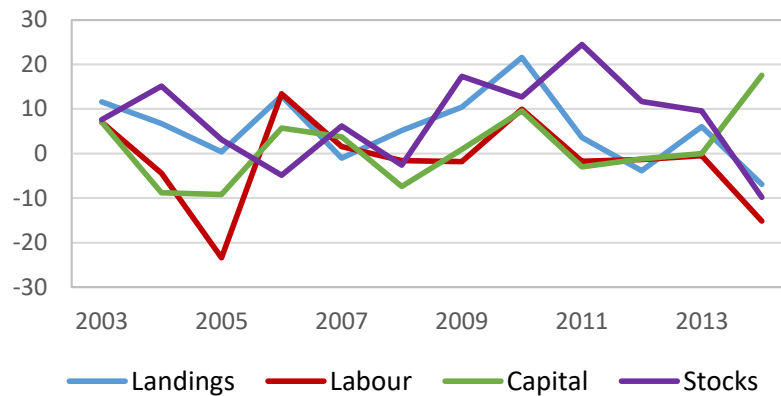
www.primefish.eu

Figure 51 Percentage changes in the landings, labour, capital and stocks in the Norwegian demersal fisheries 2003-2015.

On average, productivity decreased by 0.5 in Norway's demersal fisheries during 2003-2015. Increased landings contributed on average 5.5% to productivity growth and the contribution of smaller fleets and fewer seamen amounted on average on 0.4%. Increases in the biological capital – the aggregate demersal stock – reduced productivity by 6.4% In Table 12 productivity is also compared across two periods; 2003-2008 and 2009-2015. Whereas productivity grew by 3.6% in the first period, the decline in the second period amounted on average to 4.6%. Most of the growth in the first period can be attributed to increases in landings, which outstripped the growth of stocks. In the second period, increases in landings did not keep pace with the growth of stocks, leading to a decline in productivity. The role of capital and labour was minimal.

Table 12 Decomposition of average productivity change in the Norwegian demersal fisheries 2003-2015. Percentages.

	2003-2015	2003-2008	2009-2015
Landings	5.5	6.0	5.1
Capital and labour	0.4	1.1	-0.3
Stocks	-6.4	-3.5	--9.3
Productivity	-0.5	3.6	-4.6

These averages though mask substantial swings, as revealed by Figure 52, which shows the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. There are two large productivity peaks, in 2005 when productivity grew by 12.5% and in 2008 when the growth amounted to 10%. The growth in 2005 is mostly because of a decline in capacity, with the number of netters, longliners and trawlers falling, and a corresponding decrease in employment. In 2008, larger landings, lower fleet capacity and employment and shrinking stock all contributed to the large productivity increase. Figure 5-14 also reveals considerable productivity drops in 2011 and 2012 when productivity declined by 15.3% and

12.7%. The former can entirely be attributed to larger stocks, with the cod stocks increasing from 1.2 million tonnes to 1.6 million tonnes and the haddock size rising from 360 to 510 thousand tonnes. Stock increases also play a large part in the productivity decline in 2012, with decreases in landings also having a negative effect on productivity.
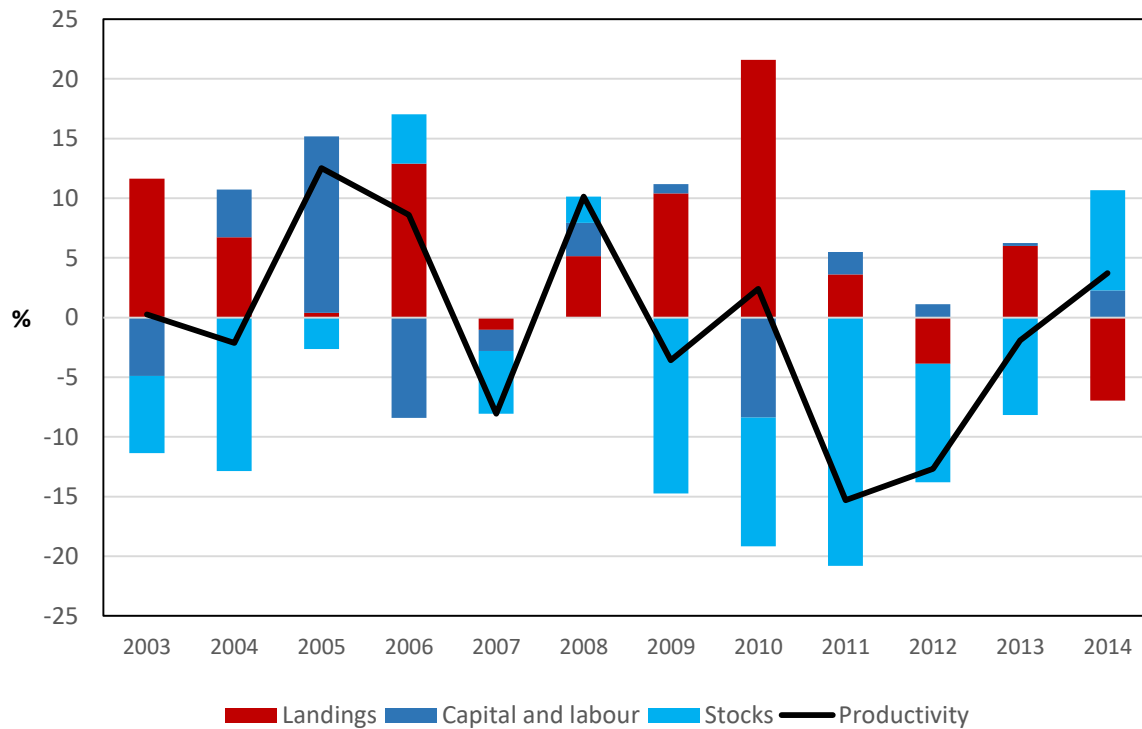

Figure 52 Decomposition of changes in the productivity of the Norwegian demersal fisheries, 2009-2014.

Demersal fisheries in the Faroe Islands

Vessels and catches

The total number of vessels in the Faroese demersal fisheries has been decreasing since 2003 when it peaked at 76 vessels. Figure 53 shows the number of vessels by three fleet segments, large trawlers, pair trawlers and longliners. The decline was largest for pair trawlers, but the number of large trawlers has also been fallen throughout the period. On the other hand, the number of longliners increased between 1993 and 2007 when the fleet was composed of 27 vessels but since then the fleet has shrunk again.
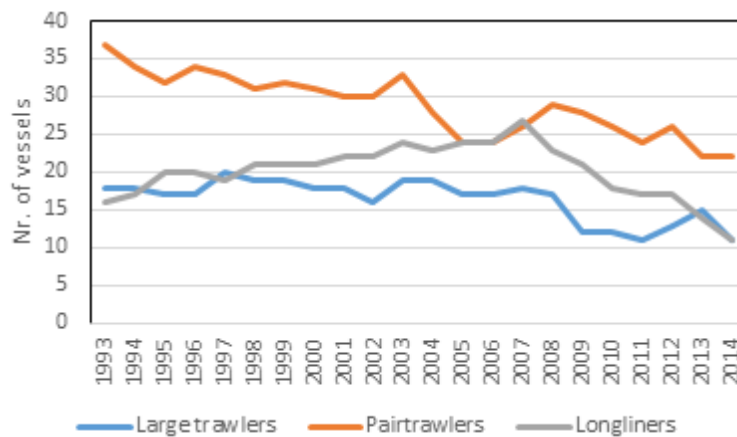

Figure 53 Number of boats in each fleet segment 1993-2014.

The share of landings of cod, haddock and saithe in all demersal fisheries has fluctuated between 60% and 90%. Catches of cod, haddock and saithe increased during the first half of the period under study, but after 2003 cod and haddock catches plummeted. Landings of saithe decreased a few years later. As the right panel of Figure 54 indicates, saithe is by far the most important of the demersal species.
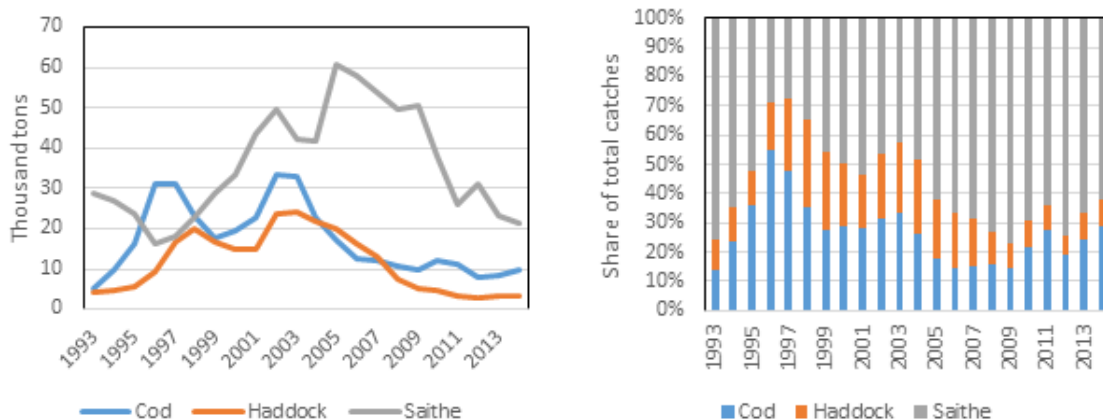

Figure 54 Landed weight of cod, haddock and saithe (left) and the share of each species in the catches of these three species (right) 1993-2004.

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Most of the demersal catches have generally been registered by pair trawlers and longliners, with only modest landings of large trawlers. Catches by longliners and large trawlers have however decreased sharply in recent years, with pair trawlers accounting for the majority of the demersal catches.
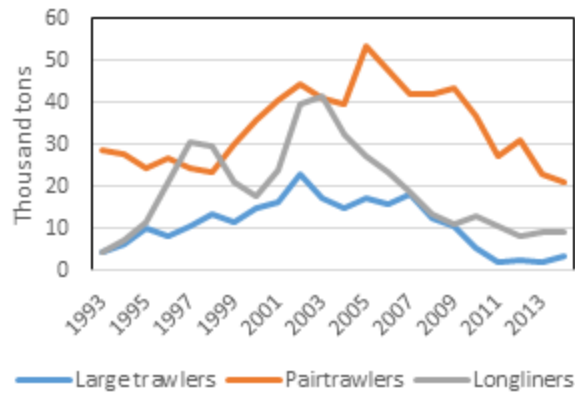

Figure 55 Landed weight by fleet segments 1993-2014.

Due to the limited data available on vessel characteristics, the capacity index for the Faroese fleet is based only on data on the total gross tonnage of each fleet segment. As shown inFigure 56, vessels have on average been getting larger, but the capacity of the fleet has shrunk due to the fact that the fleet now contains fewer vessels.

Figure 56 Average weight (GT) by fleet segment (left) and capacity index (right) of the Faroese demersal fleet 1993-2014.

Employment

The number of fishermen employed by the demersal fleet has fallen from 816 in 1993 to 507 in 2014. On average, there have been 15 seamen in the crew of the large trawlers, 14 on longliners and seven on pair trawlers.
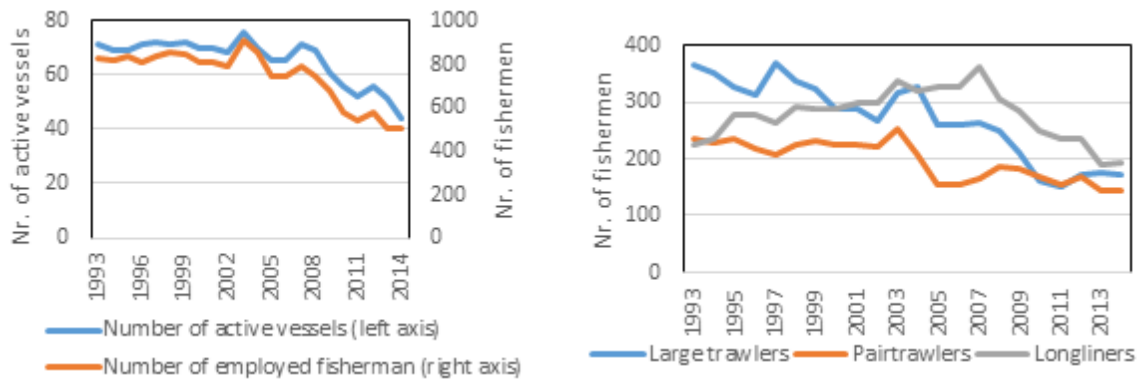
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Figure 57 Number of fishermen employed and active vessels in demersal fisheries (left) & number of fishermen employed by fleet segments (right) 1993-2014.

Stocks

The cod stock off the Faroe Islands has been reduced severely in the last 20 years. In 1996, the spawning stock measured 85 thousand tonnes but has since 2006 only been about 20 thousand tonnes. The haddock stock fluctuated wildly in the first half of the period peaking at around 90 thousand tonnes, but has since declined almost continuously and now measures only about 15 thousand tonnes. Estimates of the spawning stock of saithe also reveal large fluctuations. The stock measured 60 thousand tonnes in 1993, but more than doubled in size in 2006 before declining again to 50 thousand tonnes. In 2014, the stock measured 70 thousand tonnes.

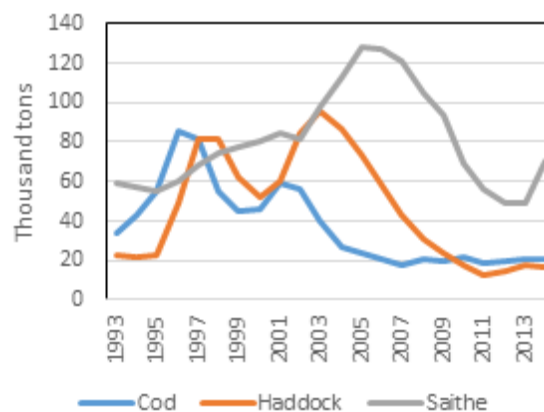*Figure 58 Stock assessment of three main demersal species 1993-2014.*

In Figure 59, the stocks of these three main demersal species have been combined to form a single composite stock measure of biological capital, which is then compared to total catches of these same species. The figure reveals how catches increased as stocks grew, and conversely how catches declined as stocks contracted.
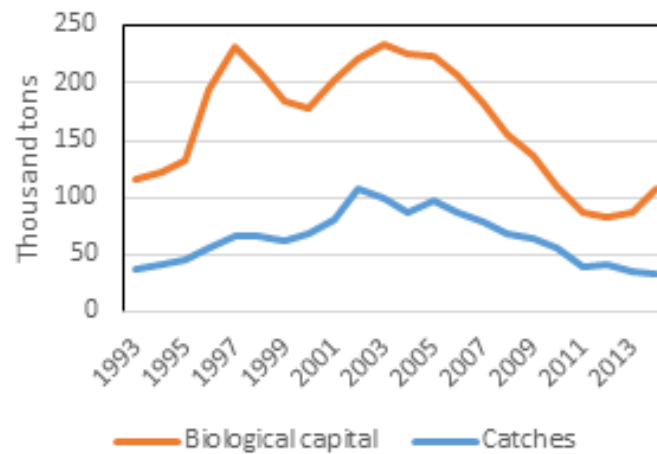
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Figure 59 Biological capital and landed weight 1993-2014.

Productivity calculations

The data used for productivity analysis of the Faroese demersal fisheries covers the period 1993-2014. Although the Faroese demersal fleet catches predominantly cod, haddock and saithe, the vessels also harvest other species. Catches of these three species constituted on average 78% of total catches. In the calculations of productivity the use of the two control inputs – capital and labour – is therefore adjusted by the share of landings of these species in total landings.

Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported inTable 13. All three components of productivity declined during the period under consideration. The reduction in landings and stocks averaged 0.5% and 0.3% per year while capital, as measured by the capacity index, and labour declined by 0.6% and 2.4%. Very high fluctuations are observed for both landings and capital with the standard deviation for both time series around 15%. The variation in capital and labour is also considerable, but still only half of the fluctuations in landings and stocks.

Table 13 Average annual growth rates and standard deviation of landings, capital, labour and stocks 1994-2014. Percentages.

	Mean	Standard deviation
Landings	-0.5	15.1
Capital	-1.2	8.2
Labour	-2.3	7.0
Stocks	-0.3	15.0

The fluctuations in landings and stocks are clearly revealed in Figure 6-8, which examines the four components of productivity in more detail. There is a rather weak positive relationship between

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landings and labour, but a much stronger positive relationship between landings and stocks. A significant positive relationship is also observed for capital and labour.
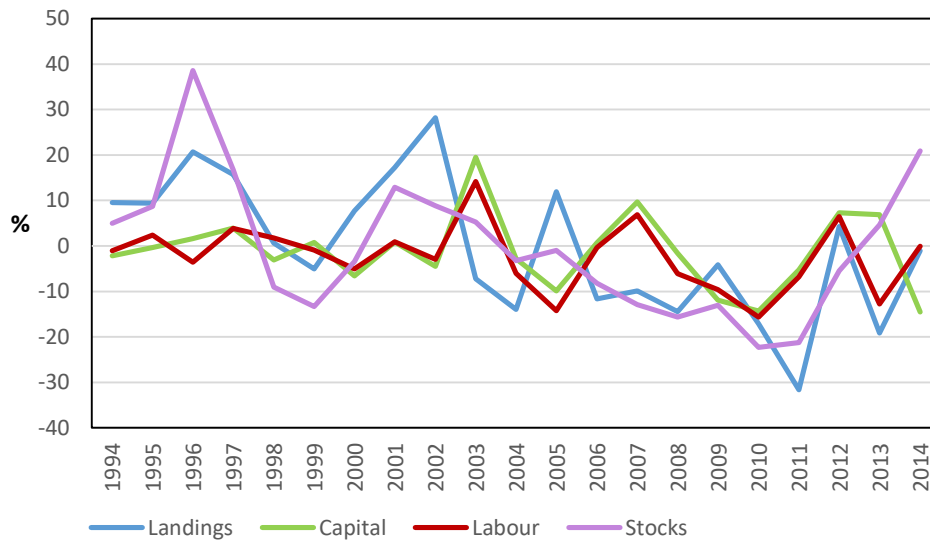

Figure 60 Percentage changes in the landings, labour, capital and stocks in the Faroese demersal fisheries 1994-2014.

On average, productivity increased by 1.5% in the Faroese demersal fisheries during 1994-2014. Decreasing landings reduced productivity growth on average by 0.5% while reduction in capital and labour and smaller stocks all had a positive effect on productivity. In Table 14, the productivity is also compared across two periods; 1994-2003 and 2004-2014. The development of productivity is very different in these two sub-periods. Whereas productivity grew on average by a healthy 2.9% in the first period, the growth came to an almost complete standstill in the second period. Of special interest here is the development of landings and stocks. During 1994-2003, landings increased on average by 9.7% between years and then decreased annually by the same magnitude in the second period. In the first period stocks increased annually by 6.0% and because this increase has a detrimental effect on productivity it shows up with a minus sign inTable 14. In 2004-2014, stocks diminished and this decline along with the reduction in capital and labour prevented productivity growth from becoming negative.

Table 14 Decomposition of average productivity change in the Faroese demersal fisheries 1994-2014. Percentages.

	1994-2014	1994-2003	2004-2014
Landings	-0.5	9.7	-9.7
Capital and labour	1.6	-0.8	3.9
Stocks	0.3	-6.0	6.0
Productivity	1.5	2.9	0.1

These averages though mask substantial swings, as revealed by Figure 61, which shows the development of productivity and its components. While the black line traces out productivity

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developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock.

There are several productivity peaks and lows, with the growth turbulence especially pronounced in 2002-2005 when productivity first increased by almost 24% only to fall by 25.7% and 7.3% the subsequent two years and then rise again by 23% in 2005. While these swings can mostly be attributed to changes in landings, it is also interesting to see the impact changes in capital and labour had on productivity. Thus, the decline in productivity in 2003 can to a substantial degree be traced to increases in the fleet capacity index and number of seamen, while reductions in employment and fleet capacity play a significant role in the productivity jump in 2005. The last two years of the study period, 2013 and 2014, are characterised by large decreases of productivity – 17.2% in 2013 and 15.5% in 2014. The causes of this are though quite different. The productivity decrease in 2013 is thus mostly due to lower catches, while increases in stock size, above all saithe, are the main reason for the poor performance in 2014.
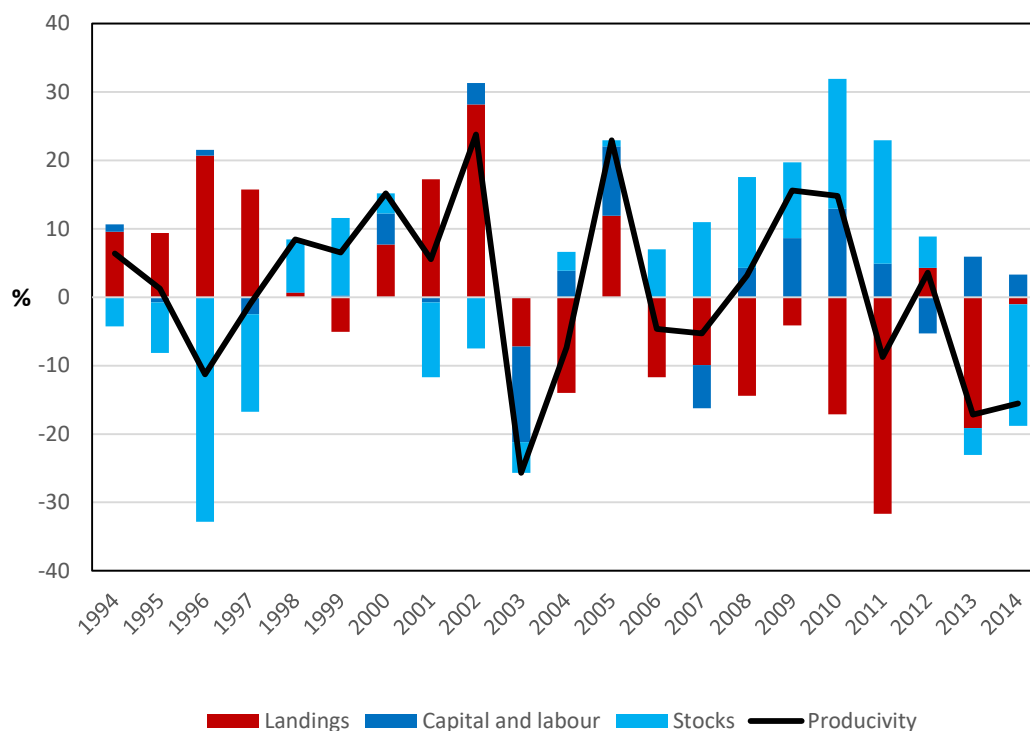

Figure 61 Decomposition of changes in the productivity of the Faroese demersal fisheries 1994-2014.

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Demersal fisheries in Iceland

Total catches of cod, haddock, saithe, redfish, wolffish and ling have fluctuated between 390 and 520 thousand tons since 1993 with cod by far the most important species, see Figure 62. Cod catches declined from 260 thousand tons in 1999 to 140 thousand tons in 2008, but have since grown again and have in recent years amounted to 220 thousand tons
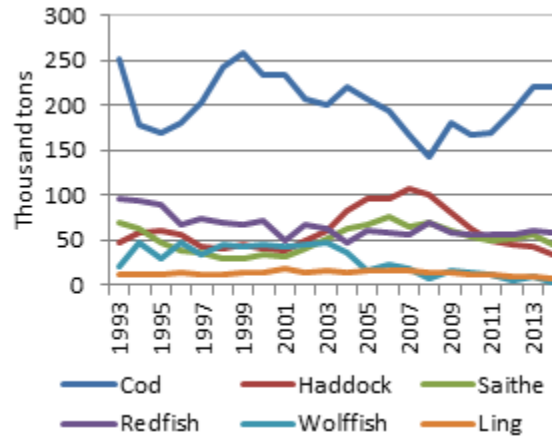

Figure 62 Total catches of demersal species 1993-2014.

Together, these species have since 1993 accounted on average for 89% of total demersal catches and 91% of the value of these catches, seeFigure 63.
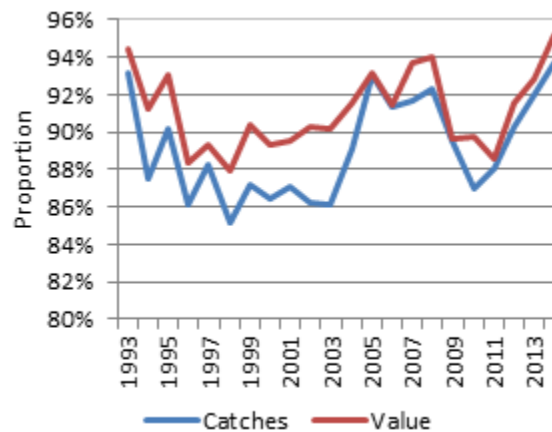

Figure 63 Proportion of the six demersal species of total demersal catches and value, 1993-2014.

The stocks of the main demersal species are generally in better biological shape now than 20 years ago, see Figure 64. Recent estimates put the spawning stock of cod at 460 thousand tons, almost four times larger than two decades ago. The growth of the stock has been especially rapid in recent years, with conservative utilisation leading to large stock improvements. The stock of golden redfish has grown from about 150 thousand tons to 350 thousand tons and saithe from100 thousand tons to 140

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thousand tons. The haddock spawning stock increased quite fast in the first five years of the 21st century, from around 60 thousand tons in 2000 to 180 thousand tons five years later, but has since declined again to 80 thousand tons.
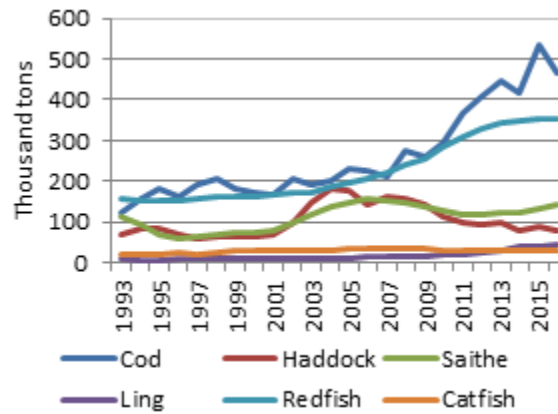

Figure 64 Estimates of spawning stock biomass of demersal species, 1993-2016.

Most of Iceland's demersal catches are registered with vessels operating bottom trawls, seeFigure 65. This holds especially true for the redfish and saithe fisheries where trawls accounted for more than 85% of in 2014. By contrast, longline is the predominant gear used in the catfish and ling fisheries.

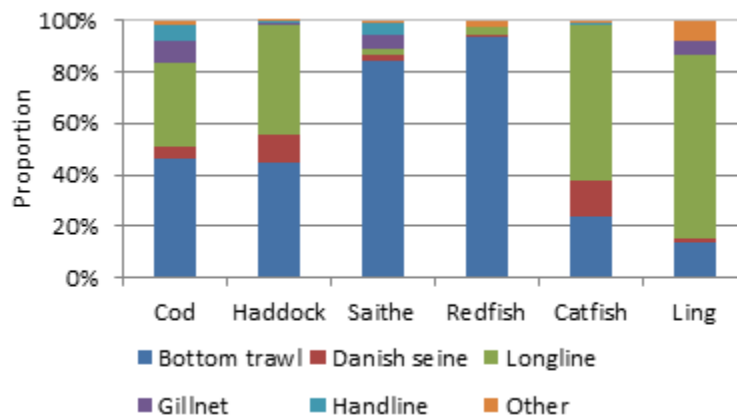*Figure 65 Proportion of total demersal catches by gear in 2014.*

Data

The data used in the Icelandic case study cover the period 2002-2014 and come from the Marine Research Institute (MRI), the Directory of Fisheries (DoF), Statistics Iceland (SI), Icelandic Transport Authority (ICA) and the International Council for the Exploration of the Sea (ICES). In what follows the data used are examined in more detail.

Fleet and catches

Vessel landing data were obtained from the Directorate of Fisheries (DoF), which is a government agency charged with monitoring fisheries and the daily administration of the fisheries management system in Iceland.[5] The data cover each and every landing in Iceland of all vessels during each fishing year (September-August) during the years 2002-2015. The data include the registration number and name of the vessel, fishery category, gear, catch area, species caught and landed weight.

The data are categorized by gear; bottom trawl, net and seine, longline and hand line, which makes it possible to analyse catches of the following fleet segments; trawlers, longliners, netters and small boats that are only allowed to use longline and hand line. In Iceland, there are currently two different types of general fishing permits, general fishing permit with a catch quota and a general fishing permit with a hook-and-line quota. In what follows the former are called regular quotas and the latter hook-and-line quotas (Agnarsson, Matthiasson and Giry, 2016). The hook-and-line quotas may only be utilised by boats smaller than 30 GRT that may only use longline or handline, but all vessels larger than 30 GRT are subject to the regular quota system. In 2009, a new coastal fishery was set up in order to open up possibilities for new entrants and increase flexibility. All registered boats, including those holding quotas, may join the fishery which runs during May, June, July and August. The fishing grounds off Iceland are divided into four areas and a pre-determined cod-cap set for each month in each of the areas. The fishery is an open-access fishery and fishing in each month and area is suspended once the cap is reached. Boats may only employ hand-line and can only fish for 14 hours per day during Monday-Thursday.

The catch data from DoF was merged with ship registers obtained from the ICT which made it possible to assemble a measure of the harvesting capital employed by each fleet segment and the demersal fleet as a whole. Apart from information on the various vessel characteristics, the registers also contain information on when and where the vessel was built, refurbishments undertaken, current owners and operators and home port.

Up until 2008, the number of vessels in all gear-categories declined, but the introduction of the coastal fisheries in 2009 led to a rapid increase in the number of vessels smaller than 30 GRT, although that fleet expansion appears to have levelled off in recent years. The number of trawlers, netters and large longliners has been drastically reduced, as is evident from Figure 66.

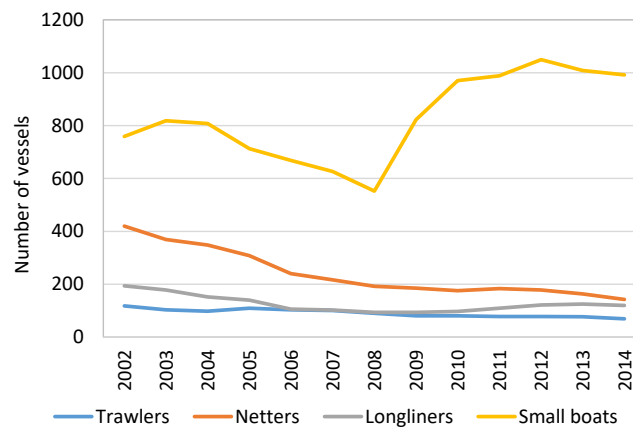[5] http://www.fiskistofa.is/english/about-the-directorate/.

Figure 66 Number of boats in each fleet segment, 2002-2014.

Catches of the six demersal species of each fleet segment have, on the other hand, been increasing since 2002 (Figure 67). In 2014, trawlers caught 58% of the demersal species, netters 10%, large longliners 18% and small boats 14%, see Figure 67 (right).
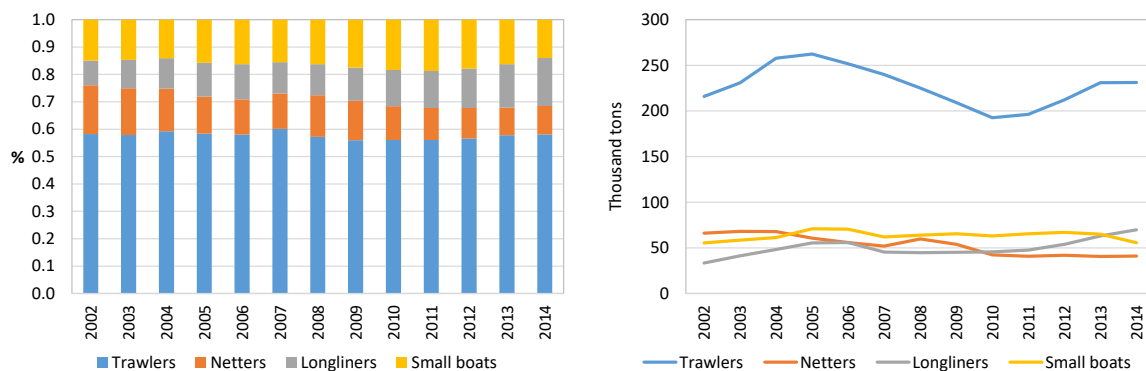

Figure 67 Landed weight by segments of the Icelandic demersal fleet (left) and share of total catch by fleet segments (right) 2002-2014.

On average, boats in all fleet segments have become slightly larger. In 2014 demersal trawlers measured 42 meters on average, netters 19 meters, large longliners 21 meters and small boats 9 meters. Large longliners have experienced the most change throughout the period since they were on average only 17 meters long in 2002.

In general, vessels have become both larger and more powerful. As Figure 68 indicates, the larger vessels have become more powerful, but the average engine size of the smallest boats declined following the introduction of the coastal fisheries in 2009 and their size has not changed much since. By contrast, engines in longliners were on average 60% more powerful in 2015 than in 2002, while the corresponding increase in the size of engine in netters and trawlers is 20% and 17%.
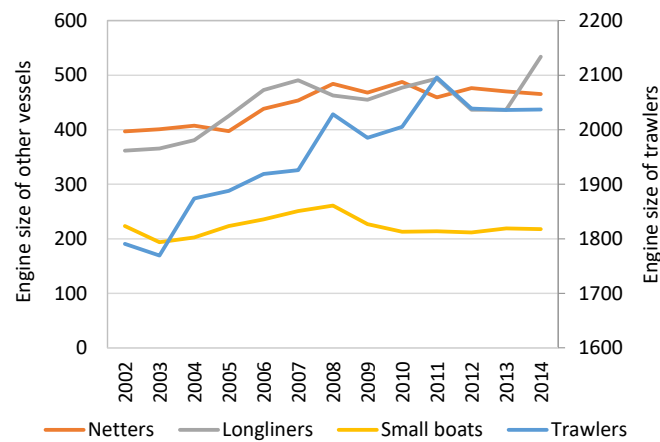
Figure 68 Average horsepower (kWh) by segments of the Icelandic demersal fleet 2002-2014.

The capacity of the demersal fleet is measured as the product of the engine size (measured in kW) and length of each vessel (measured in meters) and this then aggregated across all vessels for a measure of the capacity of individual fleet segments and the fleet as a whole. This measure does therefore both take into account changes in the number of vessels in each category, as well as changes in vessel length and engine size. As revealed in the left panel of Figure 69, the capacity of small boat fleet was 40% higher in 2014 than in 2002, while the capacity of longliners had increased by 12% over the same period. A totally different development is observed for trawlers and netters. The capacity of the former fleet segment decreased by 30% and of netters by a whopping 60%. Overall, the capacity of the fleet has decreased by 26%.
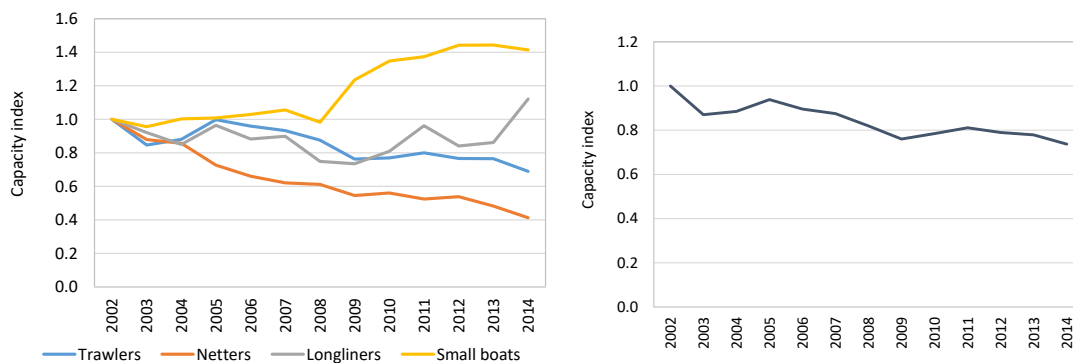
Figure 69 Capacity index of the different segments of the Icelandic demersal fleet (left) and overall capacity index of the demersal fleet (right) 2002-2014.

Employment

The labour force surveys undertaken by SI enable the bureau to estimate the number of fishermen employed by the harvesting sector as a whole, but no information is available on the number of persons employed by each fleet segment. Here it is assumed that the crew size of vessels operating different gear has remained the same throughout the study period, and the labour employed by

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different fleet segments may therefore be simply calculated as the product of the number of vessels in each segment and crew size. Ad hoc, it is assumed that each trawler has a crew of 15, longliners a crew of 14, netters and seiners a crew of eight and the smallest boats a crew of two.

The demersal fisheries now employ far fewer fishermen than a decade ago. Using the ad hoc method described above, it is estimated that he fleet employed 9,400 fishermen in 2002 but only 5,800 in 2014. As expected and shown in Figure 70, the development of the number of fishermen is closely linked to the development of the number of vessels in the fleet. The large increase in the number of small boats following introduction of the coastal fisheries in 2009, has though only led to rather small increase in the total number of crew as it is assumed that only two persons man each small boat. The number of persons employed by vessels in other fleet segments had fallen in line with the decline of active vessels.
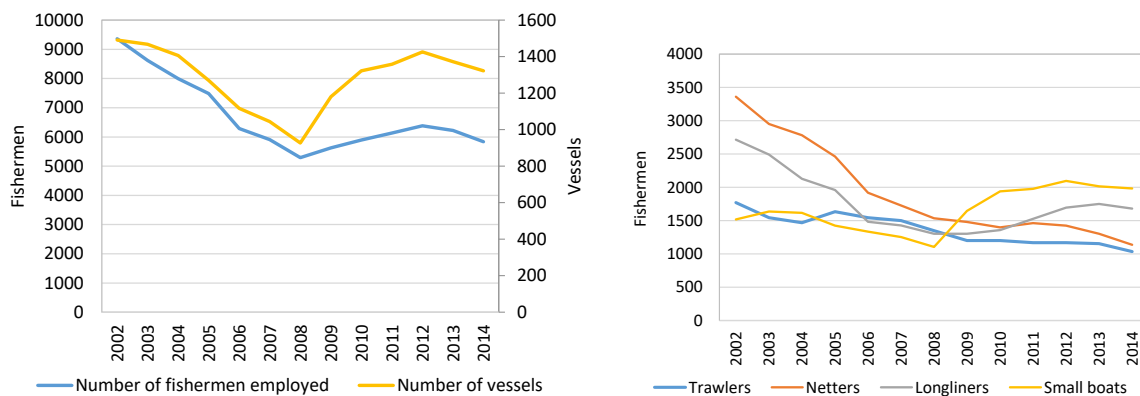

Figure 70 Number of fisherman employed and active vessles in demersal fisheries (left) & number of fishermen employed by fleet segments (right), 2002 – 2015.

Stocks

MRI is a government institute under the auspices of the Ministry of Fisheries which conducts various marine research and provides the Ministry with scientific advice based on its research on marine resources and the environment, including assessment of the stocks of the various fish species exploited in Icelandic waters. [6] Stock assessments for both demersal and pelagic fishes are published online, including assessments of the spawning stock biomass (SSB) of most species and the fishable stock of some species. Here, SSB is used as an estimate of the stock size of all the demersal species included in the study, except wolffish where an estimate of the fishable stock is used.

Figure 71 shows the development of the aggregate stock and landings of the six demersal species included in the study since 2002. The combined stock size of the six species is used a proxy for the biological capital employed by the demersal fisheries. As is evident from the figure, catches have not increased in line with growing stocks

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[6] Marine Reasearch Institute: *http://www.hafro.is/undir_eng.php?ID=1&REF=1*
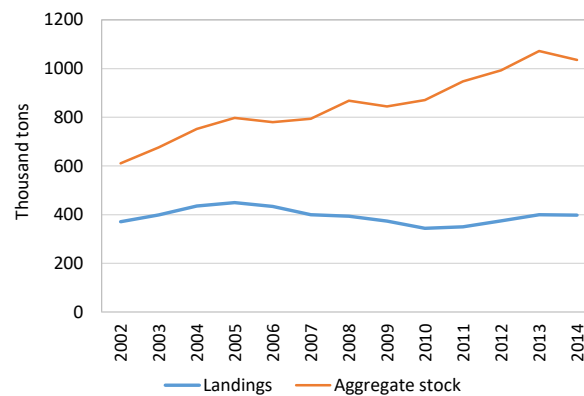
Figure 71 Landings and spawning stock biomass for the demersal species, 2002-2015.

Labour and capital share

Information on the capital and labour shares of value added are taken from the financial accounts of the fisheries compiled by SI. These are available for various vessel categories, i.e. fresh fish trawlers and freezing trawlers and pelagic freezing trawlers as well as boats smaller than 10 GRT, boats 10-200 GRT and larger boats. These categories do, however, only partially correspond to the vessel categories employed in this study. Consequently, it was decided to only use the capital and labour shares for the fisheries as a whole.

Productivity calculations

Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 15. While the aggregate stock grew by 4.4%, landings only increased by 0.6% and capital and labour declined by 2.5% and 3.9%. There are considerable fluctuations in landings, as witnessed by a standard deviation of 8.6%, while both labour and stocks show less variability. The share of labour in value-added was 63.5% on average.

Table 15 Average growth rates and standard deviation of landings, capital, labour and aggregate stock in the Icelandic demersal fisheries 2003-2015. Percentages.

	Mean	Standard deviation
Landings	0.6	6.1
Capital	-2.5	5.6
Labour	-3.9	7.3
Aggregate stock	4.4	5.1

In Figure 72, the development of the four components of productivity is examined in more detail. There is a negative relationship between landings on the one hand and all the other variables on the other hand. Of special interest is that landings and stocks are negatively correlated, indicating that landings decline as aggregated stocks decline. As revealed in Figure 72, landings and aggregate stocks move closely together up until 2008, but after the two variables are more out of step. A weak negative

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relationship exists between stocks and labour, while stocks and capital exhibit a weak positive linear relationship.
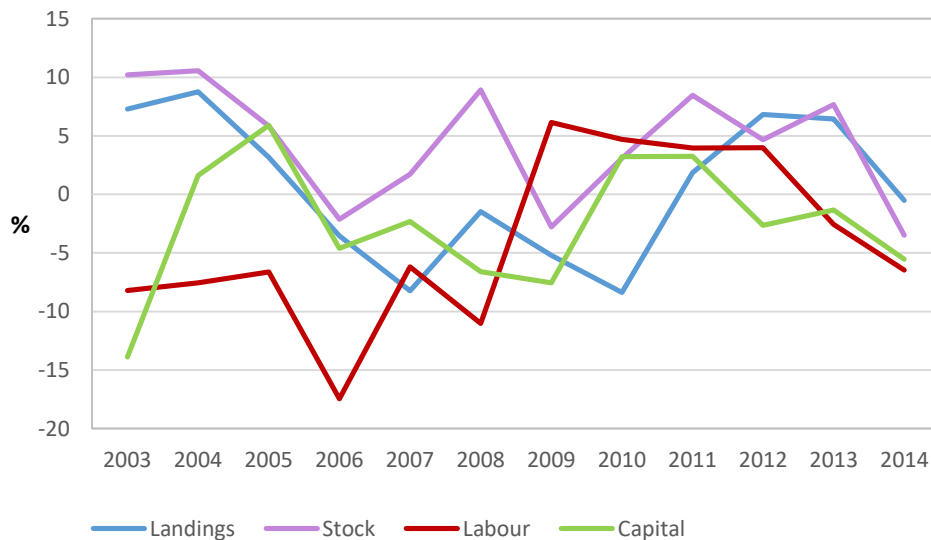

Figure 72 Percentage changes in the landings, labour, capital and stocks in the Icelandic demersal fisheries 2003-2014.

During 2002-2014, catches of cod, haddock, saithe, redfish, wolffish and ling constituted on average 85% of the total demersal catches. In the calculations of productivity the use of the two control inputs – capital and labour – is therefore adjusted by the share of landings of these species in total landings.

On average, productivity stood still in Iceland's demersal fisheries during 2003-2014. The average growth rate takes a value of 0.0%, implying that changes in landings were on average cancelled out b changes in the use of the control inputs capital and labour, and changes in the aggregate stock variable. Increased landings contributed on average 0.6% to productivity growth and the contribution of smaller fleets and fewer seamen amounted on average on 3.1%. Increases in the biological capital – the aggregate demersal stock – reduced productivity by 3.7%

Table 16 Decomposition of average productivity change in the Icelandic demersal fisheries 2003-2015. Percentages.

	2003-2015	2003-2008	2009-2015
Landings	0.6	1.0	0.2
Capital and labour	3.1	6.4	-0.2
Stocks	-3.7	-5.0	-2.5
Productivity	0.0	2.4	-2.5

In Table 16 productivity growth is also compared across two periods; 2003-2008 and 2009-2015. Productivity grew on average by 2.4% in the first period, mainly because of shedding of capital and labour. In the second period productivity fell on average by 2.5% per year. Almost of that decline can

be related to changes in the aggregate stock, which grew quite fast in 2010-2013, mostly because of good growth of the spawning stock of cod which increased from 260 thousand tons in 2009 to 450 thousand tons in 2013.

These averages though mask substantial swings, as revealed by Figure 73, which shows the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. There are two large productivity peaks, in 2006 when productivity grew by 10% and in 2014 when the growth amounted to 8%. The productivity growth in 2006 can mostly be attributed to reductions in capital and labour, as illustrated by the large dark-blue column, while the growth in 2014 is primarily due to reductions in capital and labour and a fall in the aggregate stock variable. The biggest slump in productivity occurred in 2010, when productivity declined by 14.4%, mostly due to a fall in landings, but increases in capital and labour, brought about by the introduction of the coastal fisheries a year earlier and larger stocks also played a part.
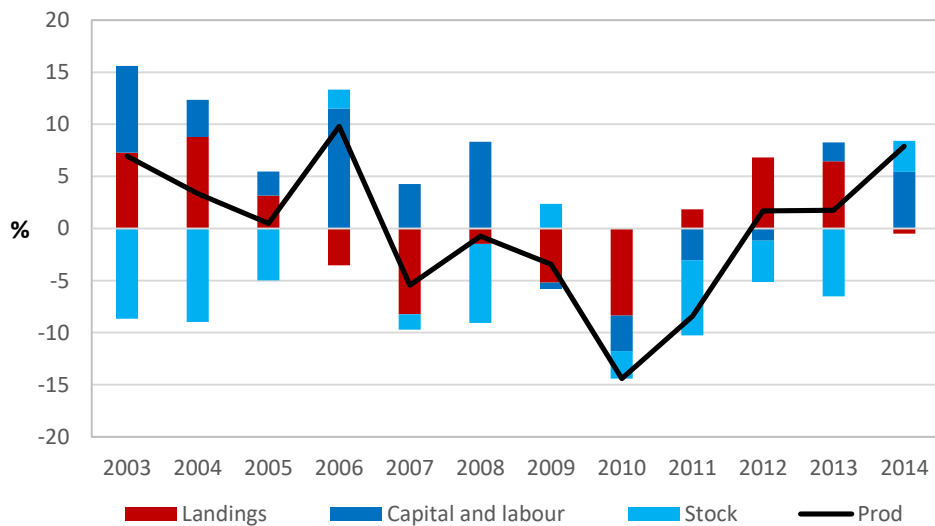

Figure 73 Decomposition of changes in the productivity of the Icelandic demersal fisheries 2003-2014.

Demersal fisheries in Newfoundland

No analysis of the Newfoundland demersal fisheries has been carried out as suitable data was not available. If such data materialise, efforts will be made to include the Newfoundland demersal fisheries in a revised version of this deliverable.

Pelagic fisheries in Denmark

This section is concerned with the fleet segment purse seiners and trawlers longer than 40 meters long that is responsible for the main part of the catches of herring and some other pelagic species in Denmark. In 2009-2013, this fleet segment registered 70-90% of all Danish herring catches, which were mostly taken from two stocks; the North Sea autumn-spawning herring and the Norwegian spring-spawning herring. In addition to herring, the fleet also catches mackerel and small pelagic species for industrial purposes.-

The total catches of herring (all stocks) and mackerel have varied over the years. Herring catches (landings) from Danish vessels reached 140.000 tonnes in 2006, followed by a fall to less than 80.000 tonnes in 2010. In the last few years, catches have totalled 120-140.000 tonnes. The value of the herring landings has fluctuated between 30 mill € in 2010 and a top of almost 90 mill € only two years later. Catches of mackerel, which is a more valuable species, have also increased in recent years.
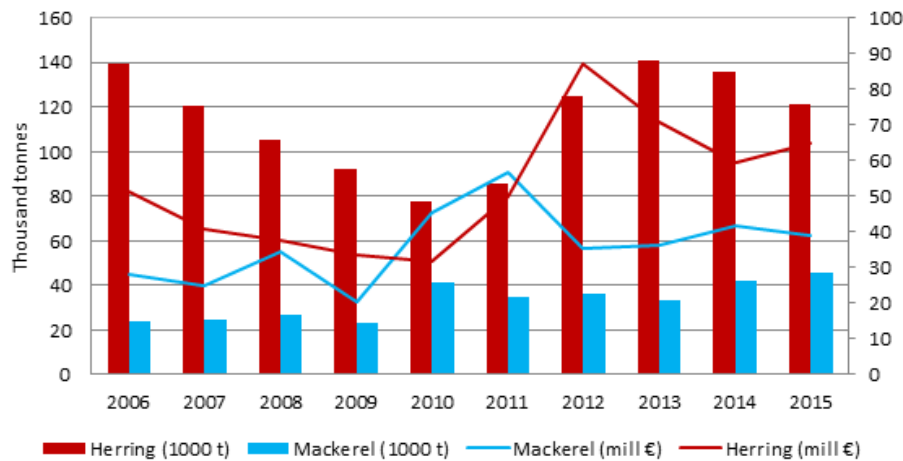

Figure 74 Value (million €) and volume (thousand tonnes) of all Danish landings of herring (all stocks) and mackerel 2006-2015. Source: Danish Agrifish Agency, dynamic landing statistics.

In recent years the value of herring and mackerel catches has amounted to 18-31% of the value of all Danish catches.
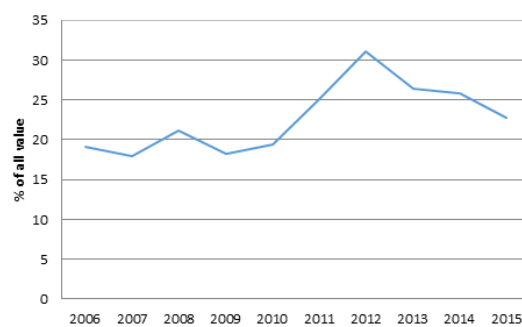

Figure 75 Relative share of landings of herring and mackerel in Danish landings of all species 2006-2015. Source: Danish Agrifish Agency, dynamic landing statistics.

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The spawning stock of the North Sea autumn-spawning herring found in ICES Subareas IV and Divisions IIIa and VIId has shown a strong upward trend in the last 35 years. Stocks are now estimated at around 2 million tonnes, after the stock was fished down to dangerous levels in the 1970s. In the last 25 years, total catches of all nations have hovered around 500 thousand tonnes, but catches have not been allowed to increase in line with the stronger stock.
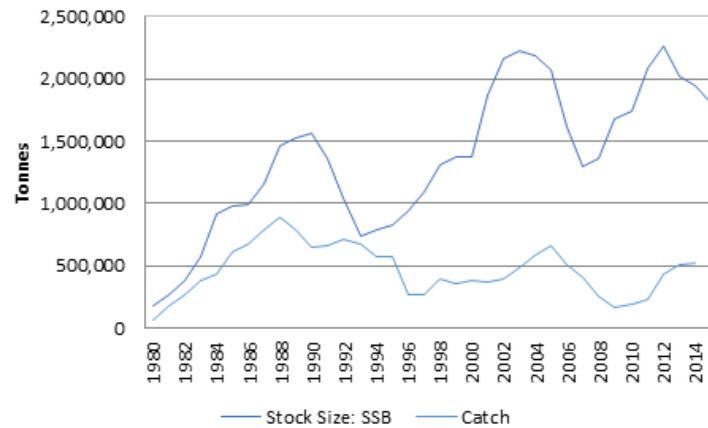

Figure 76 Spawning stock and catches of North Sea autumn-spawning herring in Subarea IV and Divisions IIIa and VIId, 1947-2014. Source: ICES, stock assessment graphs.

The spawning stock of mackerel in the Northeast Atlantic (combined Southern, Western and North Sea spawning components) has fluctuated a great deal in the last 35 years. At the beginning of the 1980s, the stock was estimated at 4 million tonnes, but declined in the next 20 years to a level of around 2 million tonnes. Since then the stock has rebounded and is now estimated at 3.5-4.0 million tonnes. The growth of the stock in the last decade has led the mackerel to migrate further north than before and a substantial proportion of the stock has ventured inside the jurisdiction of the Faroe Islands and Iceland, leading to disagreements on how this migrating stock should be shared between the neighbours in the Northeast Atlantic.
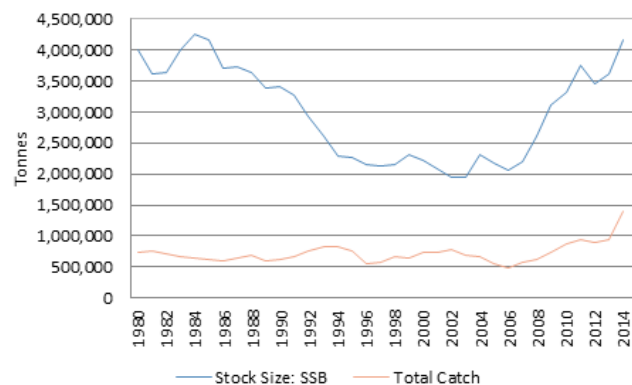

Figure 77 Spawning stock and catches of mackerel in the Northeast Atlantic (combined Southern, Western and North Sea spawning components), 1980-2014. Source: ICES, stock assessment graphs.

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Data used in study

The landings data used in the Danish case study cover the years 2009-2014 and come from The Ministry of Environment and Food in Denmark, the Danish Agrifood Agency (NAER), economic data and information on fleet-specific landings comes from Statistics Denmark (SD), and data on stock size from ICES, regarding the stock assessments (stock assessment graphs)

Vessels and landings

General landing data were obtained from The Danish AgriFish Agency (NAER), which is a government agency charged with monitoring fisheries and the daily administration of the fisheries management system in Denmark under the Ministry of Food, Agriculture and Fisheries.[7] The data cover all landings from all Danish vessels (and foreign landings in Denmark) during the period 2006-2016, but information on landings in earlier years is available in a non-digitalised form. The sources for the data base are registrations in logbooks of individual vessels and registrations from ports and auctions.

In 2009-2014, herring and mackerel catches represented on average 71% of the value of total catches by this fleet segment. The value share was highest in 2012, just over 80%, but only 59% in 2010. Other pelagic species have on average made up 26% of the total value and catches of non-pelagic species 2%.
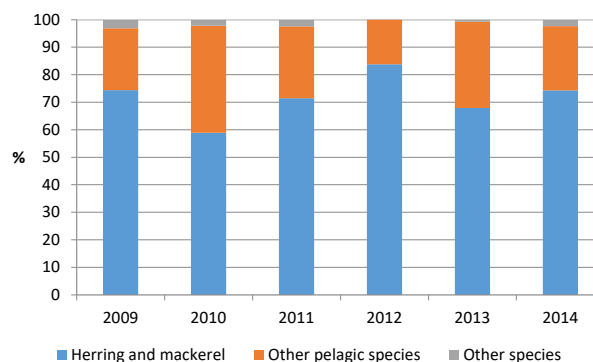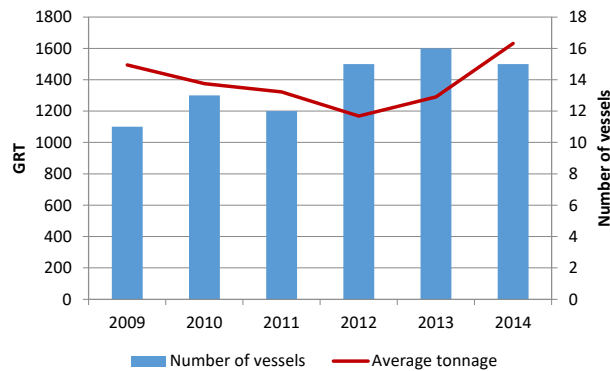

Figure 78 Value composition of catches by Danish pelagic trawlers and purse seiners larger than 40 meters long 2009-2014. Source: Statistics Denmark. REGNFI03: Fishery, financial results and balance by vessel type and accountancy item (discontinued) and FIREGN1: Accounts statistics for fishery (total) by vessel length and items.

The capital data (and fleet specific landing statistics) are all extracted from Statistics Denmark (SD), the Account Statistics for Fishery, which covers the commercial fishery by fishing vessels registered in the Denmark and includes information on all fishing vessels owned by individuals and legal entities[8].

[7] Danish Agrifish Agency, The Ministry of Environment and food of Denmark; http://agrifish.dk

Total[8] Statistics Denmark; http://statistikbanken.dk

The fleet segment consists of a few large vessels which numbered 26 in the year 2000 but only 15 in the year 2014. In2003, as a trial, herring quotas were allocated to individual vessels based on catches in previous years and the quotas made transferable. This led to a strong consolidation in the fishery, both as regards the number of vessels and operators. In 2007, a similar system of individually transferable quotas was introduced into the demersal fisheries. Pelagic vessels have also become larger in recent years. The average vessel in this fleet segment registered 636 gross registered tons (GRT) in 2000, but 1632 GRT in 2014.

Figure 79 Number and average size of Danish pelagic trawlers and purse seiners larger than 40 meters long. Source: Statistics Denmark. REGNFI03: Fishery, financial results and balance by vessel type and accountancy item (discontinued) and FIREGN1: Accounts statistics for fishery (total) by vessel length and items.

Capital employed by this fleet segment is measured as total tonnage of all pelagic trawlers and purse seiners larger than 40 meters long. This data is assessed by SD, based on account data from a fleet survey. As shown in Figure 80, the capacity of the fleet has increased considerably in recent years, with total tonnage rising from 16 thousand GRT in 2009 to almost 25 thousand GRT in 2014.
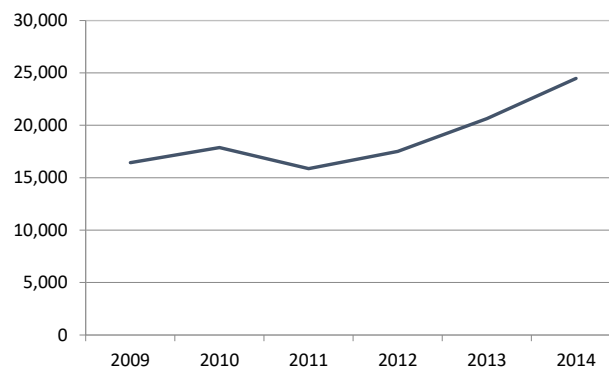
Figure 80 Capacity index of the Danish pelagic fleet, measured as the total tonnage (GRT) of the fleet segment, 2009-2014. Source: Statistics Denmark. REGNFI03: Fishery, financial results and balance by vessel type and accountancy item (discontinued) and FIREGN1: Accounts statistics for fishery (total) by vessel length and items.

Employment

The labour force data also origin from the account statistics discussed above. The labour input is calculated as the number of man-days employed in the segment, but the number of individuals employed is not available at fleet segment level. As the number of days-at-sea is known, average crew size can be estimated as average number of man days divided by average number of days-at-sea.

Total employment has varied between 16 thousand man days in 2009 and 27 thousand man days in 2013, with substantial year-to-year variations. This can both be attributed to changes in the number of fleet size and days-at-sea. As outlined above, the number of pelagic vessels has varied between 11 and 16, while the number of days-at-sea has varied between 153 in 2012 to 218 in 2010. On average, the pelagic vessels had a crew of eight, but crew size also varied between seven and ten.
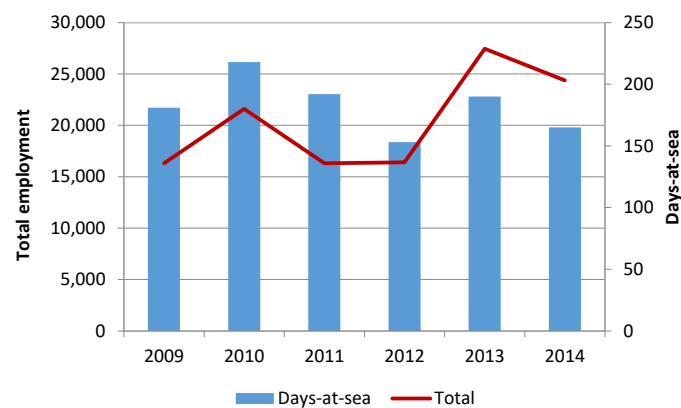

Figure 81 Average number of days-at-sea of vessels in the Danish pelagic fleet (right axis) and total employment (left axis) for the fleet segment, 2009-2014. Source: Statistics Denmark. REGNFI03: Fishery, financial results and balance by vessel type and accountancy item (Discontinued) and FIREGN1: Accounts statistics for fishery (total) by vessel length and items.

Labour and capital share

Information on the capital and labour shares of value added are taken from the financial accounts of the fleet segment, according to the Account Statistics at Statistics Denmark. Value added is here measured as the sum of wage costs, depreciation of vessels and machinery and operating profit (earnings before interest and taxes). The share of labour in value-added averaged 22%.

Stocks

The majority of Danish herring catches is taken from the North Sea autumn-spawning herring stock, but Danish vessels also harvest the Norwegian spring-spawning herring. As illustrated in Figure 82, the stock of the Norwegian herring has been declining, while the mackerel stock has been growing in size. The size of the North Sea herring stock has not changed much.
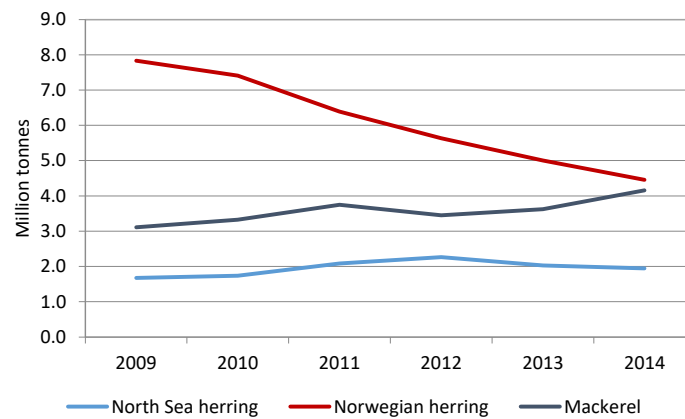
75

Figure 82 Stocks of herring and mackerel harvested by Danish vessels. Source: ICES.

Productivity calculations

Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 17. Landings increased on average by almost 10% per year while capital, as measured by the fleet capacity index, and labour both increased by 8.0%. However, aggregated stocks, which represent the combined size of the two herring stocks and mackerel stock, declined on average by 3.6%. Considerable variation between years is found for all the variables except aggregate stocks, which is rather surprising given the stochastic nature of the stock development of pelagic species in general. The standard deviation of labour is almost 32% and that of landings and capital 17% and 12%.

Table 17 Average growth rates and standard deviation of landings, capital, labour and stocks in the Danish pelagic fisheries 2010-2014. Percentages.

	Mean	Standard deviation
Landings	9.6	16.6
Capital	8.0	11.8
Labour	8.0	31.8
Aggregate stock	-3.6	3.1

The large variations in labour are clearly revealed in Figure 83, which examines the development of the four components of productivity in more detail. Employment increased by 50% in 2013, both because of changes in days-at-sea, and consequently the number of man days worked on each vessels, but also because of the addition of one more vessel to the fleet and increases in average crew size from seven to nine. There are also substantial swings in landings, especially in 2012, when herring catches almost doubled from 65 to 114 thousand tonnes.
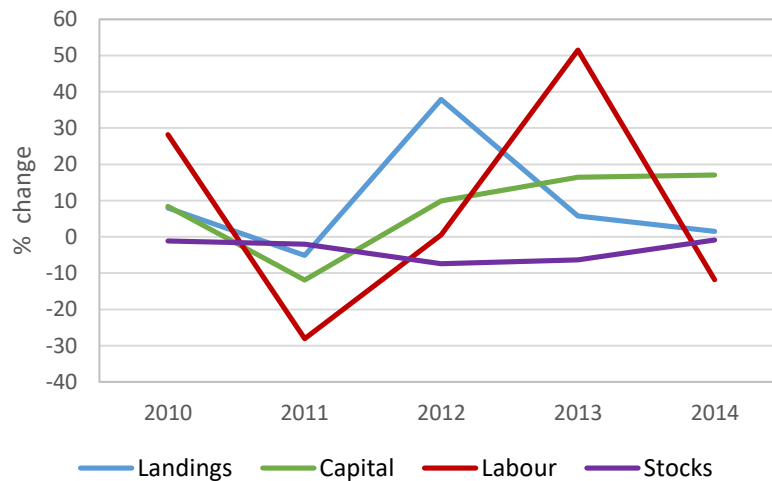
Figure 83 Percentage changes in landings, labour, capital and stocks in the Danish pelagic fisheries, 2010-2014.

For the calculations of productivity, the two input controls, capital and labour, are weighted by the relative share of catches of mackerel and herring in total catches, and the number of days-at-sea, as outlined in eq. (9) in the section on methods. The elasticity of output with respect to stocks is also set at 0.1.

On average, productivity increased by 7.6% in the Danish pelagic fisheries during 2010-2014. Most of these productivity improvements can be related to increases in landings. The increases in capital and labour observed earlier, retarded productivity growth by 2.3% percentage points, while the smaller aggregate stocks only had a marginal positive effect on productivity.

Table 18 Decomposition of average productivity change in the Danish pelagic fisheries 2010-2014.

	2010-2014
Landings	9.6
Capital and labour	-2.3
Aggregate stock	0.4
Productivity	7.6

Figure 84 outlines in more detail the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals the dominant effect that landings have had on productivity. The large increases in catches in 2010 and above all 2012, thus drive productivity growth on, while in 2013 the positive effect of increased landings on productivity are cancelled out by increases in both capital and labour, leading to a small productivity decline.
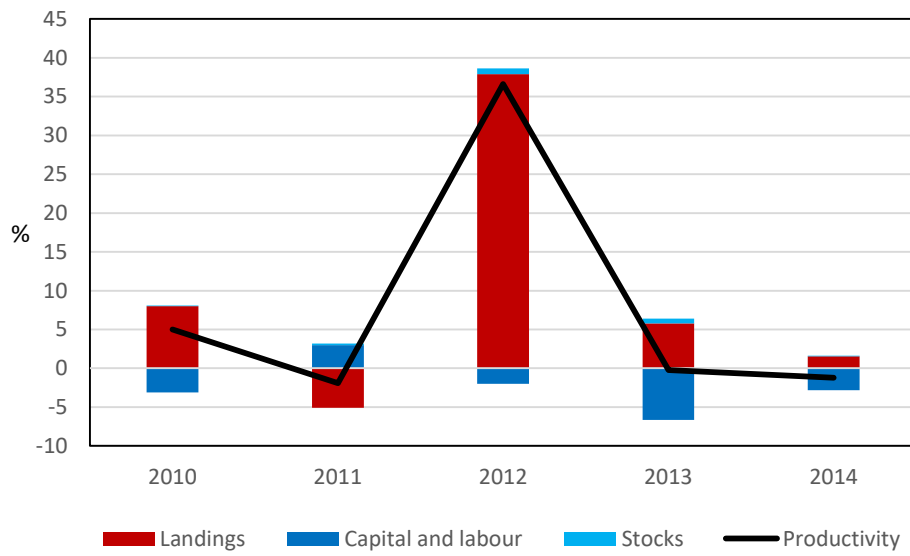
Figure 84 Decomposition of changes in the productivity of the Danish pelagic fisheries 2010-2014.

Pelagic fisheries in Germany

No analysis of the pelagic fisheries in Germany has been carried out as suitable data was not available. If such data materialise, efforts will be made to include the German pelagic fisheries in a revised version of this deliverable.

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Pelagic fisheries in the UK

Mackerel and herring represented 88% and 94% of the volume and value respectively of the pelagic species landed by the UK fleet in 2014 (Dixon, 2014). Moreover, mackerel is currently landed more than any other species by the UK fleet, approaching 300,000 tonnes in 2014, nearly three times the quantity landed in 2005,Figure 85. Landings of both species have fluctuated in the last 6 decades, and despite a recent growth due to larger quotas, an overall downward trend can be observed in both cases, with a major drop in landings of herring in the late 1970s due to overfishing and a collapse of the stock.

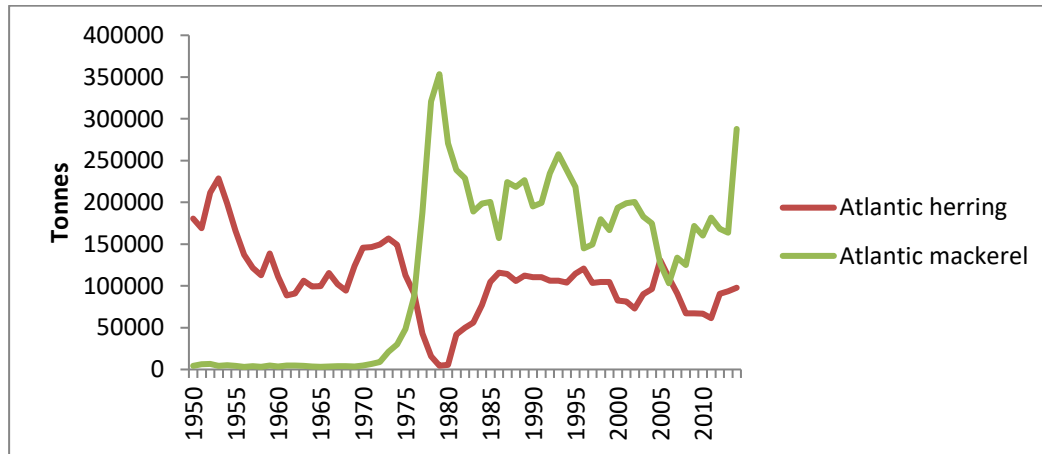*Figure 85 Landings of Atlantic mackerel and Atlantic herring by the UK fishing fleet 1950-2014. Source: FAOSTAT*

As shown in Figure 86 the majority of landings of pelagic species were captured from rectangles near Shetland and from the north coast of Scotland down to the north-west coast of Ireland.
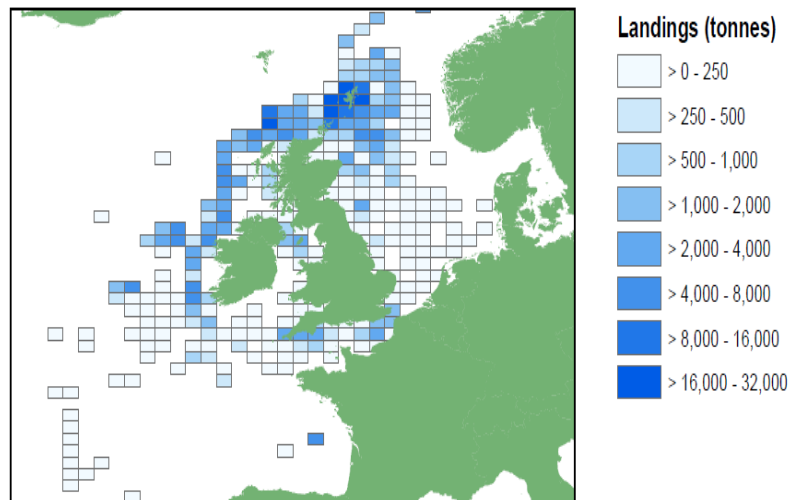

Figure 86 Quantity of pelagic fish landings by UK vessels by ICES rectangle. Source: Dixon (2014)

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Stock development

North Sea Herring – in ICES Sub-area IV (North Sea), ICES Division VIId (Eastern Channel) and ICES Division IIIa (Skagerrak – Kattegat)

After collapsing in the 1970s, the North Sea herring stock was closed to fishing for several years, before subsequently recovering. Although it fell back in the mid-1990s, it has again been rehabilitated. North Sea herring was assessed as a stock at full reproductive capacity being sustainably harvested in 2004 and 2005. This assessment weakened to a stock at risk of being harvested unsustainably in 2006 and a stock at risk of suffering reduced reproductive capacity since 2007. In 2011 and 2012, North Sea herring was assessed as being at full reproductive capacity and being harvested sustainably. In 2014, the stock was assessed as being at full reproductive capacity and being harvested below the rate that would lead to high long-term yields (Dixon, 2014).

North East Atlantic Mackerel – combined Southern, Western and North Sea spawning components

Mackerel is assessed as the single North East Atlantic (NEA) stock which combines the Southern, Western and North Sea spawning components. New management measures adopted from 2009 led to an increase of almost 33 per cent in the 2009 TAC in the NEA for mackerel, whilst maintaining measures to protect the North Sea spawning component. From 2005 to 2012 North East Atlantic mackerel has been assessed as being at full reproductive capacity but either at risk of or being harvested unsustainably. In 2004 North East Atlantic mackerel was assessed as at risk of suffering reduced reproductive capacity. Since 2013 the stock has been assessed as being at full reproductive capacity and being harvested sustainably (Dixon, 2014).

Fleet and catches

The main pelagic species caught by the UK are herring and mackerel and the fleet segment catching on average 98.5% of the species in 2008-2015 is pelagic vessels over 40 meters in length. Figure 87Figure 87 depicts the number of active vessels in the only fleet segment under study for the pelagic fisheries in the UK. The number of vessels peaked in 2010 when they reached the number of 33 vessels but in 2015 the number has dropped to 27 vessels.
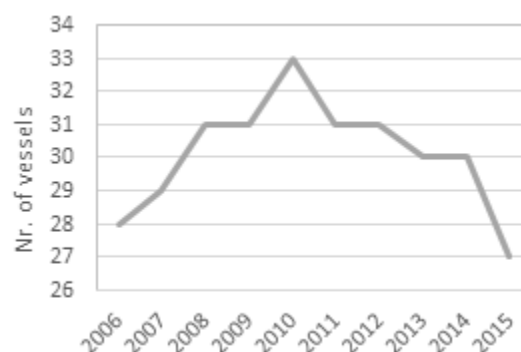

Figure 87 Number of vessels in the UK pelagic fisheries 2006-2015

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On average herring and mackerel amounted to 84% of all the fleet's catches in 2008-2015. Catches of the two pelagic species by the pelagic fleet is plotted in Figure 88. Overall, mackerel has represented about 70% of the fleet's pelagic catches, with herring counting for the other 30%
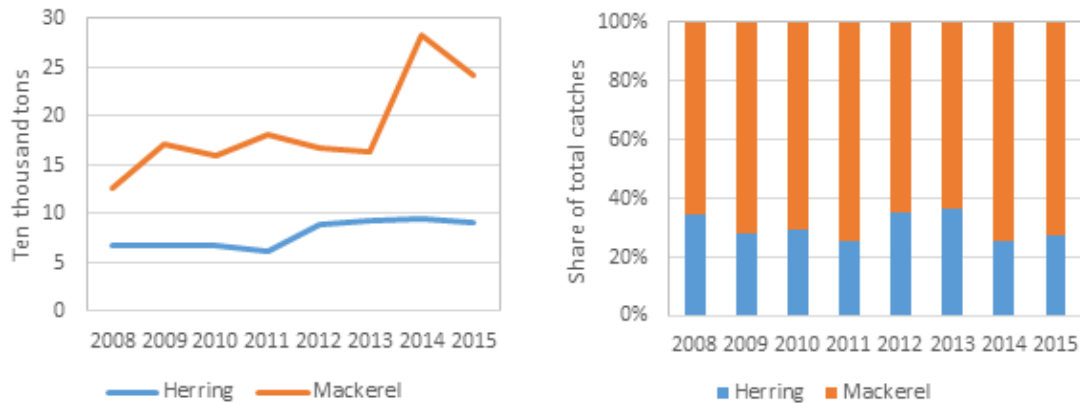

Figure 88 Landed weight of herring and mackerel by the UK pelagic fleet (left) and relative share of herring and mackerel (right), 2008-2015.

As for the average length of the fleet, it has been getting slightly larger. In 2015 pelagic vessels measured 66.3 meters on average but in 2006 they were on average 65.4 meters in length. Development of average engine power is shown in Figure 89. Average engine power has increased for the pelagic fleet, nearly 12% since 2006.
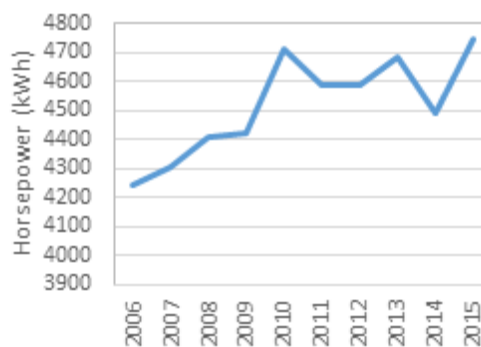

Figure 89 Average horsepower (kWh) of the UK pelagic fleet 2006-2015.

The capacity of the fleet, measured as the product of number of vessels, engine size and length, grew quite by 36% between 2006 and 2011, but has declined again and was in 2015 9% greater than in 2006.
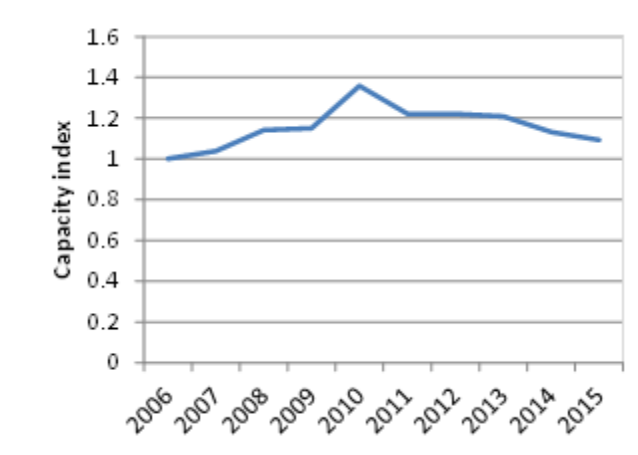
82

Figure 90 Capacity index of the UK pelagic fleet 2006-2015

Employment

Figure 91 depicts the development of employment along with the total number of vessels in UK's pelagic fisheries. There is an apparent downward trend in both series. The largest fall was experienced by fishermen employed in pelagic fisheries in 2013 when the number declined by 45%. In 2008, the fleet segment counted 31 vessels, but by 2015 the number had declined to 27 ships.
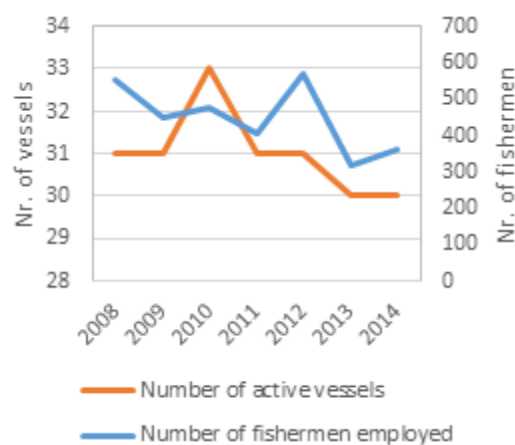
Figure 91 Number of fisherman employed and active vessels in the UK pelagic fisheries 2008–2014

Stocks

The pelagic species we involve in the study are as previously mentioned herring and mackerel. Stock assessment for two species is depicted in Figure 92(left). The mackerel stock measured two million tons in 2006, but had in 2015 grown 3.6 million tons. The herring stock also grew in the first half of the period under study, from 2.1 million tons in 2006 to 2.8 million tons in 2012, but has since declined.

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In Figure 92 (right), the stocks of the main pelagic species have been combined to form a single composite stock measure of biological capital, which is then compared to total catches of these same species. Although the level of the two time-series is different, with the aggregate stock measured in million tons and catches in thousand

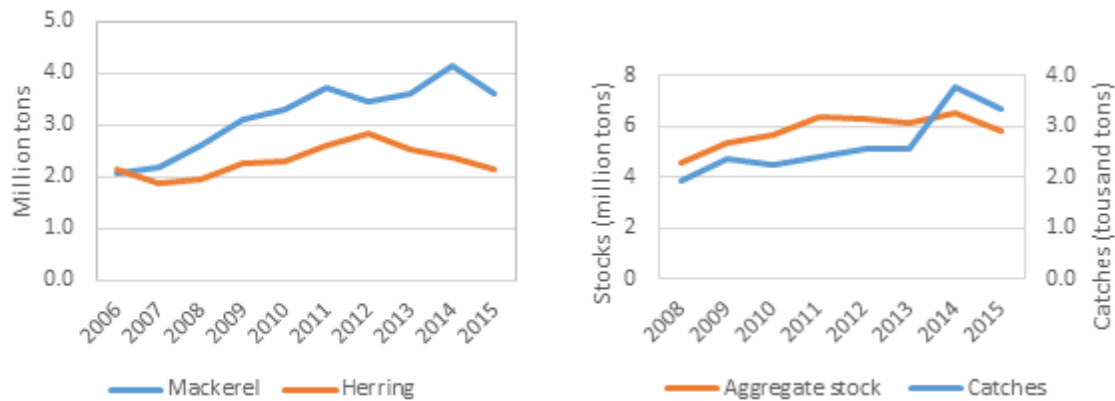*Figure 92 Stock assessment of two pelagic species 2006-2015 (left) & biological capital (sum of SSB) and the UK catches of the two pelagic species 2008-2015 (right).*

Productivity calculations

Productivity of the UK pelagic fleet was estimated for the period 2008-2014. Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported inTable 19. Landings increased on average by almost 11.1% per year and stocks by 6.2%, while labour decreased by 7%. Changes in capital were marginal. Of special interest is the high variability in labour, as revealed by a standard deviation of 32.7%. On average, the share of labour in value-added amounted to 60%.

Table 19 Average growth rates and standard deviation of landings, capital, labour and in the UK pelagic fisheries 2009-2014. Percentages.

	Mean	Standard deviation
Landings	11.1	16.1
Capital	-0.1	9.3
Labour	-7.0	32.7
Stocks	6.0	7.2

In Figure 93, the development of the four components of productivity is examined in more detail. During the period under study, UK pelagic catches have varied considerably between years, but landings have though not changed as much between years as in pelagic fisheries in some other countries. Catches increased by 20.3% in 2009 – mainly because of larger mackerel landings – and by almost 39% in 2014, mostly due to mackerel catches increasing from 160 to 280 thousand tonnes. The

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number of fishermen has declined from 450 in 2009 to 362 in 2014, although the number of vessels has hardly changed at all.
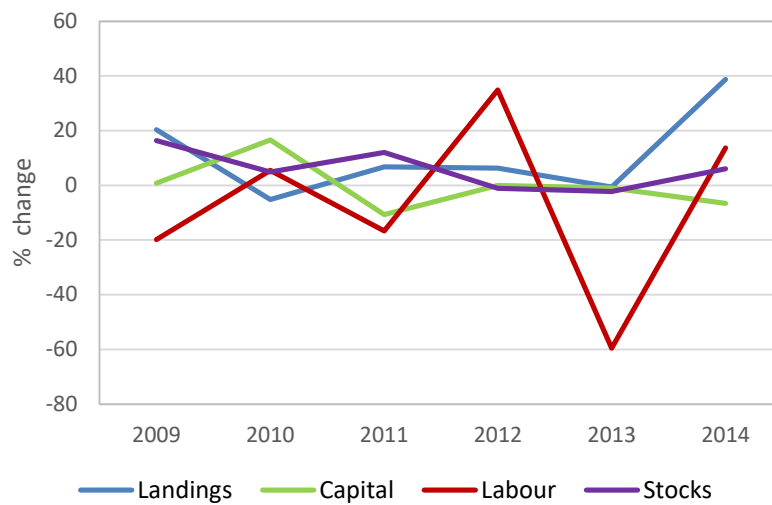

Figure 93 Percentage changes in landings, labour, capital and stocks in the UK pelagic fisheries 2009-2014.

Although, the large pelagic trawlers and purse seiners target herring and mackerel they also catch a multitude of other species. During the years 2009-2014, catches of herring and mackerel constituted on average 84% of catches by volume. In the calculations of productivity the use of the two control inputs – capital and labour – is therefore adjusted by the share of landings of these species in total landings.

On average, productivity increased by 14.7% per year over the period 2009-2014. Most of this growth can be traced to increases in landings, but reductions in fleet and employment also had a positive effect on productivity.

Table 20 Decomposition of average productivity change in the UK pelagic fisheries 2009-2014.

Landings	11.1
Capital and labour	4.2
Stocks	-0.6
Productivity	14.7

Figure 94 outlines in more detail the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals the large fluctuations observed in productivity of the UK pelagic fleet. The year-to-year changes are never smaller than 14%, with productivity increases of 30% or higher observed for three out of the six years. Changes in landings are the main reason for the high productivity observed in 2009 and 2014,

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while changes in fleet capacity and employment are the main explanations for the development of productivity observed in the four other years.
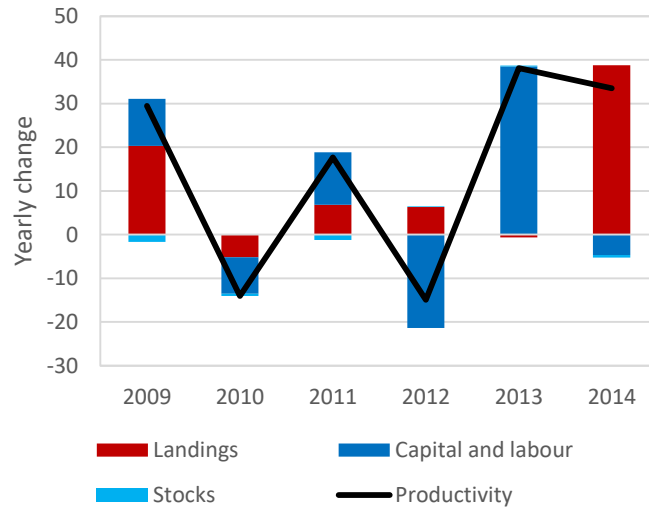

Figure 94 Decomposition of changes in the productivity of the UK pelagic fisheries 2009-2014.

Pelagic fisheries in Norway

Introduction

The Norwegian fishing fleet can be differentiated into a number of segments based on their fishing licenses, fishing gear and vessel size. License and associated quota share determines the annual fishing quotas along with the annual TAC for individual species. Roughly the fleet can be segmented as shown in Table 21.

Pelagic species are targeted by three main vessel groups; smaller coastal vessels employing a variety of fishing gears, large vessels using purse seine often in combination with trawl and large trawlers. In the coastal group a considerable share of the vessels combine both pelagic and demersal fisheries.

Table 21 Main segments of the Norwegian fishing fleet.

Demersal – coastal vessels, 0 – 500 cu. m cargo hold
Demersal – ocean-going longliners
Demersal – ocean-going trawl
Pelagic – coastal vessels, 0-500 cu cargo hold
Pelagic – ocean-going purse seine/trawl
Pelagic – ocean-going trawl
Combination demersal /pelagic – coastal vessels 0-500 cu cargo hold

Vessels and catches

The only Norwegian vessel group that is selected for the pelagic study the pelagic stocks is the combined purse seine/trawlers which mainly target herring, mackerel, blue whiting and capelin. This fleet segment included 80 vessels in 2014, but in 2001 the vessels numbered 95. The vessels have, however, been becoming larger and more powerful. In 2001, the average vessel measured 59 meters long, but in 2014 the average length was 66 meters. Average engine size has increased from 3500 kW to 500 kW over the same period.
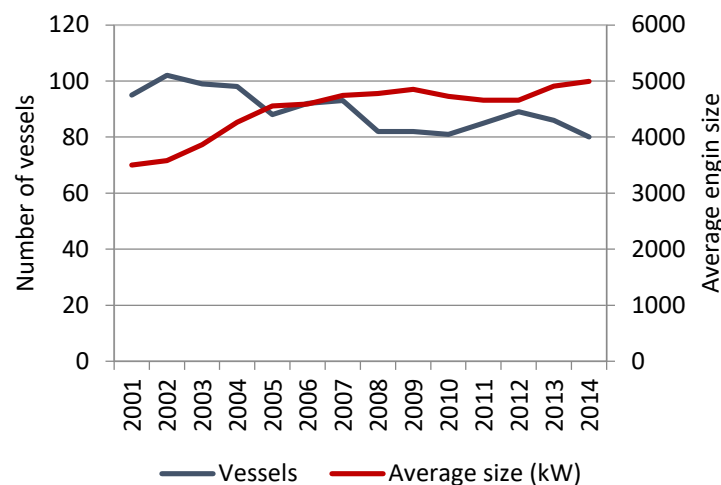

Figure 95 Number of vessels in the Norwegian pelagic fleet and average engine size.

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This development in the number of vessels and vessel size, has led to increased harvesting capacity of the Norwegian pelagic fleet, which has grown by 35% over the study period. Most of this increase occurred in the 2001-2004, but since then fleet capacity has remained relatively constant.
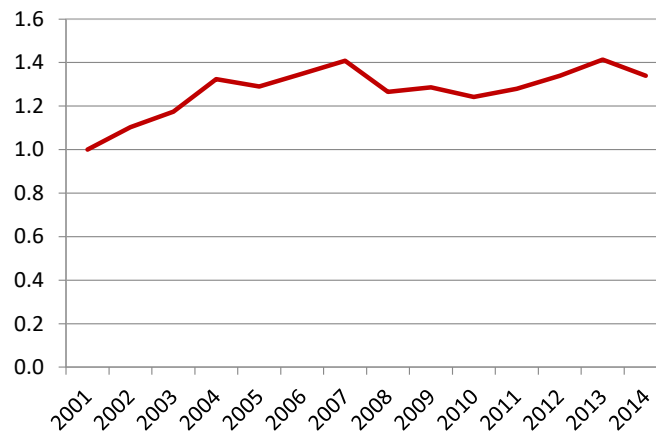
Figure 96 Capacity index of the Norwegian pelagic fleet 2001-2014.

As shown in Figure 97, herring catches have hovered between 300 and 500 thousand tons, but have in recent years been close to 200 thousand tons. While mackerel catches have been 100-200 thousand tons per year, catches of capelin have varied between 430 thousand tons in 2002 and 2 thousand tons in 2006. Catches of blue whiting and other pelagic species peaked at 850 thousand tons in 2004, but were below 100 thousand tons in 2011. In recent years these catches have rebounded to 400 thousand tons.

Figure 97 Catches of the main species exploited by the Norwegian pelagic fleet 2001-2014.

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The number of fishermen employed by the fleet segment has declined; both because there are now fewer active vessels, but also because average crew size has been reduced. In 2001, the vessels had on average a crew of almost 16, but in 2014 average crew size was down to 14.4. Consequently, the number of fishermen has shrunk from 1500 to 1150.
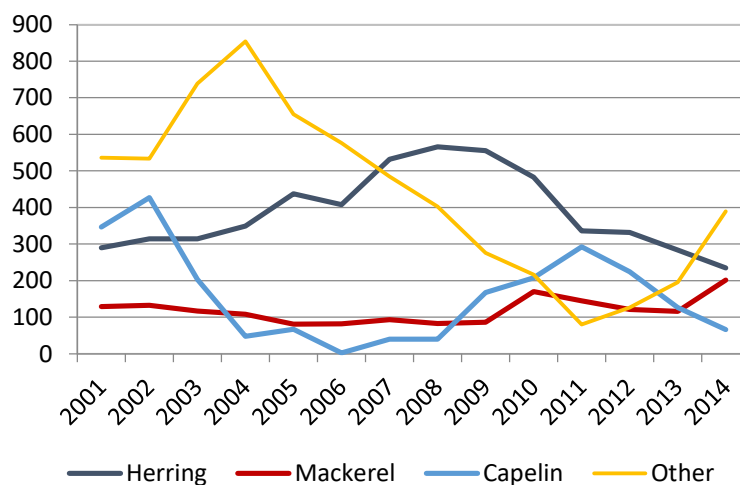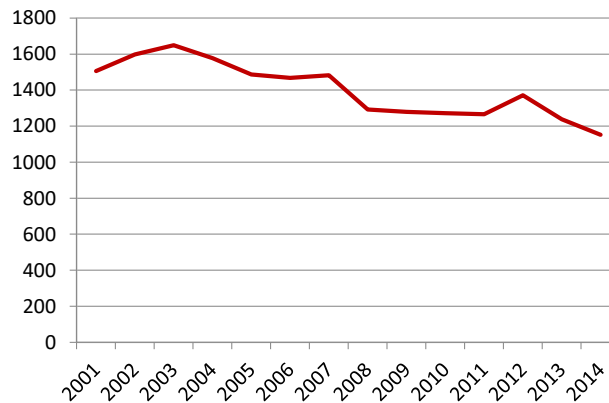

Figure 98 Number of fishermen employed by the Norwegian pelagic fleet 2001-2014.

Pelagic stock development

Herring, mackerel and blue whiting are the key species caught by the purse seiner/trawlers, both in terms of value and quantity. There are a number of herring stocks caught by the purse seiners, with the major being spring spawning herring and North Sea herring. Here we have focused only on the former. The development in these stocks are shown in Figure 99. The Norwegian herring stock and the arctic capelin stock have declined in recent years, but the fall in the stock of blue whiting appear to have halted. The mackerel stock has doubled in size in the last eight years and is now up to 4 million tons.
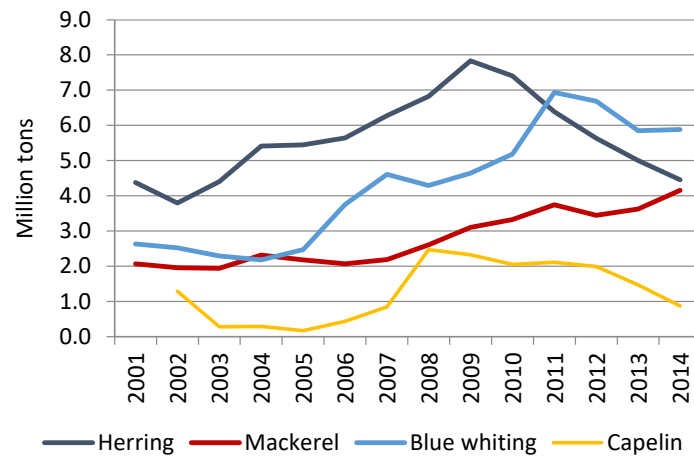
Figure 99 Spawning stocks of herring, mackerel and blue whiting 2001-2014. Million tons.

Productivity calculations

Productivity growth of the Norwegian pelagic fleet was estimated for the period 2002-2014. Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 22. Landings decreased on average by 1.7% per year, but stocks increased by 4%. Capital, as measured by the capacity index, increased by 2.2% but labour decreased by 2%.

Table 22 Percentage changes in landings, labour, capital and stocks in the Norwegian pelagic fisheries 2002-2014.

	Mean	Standard deviation
Landings	-1.7	10.3
Capital	2.2	6.3
Labour	-2.1	6.1
Stocks	4.0	9.4

In Figure 100, the development of the four components of productivity are examined in more detail. During the period under study, Norwegian pelagic catches and the aggregate stock input have varied considerably between years, but changes in capital and labour have been more modest.

Figure 100 Percentage changes in landings, labour, capital and stocks in the Norwegian pelagic fisheries 2002-2014.

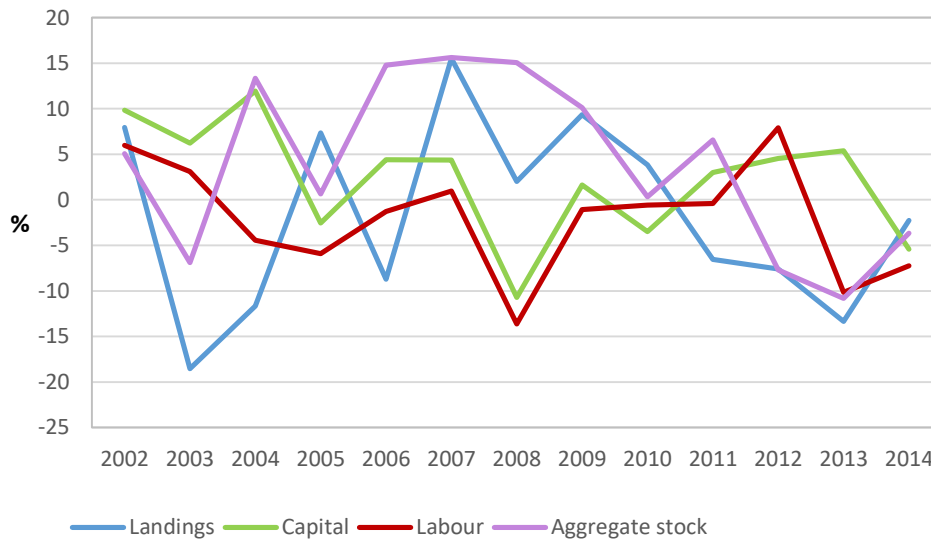During the period 2002-2014, productivity in the Norwegian pelagic fisheries declined on average by 2.5% between years. This drop in productivity is mainly explained by decreases in landings, but increased fleet capacity and larger stocks also contributed to this development. As shown in Table 23, the productivity decline has been similar in both 2002-2008 and 2009-2014. However, whereas the productivity decline in the first period could be traced to smaller landings, larger fleet capacity and larger stocks, the productivity decline in the second period could entirely be attributed to lower catches.

Table 23 Decomposition of average productivity change in the Norwegian pelagic fisheries 2002-2014.

	2002-2014	2002-2008	2009-2014
Landings	-1.7	-0.9	-2.8
Capital and labour	-0.3	-0.8	0.3
Stocks	-0.4	-0.8	0.1
Productivity	-2.5	-2.5	-2.4

Figure 101 outlines in more detail the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals the large fluctuations observed in productivity of the Norwegian pelagic fleet during the period 2003-2008 and the dominant role played by changes in landings in this development. Indeed, changes in landings are the main reason for the variations in productivity growth observed. It is only in a single year, 2008, that other factors than landings – in this case fleet capacity – have a larger impact on productivity than changes in catches.
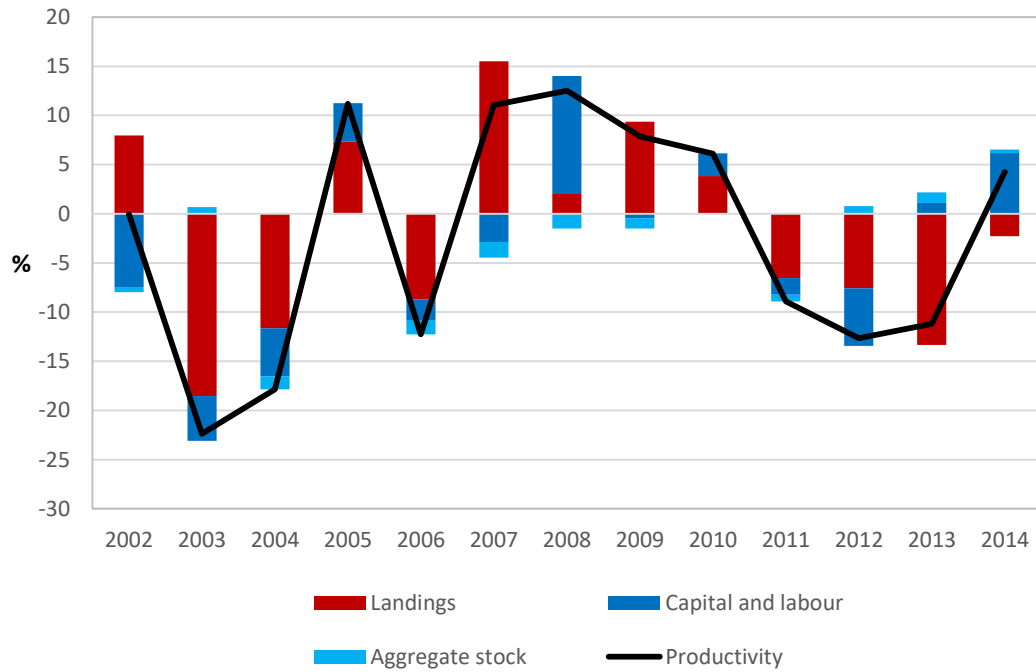
Figure 101 Decomposition of changes in the productivity of the Norwegian pelagic fisheries 2002-2014.

Pelagic fisheries in Iceland

Data used in study

The data used in the Icelandic case study cover the period 2002-2014, although observations on some variables were also available for 2015, and come from the Marine Research Institute (MRI), the Directory of Fisheries (DoF), Statistics Iceland (SI), Icelandic Transport Authority (ICA) and the International Council for the Exploration of the Sea (ICES). In what follows the data used are examined in more detail.

Vessels and landings

In this study distinction is made between two gear types; purse seine and pelagic trawl and the analysis based on the productivity of vessels employing this gear for harvesting the four main pelagic species; capelin, herring, mackerel and blue whiting. It should be noted, that in many cases the same vessel may apply both type of gear during the same year.

From 2002 the number of vessels employing this gear has increased, especially since 2009. The number of active vessels in the two main gear-categories for pelagic fisheries is plotted in Figure 102. The number of seiners has been decreasing slightly throughout the period. However, the number of pelagic trawlers has been increasing since 2009 following increases in trawlers catches of mackerel and capelin.
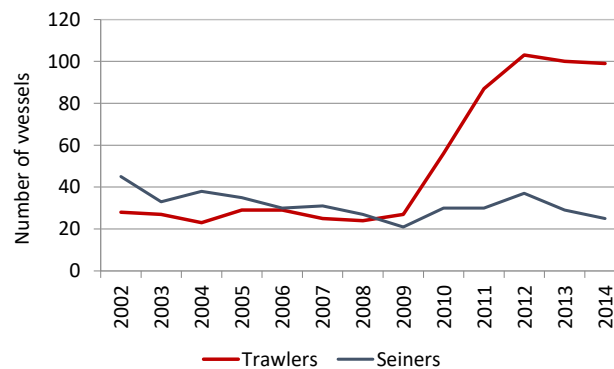

Figure 102 Number of boats in each fleet segment 2002-2014.

Catches of the four demersal species of each fleet segment have, on the other hand, been decreasing since 2002 (see Figure 103). In 2015, trawlers caught 49% of the pelagic species while seiners caught 51%. The pelagic catches have been shared fairly equally between the two gear-categories since 2002.
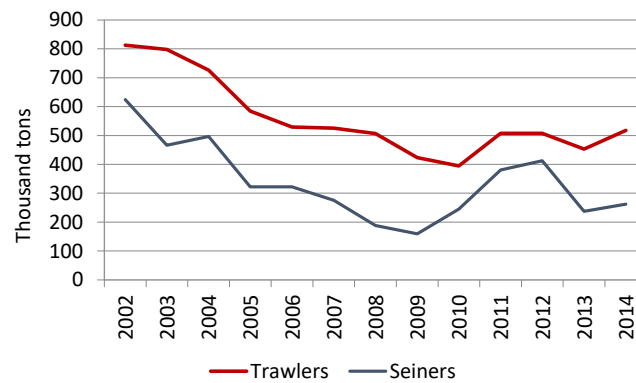
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Figure 103 Landed weight by fleet segments 2002-2014.

For the pelagic case, the catches fluctuate considerably, it is therefore important to look at catches by species. Figure 104 depicts pelagic catches by species. In the beginning of the period catches of capelin and blue whiting fell sharply and catches of these two species have in recent years been much lower than a decade ago. Herring catches have been reasonably stable. In recent years, the Atlantic mackerel has ventured further years and has been found in great quantities in both Icelandic and Faroese jurisdiction. The arrival of the mackerel prompted many vessel owners to engage in the pelagic fishery. The increase in the number of trawlers observed above can largely be traced to the arrival of the mackerel on the Icelandic pelagic scene.
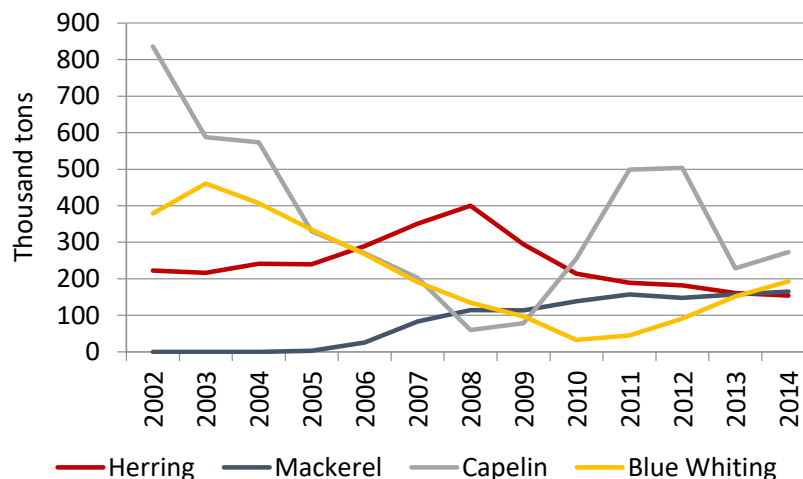

Figure 104 Pelagic catches by species 2002-2014.

On average, trawlers have become shorter but seiners larger. In 2015 the pelagic trawlers measured 53.5 meters on average, and seiners 59 meters. Seiners have also become more powerful, while the average pelagic trawler was in 2014 equipped with a less powerful engine than in 2002 (Figure 105).
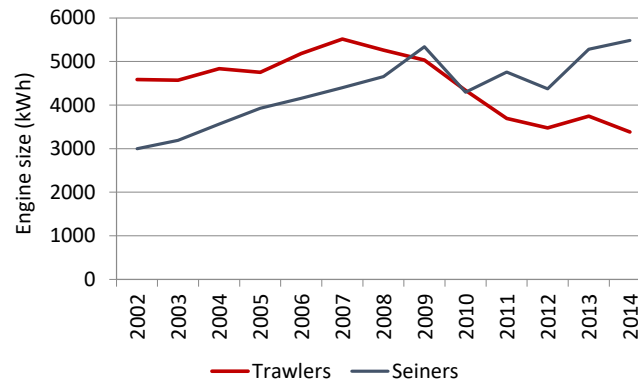
Figure 105 Average horsepower (kWh) of the Icelandic pelagic fleet 2002-2014.

The capacity of the pelagic fleet is measured as the product of the engine size (measured in horsepower) and length of each vessel and this then aggregated across all vessels for a measure of the capacity of individual fleet segments and the fleet as a whole. As shown in Figure 106, the capacity of the fleet closely follows the number of active boats in each fleet segment.
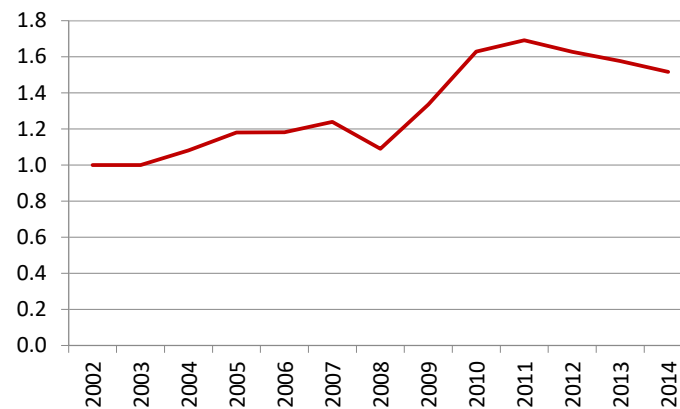
Figure 106 Capacity of the Icelandic pelagic fleet 2002-2014.

Labour

Here it is assumed that the crew size of vessels operating different gear has remained the same throughout the study period, and the labour employed by different fleet segments may therefore be simply calculated as the product of the number of vessels in each segment and crew size. Ad hoc, it is assumed that each pelagic trawler has a crew of 12 and purse seiners a crew of 8.

The pelagic fisheries now employ more fishermen than a decade ago. Using the ad hoc method described above and taking into consideration the fact that the same vessel may both employ purse seine and pelagic trawl, it is estimated that he fleet employed 400 fishermen in 2002, 1200 in 2012

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and 900 in 2015. As expected and shown in Figure 107, the development of the number of fishermen is closely linked to the development of the number of vessels in the fleet. The sharp increase in active vessels and fishermen employed is largely due to the increased number of vessels and fishermen employed on trawlers.

Figure 107 Number of fisherman employed and active vessels in pelagic fisheries 2002 – 2014.

Information on the capital and labour shares of value added are taken from the financial accounts of the fisheries compiled by SI. These are available for various vessel categories, i.e. fresh fish trawlers and freezing trawlers and pelagic freezing trawlers as well as boats smaller than 10 GRT, boats 10-200 GRT and larg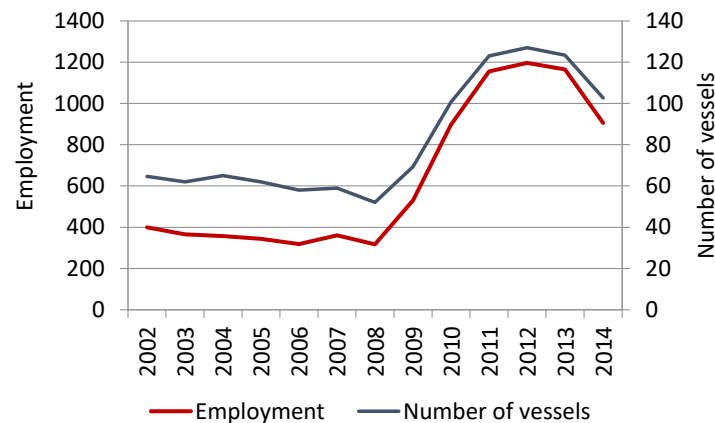er boats. These categories do, however, only partially correspond to the vessel categories employed in this study. Consequently, it was decided to only use the capital and labour shares for the fisheries as a whole.

Stocks

The development of the stocks of the main pelagic species is shown in Figure 108. The spawning stock of the Icelandic herring grew from around 300 thousand tons in the beginning of the study period to around 750 thousand tons in 2006-2008. In the ensuing years, the stock declined rapidly until 2011 due to mortality caused by Ichthyophonus infection. Continued reduction in the size of the SSB in recent years is due to a declining trend in recruitment. Fishing mortality was low during the first years of the infection period, but has since increased. The capelin stock has remained rather stable around 400 thousand tons in recent years. The mackerel stock found in the Northeast Atlantic has doubled in size in recent years, from around 2 million tons in the first half of the period to about 3.6 million tons, while the blue whiting stock has decreased from around 6 million tons in 2007 to 3.4 million tons over the same period. The stock of the Norwegian spring-spawning herring catches peaked at just under 8 million tons in 2011, but was in 2014 down to 5.6 million tons.
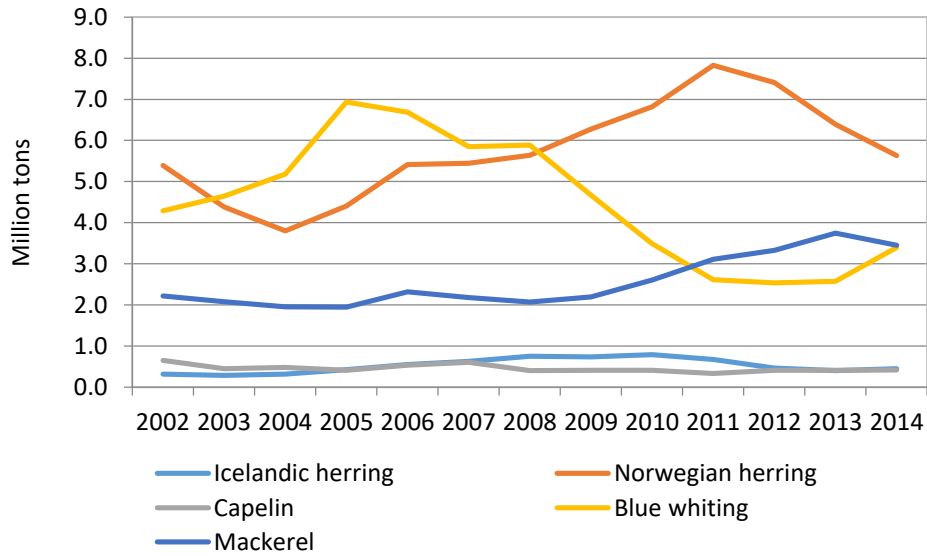
Figure 108 Stocks of main pelagic species 2002-2014.

Figure 109 shows the development of combined stock size and landings of the four demersal species (but five stocks) included in the study. The combined stock size of these species is used a proxy for the biological capital employed by the pelagic fisheries. The composite stock has hovered between 12.0 and 14 million tons for most of the years included in the study.
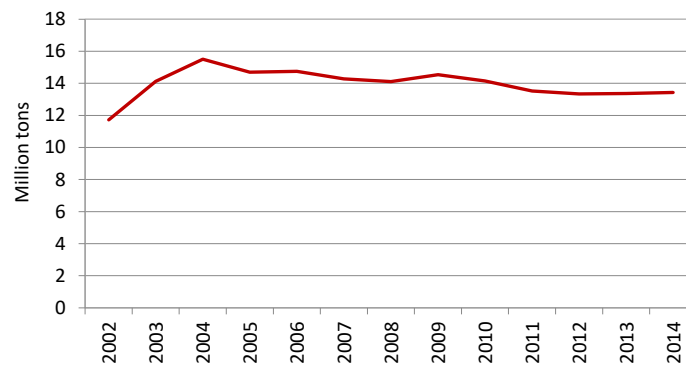
Figure 109 Composite pelagic stock 2002-2014.

Productivity calculations

Productivity growth of the Icelandic pelagic fleet was estimated for the period 32014 using the data outlined above. Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 24. Landings declined on average by 5% per year but varied a great deal between years as witnessed by a standard deviation of48.4%! Average growth of the aggregated stock amounted to 0.6%, capital grew by 4.3% and labour by 5.8%. All time series show considerable fluctuations, as the high standard deviations indicate. The variations in landings and stocks are due to the well-known fluctuations in pelagic stocks, but the large variability of the control inputs capital and labour is mainly explained by large annual variations in the number of vessels

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employing pelagic trawls in the sample and the associated changes in employment. Thus, the number of pelagic trawlers was only 27 in 2009, but had increased to 56 the following year, to 87 in 2011 and 103 in 2012. In 2014 a total of 99 vessels employing pelagic trawls registered catches. The

Table 24 Average growth rates and standard deviation of landings, capital, labour and stocks, and capital-, labour- and landing-shares in the Icelandic pelagic fisheries 2003-2014. Percentages.

	Mean	Standard deviation
Landings	-5.1	17.8
Capital	3.5	9.7
Labour	6.8	24.5
Stocks	1.1	6.7

In Figure 110, the development of the four components of productivity is examined in more detail. During the period under study, Icelandic pelagic catches have varied greatly between years. Icelandic vessels registered hardly any mackerel catches in 2002-2006, but catches in 2014-2015 were around 160 thousand tons, catches of blue whiting have decreased from 400 thousand tons at the beginning of the period to around 200 thousand tons, and capelin catches during the period have varied between 60 thousand tons in 2008 to over a 835 thousand tons in 2002. Catches of herring have, varied between 150-400 thousand tons. There is a significant positive correlation between landings on the one hand and capital and labour on the other hand, but the relationship between landings and stocks is weak. A very strong positive correlation exists between capital and labour, which is hardly surprising given the ad-hoc way used to calculate employment. Finally, there is a significant negative correlation between stocks and capital and labour.
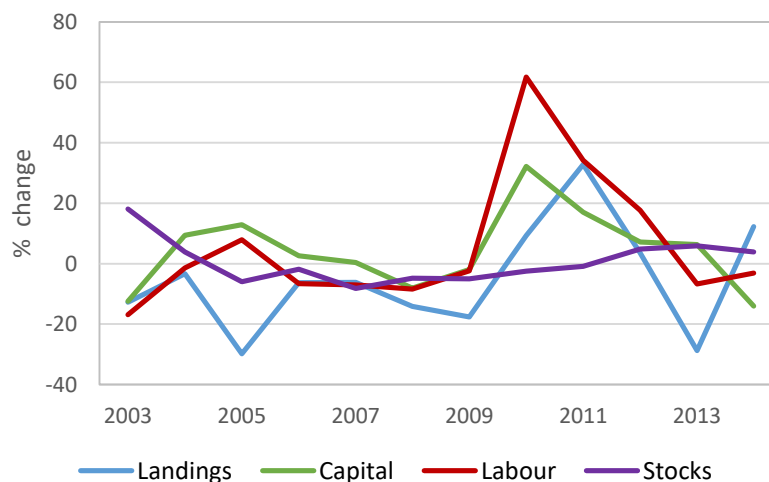
Figure 110 Percentage changes in the landings, labour, capital and stocks in the Icelandic pelagic fisheries, 2003-2013.

On average, productivity declined by 10% in the Icelandic pelagic fisheries during 2003-2014. Decreased landings retarded productivity growth on average by 5%, while the negative impact on productivity growth of increases in capital and labour amounted to 5%. Changes in stocks only had a marginal impact on productivity growth. In Table 25, the productivity growth is also compared across two periods; 2003-2008 and 2009-2014. The productivity decline is exactly the same in both periods, but the reasons for this poor performance differ substantially. Whereas lower landings are the main reason for the poor performance in 2003-2008, the productivity decline in 2009-2014 can mostly be attributed to increases in capital and labour.

Table 25 Decomposition of average productivity change in the Icelandic pelagic fisheries 2003-2014 Percentages.

	2003-2014	2003-2008	2009-2014
Landings	-5.1	-12.1	1.9
Capital and labour	-5.2	2.0	-12.5
Stocks	-0.1	-0.3	0.1
Productivity	-10.4	-10.4	-10.4

Figure 111 outlines in more detail the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals the dominant effect that landings have had on productivity. The productivity slumps in 2005 and 2013 can thus be almost entirely attributed to a decline in catches, in particular capelin, while the productivity decline in 2010 was mostly caused by increases in fleet capacity and labour.

As noted above the composite stock has remained relatively stable over the study period, with average changes only amounting to 6.7%. Indeed, changes between years only exceed 10% in three years, – 2008-2010 – whereas changes in landings exceed 10% in seven out of the 12 years covered by the study period.
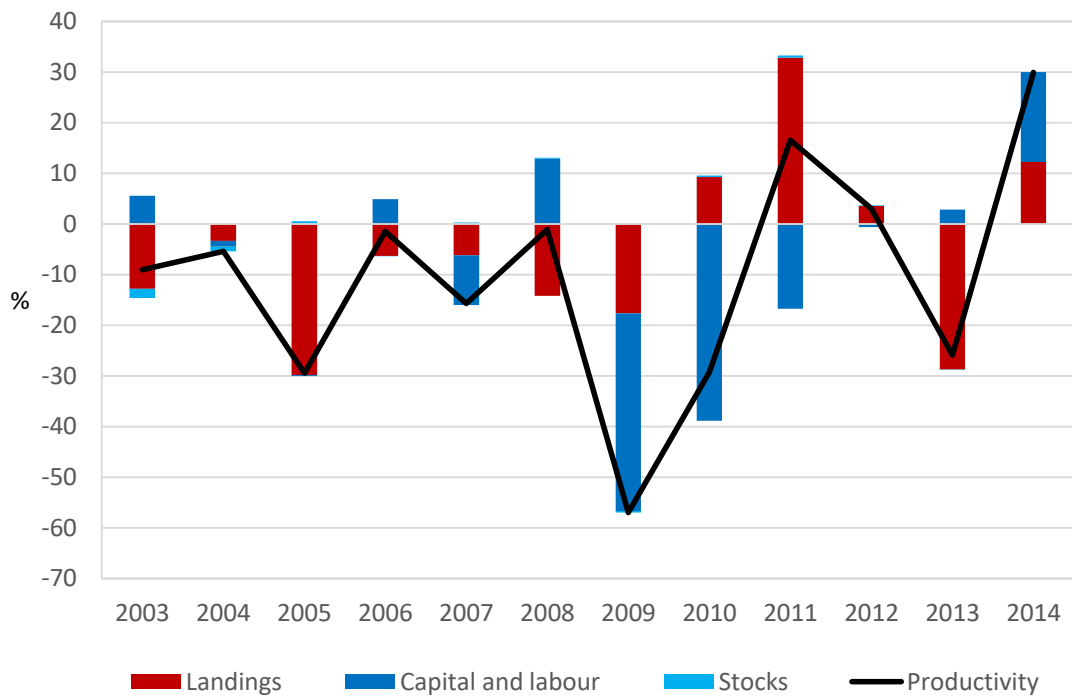
Figure 111 Decomposition of changes in the productivity of the Icelandic pelagic fisheries 2003-2014.

Pelagic fisheries in the Faroe Islands

Vessels and catches

The total number of vessels in the Faroese pelagic fisheries has been rather stable since 1994, with about 11 pelagic vessels active throughout the period. However, the development has been different between fleet segments. The Faroese pelagic fleet counted 12 vessels in 1993; five purse seiners and seven pelagic trawlers, also referred to as industrial trawlers. In 2014, the fleet included nine purse seiners and three trawlers, as well as two demersal trawlers that were harvesting mackerel.
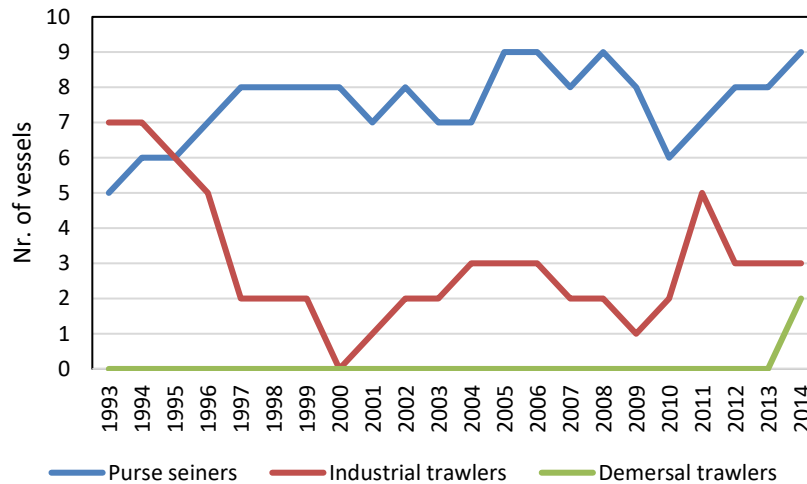
Figure 112 Number of boats in each fleet segment 1993-2014.

Blue whiting, herring and mackerel are the most important species caught by the pelagic fleet. In 2014, catches of these three species made up 83% of total pelagic landings. As Figure 113 indicates, catches of the pelagic species vary tremendously from year to year. While blue whiting catches usually make up the lions' share of the total pelagic catches, these do fluctuate a great deal and have in recent years sometimes been lower than catches of herring and mackerel.

Figure 113 Landed weight of mackerel, herring and blue whiting (left) and the share of each of these three species (right) 1993-2014.

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The capacity index for the Faroese pelagic fleet is based only on data on the total gross tonnage of each fleet segment. As shown in Figure 114, vessels have on average been getting larger having direct effect on the increase in the value of the fleet.
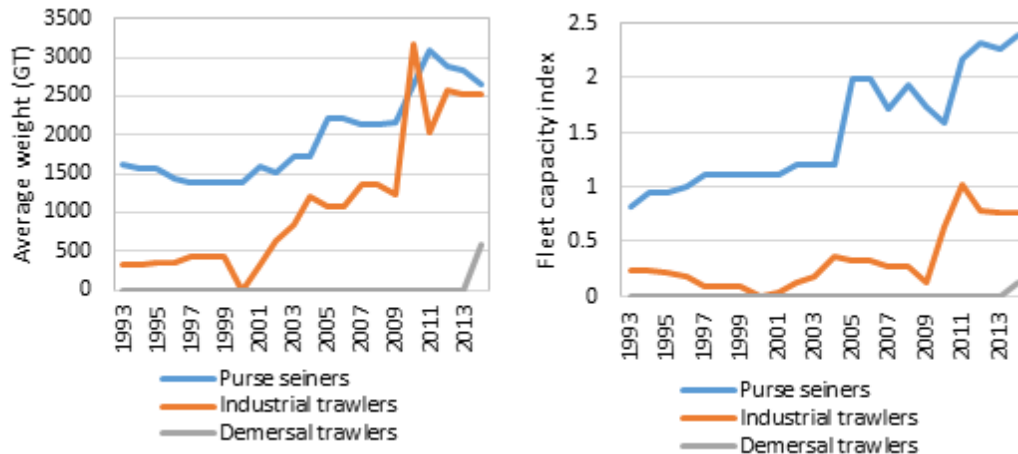
Figure 114 Average weight (GT) by fleet segment (left) and capacity index of the Faroese pelagic fleet 1993-2014.

Labour

The number of fishermen employed by the pelagic fleet has risen from 102 in 1993 to 176 in 2014. Both purse seiners and industrial trawlers have contributed to this increase in employment, see Figure 115. On average, there have been 13 seamen in the crew of the purse seiners, eight on industrial trawlers and 15 on demersal trawlers.
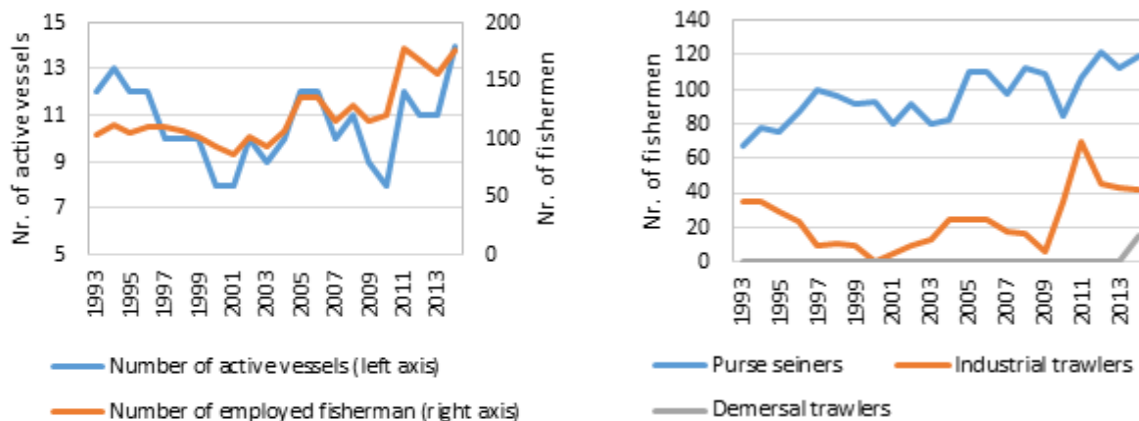
Figure 115 Number of fishermen employed and active vessels in pelagic fisheries (left) and number of fishermen employed by fleet segments (right) 1993 – 2014

Stocks

No stock assessments have been undertaken on pelagic stocks within Faroe Islands jurisdiction, but ICES regards the stocks around the islands as parts of larger stocks in the Northeast Atlantic. Figure

116 plots the spawning stock biomass for mackerel, herring and blue whiting during the period 1993-2014. As can be seen, fluctuations have been much greater for the herring and blue whiting stock than for mackerel. In recent years, herring has been decreasing while the other two stocks are growing. In the right panel of Figure 116, the stocks of these three main pelagic species have been combined to form a single composite stock measure of biological capital, which is then compared to total catches of these same species. While Faroese catches from these three major stocks have only averaged 80 thousand tons, the aggregate stock has fluctuated in size from 9 million tons in 1993 to 12.6 million tons in 2014. Faroese catches have therefore only been a fraction of the composite stocks.
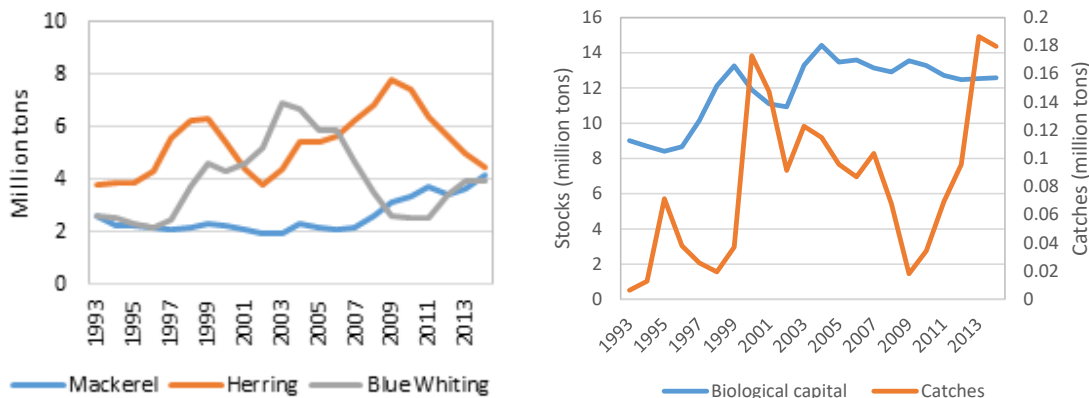
*Figure 116 Stock assessment of mackerel, herring and blue whiting (left) and biological stock and landed weight (right) 1993 – 2014.*

Productivity calculations

The data used for productivity analysis of the Faroese pelagic fisheries cover the period 2001-2014. Average annual growth and standard deviations of landings, capital, labour and aggregated stocks are reported in Table 26. Landings grew on average by 1.5% per year but with tremendous variations between years as witnessed by a standard deviation of 55.8%! Average growth of the aggregated stock amounted to 2.6%, capital grew by 8.1% and labour by 5.6%. All time series show considerable fluctuations, as the high standard deviations indicate. The variations in landings and catches are due to the well-known fluctuations in pelagic stocks, but the large variability of the input controls is explained by the fact that the pelagic fleet only counts relatively few vessels. The data at hand only have demersal trawlers taking part in the pelagic fisheries in a single year – 2014 – while the number of purse seiners varies between 7 and 9 and the number of small industrial trawlers between 1 and 5. The capacity index and number of employees can thus change considerably if the total number of vessels in the fleet only changes by one or two boats.

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This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 635761

Table 26 Average growth rates and standard deviation of landings, capital, labour and stocks in the Faroese pelagic fisheries 2002 – 2014. Percentages.

	Mean	Standard deviation
Landings	1.5	55.8
Capital	8.1	16.7
Labour	5.6	15.8
Stocks	2.6	13.2

In Figure 117, the development of the four components of productivity is examined in more detail. As shown, all time-series show relative little fluctuations in the first half of the period under study, but the second half is characterised by much more instability, especially as regards to landings. Thus, while landings of herring, mackerel and blue whiting were 90-123 thousand tons in 2002-2007, they tumbled from 103 thousand tons in 2007 to 66 thousand tons the following year and to 14 thousand tons in 2009. After remaining relatively stable the next few years, catches then increased from 34 thousand tons in 2012 to 65 thousand tons the following year, before falling again to 15 thousand tons in 2014.
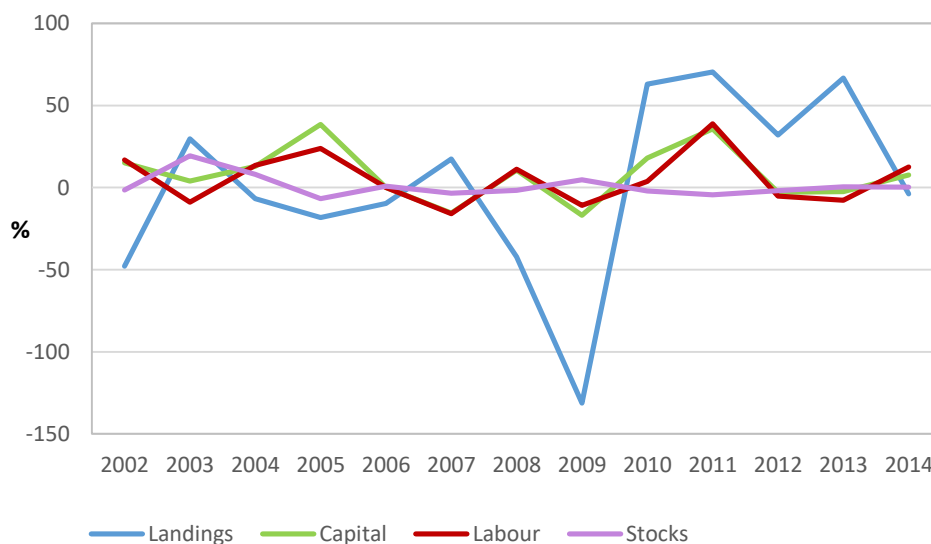
Figure 117 Percentage changes in the landings, labour, capital and stocks in the Faroese pelagic fisheries 2002 – 2014.

On average, productivity declined by 5.3% in the Faroese pelagic fisheries during 2002-2014. Increased landings contributed on average 1.5% to productivity growth, but changes in capital and labour had a negative effect on productivity. As noted above, the capacity index grew on average by 8.1% between years and labour by 5.6%. The increase in usage of these two control inputs was far greater than the average increase in landings thus reducing productivity growth. Overall, stocks played a marginal role. In Table 27, the productivity growth is also compared across two periods; 2002-2007 and 2008-2014. The productivity decline was especially severe in the first period, when productivity fell on average by almost 13% between years, but the second period witnessed a slight growth.

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Table 27 Decomposition of average productivity change in Faroese pelagic fisheries 2002 – 2014. Percentages.

	2002-2014	2002-2007	2008-2014
Landings	1.5	-5.9	7.8
Capital and labour	-6.6	-6.4	-6.7
Stocks	0.1	0.3	-0.1
Productivity	-5.1	-12.6	1.2

Figure 118 outlines in more detail the development of productivity and its components. While the black line traces out productivity developments, red shows changes in landings, dark blue changes in the capital and labour employed and light blue changes in the aggregate stock. The figure clearly reveals the dominant effect that landings have had on productivity. It is only in 2004, 2005 and 2014 that changes in capital, labour and stocks have a larger impact on productivity.
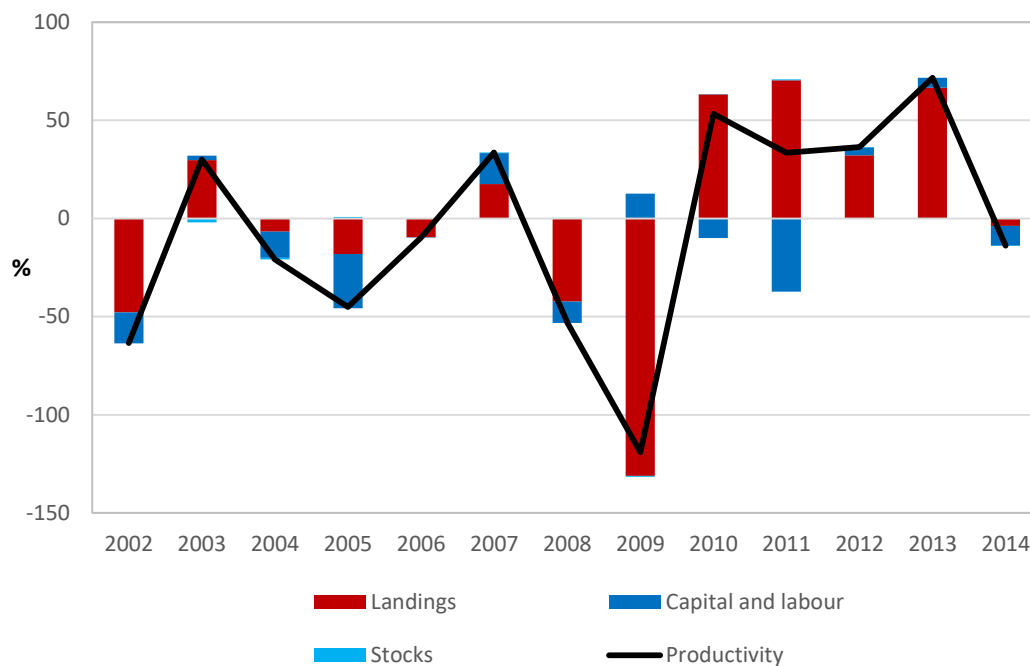

Figure 118 Decomposition of changes in the productivity of the Faroese pelagic fisheries 2002 – 2014.

Discussion

In this section the results from the productivity analysis above are compared and analysed. In Table 28 presents comparison of productivity growth in the demersal fisheries in the UK, Spain, Norway, Iceland and the Faroe Islands. For the UK and Norway, the comparison includes trawlers, netters and longliners, for the Faroe Islands both trawlers and longliners are included, but only trawlers for the Spanish NAFO fishery. The Icelandic case includes trawlers, netters, longliners and small boats that may only include handline or longline. The period for which data are available also differs between the cases, from only six years for the UK demersal fisheries and up to 21 years in the Faroese case.

On average landings increased by 1.3% between years, with the strongest average increase observed in Norway and the UK, 5.5% and 3.8%. Landings of the six species included in the Icelandic demersal fisheries increased on average by 0.6%, while landings decreased in the Faroe Islands by 0.5% Catches by the Spanish NAFO fleet contracted on average by 3.2%. The column marked capital and labour shows the contribution of changes in the use of these inputs on productivity. A plus sign thus indicates that the use of these two control inputs was decreasing, leading to a positive effect on productivity growth, while a negative signs implies that the use of capital and labour increased, retarding productivity growth. Declining levels of capital and labour have in all five cases had a positive impact on productivity in the demersal fisheries.

In this analysis stocks are treated similar to other inputs use in fisheries. Increasing stocks will therefore have a negative short-run impact on productivity, while decreasing stocks will stimulate productivity growth. In the short-run, fishing down stocks may therefore be a viable policy. A plus sign in the column marked stock indicates that the aggregate demersal stock was declining, and thus having a positive effect on productivity, but a positive sign indicates that stock was growing, reducing productivity growth. On average, the demersal stocks utilised by the fleets have been growing, indeed, it is only in the case of the Faroe Islands that the main demersal stocks have been declining slightly.

The last two columns of Table 28 show two slightly different measures of productivity. The column with the heading 3-factor productivity (3FP) shows average productivity when the effects of changes of stocks on productivity is also taken into account, which is the method that has been used for all the case studies in this deliverable. As discussed by Arnason (2003), this approach allows for a more comprehensive assessment of the development of productivity, as it includes both the effects of changes in inputs over which the harvester has some direct control – capital and labour – as well as changes in inputs that are mostly outside the control of the harvester, the biological capital or aggregate stock. The column furthest to the right shows calculations of productivity that are only based on landings and the control inputs, capital and labour. This is called 2-factor productivity (2FP). The state of the aggregate stock does here not impact on productivity.

On average productivity growth, measured as 3FP, declined in these five case studies by 1.2% per year. This average does, however, camouflage the fact that productivity grew in both the UK and Faroes Islands demersal fisheries, and was stagnant in the Icelandic fisheries. By contrast, productivity declined slightly in Norway and by a whopping 8.1% in Spain. This poor performance can mostly be attributed to changes in the aggregate demersal stock in each fishery, as the stocks making up this aggregate have been growing faster than landings, leading to a decline in productivity. The effects of allowing for changes in aggregate stock are brought to light in the column furthest to the right in the

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table which shows the calculations of 2FP. A healthy productivity growth is now observed in the UK, Norway and Iceland, and the productivity decline in the Spanish demersal fisheries is now down to 0.4%. By contrast, this method of calculating productivity leads to a smaller productivity growth in the Faroe Islands than observed in the case of 3FP. As noted above, the main demersal stocks have been declining in the Faroe Islands, leading to higher estimates of productivity when allowance is made for the changes in stock size.

Table 28 Comparison of productivity growth in the demersal fisheries of the UK, Spain, Norway, Iceland and the Faroe Islands. Percentages.

Country	Period	Landings	Capital and labour	Stock	3-factor productivity	2-factor productivity
		(1)	(2)	(3)	(4)=(1)+(2)+(3)	(5)=(1)+(2)
UK	2009-2014	3.8	2.6	-5.2	1.2	6.4
Spain	2007-2014	-3.2	2.8	-7.6	-8.1	-0.4
Norway	2003-2014	5.5	0.4	-6.4	-0.5	5.9
Iceland	2003-2014	0.6	3.1	-3.7	0.0	3.7
Faroe Islands	1994-2014	-0.5	1.6	0.3	1.5	1.2
Average		1.3	2.1	-4.5	-1.2	3.4

In Figure 119 the development of productivity in the demersal fisheries of these five nations is analysed in more detail. Two things stand out. First, the large variability of productivity of the Spanish NAFO fleet, which fluctuates wildly between -61% in 2010 and a little over 32% in both 2008 and 2011. Second, the small fluctuations in productivity observed for both the Norwegian and Icelandic demersal fisheries. The standard deviation of productivity growth is 8.7% for the former and 7.0% for the latter, as opposed to 35% for the Spanish fisheries.
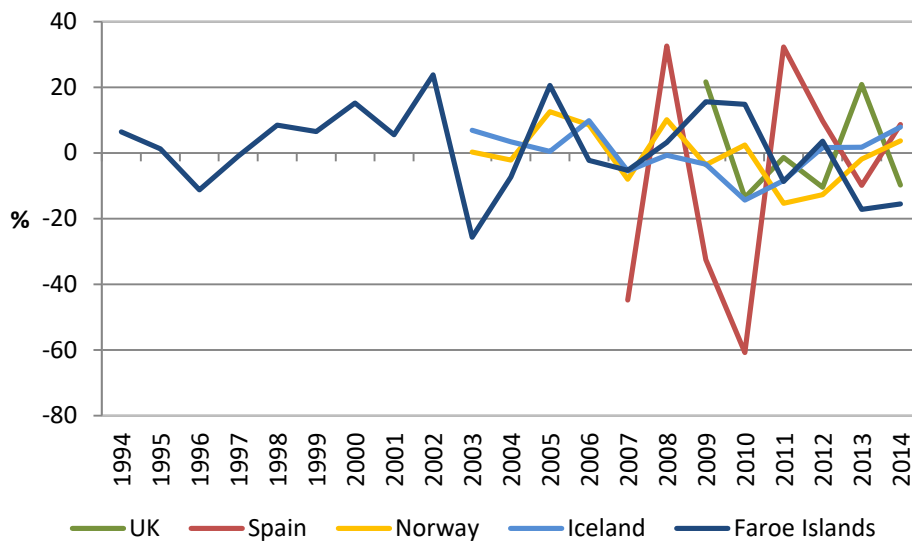
Figure 119 Development of productivity in the demersal fisheries of the UK, Spain, Norway, Iceland and the Faroe Islands. Percentages.

Turning to the pelagic fisheries, Table 29 compares the growth of productivity in the UK, Denmark, Norway, Iceland and the Faroe Islands. The length of the time-series available ranges from only five years for the Danish case to 13 years for the Faroese study. The fleets are similar in all cases, and include both purse seiners and pelagic trawlers, or vessels operating pelagic trawls.

During the period of study, landings increased on average by 11.1% and 9.6% in the UK and Denmark, only slightly in the Faroe Islands and decreased in Norway and Iceland. The use of the control inputs has decreased in the UK pelagic fisheries, mainly because of lower level of employment, but the capacity of the fleet has also diminished in recent years. The development is different in Denmark, Iceland and the Faroe Islands where the capacity of the respective fleets has grown and employment increased. In the Norwegian pelagic fisheries, the impact of changes in capital and labour on productivity is only marginal. As noted in the section of methods, the stock elasticity of output is low, or set at 0.1 in all the pelagic studies included in this deliverable. The impact of the stock input on productivity is thus minimal, but differs between countries. The pelagic stocks harvested by the UK, Norwegian, Icelandic and Faroese fleets have all grown, and this growth has hampered productivity growth, but the stocks exploited by the Danish fleet have declined, stimulating productivity growth.

As shown in the last two columns of Table 29 it does not make much difference whether productivity is measured as 3FP or 2FP, as the effects of the aggregate stock are small. Productivity has increased by around 15% in the UK pelagic fisheries and by 7.3% in the Danish fisheries, but declined in the other three countries. The decline is greatest in the Icelandic fisheries, just over 10%, 5% in the Faroese case and 2.5% in the Norwegian fisheries.

![PrimeFish logo]

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 635761

Table 29 Comparison of productivity growth in the pelagic fisheries of the UK, Denmark, Norway, Iceland and the Faroe Islands. Percentages.

Country	Period	Landings	Capital and labour	Stock	3-factor productivity	2-factor productivity
UK	2009-2014	11.1	4.2	-0.6	14.7	15.3
Denmark	2010-2014	9.6	-2.7	0.4	7.3	6.9
Norway	2002-2014	-1.7	-0.3	-0.4	-2.5	-2.1
Iceland	2003-2014	-5.1	-5.2	-0.1	-10.4	-10.3
Faroe Islands	2002-2014	1.5	-6.6	-0.1	-5.1	-5.0
Average		3.1	-2.1	-0.2	0.8	0.9

The development of productivity in the pelagic fisheries has been much more volatile than in the demersal fisheries. The variability of productivity growth, as measured by the standard deviation, ranged from 12.2% in the Norwegian fisheries (yellow line in Figure 120) to almost 55% in the Faroese fisheries (dark blue line).
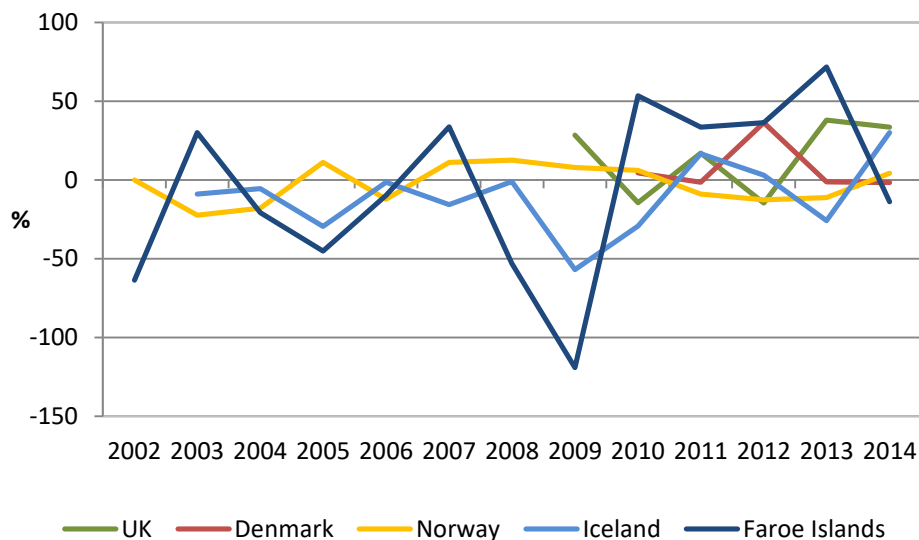

Figure 120 Development of productivity in the pelagic fisheries of the UK, Denmark, Norway, Iceland and the Faroe Islands. Percentages.

Most of this large variability in productivity can be traced to changes in landings as shown in Figure 121. The standard deviation of changes in landings is almost the same as the standard deviation of productivity growth in the Faroese, Norwegian and Danish fisheries, but slightly lower for the UK and Icelandic fisheries. Fluctuations in the level of labour and capital also explain much of the variability observed in the behaviour of productivity in the UK, Icelandic and Faroese pelagic fisheries.
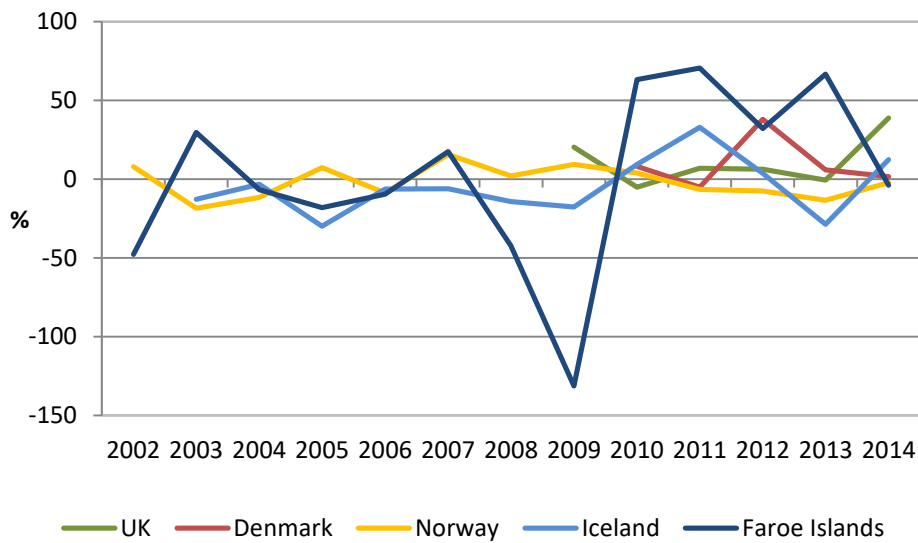
Figure 121 Changes in landings of the main pelagic species in the UK, Denmark, Norway, Iceland and the Faroe Islands. Percentages.

As noted earlier, the productivity analysis conducted in this deliverable is based on relatively sparse data. Most of the time-series are very short, in many instances only a few years, and the number of vessels engaged in the fisheries is also sometimes very small. There are, for instance, only 15-30 vessels included in the study of the pelagic fisheries in the Denmark, around 30 in the UK case and only 8-14 boats in the Faroese case study. These data limitations somewhat undermine the results obtained. When the data only span a few years, calculations of average productivity may be sensitive to drastic changes in one of the variables, for instance landings, in a single year. Longer time-series will, on the other hand, yield more robust average estimates. Likewise, changes in inputs will have relatively large impact on productivity if the fleet segment under consideration only includes a few vessels. To take an example, changes in capital and labour will have a far greater impact on productivity if a new vessel enters a fleet that already consists of 10 vessels than if the segment contains 100 vessels at the time of entry. Having better data would therefore definitely improve the reliability of these results.

Another concern is the fact that information on the number of days-at-sea was unavailable for most of the case studies. It was therefor only possible for a limited number of cases to adjust the utilisation of capital and labour by changes in the operation time of the fleet. The inability to adjust for changes at the internal margin may become especially pressing if landings change without a corresponding increase in the capacity of the fleet.

Further, it should be noted that the analysis undertaken in this deliverable does not take the value of the different species harvested into account. Thus, landings of different demersal or pelagic species are simply lumped together into a single landings variable, and stocks of different demersal or pelagic species are similarly aggregated into one composite stock. The results might have been slightly different if the aggregation of landings and stocks had been value-weighted. This is probably truer of the pelagic fisheries, as the difference in value between, for instance, herring and capelin is probably far greater than the difference in value between any of the species included in the demersal fisheries case studies.

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Conclusion

This deliverable has analysed recent productivity developments in some of the most important capture fisheries in Europe. Using data on specific fleet segments, productivity growth has been compared between the demersal fisheries in UK, Spain, Norway, Iceland and the Faroe Islands, as well as the pelagic fisheries in the UK, Denmark, Norway, Iceland and the Faroe Islands. The time period spanned by the data differs and is in some cases quite short.

Two measures of multifactor productivity have been compiled; 2-factor productivity (2-FP) which analysis how the interplay between landings on the one hand and capital and labour on the other hand, and 3-factor productivity (3-FP), which also takes into consideration the impact that changes in stock size have on productivity.

In the case of the demersal fisheries, the results obtained are quite sensitive as to which measure of productivity is used. Calculations based on 2-FP thus reveal that productivity grew on average by 3.4%, but productivity is found to have decline annually by 1.2% on average if the effects of changes in stock size are taken into account. The difference between methods of calculating productivity is not as great for the pelagic fisheries. This is mostly due to the fact that the productivity calculations do by definition not allow stocks to have as strong an impact in the pelagic fisheries as in the demersal fisheries.

Smaller fleet capacity and lower employment have had a positive effect on the productivity growth in the demersal fisheries, but growing stocks have led to deteriorating productivity. The impact of landings is mixed, but smaller landings will, *ceteris paribus*, decrease productivity and vice versa. 3-FP has on average grown by 1.5% and 1.2% in the demersal fisheries of the Faroe Islands and the UK, remained constant in the Icelandic demersal fisheries, but declined by 0.5% in the Norwegian fisheries. The performance of the Spanish NAFO fisheries has been quite poor, as productivity has decreased by 8.1% on average. This can both be attributed to growing stocks and declining landings.

Changes in productivity in the pelagic fisheries can mostly be attributed to changes in landings and changes in capital and labour, with changes in stock only having a small effect. Productivity in the UK pelagic fisheries increased on average by around 15%, with landings contributing 11% percentage points and smaller capacity and lower employment also having a positive impact. Productivity in the Danish pelagic fisheries increased on average by 7.3%, but whereas increased landings boosted productivity, increases in capacity and labour reduced productivity growth. By contrast, productivity declined in the Icelandic, Faroese and Norwegian pelagic fisheries, by 10.4%, 5.1% and 2.5% on average each year.

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