eftec

The Economic Case for Investment in Natural Capital in England:

MARINE APPENDIX

Final Report

For the Natural Capital Committee

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THE BRITISH ASSESSMENT BUREAU
ISO9001

CONTENTS

INVESTMENT CASE DEMERSAL FISH

SUMMARY

- *Demersal Fish Stocks in UK waters remain overexploited. Common Fisheries Policy targets aim to reduce fishing effort by 2015 (or 2020 latest) to levels that will allow stock recovery.*
- *The resulting foregone landings represent an ongoing short-term investment to increase stocks, generating benefits in the future.*
- *Achieving Maximum Sustainable Yield (MSY) would sustain landings above current levels, and reduce risks from stock collapse. This will benefit fishing communities and the UK economy. The potential resource rent from UK fisheries might be £573m/yr, ten times higher than currently.*

<table>
<tr><td colspan="2">Investment:
Reduction of fishing effort: bearing short-term costs of foregone landings to allow an increase in stocks. Costs are borne by fishing communities, or if they are compensated, by taxpayers. Future benefits are higher sustained landings.</td></tr>
<tr><td colspan="2">Baseline:
Overall status of fish stocks in the North-East Atlantic has shown some improvement, with the number of stocks fished at MSY increasing from 2 stocks in 2005 to 25 stocks in 2013. However, only 29% of all stocks were known to be within safe biological limits in 2013, and stock status is still unknown for 50% of stocks. In 2013, 41% of assessed stocks were outside safe biological limits, indicating that increases in catches and resource rent could be achieved for these stocks if fishing pressure were reduced and stock biomass restored.</td></tr>
<tr><td>PV of costs:
Estimated in £bns for the UK in NE Atlantic as a whole.</td><td>PV of benefits:
Potential increase in resource rent of £325m/yr from recovery & efficiencies in UK demersal fishery. Increased landings of £bns: e.g. benefits model based only on cod gives £0.86 - £4.79bn over 50 yrs.</td></tr>
<tr><td>Monetised costs:
Fishing effort reduction.</td><td>Monetised benefits:
Increased landings under single and multi-species recovery models compared to constant landings from 2015.</td></tr>
<tr><td colspan="2">Non-monetised impacts:
Transitionary support may be required to adjust to short-term costs on some coastal communities.</td></tr>
<tr><td>NPV:
N/A</td><td>Time period:
Actions allow stock recovery in 7-17 years in cod species recovery model. Benefits potentially sustainable in perpetuity.</td></tr>
<tr><td colspan="2">Key assumptions:
International (EU) cooperation in managing fishing effort to allow recovery.</td></tr>
<tr><td colspan="2">Additionality:
Additional actions are needed to achieve MSY for some stocks, resulting in additional landings.</td></tr>
<tr><td colspan="2">Synergies/conflicts:
May be complemented by actions to restore inshore shellfish stocks, and by saltmarsh improvements increasing nursery habitat for juvenile fish, both supporting more productive marine food webs.</td></tr>
<tr><td colspan="2">Impact on natural capital assets:
Biomass of marine fish species and ecological communities are natural capital assets that would be improved.</td></tr>
<tr><td colspan="2">Scale of impacts:
Applies to majority of demersal fish exploited by the English fleet. In theory, recovery of stocks</td></tr>
</table>

and hence landings could reduce prices, but this is not regarded as a significant risk.
Distribution: Reduced fishing effort and catches lead to loss of income in the short term but benefits of increased landings and lower risks in the long term. Both effects to be felt predominantly within coastal communities, mostly in Scotland and North-east England.
Uncertainties: Simultaneous recovery of all stocks to individually-assessed MSYs not feasible due to inter-species predation (biological interactions). Constraints related to mixed fisheries (where several species are caught together in the same fishery) combined with landings obligation may also affect the amount of the overall quota that can be taken. Currently the quota for cod limits exploitation of other species caught together with it, therefore recovery of the cod stock could improve landings from other related fisheries (haddock, whiting).

- ***Examples: fish stock recovery***
    - A case study of the cod, haddock and whiting mixed demersal fishery estimated the 2010 level of rent generated from UK cod fisheries as £13.4 million per year, mostly by over-24m demersal trawl vessels. With recovery of stocks, and removal of excessive effort in the fishery, rent from cod could be increased to £339.2 million per year (Bjorndal *et al,* 2010).

    - A Baltic cod case study (Döring & Egelkraut, 2008) analysed four different 50-year scenarios (status quo; recovery programme 1, reducing catches for five years then increasing over the next 20 years; recovery programme 2, reducing catches for five years then increasing over the next ten years; hypothesised sustainable catch). The net present value of recovery scenarios indicated that investing to improve fish stocks would provide benefits for discount rates up to 13.4%. The cost was €187 million in direct payments to compensate for lost profits. NPV of benefits with a 4% discount rate were €1,036 million (2008 € over 50 years).

    - NEF (2012) estimated the impact of restoring the stocks of 49 over-fished North-East Atlantic fish stocks to MSY levels by a moratorium on fishing (the option effective in the minimum time possible). Restoration was found to require investment of €10.56 billion to cover crew costs and vessel depreciation (fixed costs, capital costs and interest on the capital were not included) over a period of 9.4 years, and to generate €16.85 billion per year (value of catches), compared to a status quo of €7.04 billion per year. In practice, the transition time is likely to be longer (as policy makers are unlikely to stop all fishing to allow stocks to recover). The benefits are likely to be overestimated as the potential level of catches at MSY was taken from Froese & Proelß (2010), which estimated single-species MSY levels that are unlikely to be achieved in a multispecies and mixed fishery context.

    - Salz *et al*. (2010) simulated the recovery of stocks and elimination of overcapacity in seven important EU fisheries. In those fisheries, nominal net profit could be increased almost five-fold within a 15-year rebuilding period, with fleet size reducing from around 7,400 vessels to 5,700 vessels, and the net profit per vessel increasing 520%. The net present value of profits over the 15-year rebuilding period would be an estimated €500 million. In the case of the UK, the fleet has already gone through substantial decommissioning so further reductions are probably not necessary, at least not at any significant scale.

1. INTRODUCTION

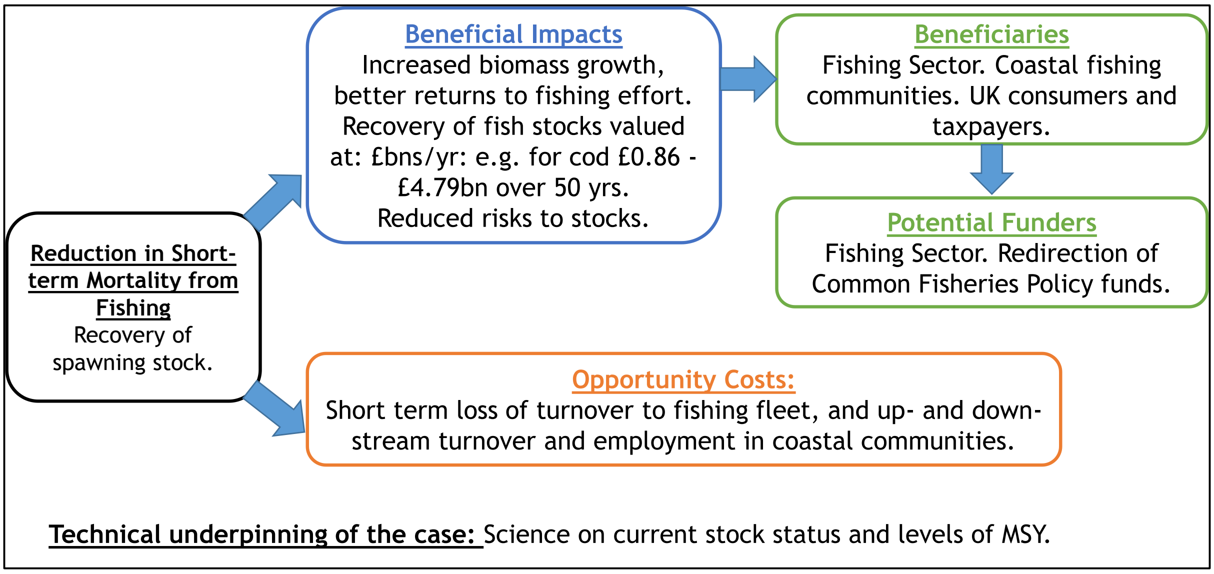
The majority of demersal fish stocks in the North Sea and wider North-east Atlantic are fished too heavily and greater catches could be achieved if stocks were allowed to replenish. Fish stocks represent a valuable natural capital asset that have the potential to provide flows of benefits (catches) such as food and food security, as well as employment in the fishing and associated sectors. These benefits could be provided indefinitely, if fish stocks are managed sustainably.

1.1 Investment Value Chain

Protection and improvement of demersal fish stocks (e.g. North Sea cod, haddock, whiting, sole) requires the reduction of fishing pressure to levels that can generate Maximum Sustainable Yield (MSY). A key objective for the EU and the UK is to restore fish stocks at least to the level of MSY in line with commitments made at the World Summit on Sustainable Development (WSSD). This is expected to restore fish stocks to biomass levels that can generate higher levels of landings (or the same level of landings for lower effort), reduce the risk of stock collapse and prevent the loss of potential future benefits through over-exploitation. Additionally, switching to less environmentally damaging gears (e.g. from bottom trawls to longlines) could reduce the negative externalities of fishing, providing additional natural capital benefits in the form of the ecosystem services provided by benthic habitats and other species that would otherwise be caught as juveniles or bycatch (Döring & Egelkraut, 2008). Further reducing fishing effort and increasing the efficiency of harvesting reduces fishing costs and can increase the resource rent obtained from fisheries to Maximum Economic Yield (MEY).

The value chain for investing in recovery of fish stocks is illustrated in Figure 1.1.

Figure 1.1: Demersal Fish Investment Value Chain



1.2 Policy context

The recently-reformed Common Fisheries Policy (CFP) (Reg (EU) 1380/2013) requires that stocks are restored and maintained above biomass levels which can produce MSY. The appropriate exploitation rate (F) should be achieved by 2015 where possible, and at the latest by 2020 for all stocks (Art 2(2)). This may be achieved through the implementation of multi-annual plans, which establish conservation measures to restore and maintain fish stocks, with quantifiable targets such as fishing mortality rates and/or spawning stock biomass and clear timeframes to reach those targets. Multi-annual plans may be either for a single species, or may be for multiple species for mixed fisheries or where the dynamics of stocks relate to one another.

The European Marine Strategy Framework Directive (MSFD) (2008/56/EC) requires that the marine environment is restored to 'Good Environmental Status' (GES) by 2020. For commercial fisheries, this requires that 'populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock'. The MSFD and CFP are thus complementary, and the CFP is expected to deliver the commercial fisheries aspects of the MSFD, and contribute to achieving GES. The UK vision of 'clean, healthy, safe, productive and biologically diverse oceans and seas' (Defra, 2002) will in part be achieved through the implementation of the MSFD.

2. THE STATUS OF MARINE FISHERIES

In the North-east Atlantic region, 62% of assessed fish stocks are fully exploited, 31% overexploited, and 7% not fully exploited (FAO, 2014). These figures represent only those fish stocks that are assessed. A large proportion of stocks are not assessed. Costello et al. (2012a) estimated that globally up to two thirds of unassessed stocks were overexploited, indicating substantial potential for stocks to be rebuilt and catches to increase. In 2012 ICES started to provide management advice for data-limited stocks (ICES, 2012), resulting in a significant increase in the number of stocks for which assessments and management advice are available.

The World Bank (2009) estimated global economic losses due to overexploited fish stocks at over US$50 billion annually. This represents an estimate of the loss of potential economic rent (considered broadly equivalent to net economic benefits). This is attributed to both depleted fish stocks which mean that there are fewer fish available to catch than there could be, and to excess fishing capacity which means that potential benefits are dissipated through excessive fishing effort.

2.1 Baseline Condition of Natural Capital Asset

English fleets have access to fish quotas beyond the boundaries of the UK EEZ, fishing throughout the North Sea, in the North-East Atlantic and beyond (

Figure). Fisheries are managed on a UK basis, within the context of the European Common Fisheries Policy.

An analysis by the European Commission in its Green Paper on the Reform of the Common Fisheries Policy (EC, 2008) found that 88% of assessed stocks in European waters were being fished beyond levels that can generate MSY, meaning that these fish populations could increase and generate more economic output if fishing pressure was reduced. Furthermore, 30 % of these stocks were outside safe biological limits, which means that they may not be able to replenish, even if fishing pressure is reduced.

Whilst the situation has shown some improvement since 2008, overall, the majority of stocks in European waters are fished too heavily and greater catches could be achieved if stocks were allowed to replenish — in 2013, 41% of assessed stocks were outside safe biological limits, indicating that increases in catches and resource rent could be achieved for these stocks if fishing pressure were reduced and stock biomass restored (Figure 2.3). Whilst the number of stocks fished at MSY increased from 2 stocks in 2005 to 25 stocks in 2013, only 29% of all stocks were known to be within safe biological limits in 2013, and stock status is still unknown for 50% of stocks (COM(2013) 319 final).

Figure 2.1. The UK EEZ highlighting English waters

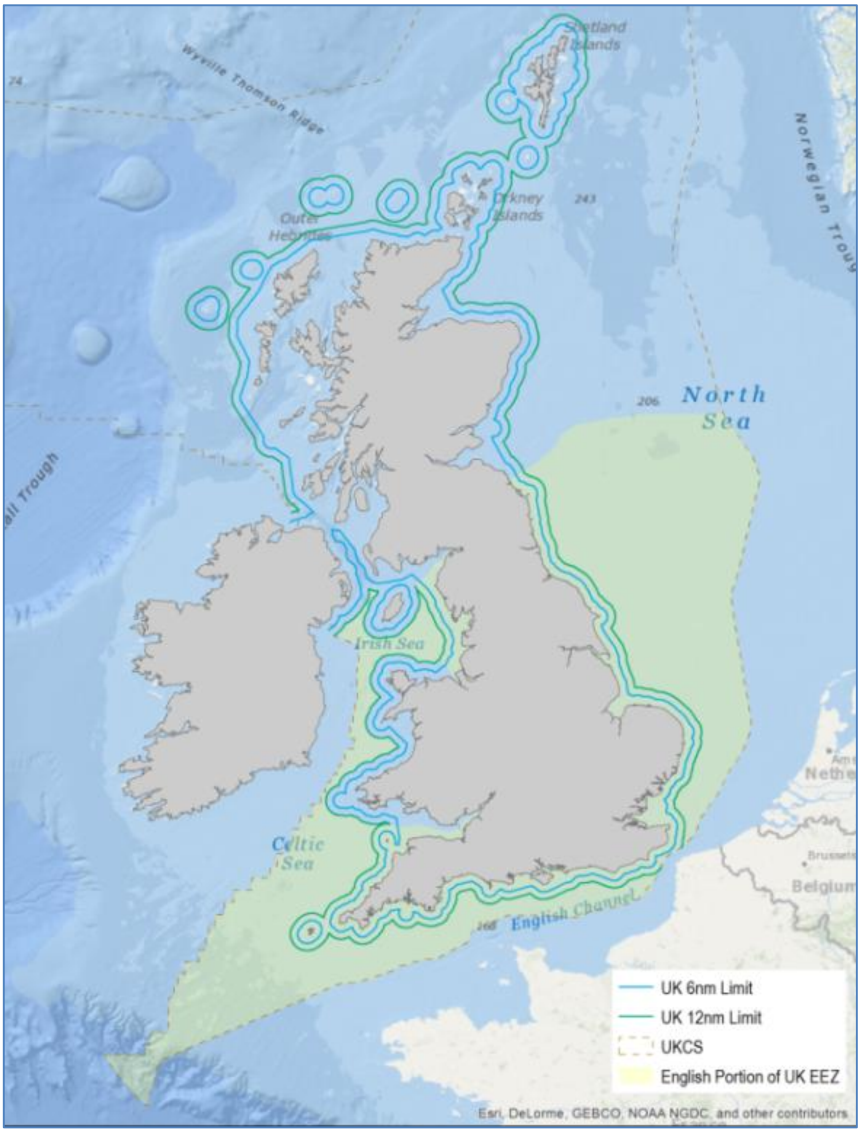
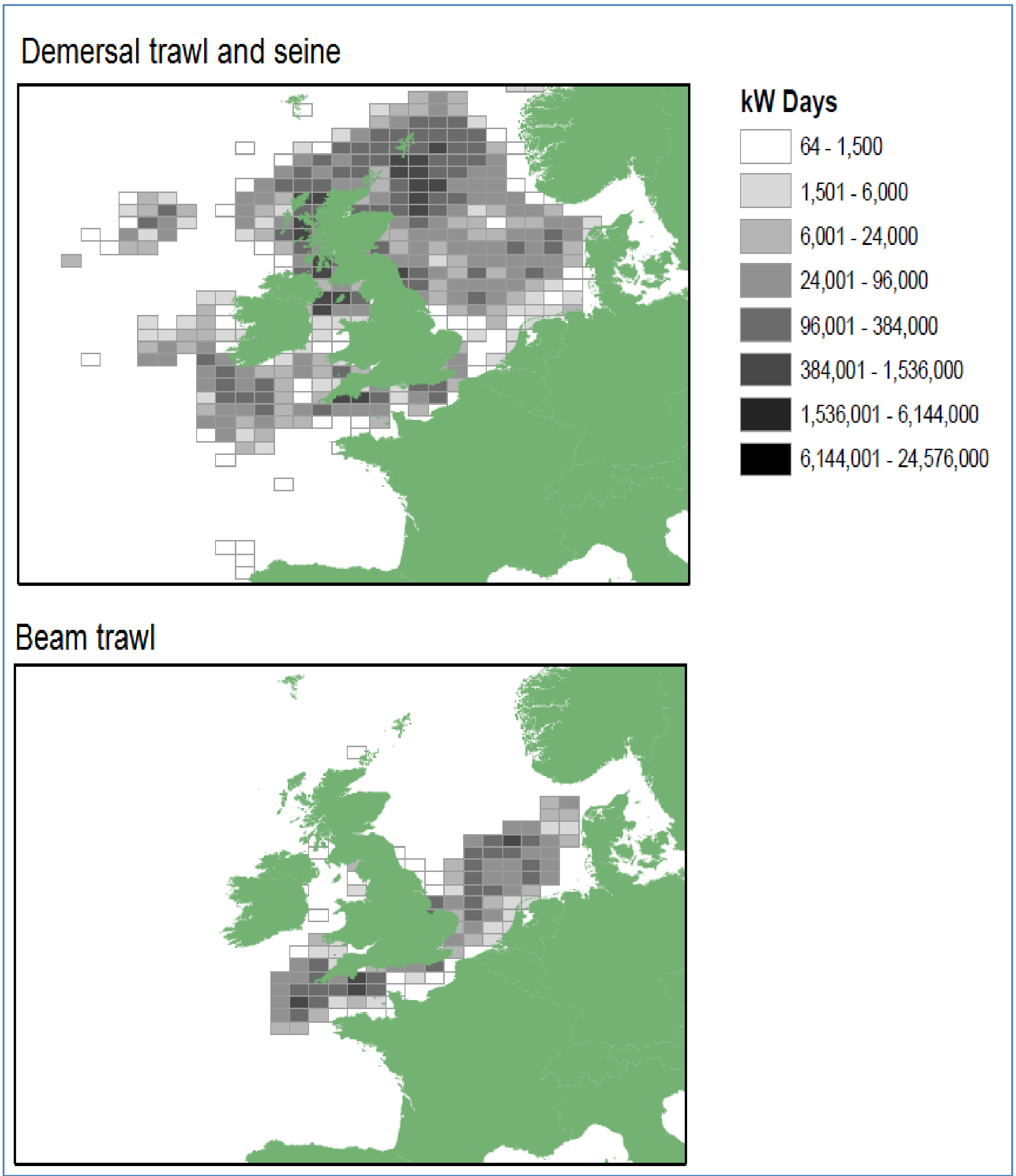


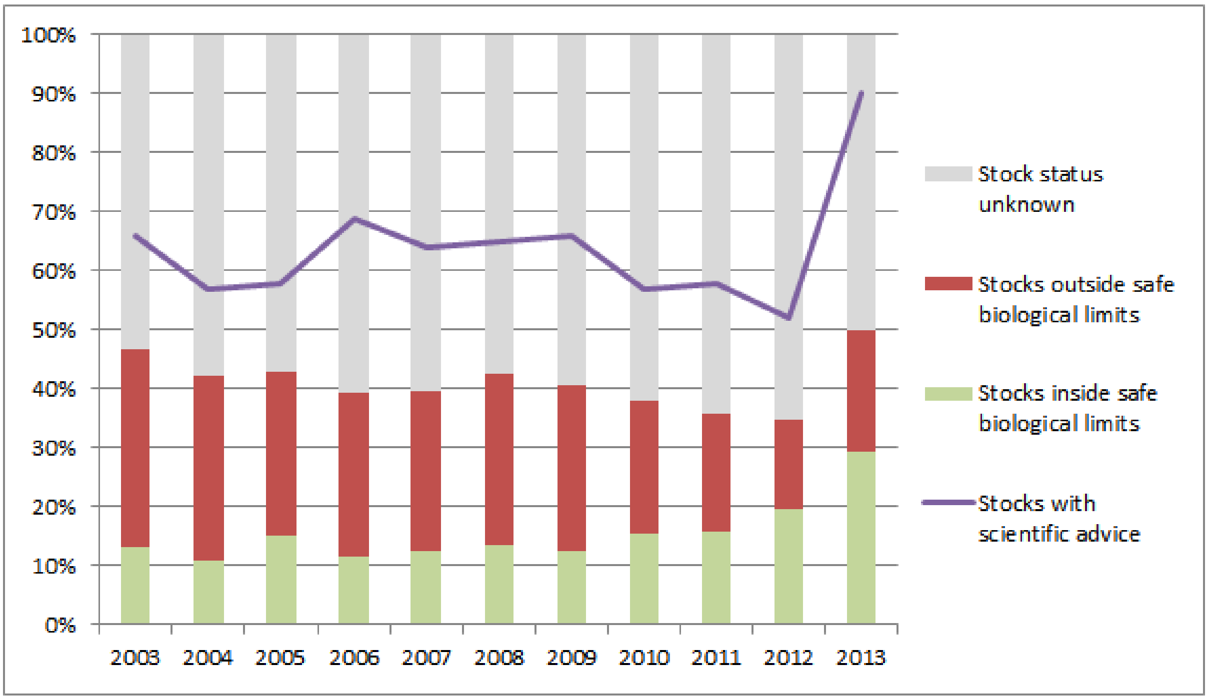
Figure 2.2. Fishing effort (kW days) by UK 10m and over demersal trawl and seine[1], and beam trawl vessels, by ICES rectangle (2013)



Source: MMO, 2014.

[1] A seine is a fishing net that hangs vertically in the water with its bottom edge held down by weights and its top edge buoyed by floats.

Figure 2.3. Status of North-East Atlantic fish stocks and percentage of stocks with scientific advice



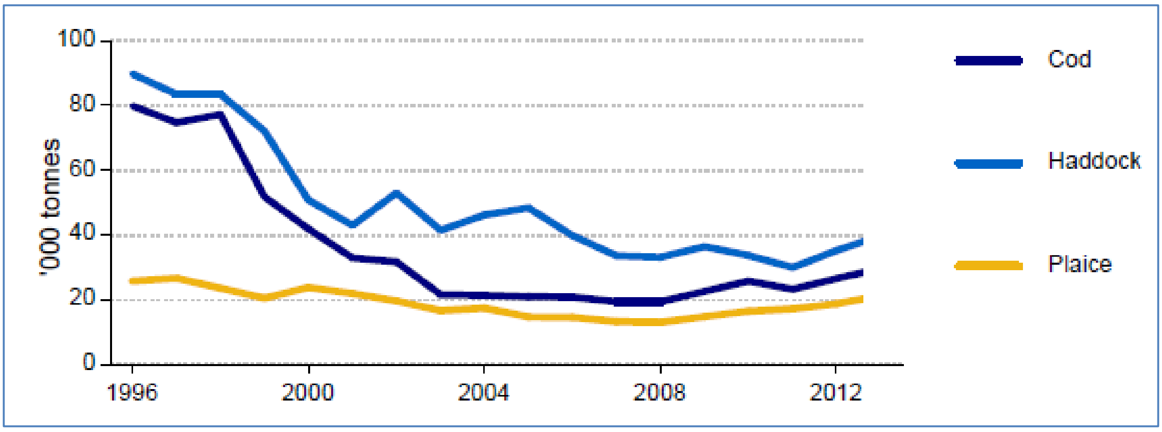
Source: COM(2013) 319 final.

The English fleet's share of UK landings was 31% in 2013. The largest component of landings by the English fleet in 2013 was demersal fish (73,700 tonnes), whereas previously pelagic fish had made up the largest component of catches (MMO, 2014). Demersal fish represented 38% of landings by volume for the English fleet, and thus represents an important component of the catch for England.

2.2 Trends

Landings of key demersal species by UK vessels from 1996 to 2013 are shown in Figure 2.4. Falling catches of cod and haddock have contributed to the large reduction in demersal landings since 1996, which were already reduced compared to the high catches in the 1970s and 1980s. In 2013, the UK fleet landed 29,000 tonnes of cod (down 63% since 1996) and 40,000 tonnes of haddock (down 56% since 1996). This represents a combined decrease of 100,000 tonnes. The real decline has been even more severe, however, as in 1996, catches of North Sea cod were already lower than catches in previous decades (see Box 1).

Figure 2.4. Landings of key demersal species into the UK and abroad by UK vessels: 1996 to 2013



Source: MMO, 2014.

In recent years, due to significant fleet restructuring and decommissioning in a number of EU Member States, and the implementation of conservation measures, stocks have started to show some signs of improvements. Out of 20 indicator fin-fish stocks in UK waters, the proportion being harvested sustainably (i.e. levels of fishing pressure are within sustainable limits) rose from around 10% in the early 1990s to around 40% in 2007.

Despite this, many stocks still have biomass levels below precautionary levels and far below levels that are capable of producing MSY. The large majority of scientifically assessed stocks continue to be fished at rates well above the levels expected to provide the highest long-term yield (Charting Progress 2, 2010).

Box 1: North Sea Cod

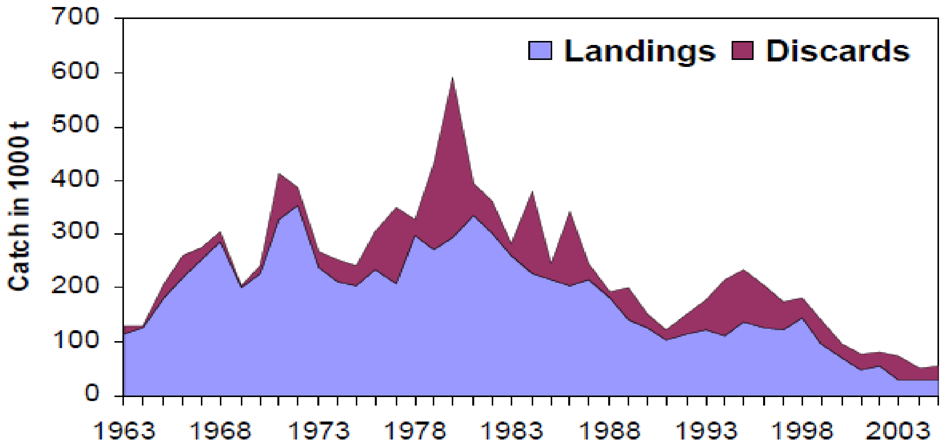
ICES (no date) describe annual landings of North Sea cod[2] over the last century. The main fleets targeting cod in the North Sea and Skagerrak are from the UK and Denmark (ICES, no date). Landings fluctuated between 50,000 and 100,000 tonnes during the first sixty years, after which landings increased to a maximum of 354,000 tonnes in 1972. In 1981 landings still reached 336,000 tonnes, but subsequently steadily declined to 28,200 tonnes in 2004 (Figure 2.52.5). These were the lowest landings since the collection of the international catch statistics started in 1903, with the exception of the period during the Second World War. Recently, the amount of discards in the fisheries has also been estimated. Total catches (landings + discards) peaked in 1980 at 590,000 tonnes.

High levels of catches from fisheries (high levels of fishing mortality), beyond what the stock could sustainably support, resulted in the spawning stock biomass declining to very low levels of around 35,500 tonnes in 2001, around half of the limit reference point (Blim[3]) of 70,000 tonnes.

[2] North Sea, eastern Channel and Skagerrak

[3] The level of spawning stock biomass below which the possibility of a total breakdown of the stock is very high and the reproductive capacity is impaired.

Figure 2.5. Time series of landings and discards of cod in the North Sea, Eastern Channel and Skagerrak



Source: ICES (2004), cited in ICES (no date).

Annex I presents a case study of the potential economic benefits of restoring North Sea cod to MSY levels for the UK. A single-species model and a single-species model with multispecies considerations are presented. In the single-species model, catches at MSY are estimated at 280,000 tonnes; when multispecies considerations are taken into account, catches at MSY are estimated at 91,000 tonnes. The results are presented in **Error! Reference source not found.**. The resent value (PV) over a 50 year timeframe is between £1.5 billion (multispecies, HMT discount rate) and £3.5 billion (single-species, HMT discount rate). Costs of restoration are not taken into account. Compared the PV of continuing current catches over the same time period (£0.61 bn) this represents an additional benefit of £0.89bn – 2.93bn (see Table 4 in Annex 1).

Table 2.1: Present value of North Sea cod to the UK over 25 and 50 years

	Present value of North Sea cod based on single-species model (2014 £m)		Present value of North Sea cod based on single-species model taking into account multi-species interactions (2014 £m)	
Discount rate	25 yrs	50 yrs	25 yrs	50 yrs
HMT	1,990	3,539	970	1,473

Note: HMT refers to the discount rate recommended in HM Treasury's Green Book (2003) which is a declining discount rate starting at 3.5%. All prices are expressed using 2014 as a base year.

2.3 Pressure/driver impacting asset

The main pressure driving the status of demersal fish stocks is fishing pressure, which represents the main source of mortality. Restoration actions must therefore address the level of fishing pressure to restore stocks. However, the ecosystem within which fisheries take place is complex and other factors may affect the rate, and final state, of recovery. Climatic variation, changes in salinity, temperature, currents and habitat can affect the size, growth and behaviour of fish stocks. Fishing activity itself, in particular bottom trawling (the main fishing method for targeting demersal stocks), changes the benthic habitat and may affect ecosystem productivity. Other economic activities, such as oil and gas exploration, shipping, tourism and gravel extraction, may also affect the marine environment and fish stocks.

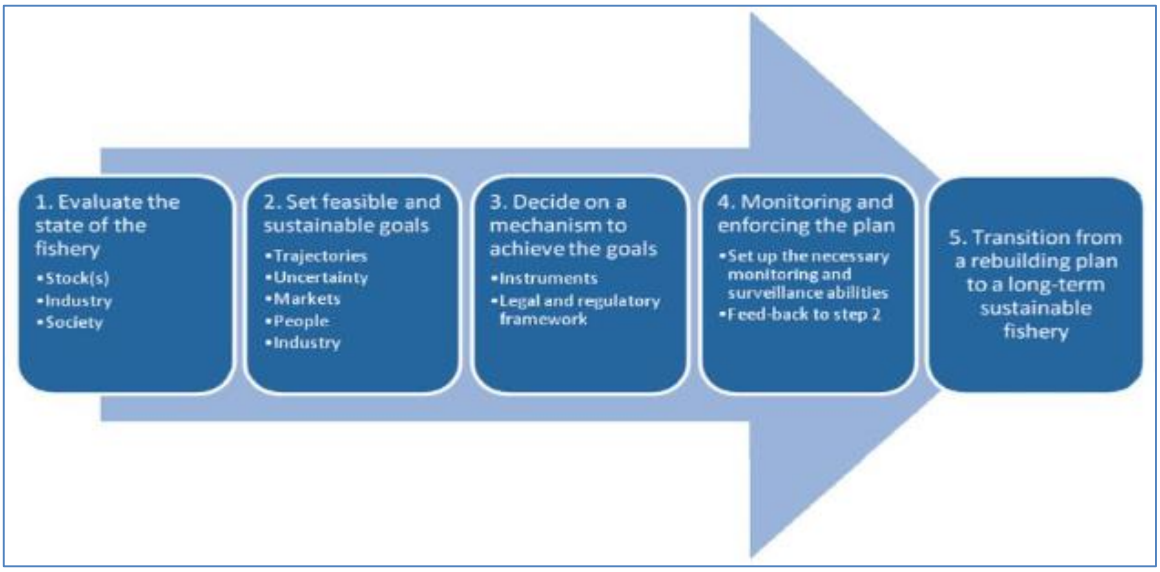
Ecosystem interactions (such as predator-prey relationships), and multispecies fisheries (fisheries that target two or more different species together) complicate efforts to protect and restore fisheries. Increased abundance of one species in the ecosystem can affect the abundance of their prey, and other species in the food web. For example, the current abundance of plaice in the North Sea may be due to the low biomass of cod, a top predator in the ecosystem. An example from the Baltic Sea shows that the low levels of cod has caused an increase in sprat stocks (prey species) who feed on zooplankton. Higher predation on zooplankton leads to greater algae growth, which is one of the main reasons for declining oxygen content in deeper layers of the Baltic Sea, which itself is one of the causes of low cod reproduction rates (Döring & Egelkraut, 2008).

3. RESTORATION ACTIONS

3.1 Rebuilding fish stocks

Protecting and restoring fisheries is a process that can be divided into several steps as outlined by OECD (2012) (Figure 3.1.3.1).

Figure 3.1. Steps of a rebuilding fisheries plan



Source: OECD, 2012.

A reduction in catches is required in order for fish stocks to be rebuilt to levels that can produce higher yields. The key factor in restoring overexploited fisheries is usually a reduction in fishing pressure. This can be achieved by limiting effort, limiting catches, technical restrictions on fishing gear (e.g. minimum mesh sizes) and minimum landings sizes. These measures aim to ensure that the rate of removals from the population allows the population to replenish itself and ensures that individual fish have a chance to spawn and replenish the stock before they are caught.

For rebuilding fisheries and ensuring sustainable long-term exploitation, EDF et al. (2014) identify three key factors that they consider are necessary for success:

- Secure tenure;
- Sustainable harvests;
- Monitoring and enforcement.

Secure tenure is important to ensure that fishermen are able to reap the benefits of rebuilding stocks, and to avoid the overexploitation that follows from open access regimes. It is often a component of creating the right incentives to achieve fishery objectives. A number of instruments might be applied to manage fisheries and protect and enhance fish stocks, which aim to provide secure tenure and achieve sustainable harvests. There is no one solution that will work in all situations, and the mix of approaches selected will depend on objectives of management, knowledge of stocks, nature and types of participants, the ability to monitor and enforce regulations, and stakeholders' involvement in the management process (OECD, 2012). An overview of different management instruments used in various fisheries in OECD countries is provided in Figure 3.2.3.2.

Figure 3.2. Typology of fishery management instruments

Control method	Control variable: Fishing effort (input control)	Control variable: Catch (output control)
Regulatory (administrative technical measures)	• Mesh size • Size/amount of gear • Area/time closures	• Size and sex selectivity • TAC
Regulatory (administrative access control)	• Limitated[1] non-transferable[3] permits/licences (LL) • Individual non-transferable effort quotas (IE) • Territorial Use Rights in Fisheries (TURF) • Other types of effort limits	• Individual[2] non transferable[3] quotas (IQ) • Community-based catch quotas (CQ) • Other types of catch limits (maximum landings or vessel catch limits – VC)
Economic market-based (economic access control or "rights-based method")	• Transferable[3] licences[1] (LTL) • Individual transferable effort quotas (ITE)	• Individual[2] transferable[3] quotas (ITQ)
Economic not market-based	• Input[4] tax • Subsidy • Charges	• Landing tax • Subsidy • Charges

1. System restricting the number of vessels authorised to fish, their individual fishing capacity, and fishing time.
2. Individual quota = fraction of a Total Allowable Catch (TAC) allocated to a vessel or fishing firm.
3. Transferable = tradable on the market.
4. Components of fishing effort (intermediate consumption, fixed capital, labour).

Source: OECD, 2006, cited in OECD, 2012.

3.2 Reducing externalities

In addition to reduced catches, a fish stock recovery programme could switch to less destructive fishing methods, even if production costs (as opposed to social costs) increase (Döring & Egelkraut, 2008). Bottom trawling damages benthic flora and megafauna, impacting bottom-living fish, invertebrates, algae populations, and predator-prey relationships (Jennings & Kaisser, 1998; Thrush & Dayton, 2002), as well as causing bycatch of non-target fish species and marine mammals. Döring & Egelkraut (2008) advocate a switch from bottom trawling to long-lining for cod in the Baltic to reduce these negative externalities of fishing activity.

3.3 Maximising returns

Increasing fishing efficiency can also increase the economic benefits of stock restoration through maximising resource rent (by reducing fishing costs, particularly where management incentives promote maximising fishing efficiency).

However, a purely economic approach to fisheries management that maximises economic rents is not always desirable. There are social reasons (including socio-economic ones, albeit not quantified in economic models of fisheries) for maintaining access for small-scale and less economically efficient vessels, reflected in the UK Government's long-term vision for fisheries. This aims for 'the best possible long-term economic benefits for society through effective management and moderate levels of exploitation', but with the proviso that:

'Access to fisheries continues to be available to small-scale fishing vessels, even if in some cases that is not the most economically efficient way of harvesting the resource. This is because the wider economic, social and environmental benefits of small-scale fishing can outweigh the comparative inefficiency in harvesting the resource and make a significant economic and social contribution to the lives of individuals and coastal communities, for example, by providing jobs, attracting tourists, providing high-quality fresh fish and maintaining the character and cultural identity of small ports throughout England.'

Defra, 2007.

3.4 Timescale of recovery

Recovery of demersal fish stocks might take 5–25 years and estimates vary considerably. Recovery times depend on both the reproduction and growth rate of the individual species, the extent to which a stock is currently overfished, and the measures taken to reduce fishing pressure. Stocks would start to rebuild within a few years of reduced fishing pressure, but may take substantially longer.

Recovery is non-linear. There is an initial cost to be borne as the stock rebuilds. The rate and trajectory of recovery will depend on the rebuilding measures adopted (a typology of which is described in **Error! Reference source not found.**). Whilst a fishing moratorium (bold line) is the uickest way to achieve the target biomass and harvest rate, a longer rebuilding phase with less severe short-term costs may be a preferable option.

The choice of rebuilding path will depend on the discount rate used, uncertainties, and other factors taken into consideration. For example, for long rebuilding time paths, current stakeholders may not be able to reap the benefits, and the composition of the stakeholder group may change over time. Furthermore, the human and physical capital in fisheries is relatively non-malleable: it is not easy for workers to move to other sectors, or for capital to move out of the fishery to other uses. Workers may have transferable mechanics skills, in rural areas transfer opportunities tend to be limited (Munro, 2010). Fishermen accumulate know-how and specific skills that are not transferable to other sectors and would be a cost to the fisheries sector if lost from it.

The length of time recovery takes makes discounting a crucial factor in analysis. While HM Treasury Green Book discount rates are used in impact assessments, fishermen's discount rates can be much higher than this. Understanding fishermen's discount rates is important in selecting rebuilding measures. For example, discount rate for fisheries in New Zealand (a country with secure tenure and access rights to fishing opportunities) range from 6.7% to 12.5%, based on the price that permanent quota rights are traded for. Statistics New Zealand uses a 9% rate (IDDRA, 2010). Higher discount rates can be expected where there is a lack of secure tenure over access to the fish resource (see section 3). Hillis & Wheelan (1994, cited in Döring & Egelkraut, 2008) estimated discount rates ranging from 25% to 40% due to the perceived uncertainty over future landings.

The recovery time for an individual species can vary greatly depending on the rebuilding strategy used. Costello et al. (2012b) estimated a recovery time for temperate monkfish from collapse of between 3 and 28 years, depending on whether a 'fast' or 'slow' rebuilding scenario was adopted, with the 'optimal' at 19 years[4]. Other species showed much less variability — the recovery time for cold temperate sole was between 3 and 5 years.

Research into the restoration of Baltic Sea cod found that with a decrease in effort (using more selective gear to allow smaller cod to escape) stocks would start to increase in as little as three years, and within five years, the spawning stock would include sufficient mature specimens such that the fishery no longer depends on the recruitment of a single year class (Döring & Egelkraut, 2008).

4. FISH STOCK RESTORATION OUTCOMES

Restoring and protecting demersal fish stocks would provide an increase in fishery yields through increased landings, providing increased levels of food provision and food security, as well as increased profits for operators, potential for increased turnover for fish processors, and increased exports.

Ecological restoration interventions can be expected to enhance ecological resilience (i.e. capacity of ecosystems to absorb disturbances and regenerate) (Folke *et al.*, 2004). Protecting and enhancing demersal fish stocks will contribute to increased resilience of the marine ecosystem, and will reduce the risk of stock collapse.

The use of less destructive fishing gears can also reduce negative environmental externalities, such as damage to benthic species and habitats, bycatch of non-target fish species and marine mammals and birds.

4.1 Economic Information on Restored Fish Stocks

Scoping studies have shown that for some fisheries, the increase in overall profit that is generated through the transition process is more than able to pay for the upfront costs of undergoing the transition and for the on-going costs of sustainable management, as well as provide a financial return for investors (EDF *et al.*, 2014). Some examples of investments and changes in fishery revenues are shown in Table 4.1.

A number of studies of economic benefits and potential resource rent from fisheries show that substantial benefits could be achieved, if stocks were restored to MSY and excess fishing capacity reduced. Key studies are summarized in
Table 4.2.

[4] In the optimal scenario, the fishery is rebuilt by fishing according to the economic optimum policy until the stock biomass exceeds 99% of the rebuilt state. In the fast scenario, the fishery is closed (i.e. effort=0) until the stock biomass exceeds 99% of the rebuilt state, and thereafter fishing proceeds according to the optimal policy. In the slow scenario, fishing effort exceeds the optimal policy by 20% for the time period it would have taken to rebuild, preventing the rebuilding threshold from being reached in the same time as it would have been under V1opt; the policy then reverts to the optimum until the biomass is within 99% of the rebuilt threshold.

Table 4.1. Increase in revenues in select fisheries

Fishery	Fishery revenues (before)	Investment activities	Fishery revenues (after)	Percent increase
Pacific halibut	US$50 million (1992)	1995: Secure tenure; monitoring and enforcement	approx. US$150 million (2008) (in 1992 US dollars [a])	200% in real terms
Ben Tre clam (Viet Nam)	US$0.837 million (2007)	2006 to 2009: Secure tenure; MSC certification	US$1.25 million (2010)	49%
New Zealand	US$1,577 million (1986)	1986: Secure tenure; monitoring and enforcement; sustainable harvests	US$3,200 million (unkn)	103%
Source: EDF *et al.*, 2014 Notes: [a]: Figures estimated from graph in MRAG (2008).				

Table 4.2. Summary of case studies on economic benefits of restoring fisheries

Case study	Details	Cost	Benefits	Reference
UK fisheries	Current patterns of TACs assumed. Economic efficiency in catching to increase rents. Increasing value of the catch (market factors, quality).	Not estimated.	Current resource rents estimated at £50 million per year. Potential resource rent of £573 million per year.	IDDRA, 2010
UK mixed demersal fishery (cod, haddock, whiting)	Recovery of stocks, and removal of excessive effort in the fishery. Takes into account mixed fishery considerations (catch constrained by haddock TAC).	Fishing costs incorporated into the model.	Resource rent could be increased from £13.4 million (2006) per year to £339.2 million.	Bjorndal *et al.*, 2010
UK Western Channel sole fishery	Assessment of current and potential rents in the sole fishery in the English Channel. The substantial sole fishery fleet overcapacity resulted in rent dissipation and reduced landings.	Reduction in short-term landings to allow stock recovery.	Present value of £120m: difference between maximum revenues under stock recovery (£140m) compared to continued overfishing and extinction (£20m).	Bjorndal T, & Bezabih M (2010)
Seven EU fisheries	Simulated the recovery of stocks and elimination of overcapacity. 15-year rebuilding period.	Fleet size reduces from around 7,400 vessels to 5,700 vessels.	Nominal net profit could be increased almost five-fold. Net present value of profits over the 15-year rebuilding period would be an estimated €500 million.	Salz *et al.* (2010)
UK share of North Sea cod	Recovery of stock to MSY - Single species estimate - Single species with multispecies considerations (TAC constrained)	Costs not estimated.	Present value over 50 years between £1,473 million (multi-species, HMT discount rate) and £3,539 million (single species, HMT discount rate).	See Annex I.
Baltic Sea cod	Four scenarios: - Status quo; - Recovery programme 1, reducing catches for five years then	The cost was €187 million in direct payments to compensate for lost profits.	NPV of benefits: €1,036 million over 50 years (4% discount rate). Investing in natural capital would provide benefits for	Döring & Egelkraut, 2008

Case study	Details	Cost	Benefits	Reference
	increasing over the next 20 years - Recovery programme 2, reducing catches for five years then increasing over the next ten years; - Hypothesised sustainable catch. 50-year timescale.		discount rates up to 13.4%.	
49 over-fished North-East Atlantic fish stocks	Restoration of stocks to MSY levels. Assumes a moratorium on fishing to restore stocks in the minimum time.	€10.56 billion to cover crew costs and vessel depreciation (fixed costs, capital costs and interest on the capital were not included). Investment (recovery) period of 9.4 years.	Benefits of €16.8 billion per year (value of catches at MSY). Benefits likely to be overestimated as MSY taken from a study that estimated single-species MSY levels. These are unlikely to be achieved in a multispecies and mixed fishery context.	NEF, 2012

5. DISCUSSION AND CONCLUSION

This analysis has examined the potential to managed fish stocks exploited by the English fishing fleet more sustainably. Reduction in effort is required in the short-term to restore stocks allowing higher catches in future. For some fisheries such investments are effectively already underway. The costs of these investments are borne by the fishing fleets and communities involved, with some contribution from UK taxpayers to the extent that the Government supports such communities.

The benefits of this investment in natural capital are both environmental and economic and include:

- Increased rate of biomass growth and, with it, reduced risk of stock collapse, and increased resilience of stocks, and the marine ecosystem, to climate change;
- Increased efficiency - in terms of higher catch per unit of fishing effort, and
- Increased market value (of fish landed).

These all contribute to increased profits in the fishing sector.

Evidence is available across a range of stocks, but one example is modelled here: for North Sea cod. Two models are used: a single-species model only, and a single-species model with multispecies considerations. The present value of increased landings (compared to current levels) with recovery over a 50 year timeframe in the UK are estimated at between £0.89bn and £2.93bn (see Box 1). The wide range in these figures illustrate the sensitivity of the results to the modelling approach used. There are also uncertainties as to whether current fishing effort will deliver the stock recovery predicted, due to both uncertainties in managing actual catches and uncertainties in the scientific advice. However, both approaches show substantial additional present value secured into the future, justifying investments in stock recovery.

This analysis is for UK landings, a substantial part of which will accrue to the English fishing fleet, particularly in North-east England, although substantial landings of cod are also made in Scotland. Sustainable management of fish stocks will have benefits for the whole of the UK, and other countries that exploit North-east Atlantic fisheries. International (particularly European) collaboration by all countries is required to manage fishing effort in a given area of sea to allow fish stocks to recover.

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ANNEX I: SINGLE-SPECIES AND MULTI-SPECIES MODELS FOR BENEFITS FROM RESTORATION OF NORTH SEA COD FOR THE UK

Fish stock models

The single-species model of fish stock assessment and management is well established (Hilborn & Walters, 1992). Its limitations are well-known, representing the stock as self-determining with regards to recruitment and disconnected from the ecosystem, however, it remains the basis for the majority of fisheries management to determine stock size and allowable catches. As such, the link between management decisions (HCRs, TACs, recommended fishing mortality to achieve MSY) and landings (provision of fish as food as an ecosystem service that can be valued), is more straightforward.

Advice for mixed fisheries and multi-species interactions is starting to be provided by ICES (ICES, 2012). In mixed fisheries, different fish species are targeted together (e.g. cod, haddock and whiting). As different species have different growth rates and sizes at maturity, it is impossible to achieve MSY for all stocks concurrently in a mixed species fishery. Either the advice for one stock (usually cod) drives the management advice for all other stocks, or wider technical interactions are considered and advice takes into consideration spatial and technical effects across the species assemblage. The choice is a policy decision — whether the priority is the status of a key species, or overall productivity across all species, which in either case can potentially be prioritised at the expense of the health of the stocks of some of those species.

Multi-species advice takes into account biological interactions such as predator-prey relationships. This can be either single-species advice incorporating biological interactions, or ecosystem-scale advice incorporating biological interactions. Multi-species models that take into account ecosystem considerations are starting to be developed. Analysis of stomach contents indicates that predation contributes significantly to the natural mortality of exploited fish species, which therefore varies from year to year, rather than being constant as assumed in single species models (Daan, 2011).

For example, in model simulations of the North Sea fisheries, maintaining a higher exploitation rate for cod (F=0.45 compared to the single-species target of F=0.19), saithe and herring, led to a yield close-to-MSY for each species in a multispecies context, and was necessary to maintain all species within precautionary limits (ICES, 2013c). Maintaining a higher exploitation rate of the predators cod and herring lowers the predation pressure on their prey and results in higher overall yields.

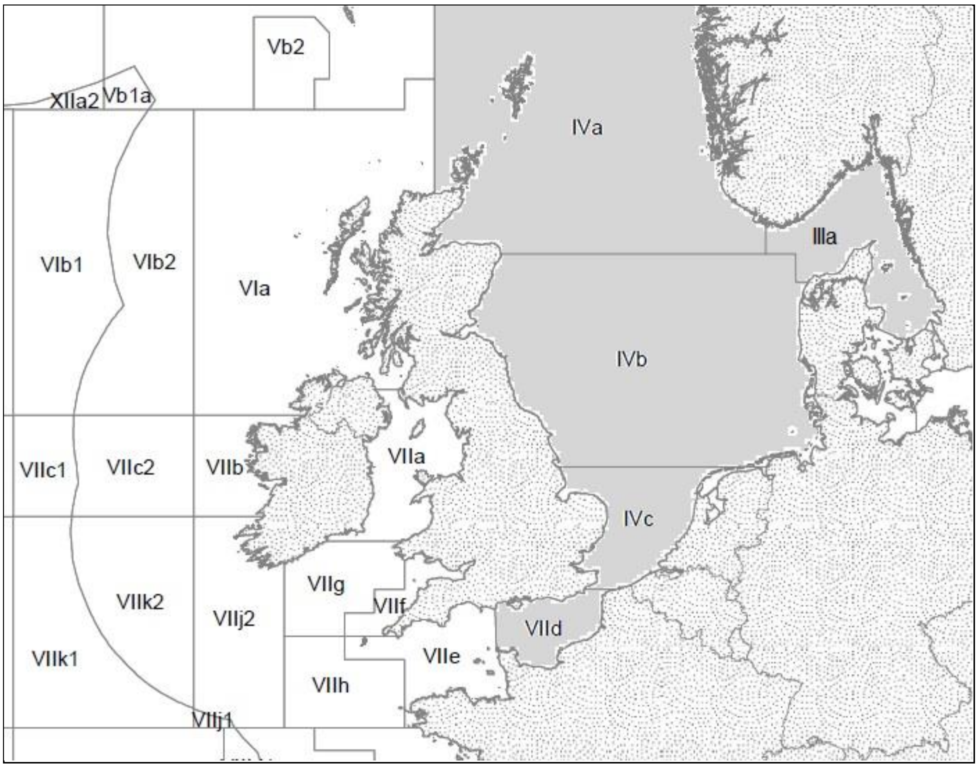
A single-species spreadsheet model was developed for North Sea cod (Gadus morhua) to explore the application of an accounting framework to production of food (fish and shellfish) from the marine ecosystem over a longer time period. It used projections of future landings based on stock assessments and incorporating management measures relating to the control of fishing pressure, and taking into account relative stability. The following parameters were included in the model:

- UK quota (tonnes), based on the projected TAC and the UK share of the TAC;
- Discards as a percentage of total catch, and the implementation of the landings obligation under the reformed CFP; and
- Cod price (£ per tonne, first sale value).

The North Sea cod stock is assessed by ICES and managed jointly by the EU and Norway. It covers ICES Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak). These

ICES Subareas are shown in Figure 1. The UK also has access to cod stocks in the Western Channel, Celtic Sea and West of Scotland; these are not included in this model.

Figure 1: ICES areas for the North Sea cod stock



For 2014, the North Sea cod (hereafter 'cod') TAC was 33,391 tonnes, a 5% increase on the 2013 TAC. The UK receives 32.9% of the TAC, which equated to 10,977 tonnes in 2014 (EU, 2014). The expected yield and stock biomass at MSY is not defined by ICES, because species interactions and density-dependent growth will start to have a bigger influence on productivity when stocks start to build up.

Projections of the expected TAC were produced by ICES for various scenarios (ICES, 2013a; 2014) and are used in the model (a departure from the constant service flow assumption) as landings from fisheries depend on stock status and management practice. The projections of landings by ICES represent the best available evidence on future landings from the stock.

A single-species model was developed, in which the TAC was capped at 280,000 tonnes. This is an estimate of the potential MSY for North Sea cod in a single-species context (HM Government, 2012).

A single-species model with multi-species considerations was also developed, in which the projected TACs were capped at 91,000 tonnes. ICES advice on multispecies considerations for North Sea stocks indicate that an MSY of 91,000 tonnes for cod might be achieved in a multispecies context (ICES, 2013c). This is likely to be a more realistic overall level of benefits that can be achieved in a multispecies context.

Modelling results and economic valuation

The costs and benefits of the recommended actions are estimated through a single-species model for cod and a single-species model with multi-species considerations. The results are shown Table 1 and Table 2, respectively.

Table 3 presents the present value of the North Sea cod fish stock over 25 and 50 years respectively.

The discount rate recommended by HM Treasury's Green Book (2003) is used, which is a declining discount rate starting at 3.5%.

All prices are expressed using 2014 as a base year.

Table 1: Single-species model for North Sea cod

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Projections of TAC based on ICES simulations, using the mid-point of two scenarios investigated by ICES (current HCR with TAC restriction, and 10% increase in TAC), since the actual management adopted in 2014 was between these two scenarios (i.e. a 5% increase in TAC was adopted for 2014)									
TAC (tonnes)	33,391	33,500	41,266	48,219	56,719	66,737	90,000	105,500	124,500	147,000
UK Quota (tonnes)	10,977	11,013	13,566	15,852	18,646	21,939	29,587	34,682	40,929	48,325
Discards as % of total catch	23%	23%	7%	7%	6%	6%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	25	25	31	36	42	50	67	79	93	109
Discounted value of landings (£ million) - HMT discount rate	25	24	29	32	37	42	54	62	70	80

- Continued

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
	Rate of increase in the TAC from 2019-2023 projected forward until reach MSY (280,000 t)							MSY capped at 280,000 t		
TAC (tonnes)	161,550	179,200	196,850	214,500	232,150	249,800	267,450	280,000	280,000	280,000
UK Quota (tonnes)	53,109	58,911	64,713	70,516	76,318	82,120	87,923	92,048	92,048	92,048
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	120	133	147	160	173	186	199	208	208	208
Discounted value of landings (£ million) - HMT discount rate	85	91	97	102	107	111	115	116	112	108

- Continued

	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
	MSY capped at 280,000 t									
TAC (tonnes)	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000
UK Quota (tonnes)	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	208	208	208	208	208	208	208	208	208	208
Discounted value of landings (£ million) - HMT discount rate	105	101	98	94	91	88	85	82	80	77

- Continued

	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053
	MSY capped at 280,000 t									
TAC (tonnes)	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000
UK Quota (tonnes)	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	208	208	208	208	208	208	208	208	208	208
Discounted value of landings (£ million) - HMT discount rate	74	72	70	68	66	64	62	60	59	57

- Continued

	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063
	MSY capped at 280,000 t									
TAC (tonnes)	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000	280,000
UK Quota (tonnes)	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048	92,048
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	208	208	208	208	208	208	208	208	208	208
Discounted value of landings (£ million) - HMT discount rate	55	54	52	51	49	48	46	45	44	42

Note: HMT refers to the discount rate recommended in HM Treasury's Green Book (2003) which is a declining discount rate starting at 3.5%. All prices are expressed using 2014 as a base year.

Table 2: Single-species model for North Sea cod, taking into account multi-species interactions

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Projections of TAC based on ICES simulations, using the mid-point of two scenarios investigated by ICES (current HCR with TAC restriction, and 10% increase in TAC), since the actual management adopted in 2014 was between these two scenarios (i.e. a 5% increase in TAC was adopted for 2014)							MSY capped at multispecies level (ICES, 2013)		
TAC (tonnes)	33,391	33,500	41,266	48,219	56,719	66,737	90,000	91,000	91,000	91,000
UK Quota (tonnes)	10,977	11,013	13,566	15,852	18,646	21,939	29,587	29,916	29,916	29,916
Discards as % of total catch	23%	23%	7%	7%	6%	6%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	25	25	31	36	42	50	67	68	68	68
Discounted value of landings (£ million) - HMT discount rate	25	24	29	32	37	42	54	53	51	50

- Continued

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
	MSY capped at multispecies level (ICES, 2013)									
TAC (tonnes)	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000
UK Quota (tonnes)	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	68	68	68	68	68	68	68	68	68	68
Discounted value of landings (£ million) - HMT discount rate	48	46	45	43	42	40	39	38	36	35

- Continued

	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
	MSY capped at multispecies level (ICES, 2013)									
TAC (tonnes)	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000
UK Quota (tonnes)	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	68	68	68	68	68	68	68	68	68	68
Discounted value of landings (£ million) - HMT discount rate	34	33	32	31	30	29	28	27	26	25

- Continued

	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053
	MSY capped at multispecies level (ICES, 2013)									
TAC (tonnes)	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000
UK Quota (tonnes)	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	68	68	68	68	68	68	68	68	68	68
Discounted value of landings (£ million) - HMT discount rate	24	23	23	22	21	21	20	20	19	18

- Continued

	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063
	MSY capped at multispecies level (ICES, 2013)									
TAC (tonnes)	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000	91,000
UK Quota (tonnes)	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916	29,916
Discards as % of total catch	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cod price (2014 £ per tonne, first sale)	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264	2,264
Value of landings (£ million)	68	68	68	68	68	68	68	68	68	68
Discounted value of landings (£ million) - HMT discount rate	18	17	17	16	16	15	15	15	14	14

Note: HMT refers to the discount rate recommended in HM Treasury's Green Book (2003) which is a declining discount rate starting at 3.5%. An additional constant discount rate is used (1.5%) to reflect the impact of climate change risk on the North Sea cod fish stock. All prices are expressed using 2014 as a base year.

Table 3: Present Value of North Sea cod recovery over 25 and 50 years

Present value (2014 £m) at HMT discount rate	North Sea cod based on single-species model		of North Sea cod based on single-species model taking into account multi-species interactions	
	25 yrs	50 yrs	25 yrs	50 yrs
	1,990	3,539	970	1,473

Table 4: Present Value of Additional North Sea cod landings under recovery scenarios compared to current landings over 50 years

North sea cod	Present Value (2014 £m) over 50 yrs	Discount rate
		HMT
Total Landings	Based on constant landings from 2015	611
	Based on single-species model	3,539
	Based on single-species model taking into account multi-species interactions	1,473
Additional landings from recovery compared to constant landings	Based on single-species model compared to constant landings	2,929
	Based on single-species model taking into account multi-species interactions	863

Note: HMT refers to the discount rate recommended in HM Treasury's Green Book (2003) which is a declining discount rate starting at 3.5%. All prices are expressed using 2014 as a base year.

INVESTMENT CASE – SHELLFISH

SUMMARY

- *Shellfish (Lobster and Brown Crab) in English waters are overexploited, and at risk of collapse particularly if effort transfers from other fisheries due to discard ban.*
- *Investing in stock recovery has costs in the short-term (reduced catches) but generates benefits in the future.*
- *Achieving Maximum Sustainable Yield (MSY) is likely to sustain landings above current levels, and reduce risks from stock collapse. This will benefit fishing communities and the UK economy, although outcomes are uncertain.*

<table>
<tr><td colspan="2">Investment:
Reduce catch in the short-term to enable future benefits from stock recovery. Reducing catch could be achieved by reductions in fishing effort through limits on pot numbers number of permitted vessels; a ban on landing egg-bearing females, and/or increased minimum landing size, or by controlling catches through implementation of a catch quota.</td></tr>
<tr><td colspan="2">Baseline:
First assessment of shellfish stocks in English waters in 2011: in most areas fisheries exploitation rates, minimum landing size and stock status are not in line with targets. Management measures do not control total catch from shellfisheries.</td></tr>
<tr><td>PV of costs:
Estimated at £20m (£6m/yr for 4 yrs).</td><td>PV of benefits:
Potential increase in catches of £120m+, avoided risk of stock collapse to 30% of current levels £340m+ (PV over 50 yrs, 2014 prices).</td></tr>
<tr><td>Monetised costs:
Foregone landings due to fishing effort reduction.</td><td>Monetised benefits:
Increased landings under recovery. Avoided loss of landings from collapse, compared to current levels.</td></tr>
<tr><td colspan="2">Non-monetised impacts:
Transitionary support may be required to adjust to short-term costs on some coastal communities. More efficient use of fishing effort. Climate change resilience.</td></tr>
<tr><td>NPV:
£100m+. BCR of 6:1 (£123m: £20m)</td><td>Time period:
Actions allow recovery over 10 years in crab and lobster species. Potentially sustainable benefits in perpetuity.</td></tr>
<tr><td colspan="2">Key assumptions:
Consequences of stock collapse similar to Spanish velvet crab fishery where landings reduced to 30% of pre-collapse levels.</td></tr>
<tr><td colspan="2">Additionality:
Additional action needed to achieve MSY, resulting in additional landings and reduced risks/costs of collapse.</td></tr>
<tr><td colspan="2">Synergies/conflicts:
May be complemented by saltmarsh improvements supporting more productive marine food webs.</td></tr>
<tr><td colspan="2">Impact on natural capital assets:
Biomass of marine shellfish species and marine ecological communities would be improved.</td></tr>
<tr><td colspan="2">Scale of impacts:
Applies to majority of shellfisheries in English waters. As UK trades shellfish in global markets,</td></tr>
</table>

diminishing returns to recovery (as a result of reduced prices in response to increased landings) are not regarded as a significant risk.
Distribution: Short-term costs of reduced fishing effort and catches, and long-term benefits of increased landings and lower risks, predominantly within coastal communities, particularly in north-east England. Stocks in better condition in the south-west, where costs and benefits of recovery expected to be lower.
Uncertainties: There is significant uncertainty in stock assessments, potential recovery and risk of collapse. No stock modeling is available at present. There is consensus over broad interpretation of available evidence.

Example: Lundy Shellfish stock recovery

Lundy's intertidal zone and surrounding marine area were designated as the UK's first Marine Nature Reserve (MNR) in 1986, which meant a ban on fisheries using trawls, dredges, or nets were banned. The main commercial fishery around Lundy is potting for lobster and crabs, and concern regarding its impacts led to designation of part of the area as a No-Take Zone (NTZ) in 2003. The NTZ was developed and agreed with local interest groups and implemented through a fisheries bylaw, extending around 3.6 km along the east coast of Lundy and 1 km out to sea. A four year experimental potting programme compared changes in the crustacean populations within the NTZ with those in two 'near control' and two 'distant control' locations which continued to be fished.

There was evidence of a rapid and large increase in the abundance and sizes of 'legal' (above Minimum Landing Size (MLS)) lobsters within the NTZ (as expected with the removal of fishing pressure). The results also indicated that spillover of lobsters under the MLS from the NTZ to adjacent areas had occurred, possibly due to increased competition for space within the NTZ, coupled with increased predation by adult lobsters on velvet crabs reducing competition between velvet crabs and juvenile lobsters. The NTZ also appeared to cause a small but significant increase in the size of brown crab (Cancer pagurus; another important commercial species for the North Devon fishing fleet) but a decrease in abundance of velvet crabs, likely due to predation and/or competition from lobsters (Hoskin et al. 2011).

1. INTRODUCTION

This evidence base looks at the case for investing in shellfish stock recovery in England. It reviews scientific evidence on the status of shellfish stocks (specially, Brown crab and Lobster), risks of collapse and potential for increased landings, in England.

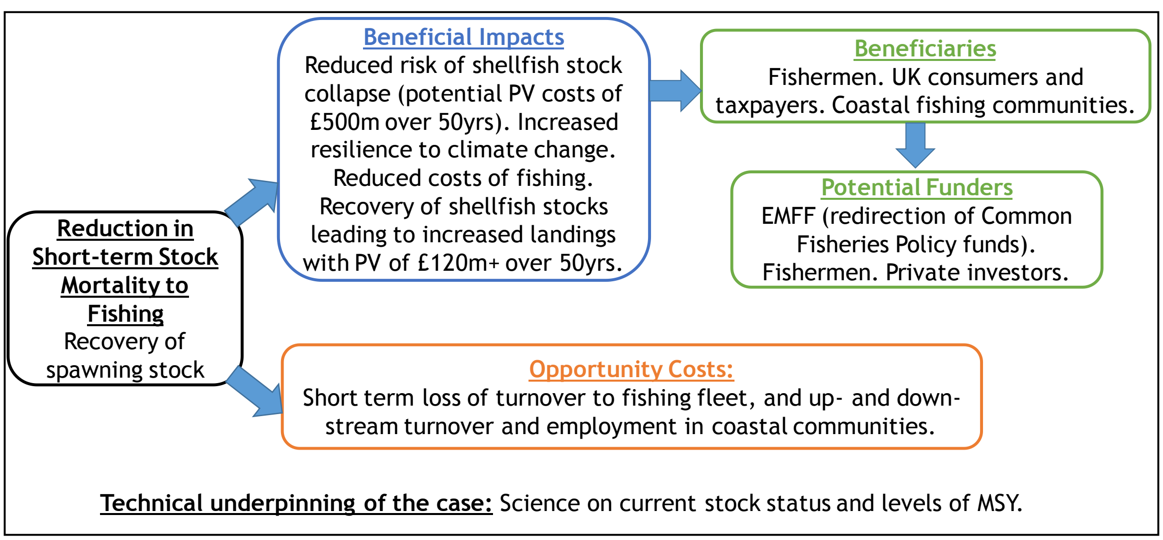
It focuses on the recovery of inshore shellfish stocks (crab and lobster) in English waters. This requires investment in the form of reduction of fishing pressure to levels that can generate Maximum Sustainable Yield (MSY). This is expected to lead to potential for increased landings (or same level of landings for lower effort), reduction of risk of stock collapse and prevention of loss of potential future benefits through over-exploitation.

Effective management and limitation of fishing effort would also avoid future increases in effort in the sector, which could be provoked as a result of increasing yields and/or changes in fishing fleet activity (e.g. due to the implementation of the discard ban in whitefish fisheries). Avoiding future increases in effort in the sector could avoid further over-exploitation and stock collapse, and associated decreases in landings and socio-economic impacts.

1.1. Investment Value Chain

The 'investment' required is a reduction of fishing effort in the short term to allow recovery of inshore shellfish stocks. An economic analysis of the costs and benefits of stock collapse or increase is presented, based on best available evidence (MMO landing statistics, Cefas shellfish stock assessments, other sources, landing statistics used are for 2009-2013 due to data deficiencies prior to 2008). The key impacts identified in this analysis are summarised in the following value chain.

Figure 0.1: Shellfish Investment Case - value chain



2. THE STATUS OF SHELLFISHERIES

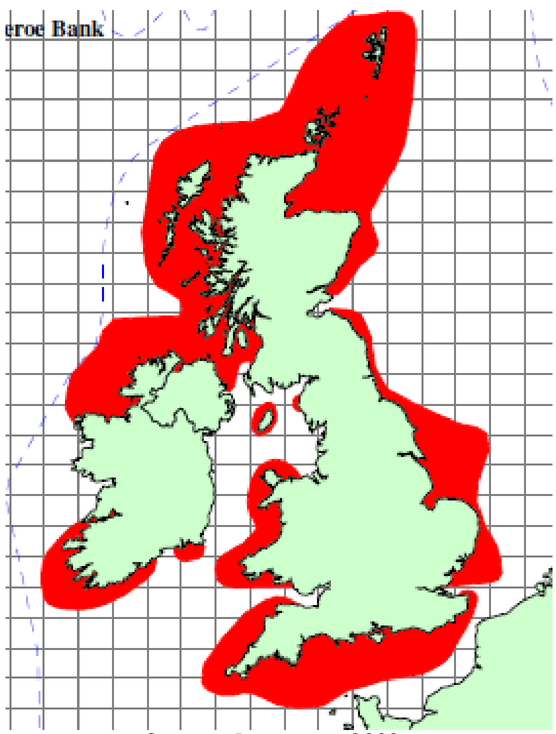
Brown crab and lobster are distributed all around the coast of the British Isles. The area of analysis comprises the marine waters of England, predominantly the inshore area.

Brown crab is widespread, with stocks distributed around the coast of the British Isles (Figure 2.1). Six stock units have been described, based upon what is known of the species' local biology and fishery. However, brown crabs may exhibit wide-ranging migrations, and the ICES Crab Working Group is progressing towards international assessments and management advice (Seafish, 2013).

Lobster is found mainly in the inshore area (Figure 2.2) Lobster stocks are mostly coastal with restricted movements once the larval phase has settled on the seabed, therefore they can be assessed and managed on a national basis (rather than at EU level) (Seafish, 2013). In English waters, five lobster stock units are used for assessment.

Crab and lobster stocks are not managed under the EU system of Total Allowable Catches (TACs) and quotas, and management controls have not restricted overall catches.

Figure 2.2: Brown crab fishing areas



Source: Bannister, 2009.

Figure 2.3: Lobster distribution

Source: Cefas, 2011e.

2.1. Baseline Condition of Natural Capital Asset

The first set of stock assessments for crab and lobster in English waters were published by Cefas in 2011. A summary is presented in Table 2.1. Proxy MSY levels were derived from 35% virgin Spawner Per Recruit (SPR) reference levels and the limit was defined as 15% virgin SPR. There is a high level of uncertainty surrounding the assessments, but most indications are that fishing intensity is too high on most stocks, and above levels that could produce Maximum Sustainable Yield. There is a high level of uncertainty with the assessments, but general consensus that fishing pressure is too high and stock sizes too low (limited evidence, high agreement) according to the Evidence Uncertainty Scoring Matrix.

In general, the stocks in the south-west (South-west lobster, and western channel crab) are in better health than those in the North Sea. Indications from stock assessments are that a reduction in fishing pressure could result in an increase in landings, or at a minimum, an increase in catch-per-unit-effort. Only crab stocks in the Western English Channel and Celtic Sea are at or around biomass levels capable of producing MSY.

Table 2.1: Summary of status of crab and lobster stocks in English waters

Species and area	Minimum landing size	Exploitation rate	Stock size	Discarding	Description	Source
Lobster						
Northumberland and Durham	○	○	○	✓	Stock size is very low, with females below the minimum recommended level. High risk of poor future recruitments. Exploitation rate is very high, significantly above the maximum recommended level, and has increased since 2008. Uncertainty score: 2.	Cefas (2011a)
Yorkshire Humber	○	○	○	✓	Stock status is very low, females are significantly below the minimum recommended level, increased risk of poor future recruitments. Exploitation rate is high, particularly around the Minimum Landing Size, but stable. Uncertainty score: 2.	Cefas (2011b)
East Anglia	○	?	?	✓	Stock status unknown due to changes in the way data have been recorded. Exploitation rate unknown due to data deficiencies. Uncertainty score: 2.	Cefas (2011c)
Southeast and South	○	○	○	✓	Stock status is low, spawning stock biomass are around the minimum recommended level, greater risk of reduced future recruitment. Exploitation rate moderate to high, around the maximum recommended level and needs to decrease significantly to achieve Fmsy. Uncertainty score: 2.	Cefas (2011d)
South-west	○	✓	✓	✓	Stock size above minimum recommended level but below MSY target, but are declining. Exploitation rate close to MSY level. Uncertainty score: 2.	Cefas (2011e)

Species and area	Minimum landing size	Exploitation rate	Stock size	Discarding	Description	Source
Crab						
Central North Sea	⭘	⭘	⭘	✓	Stock status is low and is around the minimum recommended level. Exploitation rates moderate to high, increasing but within recommended limit. Uncertainty score: 2.	Cefas (2011f)
Southern North Sea	⭘	⭘	?	✓	Stock size unknown. Landings and mortality rates are well above what is required for MSY – exploitation rates moderate to high, above max recommended level for females. Uncertainty score: 2.	Cefas (2011g)
Eastern English Channel	✓	⭘	✓	✓	Stock size moderate and above the minimum recommended threshold. Exploitation rates moderate to high, likely to be sustainable provided no further increases. Uncertainty score: 2.	Cefas (2011h)
Western English Channel	✓	✓	✓	✓	Large minimum landing size ensures multiple spawning events are possible before capture. Stock size is good, around the level required to produce MSY. Exploitation rates moderate to low, around the levels required to produce MSY. Uncertainty score: 2.	Cefas (2011i)
Celtic Sea	✓	✓	✓	✓	Stock size is good, approaching the level associated with MSY. Exploitation rates moderate, above MSY level but within recommended precautionary limit. Uncertainty score: 2.	Cefas (2011j)

Key: ✓ Satisfactory situation
⭘ Some concerns
✗ Does not achieve minimum recommended limits
? Unknown

Interpretation of symbols from ICES (2014).

[TBC: link to final report on uncertainty scores]

2.2. Trends

Cefas published the first stock assessments for Brown crab and lobster in 2011. The time series goes back to 1985 but landings data are only considered reliable from 2006, when the Registered Buyers and Sellers legislation resulted in increased landings declarations, and under-10m vessels started to submit logbook reports of their daily activity.

Landings of edible crab by English vessels into English ports have been increasing in volume and value over the last 5 years (Table 2.2). Similarly, landings of crab and lobster from the English inshore area (0–12 nautical miles zone) from all UK vessels have increased over the last 5 years (Table 2.3) Over the longer-term, crab landings have also increased, driven by crab fisheries expanding onto new grounds offshore, starting in the Channel in the 1970s and 1980s and in the Yorkshire and East Anglia fisheries in the 1990s. Since the 1980s, landings in the western Channel have fluctuated without trend, but on the east coast landings increased from the 1990s to reach a peak in 2003, but have since declined steeply (Bannister, 2009). Cost per unit effort is likely to be going up too, but there is no information about this - mainly because of the lack of information on effort.

Prior to 2008, most crab and lobster landings in England were exported to continental Europe — France, Spain and Portugal. However, following the financial crisis and economic problems in these countries, demand from these traditional markets fell. The industry has subsequently developed export markets in the Far East and China.

There is very limited information on fishing effort in the shellfish sector, as the number of pots set and the length of time they are in the water are not recorded. Although recent landings show an increasing trend, it is possible that this has been generated from an increase in fishing effort which will not be sustainable in the long term.

Table 2.2: Live weight and value of crab and lobster landed by English vessels into English ports (2009 – 2013)

Species	2009	2010	2011	2012	2013
Live weight (tonnes)					
Crabs	9,159	10,093	10,238	12,129	12,758
Lobsters	1,426	1,295	1,588	1,650	1,659
Value (£million)					
Crabs	10.76	12.66	13.66	15.81	17.12
Lobsters	12.76	12.21	15.66	15.75	16.50

Notes: Source: MMO, 2014. UK and foreign vessels landings by UK port and UK vessel landings abroad. Species selected: Crabs (C.P.Mixed Species), Crawfish, Lobsters, Mixed Crabs

Table 2.3: Live weight and value of crab and lobster landed by UK vessels from ICES rectangles overlapping the English 12nm zone

Species	2009	2010	2011	2012	2013
Species	2009	2010	2011	2012	2013
Live weight (tonnes)					
Crabs	7,992	9,015	9,843	11,650	12,385
Lobsters	1,473	1,334	1,712	1,778	1,823
Value (£ millions)					
Crabs	9.34	10.91	12.56	14.86	16.18
Lobsters	13.22	12.53	16.96	16.96	18.07

Notes: Source: MMO, 2014. Landings data by ICES rectangle for all UK registered vessels.
Species selected: Crabs (C.P.Mixed Species), Crawfish, Lobsters, Mixed Crabs
ICES rectangles selected: 28E3, 28E4, 28E5, 29E3, 29E4, 29E5, 29E6, 29E7, 29E8, 29E9, 30E4, 30E5, 30E6, 30E7, 30E8, 30E9, 30F0, 30F1, 31E5, 31E6, 31E7, 31F0, 31F1, 32E7, 32F0, 32F1, 33F1, 33F2, 34E9, 34F0, 34F1, 34F2, 35E6, 35E7, 35F0, 35F1, 36E6, 36E7, 36E9, 36F0, 37E5, 37E6, 37E7, 37E9, 37F0, 38E6, 38E8, 38E9, 39E8, 40E7, 40E8.

It is widely recognised within the industry that potting effort on crab has increased due to: the modernisation of traditional inshore fleets; advent of large mobile vivier crabbers; extension of the fisheries to offshore grounds; and the increase in number of pots being fished (Bannister, 2009).

The restriction of effort or spatial closures for certain gear types can provide opportunities for other gears that are not able to operate in the presence of the restricted gear type. For example, the Lyme Bay Fisheries and Conservation Reserve in Devon on the south coast of England was established in 2008. The resulting closure of a 200km^2 area to mobile bottom-towed fishing gear (scallop dredging, trawling) led to an increase in potting activity in the area (Attrill & Sheehan, no date). Additionally, restrictions on effort or catch in one fishery can have impacts on other fisheries, as vessels redirect their activities to take advantage of opportunities elsewhere (NSAC, 2014).

2.3. Pressure/driver impacting asset

The main pressure driving the status of crab and lobster stocks is fishing pressure, which represents the main source of mortality. In the event of a fishery being overexploited and collapsing, catches decline significantly. The decline of the velvet crab fishery in Spain in the early 1980s due to overfishing resulted in catches declining to 30% or less of levels achieved a decade earlier (see Box 2).

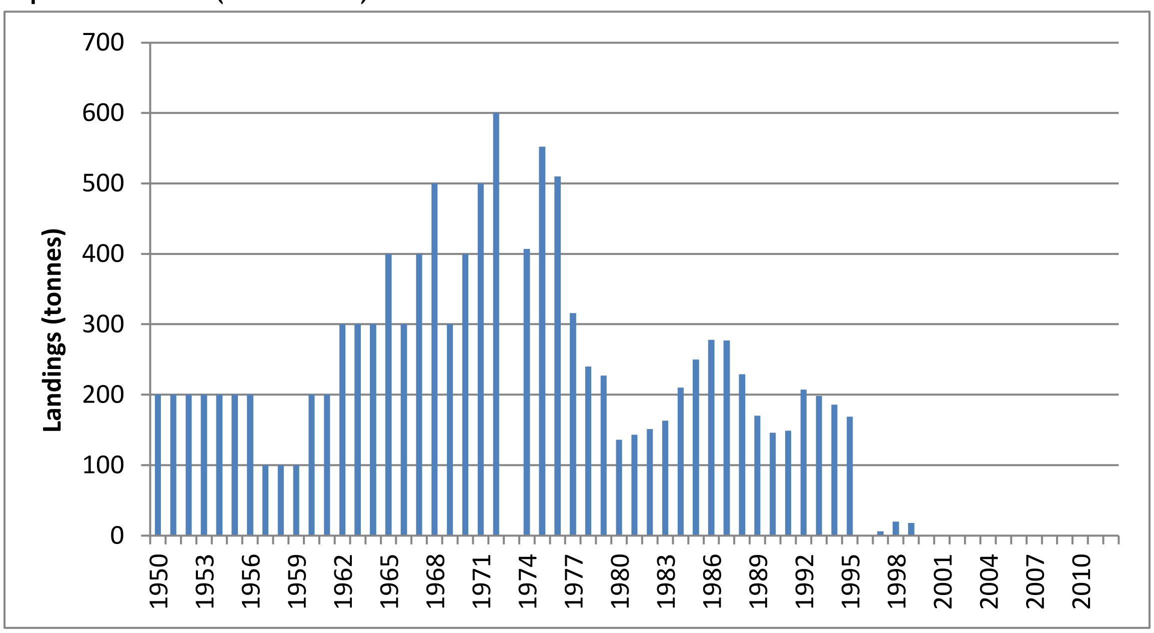
Box 2: Collapse of the velvet swimming crab fishery in Spain

In the early 1980s, the collapse of the Spanish velvet crab fishery led to new market opportunities for UK fishermen to export velvet swimming crab to Spain. The apparent collapse was due to a combination of lax enforcement of regulations and continuous heavy exploitation of the stocks (Hearn, 2002).

Reported Spanish landings of velvet swimming crabs from the North-east Atlantic area are shown in the figure below. Landings over the period 1970–1972 were on average 500 tonnes per year. In 1980–1982, this dropped to 143 tonnes per year, a decline to 29% of the previous catch levels.

In fact, the decline in the local fishery is likely to have been greater than this. The reported catches are from a wide area (North-east Atlantic). As the fishery in the Rías of Galícia declined, vessels are likely to have expanded their fishing area, maintaining a certain level of catches and masking the extent of the decline in the local area.

Landings of velvet swimming crabs by Spain from the North-east Atlantic region, as reported to FAO (1950-2012).



Source: FAO FIGIS. Species selected 'portunus swimming crabs nei'.

However, the ecosystem within which fisheries take place is complex and other factors, such as climatic variation, changes in salinity, temperature, currents and habitat can affect the size, growth and behaviour of shellfish stocks. Higher water temperatures result in faster growth rates of shellfish; and habitat features may play a role in determining both individual lobster size and population size.

Climate change and increasing ocean acidification may have a detrimental effect on shellfish stocks, as the change in ocean chemistry affects growth, activity and calcification of their shells (Miller *et al.*, 2009). However, the present understanding of the potential biological response is unknown (McNeil & Mataer, no date).

Other economic activities, such as oil and gas exploration, shipping, tourism and gravel extraction, may also affect the marine environment and shellfish stocks.

3. RESTORATION ACTIONS

In England & Wales most Brown crab stocks are overfished (i.e. fishing pressure is greater than the maximum recommended level, F > Fmax), except for male crab in the Western Channel (where F=Fmax), and fishing pressures is substantially higher than that required to produce MSY. This is reflected in a small average landing size for crab — if left to grow bigger, they could provide a higher catch.

Substantial reductions in fishing mortality for crab of 46–76% would be needed to achieve maximum sustainable yields, though this is subject to assumptions and uncertainties in the models (Bannister, 2009). An increase in fishing pressure above the present level will not produce long term gains in yield, and it will either risk the onset of overfishing or intensify overfishing.

Protecting and enhancing crab and lobster stocks would require reductions in fishing effort in the short term, and therefore reductions in catches and landings. As stocks rebuild, higher yields would be expected from lower levels of fishing effort. This would be due to the increase in stock sizes rather than increases in fishing efficiency per se.

Reductions in fishing mortality could be achieved through:

- Limitations on pot numbers (e.g. maximum number of pots per vessel, possibly with different levels for different size vessels);
- Limitations on the number of vessels permitted to fish for crab and lobster;
- A ban on landing berried (egg-bearing) females; and
- Increasing the minimum landing size, to allow individual crabs/lobsters more spawning opportunities before capture;
- Implementing a catch quota.

Analysis by Cefas (2005) concluded that for the inshore lobster fishery, an increase in minimum landing size to 90mm would be preferable to a ban on landing berried females, due to the short time-frame within which benefits are recouped (2 years, compared to 4-7 years for a ban on landing berried females), the benefits to yield per recruit expected (5–10% increase), and relative ease of enforcement.

The Shellfish Association of Great Britain (SAGB) recommend that at a minimum, fishing pressure should not be allowed to increase above the present level (Bannister, 2008). This is of particular concern in relation to the large number of under-utilised and dormant shellfish licences that are attached to vessels that do not currently target shellfish. This represents a large amount of latent capacity that could be applied in the shellfish sector and poses a risk to the sustainability of the sector. There is concern about the implementation of the landings obligation (discard ban) under the reformed CFP, due to come into effect in phases from 1 January 2015, together with the more restrictive quotas that are likely to be required to achieve the CFP goal of bringing fishing pressure down to levels commensurate with achieving MSY by 2015. The resulting constraints on fishing activity are likely to cause a number of vessels to redirect their effort from whitefish fisheries to the shellfish sector, where there are no quota restraints. This would result in a large influx of effort, increasing the level of fishing pressure, and would be likely to increase the overexploitation of shellfish stocks, similar to the situation that occurred in the Farne Deeps *Nephrops* fishery with the implementation of the cod recovery plan (NSAC, 2014).

The inshore fishing fleet (that targets shellfish) has a restricted operating range, and therefore any restriction would mean fishermen either have to leave the fishery, or target other species. However, opportunities on other species are becoming scarce as other stocks are overexploited, and there is limited availability of quotas for TAC-controlled species.

Lobster stocks are exploited more heavily than Brown crab stocks, and would benefit more from reductions in fishing pressure. Lobster stocks also have the potential to benefit more from restocking, due to the more localised nature of the fisheries (see Box 3). This might represent a strategy that could be employed in conjunction with a cap or reductions in fishing effort, to minimise the costs involved in restoring the fishery The implementation of closed areas has also been shown to provide 'spill-over' benefits for lobster (see Box 4), even though increased densities of lobsters within No-Take Zones may lead to increased levels of aggressive behaviour, causing increased risk of disease (Wootton *et al.*, 2012).

Box 3: Lobster restocking

Bannister (2013) provides examples of lobster restocking, and concludes that hatchery rearing of juveniles is feasible, but requires ongoing long-term operation and careful choice of sites. Hatchery lobsters will contribute to local egg production. Lobster restocking provides an option for restocking of empty habitat, restoration of collapsed fisheries, and enhancing yield of overfished fisheries. Lobsters are dependent on available habitat (suitable crevices for lobsters to live in) and the size of the stock can therefore be limited by the available seabed habitat.

Utilising hatchery-reared juvenile animals for stocking natural habitats for 'ranching' or stock enhancement has been successful in a few locations around the UK coast (Orkney Lobster Hatchery, 2010). Lobster restocking requires hatchery-reared juveniles (e.g. Stage XII, 12-15mm, 3 months) to be released into the environment. They should be released underwater onto boulder/cobble/creviced rock in small clusters (500–2000) to spread the risk of predation, currents etc. Release should be done in summer and autumn to avoid cold temperatures, as mobility is inhibited at temperatures below 7°C (Bannister, 2013).

Enhancing depleted fisheries *in situ* is potentially feasible technically, but quantitative issues still need case-by-case study e.g. scale of stocking required, carrying capacity effects, encounter/recovery rate factors. The recapture rate needed for lobster ranching to be profitable will depend on economies of scale of hatchery operations.

Ownership rights are needed to be able to capture the benefits of lobster restocking. The Sea Fisheries (Shellfish) (Amendment) Act 1997 extended the coverage of Several and Regulating fishery orders to encompass lobsters and other crustaceans. The Act allows additional management, over and above national or local regulations, for lobster fisheries where stocking is taking place through the use of a regulating order, and sole harvest rights can be assigned using a several fishery order. This provides the potential for secure tenure and harvesting rights for lobster restocking areas.

There is a good case to reduce fishing pressure significantly in order to achieve higher yields from brown crab fisheries in England and Wales (Bannister, 2009). However, given the uncertainties in the assessment method and data, a significant reduction in fishing pressure should be approached with caution. Further research and analysis could recommend the optimum trajectory for restoration. The risk of stock overexploitation should be considered against the potential benefits of stock recovery and the potential costs of measures that may be ineffectual.

Box 4: Indications of spill-over of lobsters from Lundy MPA

Lundy's intertidal zone and surrounding marine area were designated as the UK's first Marine Nature Reserve (MNR) in 1986, covering an approximate area of 30km^2. In 2000, this area was designated as a Special Area of Conservation (SAC) under the European Union's Habitats Directive, and in 2013, the waters around Lundy were designated as a Marine Conservation Zone (MCZ). The main commercial fishery around Lundy is potting for lobster and crabs. Fisheries using trawls, dredges, or nets were banned on designation of the MNR. Concern regarding the potential impacts of continuing fishing led to designation of part of the area as a No-Take Zone (NTZ) in 2003. The NTZ was developed and agreed with local interest groups and implemented through a fisheries bylaw, extending around 3.6 km along the east coast of Lundy and 1 km out to sea. Rocky and sedimentary habitats (mud habitats in deep water) are present within the NTZ, with the latter occupying the greater portion (Hoskin *et al*. 2011).

A four year experimental potting programme compared changes in the crustacean populations within the NTZ with those in two 'near control' and two 'distant control' locations which continued to be fished.

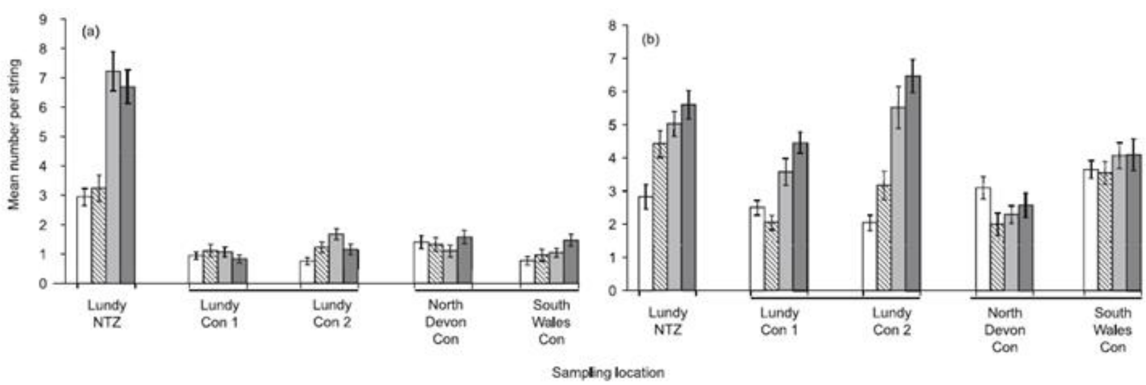


Fig. 2. Variation in the mean abundances of lobsters (*Homarus gammarus*); (*a*) legal-sized lobsters (carapace length, CL ≥ 90 mm) and (*b*) sublegal lobsters (CL < 90 mm) among NTZ, Near Control (Con 1, Con 2), and Far Control (North Devon, South Wales) locations in years 2004 to 2007. Each bar represents the mean abundance (±SE) per string of 10 pots over 5 d of sampling. Open bars are for 2004, hatched bars 2005, light grey 2006, and dark grey bars are for 2007.

Source: Hoskin *et al*. 2011.

There was evidence of a rapid and large increase in the abundance and sizes of 'legal' (above minimum landing size (MLS)) lobsters within the NTZ (as expected with the removal of fishing pressure). The results also indicated that spillover of lobsters under the MLS from the NTZ to adjacent areas had occurred (see Figure above), possibly due to increased competition for space within the NTZ, coupled with increased predation by adult lobsters on velvet crabs reducing competition between velvet crabs and juvenile lobsters. The NTZ also appeared to cause a small but significant increase in the size of brown crab (Cancer pagurus; another important commercial species for the North Devon fishing fleet) but a decrease in abundance of velvet crabs, likely due to predation and/or competition from lobsters (Hoskin *et al*. 2011).

3.1. Timescale of recovery

Reducing fishing pressure on shellfish stocks could start to realise benefits in a few years, and recovery would take up to around 10 years, depending on measures. Recovery times depend on both the reproduction and growth rate of the individual species, the extent to which a stock is currently overfished, and the measures taken to reduce fishing pressure.

For an increase in minimum landing size, benefits would be expected to start to be realised in 2 years for lobster (Cefas, 2005). For lobster restocking, benefits would be expected in 4-7 years. The benefits of technical measures for reducing fishing pressure on lobster vary regionally, and depend on compliance, but are reasonably certain to realise within 5-10 years' (Bannister, 2013). Age at maturity for Brown Crab is around 10 years (Neil & Wilson, 2008), therefore stocks can be expected to recover within that time frame.

Recovery of state in fisheries is non-linear. There is an initial cost to be borne in terms of reduced catch (which is effectively a deferral of future benefits as the stock rebuilds). The rate and trajectory of recovery will depend on the rebuilding strategy and management measures adopted. Whilst a fishing moratorium is the quickest way to achieve the target biomass and harvest rate, a longer rebuilding phase with less severe short-term costs may be a preferable option.

4. RESTORATION OUTCOME

Restoring and protecting shellfish stocks would provide an increase in yields through increased landings, providing increased levels of food provision and food security, as well as sustained profits for operators, potential for increased turnover for fish processors, and increased exports.

Stocks show the highest levels of exploitation on the east coast of England, and therefore also the highest potential for recovery. In contrast, the stocks in the south-west are in best condition, so the need for effort restrictions, and the potential for recovery, is less. Where effort is restricted on some stocks, precautionary measures should be put in place to avoid displacement of effort to other areas.

Protecting and enhancing inshore shellfish stocks can be expected to contribute to increased resilience of the marine ecosystem (i.e. capacity of ecosystems to absorb disturbances and regenerate (Folke *et al.,* 2004), particularly in the face of climate change, and reduced risk of stock collapse.

Maintaining fish and shellfish stocks at sustainable levels will contribute to avoiding stock collapse and associated biodiversity loss, contributing to the maintenance of ecosystem functions, productivity and recovery potential. Cardindale *et al.* (2012) identified that there is unequivocal evidence that biodiversity loss reduces the efficiency through which ecological communities capture biologically essential resources, produce biomass etc.; and found that biodiversity increases the stability of ecosystem functions through time, and increasing diversity of fish is associated with greater stability of fisheries yields. Similarly Worm *et al.* (2006) identified that rates of resource collapse increased and recovery potential and stability decreased exponentially with declining marine diversity, but restoration of biodiversity, in contrast, increased productivity. The valuation of these benefits is discussion a supporting note at the end of this document.

The inshore shellfish fisheries contribute significantly to coastal communities and local employment. The majority of the shellfish fleet (over 80% of vessels) comprises vessels under-10m in length operated by one or two fishermen per vessel, exploiting resources close inshore, and on a daily basis (Nautilus Consultants, 2009). Reducing the risk of stock collapse also reduces the risk of the costs on coastal fishing communities. The restoration of stocks to levels that can produce MSY would generate benefits of sustained and increased shellfish catches.

For a reduction in fishing effort to successfully result in restored stocks and future benefits, measures must be put in place to avoid future increases in effort in the fishery (which may be attracted by increasing yields in the shellfisheries, or may be pushed out of other fisheries due to increasingly stringent regulations therein). Measures to ensure secure tenure, such as effective limitation of fishing effort, and some kind of access or use right, can ensure that benefits are sustained and not dissipated through excessive effort. Measures based on catch quota would need more detailed data and scientific assessment and advice than are currently available and have relatively high administrative costs.

There are a number of uncertainties in the stock assessments for shellfish, including rates of natural mortality, larval dispersal patterns, and population dynamics. Further research could reduce these uncertainties and improve the predictions of stock assessment modelling.

5. DISCUSSION AND CONCLUSION

A number of scenarios were developed to explore the potential benefits of recovery of crab and lobster stocks, and the potential losses from overexploitation of stocks (see Section 5.1). These are described below, followed by discussion of the economic impacts of the different scenarios.

5.1. Shellfish scenarios

To explore the potential loss in value of landings if inshore crab and lobster stocks were to collapse, and the potential benefits from stock protection and enhancement, a number of scenarios were developed. These are based on the latest stock assessments by Cefas, evidence of recovery times from the literature, including predictions from simulation modelling by Cefas (2005) of different management scenarios, observations from the velvet crab fishery, and expert judgment to interpret sources such as Bannister (2013). The absolute level of losses or benefits realised may differ from thos under the different scenarios which are based on assumptions of stock behaviour and potential for recovery.

- **Scenario 1** – Status Quo (baseline). Catches of crab and lobster continue at current levels (based on the annual average for 2009-2013).
- **Scenario 2** – Protection and recovery of stocks through reduced fishing effort. Catches initially decline 20% for 3 years as fishing mortality is reduced to allow stocks to increase, then catches increase 10 percentage points per year until they reach +25% of current annual average landings. Catches reach the higher level in 2022 and remain at this level.
- **Scenario 3** – Stock collapse and recovery. Catches are stable at current levels for 5 years, then decline 15 percentage points per year, until they reach 30% of current annual average landings[5]. Catches reach the lower level in 2024 and remain at this level for 25 years. Subsequently stocks start to recover 10% per year based on the previous year's catches, until they reach the initial catch levels.
- **Scenario 4** – Stock collapse (severe)[6]. Catches decline 20 percentage points per year, until they reach 10% of current annual average landings. Catches reach the lower level in 2019 and remain at this level.

[5] Based on case study evidence from Spain (see Box 2).

[6] This is a worst-case collapse scenario. It is based on patterns of collapse in finfish stocks.

5.2. Economic Impacts:

The economic impacts of these scenarios can be calculated using the following data:

- Crab and lobster landings from the ICES rectangles that overlap the English inshore area for the period 2009–2013; and
- Average price of crab and lobster over the period 2009–2013, based on value and volume of reported landings, uprated to 2014 prices. Prices were assumed to stay constant over the period. Fishing costs were not factored in to the model.

Projections of the value of landings under each scenario are provided in **Figure 5.4**.

The net present value of landings in each scenario, using the HMT discount rate, are shown in Table 5.1 for both a 50 year timescale and a 25 year timescale.

Table 5.4: Net present value of landings under each scenario

Timescale	Scenario	Present value	Difference from baseline (scenario 1)
		(£ million) at HMT Discount rate	
50 years	1 Status Quo	734	n/a
	2 Recovery	857	123
	3 Overexploitation	394	- 340
	4 Overexploitation (severe)	120	- 614
25 years	1 Status Quo	511	n/a
	2 Recovery	579	68
	3 Collapse	283	- 228
	4 Collapse (severe)	98	- 413

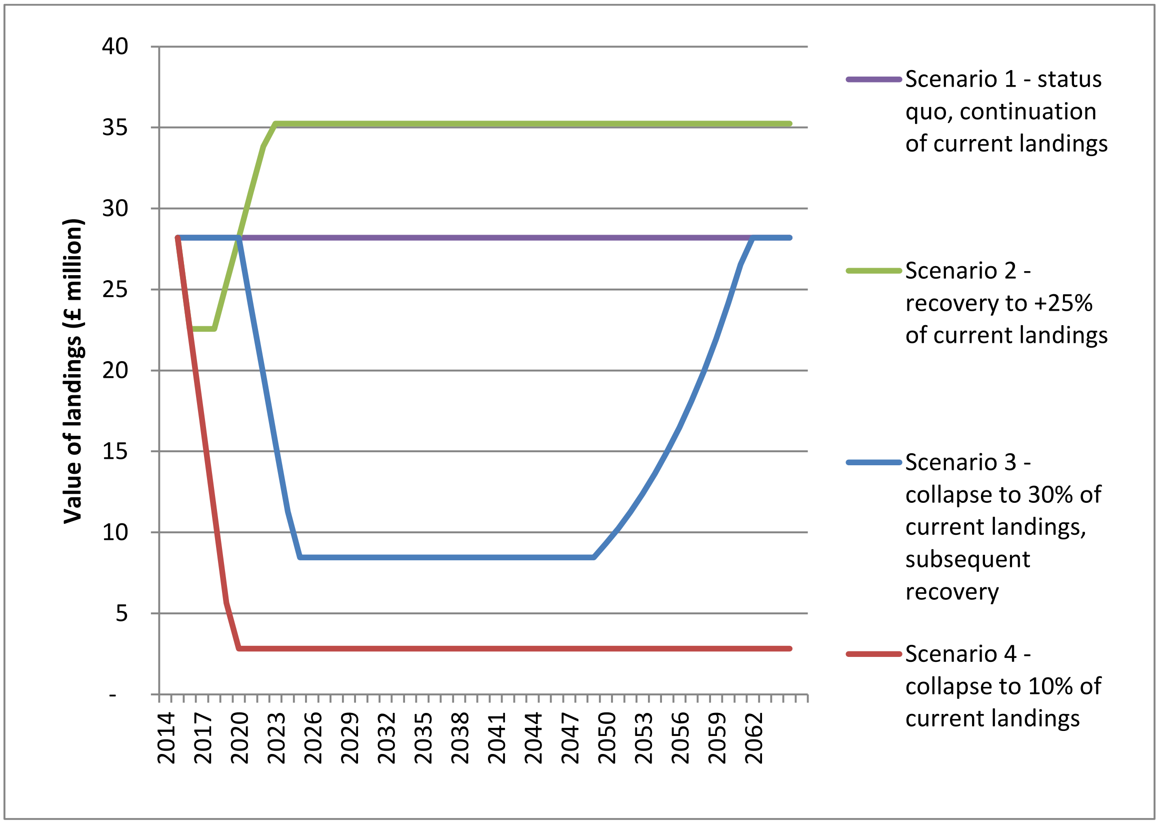
Recovery of stocks would support additional landings of £7m per year after the 7 years initial investment period. This would provide benefits with a present value (PV) of £123 million over 50 years, compared to the status quo (based on the value of landings under each scenario, using HMT recommended discount rates excluding costs not included in model). This is in contrast to overexploitation leading to stock collapse, which would result in the loss of value of landings of the order of £340–614 million (compared to status quo). The corresponding figures for a 25 year timescale are £68 million (benefits of recovery compared to status quo) and £228-413million (loss of value of landings with stock collapse due to overexploitation, compared to status quo).

The figures in Table 5.1 are uncertain due to the uncertainties in shellfisheries data that lie behind them. In addition, scenarios do not factor in fishing costs or the cost of restricting fishing effort, beyond that associated with the loss in the value of landings. However, the scenarios illustrate a range of potential values associated with shellfish collapse or recovery, demonstrating a significant potential increase in landings values from allowing stock recovery.

This benefit is outweighed by the potential risk to landings of stock collapse, which could result in loss of over half the value of the crab and lobster fisheries in England, worth at least £228-

340m over the next 25-50 years respectively, for collapse to 30% and subsequent recovery. For a severe collapse scenario (to 10% of current landings and no recovery), the associated values would be £413m-614m for 25-50 years respectively. These scenarios are illustrated in Figure 5.1.

Figure 5.4: Projections of the value of landings under different scenarios



The data modelled in Figure 5.4 indicate the scale of the short-term costs of investing in stock recovery, which is represented by the total value during the 4 years where landings under recovery scenario are below the status quo. The present value of this short-term foregone catch is £20m (some £9m for crab and £11m for lobster). This figure represents the costs of foregone landings that would need to be borne in order to invest in stock recovery. It would be mainly borne by fishermen in the inshore fishing fleet. It is an underestimate of total costs as there would be further related costs upstream and downstream economic activities, mainly in coastal communities.

5.3. Comparison of Costs and Benefits

The present value (PV) of the cost of investing in recovery of shellfish stocks is estimated at £20m of foregone landings over 4 years, plus the knock-on socio-economic costs associated with this in coastal communities. This represents a reduction of 20% against current landings, with a lost value of £6m per year. The benefits of recovery of stocks are estimated to have a PV of £123 million over 50 years, and the avoided risk of current overexploitation leading to stock collapse, which would result in the loss of value of landings of £340 million or more (PV over 50 years).

This investment therefore has a benefit:cost ratio of approximately 6:1 (£123:£20), and the added benefit of avoiding the consequences of stock collapse. If a stock collapse scenario is adopted as the baseline, then the investment has a benefit:cost ratio of 31:1 (£614m:£20m).

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SUPPORTING NOTE ON ADDITIONAL BENEFITS OF ACTIONS IN FISHERIES INVESTMENT CASES

Introduction

This is a supporting note which accompanies the fisheries investment cases considered in the Developing Economic Evidence on the Costs and Benefits of Investing in Natural Capital project. Two fisheries investment cases are outlined: (i) demersal fish and (ii) shellfish. Both cases consider the short-term costs of reduced catches and deferred future benefits from stock recovery.

In general, restoring fish stocks will result in benefits to other marine ecological communities (e.g. benthic flora and fauna) and species groups (e.g. marine mammals). However, these benefits are not directly captured in either of the two fisheries investment cases. This note briefly discusses these additional benefits with reference to key sources in the valuation literature.

Review of key economic valuation evidence

The economic value of these additional benefits is poorly covered by the literature, as is the case for many marine ecosystem services (UKNEAFO, 2011, Work package 3b). However, the available evidence shows that people have a positive willingness to pay (WTP) to preserve such benefits, with studies reflecting positive use and non-use values (e.g. Kenter, 2013). The environmental change valued in the literature is improved environmental quality as a result of achieving more sustainable levels of fishing.

McVittie and Moran (2008) estimated the use and non-use value for marine biodiversity in the UK. The study estimates the benefits of nature conservation measures in the draft Marine Bill, specifically, Marine Conservation Zones (MCZs). A contingent valuation survey is used to value environmental benefits arising from designations of MCZs described as the value of 'halting biodiversity loss'. The average WTP was found to be £30.6 per household per year in 2014 prices and aggregated at the UK population £826 million per year in 2014 prices[7]. McVittie and Moran (2008) suggest that a high proportion of this value is non-use value.

Jobsvogt *et al*. (2013) assess the value of biodiversity using a discrete choice experiment focusing on Scottish households' WTP for additional MPAs in the Scottish deep-sea. The study examines two specific dimensions of biodiversity as an ES: (i) the existence value of deep-sea species measured by the number of species present[8] and (ii) the option value of deep-sea

[7] This adjustment assumes roughly 27 million UK households in 2014. See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/189965/AllTablesNonRegionalFinal__3_.xls [Accessed November 2014]

[8] Expressed as a change of species numbers between 0% and 60% based on the scientific literature with a maximum of 1,600 species compared to the hypothetical baseline of 1,000 species.

organisms as a source of future medicinal products. As such, the study is one of the first to specifically focus on deep sea habitats. This is a growing area of research with studies offering the potential for further value transfer to be conducted in the future. The study gives a range of values low and high increases in species numbers (from 1,000 to 1,300 species and from 1,000 to 1,600 species respectively). Survey participants were told that deep-sea areas of 7,500 km2 (1.5% of Scottish waters; status quo in January 2012) are currently protected. The enhanced protection scenarios (both the 1,300 and 1,600 species scenarios) proposed a fourfold increase of the existing protected deep-sea area to 6% of Scottish waters.

The study determines the value of protecting deep sea environments in Scottish offshore waters per Scottish household per year to be £24 for the lower level of species protection and £36 for the higher level of species protection. Extrapolating this figure to gives a present value (PV) for all UK households of protecting deep sea environments from abrasion pressures of £0.77m - £2.4bn (Dickie et al, forthcoming). These figures allow for a lag in realisation of benefits following protection. The fisheries investment cases may not necessarily result in a reduction of abrasion pressure on the sea bed, but the scale of the values identified indicate a high value for protection of the marine environments in the UK.

Other evidence of individuals' WTP for benefits to other ecological communities is presented in Aanesen et al. (2014). While the study focuses on WTP for the protection of cold-water corals (CWC) off the Norwegian coast, its results may also be indicative of values held by the UK population. It may also be possible to transfer the original results to the UK context by making adjustments for income, sea area and population size. The survey conducted in the study showed a median WTP for cold-water coral protection in the range of £29 to £60 per household (Norway) per year in 2014 prices[9]. The design of the study's survey enabled a distinction to be made between a direct non-use value for CWC, and non-use values for CWCs due to their importance for the existence of fish which in turn has a use value. One result of the survey is that households' non-use values exceed use-values.

Conclusion

Investments in the restoration of specific marine habitats will necessarily affect other marine habitats. This is echoed in the marine economic valuation literature by studies which consider improvements in bundled ecosystem services (i.e. all ecosystem services provided by a given habitat) to recognise the interconnected nature of the marine environment. Valuing the bundle of ecosystem services has been present in environmental-economic valuation literature for some time. For example, Luck et al. (2009) discuss the idea of extending the concept of organisms or communities contributing to a single ecosystem service to their contribution to bundles of services (i.e. multiple services that are provided by a collection of organisms). The conclusion for the fisheries investment cases is that they will not only produce benefits of increases in fish / shellfish populations and the market values of landings. They will produce

[9] Prices are converted from Euro to GBP using an exchange rate of 1.26 € per £ on November 26th, 2014. See http://www.xe.com/currencyconverter/convert/?From=GBP&To=EUR [Accessed November 2014].

other benefits for the marine environment, and if the value (both use and non-use values) of these could also be included, the overall benefit estimates would increase.

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