Economics of Climate Resilience Natural Environment Theme: Sea Fish CA0401

A REPORT PREPARED FOR DEFRA AND THE DEVOLVED ADMINISTRATIONS

February 2013

Economics of Climate Resilience Natural Environment Theme: Sea Fish

Economics of Climate Resilience Natural Environment Theme: Sea Fish

Context of this report

The Economics of Climate Resilience (ECR) has been commissioned by Defra and the Devolved Administrations (DAs) to develop evidence to inform the National Adaptation Programme and the adaptation plans of the DAs. The report should be read in the context of other programmes of work on adaptation being taken forward separately.

The scope of the ECR

The ECR follows the publication of the UK Climate Change Risk Assessment (CCRA) in January 2012 and differs in scope from work envisaged prior to that date. While its original aim was to consider individual climate change risk metrics from the CCRA and specific adaptation options, this evolved as the project was considered across government departments. The current ECR therefore focuses on broader policy questions, with each report covering multiple climate risks and CCRA risk metrics. In this context, the economic assessment is broader than a quantitative assessment of costs and benefits – it concerns identifying and assessing market failures and other barriers to effective adaptation action, seeking to understand drivers of behaviour which hinder or promote the adoption of adaptation actions. The framework for assessing the costs and benefits of adaptation actions is considered in a separate phase of the ECR.

Questions addressed

The questions addressed by the ECR were chosen following cross-government engagement by Defra. They ask whether there is a case for further intervention to deliver effective adaptation given the current context – i.e. the current adaptive capacity of those involved and the policy framework. Criteria for the choice of questions by policy officials include: the current and projected degree of the climate change risk; priorities for additional evidence gathering beyond that already being considered in other work-streams, and the data and evidence currently available. Questions were deliberately broad to allow the wider context to be considered, rather than just individual climate metrics. However, this approach prevents a detailed evaluation of individual risks or localised issues being made. Detailed assessments of climate thresholds and the limits of specific adaptation options have also not been possible.

Analysis undertaken

The analysis has sought to build on existing assessments of current and projected climate change risks (such as the CCRA). The context in which sectors operate has been assessed, including the current adaptive capacity of relevant actors and the policy framework in which those actors function. Categories of actions currently being taken to adapt to climate change have been explored, including those which build adaptive capacity where it is currently low, and those which limit the adverse impacts or maximise opportunities, allowing identification of barriers to effective adaptation. The case for intervention is then presented.

The degree to which an adaptation action is likely to be cost-effective requires more detailed assessment, reflecting the particular context in which adaptation is being considered.

This report is underpinned by stakeholder engagement, comprising a series of semi-structured interviews with sector experts and a range of other stakeholders. This has enabled the experiences of those who undertake adaptation actions on the ground to be better understood. We are grateful to all those who have given their time.

Executive Summary

1 Executive Summary

This report addresses the question:

"What is the case for further intervention to maximise the potential opportunities for the UK that arise from the climate-change-driven movement of wild sea fish stock in response to ocean warming, whilst minimising potential adverse effects?"

Projected opportunities and threats

Rising sea temperatures, as projected by UKCP09[1], are expected to impact marine fish stocks and their distribution in the UK Exclusive Economic Zone (EEZ[2]). A key expected impact is a move northwards of some cold-water species currently popular in the UK, such as cod and haddock, out of the UK EEZ (Pinnegar et al., 2012[3]).

However, the projected movements of warm water species, (e.g. squid, anchovy and sea bass), into the UK EEZ balances this effect. A global review of the impacts of climate change on fish yields by Cheung et al., (2009b) estimates that overall, the UK would benefit from increased net yields of 1-2% between 2009-2050. Achieving this relatively low net positive effect requires action to maximise opportunities.

Sophisticated modelling techniques, applied by Jones et al., (2012), project increases in habitat suitability within the UK EEZ for a number of warm-water species[4] (**Table 1**). However, projecting the future impacts of climate change on fish yields for the UK fishing industry is complex and uncertain and although current projections use the best available models, they are subject to uncertainty. This is, in part, owing to uncertainties around the projected change in sea temperatures; the consequent impact on fish stocks and their distribution; and, the impacts of non-climate change drivers on habitat suitability[5].

---

[1] Multi-level ocean projections are given in section 6.3.4 of the UKCP09. Generally shelf seas around the UK are projected to be 1.4-4^{o}C warmer by the end of the 21st century under a medium emissions scenario.

[2] EEZ is the maritime zone adjacent to the territorial sea within which the coastal state has sovereign rights for the purpose of exploring, exploiting, conserving, and managing natural resources, both living and non-living, of the seabed, subsoil, and the subjacent waters and, with regard to other activities, for the economic exploitation and exploration of the zone (e.g., the production of energy from the water, currents, and winds).

[3] See Annex 2 for details.

[4] These opportunities include a variety of pelagic and demersal species, which could be fished by a broad section of UK vessels.

[5] These include: bathymetry, salinity; ice; primary productivity and distance to coast.

Table 1. Projected change in habitat suitability

Species	Benchmark UK catch in 1985 (tonnes)	Recorded UK catch 2010 (tonnes)	Increase in habitat suitability 1985-2050
European anchovy	0	319	+1 to +7%
European sea bass	127	739	-9 to +24%
Common squids	469	3,800	+4 to +11%
John Dory	50	332	-16 to +17%
Red mullet	62	444	-14 to +28%

Sources: Jones (2012) increase in habitat suitability, ICES recordings of UK catch for 1985 (average of 1984-1986) and Cefas landings by UK vessels into UK ports.

Given current and projected change in habitat suitability, how is the UK responding?

The industry operates within a complex regulatory framework, largely determined at EU level. The objective of policy is broadly to sustain viable fisheries as part of a healthy and resilient marine environment (OECD, 2010). Fishing quotas and other restrictions mean that vessel operators must work within given constraints. The policy framework therefore impacts the sector's flexibility to adapt, particularly through quota constraints, and the degree to which their allocation is based on historic activity.

Against the background of current policy, the adaptive capacity of the UK fishing industry as a whole is assessed to be relatively high. This is because it has strong commercial incentives to make the most of profitable opportunities. Fishing vessel operators are used to dealing with constantly changing weather, fish stock sizes and locations, and market prices for their outputs. However, the ability of some segments within the sector (e.g. small vessel operators) to adapt is likely to be more constrained than others.

A range of actions are already being taken in the UK to maximise opportunities. These include those to increase adaptive capacity where it is currently low, as well as adaptation actions to make the most of opportunities.

A range of actions currently being taken by the industry, or which may be undertaken in the future, including:

- **Travelling further to fish for current species,** if stocks move away from UK ports.

- **Diversifying the livelihoods of port communities**. This may include recreational fishing where popular angling species become locally more abundant (e.g. sea bass).
- **Increasing vessel capacity** if stocks of currently fished species increase.
- **Changing equipment to fish for different species** if new or more profitable opportunities arise**.**
- **Developing routes to export markets to match the changes in catch supplied.** These routes may be to locations such as southern Europe, which currently eat the fish which may move into the UK EEZ.
- **Stimulating domestic demand for a broader range of species,** through joined up retailer and media campaigns.

Where the degree of adoption of effective adaptation actions is low, barriers have been identified. Intervention would be required to address them.

Barriers and constraints to adaptation and the case for intervention

Barriers identified in relation to market failures, policy barriers, behavioural constraints and governance issues are:

Market failures

Information failures exist in relation to uncertainty around new or emerging species in the UK EEZ. Such information barriers often stem from the high cost associated with gathering the information through scientific studies and the time it takes to collate it.

However, as fish distributions continue to change, information on the degree of change currently occurring and expected will be necessary for effective adaptation actions to be implemented over time.

Information barriers mean that not all vessel operators are necessarily aware of best practice techniques used by foreign fleets that can allow opportunities to be maximised, given the changing distributions of fish stocks.

Although some information-sharing channels already exist in relation to maximising opportunities associated with changing fish species and their distribution, these could be enhanced. Existing channels include those provided by producer organisations and other sector organisations, such as Seafish and the Fisheries Science Partnership program.

Policy barriers

Regulation is in place to ensure sustainable catch levels, but for quotas to keep pace with changing stocks relies on scientific evidence being collected and accounted for by policy makers in a timely way. This process is lengthy and backward looking so there is a risk that quota allocations restrict fishing activity where stocks are increasing, or changing their distribution, and in some circumstances incentivise maladaptation[6].

Behavioural constraints

UK consumer preferences largely favour a relatively limited number of fish species. Although emerging species can be sold to niche markets and restaurants, for the most part, such species are exported. This limits the ability of the UK, and its local economies, to benefit from the location of the value chain within the UK. In addition, species landed by some vessels (such as smaller vessels at smaller ports) may be unable to reach the bigger exporting fish auctions.

Recommended interventions

- **Enhance the capability to monitor new and more abundant species**, involving collaborative working of fishing vessel operators with the scientific community.
- **Support the scientific and technical facilities, which can improve the understanding of new or emerging species in the UK EEZ**. This would provide the information necessary for the industry better to anticipate opportunities and make necessary investments and changes quickly.
- **Use appropriate existing communication channels to engage with vessel operators and embed learning in relation to best-practice fishing behaviours for new, or more abundant, species.** This could be through expanding existing channels to ensure more information and guidance is collected, and making information available a clear, accessible and practical way to a wide number of operators of large and small vessels.
- **Undertake research and analysis into methods to increase the flexibility with which vessels can adapt, for example by trading quotas across operator of all sizes of vessel (large and small).** Implement appropriate action to increase flexibility. The ability to trade quotas internationally is being debated as part of the reform of the common fisheries policy.

[6] Actions or investments that enhance vulnerability to climate change impacts rather than reducing them (UKCIP, 2012). For example, where species are not under quota, but emerging abundance creates potential expectations of future quota restrictions, quota allocations based on levels of historic catch can incentive overfishing in order to build up the historic catch to increase any future quota allocation.

- **Proactively support the diversification of consumer demand** through the provision of information to consumers about a wider range of fish species and through marketing. The media and retailers have been identified as particularly successful in raising awareness and increasing demand for niche species. Further options could be explored to support these activities, including educating consumers about different varieties of species, their preparation and taste.

2 UK Fishing Sector

2.1 Focus of this report

This report investigates whether individuals and organisations in the UK fisheries and fish processing sector can be expected to adapt to the opportunities and threats associated with climate change-driven warming of sea temperatures. This analysis addresses the following question set by policy leads in Defra:

What is the case for further intervention to maximise the potential opportunities for the UK that arise from the climate-change-driven movement of wild sea fish stocks in response to ocean warming, while minimising potential adverse effects[7]?

2.2 Approach

This report reflects analysis undertaken over a period of two months.

The UK Climate Change Risk Assessment (CCRA) (Pinnegar et al., 2012) indicates that the sea surface temperatures around the British Isles are expected to increase as a consequence of global warming and that this will bring about a change in species available for capture by the UK fishing industry. Some species, such as cod and haddock, are expected to move northward, out of UK territorial waters, whilst other species, such as anchovy and sea bass, are expected to move northward into the UK EEZ. This is anticipated to present challenges but also opportunities for the UK.

To assess whether the UK is able to adapt effectively to maximise the potential opportunities this may bring, this report investigates the current context in which the sector operates. This includes an assessment of the current policy landscape and the adaptive capacity of both vessel operators and consumers. Actions currently being implemented and those likely in the future are assessed in terms of their uptake and effectiveness. This allows identification of barriers to adaptation and therefore where intervention would be required to facilitate effective adaptation.

The analysis draws on a wide published evidence-base and evidence from stakeholder engagement.

[7] Consideration of shellfish, aquaculture and the impact of increased ocean acidification are therefore beyond the scope of this question.

2.2.1 Stakeholder engagement

Stakeholder engagement has been a key source of evidence, providing input from those who would be responsible for taking adaptation actions on the ground. Stakeholders include representatives from marine science, academia, as well as large and small vessel fleet owners, producer organisations and policy makers (Annex 1).

This work has also benefited from an Expert Panel of individuals from Cefas and the Marine Climate Change Impact Partnership (MCCIP). We are particularly grateful to Dr John Pinnegar of the Centre for Environment, Fisheries & Aquaculture Science (Cefas) and the Marine Climate Change Impacts Partnership (MCCIP) and to Miranda Jones of the University of East Anglia.

2.2.2 Analysis

The assessment of adaptive capacity and adaptation actions draws on an evidence-base informed by in-depth analysis of published literature and statistics, complemented by stakeholder views and expertise. Much of the analysis is drawn from modelling results prepared by Miranda Jones of the University of East Anglia and supported by the Defra project Adapting to Climate Change in the Marine Environment (ACME).

The barriers to effective adaptation, including where adaptive capacity may be constrained, are based on the categorisation of:

- Market failures: these may relate to market power and pricing signals, and externalities[8] as well as arise when information may not be timely, accurate, relevant or is incomplete;
- Policy: the framework of regulation and policy incentives;
- Behavioural: short-sightedness and willingness to act; and,
- Governance: institutional decision-making processes.

The quantitative and qualitative analysis presented differs to that of the UK CCRA, reflecting the specific question to be addressed in this report.

There are a number of uncertainties and limitations of the analysis of adaptation actions including:

[8] Where there are costs or benefits imposed on others that are not accounted for in individual decision-making.

- **Comprehensiveness:** Stakeholders across the industry were interviewed. Some stakeholders were not available for comment and they may hold alternative views or information.

- **Availability of evidence:** this report relied on the evidence and data provided by stakeholders and available published reports.

- **Uncertainties:** Evidence on the future movement of species, suitability of habitats and increases in maximum catch potential was evaluated using three different models. The results of each of these models are varied, indicating a high level of uncertainty around the scale of the challenge.

This work is focused on the potential case for further intervention to facilitate effective adaptation. It does not present cost benefit analyses. The latter would be needed to test whether actions would be justified under particular conditions or in certain locations.

2.3 Structure of the report

This report is structured as follows:

- **Section 2** describes the predicted biophysical effects of climate change on marine fin-fish in the UK EEZ and what this could mean in terms of potential opportunities or risks for the future economics of fish capture;

- **Section 3** describes the current context for adaptation, including the policy landscape and adaptive capacity;

- **Section 4** discusses in more detail the adaptation actions that are currently being taken by the sector and others to maximise opportunities associated with changing fish stocks; and,

- **Section 5** summarises the barriers to effective adaptation currently being faced by the sectors, and the case for intervention to address those barriers.

3 Scale of the challenge and opportunity

Key messages

- Sea-water temperature is expected to increase due to climate change, creating habitats suitable for cold and warm water fish at more northerly latitudes.
- A slight increase in yields will be the net effect of both reduced and increased fish stocks in different locations and across different species within the UK EEZ. Opportunities for new fisheries emerging in the UK EEZ, include species such as John Dory, sea bass, anchovy and squid.
- There is a degree of uncertainty built in to climate change modelling and projections (UKCP09)[9]. Additionally, there are few reliable measures of what this may mean for fish stocks.
- Non-climate change drivers of fish stocks and their distribution are important to recognise and include fishing effort levels, fishing gear technology and other habitat uses (such as at sea wind farms).

This Section presents an assessment of the current and projected change in fish stocks and distributions given projected climate change.

3.1 Climate-related drivers of fish stocks

Climate change is predicted to have a number of effects on the environments in which fin-fish live[10]. Fish are mobile and survive in, or move towards, suitable habitats. A number of drivers impact species distribution including, food availability, depth, salinity, shelter and suitable spawning ground. There are a number of climate-related drivers of habitat suitability. The key long-term changes identified by Pinnegar et al., (2012) include changes to seawater temperatures, and ocean acidification.

---

[9] Uncertainty in modelling climate change is due to natural climate variability, an incomplete understanding of the Earth system process and uncertainty over future emissions (Murphy et al., 2009)

[10] Other impacts could include sea level rise, which may result in a loss of coastal habitats and changes in ocean current which could affect fish recruitment (Allison et al., 2009)

3.1.1 Sea temperature

Changes in sea surface and bottom temperatures can result in a number of impacts on fish stocks:

- The 'centre of gravity' of the fish stocks move to maintain a certain temperature; this is likely to result in a movement of stocks northwards.
- Timings of the peak abundance of stocks may change.
- The spawning stock of the fish decrease/increase, as the survival of their young reduces/increases where the temperature changes.

3.1.2 Ocean acidification

Oceans may experience increased acidification due to rising CO_2 levels in the atmosphere. There is some evidence that pH levels have already dropped due to a rise in CO_2 from pre-industrial levels (Pinneger et al., 2012). The relationship between atmospheric CO_2 and ocean acidification is well understood and can be modelled.

However, the impact of increased ocean acidification on fin-fish species is not well understood, with views ranging markedly about how marine ecosystems will be affected (e.g. Le Quesne & Pinnegar, 2011). Accurate projections of this impact are a number of years away (Pinneger et al., 2012), although there is some consensus that shellfish may be particularly adversely impacted. Contradictory findings for species such as mussels mean that it is exceedingly difficult to 'scale up' to a full economic analysis. Added to this, there is great uncertainty about indirect effects, for example, climate change impacts on commercial fin-fish that consume vulnerable marine invertebrates (Le Quesne & Pinnegar, 2011).

Other impacts that are less well-understood and hence not directly addressed in this report include changes in terms of storminess, cloud cover, low oxygen and ocean currents; variabilities which may impact the distribution of species year to year. As such, the UK fishing industry is currently adapting to changes, albeit over the shorter term.

3.2 Current and projected impact of climate change on marine fish stock distributions

The effect of increasing water temperature is already being seen and measurements of the impact are currently being performed. These measurements form the basis of future forecasts under the range of UKCP09 emissions scenarios. A worldwide analysis of future global movements in fish species (Cheung et al., 2009) estimated a net 1-2% increase in catch potential in the UK EEZ by the 2050s. This net impact will be the result of many opportunities and losses from a mix of species and locations. Very few analyses have been undertaken to assess separately the impact on species and locations within the UK EEZ. Where analyses have been undertaken the results are variable.

Pinnegar et al., (2012) presents results of a simple response function model looking at the impact on distributions of stock in response to sea temperature increases and correlations between recruitment success (spawning stock survival) and climatic variables (including sea temperatures). Results are presented for species currently commercially important to the UK industry (sole, plaice, cod and haddock), and are presented in Annex 2.

This report presents more sophisticated analysis undertaken by Miranda Jones at the University of East Anglia, for Cefas (under the Defra project 'ACME' and reported in Jones et al., 2012). This analysis tests the impact through three different models and assesses both historic key species, but also emerging species. These are typically warmer water species which currently proliferate in the Bay of Biscay and may represent important future opportunities for the fishing industry. The models test both changes in habitat suitability (ranging from a highly suitable habitat ('1') to an unsuitable habitat ('0')), and distribution (identified by a latitudinal shift in the centroid of the species distribution).

Annex 3 details the three models used in Jones et al., (2012), two (MAXENT and AquaMaps) are statistically-based models, modelling responses of distributions of species over 1971-2000 against environmental data[11] during the same period, thereby obtaining a bioclimatic envelope for each species.

The third model, the Dynamic Bioclimatic Envelope Model (DBEM) (Cheung et al., 2011) uses a discriminative approach (Jones et al., 2012) and attempts to avoid the bias that might be introduced by skewed distribution of sampling effort present in many datasets collected sporadically. The DBEM combines statistical and mechanistic approaches in predicting species' distributions. It differs from other bioclimatic envelope models in simulating changes in a species' relative abundance by incorporating a logistic population growth model (Cheung et al., 2008) as well as ecophysiological parameters.

The approach initially employs a discriminative method, applying a set of key environmental 'filters', to reduce a species' potential range. From this reduced theoretical distribution, the DBEM defines the species bioclimatic envelope by its 'preference profile' (the relative suitability of different environmental values) for each environmental variable. Preference profiles were thus created by overlaying environmental data from 1971 – 2000 with maps of current relative abundance. Variables incorporated into the DBEM include sea surface temperature, sea

[11] Environmental oceanographic variables accounted for: (i) bathymetry, (ii) sea surface temperature (SST), (iii) sea bottom temperature (SBT), (iv) salinity; (v) ice; (vi) primary productivity, and, (vii) distance to coast

bottom temperature, coastal upwelling, salinity, distance from sea-ice and habitat types (coral reef, estuaries and sea mounts) (Cheung et al., 2009, 2011).

Two sets of oceanographic variables (future emissions scenarios) were obtained, (1) from the Geophysical Fluid Dynamics Laboratory Earth System Model (GFDL ESM2.1, Dunne et al., 2010) and physical climate data from an ensemble of 12 different CMIP3 models that were assessed by the fourth assessment of the Intergovernmental Panel on Climate Change (IPCC, 2007) (CMIP3-E). Both datasets represented the IPCC 'A2' emissions scenario, thus being characterised by a heterogeneous world with a continuously increasing global population and regionally orientated economic development (IPCC, 2000).

The results of these analyses are presented in **Table 2**.

Table 2. Results of modelling of changes in habitat suitability and latitudinal centroid shift between 1985-2050

Common Name	Change in habitat suitability across the UK EEZ (1985-2050)		Latitudinal centroid shift northward (km) (1985-2050)	
	Median of three models	Range of three models	Median of three models	Range of all three models
European squid	31%	+9 to +53%	445	308-625
European sea bass	20%	-9 to +24%	275	224-399
European pilchard	17%	+2 to +30%	314	178-322
European sprat	13%	+4 to +21%	224	148-278
Veined squid	7%	+4 to +11%	211	140-251
John Dory (Atlantic)	7%	-16 to +17%	264	-153(s) -428
European anchovy	5%	+1 to +7%	320	18-1192
Common sole	2%	-18 to +18%	112	-24(s) - 232
European plaice	2%	+1 to +8%	205	105-389
Whiting	1%	-14 to +4%	97	-14(s)-190
Atlantic cod	0%	-12% to +3%	223	149-343
Atlantic Herring	-2%	-20 to -1%	168	62-748
Atlantic mackerel	-3%	-7 to 0%	206	97-337
Atlantic halibut	-4%	-15 to +1%	172	27-311
Haddock	-6%	-12 to 0%	195	50-454
Red mullet	-10%	-14 to +28%	263	-27(s)-432
European hake	-10%	-11 to +2%	150	29-293
Saithe	-12%	-18 to -2%	172	78-596

Source: Jones, 2012.

Notes: (s) signifies the shift is negative and therefore southwards.

Scale of the challenge and opportunity

3.2.1 The impact of climate change on habitat suitability, and the mix of species in the UK EEZ

Although the results of all three models vary, there are species for which there is a consistently predicted increase in habitat suitability in the UK EEZ, such as squid, pilchard, sprat, anchovy and plaice. Species for which the models consistently predict a decrease in habitat suitability are fewer (e.g. herring). For a number of species it is inconclusive and the variability of the results can be broad.

The scale of the impact of climate change across all three models and species is broadly below levels of 25% change. The models identify a mix of both increases and decreases in suitability.

However habitat suitability (shown in **Table 2**) can only be seen as an indicator as to the scale of change; the mechanism by which habitat suitability directly impacts sustainable levels of catch has not been directly assessed.

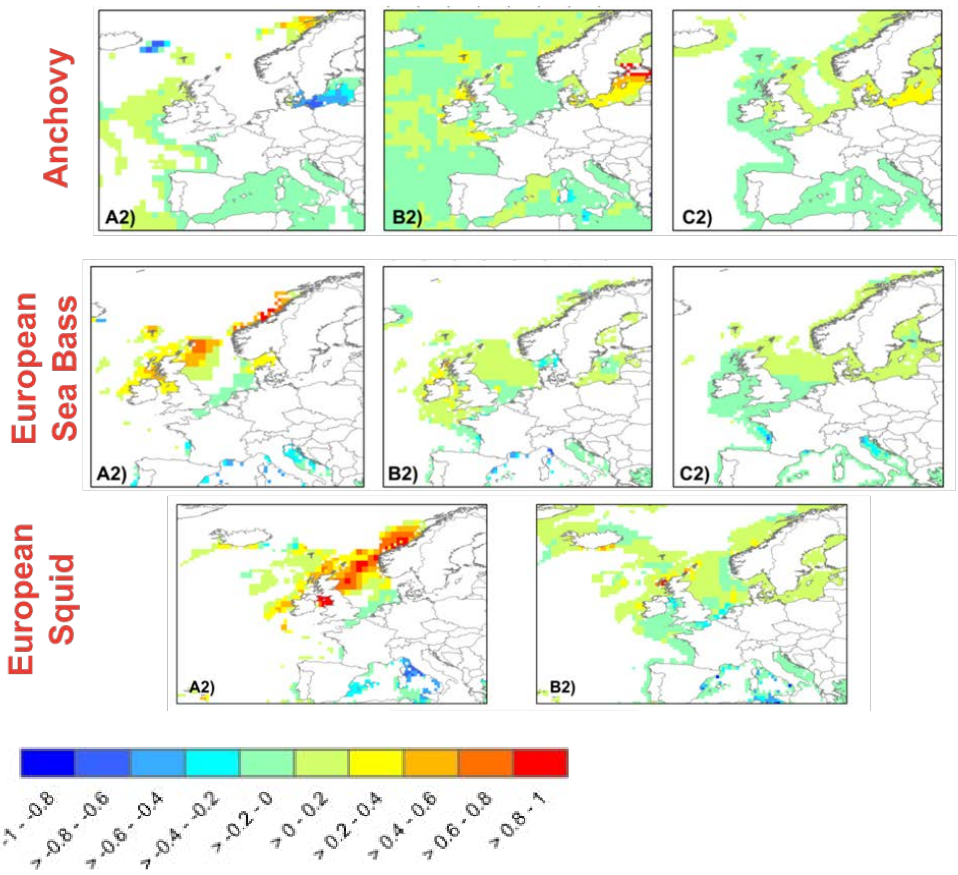
3.2.2 The impact of climate change on species locational centre of gravity

Pinnegar et al., (2012) identified that some of the key species caught today will shift their 'centre of gravity', that some species would move closer towards ports on the UK coastline, and other species would move further away. The report estimated that this would result in a net cost increase to the UK fishing industry due to the additional fuel required to travel further to catch fish. This would amount to between £1 million to £9 million per annum (in current prices) by 2020s, and potentially £10 million to £99 million in later periods.

Table 2 shows the projected change in habitat suitability based on analysis for this report. However, it is not possible to identify if emerging species are moving more quickly into the UK EEZ than other species are moving northwards out of the UK EEZ. Although the pace of change cannot be assessed with accuracy, it is understood that pelagic species (e.g. herring, anchovy, sardine, mackerel, etc.) may change at a faster pace than the demersal species, which rely more closely on changes in deeper waters and sea bed habitats.

Graphical representations of the change in habitat suitability for some example emerging species are shown in Figure 1. The green to red coloured areas show increases in habitat suitability, blue indicates habitat suitability in decline. However, it should be noted that there is variation across the models, which restricts the ability to identify the opportunities or losses at a local level around the UK coastline (for example for certain ports). Nonetheless, these graphs do illustrate that coastal habitats around southern European countries may become less suitable for anchovy, mackerel and squid and more northern coastal habitats of the UK, and Scandinavia, could become more suitable for these species.

Figure 1. Habitat suitability for anchovy, sea bass and squid

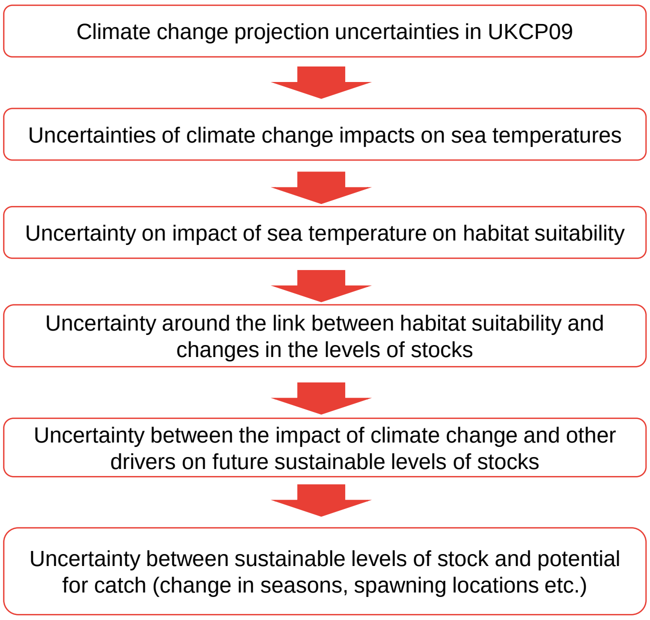


Source: Jones 2012, A2: Maxent B2: Aquamaps and C2 is DBEM, the scale is a comparable scale of habitat suitability between 0 and 1.

3.2.3 Uncertainty

The ranges presented in **Table 2.** indicate a degree of uncertainty around the impact of climate change for many of the species. As **Figure 2** illustrates, these are in addition to the uncertainties associated with climate projections and climate modelling.

Figure 2. Illustration of the nature of uncertainty in fish stock and distribution projections



Current apparent movements of some fish stocks may be due in part to a changing climate[12], but also other drivers, such as historic levels of catch (such as overfishing in southern waters may appear as a northward shift when the north and south survival of species are compared). It is therefore difficult both to distinguish any historic response to climate change and to forecast what other factors will impact changes driven by climate in the future.

3.3 Socio-economic implications

Although the fishing sector accounts for a small proportion of UK GDP, its importance at a local level is much greater, particularly for port-based communities. Around 20% of UK fishermen are located in the south west of England, with 13% in Aberdeenshire (Net Benefits, 2004). In particular ports, the fishing sector can provide as much as 20% of total employment (e.g.

[12] Murphy *et al.,* 2009, Climate projections contain a degree of uncertainty. Different climate models generated by different meteorological offices and academic institutions use different (but scientifically robust) interpretations of the climate process. The UKCP09 projections used within Pinnegar et al (2012) and this project were designed to tackle uncertainty explicitly through probabilistic outcomes and the presentation of ranges in the high, medium and low emissions scenarios. Uncertainty in climate projections and modelling arises because of three reasons:

- Natural climate variability
- An incomplete knowledge of Earth System processes
- Uncertainty over future emissions

Fraserburgh, North East Scotland; Brixham and Newlyn in South West England).

Across the UK coastline, a large inshore sector of small vessel owners employs around half of the crews of UK vessels[13]. The sector provides fresh fin-fish direct to local fishmongers, restaurants and supermarkets. Much of the inshore fleet fish profitably for shellfish (not under the scope of this report), including valuable *nephrops* (scampi), scallops, crabs and lobsters.

Changes to fish stocks and their distribution could have a greater impact at the local level, than is implied by the net changes projected for the UK.

This Section has explored the scale of the challenge or opportunity from the impact of climate change on sea fin-fish stocks and distributions. In response to this, the next Section considers the context for adaptation.

[13] Stakeholders interviewed noted that not all crews of UK vessels are staffed by UK employees. Small owner-run, single crew boats may make a larger proportion of UK employment in the fishing fleets.

4 Context for adaptation

Key messages

- The **policy framework plays a significant role** in how vessel operators act in the market. Quotas, licences and effort restrictions aim to ensure a sustainable fishing industry while maintaining a healthy and resilient marine environment. However the existence of backward-looking relative stability and quota setting processes, lack of full trading of quotas, coupled with the need for international agreement on any changes, could restrain the ability of the sector to maximise opportunities as they arise.

- Fishing vessel operators have **relatively high adaptive capacity**. They have strong commercial incentives to make the most of profitable opportunities for its viability. Fishing vessel operators are used to dealing with constantly changing weather, fish stock sizes and locations, and market prices for their outputs.

- However, some segments of the sector have lower adaptive capacity, notably operators of smaller vessels, which are not able to travel significant distances, and face constraints on the degree to which they can trade quotas.

This Section discusses the current context in which adaptation is considered in terms of the key characteristics of the UK fishing sector, the current policy framework, and the adaptive capacity of the sector and consumers.

4.1 Introduction

Whether adaptation is likely to be taken to address climate threats effectively requires two key factors to be considered:

- **Adaptive capacity** (see below): Adaptive capacity is a necessary condition for the design and implementation of effective adaptation strategies, so as to reduce the likelihood and magnitude of harmful outcomes resulting from climate change (Brooks and Adger, 2005).

- **Adaptation actions** (see Section 5): There are many adaptation actions that individuals and organisations are already taking in some parts of the sector, and which would be expected in the future. These may be in response to an event or consequence of climate change (reactive) or as a result of government policy (planned). Adaptation actions can focus on building adaptive capacity or on reducing the climate impact or maximising the opportunity. A suite of actions could form part of an effective adaptation strategy. The choice of actions will depend on the capacity of both the organisation and the sector in which it operates, and the climate change risks under consideration – these factors should be considered systematically together with non-climate risks.

4.2 Key characteristics of the fishing sector

The fishing industry is an active commercial market. There are strong incentives to realise the value from the fish stocks in the UK EEZ where it is profitable to do so. If (i) the species are profitable, (ii) the vessels are able to obtain quotas, or (iii) the species do not have quotas, the fishing sector is likely to take up the opportunities.

Vessel owners may own fleets of vessels or could be single-vessel operators. **Table 3** shows species identified in Section 3 as currently increasing in the UK EEZ. This table shows for almost all these species there were very low recordings of catches in 1985. The fact that catch by 2010 has already increased above 1985 demonstrates how commercial opportunities are already being taken by vessel operators. The market value per tonne in most cases far exceeds that of two popular fish consumed in the UK - mackerel at £820 per tonne and cod at £1,950 per tonne. This could indicate the potential value to the sector of expanding activity in these areas.

Table 3. Emerging species value

Species	Benchmark UK catch in 1985 (tonnes)	Modelled increase in habitat suitability 1985-2050	Recorded UK catch 2010 (tonnes)	Value of catch per tonne 2010 (mackerel £820, cod £1,950)
European anchovy	0	+1 to +7%	319	£797
European sea bass	127	-9 to +24%	739	£7,054
Common squid	469	+4 to +11%	3,800	£2,843
John Dory (Atlantic)	50	-16 to +17%	332	£5,595
Red mullet	62	-14 to +28%	444	£5,487

Source:Jones *et al.,* (2012) increase in habitat suitability, ICES recordings of UK catch and data provided by Cefas for the value of landings by UK vessels into UK ports.

Mixed fishing practices, such as trawling, will collect a number of species in addition to the target species. If these products do not have quota restrictions they will be landed for sale at the auctions. As stocks of these species increase, catch levels will be noticed collectively at the auctions, where processors and other buyers will be looking for profitable opportunities. When yields reach a level that could sustain a new market, any opportunities are likely to be actively identified.

Single-species fishing vessels, for example for pelagic species, often fish for species which are only seasonally abundant. Both the vessel owners and the processors of those species may have spare capacity off-season to fish for new species and have the incentive to utilise their assets and maintain staff through the off-season period.

4.2.1 Heterogeneity of the UK fishing fleets

The UK fishing fleets vary in terms of size, location and equipment. There are variations in the ability of different types of vessel to adapt.

The UK fleet is diverse with 28 vessels in the pelagic fleet fishing 286,400 tonnes per year, and 340 large demersal vessels fishing 160,100 tonnes per year. There are also 533 *nephrops* and scallop dredge vessels, catching 134,500 tonnes of shellfish, with 1,947 of small vessels using nets, hooks, and/or pots and traps (Almond and Thomas, 2010).

As shown in **Table 4**, the fleets are concentrated in a few key ports in the North East of Scotland and South West of England.**Error! Reference source not found.** There is a large in-shore fleet of smaller vessels spread all along the coastline, many focused on shellfish. Northern Ireland has a particularly large fleet fishing mussels, whilst in Scotland, six key species are fished. In the South of England and Wales, the weather is better and the smaller vessels are able to fish all year, taking a wider range of species. For example, vessels in the Brixham fleets fish for over 40 different commercial species.

Table 4. Vessel capacity across the UK

DA	Key ports	Catch capacity (GT)	Number of vessels	Proportion of vessels which are small (under 10 m)
Scotland	**Shetlands, Fraserburgh, Peterhead**	81,449	510	57%
Northern Ireland	**Belfast, Ardglass**	16,184	379	61%
England – South West	**Brixham. Plymouth, Newlyn**	5,948	1,207	81%
England – North East	**North Sheilds**	20,273	333	80%
Wales	**Milford Haven**	5,948	483	92%

Source: Almond and Thomas, (2010)

The fleets vary in profitability, which may impact the capacity to adapt. Profitability across fleets can range from very profitable pelagic fleets and profitable small *nephrops* and scallop vessels, and profitable trawlers in the south to demersal trawlers in the north making net profits of around -1% to 1% (Almond and Thomas, 2010) and Seafish (2009).

The pelagic fleets target a single species during the season. Each season is relatively short as full quotas can be caught in a six week period, so there is time in which to change gear to catch other species or move to new locations. Pelagic vessels are large and efficient and they can travel long distances. These fleets make profitable fishing from mackerel and herring, and fish for niche species such as sprats, sand eels and anchovy.

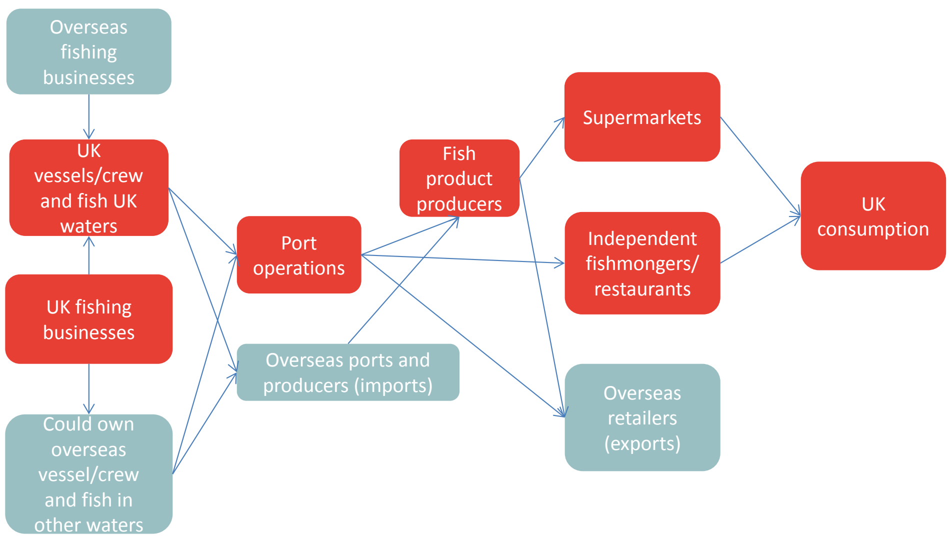
The demersal and beam trawler fleets target a single species or a mixed assemblage of different fish. The nature of trawling means they can target a number of species together. However, regulations encouraging a reduction of discards are driving investment into mesh sizes that minimise the scope of the catch.

The in-shore fleets of small and medium sized boats include a mix of vessels using dredge, nets, hooks, and pots. The fleet is large and fragmented all along the UK coastline. Around 70% of the in-shore fleets fish for shellfish, others are mixed fisheries and currently catch and land a wide variety of species. These vessels will be largely constrained by their capacity to travel, and may be too small to carry the required fuel for travelling further, or to withstand storms further out at sea.

4.2.2 The fishing industry supply chain

The UK fishing industry is part of a complex international supply chain as simplified in **Figure 3**. Only 68% of fish caught by UK vessels are landed in the UK. The UK is a net importer of fish, exporting the equivalent of 85% and importing the equivalent of 116% of fish landed by UK vessels (Almond and Thomas,, 2010). The UK fishing vessels supply consumer demand in the UK and abroad. The UK processors and retailers of fish are supplied by local landings and imports. Whether the benefits of fish movements or increases in stock will be realised in the UK economy or an economy overseas is uncertain, as each part of the supply chain can trade internationally.

Figure 3. UK fishing industry supply chain



4.3 The policy framework

Fish are a public good in the sense that no property rights are allocated and without regulation, there would be no way to prevent access to fish. The sector is therefore regulated both to remove the incentive to catch more than would be sustainable, and to protect the marine environment more broadly.

The industry operates within a complex regulatory framework, largely determined at the EU level. The objectives of UK policy in implementing EU requirements are to:

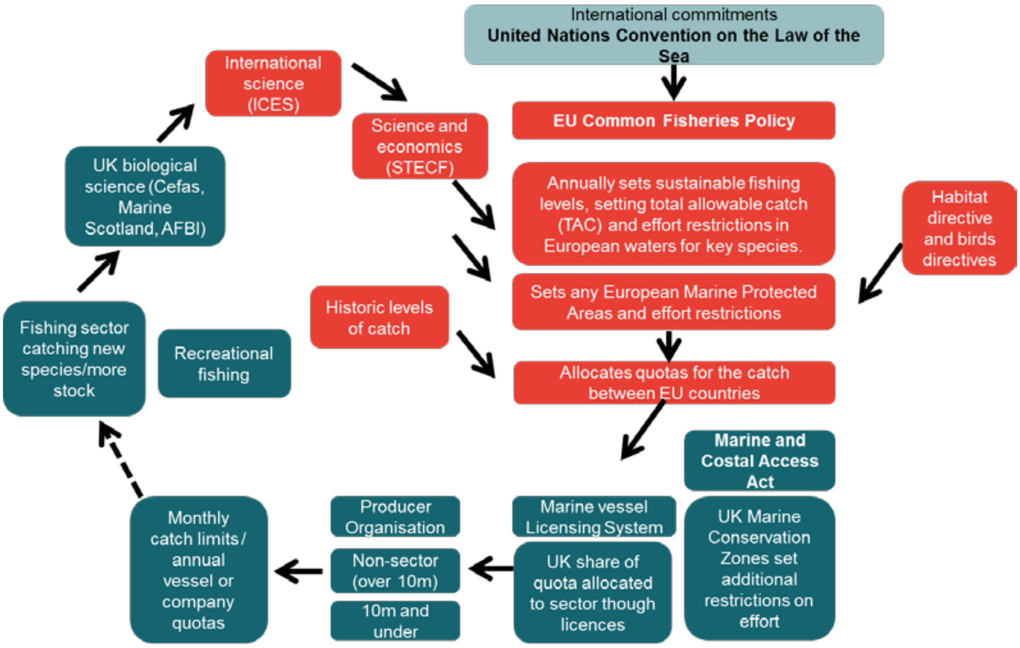
- Incentivise wealth creation in fisheries so that the productive value of the resource is captured rather than dissipated;
- Sustain viable fisheries as part of a healthy and resilient marine environment; and,
- Provide the evidence and incentives for fishers to adapt to climate change in ways that benefit themselves, the economy and wider society (OECD, 2010).

There are many international and domestic regulations for the UK fishing industry. Of particular importance are the quotas and effort restrictions in place.

4.3.1 Quotas and effort restrictions

Many species are subject to quota regulations to ensure a sustainable level of catch. **Figure 4** presents the process through which quotas are set and allocated for relevant species. The Common Fisheries Policy sets quotas each year for how much of each species can be caught in a certain area. Each country is given a quota based upon the Total Allowable Catch (TAC) and the pre-determined 'relative stability' key (based on historic catch). Feeding into this process is a range of information including detailed landing statistics from ports around the EU as well as outputs from scientific surveys conducted by fishery science institutes. Advising the European Commission are Scientific, Technical and Economic Committee for Fisheries (STECF) and the International Council for the Exploration of the Sea (ICES). ICES produce stock assessments and seek to ensure that stocks do not fall below a certain level.

Figure 4. Policy framework decision process



Quotas are then distributed to vessel operators through the Marine Vessel Licensing System and activity is monitored and reported to ensure quotas are not exceeded. Domestically, licences are tradable for large vessels. However, the market for licences is relatively opaque and it is not transparent who holds which licences and who would be willing to sell. Vessels under 10 m can lease licences from over 10 m vessels but cannot trade among themselves.

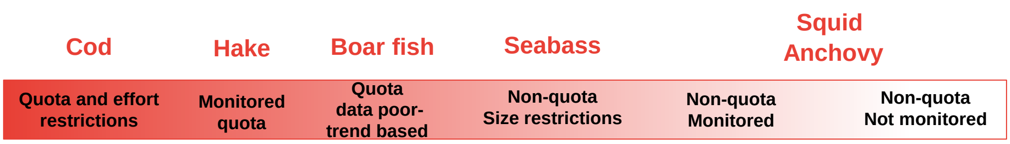
Separate to the quota regulations and limits on fishing effort, 'technical measures' may also be used to govern how and where fishers are allowed to fish. For example, these may set minimum landing sizes, minimum mesh sizes for nets, requirements to use more selective fishing equipment, limits on by-catches (catches of unwanted or non-target species), and closed areas or seasons.

When a species has a quota or effort restriction, this can be a short-term barrier to the sector taking up the current opportunities for the species. However, these restrictions increase the long-term sustainability of the particular fish stock opportunity, maximising the long-term benefit for the sector. Restrictions on quota species may encourage the diversification towards non-quota species, such as warm water species, which may be emerging in the UK EEZ.

If quotas inadvertently restrict catches to below an economically sustainable level, this may prevent opportunities being maximised by the UK. An example is hake, which has increased in stock in UK waters. There is currently little demand in the UK for hake, but there are markets in Europe. The sector has tried to create export routes to Spain, but the allocation of quota to UK vessels is not sufficient for them to make a new export route viable.

The extent to which new or emerging species are subject to quotas is explained in **Figure 5**. Although some species are not subject to quotas, where time at sea restrictions exist - such as in cod recovery zones - fishing vessels would be restricted from fishing for other species in the area.

Figure 5. Levels of regulation across species



If the regulations change (potentially with the Common Fisheries Policy reforms) to limit discarding, the need to avoid catching quota species as accidental 'by-catch' could hinder the ability of mixed vessels (such as trawlers) to target other non-quota species. For example, trawler boats which fish for sole and plaice but catch haddock in the process, have experienced increases in haddock stocks in some locations, which they are unable to exploit because the allocations of quota to those boats in the region have not been changed to reflect the stock increases.

Marine Protection Zones

Marine Protection Zones (MPZs) set by the EU, and Marine Conservation Zones (MCZs), set domestically, aim to protect living, non-living, cultural, and/or historic resources.

They can, however, impact on the fishing sector by restricting access to fishing areas; this particularly affects trawler fleets, preventing fleets from taking the opportunities presented by climate where they occur in those areas.

MCZs, within which opportunities for catching new species may be limited, need themselves to be flexible and relevant under changing conditions in the future. Allowing MCZs to be decommissioned in the future if they are no longer either in the right area or the protection is no longer necessary, could re-open waters for the fishing sector to maximise their economic activity. Assessments of MCZs' status are undertaken every six years, which should be sufficient to identify the need for changes. Raising awareness about the need to consider cases for decommissioning the MCZs could aid adaptation.

4.3.2 The influence of total allowable catch and relative stability

Setting quotas relies on collecting information about the sustainable levels of catch and gaining international agreement over the TAC. Both gaining accurate scientific knowledge and negotiating between multiple countries to meet a balance of species and economic sustainability, however, do have a natural level of inertia.

When vessels identify increases in stock, there could be a case for re-assessing the quota. Where species are already subject to quota regulations, the species will be monitored progressively. However, there is currently poor data on two thirds of European species. Scientific assessments of species can take more than a year to complete.

The process of setting quotas relies on the results of scientific assessments are published each year in June by ICES. Between October and December the Commission considers recommendations for over 200 fish stocks, and identifies any changes necessary to the TACs. In December, the Agricultural and Fisheries Council considers the Commission's proposed TACs and decides on the levels for the following year. In the UK, the TAC allocation is divided through licence allocations from the Marine and Coastal Accesses Act (2009).

Allocations based on historic access rights are used to ensure relative stability of economies, such that industries within each country have enough stability to survive in the longer term. As a result, UK fishing vessels will only benefit from any increase in stocks in the UK EEZ up to the historic catch allocation to the UK. Conversely, UK fishing vessels will continue to benefit from allocations held for species moving out of the UK EEZ. The Common Fisheries Policy reform is currently proposing to consider "managing quota rights so that fishermen are able to plan for the long-term, and benefit from improving stocks", though any change would be likely to take time to implement, given the need for international debate and agreement.

It is not currently clear if quota allocations could be updated to reflect permanent changes resulting from climate change. And if it could, how frequently this would need to be revised or how long the bilateral agreement and negotiations could take.

The Atlantic mackerel is a recent example of an attempt at country level adaptation. In practice, there are expectations that with climate change causing permanent movements of stocks, the need for these negotiations will increase in the future.

Atlantic Mackerel – changing fish distribution and quota allocations

In October 2009, Norwegian vessels, which held quotas for mackerel but were unable to catch their usual amount within indigenous waters, were escorted out of the UK EEZ for attempting to fish beyond their quota in the EU zone. It was suggested then that mackerel have altered their distribution westwards. In 2010, Icelandic and Faroese governments unilaterally increased their quotas for the Atlantic mackerel, asserting that the fish were now spawning in greater numbers in their waters during the summer (OECD, 2010). This pushed the total quotas collectively across the Atlantic to around 260,000 tonnes greater than the upper limit recommended by the scientific assessment body, the International Council for the Exploration of the Sea[14]. Subsequent negotiations between the EU and Icelandic and Faroese governments have lengthy and have not yet concluded.

Where species are not under quota, and vessels identify an increase in the species, the vessels will start to catch the fish. In some cases, scientific investigation is triggered by identification of the number of landings onshore, in other cases the vessels may specifically request the scientists assist them in identifying the best ways to fish the species and the sustainable levels that can be caught.

Scientific surveys are undertaken for many species to identify changes and opportunities in fish stocks.

4.3.3 The role of scientific evidence

The science which forms the basis of the TACs is reliant on collecting detailed landing statistics from EU ports, as well as outputs from scientific surveys conducted by fishery science institutes. Such studies may be both reaction or proactive. Reactive assessments do not have the same benefits as proactive assessment, which can alert the sector to changing conditions and enable them to actively pursue opportunities and/or put in place restrictions on catches, preventing maladaptation. Proactive assessments also increase the understanding of the species supporting TAC levels.

There is scope for improving the largely trend-based methodology of sustainable stock assessments, to a full assessment of each species. However, attempts to change the process have been resisted by the European regulators, who are slow to change. Groups like the MCCIP (Marine Climate Change impacts Partnership) and OSPAR (Oslo and Paris convention for the Protection of the Marine Environment of the North-East Atlantic) are providing the sector with

[14] http://www.guardian.co.uk/environment/2012/mar/25/mackerel-fishing-curbs-imposed

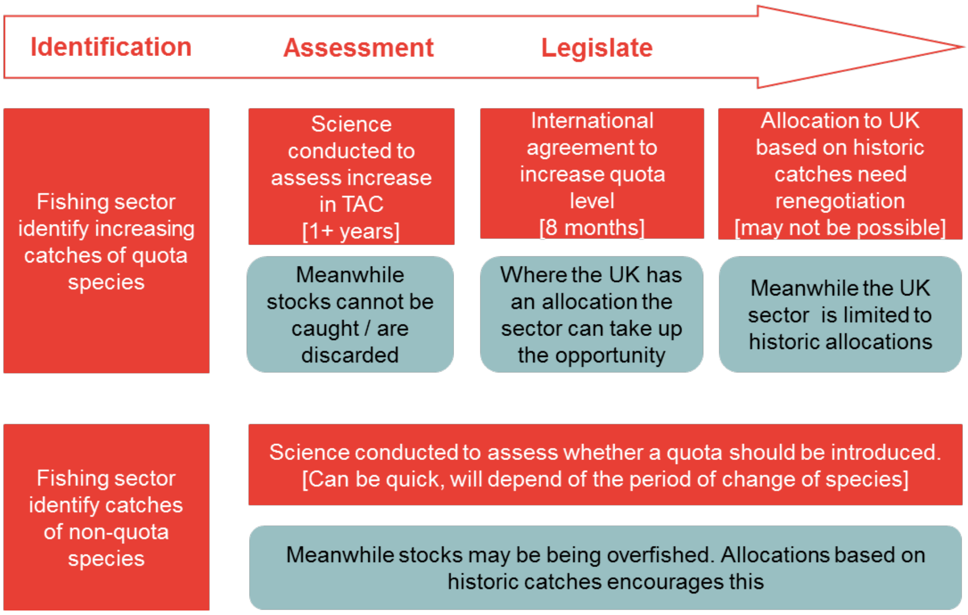
information on the expected impacts of climate change, but these do not represent a means of feeding information into TACs in 'real time'.

The scientific surveys that can be undertaken are restricted by the need for labour and funding. Currently, the majority of resources are directed to demonstrating compliance with EU and international regulations. For example, the UK does not have the resources to monitor hake in the Celtic Sea and relies on Spain or Ireland to do this. In contrast, the UK does engage in a survey of cod, (which may also contribute data on stocks of other species caught at the same time). There are currently no systematic surveys for many increasing species, such as anchovy. The UK contributes to International Bottom Trawl Surveys in the North Sea and western waters but such surveys do not adequately sample pelagic species, such as sardine and anchovy.

Sampling protocols are often heavily shaped by adherence to the EU data collection framework, which is a key constraint and provides little incentive for UK science and monitoring to change. Since 2001, the common fisheries policy has set aside funding to help national authorities collect both economic and biological data about all aspects of fisheries management and make them publically available. The current data collection framework will run until 2013, providing €50 million a year for national programmes. Collection methods are harmonised at Community level and comply with the relevant international requirements. The Member States must draw up collection programmes, specify procedures and ensure the availability of data, although such provisions are often very prescriptive and rarely consider future/emerging applications.

Reactive assessments to build scientific knowledge take time and therefore could lead to maladaptation, as shown in **Figure 6**.

Figure 6. Potential impact of delays to building scientific knowledge on fish stocks



Species which are not under quota have few restrictions on the extent and speed of adaptation.

As the commercial fishery increases, the implementation of a quota may be considered. A conservative quota may be put in place before full scientific understanding of the stock is completed. Where quotas are not in place, there could be unintended impacts on fishing vessel behaviour, particularly where a future quota is anticipated.

Given quotas are allocated based on historic catch levels (relative stability), building that historic catch track record through over-fishing in advance of a regulation being implemented could result. This is what is called an "olympic fishery" and has been seen in Iceland and the Faros with mackerel. The following box describes the example of Boarfish.

Boar-fish – An example of an olympic fishery

Boar-fish populations have traditionally experienced periods of 'boom and bust' and are thought to respond to prevailing climatic conditions. The latest increase in stocks, since 1989, has been the longest sustained period of boar-fish abundance in the UK EEZ (although similar 'outbreaks' occurred in the 1960s and early 1900s). Boar-fish have been fished by Irish fleets for a number of years and fishermen have even commissioned their own research on this species, but as the stocks have increased many vessels started fishing, and effort increased dramatically with catch levels reaching 137,503tonnes prior to the introduction of a TAC in 2010. As the TAC set subsequently at 33,000 tonnes in 2011 and 82,000 tonnes in 2012, indicating sustainable levels of catch, is below the 137,503 tonnes caught in 2009, this could indicate overfishing prior to the introduction of the quota.

Table 5. Reported landings of boar fish in EU and international waters of Subareas VI, VII, and VIII

(tonnes)	Ireland	Denmark	Scotland	Total landings	TAC
2001	120			120	
2002	91			91	
2003	458			458	
2004	675			675	
2005	165			165	
2006	2,772			2772	
2007	17,615		772	18,387	
2008	21,585	3098	0.45	24,683	
2009	68,629	15,059	0	83,688	
2010	88,457	39,805	9,241	137,503	
2011					33,000
2012					82,000

Source: ICES (2011).

Developing the scientific evidence on changing stocks is an on-going process. Across the UK, government organisations are trying to engage vessel operators in projects and to encourage collaborative working.

Vessels have the ability to collect data as they have the best visibility of discards and the status of stocks in real time. To encourage the development of scientific evidence, vessel operators are rewarded with dispensations to allow a scientist aboard or to be fitted with recording equipment (e.g. cameras and satellite loggers) and mobile technology to allow recording of real time data.

There is also work underway to develop apprentice programmes to create a structured career for young people and to inform and interest fishermen in the science. In Canada, all crew are required to take a week-long science course. In Iceland, the main vessel owners' association employs a scientist tasked with educating and engaging the industry. This has encouraged the industry to trust and understand the science and actively contribute towards it.

Information and its use for adapting effectively and sustainably will be most effective when the fishing industry is involved in the interpretation and implementation of the information. Involvement of the sector in the operation and regulation of the industry could allow policy to more readily account for the facilitation of adaptation. The objective of regionalised management, highlighted through the CFP reform reviews, attempts to adopt this approach.

The box below presents an example in which the sector contributed to the scientific evidence base.

Squid – An example of collaboration in enhancing the scientific evidence-base

Through the Fisheries Science Partnership Programme, fishermen can annually make requests to the NFFO (National Federation of Fishermen's Organisations) regarding the species it would be useful to have more scientific research on. The NFFO then make proposals to Cefas, and together they chose work they can do and raise a tender for vessels to help them. Vessels which agree to participate are rewarded in the form of capacity allowance (dispensation to land catches). They put a scientist on the vessel or monitoring technology to record catch and discards. This partnership programme has been going for 10 years. It is driven by the industry making requests.

An example of the contribution of the programme to facilitating adaptation is that of squid. Cefas was asked to help understand how and where best to catch squid, and their current stocking levels. The vessel which initially requested the research was then involved in undertaking it. As a consequence, two squid projects were funded in autumn 2006 on the north-east coast of England and in the western Channel.

Two similar projects in June 2010 and September 2005 were also funded to investigate increasing cod stocks around Greenland, where the UK has traditional access right and climate change may be having a beneficial impact.

Similar projects are being funded within the sector itself. For example, Seafish arranged for Cornish fishermen to go to Brittany to look at sardine fishing methods and then help to bring those techniques to the UK.

4.3.4 Summary of potential barriers to adaptation from the policy framework

This assessment of the current policy framework has revealed several potential barriers to effective adaptation by the sector. These are:

- The backward-looking allocation of TAC under relative stability means that the UK (and other countries) could be constrained from maximising current and emerging fish stock opportunities. Conversely, this could also be an enabler to maintaining current species catches;
- The time taken to develop scientific surveys and evidence on fish stocks could provide an incentive for short-term overfishing if a future quota is anticipated;
- Licences are tradable for large vessels but the current market for those licences is relatively opaque so it is not clear who holds licences for what and who would be willing to trade them;
- Trading of licences is currently limited for owners of small vessels – they are not able to trade with other small vessels; and,
- Identifying cases where Marine Conservation Zones could be de-commissioned, as part of the 6-year assessment, could potentially facilitate adaptation where fishing activity is currently constrained.

The fishing industry must operate within the tight restrictions of the policy framework. Having explored the policy framework in some detail the next Section looks at the capacity of the UK fishing fleets to adapt; and the adaptive capacity of the remaining supply chain (from landings at UK ports).

4.4 Adaptive capacity

For the purposes of the ECR, adaptive capacity, or the ability to adapt, is analysed using a simplified framework informed by the Performance Acceleration through Capacity Building (PACT)[15] model (Ballard et al., 2011) and the "weakest

[15] This model was chosen as it was used in the CCRA, from which this project follows on, and because in a UKCIP review of adaptation tools it was ranked as the most robust (Lonsdale *et al.,* 2010). The PACT model identifies six clear stages of development when organisations take on the challenge of climate change. These are called response levels (RLs) rather than stages, as each level is consolidated before moving to the next. RLs 2 and 3 are characteristic of 'within regime' change, RL4 is characteristic of 'niche experimentation' (or 'breakthrough projects') and RL5 is conceptualised as regime transformation. RL6 would be conceptualised at the landscape level. In this report, the RLs were used very simplistically as a comprehensive assessment of the adaptive capacity of the sector using PACT could not be undertaken. It is recommended that this be undertaken in further work.

link" hypothesis[16] (Yohe and Tol, 2002; Tol and Yohe, 2006). Both PACT and the weakest link models introduce the idea of discrete levels of an attribute and allow identification of where an actor is now and where they would like to be, while illustrating the areas that need most development to get to the desired end point (Lonsdale et al., 2010).

This project defined adaptive capacity using the CCRA definition:

Adaptive capacity

"The ability of a system/organisation to design or implement effective adaptation strategies to:

- Adjust to information about potential climate change (including climate variability and extremes);
- Moderate potential damages; and,
- Take advantage of opportunities, or cope with the consequences"

Source: Ballard *et al.,* 2011 (CCRA – modified IPCC definition to support project focus on management of future risks)

In assessing the ability of the sector to adapt to projected impacts of climate change, this analysis considers two factors: the **structure** of the sector in general terms (i.e. the role and size of different organisations involved), and the **organisations** in the sectors - the function of key players who make critical decisions and their performance (i.e. gross margins, outputs and benefits delivered). An analysis of these two factors will describe the ability of the sector to adapt to climate change and the extent to which the opportunities and risks are likely to be addressed. It should be noted that adaptive capacity is not only needed to optimise decisions based on climate change adaptation, but for other decisions with long term implications (Ballard *et al.,* 2011).

4.4.2 Structural adaptive capacity

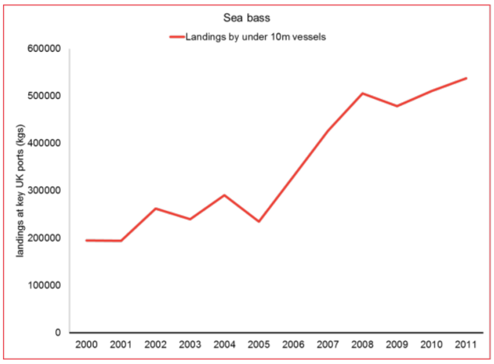
Species movements are impacted by weather variability, amongst other things (Section 2). Vessels in the fishing sector currently respond to such movements by either travelling further when necessary or taking additional catches of temporarily abundant species stocks to the market. The need to be regularly adaptive and opportunistic has meant that the fishing sector's decision process is

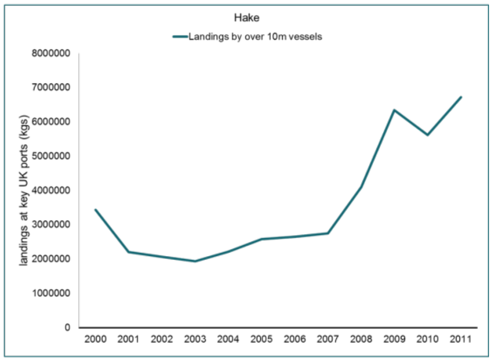
[16] The weakest link hypothesis enables assessment of the potential contribution of various adaptation options to improving systems' coping capacities by focusing on the underlying determinants of adaptive capacity. In this report, the determinants were used to assess capacity of an actor rather than an adaptation option. This was used as it provides socio-economic indicators by which an actor's adaptive capacity may be categorised. It enables the weakest part of an actor's capacity to be shown providing an area to focus adaptation responses.

relatively responsive to change. However, adapting for annual variations and the uncertainty around future stock level predictions, combined with, in some cases, low profitability, drives short-term decision-making which could reduce long-term investments in vessels and gear.

Figure 7 shows two recent examples, of sea bass and hake, where both small vessels and large vessels have taken up opportunities presented by increasing species stocks.

Figure 7. Landings of sea bass and hake by UK vessels into key UK ports (sea bass left, hake right)





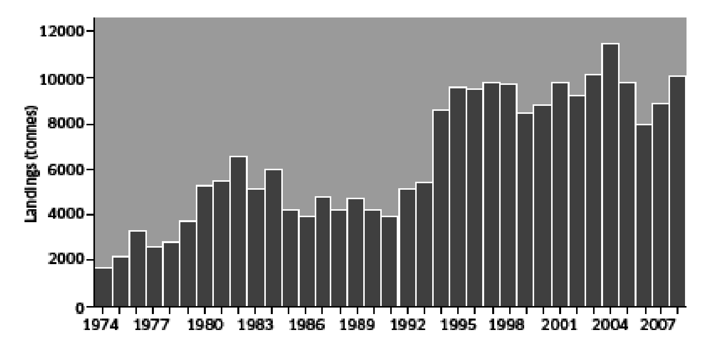
Source: Data supplied by Cefas

Scallops and shellfish are examples of the industry adapting to fish a more profitable species. Increased regulation on white fish provided the incentive for small vessels in particular to adapt to exploit more profitable shellfish stocks, including *nephrops* (see below).

Scallops - example of the UK fleets adapting to profitable species

In the mid-1970s when new restrictions were placed on fishing for cod, the industry redirected efforts into fishing for scallops, using beam trawlers suitable for converting to scallop dredgers. This was largely undertaken in the west of Scotland, where there was low profit in beam trawling activity.

Scallop landings (tonnes) by UK vessels into Scotland 1974-2010



Source: The Scottish Government, (2012)

Permits for full-time vessels increased from 248 in 1998 to 317 in 2001, including those for small dredge vessels, which increased from 1-54 over the period. Although the UK still continued to import scallops, the export market also increased for the species.

Investment activity

Some parts of the industry are likely to be slow to be entrepreneurial and target new species. However if other vessels identify and start to take opportunities, others will follow. Producer organisations will also assist coordinating the fleets and identifying opportunities.

Adaptation actions are likely to require investments and/or increases in operating costs (as illustrated in **Table 6**). The replacement rate of nets and gear is around twenty years and the vessels themselves are relatively old, many having been built in the 1980s (**Figure 8**). These will need replacing in the coming years. There is a second hand market for boats but it is a buyers' market (the number of new entrants or new boats built is less than those leaving the market or wishing to sell), and it can be difficult to sell one boat to trade for another.

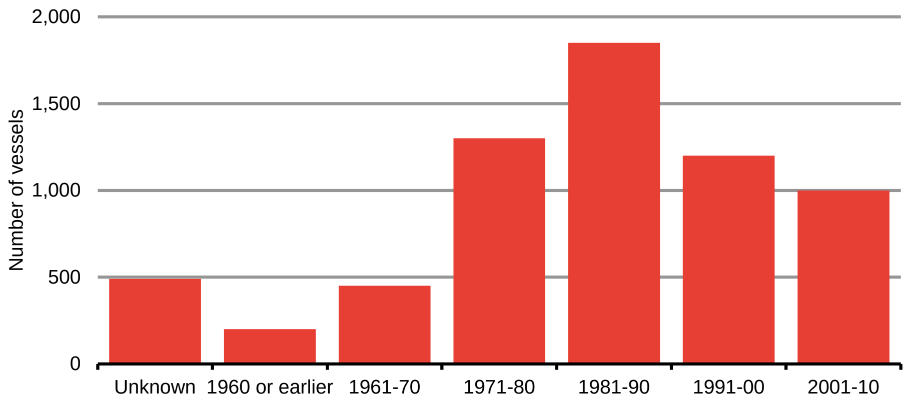
Entry into a market for a species subject to quota, either by a new vessel to the fishing industry or transferring a vessel's target species, requires obtaining a licence for that vessel to catch the target species. As licences are allocated largely based on historic catch, it can be expensive for a new vessel with no track record to purchase a licence. This can restrict new entry into the market.

Conditions on licences can also restrict the ability of vessels to change to new species, exiting one species market and entering another. This is currently the case for those with a shellfish licence, which particularly impacts small vessels. Licences for lobster, for example, were capped in 2008/9 if the vessel did not have catch track records. Vessels which currently rely on lobster are therefore trapped into continuing to catch lobster, reducing the ability of the vessel to be flexible to other species.

Table 6. Potential need for investment or cost changes

Changes to current way of fishing	Cost driver
The vessel operator's current targeted species moves closer or becomes more abundant.	Vessel operators may want to increase the capacity of their vessel to land increased catch.
The vessel operator's current targeted species moves further away.	The cost of travelling further includes fuel, wages of extra time at sea, and any foregone catch owing to increased time per trip, lowering the number of possible trips to keep within time at sea restrictions.
New species may increase in the areas the vessel fishes which the vessel may want to also catch.	The cost of new gear.
New species may increase in other locations and the vessel may wish to target these specifically.	To target a new species could require anything from new gear to a completely new vessel.

Figure 8. Age of UK fleet by year of build



Source: Based on Almond and Thomas 2010

4.4.3 Organisational adaptive capacity

This section considers the organisational adaptive capacity of the UK fishing fleet, and organisations active in the wider supply chain.

The UK fishing fleet can be divided into in-shore, demersal and beam trawlers and pelagic vessels (Section 3.2). **Table 7** summarises the adaptive capacity of these different actors. Unless otherwise specified, the data has been compiled from interviews with stakeholders, and inputs from experts.

Table 7. Summary of organisational adaptive capacity

Fleet	Enablers to adaptation	Barriers to adaptation	Policy barriers	Overall capacity to adapt
In-shore	• Currently fish mixed species. • Low operating costs. • Supply niche markets in the UK (restaurants and local fishmongers). • Net replacements rates for investments.	• Cannot travel far. • Decisions can be dominated by short-term considerations. • Generally not represented by producer organisations (may be part of associations). • Many based in small ports where access to export markers can be an issue.	• Cannot trade quotas between themselves. • Threat of losing shellfish licence if change away from shellfish. • More easily displaced by MPZs.	Are versatile and opportunistic, yet restricted to opportunities that come to them.
Demersal and beam trawlers	• Currently fish mixed species. • Will need to have replaced nets within the next 20 years of species change. • May have more incentive to change if current fishing low profit species. • Fishing for species all year round.	• Northern fleets fishing cod have low profitability. • High operating and fuel costs restrict ability to travel further or invest in new gear. • Vessels only suitable for demersal species.	• Likely to fish in cod or sole areas, so face quota and effort restrictions.	Incentivised not to travel further for current species but will face strongest policy and capacity barriers to changing species.
Pelagic	• Profitable so likely to have investment finance options. • Fish seasonally, so may have off-season underutilised capacity. • Larger vessels and ability to travel further. • No time at sea restrictions. • Currently export a large amount of stock – not reliant on the UK market for demand. • Their supply chain also work seasonally so may have underutilised capacity.	• Tend to target one species at a time. • Pelagic species can move and change quickly.	• Typically profitable species, limited by quota allocations to the UK. • Large ships which need enough quota allocation to make the industry viable.	Currently the vessels are profitable so have capacity but lack incentive.

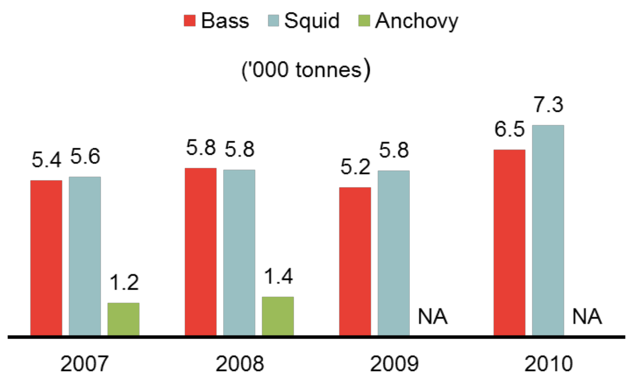
4.4.4 Adaptive capacity of organisations in the fishing industry supply chain

For the smaller boats and mixed fisheries, every fish landed is sold. The fishing fleets are incentivised by what is profitable to catch, and profitability is dependent on the level of demand in the markets and available routes to market.

Capacity of UK consumers to adapt

Import levels indicate that there is currently excess demand in the UK (relative to UK landings) for species of fish that are expected to increase due to climate change. For example, in 2010, the UK was the third largest consumer of anchovies in the EU behind Spain and Italy, with 16% of EU consumption (Eurofish International Organisation, 2012), importing $14.4 million of prepared anchovies (**Figure 9**).

Figure 9. UK imports of species expected to increase with climate change

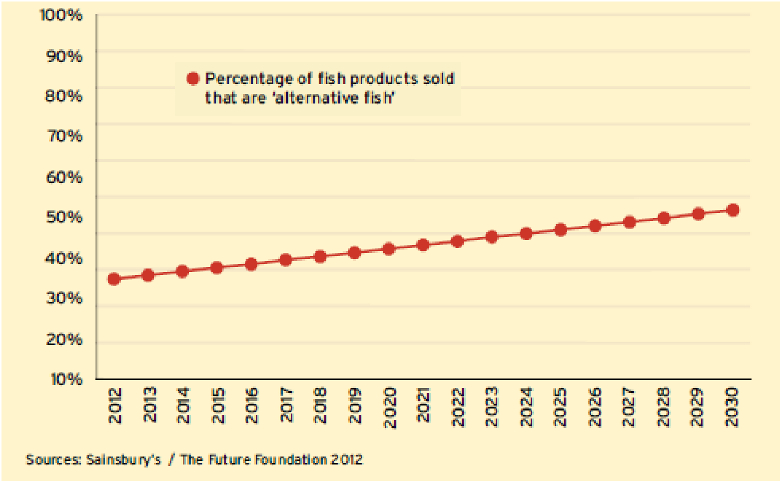


Source: Almond and Thomas (2010), and Eurofish International Organisation (2012), FAO (2012)

Consumption of fish in the UK is relatively stable, increasing by 5% between 2001-2009 in line with the population increase (Almond and Thomas, 2010). Demand is largely focused on five key species: cod, haddock, salmon, prawns and tuna. At present, this demand is largely met by imports.

Sainsbury's performed some analysis of the expected level of sales of non-'big-5' fish, as shown in **Figure 10**. This shows a gradual projected increase over time.

Figure 10. Expectations of the percentage of fish products sold that are alternative to the 'big five'



Source: Our Future with Fish, (2012)

However, overall both Sainsbury's and Waitrose believe it will be hard to move demand for niche species from occasional to mainstream consumption in the UK.

"The great majority of UK adults have already eaten and enjoyed a range of fish that extends well beyond the 'big five' - there is plenty of positive consumer experience to build on. But it is equally clear that a lack of familiarity remains a challenge as we go further down the list of fish species. While around 3/4 of fish-eating adults who have never tried various alternative fish types say they would be 'happy to try' them, this still leaves 1/4 - despite eating other types of fish - saying that they simply 'do not want to try' unfamiliar alternative species." (Sainsbury's, 2012).

Capacity of supermarkets, fishmongers and restaurants to adapt

In the UK, the consumer connection with the industry is reasonably concentrated through supermarkets. Around 88% of fish sold in the UK (by volume and value (UKNSP, 2008)) is through supermarkets. It is also influenced by restaurants, fish and chip shops and independent fishmongers, which may sell a wider variety of fish.

The concentration on a few supermarkets makes them large enough to facilitate a large-scale change in fish options. However, supermarkets primarily react to customer demand, rather than the availability of supply. Large chains of supermarkets also need minimum numbers of fish available consistently. Sustainable catch levels of some fish species may not meet these requirements.

An advantage of the in-shore fleets is that they can supply fresh fish, from the sea to shelf, within 24 hours. This is a competitive advantage for supplying supermarkets. It also enables these fleets directly to supply restaurants which demand fresh, fashionable 'niche' fish.

Capacity of overseas retailers to adapt (export markets)

The UK exports up to 50% of its catch by value (UKNSP, 2008), mainly within the EU, but also as far as China and Korea. Channels into a market can develop quite quickly if there is enough yield. However, because domestic demand is dominated by five key species, export routes have been developed over time. Export markets are considered in more detail in Section 5.

Capacity of UK fish product processors to adapt

Most non-quota species are either caught through targeted or mixed fishing, or as a by-product of catching another species. They are landed and taken to the fish markets. Some smaller boats in the in-shore fleets may transport directly to the restaurant/fishmonger.

The processing sector employs has total employment 11,864 (full time jobs) (Seafish, 2012). The processing sector is very aware of what is landed into the fish auctions. The processors and fish buyers can observe when increasing numbers of a specific species are caught, consistently or by enough vessels to create sufficient yield to supply a market. Where stocks of a species are increasing, producers will look for ways to make them profitable, such as identifying routes to market. An example of this is blue whiting. Historically used as fishmeal, as landings of the species increased, buyers identified routes to market into the cat food industry. The buyers have been adapting and creating export markets, and there are a number of joint ventures between UK fish buyers and overseas processors and commercial buyers.

4.4.5 Conclusions on adaptive capacity in the sector

This section has shown that fishing vessel operators have relatively high adaptive capacity overall. They have strong commercial incentives to make the most of profitable opportunities for its viability. Fishing vessel operators are used to dealing with constantly changing weather, fish stock sizes and locations, and market prices for their outputs. However, barriers to the UK adapting and maximising opportunities from new and emerging species remain, including:

- Some segments of the fleets have lower adaptive capacity, notably operators of smaller vessels which are not able to travel significant distances, and face constraints on the degree to which they can trade quotas.

- UK consumer preferences are for a limited number of species, which is a barrier to increasing UK markets for emerging species. However markets exist in other countries and there are examples of vessels and processors identifying and exporting to these markets.

Context for adaptation

The next section explores in more detail the actions currently being taken, and planned, in the UK to maximise adapt to projected changes in fish stocks.

5 Adaptation Actions

Key messages

Within the current policy framework, actions currently being taken, and planned, include:

- Changing location of fishing activities;
- Change gear, nets or vessels;
- Encouraging diversification and development of recreational angling;
- Identifying routes to export markets; and,
- Expanding UK consumer preferences for different fish species.

5.1 Types of adaptation action

This section looks in more detail at the adaptation actions currently being taken, and planned, in the UK given the current and projected impact of climate change on fish stocks.

Actions cover:

- Those intended to increase the adaptive capacity of the sector, where it is currently relatively low; and,
- Those that allow opportunities to be maximised (and risks minimised).

Furthermore actions include adaptation which is:

- **Planned adaptation:** this tends to be (but is not exclusively) anticipatory adaptation, undertaken or directly influenced by governments or collectives as a public policy initiative. These actions tend to represent conscious responses to concerns about climate change (Parry et al., 2007).
- **Reactive (autonomous) adaptation:** this is adaptation in response to climatic stimuli as a matter of course (without direct intervention of a public agency) (Parry et al., 2007).

In some cases, reactive adaptation actions might be ‘wrong’ or maladaptive, in the long-term or for wider society, and may need to be countered with further action, such as building adaptive capacity and taking specific actions to change and deal with the consequences.

The categories of actions set out here are not exhaustive, and each category contains a number of individual adaptation options, which in future, could be disaggregated and assessed individually.

The categories of actions were informed by literature-review and discussions with the expert panel. They were then refined and verified in the stakeholder interviews.

5.1.1 Changing location of fishing activities

Section 3 identified that most species will move northwards with warming of waters as a result of climate change. Most species considered in this study are expected to move between 100-300 km and some up to 700 km away from current locations. The requirement for travelling further will have implications for fishing costs and the time crew need to spend away from port. Adaptation actions in this category are generally reactive and include changing location by either increasing distance travelled, or changing the ports from which vessels operate.

Current/ future extent of adoption

There are already some examples of fleets travelling long distances to secure fisheries: following the cod management plan in the Irish Sea, Northern Irish trawlers began to exploit North Sea *nephrops).* Such adaptation measures can also include operating from different ports - according to stakeholders some fishermen in North Devon have tried operating from Plymouth and Brixham. It is anticipated that climate change will see the number of large vessels travelling further afield increase in response to changing distribution of fish stocks. However, stakeholders interviewed also concluded that smaller vessels are more likely to continue to operate in existing fishing zones or change their business model.

The extent of adoption is therefore assessed as **relatively low** for small vessels; and **medium to high** for large vessels.

Barriers

The costs of travelling further and staying at sea longer include **fuel and crew wages**, presenting a barrier to adaptation by sailing farther afield to continue to catch current stocks moving northwards in response to climate change.

While fuel costs only represented 6-12% of total income for the under 10m vessels in 2010, for larger vessels, travelling further can increase this to 16-22% for *nephrops* trawlers, or 22-57% for beam trawlers Seafish (2011). This percentage would be expected to increase with further increases in red diesel prices, which may occur in the future. The ability to absorb additional costs varies across the seub-sectors as they vary in business model, species focus, consumer market, technology, economic drivers and economies of scale (Cabinet Office, 2004).

Smaller vessels (under 10 m) can only operate within a certain distance of their port. Vessels are limited by their ability to operate in high seas and the amount of fuel they are able to carry. Stakeholders have reported that the costs associated with being caught in a gale can be very large.

Taking adaptation action may be further hampered by the challenges faced by smaller vessel owners in managing increasing fuel costs. According to Graham *et al.*, (2007), smaller vessel owners do not have the "resources, time money or contacts to scan their environment to get the best information they need to maximise efficiency."

A critical factor is **securing the necessary quota** to catch new species in new areas. However, whilst this can present a barrier in some cases, stakeholders have also provided examples of British vessels reaching agreements with organisations in other countries.

In-shore fleets of smaller vessels typically go out around 30 miles and fish within 10 miles. According to stakeholders, **the ability to get the catch back to the shore and into the market within 24 hours** is a key advantage for these fleets when supplying the retailers with fresh fish. This advantage would be lost if they increase their capacity and spent longer at sea travelling further.

Enablers

There are subsidies available for fuel for some vessels, facilitating adaptation. Vessel owners have also already begun to make a number of changes to their vessels to make them more efficient; these include trip planning practices, towing and steaming speeds, landing port, fishing methods, and preventative maintenance (Graham *et al.,* 2007).

Effects of measures

For **vessels able to operate in high seas, these measures will be essential** to move to new locations of fish stocks. Large vessels already travel further; they have greater engine power and can carry more fuel. For example, according to industry experts, some of the pelagic vessels have fished as far as Morocco. Pelagic species can move each year and distance travelled by individual vessels can vary considerably.

However this **measure will be less effective for smaller vessels,** which are unable to withstand conditions far from port (and risk major costs if caught in storms). It will also be less applicable for segments of the market where operating profit is low and there is a limited ability to absorb additional fuel costs.

The overall effect of this measure is considered to be **medium to high**.

5.1.2 Increase vessel capacity

Purchasing a larger vessel will enable operators to exploit potential increases in stocks of some species. It will also enable vessels to act over a larger area and travel further (Section 4.2.1). An important aspect of this measure is the shift from the <10 metre vessel category to larger vessels with different licence requirements. **Table 8** shows the current proportion of small and large vessels in the UK.

Table 8. Number of large and small vessels

	England	Wales	Scotland	Northern Ireland
Number of vessels <10m in length	2,569	442	1,491	232
Number of vessels >10m in length	552	41	666	147

Source: MMO recordings of fleet numbers in 2010 by country of administration (excludes mussel dredgers) (MMO, 2011)

Current/ future extent of adoption

62% of vessels in the UK are older than 30 years old and a large number were built in the 1980's (**Figure 8**). However, given historic over-capacity in the sector and lack of investment in new boats, there are a large number of older vessels that are on the market. Nevertheless, over the past decade over 1,000 new vessels have been constructed (out of over 6,000 vessels currently in operation) (Almond and Thomas, 2010).

It has been noted by industry experts that, while up-front costs and low immediate returns hamper new entrants obtaining finance to enter the industry, there are many cases of businesses trading up from smaller to bigger vessels.

The extent of adoption is therefore considered to be **medium**.

Barriers:

Access to capital and cost of new vessels is a critical issue, especially for smaller enterprises. According to stakeholders, if larger capacity boats need to be purchased, a new boat can cost up to £1 million or around £75,000 for a second hand boat.

The number of new vessels built over past two decades has decreased, indicating a sustained lack of investment for a long period. This could indicate a financial barrier for new boats. However it is noted that the average capacity and power of these vessels has increased by 50% (MMO, 2011).

Adaptation Actions

There is a **large second hand market for boats,** which may reduce the investment costs required. In addition according to stakeholders, over recent years, market exit is greater than entry. This means prices are low which is good for new entrants but not for businesses seeking to change vessels. (Tidd et al., 2011).

Licences go with the vessels, when vessels are changed, say from a small to large vessel. The owner will lose their previous catch history on the old vessel, which may make it difficult to obtain quota allocations on the new vessel.

According to stakeholders, a shift from a medium-sized vessel **to larger vessels might involve a change in their entire supply chain**. Many skippers or vessel owners rely on the competitive advantage of getting fresh fish to supermarkets, restaurants or fishmongers within 24 hours. This relies on operating within a small, local area. Larger vessels, however, require more days at sea to exploit efficiency advantages, and resulting in fewer, larger landings. This could affect who their buyers are.

Enablers

According to industry experts, **grant aid can support increase in vessel size and equipment**. While grant aid is particularly important for facilitating changes or improvements in equipment and technology, it can also be an important enabler for securing different vessels to exploit different species.

Effect of measure

The effect of this measure is considered to be **low** if the new vessel is in a similar category as before. According to industry experts, the ability to exploit a new species depends on how long vessels can stay out and withstand high seas. Furthermore a larger vessel has the flexibility in where it is able to operate.

If moving from being in <10 m category to >10m category, the effect could be **medium** as under this circumstance a larger vessel may be able to increase profits through spending more days at sea.

The summary of effectiveness is therefore **low to medium**.

5.1.3 Changing gear

There are opportunities for large and small vessels of many gear types to fish species occurring in the UK EEZ. **Table 9** illustrates this with the breadth of vessels and gear types within French fleets operating in the Bay of Biscay, where many of the warm water species are currently prevalent. Anchovy, in particular, is fished by pelagic trawlers; squid by large and small bottom trawlers, and sea bass by pelagic, dredgers and hooks. (Daures et al., 2009).

Figure 16 an Annex 4 illustratively compares the UK fleet to this fleet. The spread of vessel types between pelagic, demersal and in-shore fleets appears consistent with those in the Bay of Biscay (as an indicator for types of species which could move north into the UK EEZ). This indicates that there is unlikely to be substantial structural changes of the fleet. Yet each vessel may need to adapt the gear to catch alternative they may need to change gears in order to change species.

To fish for new species, vessels may need to adapt the gear used. There are a number of ways vessel owners may do this:

- Adopting flexible gear which can fish their current species and a new species;
- Changing gear altogether to target a different species; and/or,
- Buying a completely new boat with all the relevant gear for catching a new species.

These measures can involve radical changes, (e.g. moving from beam trawling to seine netting), as well incremental changes, (e.g. innovative approaches to reduce contact with the sea bed). According to experts, one of the most substantial changes in gear used would involve shifting from focusing on demersal compared to pelagic fish.

Table 9. The structure of the French fleet fishing in the Bay of Biscay in 2005 (excludes shellfish species)

	Fleet name	Number of vessels	Dependence on key species in the Bay of Biscay (%): Sole	Hake	Sea bass	Monkfish	Anchovy	Cuttlefish	Squid	Sardine
Shelf and offshore	Bottom trawlers	83	12%	6%	4%	19%		9%	10%	
	Palegic trawlers	24		8%	30%		14%			7%
	Other trawlers	13	20%	7%	3%	3%	0%	1%	2%	1%
	Palegic and bottom trawlers	29	7%	6%	15%	4%	8%	5%	6%	10%
	Netters	75	38%	30%	3%	14%		1%		
	Hooks	13		1%	19%					
	Trawlers	261	18%	4%	5%	1%		10%	6%	1%
	Seiners	28			6%		1%			57%
	Dredgers	95	17%		21%	4%		4%		
Coastal	Netters	147	36%	7%	6%	6%		1%		
	Hooks	117		2%	63%					
	Potters	41						3%		
	mixed nets, pots and hooks	266	13%	3%	26%	3%		2%		

Source: (Daures *et al.*, 2009). This fleet ignores *nephrops* vessels and the ECR combines sub-categories with a weighted average by catch weight

Current/ future extent of adoption

According to many of the stakeholders interviewed, skippers are used to updating and improving the gear they use. In a comparison of adaptability the UK fleets scored highly compared to other European countries, due to availability of funds (Graham *et al.*, 2007). This extent of adoption is also illustrated in measures used to adapt to increasing energy prices: Graham *et al.* 2007 reported that 33% of a vessels sampled reported modifying gear to respond to increasing energy costs.

The expected level of adoption is therefore considered **high**.

Barriers

Fisheries management and quota arrangements (specifying species and timing of activities) can constrain uptake of changing gear. According to experts, it is particularly difficult to change from focusing on shellfish to fin-fish due to the "pigeon-holing" effect of legislation. Furthermore, days-at-sea restrictions can effect net sizes and engine power.

While crab and lobster vessels have been profitable in recent years, it would be difficult for them to exploit emerging demersal or pelagic fisheries at a later date.

Similarly, if boats want to move from targeting *nephrops* to white fish, they will need a different category of net and a difference licence. Stakeholders mention that this is difficult due to the limited catch history required to obtain adequate quotas.

Some fleets are very specific and cannot be modified; for instance beam-trawlers and small inshore boats. The boats which are likely to be constrained from changing gear are the very specialised vessels like beam trawlers; these are very capital-intensive and are designed specifically for towing heavy gear for flatfish. Many smaller inshore boats are already able to deploy different gears on a seasonal basis so are the most able to fish many different types of species.

The ability to change gear requires investment in equipment. In surveys, where there is clear business case, skippers have been able to secure resources to adapt (Graham *et al.,* 2007). The cost-related barriers depend on the equipment required: To fish anchovy, for example, posnets are needed, which can cost around £0.25 million; to adapt a boat with nets and hauling equipment could cost as much as £1 million. By contrast, drift nets cost around £2.5k and a string of pots around £1,500.

In some cases, gear changes include adapting to species which require bait. According to stakeholders, adding facilities for bait on board is less problematic than the cost of the bait itself, which has been increasing and can cost twice as much as fuel.

The ability to invest is related to current profitability; many demersal fleets are not highly profitable and may struggle to raise funds for changing gear and vessel development.

A further cost driver related to the ability to change gear is the levels of overheads. Whilst smaller vessels may struggle to gain finance, they have lower overheads, allowing them to be change opportunistically.

Enablers

Availability of grant aid can support increases in vessel size and equipment. The European Fisheries Fund provides funding to the UK for improvements to vessels. £38 million[17] is available between 2007-2013 in the UK to help the sector adapt to changing needs related to sustainability of fisheries. Grants have been provided which can cover up to 40-50% of investments in boats and equipment.

[17] http://www.marinemanagement.org.uk/fisheries/funding/index.htm

Knowing the best way to fish new species and the most up-to-date methods and technologies is not a barrier as vessels in the UK currently fish many of the species which are expected to increase in stock. Many vessels are already catching red mullet, bass and John Dory by trawling. Maximising value by using lines and live bait is already practised in the Channel Islands and has been taken up on the South Coast of England. Although most new species are likely to come from southern waters as increasing water temperature allows them to extend their range, key actors in the sector are already familiar with new species:

- The UK fish industry already knows the species in Biscay, the Iberian Peninsula and the Mediterranean.
- UK scientists and technologists already cooperate with their peers in Southern Europe.
- Organisations such as Seafish assist the transfer of knowledge from countries where species are currently being caught to the UK. For example, Seafish arranged for Cornish fishermen to go to Brittany to look at sardine fishing methods and then help to bring those techniques to the UK.

Effects of measure

According to experts modifications of vessels is technically feasible in many cases and new nets and gear can be attached to most boats. However, making such modifications is limited by the equipment needed for the species of fish now being prioritised, and the type of vessel requiring modification.

The type of fish species prioritised may also influence the rate of adaptation action. Pelagic species react quickly to changing sea temperatures, but most species which rely on seabed habitats change their distribution at a slower pace. However, observed changes in fish species typically show that the pace of change is slow enough for a gradual adoption of new equipment in the UKs fishing fleets

Furthermore, it is unlikely, that vessel owners would make changes today which would prevent them being flexible in the future. The lifespan of gear and vessels is such that they would not outlive potential species changes in the future.

The effectiveness of this action is therefore considered **low to medium**, though could increase to **medium/high.**

5.1.4 Development of the recreational fishery sector

These actions include responding to changing availability of fish stocks, by both proactively and reactively diversifying livelihoods. This can include the (temporary or permanent) use of vessels for recreational activities, or in other sectors, such as renewable energy. These measures also include promoting angling from the shore, use of charter boats and private vessels.

Current/ future extent of adoption

According to experts, the fishing sector has experienced major changes over the past decade, with the number of part-time fishermen increasing. At the same time, other sectors such as tourism, have increased in importance.

Diversification is increasingly recognised as an important element in the development of fishing communities. In some rural communities, while other aspects of tourism has decreased by over 10% over the past two years, income related to fishing (both river- and sea-based combined) has increased by between 10-25% per annum (Brown et al., 2012).

The extent of adoption is therefore assessed as **medium**.

Barriers

Many of the alternative sources of income have barriers to entry (investment, training, marketing required). Also, it is difficult to monitor angling numbers properly (Brown et al., 2012). Experts mentioned that increasing numbers of part-time and leisure fishermen may also result in unsustainable fishing, as the informal provisions of fish to restaurants and small scale distributors is more difficult to control and monitor

Information on the contribution of recreational fishing is currently poor. However, further efforts in the Sea Angling 2012 survey which is a scientific study of sea angling activities in England, will build the understanding of the recreational fishing sector (MMO, 2012). According to stakeholders, an assessment of its economic and social value is anticipated to strengthen its positioning alongside commercial fisheries.

Enablers

The size and growth of other industries active in coastal communities is well documented (e.g. tourism).

For recreational angling to be exploited, communities need to make sure the offer is "easily understood, affordable and well publicised" (Brown et al. 2012). At the same time, adequate provision is needed at the community level related to maintenance, management of clubs/associations, provision of advice and co-ordination (Brown et al., 2012).

The new Inshore Fisheries and Conservation Authorities (IFCAs) set up under the Marine and Coastal Access Act (2009) have local angling experts involved. They are able to ensure recreational fishermen's interests can be represented as plans for sustainable exploitation of fish stocks are developed (MMO, 2012).

Sea Anglers are considered by experts to have a strong "conservation ethic"; for instance they practice catch-and-release for a number of species (including bass).

Adaptation Actions

Effect of measures

Of the species considered for this study, several are regarded as important to recreational fishermen (e.g. sea bass). It is estimated that up to 2 million people go sea fishing each year (MMO, 2012). This includes boat and shore anglers who practice throughout the year, as well as tourists. However, the importance of this sector is poorly understood, and further information on the social and economic benefits of recreational fishing will only be obtained on the publication of the Sea Angling 2012 survey, due to report in December 2012 (MMO, 2012).

Measures to promote fisheries have been shown to have a large socio-economic benefit for the development of recreational fisheries. For instance, in one small Scottish community, efforts to increase angling-based tourism could result in a 10% rise anglers resulting in a further three full time equivalent jobs and additional £100,000 economic contribution (Brown et al., 2012).

Conversely, measures to diversify could prevent vessel owners in any return to commercial fisheries. According to entry and exit models (Tidd and Padda, 2011), fishermen rarely come back into the sector once they have diversified (especially as newer and larger vessels acquire quota from vessels exciting the fleet). It is therefore unlikely that recreational fishing is an effective measure to manage long-term shifts to new species appearing in UK waters.

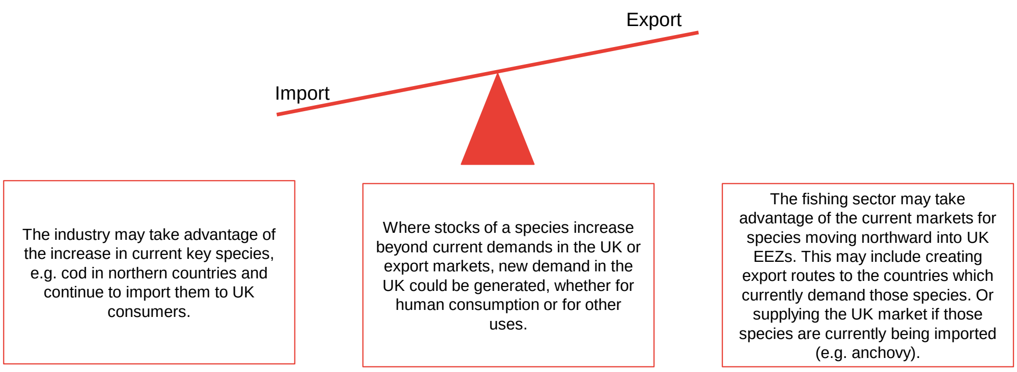
The effectiveness is therefore assessed as **medium.**

5.1.5 Identify export markets and enable UK market operations

Markets may adapt in response to opportunities presented by climate change in a number of ways: **Figure 11** illustrates three key actions which may be taken.

An important adaptation action to respond to increasing populations of particular species is maximising trade opportunities. This is especially important if domestic consumer demand is slow to materialise. Actions can include supporting information provision, building capacity to export and addressing other barriers to entry.

Figure 11. Adaptation actions and the UK balance of trade



Current/ future extent of adoption

The export markets are well-developed in the UK as businesses already sell established species to other countries (e.g. much of the pelagic species are sold out of the UK). For instance, squid has been exported for 15-20 years to Spain and Italy and these countries may remain key markets even as fish stocks move northwards. Similarly, in the UK demand for northern cold water fish (such as cod) remains high, whilst supply has switched from more northern providers - 80% of cod consumed in the UK is currently imported from Iceland or Norway.

Furthermore, markets are likely to adapt quickly to new species, as according to experts, channels into the market can develop quite quickly where yield is high enough to supply a market.

The expected effectiveness is therefore assessed as **medium to high**.

Barriers

The operators of fish markets do not always receive a detailed forecast of supply from producer organisations or individual vessel owners. This forecast would be derived from quotas and historic fishing activities and could help stimulate demand (Fishing for Markets, 2011).

Ineffective communication can be a barrier resulting in auction markets unable to avoid over-supply and or inconsistent prices. This can be addressed through improving communication technologies between vessels, markets and processors. However it is noted there is "currently little dissemination of information and communication between markets and businesses further down the supply chain." (Fishing for Markets, 2011).

Enablers

Some auctions, such as those at Plymouth and Shetlands, are developing remote buying systems, which can open access to wider markets (Fishing for Markets 2011). Processors are quick to identify markets and develop technologies which enable the fish to be transported further. Fish can be transported fresh, frozen, dried and vacuum packed to extend the distance they can be delivered.

For new fisheries, the development of effective coalitions between fishing associations (and fishermen), UK and European markets have been considered as "effective vehicles to drive markets for under-utilised species".

A key requirement in supporting export markets is the level of services and the ability secure best prices for fish. Some leading international markets provide support such as transport for landing, advice on best days to land, etc. (Fishing for Markets, 2011).

Effect of measures

As discussed in Section 5, the UK exports the equivalent of 85% of its landed stock (Almond and Thomas, 2010) supported by demand in the UK and abroad.

The strong demand in export markets increases the profitability for many UK vessel operators. For vessel operators to want to supply these species to a domestic market instead would require demand and prices in the UK to be as high or higher, and for adequate demand to realise those values. **Table 10** shows this is not yet the case for species such as sea bass and squid.

Table 10. Comparison of implied values of species in the local verses export markets (2010)

Species	UK import value (£000 per tonne)	Export value (£000 per tonne)
Sea bass	£4.59	£5.89
Squid	£2.29	£3.55

Source: Almond and Thomas (2010), calculated from import and export quantities and values

The effectiveness is therefore assessed as **medium**

5.1.6 Encourage consumer demand for emerging species

The actions to encourage domestic consumer demand of alternative (non-'big-five' species) include proactive measures to influence behaviour of consumers. It includes provision of information through multiple media channels (e.g. magazines, television etc.) and labelling, among other approaches. However those involved in the programmes have noted that they are most effective where they are widespread and sustained. They also note that it can take years to change preferences.

Current /Future extent of adoption

There are several examples of specific campaigns by retailers to influence consumer demand:

- Waitrose has run programmes with customers using recipe sheets and magazine articles showing people how to prepare fish products.

- In 2011, Sainsbury's ran a campaign "switch the fish". This initiative challenged the supermarket's customers to try an "alternative" fin-fish species. Customers who asked for one of the "Big 5" species - cod, haddock, tuna, salmon or prawns, which account for 80% of the British retailer's total seafood sales - were offered one free portion of coley, hake, mackerel, megrim, pouting or rainbow trout. This was considered to be successful at increasing fish purchases (Our Future with Fish, 2012).

- Sainsbury's found that Celebrity chefs have been influential in aiding understanding about tastes and preparation of niche species. If the stores support this by providing the species, this enables demand.

However, stakeholders have noted that there has not been a major and sustained campaign to change behaviour.

The extent of adoption is therefore considered **low to medium.**

Barriers

Existing dominant species closely meet consumer attributes. This same performance does not exist to the same extent in some of the other species. In particular there are several key barriers that need to be considered:

- **Taste.** UK consumers typically prefer a mild-flavoured fish, such as cod and haddock.

- **Preparation time.** Consumer surveys by Sainsbury's found that one of the key barriers to UK demand changes is the preparation time. Species similar to the current species in terms of size, and number of bones are able to access the market with more ease that others.

- **Price of products.** According to a retailer, people will only respond to a limited extent to lower pricing. The quality and attributes of fish is critical (e.g. some consumers consider coley is only suitable for pets).

Adaptation Actions

- **Consumer perception of sustainability.** Some retailers focus on species that are under quota-management; these tend to be the species that are well understood and as a result there is less of a risk to corporate reputation associated with concerns of over-fishing.

- **Discard policies.** Some retailers have policies related to avoiding discarding. To meet this obligation, they want to promote a market for other species caught in mixed fishing activities.

- **Lack of understanding.** Several of the retailers consulted considered that a poor understanding about different consumer options inhibits change. A key enabler, therefore, is the existence of a major campaign using different media; this can include magazines, television as well as mainstream chef endorsement. At the same time, the campaign has to ensure people know where they can buy the fish in question. According to stakeholders, this is particularly important, as some fish-mongers may not want to risk including new species.

- **Comparative promotions.** Some alternative fish species are presented by food manufacturers in comparison to existing species. For example, one processor presented a new species as "just as good as cod"; instead stakeholders have mentioned that campaigns should draw attention to the inherent qualities of new species.

- **Demand-led retail.** Retailers are primarily directed by the demands of their key customers rather than availability of supply. Large chains of supermarkets also need minimum numbers of fish available consistently. Sustainable catch levels of some species may not meet these requirements.

Other barriers to influencing consumer demand for alternative fish species experienced by restaurants are presented in **Table 11**.

Table 11. Barriers and Enablers for restaurants to sell niche species

	Restaurants	Consumers
Enablers	• Lower price and higher margin compared to "high status" species • Taste • Ethical sourcing (local appeal restaurants)	• Taste and freshness • Sustainability and ethical sourcing • Novelty dishes • Recommended by waiting staff • Inspired by chef's skills and "specials"
Barriers	• Perception that customers are unadventurous and must have salmon, sea bass, Dover sole and cod on the menu • Lack of consistent market availability • Lack of knowledge of, and experience of working with, some species • Unwillingness by waiting staff to promote under-utilised species on menus • Lack of wider promotion of the species – for example on television and in magazines	• Fear of trying something new and wasting money if they don't like it • Fear of bones • The names of some fish • Lack of knowledge of some species • Lack of wider promotion of the species –for example on television and in magazines • Perceived status and quality of unfamiliar fish

Source: Fishing For The Markets (2012)

Furthermore, there are some specific issues associated with the some of the species likely to be more prevalent in the UK:

- **Anchovy:** This is a bony fish and is unlikely to ever be a mainstream product for retailers.
- **John Dory:** This species has potential but some retailers are concerned about the stock assessment: If it starts to be harvested commercially it could be considered an unsustainable species to supply.
- **Squid:** While many people eat squid when travelling elsewhere in Europe, it does not often translate favourably back in the UK. This species does, however, respond following retailer-based advertising or recipe cards.
- **Sea Bass:** This is already a species with growing importance for UK retailers. People also often chose sea bass when they eat out as it is seen as more exclusive than cod. However, it is not seen as an everyday food as it is more expensive.
- **Red Mullet (and red snapper):** This is often benchmarked against cod or haddock; but increasingly retailers are trying to position this in a totally different market.

Adaptation Actions

Effect of measures

There are several examples where consumer demand for new species has increased. These are illustrated below. In many cases, the markets for these products have been promoted by campaigns developed and implemented by the retailers.

It is notable that the effect of the measure is **low** for vessels themselves; as fish caught will be exported in the absence of a domestic market. However, for retailers, consumers and governments interested in exploiting a changing climate to create new jobs in different parts of the value chain, stimulating consumer demand could become an important adaptation measure. It is also important to avoid maladaptation in terms of increased accidental by-catch.

The effectiveness is therefore assessed as **medium.**

Anchovy – example of market growth

The total volume of the UK anchovy imports has doubled in the period 2000-2008, from 700 tonnes in 2000 to 1,400 tonnes in 2008. In terms of value, the UK imported anchovies for USD 16.7 million in 2008, up from USD 5.8 million in 2000. The main part of the value, 86% or USD 14.4 million, is made up by prepared and preserved anchovy products, while the rest, 14% or USD 2.3 million, is contributed by imports of fresh and frozen anchovies.

Source: Eurofish International Organisation (2012)

Sea bass - example of a species achieving success in the UK consumer market

While the 'big five' fish species still dominate the consumer shopping basket, there are signs that some of the lesser-known species are gaining in popularity. Sainsbury's sales data suggest that sea bass, hake, pollock, coley and tilapia are rising in popularity.

Sainsbury's classify sea bass as a popular performer; sales volumes rose 57% during 2011. (Our Future with Fish, 2012).

Salmon - an example of a species moving from niche to mainstream

In the current market, species outside the main five are considered niche products. The challenge is moving from niche to mainstream. The salmon aquaculture industry is a good example. Today, farmed salmon is a core product and wild salmon, niche. This has taken 25 years and many barriers (described above) had to be addressed.

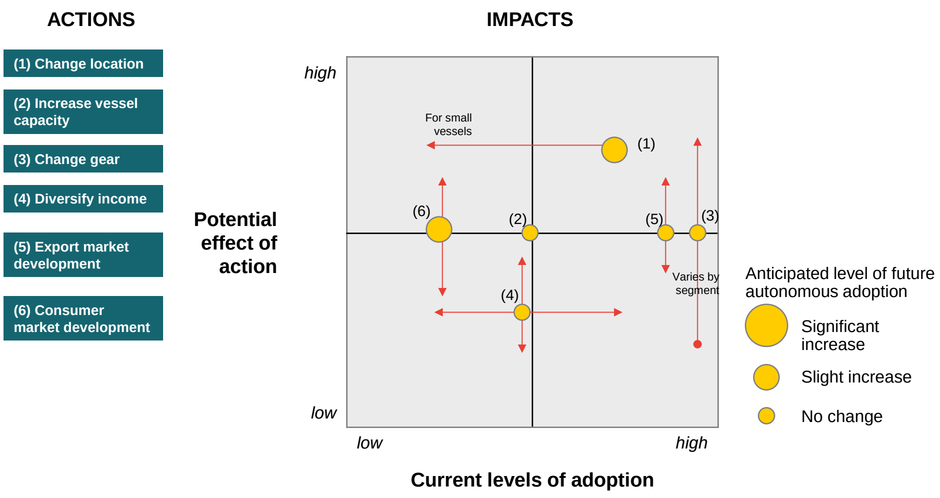
The retailer also tried to develop markets for farmed cod using the same mode. Unfortunately it did not have the same eating quality and was considerably more expensive. This initiative did not work.

Source: Stakeholder interview

5.2 Estimating the impact of adaptation

Figure 12 provides a simplified summary of the current and future levels of adoption of the adaptation actions, and their effectiveness. The summary uses the classifications 'high, medium and low' used above. The assessment is based the evidence presented in this Section and stakeholder discussions. **Figure 12** is intended to be an overview of the findings set out in this report, rather than a further analysis of effective adaptation and is intended to provide a basis for further discussion as part of future stakeholder engagement.

Figure 12: Summary of current and anticipated effects of different adaptation actions



Source: based on evidence presented in this report

Note: Scales are qualitative and relative to the sectors included. The current levels of adoption include decisions that are infrequent (e.g. changing vessels) as well as common practice (such as changing fishing practices). The position of each measure is based on the classification used within this Section, but could vary considerably depending on sub-segment.

Adaptation Actions

There are a number of key points to note:

- There is much variability on the effect of alternative adaptation actions. This is primarily related to the differences between different species and segments of the fishing sector.

- Many of the important adaptation actions are already well understood and do not necessarily represent a fundamental change in business models or ways of working.

- Stimulating local demand could be important in stimulating a mass market for some of the species likely to increase in the future, but is currently limited in extent of application.

Where actions are in the top-left quadrant of **Figure 12**, this implies that there are barriers to what might otherwise be relatively effective actions being implemented (where they would be justified through cost-benefit analysis). Likewise, where actions are in the bottom-right quadrant, there may be barriers to actions being more effective.

5.2.1 Barriers to effective adaptation

Key barriers that have been identified include:

Market failures

Information barriers mean that not all vessel operators are necessarily aware of best practice techniques and actions that can allow opportunities to be maximised, given the changing distributions of fish stocks.

Although some information-sharing channels already exist in relation to maximising opportunities associated with changing fish species and their distribution, these do not reach all vessel operators. Existing channels include those provided by producer organisations and other sector organisations, such as Seafish and the Fisheries Science Partnership programme.

Information failures also exist in relation to uncertainty around new or emerging species in the UK EEZ. Such information barriers often stem from the high cost associated with gathering the information through scientific studies and the time it takes to collate it.

However, as fish distributions continue to change, information on the degree of change currently occurring and expected will be necessary for effective adaptation actions to be implemented over time.

Policy barriers

Regulation is in place to ensure sustainable catch levels, but for quotas to keep pace with changing stocks relies on scientific evidence being collected and accounted for by policy makers in a timely way. **Developing of scientific evidence is reactive and slow** so there is a risk that quota allocations do not keep pace with changing stocks and potentially restrict fishing activity where stocks are increasing, or changing their distribution.

Quota allocations based on historic levels of catch (relative stability) could restrict the ability of the UK to maximise opportunities from stocks increasing in the UK EEZ. Quotas could also create incentives for maladaptation**.** For example, for species not under quota, where emerging abundance creates potential expectations of future quota restrictions, the incentive to overfish could arise in order to build up the historic catch to increase any future quota allocation.

Small vessels cannot trade licences freely; the market for quota availability between large vessels is opaque. Licences based on past catch levels reduce the flexibility to change species and maintain licence levels.

Behavioural barriers

UK consumer market preferences are showing signs of change, but preferences are still dominated by the 'big five' fish species.

Governance barriers

Small vessels spread along the coast may not have access to key export auctions.

Adaptation Actions

6 Case for intervention

Key Messages

- Given the uncertainty of the science and changes in fish stocks, many adaptation actions hinge around building adaptive capacity.
- As a consequence it is assumed that the sector will be subject to regular review and continual re-assessment of opportunities.
- Many of the short-term actions involve identifying and assessing measures to increase the resilience of the UK fleet to changing species availability. There are a few breakthrough projects - these include initiatives to stimulate consumer demand, which will need to be sustained and creative (for example for over for 10 years +). Other breakthrough projects could be associated with the development of capacity within the recreational fishing sector.

This Section presents the case for intervention. It first explores adaptive management to demonstrate how an effective adaptation strategy can be developed. It then discusses illustrative 'what if?' scenarios that show the potential gain if barriers identified in Section 5 are overcome. It concludes with recommended interventions to address the barriers to effective adaptation.

6.1 Adaptive management

The projected nature and impacts of climate change in the UK over future decades, particularly when considering to the 2050s and beyond, are subject to a degree of uncertainty. Although this makes it difficult to make decisions on how to ensure organisations are resilient, it does not mean action should not be taken.

Uncertainties are particularly problematic for planning adaptation options with long life-times, as they are costly to reverse and dependent on assumptions made about future conditions. If forecasts prove to be incorrect, the action could lead to maladaptation, wasted investments or unnecessary retrofit costs (Reeder and Ranger, 2011). Adaptation decisions must therefore be as flexible as possible to a fast changing and uncertain climate (Hall, 2007).

In this project, adaptive management is suggested through an illustrative adaptation roadmap as a pragmatic and effective way to allow appropriate actions to be taken in the presence of uncertainty. It involves constant monitoring and reviewing of actions taken, and further small iterative steps to be taken consistent with a strategic direction. Adaptive management allows parties to learn over time and for new information to be reflected in decision-making processes. The intention is to maintain as much flexibility as possible for future options. The essence of the approach is to be clear on the direction of travel, or the vision for the desired outcomes or the management/goals, and the uncertainties about how to achieve these outcomes (Murray & Marmorek, 2004).

Adaptive management encourages decision-makers to pose 'what if' scenarios and take an approach whereby decisions are made over time continuously. This approach allows **flexibility to be incorporated into adaptation measures from the start**, e.g. by using measures that are suitable over a broad range of possible future climates or by designing the adaptation measure so it can be readily adjusted (Fankhauser et al., 1999). Flexibility is also incorporated into the overall adaptation strategy by putting the adaptation into a sequence, and leaving options open to deal with a range of possible future scenarios.

6.1.1 An illustrative adaptation roadmap

The roadmap developed here is intended to show "packages" of actions that can be implemented over time – actions shown can be found within the categories discussed in Section 5. This report has not developed a detailed adaptation pathway, such as the Thames Estuary 2100 Report, because the "known thresholds" for climate change risks, and the relative impacts of the actions against those risks (Reeder and Ranger, 2011), have not been assessed. The ECR considers a number of different risks and categories of adaptation actions, and these are set out in a timeframe to illustrate how the issues could be managed adaptively (**Figure 13**). Future work should analyse the thresholds of individual climate risks and what the limits of specific actions may be in reducing that risk. Prioritising adaptation options in the face of uncertainty leads to a focus on those options that are:

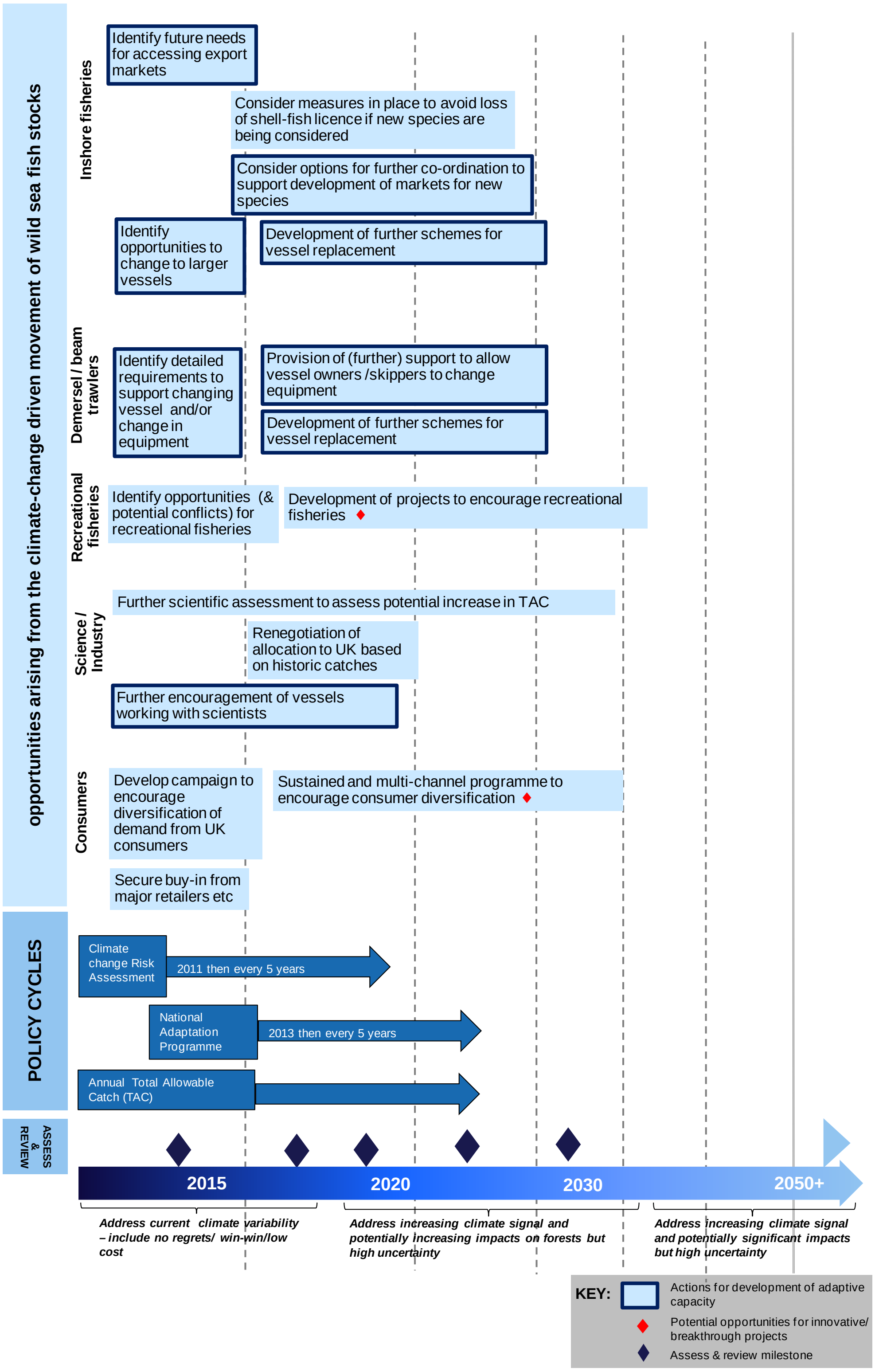
- **No-regrets**: actions which are worthwhile (i.e. they deliver net socio-economic benefits) whatever the extent of future climate change. These types of measures include those justified under current climate conditions (UKCIP, 2007). They include measures such as supporting diversification of fish species available to consumers;

- **Win wins**: actions that minimise climate risks or exploit opportunities, but also have other social, environmental or economic benefits (UKCIP, 2007). A good example here is supporting development of science, which contributes to avoidance of overfishing;

- **Strategic options with long lead times** can include vessel replacement and supporting major changes in specific segments of the UK fleet.

The roadmap involves putting in place incremental adaptation options, rather than undertaking large-scale adaptation in one fell swoop. Measures are designed to allow for incremental change as knowledge, experience and technology evolve. Delaying a specific measure can be part of this approach, where that decision is accompanied by a commitment to continue to build adaptive capacity and monitoring and evaluating the evolving risks (UKCIP, 2007). In the long term, the direction of travel may need to change, and incremental changes may no longer be appropriate. Transformational adaptations would then be required, including those that are adopted at a much larger scale or represent a major shift in the fishing industry and associated value chain. Anticipatory transformational adaptation is extremely difficult to implement because of uncertainties about climate change and associated adaptation benefits, high costs, and institutional and individual mind-set that prefer to maintain existing resource systems and policies, rather than create transformational change.

Figure 13: Summary of selected illustrative roadmaps



Source: Based on analysis in this report

Case for intervention

It should also be recognised that any action chosen should be taken with the engagement of stakeholders and based on appropriate data to allow progress and emerging outcomes to be monitored and reviewed.

The roadmaps are not intended to be comprehensive or exhaustive, as there are many other roadmaps to consider. Instead, **Figure 13** is intended to be an indicative illustration of some of the actions that are likely to be effective up to the 2050s and when key review points should occur. Some of the actions within the roadmap will occur reactively, and some will require further support from others.

The roadmaps incorporate review points, where policy and practice can be assessed and evaluated in the light of new developments, new information and emerging understanding on climate risks and research outputs. The review points are designed to coincide with policy cycles (e.g. of the National Adaptation Programme and Climate Change Risk Assessment) as well as at points where adaptation actions should be maturing. These frequent review points will allow roadmaps to be developed iteratively and with consideration of inter-dependencies and linkages across options.

Coordination

There are many interdependencies between the options in the roadmaps. Many of the options rely on capacity-building and the framework for adaptation. For example, scientific research will influence vessels used. This foundation must be established before other, costlier, options can be taken.

In addition, there are many dependencies on actions in other sectors that need to be considered to lead to effective adaptation. For example, investments in port and transport infrastructure will affect the location and activities of vessels.

Underpinning all of these roadmaps is the need to consider the conditions under which adaptation actions as a whole are likely to be effective. Appropriately mitigating the impacts of climate threats, and making the most of opportunities, requires a range of conditions to be in place, such as the policy framework and other supporting mechanisms.

6.2 'What if?' analysis

The roadmaps illustrated in **Figure 19** shows packages of actions that could address particular climate threats or opportunities, in the presence of uncertainty. Roadmaps do not, however, provide an indication of the extent to which the impacts of those threats could be mitigated, or opportunities maximised. To capture this, illustrative 'what if?' scenarios have been explored.

These show what the impacts might be under particular assumptions regarding specific adaptation actions. It is important to note that more detailed analysis would be required to develop accurate estimates of the scale of the effects.

Scenarios explored relate to:

- The sector changing gear in order to take the opportunities of emerging species.
- Increasing consumer demand for niche or emerging species.

6.2.1 Scenarios explored

The purpose of these 'what-if' scenarios is to draw on available evidence and expert advice to illustrate the potential scale of relative effects where particular adaptation actions are taken. It should be noted that 'what-if' scenarios are not intended to be projections. Rather, they are intended to illustrate potential outcomes under certain assumptions.

What if the sector adapted their vessels and made the most of the opportunities presented by emerging species?

This scenario attempts to illustrate the opportunities which could be taken up by UK vessels. The approach is to look at how this could vary by port, based on the current species targeted by vessels from those ports.

There are a number of data limitations and a high level of uncertainty when assessing potential opportunities presented by emerging species. Key limitations include:

- The indicator used here for the potential impact of climate change is the change in habitat suitability. It is not known how this would impact the change in levels of catch but is used to show the potential scale and direction of change. For this illustration, the corresponding percentage increase in habitat suitability has been applied to the level of landings in order to provide illustrations of potential catch out to the 2050s (in the absence of sustainability considerations).
- The change in habitat suitability is an aggregated value across the UK EEZ. How this impacts locally has only been mapped for a few species (Jones et al., 2012). Large vessels from any port may in fact be able to travel long distances, so it is difficult to be specific about location. An assumption is made that they would be able to benefit proportionately from the overall level of opportunities. For small vessels, which are more likely to have restricted ability to travel, a separate assessment using the mapped opportunities has been undertaken.

Case for intervention

- Only data on landings by port have been used. For many species (particularly pelagic species), large proportions of the catch by UK vessels are landed abroad. Therefore the expected losses and opportunities could be much greater.

- Finer detail would be required to understand the investment costs required to make any changes and any increased operating costs to take up the opportunities.

Section 4 identified a key barrier to vessels adapting could be the levels of available quotas. The analysis below uses current levels of landings to reflect the sustainable level; it is here assumed that an increase in habitat suitability would increase the sustainable catch (TAC) proportionately. The does not include any restrictions on species currently not under quota, should quotas for these species be introduced the opportunities taken up will be restricted.

Implications for large vessels (>10 m in length)

Without making the most of potential opportunities, the sector would be likely to suffer the adverse effects from climate change. Pinnegar et al., (2012) assessed that the costs of travelling further to catch current species would be classified as low, between £1 -9 million annually in the 2020s across the range of emissions scenarios.

Using changes in habitat suitability as an indicator of the amount of stock which could potentially be caught, and the levels of TAC which may be set,

Table 13. indicates the potential impact on landings by port. Ports used for illustration are Brixham, Milford Haven, Ardglass, and Peterhead. The levels of potential catch by 2050 are estimated assuming a straight-line gradual increase over the period 1985-2050 in line with the change in habitat suitability, extrapolating from 2011 catches (to account for potential levels of overfishing and unquoted species in 1985, the base year of the habitat suitability modelling). For species which had very low landings by UK vessels in 1985 (the base year), such as anchovy, sea bass, anchovy, John Dory, red mullet and squid, the results should be considered as more speculative[18].

This report does not consider shellfish. Ports such as Milford Haven and Ardglass which have higher proportions of landings of shellfish appear relatively less affected.

---

[18] Current catches are assumed to represent the first 26 years of a gradual increase and so have been simply extrapolated for a further 39 years.

This analysis suggests ports, such as Brixham, which currently fish for a diverse range of species (**Table 12**), could benefit from a number of opportunities and could be less exposed to potential losses.

Table 12. Value of current (2011) landings at the port by large UK vessels (£'000s)

Species	Brixham	Milford Haven	Ardglass	Peterhead
European anchovy	315.6	0.0	0.0	0.0
European sea bass	188	1.4	0.0	0.0
Atlantic cod	50	12.0	14.1	14,861
European squid	784	5.7	19.4	883
Haddock	88	19.2	9.3	19,506
European hake	3.4	114.3	9.0	2,718.3
John Dory (Atlantic)	125	195	0.4	24.4
Atlantic mackerel	38	0.0	2,447	52,169
European pilchard	6.3	0.0	0.0	0.0
European plaice	822	13.3	3.2	272
Red mullet	232	0.1	0.0	5.4
Common sole	3,354	139.9	6.6	0.2
European sprat	255	0.0	43.6	0.0
Whiting	88	9.6	0.7	5,657

Source: Analysis of Cefas data on landings by UK vessels at UK ports

Table 12 shows that vessels landing in Brixham are landing a number of different species including emerging species of both pelagic and demersal types (e.g. anchovy, sea bass, John Dory, red mullet). The more northern ports of

Petershead and Ardglass are more reliant on landings of traditional species, some of whose habitats are predicted to decrease in suitability, such as mackerel and halibut. Both ports have current landings of squid, a species which has been emerging since 1985.

Table 13 shows the implied illustrative ranges of annual increase or decrease in landing, based on the projected change in habitat suitability.

Table 13. Illustrative range of increase/decrease in the annual catch in 2050 relative to 2011 (£000's)

	Habitat suitability increase across the UK EEZ from 1985-2050 (range from three models)	Brixham (range)		Milford Haven (range)		Ardglass (range)		Peterhead (range)	
		From	To	From	To	From	To	From	To
European anchovy	+1 to +7% *	473.4	473.4						
European sea bass	-9 to +24% *	281.2	281.2	2.1	2.1				
Atlantic cod	-12 to +3%	-3.8	0.9	-0.9	0.2	-1.1	0.3	-1124.0	264.3
European squid	+4 to +11% *	1175.4	1175.4	8.6	8.6	29.2	29.2	1323.9	1323.9
Haddock	-12 to 0%	-6.6	0.0	-1.5	0.0	-0.7	0.0	-1475.2	0.0
European hake	-11 to +2%	-0.2	0.0	-7.9	1.4	-0.6	0.1	-187.7	32.4
John Dory (Atlantic)	-16 to+17% *	187.1	187.1	292.3	292.3	0.6	0.6	36.6	36.6
Atlantic mackerel	-7 to 0%	-1.7	0.0			-105.7	0.0	-2254.2	0.0
European pilchard	+2 to +30%	0.1	1.0						
European plaice	+1 to +8%	4.9	38.3	0.0	0.6	0.1	0.1	1.6	12.7
Red mullet	-14 to +28% *	347.6	347.6	0.2	0.2			8.1	8.1
Common sole	-18 to +18%	-390.3	337.9	-16.3	14.1	-0.8	0.7	0.0	0.0
European sprat	+4 to +21%	6.0	29.7			1.0	5.1		
Whiting	-14 to 4%	-7.9	2.1	-0.9	0.2	-0.1	0.0	-503.3	133.6

Source: simplified application and extrapolation of habitat suitability estimates from Jones *et al.,* (2012). The (*) mark species for which there were no reported catches by UK vessels in 1985 (ICES records of catches), so a simplifying assumption is made that the current 2011 volumes of catch are a result of the increase in habitat suitability and that this increase would continue at an equal rate between 2011 and 2050 hence no range is shown.

Implications for small vessels (<10 m in length)

Small vessels are restricted from travelling and so are not as likely to be able to benefit from opportunities arising further way from the UK shoreline.

The increase in habitat suitability (between 1985-2050) has only been mapped locally by Jones (2012) for four species, which are currently emerging in the UK EEZ. These maps were presented in **Figure 1** and illustrate localised opportunities and uncertainties.

Annex 5 compares the current (2010) landings at four tested ports (Brixham, Milford Haven, Ardglass, Peterhead) by small UK vessels of these species, and the resulting increases or decreases in habitat suitability in the immediate locality of the ports as pictured in **Figure 1**. **Table 14** combines these measures to illustrate potential localised opportunities and uncertainties:

- Within the locality of the Brixham port, three of the emerging species are already caught; however the models project uncertainty around whether there will be increasing opportunities for John Dory, sea bass and anchovy. All models predict some loss of habitat suitability for the squid, which is currently caught by small vessels; this implies a potential loss for the small fleets in the future.

- Within the locality of the Milford Haven port, only sea bass is currently caught and the models are inconclusive about whether this species will increase in the future. Small vessels do not currently land anchovy, yet all models expect local waters to become more suitable in the future.

- Within the locality of Ardglass, a similar result is seen. Squid are currently landed and the models are inconclusive about whether there will be opportunities from this species in the locality in the future. Anchovy is not currently landed by small vessels, but the local waters are expected to increase in habitat suitability for this species.

- Small vessels at Peterhead currently only catch squid of these four species and all models project an increase in the local habitat suitability, which could result in a local opportunity. The models also project increases in suitability for sea bass, which is not currently caught by the small vessels. This may represent an opportunity for the vessels to fish for the species or an increase in the angling industry.

Table 14. Illustrative potential opportunities for vessels which cannot travel far from the ports

	Brixham	Milford Haven	Ardglass	Peterhead
European Anchovy	U	+	+	U
John Dory	U	U	U	U
European sea bass	U	U	U	+
European squid	-	-	U	+

Red represents a potential loss, species are currently landed and habitat suitability is expected to decrease

Green + represent a potential gain, species are currently landed and habitat suitability is expected to increase. U represents unknown impact on current landings, species are landed at this port but the habitat suitability varies from positive to negative across models

Amber + represent a potential gain, species are not currently landed but habitat suitability is expected to increase. U represents no current landings and the habitat suitability varies from positive to negative across models.

Source: Estimated from Jones (2012) graphical modelling across UK EEZ to identify localised changes of habitat suitability aligned with Cefas records of landing at those ports

What if additional domestic demand were created for the species presenting an emerging opportunity?

This scenario considers what if the retailers of fish stocks were to run campaigns to increase domestic demand to emerging species; and whether this may result in a profitable market for these species in the UK.

For two example species (sea bass and squid), for which imports and exports into the UK are currently recorded by the MMO, current consumption is estimated and presented in **Table 15**. Domestic consumption currently exceeds levels of domestic supply.

In the absence of additional action, future domestic consumption may be expected to increase, possibly in line with the population; ONS population projections estimate an increase of 10%-42% between 2010 and 2051. However, future level of demand for the species will be driven by a number of factors, including preferences or pricing. Also, noted in Section 4, Sainsbury's has reported an increase in sales of sea bass over 2011 of 57% (Sainsbury's, 2012).

Case for intervention

Table 15. Current demand for emerging species (using examples of sea bass and squid).

(tonnes)	2010 UK landings by UK vessels	2010 UK imports of species	2010 UK exports of species	Implied UK consumption in 2010
Sea bass	691	6,485	333	6,843
Squid	3596	7,336	3,117	7,817

Source: Cefas landings data and Almond and Thomas (2010) import and export figures

Table 16 illustrates the 'what if?' scenario results. This shows that if the UK wished to meet domestic demand through UK landings then landings would need to be around 10-14 times higher than 2010 for sea bass and 2-3 times higher than 2010 for squid.

Table 16. Potential UK consumption (tonnes)

Species	Implied UK consumption in 2010	Illustrative consumption in 2051 after accounting for a population increase between 10%- 42%
Sea Bass	6,843	7,527 – 9,717
Squid	7,817	8,599-11,101

Although subject to uncertainty, projections suggest increases in habitat suitability for these species of up to 24% for sea bass and 9-53% for squid. Therefore, it is likely that imports would still be required, but the UK could benefit from the UK supply chain activity associated with these species (for example, processors, retailers etc.), particularly as these species have a relatively high market value, as shown in **Table 17**.

Table 17. Relative average UK import and export values, 2010

	2010 import value per tonne	2010 export value per tonne
Sea bass	£4,590	£5,895
Squid	£2,286	£3,551

Source: Almond and Thomas (2010)

The available evidence on the effectiveness of marketing campaigns is building. For example, following a year of high profile awareness campaigns in 2011 Sainsbury's has reported an annual increase of sea bass sales of 57%[19], pollock 15%, trout 29%, and tilapia 117%. Sainsbury's "switch the fish" campaign resulted in sales of sustainable fish varieties (including saithe, pouting, rainbow trout, hake and megrim) increasing 32% year-on-year. Although there are behavioural barriers to increasing consumption specific to different types of species (as noted in Section 4), these results shown by Sainsbury's identifies that it should be possible to achieve various levels of increases in consumption with media and retail campaigns.

There are many wider implications and uncertainties associated with increasing domestic demand for emerging species. For example, there could be displacement effects on other foodstuffs bought by UK consumers, which could impact on other supply chains in the UK. There would also be likely to be uncertain price effects if domestic demand were to increase.

6.3 Recommendations

The case for further intervention by government or other bodies flows from the evidence presented throughout this report.

The case for intervention by government or other bodies is likely to exist where:

- **Organisations or individuals lack the adaptive capacity** to be able to adequately prepare for climate change. It is critical to **target vulnerable groups or organisations** who are often lacking in adaptive capacity and must rely on others' adaptive actions.

- There are **significant barriers or constraints** to implementing effective adaptation action. This may be because markets lack the required information to allow appropriate signals to be sent to parties to take appropriate action.

[19] http://www.j-sainsbury.co.uk/%5Cmobilenewsarticle?id=6875

- The **UK may otherwise become 'locked in'** to a path that could lead to maladaptation or removes the flexibility required to effectively manage uncertainty

Importantly, **whether actions are implemented should be guided by appropriate and proportionate assessment of the costs and benefits of action** (including those that can be monetised and those than cannot) relative to the alternatives (including no further action). This must include the consideration of expected benefit of buying time and flexibility to adapt in the future.

It is important to prioritise actions on the basis of the extent to which they are 'no-regrets' (deliver benefits irrespective of climate change), 'win-wins' (deliver co-benefits aside from adaptation), low cost, or they are able to avoid 'lock-in' to actions which may otherwise lead to maladaptation. Building adaptive capacity is a top priority in the short-term.

The key findings from this analysis highlight the following barriers and case for intervention to address them:

Addressing market failures

Information failures exist in relation to uncertainty around new or emerging species in the UK EEZ. Such information barriers often stem from the high cost associated with gathering the information through scientific studies and the time it takes to collate it.

However, as fish distributions continue to change, information on the degree of change currently occurring and expected will be necessary for effective adaptation actions to be implemented over time.

Recommended intervention

Enhance the capability to monitor new and more abundant species, involving collaborative working of fishing vessel operators with the scientific community.

Support the scientific and technical facilities, which can improve the understanding of new or emerging species in the UK EEZ. This would provide the information necessary for the industry to better anticipate opportunities and make necessary investments and changes quickly.

Information barriers mean that not all vessel operators are necessarily aware of best practice techniques used by foreign fleets that can allow opportunities to be maximised, given the changing distributions of fish stocks.

Although some information-sharing channels already exist in relation to maximising opportunities associated with changing fish species and their distribution, these could be enhanced. Existing channels include those provided by producer organisations and other sector organisations, such as Seafish and the Fisheries Science Partnership program.

Recommended intervention

Use appropriate existing communication channels to engage with vessel operators and embed learning in relation to best-practice fishing behaviours for new, or more abundant, species. This could be through expanding existing channels to ensure more information and guidance is collected, and deliver it in a clear, accessible and practical way to a wide number of operators of large and small vessels.

Addressing policy barriers

Regulation is in place to ensure sustainable catch levels, but for quotas to keep pace with changing stocks relies on scientific evidence being collected and accounted for by policy makers in a timely way. This process is lengthy and backward-looking so there is a risk that quota allocations restrict fishing activity where stocks are increasing, or changing their distribution, and in some circumstances incentivise maladaptation[20].

Recommended intervention

Undertake research and analysis to make the compelling case to increase the flexibility with which vessels can adapt, for example by trading quotas across operator of all sizes of vessel (large and small). Implement appropriate action to increase flexibility. The ability to trade quotas internationally is being debated as part of the reform of the common fisheries policy.

Addressing behavioural constraints

UK consumer preferences largely favour only a relatively limited number of fish species. Although emerging species can be sold to niche markets and restaurants, for the most part, such species are exported. This limits the ability of the UK, and its local economies, to benefit from the location of the value chain within the UK. In addition, species landed by some vessels (such as smaller vessels at smaller ports) may be unable to reach the bigger exporting fish auctions.

Recommended intervention

Proactively support the diversification of consumer demand through the provision of information to consumers about a wider range of fish species and through marketing. The media and retailers have been identified as particularly successful in raising awareness and increasing demand for niche species. Further options could be explored to support these activities including educating consumers about different varieties of species, including their preparation and taste.

[20] For example, for species not under quota, but emerging, abundance creates potential expectations of future quota restrictions; quota allocations based on levels of historic catch can incentive overfishing in order to build up the historic catch to increase any future quota allocation.

Case for intervention

Annex 1 – Key stakeholders

- John Butterworth, Chief Executive North Devon Fishermen's Association and FLAG
- Quentin Clark, Waitrose
- Caroline Cowan, Head of Fisheries Negotiation and Stock Conservation, Marine Scotland
- Hazel Curtis, Chief Economist, Seafish
- Tony De La Hunty, Chairman of the NFFO South East Committee
- Matt Frost, Marine biologist for the Marine Climate Change Impact Project (MCCIP)
- Ian Gatt, Chief Executive, Scottish Pelagic Fishermen's Association
- Phil McMullen, MMO
- John K Pinnegar, Program Director for Cefas Marine Climate Change Centre (MC^3), Cefas
- Angus Radford, South East Marine Area Manager of the MMO
- Dale Rodmell, Chief Executive of the NFFO and small vessel owner

Annex 2 – Climate change projections

This annex outlines standard UKCP09 projections and then presents a summary of the impact of climate change on marine fish as assessed in the CCRA (Pinnegar et al, 2012).

UKCP09 projections[21]

The UK Climate Projections (UKCP09) provides projections of climate change for the UK. These projections cover changes in a number of atmospheric variables, using different temporal and spatial averaging. They are given for several future time periods under three future emission scenarios. Climate change over land includes more variables, at a higher resolution, than those over sea.

Projections of the climate variables in UKCP09 methodology are made using multiple climate models. The output of the climate models is used to estimate probabilities, rather than giving single values of possible changes. Probabilities are introduced to treat uncertainties associated with climate projections.

This annex begins with an explanation on the background on uncertainties associated with climate projections. It is followed by a paragraph that explains the UKCP09 methodology and how uncertainties are accounted for. The next paragraph explains how to interpret probabilities in UKCP09 output and the annex ends with a discussion on the limitations of UKCP09.

Background on uncertainties in climate projections

There are three major sources of uncertainties in estimating future climate change:

- Natural Climate Variability;
- Incomplete understanding of Earth System process and the inability to model the climate perfectly; and,
- Uncertainty in future greenhouse gas emissions

The major sources are discussed individually below.

Natural Climate Variability

Natural variability has two principle causes. One arises from natural internal variability which is caused by the chaotic nature of the climate system. Ranging from individual storms which affect weather, to large scale variability due to interactions between the ocean and the atmosphere (such as El Nino). Climate

[21] This annex is largely based on Murphy et al., 2009 and UKCP09, © UK Climate Projections, 2009.

can also vary due to natural external factors. The main causes are changes in solar radiation and in the amount of aerosols released (small particles) from volcanoes.

Representation of Earth's System in Climate Models

The second main source of uncertainty arises due to modelling of the future climate. The only way we can calculate how the climate will change due to human activity is through the use of mathematical models of the earth's climate system. These models are known as Global Climate Models (GCMs). They describe the behaviour of different climate components and interactions between them. The components include the atmosphere, the oceans, the land and the cryosphere. Each interact to produce many types of feedbacks, both positive and negative. The net effect will determine how climate evolves in response to changes in greenhouse gasses.

Uncertainty in models is caused by an incomplete knowledge of the climate system and the inability to model it perfectly. Representations of physical processes within the climate system are based on a mixture of theory, observations and representation. Representations may be limited by physical knowledge, as well as by computing power, and lead to errors, which inevitably cause uncertainty. All modelling groups seek to represent climate processes in the best possible way in their models. This is based on subjective judgement, which causes different strengths of feedbacks in different models. This means that different models give different results, although they all use plausible representations of climate processes.

Future Greenhouse Gas Emissions and SRES

The final source of uncertainty arises due to future emission scenarios of greenhouse gases and aerosols. This will depend on many socio-economic factors such as changes in population, GDP, energy use and energy mix. The Intergovernmental Panel on Climate Change (IPCC) published a Special Report on Emission Scenarios (SRES) (Nakicenovic and Swart, 2000), in which climate-relevant emissions were calculated based on a number of storylines. Each of these storylines describes a possible way of how the world might develop. Differences between them arise due to the different assumptions about future socio-economic changes. They assume no political action to reduce emissions in order to mitigate climate change.

UKCP09 methodology

In UKCP09, uncertainties mentioned above are accounted for when doing climate projections. Uncertainties are treated by generating projections of change as estimated probabilities of different outcomes. This means that probabilities are attached to different climate change outcomes, which provides information on the estimated relative likelihood of different future results.

To do this, UKCP09 assumes that uncertainties manifest themselves in different climate projections from different climate models. Probability distributions of the future climate can then be generated by using projections from a large number of models or variants from a single model.

UKCP09 use a combination of projections from the following models:

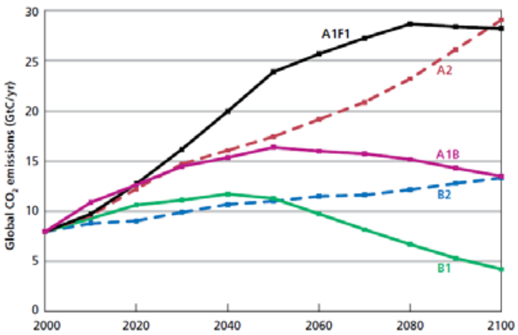
- A very large number of variants of the Meteorological Office Hadley Centre model; and

- 12 international models used in inter-comparison studies of the fourth IPCC report.

Probabilities are based on a large number (ensembles) of climate model simulations, but adjusted according to how well different simulations fit historical climate observations. This is done in order to make them relevant to the real world. By presenting probabilities based on ensembles of climate models, UKCP09 takes into account both modelling uncertainty and uncertainty due to natural variability.

It does not however include uncertainty due to future emissions. Currently there is no accepted method of assigning relative likelihoods to alternative future emissions. UKCP09 therefore presents probabilistic projections of future climate change for 3 future emission scenarios. They are selected from three scenarios developed in SRES and referred to as Low, Medium and High emissions, which corresponds to A1FI, A1B and B1 scenarios in SRES. **Figure 14** indicates these scenarios in terms of CO_2 emissions with solid lines (black: High Emissions, purple: Medium Emissions, green: Low Emissions). Each scenario also includes emissions of other greenhouse gases. Although the three UKCIP emission scenarios span the range of marker scenarios in SRES, there are additional scenarios, both higher and lower, that they do not encompass.

Figure 14. Global annual CO_2 emissions under the three IPCC SRES scenarios



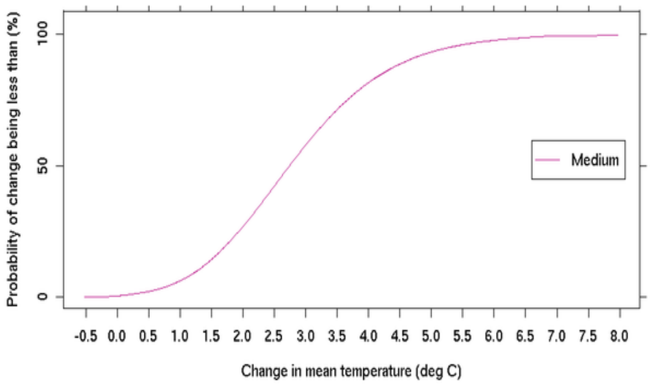
Source: Murphy *et al*., 2009
Note: The dotted lines are two SRES emission scenarios used in previous UK Climate Projections, but not in UKCP09.

Probability in UKCP09

Probabilistic projections assign a probability to different possible climate change outcomes. Probability given in UKCP09 output is seen as the relative degree to which each possible climate outcome is supported by the evidence available. It takes into account the current understanding of climate science and observations.

Probability in UKCP09 does not indicate the absolute value of climate changing by some exact value. Instead it states the probability of climate change being less than or greater than a certain value using the Cumulative Distribution Function (CDF). This is defined as probability of climate change being less than a given amount. An example is given in **Figure 15**. The CDF (for the 2050s mean summer temperatures in the London area, with a medium emission scenario) shows that there is a 10% probability of temperature change being less than 1 degree and 90% probability of temperature change being less than 5 degrees. These statements also work inversely, where one could say there is a 10% probability of temperature change being greater than 5 degrees and a 90% probability of temperature change exceeding 1 degree.

Figure 15. Example of cumulative distribution function for 2050s mean summer temperatures in the London area for the medium emission scenario



Source: UKCP09

The figure above does not say that the temperature rise will be less than 5 degrees in 90% of the future climates, because there will only be one climate. It rather indicates that there is 90% probability (based on data and chosen methodology) that the temperature rise will be less than 5 degrees.

Limitations

The procedure used in UKCP09 to convert ensembles of climate models into probabilistic estimates of future climate also includes some subjective choices and assumptions. This means that the probabilities themselves are uncertain, because they are dependent on the information used and how the methodology is formulated. Furthermore, the system cannot be verified on a large sample of past cases. Current models are, however, capable of simulating many aspects of global and regional climate with considerable skill. They do capture all major physical and biochemical systems that are known to influence our climate.

The impact of climate change on marine fish

Pinnegar et al (2012) used two assessments of the impact of climate change on marine fish. The movement of fish species and the impacts on the biomass of the spawning stock.

Pinnegar et al (2012) presents analysis using historical commercial catch datasets to derive a response function for future climate change. This function specifies both longitudinal and latitudinal shifts in species distributions. The results of this analysis are presented in **Table 18**.

Table 18. Projected distribution shift of sole, plaice, cod and haddock between 1961-1990 and 2070-2099 in the North Sea

Assuming that the mean sea surface temperature rises from 10.2ºC (observed)

Species	Lat (1961-1990)	Long (1961-1990)	Depth (m)	Lat (2070-2099)	Long (2070-2099)	Depth (m)	Depth Shift (m)	Distance shift (km)	Direction
Sole	53.58	2.90	31.6	52.87	2.15	26.5	-5.0	93.5	SW
Plaice	55.66	3.79	51.2	56.33	1.86	60.0	+8.8	141.4	NW
Cod	57.52	1.19	101.7	57.58	2.28	99.5	-2.2	65.4	NE
Haddock	58.57	0.76	101.2	58.50	1.12	97.6	-3.6	22.3	NE

Source: Pinnegar et al 2012

Pinnegar et al (2012) presents analysis following the approach taken by Cook and Heath (2005), using an age-structured population model, including a seawater temperature term in the Ricker stock-recruitment relationship (i.e. the relationship between the number of adult fish and the number of juveniles entering the system the following year) for North Sea cod, plaice saithe and whiting. **Table 19** presents their results, which show a decreasing spawning stock with the cold water species and increasing stocks with the warm water species.

Table 19. Projections of spawning stock biomass for North Sea commercial fish stocks in the period 2070-2099

	Spawning Stock Biomass (1000s tonnes)	
Species	**2070-2099 (no climate effect)**	**2070-2099 (climate change included)**
Cod	270	103
Plaice	241	101
Whiting	933	1,640
Saithe	459	622

Source: Pinnegar et al 2012

Annex 3 – Summary of species movement modelling

Data

Species occurrence data were obtained from three global online databases: the International Council for Exploration of the Sea (ICES) EcoSystemData database (http://ecosystemdata.ices.dk); the Ocean Biogeographic Information System (OBIS) (Vanden Berghe, 2007; http://www.iobis.org) and the Global Biodiversity Information Facility (GBIF) (http://data.gbif.org), all last accessed in 2011. Occurrence records were spatially aggregated at the level of 0.5° latitude x 0.5° longitude and rigorously filtered according to criteria detailed in Jones *et al.* 2012. This minimised recording errors due to data being compiled from many sources and gave a binary value of presence or absence of each species for each cell.

A range of environmental oceanographic variables for predicting species distributions using Maxent and AquaMaps were chosen (Jones *et al.*, 2012). These variables were: bathymetry, sea surface temperature (SST), sea bottom temperature (SBT), salinity; ice; primary productivity, and distance to coast. Two sets of oceanographic variables were obtained, from Geophysical Fluid Dynamics Laboratory's Earth System Model (GFDL ESM2.1, Dunne *et al.*, 2010) and physical climate data from an ensemble of 12 different CMIP3 models that are assessed by the fourth assessment of the Intergovernmental Panel on Climate Change (IPCC AR4) (CMIP3-E). The later was obtained from the World Climate Research Program (WCRP) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (http://esg.llnl.gov:8080). This would allow the variation resulting from alternative climate datasets to be assessed for this set of species. Both datasets represented the A2 climate scenario, thus being characterised by a heterogeneous world with a continuously increasing global population and regionally orientated economic development (IPCC 2000). The oceanographic variables were interpolated onto a 0.5° latitude x 0.5° longitude global grid using the nearest-labour method.

Species Distribution Models

Three Species Distribution Models (SDMs) were applied to model species' distributions of commercially targeted fish species. Two of these, the generative Maxent (Phillips *et al.*, 2006) and AquaMaps (Kaschner *et al.*, 2006), apply a statistical approach to modelling species' distributions. Species' current distributions (averaged over 30 years from 1971 to 2000) were predicted by associating species' occurrence data with averaged 'current' environmental data (1971 – 2000), thereby obtaining a bioclimatic envelope for each species. The third model, the Dynamic Bioclimatic Envelope Model (DBEM) (Cheung *et al.,* 2011) and associated *Sea Around Us Project* model (Close *et al.*, 2006) uses a discriminative approach (Jones *et al.,* 2012) and also attempts to avoid the bias that might be introduced by skewed distribution of sampling effort present in many datasets collected sporadically. Bioclimatic envelopes constructed from all SDMs were applied to a 30 year-averaged dataset of the same set of environmental variables centred on 2050 and representing future climate. Habitat suitability values were standardized to give values of relative habitat suitability between 0 and 1.

Latitudinal centroids were calculated for each species within each SDM-GCM combination using the following equation for distribution centroids (Cheung *et al.*, 2011):

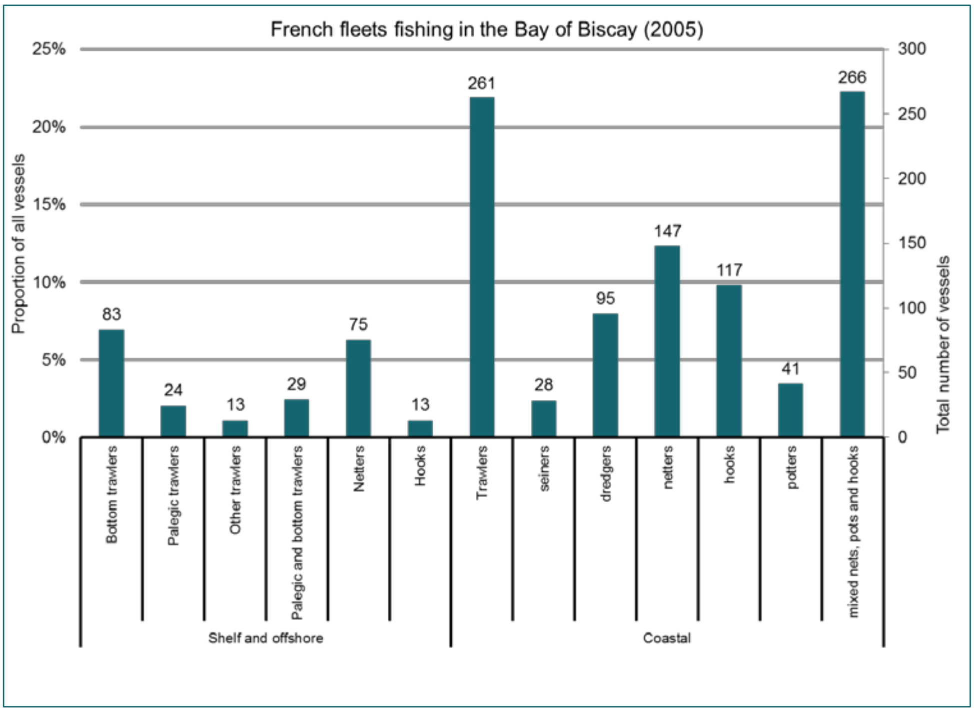
$$C = \frac{\sum_{i=1}^{n} Lat_i \cdot Abd_i}{\sum_{i=1}^{n} Abd_i}$$

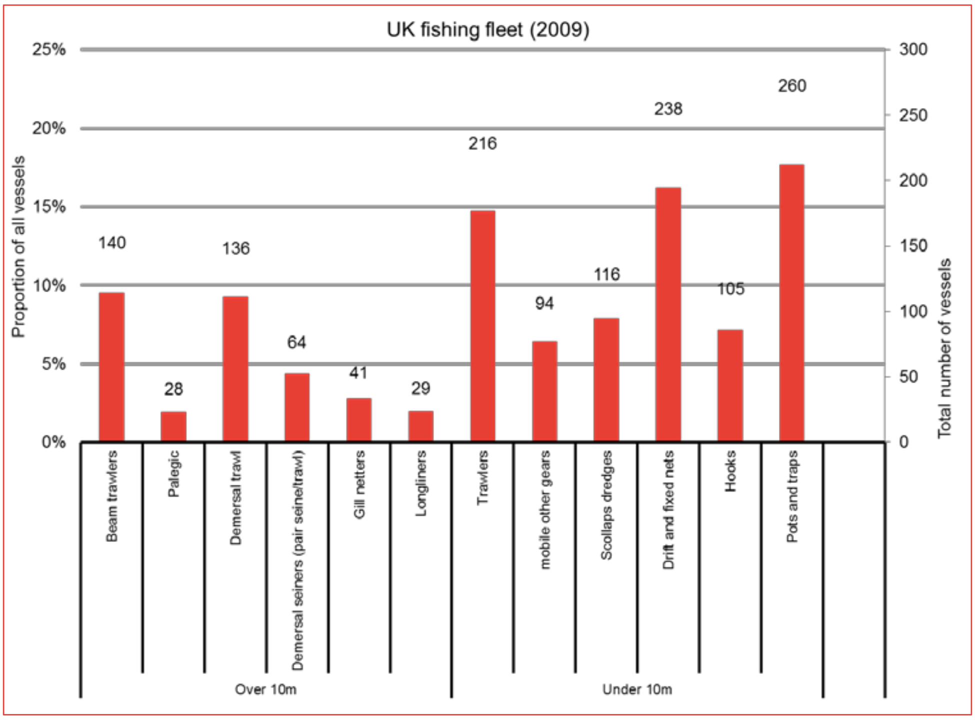
Annex 4 – UK fishing fleets

Comparison of UK fleets to fleets currently fishing in the Bay of Biscay

The distribution of the UK fleet across different vessel types have been summarised using data from Seafish (2009). To identify if the UK fleet would need to change markedly in the future to fish for emerging species, this report has attempted to compare the current UK fleet with fleets that currently fish in waters where the emerging species are currently present. Data on a fleet which fishes in the Biscay has been summarised in the most comparable way to the recording of the current UK fleet (both sets of data ignore nephrop fishing vessels). Data on the comparable fleet has been sourced from Daures et al 2009, and the ECR combines sub categories to best match those of the UK fleet. Although it would be difficult to identify whether the vessels have similar gear or capacity, this table can show that overall the variety of vessels is similar in both fleets and it may be unlikely that a drastic shift in the type of vessels would occur in the future.

Figure 16. Comparison between current UK fleet structure and those fishing in the Bay of Biscay





Sources: Daures (2009) and Seafish (2009)

Annex 5 – Data for “what if?” analyses

Section 4 tests what opportunities the fishing industry would be able to take up if it changed gear to fish for emerging species. **Table 20** identifies the current landings in the UK by small vessels (defined in this report as those equal to or less than ten meters in length) at four ports across the UK. 2010 UK landings are compared to changes in modelled potential changes in habitat suitability. Localised impacts are only available from Jones et al (2012) for four species considered to be emerging in the UK EEZ today: anchovy, john dory, sea bass and squid.

Table 20. 2010 UK landings (by port of administration) by UK vessels <10m

(tonnes)	Brixham	Milford Haven	Ardglass	Peterhead
European Anchovy	0.0	0.0	0.0	0.0
John Dory	2.9	0.0	0.0	0.0
European sea bass	35.8	8.1	0.0	0.0
European squid	7.0	0.0	0.1	7.7

Source: Data from Cefas landings records

The current economic activity of small vessels in relation to these species is compared to modelled projections of future changes in the suitability of local water habitats for the species. Local changes in habitat suitability are presented in **Figure 17** for three different modelling results, and represent estimated changes between 1985-2050 in habitat suitability on a scale of 0 and 1. The ranges of projections and summarised in **Table 21** and compared to the current landing in **Table 20** to illustrate certainty and type of local opportunities which may be presented by these four emerging species with the current experience and capacity for fishing them.

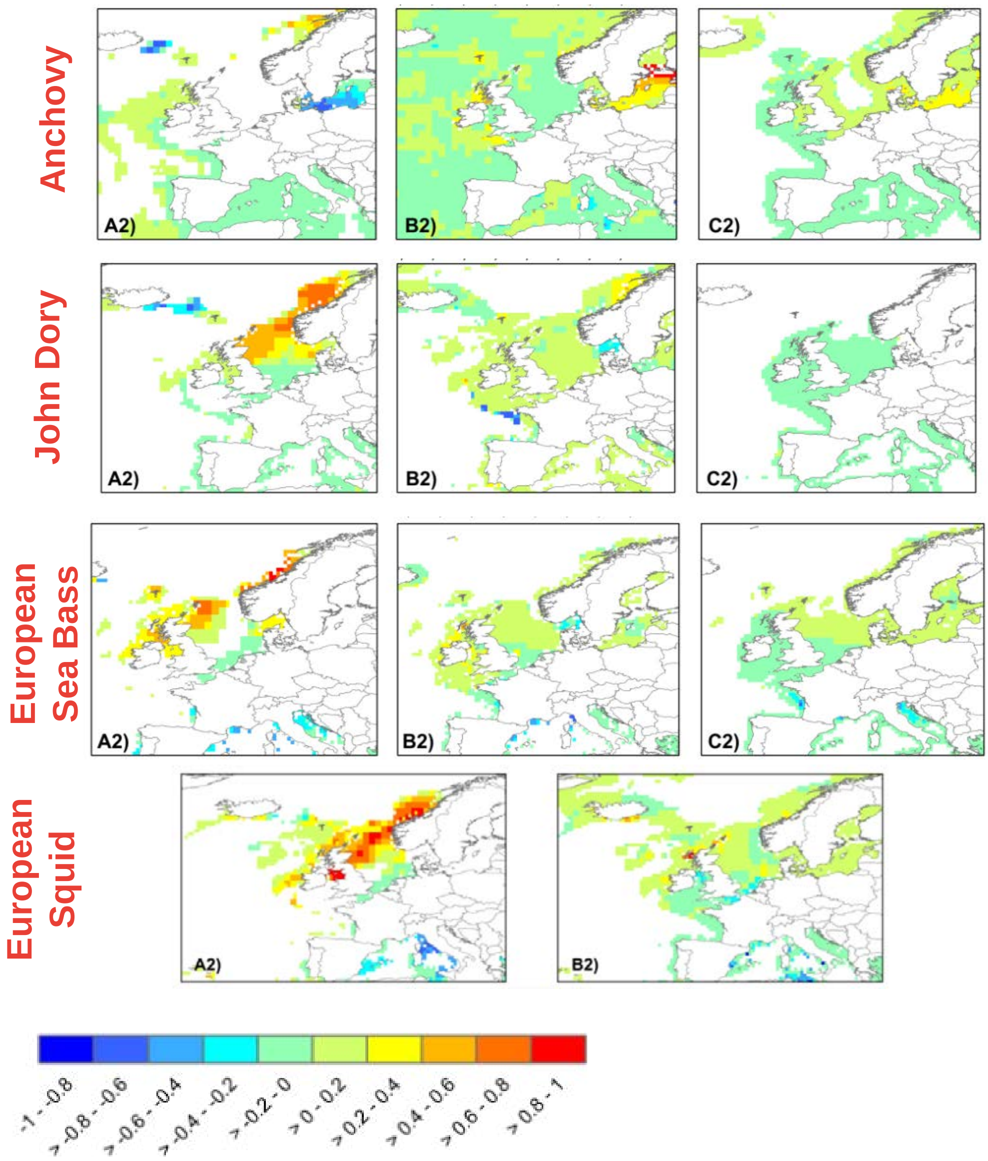
Table 21. Range of assessed increases or decrease in habitat suitability (between 1985-2050) locally to ports

	Brixham	Milford Haven	Ardglass	Peterhead
European Anchovy	-0.2 to +0.2	0 to +0.4	0 to +0.4	-0.2 to +0.2
John Dory	-0.2 to +0.2	-0.2 to +0.2	-0.2 to +0.2	-0.2 to +0.6
European sea bass	-0.2 to +0.2	-0.2 to +0.2	-0.2 to +0.6	0 to +0.6
European squid	-0.2 to 0	-0.2 to +0	-0.4 to +1	0 to +1

Source: Heat maps produced from Jones (2012) presented in Figure 17

Note: (Values represent a standardised habitat suitability scale, the change is the estimated change within this 0-1 scale)

Figure 17. Localised estimated changes in habitat suitability (calculated by three different models)



Source: Jones (2012), A2, B2 and C2 refer to three different models run by Jones (2012) described in Annex 3

Annex 5 – Data for "what if?" analyses

Annex 6 - References

Allison E.H., Perry A.L., Badjeck M.-C., Adger W.N., Brown K., Conway D., et al., 2009. *Climate change and fisheries: a comparative analysis of the relative vulnerability of 132 countries.* Fish and Fisheries; 10: 173–96.

Almond. S., and Thomas. B, 2010. *The UK Fishing Industry in 2010 Structure and Activity,* Marine Management Organisation

Badjeck. M-C., Allison. E., Halls. A. and Dulvy. N., 2009. *Impacts of climate variability and change on fishery-based livelihoods,* Marine Policy

Ballard, D.I., Black, D.G., Lonsdale, K., Hague, B., 2011. *Assessment of the UK's Adaptive Capacity for Responding to the Impacts of Climate Change.* Defra Project Code GA 0204

Brooks, N. and W.N. Adger, 2005: *Assessing and enhancing adaptive capacity. Adaptation Policy Frameworks for Climate Change*, B. Lim, E. Spanger-Siegfried, I. Burton, E.L. Malone and S. Huq, Eds., Cambridge University Press, New York, 165-182

Brown, A, Djohari, N, Stolk, P., Jan 2012. *Fishing for answer. Final report of the social and community benefits of angling project.* Available at www.resources.anglingreseearch.org.uk

Cabinet Office, 2004. *Net benefits: A sustainable and profitable future for UK fishing,* Prime Minister's Strategy Unit, Cabinet Office.

Cheung W.W.L, Dunne J, Sarmiento JL, Pauly D., 2011. *Integrating ecophysiology and plankton dynamics into projected maximum fisheries catch potential under climate change in the Northeast Atlantic.* ICES Journal of Marine Science 68: 1008–1018

Cheung. W.W.L., Pinnegar. J., Merino. G., Jones. M., and Barange. M., 2012. *Review of climate change impacts on marine fisheries in the UK and Ireland.* Aquatic Conservation: Marine and Freshwater Ecosystems 22: 368-388

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Pauly D., 2009. *Projecting global marine biodiversity impacts under climate change scenarios.* Fish and Fisheries 10: 235–251

Cheung .W.W.L, Lam VWY Sarmiento.J.L., Kearney. K.., Watson. R., Zeller, D. and Pauly. D., 2009. *Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change.* Global Change Biology. 16, 24-35

Cheung WWL, Lam VWY, Pauly D., 2008. Modelling Present and Climate-Shifted Distributions of Marine Fishes and Invertebrates. Fisheries Centre Research Report 16 (3).

Close C, Cheung W, Hodgson S, Lam V, Watson R, et al., 2006. Distribution ranges of commercial fishes and invertebrates. Fisheries Centre Research Report 14: 27 - 37.

Cook R. M, and Heath M. R., 2005. *The implications of warming climate fror the management of North Sea demersal fisheries.* ICES Journal of Marine Science, 62: 1322-1326.

Cooper., J., 2009. *Coastal economies and people, Marine Climate Change Ecosystems Linkages Report Card 2009* (Eds. Baxter J., Buckley. P., and Frost. M.) Online scoience reviews, 18pp

Curtis. H., and Brodie. C., 2011. *2009 Economic Survey of the UK Fishing Fleet*, Seafish Economics

Daures. F., Rochet. M., Van Useghem. S., and Trenket V., 2009. *Fishing fleet typology, economic dependence, and species landing profiles of the French fleets in the Bay of Biscay 2000-2006.*

Dunne JP, Gnanadesikan A, Sarmiento JL, Slater RD., 2010. *Technical description of the prototype version (v0) of tracers of phytoplankton with allometric zooplankton (TOPAZ) ocean biogeochemical model as used in the Princeton IFMIP model.* Biogeosciences 7: 3593

Eurofish International Organisation, 2012. *Overview of the world's anchovy sector and trade possibilities for Georgian anchovy products Organisation*, available at: http://www.fao.org/fileadmin/user_upload/Europe/documents/Publications/Anchovies_report_2.03.2012.pdf

Fisheries administrations in the UK, Feb, 2012. *Rules for the management of the UK's fisheries quotas in areas I, II, IV, VI and VII (and associated areas) and in Faroese waters (Vb) for 2012*

Fishing For The Markets, 2012. http://www.fishingforthemarkets.com/about-us.html . Website accessed May 2012.

Fishing for the markets, 2011. *Summary and recommendations from the 'Fishing for the Markets' programme (Market led Sustainability)* Defra R & D project code: MF1219

Fankhauser, S., Smith ,J. And Tol, R., 1999. *Weathering climate change: some simple rules to guide adaptation decisions.* Ecological Economics, 30 (1999) 67–78

Graham, K, Curtis, H, Rossiter, T., 2007. *Improving fuel efficiency in the UK fishing fleet.* ICES, CM 2007/M 08.

Hall, J.W., 2007. *Probabilistic climate scenarios may misrepresent uncertainty and lead to bad adaptation decisions.* Hydrological processes, 21(8), 1127-1129

Heath. M., Neat. F., Pinnegar. J., Reid. D., Sims. D., and Wright. P., 2012. *Review of climate change impacts on marine fisheries in the UK and Ireland. Aquatic Conservation: Marine and Freshwater Ecosystems* 22: 337-367

ICES, 2011. *Widely Distributed and Migratory Stocks Boarfish in the Northeast Atlantic, Advice for 2012 (published September 2011)* Available at http://www.ices.dk/committe/acom/comwork/report/2011/2011/boc-nea.pdf

Inglis, K., 2010. *Fisheries governance in the UK: Challenges and opportunities in a changing climate*, Defra

IPCC, 2000. *Emission Scenarios, Summary for Policymakers.* eds. Nakicenovic N, Swart R (eds). Cambridge University Press: Cambridge.

IPCC, 2007. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds.) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp

Jones, M., 2012. *Methods for predictions of habitat suitability and maximum catch potential on marine species in the North Sea* (Annex 3, this document).

Jones MC, Dye SR, Pinnegar JK, Warren R, Cheung WWL, 2012. *Modelling commercial fish distributions: Prediction and assessment using different approaches*. Ecological Modelling 225: 133–145.

Kaschner K, Watson R, Trites A, Pauly D, 2006. *Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model.* Marine Ecology Progress Series 316: 285–310. doi:10.3354/meps316285

Le Quesne, W.J.F. Pinnegar, J.K., 2011. *The potential impacts of ocean acidification: scaling from physiology to fisheries*. Fish and Fisheries 13: 333-344.

Lonsdale, K.G., Gawith, M.J., Johnstone, K. Street, R. B., West, C. C. and Brown, A. D., 2010. *Attributes of Well-Adapting Organisations, A report prepared by UK Climate Impacts Programme for the Adaptation Sub-Committee*

Lowe, J.A., Howard, T.P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S. and Bradley, S., 2009. *UK Climate Projections Science Report: Marine and Coastal Projections*. Met Office Hadley Centre, Exeter

McIlgorm. A., Hanna. S., Knapp. G., Le Floc'H. P., Millerd. F., and Pan. M., 2009. *How will climate change alter fishery governance? Insights from seven international case studies*. Marine Policy.Murphy, J.M., Sexton, D.M.H., Jenkins, G.J., Boorman, P.M., Booth, B.B.B., Brown, C.C., Clark, R.T., Collins, M., Harris, G.R., Kendon, E.J., Betts, R.A.,Brown, S.J., Howard, T. P., Humphrey, K. A., McCarthy, M. P., McDonald, R. E.,Stephens, A., Wallace, C., Warren, R., Wilby, R., Wood, R. A. (2009), *UK Climate Projections Science Report: Climate change projections*. Met Office HadleyCentre, Exeter.

MMO, 2012. *Sea Angling 2012* website
http://www.marinemanagement.org.uk/seaangling/ accessed June 2012

Murphy, J.M., Sexton, D.M.H., Jenkins, G.J., Boorman, P.M., Booth, B.B.B., Brown, C.C., Clark, R.T., Collins, M., Harris, G.R., Kendon, E.J., Betts, R.A., Brown, S.J., Howard, T. P., Humphrey, K. A., McCarthy, M. P., McDonald, R. E., Stephens, A., Wallace, C., Warren, R., Wilby, R., Wood, R. A., 2009, *UK Climate Projections Science Report: Climate change projections*. Met Office HadleyCentre, Exeter.

Murray, C. and D.R. Marmorek, 2004. *Adaptive Management: A spoonful of rigour helps the uncertainty go down.* In: Proceedings of the 16th Annual Society for Ecological Restoration Conference, Victoria, BC, August 24-26, 2004. Available at: http://www.essa.com/media/Murray_Marmorek_adaptive_management_SER_conference.pdf Accessed on 20 May 2012

Nakicenovic, N. and Swart R., 2000. *Emissions Scenarios*, Special Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, p.570.

OECD, 2010. *The Economics of Adapting Fisheries to Climate Change.* OECD Publishing, http://dx/doi.org/10.1787/9789264090415-en

Parry, M., Canziani, O., Palutikof, J., Van der Linden, P. & Hanson, C., 2007. Climate Change 2007: *Impacts, Adaptation and Vulnerabilities. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press

Phillips SJ, Anderson RP, Schapire RE, 2006. *Maximum entropy modeling of species geographic distributions.* Ecological Modelling 190: 231–259

Pinnegar. J., Viner. D., Hadley. D., Dye. S., Harris. M., Berkout. F., and Simpson. M., 2006. *Alternative future scenarios for marine ecosystems*, Defra

Pinnegar. J., Watt. T., and Kennedy. K., 2012. *Climate Change Risk Assessment for the Marine and Fisheries Sector.* Defra GA0204

Pinnegar. J., Cheung. W., and Heath. M., 2010. *Fisheries, MCCIP Annual Report Card 2010-11,* MCCIP Science Review, 19pp

Puch, D., 2008. *Socio-economic indicators of marine-related activities in the UK economy.* TSO Project OSR 07-04

Reeder, T., and Ranger, N., 2011. *How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 Project.* World Resources Report, Washington DC.

Robinson. R., Learmonth. J., Hutson. A., Macleod. C., Sparks. T., Leech. D., Pierce. G., Rehfisch. M., and Crick. H., 2005. *Climate Change and Migratory Species.* Defra CR0302

Sainsbury's, *Our Future With Fish*, 2012.

Scottish Government, 2012. Fish and Shellfish Stocks 2012: Scallop. Available online at http://www.scotland.gov.uk/Publications/2012/05/9899/24 (accessed August 2012)

Seafish, 2009. *2009 Economic Survey of the UK Fishing Fleet* Available at http://www.seafish.org/media/Publications/2009_Fleet_Econ_Report_Final_6May11.pdf

Seafish, 2012. *2012 Survey of the UK Seafood Processing Industry*, available at http://www.seafish.org/media/Publications/2012_Survey_of_the_UK_Seafood_Processing_Industry.pdf

Tidd,A, H, Padda, G, 2011. *Exit and Entry of fishing vessels: an evaluation of factors affecting investment decisions in the North Sea English beam trawl fleet.*

Tol, R., and Yohe, G., 2006. The weakest link hypothesis for adaptive capacity: an empirical test

UKCIP, 2012. *UKCIP Glossary* online. Available at: http://www.ukcip.org.uk/glossary/ [accessed on 19 December 2012]

UKCIP Principles of Good Adaptation, available online at http://www.ukcip.org.uk/essentials/adaptation/good-adaptation/

UKNSP, The United Kingdom National Strategic Plan for the European Fiosheries Fund, 2007-2013, 2008.

Yohe, G., and Tol, R., 2002. *Indicators for social and economic coping capacity: moving toward a working definition of adaptive capacity*, Global Environmental Change 12 (2002) 25–40;

http://79.170.40.182/iukdirectory.com/iuk/pdfs/Working%20together.pdf

FRONTIER ECONOMICS EUROPE
BRUSSELS | COLOGNE | LONDON | MADRID

Frontier Economics Ltd, 71 High Holborn, London, WC1V 6DA
Tel. +44 (0)20 7031 7000 Fax. +44 (0)20 7031 7001 www.frontier-economics.com

IRBARIS LLP
LONDON | WASHINGTON D.C.

Irbaris LLP, Centre Point, 103 New Oxford Street, London WC1A 1DD
Tel: +44 (0)20 3102 5455 Fax: +44 (0)20 3102 5456 www.irbaris.com

ECOFYS
LONDON | NETHERLANDS | BELGIUM | UNITED STATES | GERMANY | CHINA

ECOFYS UK, 1 Allie Street, London E1 8DE
Tel: +44 (0)20 7423 0970 Fax: +44 (0)20 7423 0971 www.ecofys.com