

Understanding and responding to climate change in the UK seafood industry:

Climate change risk adaptation for wild capture seafood

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A Seafish report to the UK Government under the
Climate Change Adaptation Reporting Power.

Authors: Dr Angus Garrett (Seafish), Paul Buckley (Marine Climate Change
Impacts Partnership), Dr Stewart Brown (Stewart Brown Associates Ltd).

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This document combines data, opinions and conjecture and is a position paper at the time of press. It is important to bear in mind that evidence today might suggest trends that turn out to be very different in the longer-term.

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Executive summary

This document is a climate change adaptation report for the UK wild capture seafood industry. The report considers the major industry impacts arising from key climate change drivers and sets out major areas of adaptation action. The report has been produced by Seafish, in collaboration with key partners, for the UK Government under the Climate Change Adaptation Reporting Power.

The Seafish mission is to secure a profitable, sustainable, and socially responsible future for the UK seafood industry. An important underlying function for Seafish in achieving this mission is to help *protect* the industry in the face of natural and man-made risks and challenges. Climate change and adaptation is a strategic challenge facing the industry, and this reporting exercise is an important part of responding to that.

This exercise, conducted in 2014 / 15, aimed to support the UK seafood industry to develop a managed adaptive approach to climate change. Two objectives were set out – i) provide a review of projected climate change impacts with implications for seafood, and ii) identify relevant seafood industry adaptation responses (these responses will rest with industry bodies and others to take forward). Focussing on UK wild capture seafood (domestic and international), the exercise relied on research evidence and industry experience (engaging around 40 stakeholders).

Five principal climate change drivers are relevant to seafood. These are: sea level rise; changes in storms and waves; temperature change; ocean acidification; and changes in terrestrial rainfall.

From a scientific perspective, those observing climate change highlight a number of implications for the seafood industry across offshore and onshore sectors: alteration of ocean ecosystems; changing catch potential; regional shifts in stock distribution and increased severity of storms and

flooding. From an industry perspective, those experiencing climate change acknowledge near term climate related events (storms, flooding, changing fish distribution, etc) but highlight that action to adapt to climate change is largely a low priority when compared to other imperatives. Climate change forms part of a range of risks and uncertainties the industry routinely faces. Such inherent unpredictability constrains taking a longer view and planning ahead. Notwithstanding these uncertainties, a number of adaptation responses are identified.

In a UK domestic context, across whitefish, pelagic and shellfish capture fisheries, two main climate change drivers that lead to priority risks are *increased storminess and waves* and *air or sea temperature change*. In shellfish fisheries, an additional driver is *change in rainfall / run-off*. These give rise to both threats and opportunities. For example in whitefish and pelagic there are threats and opportunities presented by changes to distribution of target species, as some traditional species move away, and warmer water species move in. An example in shellfish fisheries are the threats and opportunities generated by increases or decreases in the prevalence of non-natives / jellyfish. Onshore, the two main drivers similarly lead to priority risks but are compounded by *sea level rise and extreme water levels* and *changes in rainfall / run off*. A number of threats arise for onshore operators, including damage to site infrastructure (ports and processors), integrity of electricity supplies, transport disruption (including ferries), integrity of housing, and reduced employment.

In the UK domestic context, responses in offshore fisheries that are currently underway include improved scientific advice and data collection through partnership working. However, adaptation requires much closer science-industry collaboration and engaged research in the short term, and a move towards a more robust and strategic fisheries knowledge base in the medium term. Governance of fisheries (including regulated ('Relative Stability') and non-regulated species) should also be examined in the short, medium and long term particularly given the need for institutional arrangements to be able to respond in the face of climate change. Vessel owners are already enhancing operational safety, and in the short term need to keep a watching brief on how climate change is affecting fisheries. Longer term, fleet wide vulnerability should be reviewed. Onshore, port authorities in the UK are investing in actions to build port resilience but should improve risk management. The vulnerability of freight ferries should be assessed. Short term action to improve marketing of seafood is required at the processing stage; longer term there may be a requirement to relocate processing sites inland.

In an international context, across whitefish, pelagic and shellfish capture fisheries, the same two climate change drivers lead to priority risks i.e. *increased storminess and waves* and *air or sea temperature change*. However, in contrast to the UK domestic context, an additional driver for shellfish fisheries is *ocean acidification and deoxygenation*. In whitefish and pelagic, changes in air or sea temperature suggest some impacts that could be both threats and opportunities, for example in terms of changes to distribution of target species. In shellfish, risks are generated by the introduction of non-native species but also, through acidification, by changes in distribution or catch potential of target species. Onshore, risks are compounded by *sea level rise and extreme water levels and changes in rainfall / run off*. This gives rise to threats for onshore operators such as damage to site infrastructure (including vessels and gear) and coastal processing facilities. In some instances, changes in fisheries may impact on national economies and food security for the country of origin.

For industry operating in an international context, responses in offshore fisheries include an immediate review of key sources of existing supply and available options. In the short term the impacts of changes in specific regional supplies

should be monitored and assessed whilst in the medium term the viability of enhanced regional productivity should be considered. Adaptation requires action in the short term to develop much closer science-industry links that can better understand climate driven regional changes in the Arctic, North Atlantic and Pacific and Indian oceans. In the face of changing fisheries, the governance of fisheries should be reviewed in the short term to ensure the concept of climate change adaptation is embraced and ensure international management regimes provide early resolution on 'rights to fish', in the medium term adaptation should be enhanced through active engagement with overseas stakeholders. For overseas fleets, action currently underway includes enhancing operational safety, proposed action in the short term includes incorporating climate change in vessel and gear design and investment decisions (to maintain ability to catch and capacity to respond to enhanced productivity). Onshore, proposed responses in the short term concern the processing stage; a focus on improved resilience and capacity of overseas facilities (including modelling of extreme events on facilities but also ensuring flexibility over sources of fish and contingency planning).

In adapting to climate change, important barriers need to be recognised. Climate change is uncertain and the wild capture industry inherently unpredictable. Climate change is a relatively low priority for the industry, and successful adaptation is subject to a wide number of interdependencies.

Given these barriers, a climate change adaptation framework is recommended rather than a centralised 'grand' plan. Specific adaptation responses should fall within the corporate planning process of the relevant 'owner' stakeholder. High level monitoring and regular review of adaptation responses across industry domains and stakeholders is also recommended and an ongoing review of climate change impacts maintained. Suggested adaptation principles include 'industry demand-led actions' and 'boundary spanning' support. Initial resources allocated to adaptation should be moderate (reflecting industry priorities) with adaptation responses appraised, monitored and evaluated as to whether they support longer term decision-making and 'future-proof' the industry.





1. Introduction

1. Introduction

This document is a climate change adaptation report for the UK wild capture seafood industry. The report considers the major impacts on the industry arising from key climate change drivers and sets out major areas of adaptation action. The report has been produced by Seafish in collaboration with key partners for submission to the UK Government under the Climate Change Adaptation Reporting Power.

The Sea Fish Industry Authority (Seafish) was established under an Act of Parliament in 1981 as a UK Non-Departmental Public Body funded by industry levy. Seafish incorporated the rights, obligations and property of its two predecessor organisations (the White Fish Authority and the Herring Industry Board).

The Seafish mission is to secure a profitable, sustainable, and socially responsible future for the UK seafood industry. In delivering the mission and objectives, the organisation has three underlying functions: to protect, promote, and inform the industry.

The forthcoming corporate plan articulates how the organisation will fulfil this mission. These underlying functions underpin three strategic outcomes (Enhancing reputation, Promoting consumption, and Informing decisions) associated with four corporate objectives:

1. Enable the industry to make informed and ethical business decisions.
2. Ensure the industry is better understood by regulators, media and consumers.
3. Create the tools to help industry increase the consumption of seafood.
4. Ensure seafood is well trusted and understood by regulators, media and consumers.

Of the three underlying functions, *protecting* the industry is an important function directly related to understanding and responding to *climate change* developments.

This chapter opens with the general requirement to understand and respond to climate change which is then placed in the context of the UK seafood industry. The remainder of the chapter describes this UK seafood adaptation reporting exercise – the subject of this report – in terms of the approach taken and research aims and

objectives, plan and quality criteria. This chapter is supported by Annex 1, 2 and 3.

1.1 Requirement and purpose

A number of longer-term developments including climate change, ecological constraints, globalisation and human population changes (growth and tastes) influence the operation and functioning of global food systems. Strategic challenges arising from these developments include mitigating and adapting to climate change, effective management of scarce resources, and securing food whilst ensuring economic viability. With increasing volatility in weather, and wider changes in environmental conditions, the importance of *climate change* is increasing.

Climate change affects everyone regardless of national and business boundaries. Climate change developments are likely to affect nearly every part of the seafood industry (from production to consumption). Such developments may be negative, but could also be positive.

Observations suggest current rates of change far greater than in recent history. As such industry stakeholders will need to:

- Engage and collaborate in understanding climate change.
- Respond by changing practices and adapting to new conditions (recognising that responses should remain flexible, because of inherent uncertainties).

Responding can mean changing practices to mitigate as well as adapt to climate change. Mitigating climate change concerns changing practices to reduce our impact on the environment, for example by reducing greenhouse gas emissions. Adapting to climate change concerns changing practices to ensure we can cope with a new operating environment e.g. strengthening physical infrastructure.

Whilst mitigation is an important consideration, our concern here is adaptation to climate change. The introduction of the UK Climate Change Act (2008) enshrined a number of powers to support adaptation. This includes the Secretary of State's Adaptation Reporting Power (ARP) which supports a National Adaptation Programme. The Programme involves iterative cycles of reviewing and responding to climate change developments and the production of regular adaptation reports. A number of industry sectors have already engaged in this process, producing either

Table 1.1 Example ARP reports relevant to seafood

Sector	Organisations reporting	Example adaptation actions
Electricity generators, grid and distribution	Range of energy suppliers, transmitters and distributors (almost 30 in total)	Review and update current site flood risk assessments in response to flooding and storm surge risk. Investment plans to defend vulnerable sub-stations.
Road and rail	Highways Agency; Network Rail Infrastructure Limited; Network Rail Infrastructure Limited	Development of a climate change adaptation framework strategy by the highways agency; Protection of railway assets from the impact of extreme weather conditions.
Ports	12 reports including ABP (Immingham, Southampton, Hull; Humber), Felixstowe, Port of London	Review quay height during refurbishment / upgrade programmes in response to sea level rise; Amend scheduling if required due to changes in storminess.

mandatory or voluntary adaptation reports. To date over eight sectors have already participated, with around 100 organisations submitting adaptation reports including government agencies and critical infrastructure providers. Mandatory reports have been produced by operators in strategic sectors, such as utilities. Other reports have been produced on a voluntary basis.

Sectors of relevance to this ARP report, organisations reporting and example adaptation actions are shown in Table 1.1. The risk assessment for this report draws on the findings from these sectors where relevant (e.g. impacts on port infrastructure or integrity of electricity supply).

1.2 The UK seafood industry and adaptation requirement

The UK seafood industry, being reliant on wild capture and aquaculture produced raw material, is diverse, complex and dynamic. This exercise is concerned with wild capture seafood only (see section 2.4). Being concerned with a natural resource, the wild capture industry is inherently *uncertain*. Perhaps unsurprisingly the UK seafood industry, dealing with day-to-day realities, in highly uncertain conditions, does not tend to think far ahead (often a forward view is no more than one year ahead).

Seafish considers climate change to be an important issue for the UK seafood industry and one that Seafish and the industry should respond to (Seafish Executive, 2013). There is a need to understand climate change developments, implications for the UK seafood industry and practical responses from industry and Seafish.

This adaptation reporting exercise concerns industry adaptation to climate change. Seafish is one organisation in the industry landscape and

provides a support function to the industry rather than discharging any core industry function (i.e. sourcing, transforming, selling seafood). As such this seafood adaptation report is distinct from other ARP reports previously produced, e.g. those in the utility sector, in that the focus is on the UK seafood industry rather than the activity of the reporting organisation.

As this exercise confirms (see Chapter 3), climate change – being one of a range of broad challenges confronting the industry – ranks relatively low in industry priorities. Anticipating this low priority, engaging in this adaptation exercise is done on a voluntary basis with industry. The content in this report reflects the extent to which industry wish to engage with climate change developments.

Furthermore, given the levels of uncertainty in industry operating conditions, we need to recognise the limitations of an adaptation reporting exercise. More specifically, such an exercise should acknowledge the balance required between research resources and value of findings, avoiding resource intensive fieldwork which may prove of limited value to industry. Notwithstanding these limitations, the National Adaptation Programme, the ARP process, and voluntary reporting provides a useful framework through which the industry might periodically review climate change developments and manage the risks arising.

1.3 Approach

In approaching this exercise it is acknowledged that adaptation reporting is likely to be a recurring process over the long term. This, therefore, is the first of potentially further

adaptation exercises focused on the interests of the UK seafood industry (defined in Chapter 2). Any subsequent assessments will be subject to additional insights and influences as: (a) climate change effects become more evident and impactful; (b) the resolution of the scientific evidence on climate change and its implications for seafood become greater; and (c) understanding of the requirement for, and benefits of, timely adaptation become more fully and widely understood in the industry.

In defining the scope of the assessment, two main 'systems' have been identified viz. 'domestic' and 'international' (see Chapter 2 for more detail). In this study these systems have been assigned working boundaries that are shaped by the geographic distribution of the primary sources of the UK's seafood supplies. In terms of mode of production, the present assessment is confined to the parts of the industry linked to wild capture fisheries. This focus reflects prudence in use of limited resources and recognising this was a first, exploratory exercise. The important contribution to seafood from aquaculture merits its own adaptation action plan: whether a similar exercise should be conducted will be subject to industry interest.

In designing the approach to this initial exercise which is focused on the risks and responses relevant to an industry sector rather than Seafish as an organisation, consideration is given to its exploratory status as well as to learning from the approaches described in ARP reports that have already been published. These matters also influence the definition of scope, the budget and time allocated to the work, and the research methods deployed. Given the perception of a relatively low priority assigned to considering climate change consequences among many in the UK seafood industry, the approach taken reflects a judgement by Seafish as to what constitutes an 'appropriate' (i.e. moderate) level of resource for the study from levy.

Whilst the initial perception of low industry priority was broadly confirmed (but with exceptions), it is nonetheless an industry that takes consideration of scientific and commercial issues around 'sustainability' as the norm. During discussion with industry stakeholders, it has been important to keep to the fore the likely inter-relationships between climate change stressors and the sustainable exploitation of natural resources.

Throughout the present exercise, the interests of the UK seafood industry are paramount, an industry which is defined broadly here to include the following industry functions: wild capture; trading, processing and product manufacture; wholesale and retail / food service. In scope, it also includes three specific sub-sectors (whitefish, pelagic and shellfish) which are considered across each system (domestic and international).

1.4 Research aims and objectives

The aim of this research is to *support the UK's seafood industry to develop a managed adaptive approach to climate change*. To achieve this, there are two overarching objectives:

- To provide a review of projected climate change impacts with implications for seafood.
- To identify relevant seafood industry adaptation responses.

This report will be submitted to the UK Government through the ARP process. The ARP findings will then be fed into the National Adaptation Programme. More directly, it is intended to support progress towards beneficial outcomes for the UK seafood industry by communicating changed practices (adaptation responses) already underway in parts of industry, by raising awareness of threats and opportunities; and by stimulating new action.

1.5 Research plan and methods

This research was conducted over a period of nine months and included the following main tasks:

- Research design.
- Review of published literature.
- Group workshops and individual consultations with industry stakeholders.
- Identification of potential impacts and a structured assessment of risks, threats and opportunities – using secondary and primary sources of evidence.
- Development of adaptation plans – together with indicative implementation, monitoring and evaluation components.
- Draft reporting – initial review by industry experts.
- Final reporting and publication (planned) – including communication of findings towards industry.

The report as presented is underpinned by published evidence and draws upon industry experience. The evidence utilized is based on a wide ranging literature review drawing on selected, key literature sources on climate science, fisheries science and seafood policy. This evidence is fully referenced in the text. Through substantive consultation, the report also draws upon the knowledge and experience of industry, supported by that of staff at Seafish and Cefas. Contributions have been received from over 30 industry stakeholders, 16 through semi-structured interview either by telephone or face-to-face, and the remaining 14 through group discussion in three industry workshops (in Aberdeen, London and York). Whilst these stakeholders are drawn from different parts of the industry (see Annex 3 for a list of the contributors), it is not claimed that they are representative of the industry in any formal or statistical sense.

The various opportunities for industry engagement during the research phase were used for multiple purposes: (i) to put initial findings from the literature review in front of industry experts in order to provide the context for discussion; (ii) to validate conclusions emerging from the exercise; (iii) to obtain insight and information additional to that gleaned from the literature review; and (iv) to obtain advice on industry priorities and on what might be feasible in terms of adaptation responses.

1.6 Research quality criteria

This section sets out the research design criteria and practices by which Seafish has sought to assure the quality of this exercise.

It also relevant to consider issues concerned with quality that may arise in an *ex post* assessment by others. In particular, issues around third party assessment are discussed with reference to the published work of researchers at Cranfield University who have reported on the evaluation of the quality of other climate change risk assessments of Reporting Authorities (Drew et al, 2010). The qualitative framework which underpins the Cranfield approach examines a set of 'attributes' (eight key attributes and 28 sub-attributes) considered to be essential requirements in the reports of Reporting Authorities. The attributes of this report relative to the 'Cranfield attributes' are examined in detail in a technical annex (Annex 2).

There are a number of underlying factors of note. Firstly, the rationale for the present exercise is to develop an adaptation response appropriate to the UK seafood industry as a whole or to its major

constituent parts (e.g. wild capture of pelagic fish, processing of whitefish). The purpose is not to devise an adaptation response for the corporate entity that is Seafish. Whilst there are responses (actions) that may be appropriate for Seafish to take, these will be to provide support for its industry stakeholders rather than to adapt its own operations. Any Seafish action will first need to be discussed and endorsed in a process of industry engagement over the use of levy i.e. the Seafish panel process (see sections 2.3 and 5.3). This process lies outside the engagement undertaken for this exercise.

Secondly, the present exercise relies on two sources of knowledge: scientific evidence and industry experience. This is in line with the wider debate in the seafood industry about the appropriate science / industry interface as illustrated, for example, in the need to bring fishermen's experience into fisheries management (see industry feedback in Chapter 4). The criteria should therefore pay particular attention to the attributes that relate to these two sources of knowledge.

These factors may differentiate the attributes of relevance to this plan from those designed for the wider portfolio of reports of Reporting Authorities (RA). These factors influence how this plan should (or can) be evaluated for quality by others. Those attributes considered to be most relevant and strongly associated with the present exercise are:

- Evidence
 - Attribute 2.4 – the RA's (i.e. Seafish's) risk assessment quantifies, or otherwise estimates or characterizes, the impact and likelihood of risks occurring at various points in the future.
 - Attribute 3.1 – RA adopts the latest set of UK Climate Projections or other appropriate scenarios or climate information.
- Experience
 - Attribute 3.3 – RA's risk assessment includes consultation with interested parties or stakeholders – an especially notable feature.
 - Attribute 5.2 – RA's adaptation plan includes a detailed action plan covering its priority areas. This should ideally include timescales, resources and responsibilities and be included in the report.

The prime quality considerations here have been as follows:

- Ensure the use of authoritative and up-to-date sources on the nature and likely effects of climate change, with full references provided.
- Ensure the use of similarly credible sources which report on the actual, or forecast, climate change consequences specifically on fish resources and the seafood industry (broadly defined), again fully referenced.
- As indicated earlier, whilst underpinned by a wide ranging review of the literature, this report relies on selected key references to inform and justify risk assessments, interpretations and recommendations.
- Assure for relevance and feasibility in terms of adaptation proposals through consultation with industry experts – as indicated earlier, although of notable value, it cannot be claimed that the contributors are ‘representative’ of the industry.

Judgements on the elements of scientific evidence to reference in the report have had to be made. For the UK seafood industry, at least at this time, justification for active engagement in adaptation responses needs to be grounded in climate change consequences underpinned by evidence in which there is high confidence. Moreover, the evidence of most value at this time is that which points with high confidence to consequences for the industry that are anticipated over a timeframe which, while it may ‘stretch’ business planning horizons, is not of an order of magnitude greater than these horizons.

Consideration of quality assurance issues has been given to both the ‘sensing’ and ‘responding’ phases of the approach used in this study (see Annex 1 on methodology). The challenge has been greater in the ‘responding’ phase.

The greatest ‘quality’ challenge, arguably, is to ensure (and to make transparent in reporting) a robust ‘logic’ when making links between the various sources of scientific evidence and

between these and the implications for the UK seafood industry. These issues arise in both the ‘sensing’ and ‘responding’ phases of the approach adopted in this exercise (see Annex 1 on methodology). Where assumptions have had to be made, they are made explicit in the text. However, establishing robust links to quantifiable risks, threats and opportunities for the UK seafood industry should be viewed as a ‘work in progress’. As Daw et al (2009) indicate, there is increasing uncertainty as we move from the consideration of global climate trends and projections through to the likely social and ecological responses (i.e. from left to right in the diagram below). This introduces a cautionary note in the context of the present report where the ultimate purpose is to consider adaptation responses for the benefit of an industry to address threats and opportunities.

1.7 Limitations

Through consultation with industry, the nature of the UK seafood industry’s engagement within the ‘domestic system’ and the ‘international system’ is examined. This provides a frame within which the significance of climate change and its associated risks, threats and opportunities industry can be considered for UK seafood businesses (for import-dependent and domestic-dependent businesses respectively).

Perhaps unsurprisingly, engagement with industry stakeholders in the ‘domestic system’ on climate change has proved to be more straightforward and extensive. This is probably because domestic stakeholders already tend to have closer links with a ‘soft infrastructure’ that supports conversations on topics such as fisheries science, sustainability, quotas, reputational risk, etc of relevance to the UK’s fleet and to the domestic industry it supplies. By contrast, many import dependent UK firms and their representative bodies may be relatively remote from Regional Fisheries Management Organisations, their sub-committees and meetings internationally where consideration of climate change adaptation does already or could take place.



Figure 1.1. Increasing uncertainty along the pathway of impacts of climate change (after Daw et al, 2009, Fig 4)



2. The UK seafood industry

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In considering climate change impacts on the UK seafood industry it is necessary to have a common language on how the industry landscape is represented. The industry representation frames investigation, discussion and agreement on risks, impacts, priorities and responses.

This chapter provides a representation of the seafood industry landscape, summarising the main risk management arrangements supporting the industry including the role of Seafish. The chapter concludes with an overview of those elements of the industry landscape that are within the scope of this ARP exercise. This chapter is supported by Annex 4 and 5.

2.1 Seafood industry landscape

In representing the industry, we define what we mean by the seafood industry and by the term 'seafood product'. Thereafter we set out basic industry functions and activities that underpin the delivery and use of such products.

It is also necessary to appreciate how basic functions interrelate, as seafood systems, in the delivery of seafood products. This supports our understanding of the direct and indirect impacts arising from key risks. Although the seafood industry is diverse, complex and dynamic, basic industry functions interrelate – as seafood systems – in ways that reveal general patterns regardless of product and regional location.

Finally, it is important to identify seafood systems that may have distinct characteristics. Whilst climate change impacts may be global, system characteristics may mean that understanding the priority impacts and risks and being able to respond with adaptation actions present particular challenges.

2.1.1 Defining industry functions and activity

By the term 'seafood product' we mean *any aquatic food product (fish, molluscs, crustaceans, echinoderms and other forms of marine and freshwater life) regarded as food for human consumption or feed for animal consumption* (British Standards Institution, 2012). The basic industry functions underpinning seafood products include:

- **Stocks** – the geographical location and ecological context for the fish source (e.g. Barents Sea, North Atlantic, or North Sea).
- **Capture / production** – the capture of wild aquatic organisms or the production of aquatic organisms through aquaculture.
- **Transport and distribution** – the movement of seafood products between stages of production.
- **Trading, processing and storage** – the receiving, preparation, preservation and packing, storing and dispatching of seafood products.
- **Market / sales outlet** – sale through retail, food service, wholesale and feed suppliers.
- **Consumption** – out-of-home and in-home consumption (chilled / frozen storage, cleaning, cooking, and eating).
- **Waste** – collection / treatment of waste products (including packaging) to landfill, incineration recycling, or composting.

These functions can be further characterised by major species grouping (e.g. whitefish, pelagic, shellfish, salmonids), specific species (e.g. cod, haddock, herring, mackerel, crab, Nephrops, etc), and product format / processed form (e.g. whole, fillets / loins, smoked, prepared, etc).

2.1.2 Seafood systems

In delivering seafood products for consumption, the basic industry functions (above) interrelate as seafood systems. *Seafood systems* identify the types of industry actor associated with industry functions and activities that may be impacted (positively or negatively) by climate change developments. Figure 2.1 illustrates a 'generic' system structure based on life-cycle and value chain concepts for capture fisheries.

Figure 2.1 Capture fisheries

Stocks	Capture / production		Transport and distribution	Trading, processing, storing	Market / sales outlet	Consumption	Waste
Target species	Capture fleets	Landing ports and auctioning markets	Air, sea, and road freight	Primary and secondary processors, importers and exporters, traders	Retail Food Service Wholesale Feed suppliers	'In-home' and 'out-of-home' consumers	Under-utilised product at all stages
Supporting inputs							
Fisheries management	Fishing gear Bait Cooling materials Fuels/energy Packaging Maintenance materials Equipment manufacturers	Fuels / energy Cooling materials Packaging Maintenance Vessel building / repair Equipment manufacturers	Transport infrastructure Cooling materials Fuels / energy	Ingredients Materials for processing Cooling materials Fuels / energy Packaging Maintenance materials			
Media, NGOs, Scientific community							

Annex 4 provides further detail of the basic functions, main systems and key species within the UK seafood industry.

2.1.3 Characterising major UK seafood systems in a global context

The seafood industry can be considered to operate as many subsystems (regional, sectoral), of varying degrees of interdependence, nested within one overarching global system.

How seafood systems inter-relate within the global context can reveal specific systems with shared characteristics. In the global context, from a UK perspective, there are at least two major seafood systems with distinct characteristics:

- A domestic system – defined as a system reliant on domestically sourced material (material caught from North Atlantic stocks and landed in the UK, material farmed in the UK). Within the 'domestic system', the key UK actors are vessels, agents and merchants in the UK handling material landed / farmed in the UK; UK processors of fish; and the downstream supply chain in the UK of all of the former including food service companies, retailers and exporters.

- An international system – defined as a system reliant on internationally sourced material (material caught from stocks in the North Atlantic and elsewhere landed outside the UK, material farmed outside the UK). Within the 'international system', the key UK actors are agents and merchants in the UK importing fish and shellfish that is caught, landed or farmed and possibly processed outside of the UK; UK processors of imported fish; and the downstream supply chain in the UK of all of the former including food service companies, retailers and re-exporters.

It is notable that from a UK perspective, seafood material is generally imported for UK consumption whilst material originating in the UK is largely exported for overseas consumption. The UK consumer maintains a robust preference for salmonids (farmed salmon), whitefish (cod, haddock and Alaskan pollock), pelagics (tunas) and shellfish (cold-water prawn, and farmed warm-water prawn) – see Table 2.1 for example. Meanwhile, UK landings volumes are dominated by mackerel and herring (pelagics), Nephrops (shellfish) and cod and haddock (whitefish).

The trade position is such that the UK imports over twice the volume of seafood from outside the EU whilst exporting a large share of landed volumes. Important source regions for wild caught seafood imports include:

- North Atlantic and North Pacific for whitefish (cod, haddock and Alaskan pollock).
- Indian ocean and other equatorial regions for pelagics (tunas).
- North Atlantic for shellfish (cold-water prawns).

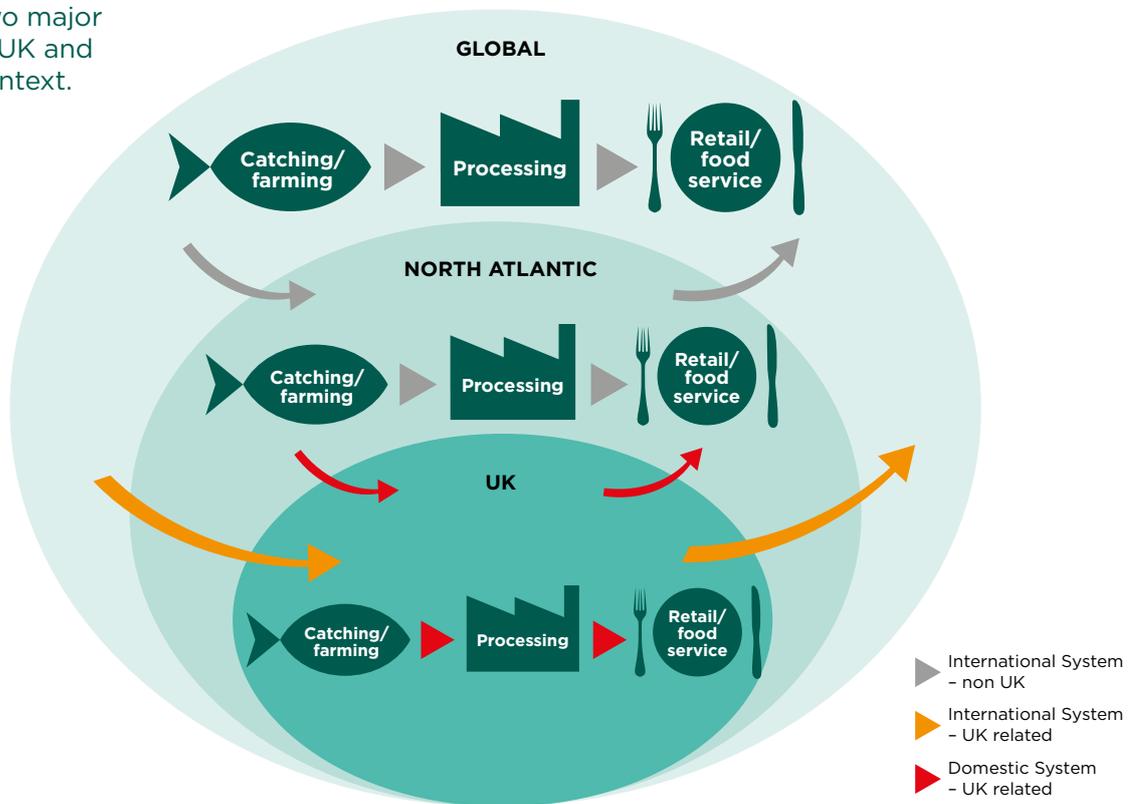
Important export destinations include the East and Far East for pelagic material (mackerel and herring), and continental Europe and the Far East for shellfish (Nephrops).

This balance of trade highlights a structural segregation between stakeholders in the domestic system (dominated by producers – fishing and farming) and the international system (dominated by processors/manufacturers). Figure 2.2 illustrates the simplified relationship between these two major systems, the UK and the global context.

Table 2.1 Top eight species by UK retail sales volume 2014 (Source: Nielsen 061214)

	Value (£'000)	Volume ('000 kg)	% of total fish volume
Tuna	364,988	55,693	17%
Salmon	861,974	54,201	16%
Cod	354,940	43,179	13%
Pollock	132,877	27,180	8%
Cold-water prawns	211,679	20,640	6%
Haddock	194,769	19,427	6%
Mackerel	115,225	14,689	4%
Warm-water prawns	202,647	12,511	4%
Total Fish	3,148,511	337,030	100%

Figure 2.2 Two major systems, the UK and the global context.



2.2 Seafood industry operating conditions: strategic challenges

A myriad of developments contribute to the overall operating conditions for seafood industry systems that, in turn, affect the performance of industry functions. Several strategic developments are noteworthy in this respect:

- Marine conditions: biological cycles in fish ecology.
- Social conditions: population growth and globalisation.
- Biosphere conditions – climate change.

These, in turn, present several strategic challenges to industry performance, such as:

- Managing shared resources.
- Responding to global economic and financial conditions.
- Ensuring food security.
- Mitigating GHG emissions and adapting to climate change.

These developments present a range of natural, as well as man-made, risks. At a more general level, the heightened risk environment has, for some, led to speculation about our entering a 'risk society' (Beck, 1992), and a 'runaway world' (Giddens, 2002).

In seafood, the need to respond to risks has led to a growth in scrutiny across the seafood industry over the last 15 years (see Garrett et al, 2009). The seafood industry sits within a wider network of actors reviewing, monitoring and proposing actions. These actors – that include industry bodies, associations, academia, policymakers, NGOs and media – provide a means by which risk can be managed and adaptation action supported as described in the next section.

2.3 Supporting risk management and adaptation action in the UK seafood industry

A number of mechanisms exist to support industry in *sensing* and *responding* to risks in the wider environment. Over and above corporate risk procedures of individual businesses, these include discussion fora, collaborative initiatives, codes of practice, and legislation.

Representative and governance organisations support the sensing of risks (by providing opportunities for discussion and debate). Their supporting processes (discussion fora) facilitate communication and understanding of changes affecting the industry. Discussion fora often already cover issues such as 'sustainability' or 'regulatory developments' and might be well placed to broaden discussions to include climate change where this is not already on the agenda. A number of important mechanisms are highlighted in Table 2.2.

Table 2.2 Example mechanisms to support risk management

Level	Key organisations	Processes supporting risk management	Cycle / regularity
International	FAO	Committee on Fisheries (COFI)	Two years
	Regional Fisheries Management Organisations (RFMOs)	RFMO meetings	At least one per year
	The Commonwealth	Commonwealth Heads of Government Meeting	Two years
	European Commission	Scientific, Technical and Economic Committee for Fisheries (STECF)	Three per year (plenary)
UK	Seafish	Internal – Board, Audit and risk committee	Six per year
		External – Industry panels	Three per year
Industry	Associations (e.g. SFF, NFFO, FDF, BFFF)	Committees, industry fora	Several per year

Managing risks, however, requires more than the capability to sense risks through increased scrutiny; the ability to respond to changes is equally important. The ability of industry to respond is an issue of both vulnerability and adaptive capacity. This varies across national boundaries (Allison et al, 2009) and is a particularly important consideration for stakeholders in the international system.

Increased scrutiny has led to mechanisms that support industry response to risk (by influencing industry practice and – potentially – supporting adaptation). Example mechanisms include: legislative frameworks, regulation and voluntary codes of practice often developed by industry in collaborative ventures. Important legislative frameworks and regulation that affect the seafood industry have been developed in areas of fisheries management (e.g. Common Fisheries Policy), authenticity (e.g. Illegal, Unreported, and Unregulated (IUU) regulation), environmental and marine conditions (e.g. Marine Strategy Directive, Water Framework Directive) and in food safety.

Over and above the corporate actions of individual businesses, a number of organisations provide services to help the UK seafood industry respond to changes in operating context. Again, these may be suitable mechanisms to support industry response to climate change, where this is not already on the agenda. A number of important support areas are described in Table 2.3 some of which are described in further detail in Annex 5 as potentially supporting climate change adaptation responses.

Of the mechanisms supporting risk management, Seafish can be considered an important actor for the UK seafood industry. However – as with all support functions – there are limitations. Seafish cannot own risk areas, such as climate change, and of the related adaptation actions Seafish can own only those falling within its remit.

2.4 Boundaries and exclusions

The focus and scope of this ARP exercise provides the boundary for reviewing climate change developments, assessment of risks and adaptation action and planning. The focus of the ARP is on wild capture seafood. The scope of this ARP is concerned with selected industry functions ‘cradle-to-gate’, rather than covering the entire industry

system ‘cradle-to-grave’ and species (whitefish, pelagic and shellfish). The functions of Seafish, as an organisation in its own right, are of interest *to the extent that these support those industry functions likely to be affected by climate change.*

The cradle-to-gate boundary for seafood products includes the following functions: Stocks, Capture / production, Transport and distribution, and Processing. On this basis, the following activities, where they occur, are within scope:

- Fishing, including preparation and transport to and from fishing grounds.
- Landing and auctioning.
- Processing and storing.
- Transport and distribution including packing.

The cradle-to-gate boundary includes the following species and groupings:

- Domestic
 - o Whitefish (cod, haddock, monkfish, whiting, etc).
 - o Pelagic (herring, mackerel, etc).
 - o Shellfish (crab, lobster, Nephrops).
- International
 - o Whitefish (Alaskan pollock, cod, haddock, etc).
 - o Pelagic (anchovy, sardine, tunas).
 - o Shellfish (cold-water prawn).

Subsequent functions / activities are out of scope (i.e. Market / sales outlets, Consumption and Waste) as are salmonids. Aquaculture produced seafood is not the focus of this ARP exercise. The focus only on wild capture in this first ARP exercise by Seafish is justified on the basis of its importance and maturity as an industry sector (with well-developed institutions and risk management mechanisms) and that it provides a useful platform for a subsequent ARP exercise focussed on aquaculture systems (see Annex 1). It should be noted that material from aquaculture production is a significant, and increasingly important, component of seafood supply. Aquaculture already provides important species to the UK consumer (for example salmon and warm-water prawn in Table 2.1) and is anticipated to expand to equal the wild capture contribution to the overall total 187million tons global fish supply by 2030 (World Bank, 2013: 39-40).

Table 2.3 Mechanisms influencing industry practices

Level	Example organisations	Support function	Examples
International	Intergovernmental Panel on Climate Change (IPCC)	Scientific body under the auspices of the UN which reviews and assesses scientific, technical and socio-economic information produced worldwide relevant to understanding climate change.	Publish regular Assessment Reports – the 5th Assessment reviews evidence relevant to ocean systems and food security.
	Agencies such as: International Maritime Organisation (IMO), International Council for the Exploration of the Sea (ICES), World Bank	Research and information (addressing knowledge gaps).	e.g. Legislation on vessel design and safety, etc (IMO).
	Food and Agriculture Organisation (FAO) – Fisheries and Aquaculture Department	A mission to strengthen global governance and managerial / technical capacities of members, and to lead consensus-building towards improved conservation and utilisation of aquatic resources.	Publish 'State of World Fisheries and Aquaculture' and various 'Codes of conduct'. Works with the Global Partnership Climate, Fisheries and Aquaculture (PaCFA), to raise awareness of climate change issues and to promote a coordinated response from the wild capture fisheries and aquaculture sectors.
	Regional Fisheries Management Organisations (RFMOs)	International organisations formed by countries with fishing interests in an area or species.	Some have a purely advisory role but most have management powers to set catch and fishing effort limits, technical measures, and control obligations.
	European Commission (particularly Directorate-General for Maritime Affairs)	Manages two policy areas: (i) integrated maritime policy; and (ii) common fisheries policy (CFP). Sustainable Fisheries Partnership Agreements allow EU fleets to fish in third countries' Exclusive Economic Zones. Plays active role in bodies established under UN Convention on the Law of the Sea (UNCLOS) and UN Fish Stocks Agreement (UNFSA), and in six tuna and 11 non-tuna RFMOs.	Marine policy (e.g. Marine Strategy Directive), Fisheries and Trade policy (e.g. Common Fisheries Policy – has four main action areas: (i) fisheries management; (ii) international policy; (iii) market and trade policy; and (iv) funding via the European Maritime and Fisheries Fund (2014-2020) which supports transitioning to sustainable fisheries).
	EU Framework Programme for Research and Innovation: Horizon 2020	Includes research on climate change, food security and ocean systems.	The recent call for RTD proposals' to support the implementation of the 2013 Galway Statement on an Atlantic Ocean Research Alliance involving the EU, USA and Canada.
	Commonwealth Secretariat	Provides guidance on policy making, technical assistance and advisory services to 53 Commonwealth member countries.	Resourcing of projects which help build resilience to climate change and improve marine management.
UK	Seafish	Industry collaboration, promotion, research and information.	Research, industry groups.
	Universities / research institutes (e.g. Plymouth Marine Laboratory) and research councils	Research and information (addressing knowledge gaps).	NERC 'Quest Fish' research programme.
	UK Government, administrations, agencies e.g. CEFAS, Marine Scotland, Marine Climate Change Impacts Partnership (MCCIP)	Fisheries and Marine policy, monitoring Research and information (addressing knowledge gaps).	UK and Scottish Marine Bills, MCCIP report cards.
Industry	Associations e.g. SFF, NFFO, FDF, BFFF	Industry collaboration and policy positions.	Specific projects.
	Collaborative ventures e.g. Sustainable Seafood Coalition, Sustainable Fisheries Partnerships, Cold Water Prawn Forum	Industry collaboration and policy positions.	Voluntary initiatives, programmes and projects.





3. Climate change perspectives

3. Climate change perspectives

In summarising the main impacts on the UK seafood industry relating to climate change it is necessary to draw upon what is being observed as well as what is being experienced. In doing so, this chapter draws upon two sources; published evidence and on-the-ground experience. Accordingly, the chapter opens with a summary of climate change impacts as seen from a scientific perspective and concludes with a summary of impacts as seen from an industry perspective. This chapter is supported by Annex 6.

As the UK seafood industry incorporates a domestic and international component, both global and regional climate change impacts are considered in this report. As the primary focus of this assessment is marine wild capture fisheries, climate change impacts affecting marine and coastal environments are the main areas of consideration. Terrestrial impacts of climate change are still considered, albeit to a lesser degree, as they could affect supply chain elements that are in scope (i.e. the transportation and processing of catch).

Bearing this in mind, the principal physical climate change drivers of interest for this report are:

- Sea level rise and extreme water levels.
- Changes in storms and waves.
- Changes in temperature.
- Ocean acidification and de-oxygenation of sea water.
- Changes in terrestrial rainfall (i.e. through surface flooding of land-based infrastructure, plus its role in transferring water, contaminants and pollutants from land to sea).

It should be noted that the information provided in this climate change overview section is based on a few key sources of information. The following section on risks and adaptation actions are based on an extensive review of relevant literature (see Annex 6).

3.1 Scientific perspective on climate change

The following sub-sections summarise current scientific understanding of the physical climate change drivers described above, at both a global level (of relevance to the international system) and regional level (of relevance to the domestic system). Broad implications for both the international and domestic systems are highlighted.

3.1.1 International system – physical climate change drivers

The most authoritative source of information on global climate change continues to be the periodic assessment reports produced by the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 under the auspices of the United Nations to provide an internationally accepted view on climate change. The IPCC produces periodic assessment reports which have the agreement of leading climate scientists and the consensus of participating governments. Unless otherwise stated, the information provided below draws on the findings from the WG1 report [the physical science basis] produced for the latest [5th] IPCC assessment report (2013).

The latest estimates of global physical climate change drivers of relevance to the international system can be summarised as in Table 3.1.

Implications for international wild capture fisheries

A brief summary of key implications of climate change for the international wild capture fisheries industry is provided in this section. These are context (including fishery and geography) specific. They include factors that are also likely to impact domestic system fisheries.

The implications for global fisheries resources have been summarised in a report published jointly by the University of Cambridge and the Sustainable Fisheries Partnership (Holmyard, 2014) which is based on IPCC's Fifth Assessment Report. These include:

1. *Alteration of ocean ecosystems with knock-on impacts on fisheries.* Effects of climate change and acidification are altering ocean ecosystems. Key drivers include rising water temperature, rising levels of carbon dioxide (CO₂) uptake from the atmosphere and hypoxia (inadequate oxygen).

Table 3.1 Physical climate change drivers in the international system

Physical climate change driver	Rates of change (Source: IPCC (2013) unless otherwise stated)
Sea level rise	Past: Over the period 1901-2010, global mean sea level rose by 0.19 metres.
	Future: A global sea-level rise of between 0.29 and 0.82 metres is projected by the end of this century, depending on greenhouse gas emissions.
Temperature	Past: Globally averaged combined land and ocean surface temperature rise of 0.85 degrees centigrade from 1880-2012.
	Future: Surface ocean warming (upper 100m) of 0.6 to 2.0 degrees centigrade is projected for the future. Best estimates of surface air temperature rise are between 1.0 and 3.7 degrees centigrade.
Storms and waves	Past: Although there is little evidence for an increase in long-term tropical cyclone activity in the past 100 years, it appears that the frequency and intensity of the strongest tropical cyclones has increased in the North Atlantic since the 1970s. Confidence in large scale changes in extreme extra-tropical cyclones is low. There is evidence that mean significant wave height in the North Atlantic (North of 45 degrees latitude) has increased since the 1950s, with typical winter season trends of up to 20cm per decade.
	Future: It is more likely than not that there will be an increase in the strongest tropical cyclones in the North Atlantic, as well as the Western North Pacific. There is low confidence in future projections of extra-tropical cyclone activity. There is also low confidence in future wave model projections.
Ocean acidification and de-oxygenation	Past: The pH of the ocean surface has decreased by 0.1 units since the start of the industrial revolution. It is likely that tropical ocean oxygen minimum zones have expanded in recent decades.
	Future: A further decrease of up to 0.3 pH units is possible by the end of the 21st century and it is anticipated that oxygen depletion across global oceans will increase in the future as oxygen solubility is reduced at higher temperatures, and temperature stratification reduces mixing of oxygenated surface waters.
Changes in terrestrial rainfall	Past: Averaged over Northern Hemisphere mid-latitudes, precipitation has increased since 1901 but patterns are less clear elsewhere.
	Future: High latitudes and the equatorial pacific are likely to experience an increase in annual precipitation. A tendency towards wet areas getting wetter and dry areas getting dryer is likely in mid-latitudes.

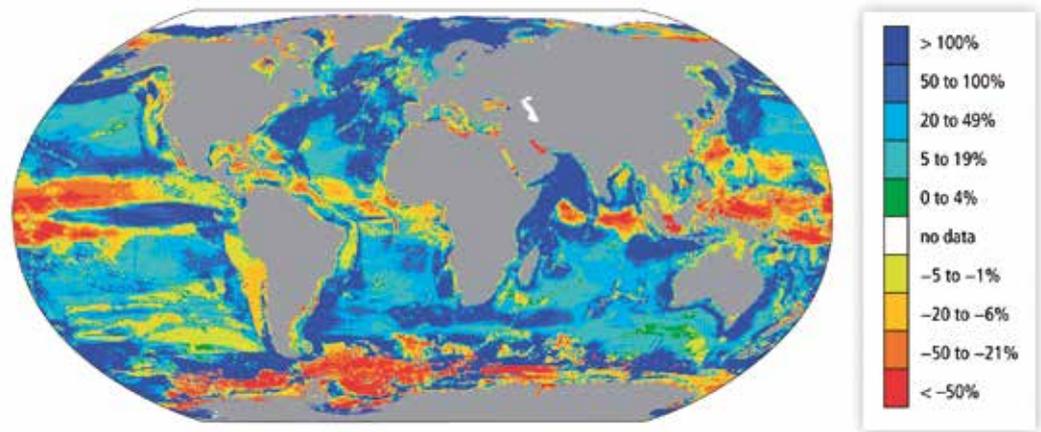
2. Changing catch potential. The projected impacts on fisheries are negative on a global scale and anticipated to be severely so in many regions. The major effects will include: displacement of stocks and mortality of shellfish from more acidic water. However, in some places it is projected that fish stocks will increase. Figure 3.1 shows the projected change in catch potential over the next c. 40 years. It shows, for example, an anticipated reduction in overall catch potential in the tropics. It is argued that the impacts of climate change and ocean acidification on fish resources are generally exacerbated by factors such as overfishing, habitat loss and pollution. There is an increase in the number of 'dead zones' in the ocean, as well as to an increase in harmful algal blooms (some of which can be exacerbated by rainfall changes and terrestrial food production impacts). Furthermore, coral reef ecosystems are in rapid decline: this risks the potential collapse of some coastal fisheries.

3. Regional shifts in stock distribution. The migration of commercial species in response to climate change will challenge the existing agreements between governments over fisheries regulations. An example of the impact of stock migration is the movement of Atlantic mackerel to Icelandic waters recently which has led to Icelandic and Faroese vessels fishing this stock outside of an international management agreement.

4. Increased severity of tropical storms and flooding. This has implications for both onshore and offshore operations. These effects will test the resilience of ports / harbours, vessels and their gear in harbour, and coastal processing and transport facilities. Offshore, increased storminess and waves have implications for time at sea, safety at sea, and the effectiveness of vessels and gear.

Figure 3.1 Projected global redistribution of maximum catch potential of ~1,000 exploited fish and invertebrate species¹ (Source: IPCC, 2014)

Change in maximum catch potential (2015-2060 compared to 2001-2010, SRES a1B)



3.1.2 Domestic system – physical climate change drivers

The domestic system is likely to experience a confluence of climate change impacts constrained or exacerbated by the regional characteristics of the UK / North Atlantic. Impacts will vary locally dependent on such factors as proximity to land mass, shallow waters, enclosed spaces, exposure to open water and natural variation.

For some climate change drivers such as sea level rise, ocean acidification and de-oxygenation, global trends are broadly mirrored at the regional scale of interest (i.e. North-East Atlantic), albeit with some local variations. In other aspects, notably sea temperature rise, some observed and projected changes are higher than the global average, significantly so in some cases.

In the UK, the Marine Climate Change Impacts Partnership (MCCIP) has been collating scientific evidence on coastal and marine climate change impacts since 2006. MCCIP report cards (and supporting review documents) represent the most comprehensive source of information on marine climate change impacts relevant to domestic wild capture fisheries. Most of the information provided in the table below is taken from MCCIP reviews on each of these topics.

The latest estimates of regional physical climate change drivers of relevance to the domestic system can be summarised as in Table 3.2.

Implications for domestic wild capture fisheries

A brief summary of key implications for the domestic wild capture fisheries industry is provided in this section. This summary draws principally on a few key review papers on sea fish and fisheries (Cheung et al. 2012; Simpson et al. 2013; Wright et al. 2013 and Pinnegar et al. 2013) produced for MCCIP report cards (MCCIP 2012; 2013), (MCCIP 2012) as well as a Defra commissioned report on the economics of climate resilience: Sea Fish (Defra, 2013) and a North Sea climate change and fisheries assessment (Pinnegar et al. *submitted*). This information is supplemented by specific examples from the growing body of literature on climate change and fish biology in the UK, and a wide range of other ARP reports (e.g. ports authorities) that have direct relevance to onshore infrastructure and operations (e.g. ABP, 2011). The main implications for the domestic system are:

1. *Changing catch potential.* With regards to the fisheries resource itself, warming in UK waters is expected to lead to further declines in traditional cold-water species (e.g. cod and haddock), whilst warm-water species become more abundant (e.g. John Dory, squid, anchovy and red mullet). Changing catch potential has important implications for quota allocation as species move across international boundaries. See, for example, Figure 3.2.

¹ Projections compare the 10-year averages 2001-2010 and 2051-2060 using SRES A1B, without analysis of potential impacts of overfishing and ocean acidification.

Table 3.2 Physical climate change drivers in the domestic system

Physical climate change driver	Rates of change (Source: IPCC (2013) unless otherwise stated)
Sea level rise	Past: Since 1901, sea level around the UK has risen by an average of 0.14 metres (Horsburgh and Lowe, 2013). Future: A further sea-level rise of between 0.12 to 0.76 metres is projected for the UK by the end of this century, depending on the greenhouse gas emission scenario applied (low, medium and high) and geographical location (the relative effects of local land uplift or subsidence mean that increases are likely to be greater in the south of the UK) (Lowe et al, 2009).
Temperature	Past: Over the last century, sea temperature around the UK has risen between 0.5 and 1 degrees centigrade over the same time period (Met Office, 2011). Future: General increases in sea surface temperature of between 2.5 and 3 degrees centigrade are projected by the end of this century, with greatest increases in autumn off the south and south-east coasts.
Storms and waves	Past: Whilst confidence in large scale changes in extreme extra-tropical cyclones is low, there is some regional evidence that there has been an increase in storminess over the mid and high latitude North Atlantic, and that for very strong winter cyclones, mean intensity has increased (Wang et al, 2012a; 2012b; Met Office, 2014). There is also evidence that mean significant wave height in the North Atlantic (North of 45 degrees latitude) has increased since the 1950s, with typical winter season trends of up to 20cm per decade (Woolf and Wolf, 2013). Future: There is low confidence in future projections of both extra-tropical cyclone activity and wave heights.
Ocean acidification and de-oxygenation	Past: Ocean pH varies locally on an inter-annual basis and some areas may be more vulnerable than others to the average global pH reduction of 0.1 units since the start of the industrial revolution (Williamson et al, 2013). Similarly oxygen depletion will vary locally, but there is evidence for an increase in seasonal oxygen depletion in the North Sea over recent decades (Queste et al., 2013). Future: Global changes in pH and oxygenation will continue in the future, with their degree of impact around the UK varying according to local conditions.
Changes in terrestrial rainfall	Past: Since records began in 1766, there has been no significant change in mean annual rainfall across the UK, but the distribution and intensity has changed, with a tendency towards more heavy winter precipitation events and less extreme summer rainfall (Met Office, 2011). Future: By the end of this century, annual UK rainfall is projected to be about the same, or slightly higher, but with drier summers, especially in the south and south-west and wetter winters, especially in the west of the UK are projected (Lowe et al. 2009).

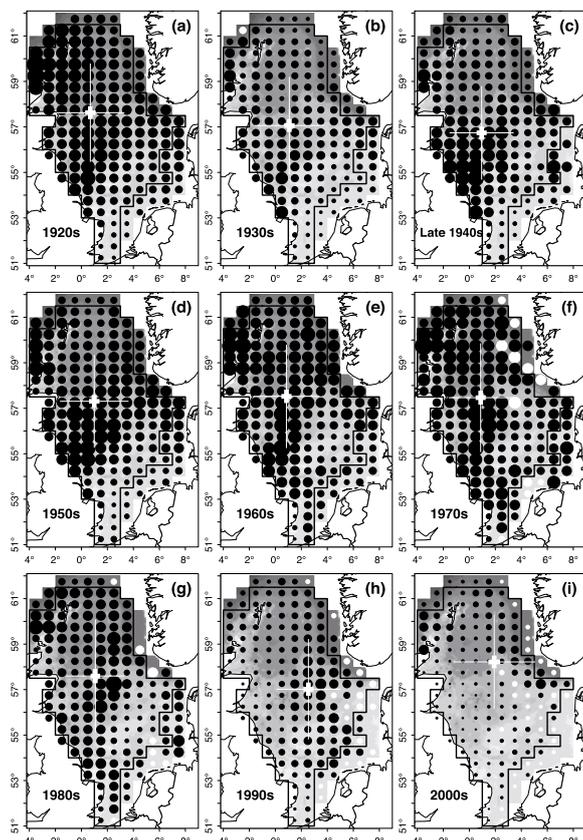


Figure 3.2. Decadal changes in North Sea cod distribution, 1920s–2000s, based on fisheries lpue (landings per unit effort by British trawlers)². (Source: Engelhard et al, 2014)

Changes in prevalence of harmful algal blooms, pests and disease, jellyfish and non-natives could have important consequences, both positive and negative. This is particularly the case for shellfish: in the longer-term, ocean acidification could impact on shell-forming organisms to the detriment of the shellfisheries and wider food web dynamics.

² The area sizes of the black circles are proportional to cod lpue, normalized by decade and corrected for the average spawning stock biomass (SSB) in each decade, to visualize the stock's long-term biomass dynamics. In rectangles where no lpue data were available in a given decade (no effort by British trawlers), white circles represent the long-term average lpue for the given rectangle (again corrected for mean decadal SSB). For each map, the white cross indicates the centre of gravity of cod distribution, with its standard error (shorter, thick white lines) and standard deviation (longer, thin white lines) in the longitudinal and latitudinal directions. The black-lined polygon encompasses those rectangles included in the analyses on centres of gravity of distribution. Bathymetry is indicated by light to dark grey shading (from shallow to deep).

2. *Impacts on offshore operations and assets.* Any increase in storm intensity and frequency could increase the risk of damage to boats, especially smaller vessels, and potentially put lives at risk. Deployment and performance of gear is also adversely affected in stormy conditions. The ‘catchability’ of some target species is affected by both stormy conditions and temperature regimes due to effects on fish depth and visibility (e.g. for line fisheries).

3. *Impacts on onshore operations and assets.* Sea level rise and surge events, as well as extreme storms and waves could damage, or cause widespread disruption to onshore operations and assets. This includes damage to port and harbour assets (including boats), fish processing sites and local housing and amenities. At the local level, changes in terrestrial rainfall could increase flood threats to onshore operations. Extreme events could also disrupt onshore operations through loss of days at sea, impacts on transport routes (e.g. roads and ferries) and loss of electricity supply at ports and harbours and processing sites.

For more information on these key points, and links to key references, please see Annex 6.

3.2 Industry perspectives on climate change

Issues arising during industry consultations concerning interests, attitudes and experiences associated with climate change and its consequences are reported and discussed below. A number of key messages emerge which suggest what may be feasible in terms of industry engagement in adaptation responses over the short to medium term. The messages taken from the industry consultations are as follows:

- The UK seafood industry is based on an activity viz. wild capture of fish and shellfish, that is inherently unpredictable.
- In general, the industry considers itself to be highly adaptable to current operating conditions – this is considered to be a ‘core’ capability, by necessity.
- The industry faces tough and variable market conditions – it is impacted by environmental, regulatory and economic change on an ongoing basis. As an illustration, a contributor involved in the wholesale and food service parts of the UK industry notes that the key

business drivers and influences are changing legislation, ‘politics’, cyclical quota and changing eating habits.

- This is an industry for which addressing issues around the sustainability of a nature resource is commonplace – it is used to assessing the implications of scientific evidence for the purposes of stock assessments and quota. The UK fleet is directly affected, albeit to differing degrees, by natural variability in weather and sea-state as these affect ports / harbours and operations at sea.
- Political influences and fisheries governance regimes operate differently and can have different impacts on the UK industry in different places: this is especially relevant of course to those in the UK industry that are reliant on imports.
- The time horizons with which different parts of the UK industry operates also vary but typically they are short term relative to the time spans over which climate change projections are made – many firms have to cope with short term ‘certainty thresholds’. Planning horizons of less than 18 months are not atypical of many businesses. As one contributor put it: *“Climate change in even a five-year timeframe may be irrelevant when business survival may be a question of a few years”*.

Low priority for many at present: taking action to adapt to climate change is not presently a priority for the majority of industry contributors to this study. Industry highlight the effect of near term events – severe storms affecting ports in Fraserburgh and Peterhead and in the South West, stormy conditions affecting crew safety, flooding of processing units, changing distribution of species for example – particularly in the domestic context. However, the connection between climate change and its commercial significance for the industry is commonly (but not exclusively) regarded as tenuous to date. In any event, making adaptation responses is seen by many to be of relevance only to a minority of firms that do or could (by having the financial means) take a longer term view and to do so on a macro scale.

An industry used to managing risks and uncertainties: the case for this industry to engage with and invest in adaptation to climate change needs to be considered in the context of the risks and uncertainties that it already (routinely) faces and its ability to find resource for this amongst

other competing demands. However, one feature of the discussions held during this study has been an acknowledged new appreciation of the merits of taking climate science into account in strategic fisheries management. This is triggered domestically by: (a) geographic shifts in mackerel stock in the North Atlantic which led to an international dispute; and (b) temperature changes which are impacting cod and cold-water prawn stocks in the North Atlantic and Arctic.

The diverse nature of the industry contributors to the study provides a number of more specific insights. These are shared below.

Facing common issues: at a high level, some contributors feel that many of the risks associated with climate change for larger processors will be similar regardless of the type of catch. From this perspective, the matters of most relevance are those that may have adverse impacts on supply globally as otherwise firms will 'shop across the world' as necessary. The key factor here is the 'total sellable catch that is available', with 'sellable' being a concept which embeds: (i) a species that is liked by consumers; (ii) supplied from a fishery that is sustainable; and (iii) with welfare issues in the supply chain that are socially acceptable.

Views conditioned by the supply chain: the scope and depth of business interest today in climate change adaptation appears to vary depending on position in the supply chain, and in particular the extent to which firms operate with an integrated supply chain. For illustration, a (hypothetical) UK importer which has invested in a processing facility in the Maldives will be more concerned with, and may wish to be more alert to, climate change impact and associated operational resilience at that location.

Regulation, environment and ethics: issues that may come into play for importers as a result of geographic shifts in species distribution include changes in tariffs, trade regulations and market access. For major retailers there are also two important constraints on sourcing which are linked to the focus of campaigning Non-Governmental Organisations (NGOs) and consumer attitudes / perceptions: these concern environmental (sustainability) and ethical issues.

'Tradeability' and market share: the nature of industry interest also depends on the degree of localisation of the caught species which is being taken by processors and major retailers e.g. a business that wishes to retain 'ownership' of a high proportion of a high value 'exotic' species sourced from (say) Sri Lanka will be more concerned with, and wish to be alert to,

climate variability and climate change impacts on stocks and their catch potential at that location. This is especially so in the case where the business needs to retain ownership of a certain proportion of the catch in order to secure and retain a premium price in the market(s). In short, what affects competitive advantage is likely to vary depending on how tradable the catch of a particular species is internationally. Different issues will arise for those within the export / import and processing community that operate with internationally traded species - able to access supplies from multiple locations - and those that operate with an integrated supply chain and with reliance on a narrower source of supplies.

Access to supplies: for many processors reliant on tradable species, the response to geographic changes in distribution or productivity will be to adapt by going elsewhere to source the fish they require. This is the likely response reported by one importer of tuna, a highly migratory species whose distribution is projected to shift due to climate change. However, in doing so it is acknowledged that in changing sources in some circumstances importers may be swapping risks in one place for risks in another: it is acknowledged that in the global market some places are more difficult when it comes to sourcing supplies than others. Whilst Russia is viewed as especially 'challenging', it is reported that c. 50% of the supplies obtained by some importers of whitefish are now from Russian-controlled waters: "*A situation barely imagined ten years ago*".

Business foresight and planning: another factor in discussions with industry relates to business time horizons relative to the time span of climate change projections. When investing in the capability to bring fish ashore as a ready product, it is reported that some of those importing whitefish through vertically integrated supply chains typically consider business risks and responses within a three-five year time window. However, some could be involved in foresighting within a 20-25 year window: the investment decision by a member in a new trawler could involve looking forward to 2050. For such an investment decision made in 2015-2020, the payback period would be 2030-2050. With these timeframes in mind, emergent consequences of climate change may be perceived as much more relevant to this type of investor.

Reactive businesses: the fish processing sector in the UK is made up of small firms employing between five and 20 staff (the majority of firms) plus a small number of large companies. The smaller companies typically operate with trading relationships which involve business planning on a week-to-week basis: merchants tend to believe that they are agile and highly skilled at finding the fish they need from whatever sources are currently offering to supply. Smaller merchants tend to be reactive rather than proactive in response to business risk: in any event, in general smaller firms have little or no resource to use in adapting to potential business risks. According to one contributor, this is one reason why firms join industry associations.

Proactive businesses: for the larger processors, including those importing fish to the UK, sourcing is more likely to involve strategic, collaborative arrangements with suppliers – *“they have their suppliers mapped out”*. Even here, the nature of the industry requires business planning on relatively short time scales: one importer of Alaska pollock which is supplied in two seasonal periods per annum works a year ahead in terms of contracting for supplies; an importer of mackerel buys through annual contracts. Importers of large volume, commodity items may look to buy in year one for supply the following year, and aim to form a view on buying decisions for a further year ahead.

Business planning constraints: however, there are constraints to forward planning e.g. catch quota often proves to be a major factor which may alter on an annual basis. As one processor points out: *“Sometimes biology changes more quickly than expected, sometimes the scientific evidence changes more quickly than expected and these can result in significant quota changes.”* However, notwithstanding these limits, the study learned of one major processor which has recently taken a business decision to monitor the evidence emerging on ocean acidification and the potential consequences for its sources of supply.

Contingency: major retailers generally ensure flexibility over their sources and have contingency plans in place as they recognise that changes in product availability can occur over time. For example, one retailer refers to having access to several different sources of Skipjack tuna to call on. However, there may be cases, albeit relatively rare, of reliance on a very discrete source fishery or to situations in which all the fisheries supplying a particular species are affected adversely at the same time. The general decline in cold-water prawn that has been associated with a general increase in whitefish stocks (notably cod) in the North Atlantic is given by one contributor as an example of the latter.

The risk assessment and adaptation response for those in the domestic and international systems are considered in Chapter 4.



4. Overview of risks and adaptation actions

4. Overview of risks and adaptation actions

In adapting to climate change impacts, it is necessary to consider the more important areas of impact and also to prioritise adaptation responses. This chapter opens with a brief description of how climate change risks have been assessed and responses prioritised. The chapter then provides a description of specific risks and adaptation actions for the domestic system which is then followed by a similar description for the international system. This chapter is supported by Annex 7, 8, 9 and 10.

This chapter identifies the priority risks, threats and opportunities affecting both domestic and international aspects of the UK seafood industry. Following a detailed risk assessment exercise which identified broad relationships between the main climate drivers and a wide range of potential impacts (see Annex 8) the highest priority risks, threats and opportunities for the industry are highlighted here.

The risk assessment exercise used a scoring system based on the proximity and importance of each identified impact (see Table 4.1 and Annex 1 for more details). For each impact, importance and proximity scores were added together. Impacts that had a score of six, or above, were considered a high priority (shaded area in Table 4.1). High priority impacts were taken forward

to the full risk assessment. This is because the proximity / and or importance of those issues mean they require further consideration by the industry and adaptation responses may be required. The risk assessment exercise includes both threats and opportunities.

With regard to proximity, we are specifically interested in physical changes in climate and when these are likely to become significant enough to affect the onshore and offshore industry activities under consideration. With the caveat that timings will vary³, we consider the following as reasonable overall timelines:

- **Changes in storms and waves:** there is already some evidence for increased storminess and waves *happening now* in the high latitude north Atlantic (e.g. see Wang et al. 2013). Industry have reported numerous instances of damage to port infrastructure and recent storms have affected time at sea for the domestic system, as well as changes affecting the international system (e.g. through changes in tropical cyclone intensity).
- **Changes in temperature:** impacts of changes in sea temperature are *happening now* and already affecting catch potential domestically for some species (e.g. cod), as appears to be the case for important commercial species in the international system (e.g. cold-water prawn).

Table 4.1 Risk assessment matrix

		Importance*			
		(range and scale of consequences to the industry, based on current levels of resource)			
		(1) Few, small scale impacts = some minor threats and / or opportunities	(2) Many, small scale impacts = moderate threats and / or opportunities	(3) Few, large scale impacts = some significant threats and / or opportunities	(4) Many, large scale impacts = major threats and / or opportunities
Proximity (time to consequence occurring)	(4) Now	5	6	7	8
	(3) Within next 20 years	4	5	6	7
	(2) Within next 50 years	3	4	5	6
	(1) Over 50 years	2	3	4	5

*The importance scale descriptions are abbreviated in this table, for the full descriptions see Annex 1

³ Physical change in the climate (e.g. temperature) may result in changes in the marine environment with species impacts, regional impacts, and ultimately with consequences for industry (industry impacts). There is therefore scope for lagged effects and variation in timelines. It isn't always the case that industry will experience an impact in the current period just because a physical change in climate - e.g. temperature - is taking place in the current period. For example, we might be confident that the distribution of, say, cod around the UK, is already responding to warming around the UK, but for impacts on growth rate of whitefish species these may become more apparent in the next couple of decades.

- **Changes in terrestrial rainfall:** global changes in the distribution and intensity of rainfall could have impacts *within the next 20 years* (short to medium term) on onshore facilities (through terrestrial flooding) as well as the water quality of nearshore waters through run-off.
- **Sea level rise and extreme water levels:** impacts from sea level rise, whilst already occurring, is likely to have more significant impacts *within the next 50 years* (long term / by mid-century) as increased water levels start to pose more of a risk to onshore site protection measures (e.g. at ports), especially if sea level rise accelerates over time.
- **Ocean acidification and de-oxygenation of sea water:** the impacts from ocean acidification, as well as the de-oxygenation of wild capture fisheries is less certain at this time, but these could have important impacts *within the next 50 years* (i.e. in the longer term, for example acidification on shell-forming commercial species).

To see the full detailed risk assessment, including detailed comments (and key references) on proximity and importance of each risk, threat and opportunity identified, please go to Annex 10.

With climate change impacting across time periods (immediate, short, medium and long term), adaptation responses can be considered to range from specific actions to broader action areas. In the near term we can expect responses described as *specific actions* that can be well-defined in terms of identifiable owners, clear objectives, resources and timetable, etc. In the longer term, however, there is less clarity and as such we can expect responses to resemble *action areas* that require further discussion and development to define what the specific objective, resources, timeframes and owners ought to be.

Adaptation responses were identified in close consultation with industry using workshops and one-to-one interviews. The adaptation response assessment followed a category based system according to speed of adaptation response (inertia) and scale of resource. Speed of adaptation response was captured in terms of immediate, short term, medium term and long term. Scale of resource was captured as minor, moderate, significant and major. Industry experience and judgement was sought to assess adaptation responses against these categories, where this was not available the authors used their informed judgement. Further industry critique was obtained through feedback on draft versions of this report.

Table 4.2 Adaptation response assessment matrix

			Scale of resource			
			Minor	Moderate	Significant	Major
			Available resources can be used to develop adaptive responses	Requires internal resources to be reallocated to develop adaptive responses	Requires some additional external resources to develop adaptive responses	Requires substantial additional external resources to develop adaptive responses
Speed of response (inertia)	Immediate	Within 2 years				
	Short term	2-5 years				
	Medium term	5-15 years				
	Long term	15 years plus				

4.1 UK seafood – domestic

This section concerns the domestic system and describes the specific impact risks arising from climate change drivers and suggested adaptation actions. Some of these impacts are happening now (see Boxes 4.1 and 4.2) whilst others are anticipated in the near future.

Box 4.1 Climate change (temperature change) and ...

... wild capture fish and shellfish stocks

What is the issue?

Changing climatic conditions have been linked to changes in the abundance and distribution of commercial fish stocks of relevance to the domestic system. In some cases this is leading to new (e.g. boarfish) or enhanced opportunities to exploit 'warm-water' commercial stocks (e.g. squid, John Dory, seabass, red mullet and anchovy), whilst more traditional 'cold-water' stocks become increasingly threatened (e.g. cod and haddock).

Example(s):

- A recent expansion in the abundance of boarfish (which only Denmark, Ireland and UK have quota for) could be linked to climate change leading to new commercial opportunities. For example, Ireland has now opened markets to China.
- Off north-east Scotland, where most squid is found, more boats are now trawling for squid than the region's traditional target species, such as haddock and cod.

... changing fish distributions and their implications for quota management

What is the issue?

The impact of climate change on fish species distribution has the potential to lead to international disagreements as stocks move across international boundaries.

There are not only issues with non-EU countries declaring quota, but also the mal-adaptation of EU quota systems under 'relative stability' which lacks the flexibility to respond to geographical shifts of fish species.

Example(s):

- Recent disagreements over mackerel quotas when the species had suddenly attained high abundance in Icelandic and Faroese territorial waters. This development requires a broadening of the parties involved in the quota agreement for mackerel but as yet this remains unresolved. It is not clear if mackerel are spreading out or shifting distribution (by 2014 mackerel had reached as far as Greenland), but either way it is important to understand the role of climate change given the political implications for quota allocations.

4.1.1 Priority risks for industry functions

The initial risk assessment exercise for the domestic system was based upon a review of the literature, and then tested with industry stakeholders. For the domestic system, stakeholders provided a significant input into this process through two stakeholder workshops (with the Scottish Fisherman's Federation and the National Federation of Fishermen's Organisations) and through a series of 1:1 conversations with identified industry specialists to ensure all issues were adequately covered and that the key risks, threats and opportunities identified in the literature review resonated with industry practitioners.

The risk assessment considered both offshore issues (i.e. fishery resource availability and operations at sea) and onshore issues (i.e. the ports, transport links, processing activities and communities that support the industry onshore).

This section provides a summary of the key risks, threats and opportunities identified for both offshore and onshore aspects of the industry. Annex 8 provides a more detailed description of each risk, threat and opportunity, outlining the range of impacts identified, industry perspectives, and a rationale for scoring.

4.1.1.1 Offshore: fishery resources and offshore operations

This part is split according to the three distinct types of wild capture fisheries identified in the introductory section, namely; whitefish, pelagic and shellfish capture fisheries. For fishery resources and offshore operations, there are priority risks representing both threats and opportunities. These are marked as red (threats) and green (opportunities) in Table 4.3 below.

For whitefish, pelagic and shellfish capture fisheries, the two climate change drivers that led to priority risks were increased storminess and waves and air or sea temperature change. In shellfish fisheries, an additional driver was changes in rainfall / run-off. In some instances there are both threats and opportunities. For example in whitefish and pelagic there are threats and opportunities presented by changes to distribution of target species, as some traditional species move away, and warmer water species move in. An example in shellfish fisheries are the threats and opportunities generated by increases or decreases in the prevalence of non-natives / jellyfish.

4.1.1.2 Onshore: onshore operations

This part looks at impacts of climate change on ports and harbours; coastal communities; transportation and processing activities that supports the wild capture industry.

The three climate change drivers that led to priority risks were sea level rise and extreme water levels; increased storminess and waves and changes in rainfall / run off.

For onshore operations, priority risks and threats were identified (no opportunities). These are marked as red in Table 4.3.

Box 4.2 Climate change (increased storminess) and impacts on onshore and offshore operations

What is the issue?

Changes in the frequency and intensity of storms have the potential to cause major disruption to both onshore and offshore operations. On land, port and harbour infrastructure, as well as day-to-day operations, can be adversely affected by storms, as can processing plants and transport routes to market. At sea, the ability to go out to fish, especially for smaller vessels, is an issue, as is the safe deployment and performance of gear.

Example(s):

- Recent storms have led to substantial physical damage to port infrastructure (e.g. the lighthouse and other properties at Fraserburgh, as well as over-topping of sea defences at Peterhead, damaging equipment and housing). The port authority at Peterhead is already investing in higher sea walls.
- The winter of 2013-14 was extremely stormy, especially in south of the UK, which meant boats were stuck in port for long periods.
- In the pelagic sector storminess and waves are already seen to be making an impact. Waves are threatening crew on the existing deck where fish is being pumped aboard from alongside. A number of vessels have built a raised deck and placed the pump higher so that crew members are away from swells (and clear of danger). New build vessels are relocating the pump to the stern i.e. pumping fish from aft as this is safer than pumping from alongside.

Table 4.3 Key offshore and onshore threats (red) and opportunities (green) – domestic

OFFSHORE					
	Sea level rise, extreme water levels	Increased storminess and waves	Air or sea temperature change	Ocean acidification and deoxygenation	Changes in rainfall / run off
WHITEFISH					
a) Fishery resources					
i. Alterations in species phenology			●		
ii. Impacts on choke species (linked to landing obligations)			● ●		
iii. Changes to growth rate of target species			● ●		
iv. Changes to the distribution of target species			● ●		
v. Changes to year-class strength (including larval survival)			● ●		
vi. Migration patterns of target species (timing and routes)			● ●		
b) Offshore operations					
i. Staff physical working conditions		●			
ii. Gear deployment / performance		●			
iii. Damage to fleet		●			
PELAGIC					
a) Fishery resources					
i. Migration patterns of target species (timing and routes)			●		
ii. Alterations in species phenology			●		
iii. Changes to the catchability of target species		●	●		
iv. Changes to growth rate of target species			● ●		
v. Changes to the distribution of target species			● ●		
vi. Changes to year-class strength (including larval survival)			● ●		
b) Offshore operations					
i. Staff physical working conditions		●			
ii. Gear deployment / performance		●			
SHELLFISH					
a) Fishery resources					
i. Presence of HABs		●	●		●
ii. Presence of pests and diseases					●
iii. Changes to year-class strength (including spatfall)			● ●		
iv. Presence of non-natives / jellyfish			● ●		
v. Changes to the distribution of target species (including squid)			●		
vi. Changes to growth rates of target species			● ●		
b) Offshore operations					
i. Staff physical working conditions		●			
ii. Gear deployment / performance		●			
iii. Damage to fleet		●			
ONSHORE					
a) Ports and harbours					
i. Damage to site infrastructure	●	●			●
ii. Boat damage in ports / harbours		●			
iii. Integrity of electricity supply					●
b) Employment and fishing communities					
i. Integrity of housing and local amenities	●	●			
ii. Days at sea		●			
c) Transportation of catch					
i. Disruption to ferry service		●			
d) Processing of catch					
i. Damage to site infrastructure	●	●			●
ii. Integrity of electricity supply					●

4.1.2 Adaptation responses

This section highlights where the industry is already adapting to the key impacts of climate change described in this report (either directly or indirectly), as well as areas where further adaptation responses may be required.

Adaptation responses, where appropriate, include short-term actions that could be put in place with little resource implications, along with a broader-set of longer term, strategic action areas that are relevant to a wide range of the issues raised. Recommendations concerning implementation of these responses, as well monitoring and evaluation measures, are provided in Chapter 5.

As in the previous section on risks, adaptation responses are split by offshore (fishery – whitefish; pelagic and shellfish / operations) and onshore (ports, communities, transport, processing). When developing adaptation responses with industry, specific responses were not separated according to whitefish, pelagic or shellfish capture, rather they were centred on the fisheries knowledge base, governance and autonomous actions by industry (the fleet, ports, processors, etc).

4.1.2.1 Offshore: fishery resources – whitefish, pelagic and shellfish capture fisheries

Fisheries knowledge base

Responses *currently underway* include actions to improve **scientific advice and data collection through partnership working**:

- Fisheries-science partnership initiatives have helped to improve dialogue and have also linked with advisory councils. Lead: Fisheries Science Partnerships.
- Development of training and education modules for fishermen that build capability in fishermen’s knowledge of fisheries science and environmental awareness. These modules will be included in the Seafish three-week Introduction to Commercial Fishing course for new entrants to the industry. Lead: Fishing into the Future (with Seafish).

Proposed responses in the *short term* concern **developing much closer science-industry collaboration and engaged research**. This includes:

- **Science communication:** better communication of relevant research to the industry (not just the fishermen, but also those engaged in wider industry functions such as processors, who may need to adapt practices to any shifts in species being observed) and to inform setting of Total Allowable Catch (TAC). This is not just about long-term change; this should be done in a timely fashion to inform the industry of any seasonal climate anomalies to enable plans to be activated. Lead: Industry trade associations / scientists. Resource: moderate-significant.
- **Industry log sheets as a data source:** incorporation of fishermen’s log sheets to provide real time data on catch, days at sea, etc to inform MSY calculations. It is recognised that there are data protection limitations to this. Detailed vessel data are already provided and these are wholly available to some (e.g. certain individuals within Government) under strict limitations on use. As such it is envisaged that data sharing will be via industry controlled data to ensure data protection rules are adhered to. Lead: industry / scientists. Resource: moderate-significant.
- **Quota allocations:** engage fisherman with the quota allocation discussions so they can provide ground truthing on stock levels. Lead: industry / scientists. Resource: moderate-significant.

Proposed responses in the *medium term* concern **developing a more robust, strategic fisheries knowledge base** that channels relevant data / information to support decisions / actions in real time. This includes:

- **Strategic fisheries science:** a vision for better, more strategic fishery science that avoids ‘fire-fighting’ and takes a long term view that ensures traditional fisheries science interfaces with other research areas e.g. climate change as well as other stakeholders e.g. government and industry. Lead: scientists / industry / Govt. Resource: significant.
- **Industry as knowledge source:** industry is integrated into the scientific process, both as a source of data and as a valuable source of ‘on the ground’ knowledge (e.g. on the current state of fish stocks such as saithe or haddock). Lead: industry / scientists / Govt. Resource: significant.

Governance

Proposed responses in the *short term* concern **ensuring swaps / transfers**. Swaps and transfers could help to deal with any change in stocks linked to climate variability. Lead: industry. Resource: moderate.

Proposed responses in the *medium term* concern a **review of the outcomes of domestic quota market operation**. The market system of allocating quota within the UK should be reviewed to ensure it is fair, flexible and adaptive to climate change impacts. A fair market should be balanced with any market failures addressed (through a market ombudsman or appropriate regulation) that might otherwise aggravate seasonal shifts in the relative abundance and distribution of stocks. Any changes to the fleet would have knock-on effects from port infrastructure (e.g. number of berths) that would need to be considered, which in itself is affected by climate change (see below). Lead: UK Govt / EU / scientists / industry. Resource: significant-major.

Proposed responses in the *long term* include a **review of management (governance) arrangements for all species**. Management arrangements of species inside the TAC system ('Relative Stability') and outwith the TAC system (eg bass, trigger fish, sea bream, red mullet, squid, etc) should be reviewed to consider how they can better reflect changed circumstances in EU fisheries partly arising from climate change. It is recognised that not all parts of the industry feel this is a priority adaptation response. It is also recognised that, although such a fundamental issue demands a long term time horizon, external circumstances may raise this as a priority response to be activated in the short to medium term (for example as the landing obligation interacts with changes in stock distribution and challenges fleet sustainability). The review and its scope requires further consideration (it could, for example, consider the geographical distribution of stocks and the relevance of concepts such as zonal attachment) but should be conducted with due regard to minimising disruption and avoiding unnecessary commercial disruption. Lead: UK Govt / EU / scientists / industry. Resource: major.

4.1.2.2 Offshore: offshore operations

Fleet operation

Responses *currently underway* include the following actions to **enhance operational safety**:

- Raised decks and moving gear, pump and crew operations to the stern to enhance safety (pelagic fleet). Lead: industry.
- Personal Flotation Device (PFD) initiative to improve 'man overboard' situations. Lead: 'The Fishing Industry Safety Group' (Maritime and Coastguard Agency, RNLI, Seafish and industry).
- Safety at Sea training for fishermen. Lead: Seafish-approved training providers.

Proposed responses in the *short term* include the following to **keep a watching brief on climate change and potential responses**:

- **Horizon scanning**: climate change issues being incorporated into horizon scanning exercises (e.g. by industry trade associations). Lead: industry trade associations. Resource: minor.
- **Learning from others**: a review of practices used for warmer water fisheries would help inform any changes required in domestic fisheries. Lead: industry trade associations. Resource: minor.

Proposed responses in the *medium term* concern the **review of fishing seasons in response to disruptions**. Liaise with government to review whether fishing seasons fit with fishing opportunities should disruptions prove to be significant. Lead: industry / UK Govt. Resource: significant.

Proposed responses in the *long term* include **assessing the vulnerability of fleets across the EU**. Consideration should be given to the increased vulnerability of fleets to extreme weather operating in Northern Europe, as opposed to the Mediterranean, by the EU when allocating funds to respond to these issues. Lead: EU research. Resource: major.

4.1.2.3 Onshore: onshore operations

Port operation

Responses *currently underway* include the following actions to **build port resilience**:

- **Establishing port emergency operating procedures:** ports have their own emergency operating procedures that would include staff being on stand-by / storm watch, making sure moorings are secure and putting springs on vessels (cross-tying vessels to port) and limiting car parking on quayside. Lead: port / harbour authorities.
- **Introducing port closures as necessary:** closed seasons on port operations (e.g. Portleven and Mousehole). Lead: port / harbour authorities.
- **Providing emergency financial support for ports:** state aid to repair (but not to enhance) protection to small ports in England following storms (e.g. following 2013 / 14 winter storms). Lead: port/harbour authorities.
- **Building port resilience:** resilience workshops and planning (started in 2009) for ports in England. This will involve setting up port led planning groups. In 2014, DoT also published the 'Transport Resilience Review: a review of the resilience of the transport network to extreme weather events' which includes ports. Lead: Department of Transport.

Proposed responses in the *immediate term* include **ensuring ports are a safe haven** with alternative safer berths made available for most vulnerable vessels. Lead: port / harbour authorities. Resource: moderate.

Proposed responses in the *short term* concern **improving port risk management** and include:

- **Using available business planning templates for ports:** use DoT business plan templates (circulated each year) to check adaptation planning and identify gaps at individual port level. Lead: port / harbour authorities. Resource: minor-moderate.
- **Providing overview of site protection at ports:** expert overview of site protection measures at major fishing ports. Lead: industry associations. Resource: moderate.

Transport operation

Proposed responses in the *short term* include **assessing the vulnerability of freight ferries**. Expert study into the vulnerability of freight ferries to storminess and sea state changes with recommendations for the industry to build resilience. UK Govt administrations. Resource: significant.

Processor operation

Responses *currently underway* include the following actions to **develop markets for domestic caught seafood products**: Seafood Scotland already exists to develop markets based on what is available from Scottish caught fish. Lead: Seafood Scotland.

Proposed responses in the *immediate term* include **developing marketing strategies for the rest of the UK** e.g. presence at international fairs to encourage export markets to buy species of fish that are becoming more abundant in UK waters. Currently this is available to Scotland only through Seafood Scotland. Lead: industry trade associations (e.g. Fishmongers Hall, London). Resource: moderate.

Proposed responses in the *short term* include **establishing specific seafood marketing organisations** for England, Wales, and Northern Ireland. Lead: industry trade associations. Resource: significant.

Proposed responses in the *long term* include **re-location of processing sites inland**: Moving operations inland would protect against flood risk, but would be dependent on the flexibility of local planning regulations. Lead: processors / planning inspectorate. Resource: major.

Additional adaptation responses for further consideration, not captured directly from stakeholder sources but drawn from relevant literature, can be found in Annex 9.

Table 4.4 Adaptation responses – domestic system

		System	Adaptation response	Owner	Scale of resource			
					Minor	Moderate	Significant	Major
Speed of response (inertia)	Underway	Fishery	Scientific advice and data collection through partnership working	Fisheries Science Partnerships				
		Fishery	Development of training and education modules for fishermen	Fishing into the Future (with Seafish)				
		Operations	Enhance operational safety (raised decks)	Industry				
		Operations	Enhance operational safety (Personal Flotation Devices)	The Fishing Industry Safety Group				
		Operations	Enhance operational safety (Safety at Sea training)	Seafish-approved training providers				
		Ports	Build port resilience	Port / harbour authorities / Department of Transport				
		Processing	Develop markets for available domestic seafood	Seafood Scotland				
	Immediate (<2 years)	Ports	Ensure berth allocations for vulnerable vessels	Port / harbour authorities				
		Processing	Develop marketing strategies for seafood in rest of UK	Industry trade organisations				
	Short term (2-5 years)	Fishery	Develop close science-industry collaboration and engaged research	Industry trade associations / scientists				
		Fishery	Ensure quota swaps / transfers	Industry				
		Operations	Keep a watching brief on climate change and potential responses	Industry trade associations				
		Ports	Improving port risk management	Port / harbour authorities				
		Transport	Assess vulnerability of freight ferries	Government				
		Processing	Establish specific seafood marketing organisations for rest of UK	Industry trade organisations (e.g. Fishmongers Hall)				
	Medium term (5-15 years)	Fishery	Developing a more robust, strategic fisheries knowledge base.	Scientists / industry / Govt				
		Fishery	Review of domestic quota allocation	EU / UK Govt / Fisheries scientists / industry				
		Operations	Review of fishing seasons in response to disruptions	Industry / Government				
	Long term (>15 years)	Fishery	Review 'Relative stability' (Governance) arrangements	EU / UK Govt / Fisheries scientists / industry				
		Operations	Assess vulnerability of fleets across the EU	EU research				
		Processing	Re-locate processing sites inland	Processors and planning inspectorate				

4.2 UK seafood – international

This section concerns the international system and describes the specific impact risks arising from climate change drivers and suggested adaptation actions. Some of these impacts are happening now (see Box 4.3) whilst others are anticipated in the near future.

4.2.1 Priority risks for industry functions

The assessment is informed by an extensive literature review plus the views of industry stakeholders that have been consulted during this exercise: the key literature sources are noted in the assessment matrices in Annex 10. Industry views are summarised later in this section.

Industry input for the international system was obtained through one workshop (with members of the UK importers forum) plus a series of 1:1 consultations. A list of contributors is provided in Annex 3. In a number of cases, the consultations were with stakeholders with a specific interest in the international system. However, there are instances in which insights from stakeholders in the domestic system can be generalised and extrapolated internationally.

This section also sets out briefly the rationale for the risk scoring based on both the primary and secondary sources of evidence.

As for the domestic system, the risk assessment considered both offshore issues (i.e. fishery resource availability and operations at sea) and onshore issues (i.e. the ports, transport links, processing activities and communities that support the industry onshore). A third part briefly considers wider socio-economic consequences.

This section provides a summary of the key risks, threats and opportunities identified for both offshore and onshore aspects of the industry. Annex 8 provides a more detailed description of each risk, threat and opportunity, outlining the range of impacts identified, industry perspectives and a rationale for scoring.

Box 4.3 Climate change (temperature change) and cold-water prawns

What is the issue?

The Arctic and North Atlantic oceans are the key source region for cold-water prawns, with import sources for UK consumption being Denmark and Canada. This commercial fishery has been subject to substantial change recently, including stock and quota reductions.

Aschan (2014) discussed the global decline in cold-water prawn stocks. This included causal links to larger and expanding cod stocks, predation by young cod reducing shrimp recruitment to the fishery, and emerging mismatches in time and space of processes in the marine ecosystem resulting in recruitment failure.

Temperature increase is regarded as the most likely main underlying reason for decline, due to direct and indirect effects. Aschen notes that although temperatures will rise, natural oscillation will hide this fact in the short term in some areas. However, the consequences for cold-water species such as *Pandalus borealis* may be dramatic.

Example(s):

The Arctic Ocean is experiencing a measurable and dramatic decrease in sea ice, estimated to be greater than 5% reduction per decade. It is forecast that the entire sea ice of the Arctic will be lost during the summer months in a few decades. According to Wassmann (2013) as a consequence of climate change: "A new, ice-free, stratified and completely unknown ecosystem will arise."

Its characteristics will include the following:

- At the end of this century, prawns (and other fish species) will feed over a larger area as compared to today.
- Climate change may favour cold-water prawn in new productive regions, whilst more southerly areas may lose out.
- Like other bottom-dwelling forms, prawns depend on primary production and what is 'left over' in the upper water column and sinks to the bottom.

Although not feasible yet to estimate the scale of the cold-water prawn resource from primary production forecasts only, it may be possible to indicate where prawn stocks will be located in future decades e.g. north of Svalbard due to better feeding grounds and in extensive new feeding grounds across the Kara Sea and along the outer Siberian shelf, whereas the Barents Sea may have smaller quantities than now, in particular in the south.

The availability of the Barents Sea stock is expected to fall as it moves east out of 'shared' waters into Russian waters. According to Wassmann (2013): "Russia is the big climate winner in the Arctic Ocean". By 2100 Russia may see a 55% increase in stocks. From an industry perspective, the author recommends looking into the option of gaining better access to Russian territorial waters and/or quotas, or to investing in Russian cold-water prawn interests.

4.2.1.1 Offshore: fishery resources and offshore operations

This part is split according to the three distinct types of wild capture fisheries identified in the introductory section, namely whitefish; pelagic and shellfish capture fisheries preceded by a general set of risks to wild capture. For offshore operations and fishery resources, there are both threats *and* opportunities.

For whitefish, pelagic and shellfish capture fisheries, the climate change drivers that led to priority risks were increased storminess and waves, air or sea temperature change. In shellfish fisheries, an additional driver was ocean acidification.

For whitefish, pelagic and shellfish capture fisheries, priority risks representing both threats and opportunities were identified based on the literature review. These are marked as red (threats) and green (opportunities) in Table 4.5 below.

Changes in air or sea temperature suggest some impacts that could be both threats and opportunities. For example in whitefish and pelagic there are changes to distribution of target species. In shellfish, risks are generated by changes in the prevalence of non-native species.

The industry views are expressed through the recommended adaptation responses outlined in section 4.2.2.

4.2.1.2 Onshore: onshore operations (including transportation)

The climate change drivers that led to priority risks were sea level rise and extreme water levels; increased storminess and waves, and changes in rainfall / run off.

For onshore operations, priority risks and threats were identified (i.e. no opportunities). These are marked as red in Table 4.5 below.

The industry views are expressed through the adaptation responses outlined in the next section of this report.

4.2.1.3 Socio-economic conditions internationally

It is widely acknowledged that at the present state of knowledge, the degree of uncertainty in projections increases as one seeks to link global climate change to regional scale marine ecosystem change to socio-economic consequences.

The industry views are expressed through the recommended adaptation responses outlined in the next section of this report.

4.2.2 Adaptation responses

This section highlights areas where adaptation responses may be required for those stakeholders with an interest in the international system. The responses include specific short-term actions that could be put in place with little resource implications as well as a broader-set of longer term, action areas that are relevant to the issues raised. Recommendations around implementation of these responses, as well monitoring and evaluation measures are provided in Chapter 5.

The adaptation responses are those deemed to be of greatest relevance to the import-dependent UK seafood industry given the industry's state of knowledge and concern with climate change at this time. Throughout there is an acknowledgement of the need to gain more general industry endorsement of the business relevance of climate change and of taking action to adapt to its consequences – in the words of some industry contributors, to address the 'so what?' question that presentations on climate change to the industry can sometimes elicit.

When developing adaptation responses with industry, specific responses were not separated according to whitefish, pelagic or shellfish capture, rather they were centred on sourcing options and strategies, the fisheries knowledge base, governance and autonomous actions by industry (the fleet, ports, processors, etc).

Table 4.5 Key offshore and onshore threats (red) and opportunities (green) – international					
OFFSHORE					
	Sea level rise, extreme water levels	Increased storminess and waves	Air or sea temperature change	Ocean acidification and deoxygenation	Changes in rainfall / run off
Wild capture (general)					
i. Changes in species distribution and fisheries productivity (+ve and -ve effects)			● ●		
ii. Loss of fisheries production at lower latitudes			●		
iii. Enhanced fisheries production at high latitudes			●		
iv. Impact on international fisheries governance and access rights			●		
WHITEFISH					
a) Fishery resources					
i. Changes in distribution or catch potential of target of species (general)			● ●		
- Arctic fisheries			● ●		
- North Atlantic Fisheries			● ●		
- North Pacific (Alaska and Bering Sea) fisheries			● ●		
- Mid Atlantic – offshore Senegal, The Gambia, Sierra Leone, Ghana			●		
b) Offshore operations					
i. Gear deployment / performance		●			
PELAGIC					
a) Fishery resources					
i. Changes in distribution or catch potential of target species (general)			●		
- Tuna fisheries			●		
- Pacific Ocean anchoveta and sardine fisheries			●		
SHELLFISH					
a) Fishery resources					
i. Changes in distribution or catch potential of target species				●	
ii. Introduction of non-native species			●		
b) Offshore operations					
i. Staff physical working conditions		●			
ONSHORE					
a) Ports and harbours					
i. Damage to site infrastructure	●	●			●
ii. Vessels / gear damage in ports / harbours		●			
c) Onshore processing					
i. Disruption or damage to coastal processing facilities	●	●			●
SOCIO-ECONOMIC CONDITIONS					
i. Impact on national economies of changes in fisheries			● ●	●	
ii. Impact on food security of changes in fisheries			●	●	

4.2.2.1 Offshore: Fishery resources and offshore operations

Sourcing options and strategies

Proposed responses in the *immediate term* include a **review of key sources of existing supply and available options**:

- **Security of supply**: undertake strategic risk assessments on specific sources of imports to the UK – taking account of climate change and variability. Lead: UK industry – especially integrated supply chains. Resource: moderate.
- **Security of supply** – from regions in lower latitudes: maintain, or increase where possible, flexibility over sources of supply, access monitoring data on regional biomass. Lead: UK industry collaborating with UK Govt / scientists. Resource: moderate-significant.

Proposed responses in the *short term* include **monitoring and assessing the impact of changes in specific regional supplies**:

- **Loss of productivity of whitefish stocks at lower latitudes**: establish a ‘watching brief’ on supplies from lower latitude fisheries and the response being taken to changes by suppliers. Lead: UK industry with support organisations. Resource: moderate-significant
- **North Atlantic whitefish fisheries**: assess nature and commercial value of newly introduced species and increased productivity of existing species – e.g. what commercial value in increased stock of polar cod? Lead: UK industry with scientists. Resource: moderate-significant.
- **Pacific anchovy and sardine fisheries**: ensure importers are informed on future projections. (There are issues here around better understanding of the threat to catch potential – temporary or permanent change in prospect? Also, threats to supplies if the regional industry cannot adapt to sourcing from more distant grounds.) Lead: UK industry bodies supported by scientists. Resource: moderate.

Proposed responses in the *medium term* include **assessing the viability of enhanced regional productivity**: Specifically in whitefish fisheries at higher latitudes, investigate new species to establish whether the material can be commercially fished, is economic to process, meets consumer taste profile, has sufficient biomass and is a suitable substitute for existing

supplies. Lead: UK industry with Govt / scientists. Resource: moderate.

Fisheries knowledge base

Proposed responses in the *short term* include **promoting an awareness of climate change in the North Atlantic pelagic fishery**: specifically the role of climate change on shifting the distribution of target species. Lead: UK industry / UK Govt and scientists. Resource: moderate.

Proposed responses in the *medium term* include **developing much closer science-industry links to understand climate driven regional changes**:

- **Enhanced productivity of whitefish fisheries at higher latitude**: Also: ensure appropriate understanding of the impact of new species on the ecosystem and factor this into management regimes. Lead: UK industry / Govt / scientists. Resource: moderate-significant.
- **North Atlantic pelagic fishery**: ensure good understanding and effective communication with industry of the nature and extent of distributional shifts in stock (e.g. mackerel) – where are stocks moving to and what is filling the gap? Lead: Govt / scientists supported by UK industry bodies. Resource: moderate.
- **Pacific and Indian ocean tuna fisheries**: ensure good understanding, and effective communication with industry, of the nature and extent of distributional shifts in stock. Lead: UK industry (subject to further clarification on demand for this action). Resource: moderate-significant.

Governance

Proposed responses in the *short term* include:

- **Ensuring management regimes embrace the concept of climate change adaptation** (particularly where there is enhanced productivity of whitefish at higher latitudes, in the North Atlantic pelagic fishery and in Pacific and Indian ocean tuna fisheries). Lead: international industry bodies / Govts / scientists. Resource: moderate-significant
- **Ensuring international fisheries management regimes provide early resolution on ‘rights to fish’** (effective arrangements should be in place to ensure early resolution and agreement on ‘rights to fish’ where distributional shifts are occurring). Lead: industry bodies / RFMOs supported by scientists / Govts. Resource: moderate-significant.

Proposed responses in the *medium term* include **engagement with overseas stakeholders to support climate change adaptation:**

- **Regional management of pelagic fisheries:** engage with stakeholders in regional fisheries internationally to ensure that RFMOs are taking appropriate account of climate change projections in their forward plans. Lead: industry bodies / RFMOs supported by scientists / Govts. Resource: moderate-significant.
- **Regional food security – especially at lower latitudes:** consider investment opportunities in alternative food production systems, notably aquaculture. Lead: UK industry / investors. Resource: significant-major.
- **Regional food security – especially at lower latitudes:** manage decline through putting in place effective, joined-up management regimes – take account of climate projections and their implications for stocks, e.g. by capping fishing effort, in all relevant regions. Lead: international regional management bodies and Govt supported by scientists. Resource: moderate-significant

Fleet operation

Responses *currently underway* include actions to **enhance operational safety**, specifically the now ratified IMO convention on standards of training and certification of ‘watchkeepers’ (fishing sector). This is due to be implemented in the UK by 2017. Lead: international Maritime Organisation

Proposed responses in the *short term* include steps to improve industry resilience:

- **Maintain ability to catch:** companies planning new vessels or new gear should consider the implications of climate change for design and investment decisions – part of ‘future proofing’ the business. Lead: UK industry with marine engineers and designers. Resource: moderate-significant.
- **Ensure capacity for enhanced productivity of whitefish fisheries at higher latitude:** capacity building in fleet – ensure access for industry to knowledge of climate risks to support investment decisions relating to e.g. new vessels and gear. Lead: UK industry supported by scientists. Resource: moderate.

4.2.2.2 Onshore: onshore operations

Processor operation

Proposed responses in the *short term* include measures to **improve resilience and capacity of overseas facilities:**

- **Resilience of onshore facilities:** develop better modelling of extreme events, their nature, frequency and location in order to better assess the likely resilience of those onshore facilities of interest to the UK seafood industry. Lead: UK industry / Govt and scientists. Resource: moderate.
- **Resilience of onshore facilities:** the management plans for fisheries in the international system should all incorporate assessments of resilience in the light of climate change projections. Lead: international regional management bodies and Govts / international industry. Resource: moderate-significant.
- **Contingency:** importers should ensure flexibility over sources and maintain / upgrade contingency plans to help cope with damage / disruption to onshore facilities at overseas locations resulting from climate change. Lead: UK industry. Resource: moderate-significant.
- **Ensure capacity for enhanced productivity of whitefish fisheries at higher latitude:** capacity building in processing – ensure access for industry to knowledge of climate risks to support investment decisions relating to e.g. new processing facilities handling the product, and building distribution links. Lead: UK industry supported by scientists. Resource: moderate.

Proposed responses in the *medium term* include maintaining a **watching brief on climate change and potential responses overseas:**

- **Alerting:** establish a source of awareness raising and ‘early warning’ information relevant to firms reliant on, or planning to invest in, facilities at overseas’ locations – up to 10 years foresight would be useful. Lead: UK industry and scientists. Resource: moderate.
- **Regional food security:** especially at lower latitudes: establish ongoing monitoring of food supply / security for local communities – especially of developing countries. Lead: Govt and scientists. Resource: moderate-significant.

A number of additional points have been raised with respect to the set of actions set out earlier.

On translating evidence on shifts in species distributions into international agreements, contributors point to the lessons that should be learned from the recent mackerel dispute in the North Atlantic. As the distribution of the stock changed, the fishery's management plan was not adjusted and ratified. This led to hostility between on the one side the 'incumbent' stakeholders i.e. those who used to have the rights to fish when the stock was in their jurisdiction and on the other, 'new' stakeholders i.e. those starting to fish when the stock entered their jurisdiction.

On shifts in the distribution of tuna stocks in the Pacific and Indian oceans, industry contributors argue that as UK importers can obtain tuna from multiple sources, the consequences of climate change on tuna stocks should not be regarded as a major risk to UK industry at this time.

On the eastern Pacific anchovy stock, changes in distribution and catch potential offshore Chile are forecast to result in drastic reduction in landings. This is a fishery whose productivity and catch potential has been characterised historically by a high variability. Although different anchovy species are found in a wide range of locations in mid latitudes, the supplies from Chile dominate the global market. Downturn in anchovy productivity in this fishery is regarded as a major issue: loss of catch could mean the removal of many tonnes of protein out of the 'system' with downstream implications. Any substantial fall in the supply of anchovy will affect for example aquaculture and its feed inputs.

On damage to ports / harbours and onshore infrastructure / facilities as a consequence of more intense and / or more frequent storms, for stakeholders in the 'international system' this is likely to be most relevant to importers that have an integrated supply chain and operate facilities at overseas locations. For those making investments in facilities overseas, there is seen to be merit in having a source of awareness raising and importantly 'early warning' (e.g. up to 10

years' foresight) information on consequences of climate change on key infrastructure. The purpose is to give the industry 'time to prepare' and intelligence on where / where not to locate onshore and port facilities e.g. ensuring that commercial buildings are located away from quayside areas. For UK businesses, this intelligence may be useful in promoting local stakeholder investment in the resilience of port / harbour operations and processing plants located in third countries. (It is likely that insurers internationally will already have regard to these issues.)

Additional adaptation responses for further consideration, not captured directly from stakeholder sources but drawn from relevant literature, can be found in Annex 9.

Table 4.6 Adaptation responses – international system

		System	Adaptation response	Owner	Scale of resource			
					Minor	Moderate	Significant	Major
Speed of response (inertia)	Underway	Offshore	IMO convention on standards of training and certification of 'watchkeepers' (fishing sector)	IMO				
	Immediate (<2 years)	Fishery	Review of key sources of existing supply and available options	UK Industry - especially integrated supply chains / UK Govt / scientists				
	Short term (2-5 years)	Fishery	Monitoring and assessing the impact of changes in specific regional supplies	UK industry bodies / Support organisations / Govts / scientists				
		Fishery	Promoting an awareness of climate change in the North Atlantic pelagic fishery	UK Industry / UK Govt / scientists				
		Fishery	Ensure management regimes embrace the concept of climate change adaptation	International industry bodies / Govts / scientists				
		Fishery	Ensuring international fisheries management regimes provide early resolution on 'rights to fish'	Industry bodies / RFMOs / scientists / Govts.				
		Offshore	Maintain ability to catch	UK and international industry / marine engineers and designers				
		Offshore	Ensure capacity for enhanced productivity of whitefish fisheries at higher latitude	UK and international industry / scientists				
		Processing	Improve resilience and capacity of overseas facilities	UK and international industry / Govt / RFMOs / scientists				
	Medium term (5-15 years)	Fishery	Assessing the viability of enhanced regional productivity	UK industry / Govt / scientists				
		Fishery	Developing much closer science-industry links to understand climate driven regional changes	UK industry / Govt / scientists				
		Offshore	Engagement with overseas stakeholders to support climate change adaptation	UK industry / industry bodies / investors / RFMOs / scientists / Govts				
		Processing	Maintain a watching brief on climate change and potential responses overseas	UK industry / Govt / scientists				
	Long term (>15 years)		-					





5. Responding and adapting to climate change in UK seafood

5. Responding and adapting to climate change in UK seafood

The chapter opens by highlighting important aspects of adaptation implementation; barriers, and interdependencies. The chapter then recommends a framework for action and adaptation and closes with a set of suggested principles in terms of implementation, resourcing, leading and monitoring responses. This chapter is supported by Annex 5.

Adaptation responses range from near term *specific actions* to longer term *action areas* requiring further consideration and development. There are important barriers to activating adaptation responses, including those that stem from the wide range of interdependencies. Industry consultees provide recommendations on who should take responsibility for the adaptation actions: this advice is summarised below. Advice on the role that may be appropriate to Seafish in supporting adaptation actions is also reported. To be most effective adaptation responses ought to integrate with mechanisms that already exist to support industry risk management (see Section 2.3). A coordinating role taken on by one of the support organisations may be an appropriate means of achieving this integration.

5.1 Barriers to adaptation

A number of important barriers to adaptation may need to be overcome. These include:

- **Climate change is an emergent development influencing a dynamic, unpredictable, industry** such that direct links with seafood impacts can be unclear, unanticipated (and may be suddenly experienced) and often only understood in retrospect. Although the industry considers itself highly adaptable to near term changes (see section 3.2) this is not the same as, and could impede, adaptation to longer term fundamental shifts in the operating environment. Keeping abreast of such longer term developments calls for regular horizon scanning and reviewing of experience and evidence.
- **Climate change is not presently a priority for the seafood industry.** This is unsurprising given the range of challenges facing industry operators, and that the connection between climate change and its commercial significance is commonly regarded as tenuous. In the face of this, awareness raising and communication would seem an important consideration.

- **Successful adaptation is subject to a wide range of interdependencies.** This aspect (see following section), coupled with the tendency for operators – across many organisations and sectors – to work in silos and towards specific interests, does not lend itself to smooth adaptation pathways. *This may be a particular challenge for those operators within the international system where distance and cultural factors (language, business norms, regulatory frameworks, etc) and resources can impede shared understanding and adaptation. For example any adaptation response concerned with a review of fishery management arrangements would encounter this as a major challenge.* Boundary-spanning and unblocking roles may be appropriate within the portfolio of support to industry to ensure responses are integrated ('joining-the-dots' and ensuring 'flow').

The adaptation responses identified in this exercise are indicative and require further consideration and development. This is considered in section 5.3 (below). However, it should be recognised that the above barriers – individually or jointly – may contribute to a lack of industry buy-in to the adaptation responses.

5.2 Adaptation interdependencies

There are clear interdependencies to consider if the seafood industry is to adapt to climate change impacts. These can be thought of as a hierarchy of interdependencies, for example: within seafood supply chains (e.g. between capture and onshore sectors) and across subsystems (e.g. between pelagic and whitefish), between systems (domestic and international) and sectors (seafood with other sectors e.g. utilities or other protein / food sectors).

Examples of interdependence include areas:

- **Within existing seafood supply chains,** for example due to changing availability of supply. Changes at one stage (e.g. catching) can affect the stability or viability of subsequent stages i.e. processing end markets. Within the domestic system for example, diminishing volumes of particular species increases landings volatility and uncertainty undermining the ability to build markets (it is very difficult to build markets on one tonne of material from the inshore fleet for example). In addition there may not be the resources to promote new species and grow new markets. In the short term, forward information from the catching sector is required to highlight changing supplies and enable

onshore to respond by switching material. In the longer term, the processing sector needs to find markets that will absorb that changing product and industry needs to have the ability to collectively market the product (all of this within a very tight cost environment). Within the international system for example, potential increases in species volumes (e.g. higher latitudes) may offer new market opportunities, however only if these species are suitable for consumption and the fishery managed appropriately. In the short term this may require buyers to collaborate in order to investigate and understand the landscape (changes to distribution and assessment of social / economic / environmental aspects of accessing the resource) and collaboration between stages in order to educate and capacity build in fleet and processing (with potentially new vessels executing the fishery, new processing facilities handling the product and building distribution links, etc).

- **Across subsystems (whitefish, pelagic, shellfish)**, for example when trying to diversify operations. Increased variation in species can cause problems for operators looking to switch material. Within the domestic system, catching and processing operators can switch species quite comfortably within, say, whitefish. However there are problems when trying to branch out to pelagic or shellfish. For the catching sector, vessels operating under the CFP are confined to either pelagic or whitefish, and increasingly to Nephrops. In the past vessels had the flexibility to switch target species, for example until the mid-1970s Scottish vessels would switch from pelagic to whitefish. However increasingly restrictive management removes the flexibility to switch between species. For processing operators, moving from whitefish into pelagic or shellfish requires new operating procedures, plant and layout (pelagic fish is oily and plant needs to be cleaned whilst shellfish requires sealed off areas, regular testing, etc in order to deal with contamination).
- **Between domestic and international systems**, for example arising from changes in species distribution. Within the domestic system, changes in distribution may lead to changes in species and also species size. If this were to happen then the markets the domestic onshore industry have developed for currently available material may be lost. Furthermore, if species size changed, domestic operators may lose their existing market niche and find themselves in direct competition with operators in the international system. An example of this is the

potential loss of small haddocks which the industry NE Scotland is famed for, and forms the 'bread and butter' of the regions industry. If changes lead to larger sizes the onshore industry may find itself in direct competition with high volume supplies from overseas (e.g. Iceland, Norway).

- **Between seafood and other sectors**, for example between seafood and the public sector (research and policy community) arising from different objectives and modes of working. Across the domestic and international systems, administrative frameworks supporting fisheries management can impede the ability of industry to adapt to shifts and distribution changes in specific fisheries. For example, ICES designated areas of the sea were originally designed for political purposes, such as exploiting the seabed, rather than fisheries management purposes. This imposes restrictions because fish are so mobile. Although new regional arrangements such as South West Atlantic Waters (Portugal / Spain), North West Atlantic waters (France to Shetland isles), North Sea basin (Norway, UK, Netherlands, Germany) and Western Baltic have been created to overcome the restrictions presented by fish moving across boundaries (e.g. hake / haddock / Northern shelf monkfish are straddling stocks), these basins remain unconnected. This requires better co-ordination between silo areas concerned with migratory stocks to make sure flexibility is not sacrificed. Responsibility lies with those participating in the regional management i.e. National Government representatives. Further examples include interaction between the seafood sector and the logistics and transport sector. Ports and transportation provide critical support functions to the seafood sector with their own climate change adaptation priorities. Collaboration will be required to ensure the needs of the seafood sector (critical ferry routes and port infrastructure for example) are highlighted and addressed in transport sector initiatives. Other sectoral interdependencies include the seafood sector and the utilities sector - particularly electricity in terms of ensuring the continued provision of energy directly to the seafood sector but also indirectly in terms of offshore renewables (that can indirectly maintain the viability of coastal ports). Finally, interdependence of the seafood sector and other food sectors should not be overlooked. Climate change and impacts of

terrestrial protein and food production systems can have an important effect on the marine environment e.g. changes in rainfall and run-off can increase nutrient loading, contribute to eutrophication and de-oxygenation. Such impacts and the adaptation responses of agricultural sector can therefore have a dramatic influence on the nature of presently understood seafood threats and opportunities.

Many, but not all, of the above can be supported by closer relationships and communication between stakeholders in coordinating their respective adaptation responses. However although adaptation highlights areas of interdependence, this does not always suggest closer relationships or integration is the appropriate remedy. There are pros and cons of having an integrated chain for example. In the traded sector, say, operators indicate independence, agility and flexibility as critical features to ensure resilience for these stakeholders.

5.3 Climate change adaptation framework in seafood

As this exercise concerns risks and response across the seafood industry, adaptation responses fall within the domain of a range of stakeholders. The seafood industry is diverse, complex and dynamic. These characteristics do not lend themselves to centralised approaches as can be seen in other ARP exercises in which the reporting organisation discharges the functions of the industry (e.g. utility companies) or in other sectors seeking to respond to similar concerns (see for example the sustainability roadmaps developed by the dairy sector, (Defra, 2010b)). It is therefore inappropriate to consider implementation in terms of a *grand plan or programme of adaptation action* for the UK seafood industry. Rather, an *implementation framework* is more appropriate. Therefore, with this in mind, **it is recommended that:**

1. **Specific adaptation responses are integrated into existing corporate planning processes of the relevant ‘owner’ stakeholder.** This will ensure responses are considered and activated ‘in context’, securing strategic corporate commitment and integrated into existing risk management mechanisms (see Chapter 2). Specifically this will ensure that the specific definition and *ex-ante* cost-benefit appraisals of proposed responses, the implementation

of actions (the nominated responsibility, investment and timescale), and *ex-post* evaluation judgements over effectiveness, efficiency and sustainability are undertaken at the appropriate level.

2. **A high level monitoring and review of climate change responses is established across industry domains and relevant stakeholders.** At this level, monitoring would involve a regular review of adaptation responses by stakeholder (reflecting the key climate change risks as they affect different parts of the seafood industry), a review of completed actions and their effectiveness, and an opportunity to capture lessons learned and to generate synergies. *Given the industry support remit of Seafish, it’s position within the existing risk management mechanisms serving the UK seafood industry (see Chapter 2), and the likelihood of a subsequent request for an updating ARP report within the next five years, Seafish (Board and Panels) may wish to consider Seafish playing this high level monitoring and review role.* The Seafish corporate plan for supporting the UK seafood industry would provide a logical three-year period within which to monitor and report on adaptation responses.
3. **An ongoing review of climate change impacts on wild capture fisheries is maintained.** As the Marine Climate Change Impacts Partnership already reviews climate change impacts on all aspects of the marine environment, *MCCIP may wish to consider this role.* MCCIP could utilise the links to stakeholders established through this process to ensure that key messages are reaching industry practitioners.

5.4 Implementing adaptation responses - suggested principles

Industry demand-led actions. There are a number of actions in the Tables 4.4 and 4.6 whose implementation should, it can be argued, be advanced only with a clear and specific expression of industry demand. These include:

- ‘Undertaking ‘due diligence’ over the nature and significance of changes in distribution and productivity of species of particular importance to import-dependent parts of the UK industry’.
- ‘Undertake risk modelling and contingency planning for specific infrastructure of prime importance’.

- ‘Assess feasibility and business value of taking advantage of the forecast increase in Polar cod stocks’.
- Any actions regarding tuna fisheries, given the feedback from industry consultees that UK importers consider they have sufficient flexibility over sourcing to make their supply chains resilient for the foreseeable future.

Actions in support of adaptation actions towards the development of new markets (e.g. ‘in response to monitoring and early alerts to changes of significance to UK importers, give early consideration to the development of markets for different – replacement – species) will also require industry participation to be effective.

Importers’ views will also be relevant in framing demand for UK Government action, should any be required, to influence responses to climate change by international fisheries governance bodies.

Actions to link climate and fisheries science.

Amongst actions whose implementation may require substantial resource are those associated with ensuring appropriate and linking evidence from climate science and fisheries science in support of the seafood industry in the UK. This may involve further investment in relevant parts of the UK research base and in the collation and assessment (for UK industry implications) of the output from the international scientific effort in the cognate fields.

There is merit in taking stock of the UK knowledge-base and its current engagement with the UK seafood industry on the risks, threats and opportunities associated with climate change. In a UK context, investment in strategic research is in the gift of Government and its research-funding bodies but implementation which will lead to successful outcomes also requires participation of industry stakeholders to frame and pull on outputs. However, it may be that the key requirement is not (just) a different focus for strategic research investment in support of the industry but investment in new boundary spanning functions that can draw together and translate evidence from climate and fisheries science and combine with industry experience to support long term industry adaptation.

Support action – role of key support organisations; Seafish and MCCIP. A potentially important action for support organisations is the boundary spanning function required to support interdependencies. Resources are required for this function, not to generate further information

(which can be generated by other parties), but in terms of capability to bring stakeholders together and combine experience and scientific information to produce concrete actions. Drawing upon Chapter 2, Seafish and MCCIP could play important roles in supporting interdependencies in a domestic UK context. Meanwhile, Seafish and MCCIP in concert with other third party mechanisms (e.g. institutions such as FAO and Commonwealth, key regional stakeholders such as RFMOs, and industry platforms such as the Cold Water Prawn Forum – see Annex 5 for further detail) may be required for this function in an international context.

According to industry contributors who commented specifically on the role of Seafish in supporting adaptation actions, the objective of a response by Seafish should be to: (i) provide a relevant, accessible knowledge-base for industry; and (ii) encourage and help industry ‘*take a closer look*’ at the implications of climate change for their business future.

Other related aspects of such support could include:

- Providing exemplar / interesting industry actions that are being taking within the UK and the wider international industry i.e. support ‘learning for development’.
- Information gathering and assessment to allow Seafish to communicate UK seafood industry strategic needs and priorities effectively to the research community and UK Government in the light of climate change evidence.

A role for Seafish is envisaged in horizon scanning and communication, with appraisal of this contribution based on “*evidence of the industry keeping pace with the changes in catch – nobody kept pace with the mackerel going to Greenland*”.

Whilst in terms of the relevant science, the key role is likely to be that of the MCCIP, Seafish can contribute in important ways to translating the evidence in ways which will help industry to deal with the implications of evidence from the science-base.

Contributors note that if the industry and its representative bodies are themselves alerted and better informed on issues of concern arising from climate change, they will be in a better position to act on their own behalf to influence Government actions.

Characteristics of a Seafish contribution should, according to contributors, be as follows:

- Focused on the nearer term impacts of climate change.
- Provides an accessible knowledge base that is both based on a systematic approach to the review of codified scientific evidence plus anecdotal evidence (e.g. from skippers in the domestic system).
- Able to provide a quick response in terms of signposting / advice on sources of information if and when industry show an interest / look for assistance.
- Deploys only a low level of resource to this initiative for now.

Relevant success factors are viewed as: an information / communication service is established and is made use of by industry – monitoring number of hits / queries to track the level of industry interest; case study evidence of industry taking up and exploiting the intelligence they receive for business benefit. It is clear that, with current levels of uncertainty, industry action will be prompted by *direct* business benefit.

5.5 Resourcing, leading, monitoring adaptation responses – suggested principles

Build from an initially moderate resource allocation. Taking action to adapt to climate change is not presently a priority for the majority of industry contributors. In general, the message from industry contributors is that, notwithstanding the time scale, scale of resource and range of contributors required to achieve fully effective adaptation response, the response for now should be moderate in terms of resource allocation in most cases in order to achieve a greater level of awareness and ‘buy-in’ to the concept of climate change adaptation by industry both at the level of individual firms and of industry representative bodies in the UK.

Encourage strategic industry leadership. It appears that some larger UK companies in the industry are already alert to climate change risks, threats and opportunities: subject to commercial-in-confidence issues, the sharing of information on their motivations for taking account of climate factors in business decision making may awaken wider interest in the industry. Similarly, the availability of case study information on climate change adaptation actions being taken by international peers may prompt more UK firms to act.

Appraise adaptation responses. In the short to medium term, the appraisal of adaptation responses should take into account:

- Evidence of businesses and their associations to engage in climate change adaptation as an industry-wide issue of strategic importance (as they do on ‘sustainability’ matters).
- The need to future proof specific adaptation actions against:
 - o sustainability principles (economic, social and environmental), and
 - o a low carbon world (avoiding seafood industry CO2 emissions hotspots⁴).

Further prioritisation of actions should be supported by a full options appraisal procedure. The appraisal of adaptation actions should be undertaken within stakeholders’ existing decision-making procedures. Devising a new, additional, options appraisal procedure is considered inappropriate since adaptation action will be the responsibility of a range of stakeholders (on the part of industry, Seafish, and ‘Other’ organisations) in specific contexts (e.g. different ‘system levels’), and there is a need to embed adaptation into day-to-day business.

It is envisaged that appraisal procedures will follow specific actions and owners, for example:

- Industry – corporate appraisal procedures.
- Seafish – Seafish industry panel process.
- Other – public funding appraisal procedures (e.g. European Maritime and Fisheries Fund).

⁴ As highlighted in PAS2050-2:2012 Assessment of life-cycle greenhouse gas emissions: supplementary requirements for the application of PAS2050: 2011 to seafood and other aquatic food products.

Implementing, monitoring and evaluating adaptation responses will require a framework that:

- Identifies relevant and practical monitoring indicators for implementing actions as well as the overarching ARP process. Practical indicators give particular consideration to data that are easily and consistently available.
- Embeds monitoring and evaluation into existing mechanisms such as industry reviews or corporate procedures. The former may include regular industry events (e.g. industry association AGMs, conferences), the latter may include the Seafish corporate cycle (e.g. annual corporate reporting, Seafish corporate plan monitoring and evaluation, and UK Government quinquennial review of Seafish).

In the near term, monitoring and evaluation will need to capture evidence of individual firms using sources of evidence on climate change in business planning.

Over the longer term, monitoring and evaluation will need to examine the extent to which the industry has invested in adaptation actions. Actions that involve substantial changes to business practices made in a timely manner. This is likely to require the assembly of case study evidence of lead adopters of change.

Finally, the responses over the longer term should be evaluated on the basis that adaptation actions are supporting the UK industry in longer term decision-making (including making better investment decisions). In other words they assist the industry in better 'future proofing'.

References

- Allison E.H., Perry A.L., Badjeck M-C., Adger N.W., Brown K., Conway D., Halls A.S., Pilling G.M., Reynolds J.D., Andrew N.L and Dulvy N.K. (2009) Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, Blackwell Publishing Ltd.
- Anon (undated) *Climate variability and fisheries: Collapse of Anchovy Fisheries and the expansion of Sardines in upwelling regions*. <http://www.pfeg.noaa.gov/research/climatamarine/cmffish/cmffishery4.html>
- Anon (2010) *The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates*. Global Report of the Economics of Adaptation to Climate Change Study (Consultation Draft), World Bank.
- Anon (2011a) *Mauritius Environment Outlook Report*. Ministry of Environment and Sustainable Development, Government of Mauritius.
- Anon (2011b) *Marine bioinvasions and climate change*. Report of the Invasive Species Advisory Committee, US Department of the Interior. http://invasivespecies.gov/ISAC/White%20Papers/ISAC_Marine_Bioinvasions_WhitePaper.pdf
- Anon (2013) *International threats and opportunities of climate change for the UK*. PWC Report.
- Anon (2014a) *Arctic Shipping: Navigating the Risks and Opportunities*, Marsh Risk Management Research Report. <https://uk.marsh.com/NewsInsights/MarshRiskManagementResearch/ID/41589/Arctic-Shipping-Navigating-the-Risks-and-Opportunities.aspx>
- Anon (2014b) *Human Dynamics of Climate Change: Technical Report*. The Met Office. http://www.metoffice.gov.uk/media/pdf/n/d/HDCC_technical_report.pdf
- Anon (2014c) *Atlantic HMS management-based needs and priorities*. Report of the Highly Migratory Species Management Division, National Marine Fisheries Service, Maryland, USA.
- Anon (2014d) *Marine invasive species in the Arctic*. Report for the Nordic Council of Ministers. <http://www.psmfc.org/ballast/wordpress/wp-content/uploads/2011/05/Marine-invasive-species-in-the-Arctic-Norden-2014.pdf>
- Aschan, M (2014) Current status and outlook for stocks and fishery of *Pandalus borealis* in the North Atlantic. Presentation to the International Cold Water Prawn Forum Industry Meeting, Paris. <http://icwpcf.com/wp-content/uploads/2014/11/1-Michaela-Aschan-2014.pdf>
- Associated British Ports (ABP) *Adaptation Reporting Power Report (2011) for Humber, Hull, Immingham and Southampton Harbour Authorities*. 60 pp.
- Baker-Austin, C., Campos, C.J.A., Turner, A., Higman, W.A. and Lees, D. (2013) Impacts of climate change on human health, *MCCIP Science Review 2013*, 257-262, doi:10.14465/2013.arc27.257-262.
- Barange and Perry (2009) Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In Cochrane et al (eds). *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge*. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp. 7-106.
- Baudron AR, Fernandes PG (2014) Adverse consequences of stock recovery: European hake, a new 'choke' species under a discard ban? *Fish and Fisheries*. DOI: 10.1111/faf.12079.
- Baudron AR, Needle CL, Rijnsdorp AD, and Marshall TC (2014) Warming temperatures and smaller body sizes: synchronous changes in growth of North Sea fishes, *Global Change Biology*, Volume 20, Issue 4, pages 1023-1031, DOI: 10.1111/gcb.12514.
- Beck, U. (1992). *Risk Society: Towards a New Modernity*. Sage publications, London.
- Bell J., Ganachaud A., Gehrke P., Hobday A., Hoegh-Guldberg O., Johnson J., le Borgne R., Lehodey P., Lough J., Pickering T., Pratchett M., Sikivou M., Waycott M. (2013) *Vulnerability of fisheries and aquaculture to climate change in Pacific Island countries and territories*. FAO/Secretariat of the Pacific Community Workshop, 5-8 June 2012, Noumea, New Caledonia. FAO Fisheries and Aquaculture Proceedings No. 28. Rome.
- Beniston M (2010) *Climate change and transportation; the scientific basis*. Presentation to the UNECE-UNCTAD Conference September, 2010.
- Beszczynska-Möller, A. and Dye, S. R. (Eds.) 2013. *ICES Report on Ocean Climate 2012*. ICES Cooperative Research Report No. 321. 73 pp.
- Brander (2010) Impacts of climate change on fisheries. *Journal of Marine Systems* 79, 389-402.
- Brecht H., Dasgupta S., Laplante B., Murray S. and Wheeler, D (2012) Sea-Level Rise and Storm Surges: High Stakes for a Small Number of Developing Countries. *Journal of Environment and Development* 2.1 pp. 120-138.
- Bresnan, E., Davidson, K., Edwards, M., Fernand, L., Gowen, R., Hall, A., Kennington, K., McKinney, A., Milligan, S., Raine, R. and Silke, J. (2013) Impacts of climate change on harmful algal blooms, *MCCIP Science Review 2013*, 236- 243, doi:10.14465/2013.arc24.236-243.
- British Standards Institution (2012) *PAS2050-2:2012 Assessment of Lifecycle Greenhouse Gas Emissions - Supplementary Requirements for the Application of PAS2050:2011 to Seafood and Other Aquatic Food Products*. BSI Standards Ltd, London.

- Capuzzo E, Stephens D, Silva T, Barry J, Forster RM (2015) Decrease in water clarity of the southern and central North Sea during the 20th century. *Global Change Biology*. doi:10.1111/gcb.12854.
- Cheung W.W.L., Lam V.W.Y., Sarmientoz J.I., Kearney K., Watson R., Zeller D. and Pauly D. (2010) Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology* 16, 24-35.
- Cheung, W.W.L, Pinnegar, J., Merino, G., Jones, M.C. 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, W.W.L., Watson, R. and Pauly, D. (2013) Signature of ocean warming in global fisheries catch. *Nature* 497, pp. 365-368.
- Coll, John; Woolf, David K.; Gibb, Stuart W.; Challenor, Peter G. 2013 Sensitivity of ferry services to the western isles of Scotland to changes in wave and wind climate. *Journal of Applied Meteorology and Climatology*, 52 (5). 1069-1084. 10.1175/JAMCD-12-0138.1.
- Cochrane K., De Young C., Soto D., and Bahris T. (eds: 2009). *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge: overview of current scientific knowledge*. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO 212p.
- Cook, E.J., Jenkins, S., Maggs, C., Minchin, D., Mineur, F., Nall, C. and Sewell, J. (2013) Impacts of climate change on non-native species, *MCCIP Science Review 2013*, 155-166, doi:10.14465/2013.arc17.
- Collins M. (2013) *Projections of long term climate change: Regional changes and the Atlas*. In: *Climate Change 2013: the Physical Science Basis*. Working Group 1 Contribution to the IPCC Fifth Assessment Report. http://www.ipcc.ch/pdf/unfccc/cop19/cop19_pres_collins.pdf
- Daunt, F. and Mitchell, I. (2013) Impacts of climate change on seabirds, *MCCIP Science Review 2013*, 125-133, doi:10.14465/2013.arc14.125-133.
- Daw, T.; Adger, W.N.; Brown, K.; Badjeck, M.-C. (2009) *Climate change and capture fisheries: potential impacts, adaptation and mitigation*. In K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge*. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp.107-150.
- Defra (2010a) Charting progress 2: An assessment of the state of UK seas, TSO, London, 166 pp.
- Defra (2010b) *Review of industry, Government and other action to improve the sustainability of fish and shellfish production and consumption*. Poseidon Aquatic Resources Management Ltd for Department for Environment, Food and Rural Affairs (Defra), UK.
- Defra (2013) *Economics of Climate Resilience: Natural Environment - Sea Fish CA0401*. Frontier Economics Ltd for Department for Environment, Food and Rural Affairs (Defra), UK. 101 pp.
- Dasgupta S., Laplante B., Meisner, C., Wheeler D. and Yan J. (2007) *The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis*. World Bank Policy Research Working Paper 4136.
- Dickey-Collas, M., Mc Quaid, N., Armstrong, M.J., Allen, M. and Briggs, R.R., (2000). Temperature dependent stage durations of Irish Sea *Nephrops* larvae. *Journal of Plankton Research*, 22, 749-760.
- Drew, G.H., Pollard, S.J.T., Rocks, S.A. and Jude, S.R. (2010) *Evaluating the risk assessments of Reporting Authorities under the Climate Change Act, 2008*, The Collaborative Centre of Excellence for Understanding and Managing Natural and Environmental Risks (Risk Centre.), Cranfield University, UK, 35 pp.
- Dulvy, N.K., Reynolds J.D., Pilling G.M., Pinnegar J.K., Phillips J.S., Allison E.H. and Badjeck M-C (2010) Fisheries management and governance challenges in a climate change. (Chapter 1) In: *The Economics of Adapting Fisheries to Climate Change*, OECD Publishing. <http://dx.doi.org/10.1787/9789264090415-en>.
- Engelhard, G. H., Righton, D. A. and Pinnegar, J. K. (2014), Climate change and fishing: a century of shifting distribution in North Sea cod. *Global Change Biology*, 20: 2473-2483. doi: 10.1111/gcb.12513.
- Environment Agency (2010) *Managing the environment in a changing climate*. A report to Defra and the Welsh Assembly Government in response to a direction to report under the Climate Change Act 2008.
- EPA (undated-a) *Climate change and transportation*. United States Environmental Protection Agency web site. <http://www.epa.gov/climatechange/impacts-adaptation/transportation.html>
- EPA (undated-b) *Climate change and coasts*. United States Environmental Protection Agency web site. <http://www.epa.gov/climatechange/impacts-adaptation/coasts.html>
- Evans K., Brown J., Bell J., Nicol S., Lehodey P. and Sen Gupta A. (2012) *Progressing adaptation to climate variability and change in Western and Central Pacific Ocean tuna fisheries*. Presentation to the Eighth Regular Session of the Western and Central Pacific Fisheries Commission Scientific Committee, At Busan, Korea.
- Evans, P.G.H. and Bjørge, A. (2013) Impacts of climate change on marine mammals, *MCCIP Science Review 2013*, 134-148, doi:10.14465/2013.arc15.134-148.
- Franke, A. and Clemmesen, C. (2011) Effect of ocean acidification on early life stages of Atlantic herring (*Clupea harengus* L.), *Biogeosciences*, 8, 3697-3707, doi:10.5194/bg-8-3697-2011.
- Felixstowe Dock and Railway Company (2011) *Adaptation Reporting Power Report*, 26 pp.

- Fossa, J.H., Bellerby, R., and Jakobson, T (undated) Consequences of Ocean Acidification for Fisheries. Presentation for the Special Committee on Oceanic Research, International Council for Science (ICSU). www.scor-int.org/High_CO2_II/Presentations/Fossa.pdf
- Frommel, A., Maneja R, Lowe D, Pascoe CK, Geffen AJ., Folkvord A, Piatkowski U, Clemmesen C (2014). Organ damage in Atlantic herring larvae as a result of ocean acidification. *Ecological Applications* 24:1131-1143. <http://dx.doi.org/10.1890/13-02971>.
- Garrett, A., Galloway, K., and MacMullen, P (2009) The credit crunch – recent developments and longer term implications for UK seafood processors. *Seafood Strategic Outlook Edition 6*, Winter 2009. Seafish.
- Giddens, A. (2002). *Runaway world: How globalisation is reshaping our lives*. Profile books. London.
- Hannesson (2010) Climate change, adaptation and the fisheries sector. (Chapter 8) In: OECD (2010) *The Economics of Adapting Fisheries to Climate Change*, OECD Publishing. <http://dx.doi.org/10.1787/9789264090415-en>.
- Hanson, S., Nicholls R., Ranger N., Hallegatte S., Corfee-Morlot J., Herweijer C. and Chateau J. (2011) A global ranking of port cities with high exposure to climate extremes. *Climatic Change* 104, pp.89-111.
- Haynie, A.C. and Pfeiffer, L. (2013) Climatic and economic drivers of the Bering Sea walleye pollock (*Theragra chalcogramma*) fishery: implications for the future. *Canadian Journal of Fisheries and Aquatic Sciences*, 2013, 70(6): 841-853.
- Heathrow Airport (2011) *Adaptation Reporting Power Report*, pp.129.
- HELCOM (2010) *Ecosystem Health of the Baltic Sea 2003-2007: HELCOM Initial Holistic Assessment*. Baltic Sea Environment Procedures. No. 122. <http://www.helcom.fi/Lists/Publications/BSEP122.pdf>
- HM Revenue and Customs: data on fish 'landings' in the UK, including by capture area. <http://www.marinemanagement.org.uk/fisheries/statistics/annual.htm>
- Hollowed, A.B., Kim, S., Barange, M. and Loeng, H. (Eds.) 2013. *Report of the PICES/ICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish*. PICES Sci. Rep. No. 45, 197 pp.
- Holmyard N. (2014) Climate Change: implications for fisheries and aquaculture. Key findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report. University of Cambridge and Sustainable Fisheries Partnership.
- Horsburgh, K. and Lowe, J. (2013) Impacts of climate change on sea level. *MCCIP Science Review 2013*, 27-33, doi:10.14465/2013.arc04.027-033.
- ICES (undated) *Climate change: changing oceans*. <http://www.ices.dk/news-and-events/Documents/Press%20Room/ICES%20CLIM.pdf>
- IPCC (Intergovernmental Panel for Climate Change) (2013) Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- IPCC (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
- IPCC (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.
- IPCC (2014) Summary for Policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.
- International Civil Aviation Organization (ICAO) High Level Safety Conference (2010) Presentation from European Aviation Safety Agency and Eurocontrol. See also: <http://www.greenaironline.com/news.php?viewStory=804>
- Johnson, T. (undated) Fisheries adaptations to climate change. Report by the Alaska Sea Grant Marine Advisory Program. http://seagrant.noaa.gov/Portals/0/Documents/what_we_do/climate/AK%20SG%20Fisheries%20Adaptations%20to%20Climate%20Change.pdf
- Johnson, J., Bell, J. and De Young, C. (2013) *Priority adaptations to climate change for Pacific fisheries and aquaculture: reducing risks and capitalizing on opportunities*. FAO/Secretariat of the Pacific Community Workshop, 5-8 June 2012, Noumea, New Caledonia. FAO Fisheries and Aquaculture Proceedings No. 28. Rome.

- Jones, M. C., Dye, S. R., Pinnegar, J. K., Warren, R. and Cheung, W. W. L. (2014), Using scenarios to project the changing profitability of fisheries under climate change. *Fish and Fisheries*. doi: 10.1111/faf.12081.
- Katikiro, R., Schwerdtner Máñez K., Flitner M. and Badjeck M.C. (eds, 2010) Fisheries Production Systems, Climate Change and Climate Variability in West Africa: an Annotated Bibliography. Leibniz Center for Tropical Marine Ecology, Bremen, Germany and WorldFish Center, Penang, Malaysia.
- Lehodey at al 2011. Vulnerability of oceanic fisheries in the tropical Pacific to climate change. In J.D. Bell, J.E. Johnson and A.J. Hobday (eds.) *Vulnerability of tropical Pacific fisheries and aquaculture to climate change*, pp. 433-492. Noumea, New Caledonia, Secretariat of the Pacific Community.
- Leurig, S. (2011) Climate change risk disclosure by insurers: evaluating insurer responses to the NAIC Climate Disclosure Survey. CERES Report. <http://www.ceres.org/resources/reports/naic-climate-disclosure/view>
- Link J., Griffis R. and Busch S. (Eds. 2015) Climate science strategy (draft for public review). Report of the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.
- Lowe, J.A., Howard, T.P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., et al. (2009) UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK.
- Lynam CP, Heath MR, Hay SJ, Brierley AS (2005) Evidence for impacts by jellyfish on North Sea herring recruitment. *Marine Ecology Progress Series* 298:157-167.
- Macfadyen, G. (2010) *Addressing potential impacts of climate change on fisheries trade*. BIORES v. 4.4.
- MacKenzie B.R., Payne R.P., Boje J, Høyer J.L. and Siegstad H.(2014) A cascade of warming impacts brings bluefin tuna to Greenland waters. *Global Change Biology* 20.8.
- Martin J and Planque (2006). Variability in the onset of hatching of *Maja brachydactyla* Balss, 1922 (Brachyura: Majidae) in the English Channel in relation to sea temperature. *Invertebrate Reproduction and Development*, 49:3, 143-150.
- Mayor D. J., Everett N. R., Cook K. B. (2012). End of century ocean warming and acidification effects on reproductive success in a temperate marine copepod. *Journal of Plankton Research*, 34: 258-262.
- MCCIP (2012) *Marine Climate Change Impacts on Fish, Fisheries and Aquaculture*. Eds.: Frost, M.T., Baxter, J.M., Buckley, P.J., Cox, M., Dye, S.R., Withers Harvey N. Summary Report, MCCIP, Lowestoft, 12pp.
- MCCIP (2013) *Marine Climate Change Impacts Report Card 2013*. Eds.: Frost, M.T., Baxter, J.M., Bayliss-Brown, G.A., Buckley, P.J., Cox, M., Withers Harvey N. Summary Report, MCCIP, Lowestoft, 12pp. doi: 10.14465/2013.arc00.000-000.
- Meager JJ, Batty RS (2007) Effects of turbidity on the spontaneous and prey-searching activity of juvenile Atlantic cod (*Gadus morhua*). *Philosophical Transactions Royal Society B* 362:2123-2130.
- Met Office (2011) *Climate: observations, projections and impacts* [pdf] <http://www.metoffice.gov.uk/media/pdf/t/r/UK.pdf>
- Met Office (2014) *The recent storms and floods in the UK* [pdf] Available at: http://www.metoffice.gov.uk/media/pdf/1/2/Recent_Storms_Briefing_Final_SLR_20140211.pdf
- Michel (2012) Environmental Pressures in the Indian Ocean. In Michel and Sticklor (eds) *Indian Ocean rising: Maritime Security and Policy Challenges*. Stimson.
- Milford Haven Port Authority (2011) *Adaptation Reporting Power Report*, 40pp.
- Natural England (2010) *Assessing and responding to climate risks to Natural England's objectives*. Report to the Secretary of State for Environment, Food and Rural Affairs.
- OECD (2010) *The Economics of Adapting Fisheries to Climate Change*. OECD Publishing. <http://dx.doi.org/10.1787/9789264090415-en>
- Pearce-Higgins, J.W. and Holt, C.A. (2013) Impacts of climate change on waterbirds, MCCIP Science Review 2013, 149-154, doi:10.14465/2013.arc16.149-154.
- Perry R.I. (2011) Potential impacts of climate change on marine wild capture fisheries: an update. *The Journal of Agricultural Science* 149, pp. 63-75.
- Pinnegar, J., Watt, T. and Kennedy, K. (2012) CCRA Risk Assessment for the Marine and Fisheries Sector. UK 2012 *Climate Change Risk Assessment*: Defra, London. 204pp.
- Pinnegar, J.K., Cheung, W.W.L., Jones, M., Merino, G., Turrell, B. and Reid, D. (2013) Impacts of climate change on fisheries. *MCCIP Science Review 2013*, 302-317, doi:10.14465/2013. arc32.302-317.
- Pinnegar, J., Engelhard, G. and Jones, M.C. *Climate Change Impacts on North Sea Fisheries for the North Sea Region Climate Change Assessment* (NOSSCA) (submitted).
- Pörtner, H.-O., D. Karl, P.W. Boyd, W. Cheung, S.E. Lluch-Cota, Y. Nojiri, D.N. Schmidt, and P. Zavialov, 2014: Ocean systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 411-484.

- Queste, B.Y., Fernand, L., Jickells, T.D. and Heywood, K.J. (2013) Spatial extent and historical context of North Sea oxygen depletion in August 2010. *Biogeochemistry*, 113, 53-68.
- Ramsbottom, D, Sayers, P. and Panzeri, M. (2012) CCRA Risk Assessment for the Floods and Coastal Erosion sector. *UK 2012 Climate Change Risk Assessment*: Defra, London. 272pp.
- Rijnsdorp, A. D., and Millner, R. S. (1996). Trends in population dynamics and exploitation of North Sea plaice (*Pleuronectes platessa* L.) since the late 1800s. *ICES Journal of Marine Science*, 53: 1170-1184.
- Roberts, S (2009). 'Britain's most hazardous occupation: Commercial fishing'. *Accident Analysis and Prevention* 42: 44-49. doi:10.1016/j.aap.2009.06.031.
- Rutterford LA, Simpson SD, Jennings S, Johnson MP, Blanchard JL, Schon P-J, Sims DW, Tinker J, Genner MJ (2015) Future fish distributions constrained by depth in warming seas, *Nature Climate Change*, Volume:5, Pages:569-573, doi:10.1038/nclimate2607.
- Seafish (2012) Responsible Sourcing Guide: cold-water prawns. http://www.seafish.org/media/Publications/SeafishResponsibleSourcingGuide_coldwaterprawns_201012.pdf
- Seafish (2014) *Addressing the issue of 'choke' species in a mixed fishery (Blog) Posted on 24 January 2014.* <http://www.seafish.org/about-seafish/blog/2014/1/20/addressing-the-issue-of-choke-species-in-a-mixed-fishery>
- Secretariat of the Convention on Biological Diversity (2014) *An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity* (Eds: S. Hennige, J.M. Roberts and P. Williamson). Montreal, Technical Series No. 75, 99 pp.
- Sheahan, D., Maud, J., Wither, A., Moffat, C. and Engelke, C. (2013) Impacts of climate change on pollution (estuarine and coastal). *MCCIP Science Review 2013*, 244-251, doi:10.14465/2013.arc25.244-251.
- Shelton, C. 2014. *Climate change adaptation in fisheries and aquaculture - compilation of initial examples*. FAO Fisheries and Aquaculture Circular No. 1088. Rome, FAO. 34 pp.
- Simpson, S.D., Blanchard, J.L. and Genner, M.J. (2013) Impacts of climate change on fish, *MCCIP Science Review*, 113-124, doi:10.14465/2013.arc13.113-124.
- Smith D. (2007) Rapid sea-level rise. In: *360 Risk Project*, Lloyds report. www.lloyds.com/360.
- Stramma, L., Schmidtko, S., Levin, L.A. Johnson, G.C. (2010) Ocean oxygen minima expansions and their biological impacts. *Deep-Sea Research Part I - Oceanographic Research Papers* 57 (4): 587-595.
- Sumaila, U.R. and Cheung, W.W.L. (2010) *Cost of Adapting Fisheries to Climate Change*. The World Bank Discussion Paper No. 5.
- Vallejo N., Hauselmann P. and Asante R. (2009) *The role of supply chains in addressing the global seafood crisis*. United Nations Environment Programme report.
- van der Molen, J., Aldridge, J.N., Coughlan, C., Parker, E.R., Stephens, D., Ruardij, P., 2013. Modelling marine ecosystem response to climate change and trawling in the North Sea. *Biogeochemistry* 113, Issue 1 (2013), Page 213-236 DOI 10.1007/s10533-012-9763-7.
- Wang, X.L., Feng, Y. and Swail, V.R. (2012a) North Atlantic wave height trends as reconstructed from the 20th century reanalysis. *Geophysical Research Letters*, 39, L18705. doi: 10.1029/2012GL053381.
- Wang, X.L., Feng, Y., Compo, G.P. Swail, V. R., Zwiers, F. W., Allan, R. J. and Sardeshmukh, P. D. (2012b) Trends and low frequency variability of extra-tropical cyclone activity in the ensemble of twentieth century reanalysis. *Climate Dynamics*, 40, 2775-2800.
- Wassmann P. (2013) How will climate change affect the Cold Water Prawn? Presentation to the International Cold Water Prawn Forum.
- Westlund L, Poulain F, Bage H, van Anrooy R (2007) *Disaster response and risk management in the fisheries sector*. FAO Fisheries Technical Paper. No. 479. FAO, Rome.
- Williamson, P., Turley, C., Brownlee, C., Findlay, H.S., Ridgwell, A., Schmidt, D.N., Schroeder, D.C., Blackford, J., Tyrell, T. and Pinnegar, J.K. (2013) Impacts of ocean acidification. *MCCIP Science Review 2013*, 34-48, doi:10.14465/2013.arc05.034-048.
- Wright, P. (2013) Impacts of climate change on ports and shipping, *MCCIP Science Review 2013*, 263-270, doi:10.14465/2013.arc28.263-270.
- Wolf, D. and Wolf, J. (2013) Impacts of climate change on storms and waves, *MCCIP Science Review 2013*, 20-26, doi:10.14465/2013.arc03.020-026.
- World Bank (2010) *The costs to developing countries of adapting to climate change - new methods and estimates. The Global Report of the Economics of Adaptation to Climate Change Study (Consultation Draft)*.
- World Bank (2013) *Fish to 2030: Prospects for Fisheries and Aquaculture*. World Bank and International Food Policy Research Institute (IFPRI), Washington DC.
- Zsomboky, M., Fernandez-Bilbao, A., Smith, D., Knight, J. and Allan, J. (2011) *Impacts of Climate Change on Disadvantaged UK Coastal Communities*, March, Joseph Rowntree Foundation: York.
- WWF (2013) *Impacts of Climate on Tuna Fisheries*. WWF South Pacific Factsheet. http://awsassets.panda.org/downloads/climate_change_factsheet_final_1.pdf



ANNEXES

Annex 1: Methodology

Scoping

The approach addresses two complementary subjects:

1. climate risk to key functions / activities of the UK seafood industry.
2. climate risk to achieving the mission and strategic objectives of Seafish.

From an industry perspective, the working boundaries for the assessment are:

- The seafood industry system involving wild catching / harvesting, processing, transport to customer gate:
 - o Aquaculture (farming of fish and shellfish) is out of scope – for reasons of resource limitations, this could be covered in a future study.
 - o Wild salmon is out of scope – this is not within Seafish’s remit.
- Wild catch demersal, pelagic and shellfish species are all in scope.
- Both the domestic and international ‘systems’ are in scope – i.e. climate impacts on the sourcing of imports of wild catch fish and shellfish as well as domestic landings are considered.

For Seafish, the working boundaries are provided by its mission and strategic objectives i.e.

- Mission: securing a profitable, sustainable, and socially responsible future for the UK seafood industry.
- Strategic objectives:
 1. *To enable the industry to make informed and ethical business decisions.*
 2. *To ensure the industry is better understood by regulators, media and consumers.*
 3. *To create the tools to help industry increase the consumption of seafood.*
 4. *To ensure seafood is well trusted and understood by regulators, media and consumers.*

The focus only on wild capture in this first ARP exercise by Seafish is justified on the basis of its importance and maturity as an industry sector (with well-developed institutions and risk management mechanisms) and that it provides a useful platform for a subsequent ARP exercise focused on aquaculture systems. Elsewhere, Sumaila and Cheung (2010) in their consideration of the likely cost of adaptation to climate change for the fisheries industry internationally, have similarly focused only on marine wild capture fisheries for a number of reasons: (i) the study of the impact of climate change on these fisheries is regarded as more advanced than is the case with inland fisheries and aquaculture; (ii) marine capture fisheries are still over 50% of the total value of global fisheries; wild capture supports many economically vulnerable coastal communities, especially in developing countries. Finally, the authors argue that both inland fisheries and aquaculture are likely to suffer similar challenges identified for marine capture fisheries.

Process steps

The process of investigation is designed to support the industry in ‘sensing and responding’ to climate change impacts. ‘Sensing’ refers to the process of identifying and establishing the likely impacts of climate change on the industry. ‘Responding’ refers to the identification, and subsequent implementation, of adaptation actions that should be taken to address threats and any opportunities arising from climate impacts.

Four process steps are described below.

Step 1: Establish analytical framework

- In designing an approach and research methodology, the ARP reports produced by the Environment Agency (2010) and Natural England (2010) are drawn on, in particular their approach to assigning a confidence estimate to ratings of impact and response based on the nature of the available evidence base rather than a probability of occurrence. The confidence tables guide levels of confidence in climate change impact and adaptation response (see Table 3 under ‘sensing’ and under ‘responding’).

- The criteria used to assure the quality of our research design draws upon the Cranfield University (CU) evaluation of previous ARP exercises:
 - The CU evaluation of previous ARP exercises has been reviewed.
 - CU attributes and sub-attributes have been tailored to produce a checklist for this study.
 - This checklist has been used to guide research in this study.

Step 1.1: Specify objectives and functions

- Describe the key functions / activities in the industry system in scope.
- Describe the mission and strategic objectives of Seafish.

Step 1.2: Set decision-making criteria

- Identify and adopt a set of parameters for decision-making on risk prioritisation:

On sensing

1. *Importance* – assessment of likely importance to industry and / or Seafish.
2. *Proximity* – identifying time to when consequences are likely to occur – or in other words, when action (change in practice) may be required (by industry and / or Seafish) in response to climate change.
3. *Confidence* – in the evidence for a climate driver and associated impact, drawing on both evidence from published scientific literature and industry experience.

On responding

1. *Inertia* – this factor concerns speed and / or ease of making an effective response.
2. *Resources* – required to be deployed by industry and / or Seafish to effect a response.
3. *Confidence* – in the estimate of inertia and resources based on documentary evidence and industry experience.

The approach to decision making on the above factors utilises the various rankings defined below. It is important to emphasise that the objective here has been relative risk prioritisation. In many cases the rankings are ‘judgement-based’ rather than derived from quantitative evidence.

Sensing

Part A – Risk Assessment (sensing)

1) IMPORTANCE (RANGE and SCALE of consequences)

Score (negative)	Categories
1	Few, small-scale impacts providing some minor threats across the industry
2	Many, small-scale impacts providing moderate threats across the industry
3	Few, large-scale impacts providing some significant threats across the industry
4	Many, large-scale impacts providing major threats across the industry
Score (positive)	Categories
1	Few, small-scale impacts providing some minor opportunities across the industry
2	Many, small-scale impacts providing moderate opportunities across the industry
3	Few, large-scale impacts providing some significant opportunities across the industry
4	Many, large-scale impacts providing major opportunities across the industry

2) PROXIMITY (TIME to consequence(s) occurring)

Score	Categories
1	Over 50 years
2	Within next 50 years
3	Within next 20 years
4	Now

3) CONFIDENCE (Sensing)

Score	Categories
High	Good agreement for climate driver trends and consequent impacts based on many, coherent studies
Medium	Good agreement for climate driver trend and consequent impacts based on expert scientific judgement and / or industry knowledge
Low	Low agreement on climate driver trend and limited understanding of consequent impacts

When importance and proximity scores are added together, those risk issues (threats or

opportunities) that score six or above are judged to be candidates to be taken forward to the full risk assessment process. The proximity and / or importance of these higher scoring issues merit further consideration by the industry of adaptation responses that may be required. However, only those candidates that score medium or above on confidence level are taken forward to the full risk assessment.

Responding

Adaptation responses may be specific to one issue (e.g. responding to impacts on transport links) or may encompass a range of issues (e.g. increasing flexibility around the governance of fishery resources). Responses may relate to specific actions as well as broad action areas (areas that require further consideration before specific actions can be agreed / defined).

Part B – Response Assessment (responding)

1) INERTIA (Speed of response)

Score	Categories
Long term	15 years +
Medium term	5 to 15 years
Short term	2 to 5 years
Immediate	Within 2 years

2) RESOURCES

Score	Categories
Minor	Available resources can be used to develop adaptive responses
Moderate	Requires internal resources to be reallocated to develop adaptive responses
Significant	Requires some additional external resources to develop adaptive responses
Major	Requires substantial additional external resources to develop adaptive responses

3) CONFIDENCE (Responding)

Score	Categories
High	Good agreement on inertia and resources with understanding of response level based on many, coherent studies
Medium	Good agreement on inertia and resources with understanding of response level based on expert judgement
Low	Low agreement on inertia and resources with limited understanding of response level

In establishing confidence in the adaptation responses, this exercise relies on expert judgement from industry stakeholders in

workshop meetings, one-to-one interviews and further critique through feedback on early draft reporting (see Step 3 and Step 4 below). Confidence levels should be enhanced as adaptation responses are considered in greater depth within individual stakeholder corporate planning processes (that should include project appraisal).

Step 2: Risk screening

The key risks established through Steps 1.1 and 1.2 are then screened to determine their relevance to UK industry functions / activities. A long list of potential industry relevant issues is identified for both onshore and offshore activities (e.g. disruption to port activities or changes in wild capture species distribution). The sensitivity of each issue to the five climate drivers of interest is checked and where there is a match, the issue is taken forward for risk assessment. This long list of climate sensitive issues is tested and refined throughout the stakeholder consultation period to ensure all relevant issues are captured. These issues might affect the UK industry functions / activities directly, as well as the role that Seafish plays in supporting the UK industry.

Step 3: Fieldwork

Fieldwork for this exercise involves workshop meetings and one-to-one interviews. This supports:

Step 3.1: Drawing on evidence and experience to characterise and assess risks

The identification and assessment of risks to climate vulnerable industry functions / activities and Seafish objectives are supported by: (a) an extensive literature review; and subsequently by (b) consultation with domain expertise in Seafish and its partner organisations; and (c) through facilitated discussions with industry representatives at a series of workshops and one-to-one consultations. The engagement with industry provides new, additional insights as well as ‘sense checking’ / validating the findings from the literature review and in-house expert sources.

We are mindful in the context of climate change and its consequences (positive or negative) for the UK seafood industry of inherent uncertainties associated with some outcomes and impacts. For example, Sumaila and Cheung (2010) note that while aspects of the potential impacts of climate change on fisheries are considered likely, the overall impacts and the capacity and cost for adaptation remain uncertain. Whilst

it is very likely that climate change will cause a shift in the distribution of fish stocks – and indeed these authors report that climate-induced shift in distributions of commercial stocks have already been observed in recent decades – the projections of changes in the potential catch, and their effects on the fishing sectors, are considered uncertain.

Also, research into the effects of climate change on commercial fish stocks through ocean acidification, hypoxic zones, coral bleaching, etc is still fairly immature. The authors conclude that: “In socioeconomic terms, the potential response of seafood markets to climate change or changes in seafood demand and supply are unclear. These add uncertainty to our understanding of the potential impacts of climate change on the fishing sector.”

Step 3.2 Drawing on industry experience to identify options for adaptation

Industry experience is drawn on to identify adaptation action already underway and possible adaptation responses for all sensitive industry activities / functions and Seafish objectives over specific time periods:

- Currently underway.
- Immediate – within 2 years.
- Short-term – up to 5 years.
- Medium-term – 5-15 years.
- Long-term – 15+ years.

Adaptation responses are likely to be suited to particular stakeholders since they will be qualitatively and quantitatively different. For example responses may range from taking immediate and clearly defined ‘practical action’ (responses delivered on the ground) to investigating ‘action areas’ (responses requiring further work to scope and define).

Where adaptation responses relate to specific actions, the aim is to ensure – where possible – that these are SMART, namely Specific (to sensitive functions / objectives), Measurable, Achievable, Realistic, and Time bound (specific to the periods above).

Moreover, the aim is to ensure each response has an identified ‘owner’ in industry, Seafish and / or

another public agent (‘Other’). As anticipated industry responses largely fall within ‘immediate’ or ‘short term’ periods: Seafish and ‘Other’ responses fall largely within ‘medium’ and ‘long term’ periods.

Step 4: Reporting and validation

The findings from the literature review and the fieldwork are drawn together to produce a draft report. All stakeholders participating in the fieldwork have an opportunity to read and critique this draft and ensure the conclusions are valid. Feedback is incorporated to produce the final ARP report.

Annex 2: Quality assessment and the 'Cranfield attributes'

A qualitative evaluation framework underpins the work of researchers at Cranfield University (Drew et al, 2010) on the evaluation of risk assessments of Reporting Authorities under the Climate Change Act, 2008. The Cranfield report emphasises the need to show a robust evidence base; close links between prioritised risks and the corresponding adaptation actions; and implementation of management actions (to ensure threats and opportunities are, in practice, managed). In evaluation, the Cranfield approach uses a framework of 'key attributes' considered to be essential requirements in the reports of Reporting Authorities, eight key attributes and 28 sub-attributes. The evaluation is then based on scoring each attribute on a Likert-type scale as to whether evidence for that attribute is *'not present'*, *'partially complete'*, *'complete'* or *'complete and fully integrated'*. These attributes, and the associated scoring, are used to evaluate *'the risk assessments within the Adaptation reports and ... allow a synthesis of the strengths and areas for improvement both within and between sectors'*.

As will be discussed below, only a sub-set of the 'Cranfield attributes' appear well suited for application in the present context. The table uses 'traffic light' colour coding to indicate how this report measures up, in view of Seafish, with respect to the 28 sub-attributes defined by the Cranfield group. Those attributes considered to be most relevant and strongly associated with the present exercise are:

- Evidence
 - o 2.4 the RA's (i.e. Seafish's) risk assessment quantifies, or otherwise estimates or characterises the impact and likelihood of risks occurring at various points in the future.
 - o 3.1 RA adopts the latest set of UK Climate Projections or other appropriate scenarios or climate information.
- Experience
 - o 3.3 RA's risk assessment includes consultation with interested parties or stakeholders - an especially notable feature.
 - o 5.2 RA's adaptation plan includes a detailed action plan covering its priority areas. This should ideally include timescales, resources and responsibilities and be included in the report.

Assessment of attributes

SUB-ATTRIBUTE	STRENGTH with respect to the 'Cranfield attribute'	COMMENT
1.1 Climate change demonstrably a key consideration in corporate planning and processes of the Reporting Authority (RA).	Moderate	<p>The purpose of Seafish is to encourage, inform and assist its stakeholders in the UK seafood industry to take account of and respond effectively to the potential consequences of climate change.</p> <p>One objective is to have climate change become a key consideration in corporate planning and processes of the industry. This is a desirable outcome of the activities and outputs that may follow actions proposed in this report rather than something that can be demonstrated at this time.</p> <p>By undertaking this study, including engaging its industry stakeholders in the process, Seafish is demonstrating consideration in corporate planning and processes, albeit in a preliminary way. This will continue through communication and discussion of the report's findings with industry: continuation of corporate involvement in these issues will depend on the results of these discussions.</p>
1.2 RA presents a clear analysis of climate risks on business operations for specified periods into the future and includes high priority climate related risks and timescales.	Moderate	<p>Given the rationale and objectives set by Seafish for this study, this analysis of climate risks on business operations focuses on the operations of the UK seafood industry, not on those of Seafish, except to the extent that Seafish may have a role in assisting industry to manage these risks.</p>
1.3 Adaptation plan is clearly embedded in the RA's business.	Moderate	<p>As indicated above, the intent here is to establish an adaptation plan for the UK seafood industry (albeit preliminary and in outline in this first exercise), not for Seafish as an organisation.</p> <p>However, the report does present a number of recommended actions in support of the UK seafood industry that, if endorsed by industry, would lead to Seafish embedding climate-related activities into its future operations.</p>
1.4 RA includes some prior evaluation of how its climate change risks impact upon or are affected by stakeholders.	Weak (not applicable)	<p>Whilst consultations with industry stakeholders has been a notable feature of this study, the focus of these has been forward looking and industry-centred only. There is no prior evaluation of Seafish's climate change risks given in this report: this is not deemed relevant given its rationale and objectives.</p>
1.5 RA considers the existing policies and procedures relating to climate impacts, and the effect the weather has on operations and the achievement of the organisation's strategic objectives.	Weak (not applicable)	<p>The focus as already indicated is on industry operations therefore this sub-attribute is deemed to be of little relevance here.</p> <p>There is consideration in the report of climate change evidence which points to risks from increased frequency and intensity of extreme weather events.</p> <p>Given its role in supporting the UK seafood industry, including in achieving the strategic objectives as set by industry, it is appropriate for Seafish in this report to bring this evidence to the attention of its industry stakeholders through this report (and potentially in other ways).</p>
2.1 RA adopts a conceptual risk framework for organisational, rather than locational risks.	Weak (not applicable)	<p>Seafish has adopted a conceptual risk framework for the UK seafood industry and its sub-sectors rather than for any individual organisation. Within this, the report considers both functional and geographic / locational risk factors.</p>
2.2 RA identifies the key climate variables and the potential impact on the organisation.	Weak (not applicable)	<p>The focus in this report is on identifying the key climate variables and potential impact on the UK seafood industry not Seafish.</p>
2.3 RA provides clear criteria for likelihood and consequence that are appropriate and specific to their organisation.	Weak (not applicable)	<p>The focus in this report is on matters specific to the industry not specific to Seafish except in the sense that Seafish has a role in supporting its industry stakeholders.</p>
2.4 RA's risk assessment quantifies, or otherwise estimates or characterises the impact and likelihood of risks occurring at various points in the future.	Strong	<p>The report draws on published evidence on climate change effects projected over time in characterising the impact and likelihood of risks, using the concept of 'proximity' (see Annex 1). It utilises a relative scoring method (explained in Chapter 4).</p>

SUB-ATTRIBUTE	STRENGTH with respect to the 'Cranfield attribute'	COMMENT
2.5 RA presents all the organisation's strategic risks from climate change on a likelihood / consequence matrix, where possible including the climate thresholds above which climate change poses a threat to the organisation.	Moderate	<p>The report considers risks for the industry, not for Seafish. In prioritising responses, it utilises a structured risk assessment which includes both likelihood and importance factors as judged from an industry perspective (see Annex 1 on risk assessment details).</p> <p>It has not been possible consistently to quantify the climate change thresholds above which climate change poses a threat to the industry.</p>
2.6 RA considers short, medium and long term risks of climate change disaggregated into different locations where appropriate, and includes an assessment of the level of confidence in these calculations.	Moderate	<p>The report makes reference to confidence levels for the evidence on risks over the short, medium and long term, and on risks associated with different geographic regions of interest to the UK seafood industry.</p> <p>However, as indicated in the main text, there is a trend towards increasing uncertainty from consideration of global climate trends and projections through to likely social and ecological responses.</p>
3.1 RA adopts the latest set of UK Climate Projections or other appropriate scenarios or climate information.	Strong	The report draws on the latest climate projects made by the Inter-Governmental Panel on Climate Change (IPCC) and the UK Met Office, as well as other published sources.
3.2 RA demonstrably assesses using the best evidence suitable to organisational need.	Moderate	The report draws on a substantial body of secondary evidence from authoritative published sources as well as from expert industry contributions to primary research. It references these sources and describes how they have been utilised. The evidence based that is used is judged to be wholly suitable to meeting the rationale and objectives set by Seafish for the exercise, i.e. for industry need.
3.3 RA's risk assessment includes consultation with interested parties or stakeholders.	Strong	Consultation with industry stakeholders is a notable feature of this exercise.
4.1 RA's risk assessment includes a statement of the main uncertainties in the evidence, approach and method used in the adaptation plan and in the operation of the organisation.	Moderate	References are made to the main uncertainties in sections 1.5 and 1.6. This includes referencing an FAO publication that acknowledges a trend towards increasing uncertainty from consideration of global climate trends and projections through to likely social and ecological responses.
4.2 RA's adaptation responses explicitly account for uncertainties and interdependencies of actions, including the actions of others on the adaptation plan.	Moderate	<p>See above for note on appreciation of uncertainties.</p> <p>The report notes the likely dependencies on the other organisations in responding to climate change, notably in the international system (e.g. regional fisheries governance bodies).</p>
4.3 RA's adaptation plan includes a clear statement of assumptions which are well evidenced and justified.	Moderate	<p>Where the available evidence does not permit a robust 'logic' in linking between different sources of evidence or between evidence and interpretation, assumptions have been made, and made explicit in the text. Assumptions tend to be necessary where the linkages cannot be 'well evidenced and justified'.</p> <p>As already stated, there are inherent uncertainties in linking evidence on climate trends and projections through to likely responses by social, ecological and economic systems.</p>
5.1 RA provides priority areas for action that are demonstrably linked to the development of a risk based adaptation plan.	Strong	This is core to the exercise that has been undertaken. Prioritisation has in large part been undertaken in consultation with industry experts.
5.2 RA's adaptation plan includes a detailed action plan covering its priority areas. This should ideally include timescales, resources and responsibilities and be included in the report.	Strong	The report includes recommended responses (actions and action areas) that are regarded as priorities: they are each accompanied by commentary on timescales, resources and responsibilities. These are indicative only and for the reasons stated in the in text (i.e. the requirement for Seafish to gain endorsement to utilise levy) cannot be taken as a commitment at this time.

SUB-ATTRIBUTE	STRENGTH with respect to the 'Cranfield attribute'	COMMENT
5.3 RA's risk management actions are targeted to demonstrably reduce risks to a defined (by the organisation) level of residual risk.	Weak (not applicable)	Given the industry focus of this exercise rather than risks to Seafish (or any other individual organisation), this is not an attribute of the present report. Notably, one recommended response proposed by an industry contributor is to establish the means of conducting 'due diligence' on individual risks and associated potential adaptation responses.
5.4 RA's adaptation plan is subject to appraisal against sustainability principles, and specifically to an appraisal of costs and benefits.	Weak	This is not an attribute of the plan at this time beyond a conceptual appreciation of the interface between climate change stressors and sustainability, The evidence analysed to date on social, ecological and / or economic consequences does not permit an appraisal of costs and benefits.
6.1 RA's risk assessment allows an evaluation of net benefits and / or opportunities arising from the impacts of climate change.	Weak	This is not an attribute of the plan at this time beyond a conceptual appreciation. The evidence analysed to date does not permit an assessment in quantitative terms of 'net' benefit and / or opportunities arising.
7.1 RA's adaptation plan includes strategies to deal with the level of quantified risk and retains flexibility over which future course of action to follow as knowledge improves and projections change.	Moderate	Seafish acknowledges the preliminary, exploratory nature of this report and envisages adaptation reporting being a recurring process, subject to the wishes of the industry. In such a recurring process, the report acknowledges the need for amending any plan in the light of improved knowledge and changed projections.
7.2 RA's adaptation plan includes a statement of the barriers to implementation and a means for overcoming these.	Moderate	Whilst inappropriate to refer to it being a 'barrier', as a precursor to implementing those actions that require an input from Seafish, further discussions on the merits and means of implementation will need to take place. The report describes the steps that Seafish needs to take.
8.1 Where possible, the RA's report shows progress already made against its adaptation plan.	Weak (not applicable)	The report makes reference to instances where industry stakeholders have already implemented adaptation actions (see sections 4.1.2 and 4.2.2). It is not relevant in the present context to consider progress already made against a Seafish adaptation plan – none exists.
8.2 RA makes clear provision for the evaluation of the effectiveness and viability of its adaptation plan.	Weak (not applicable)	Design of a monitoring and evaluation framework in the present context will follow on from agreement between Seafish and its industry stakeholders to implement the recommendations of the report, in part or in full. In the course of agreeing to take forward any actions, Seafish commits to ensuring a monitoring and evaluation framework is designed and implemented from the outset. References to evaluation are made at a general level in this report: it is inappropriate to detail evaluation provision in advance of firming up on those actions that will be endorsed by industry.
8.3 RA makes clear provision for monitoring thresholds, above which climate change impacts will pose a risk to the organisation, and their incorporation into future risk assessments.	Weak	This is not an attribute of this report. Thresholds of this type cannot be quantified for monitoring purposes at this time for the seafood industry.
8.4 RA makes clear provision for the monitoring of residual risks from climate change on the organisation and its stakeholders.	Weak	This is not an attribute of this report. The challenge of this exercise is to identify and gain endorsement from industry for key risks facing the industry – consideration of 'residual risks' is a step too far at this time.
8.5 RA offers evidence that the production of the risk assessment and adaptation plan has led to a change in the organisation's management of climate risks.	Weak (not applicable)	This is not an attribute of this report. However, what is an attribute of this exercise is that it has catalysed a first engagement between Seafish and a sub-set of industry stakeholders on the issue of climate change. Moreover, the production of this report is a tangible demonstration of the willingness of Seafish to commit (moderate) resource to exploring the subject of adaptation on behalf of its stakeholders. The report makes clear that the desired outcomes would involve changes in industry practice. This report cannot demonstrate evidence of this as yet beyond pointing to some actions already being taken by individual companies.

Annex 3: List of consultees

Industry

1.	Trevor Bartlett	Burgons and Blue Seafood Company Ltd	20.	John Rutherford	Frozen at Sea Fillets Association
2.	Jay Mackay	Scottish Fishermen's Federation	21.	Huw Thomas	Morrisons
3.	Mike Berthet	M&J Seafoods	22.	Robert Stevenson	Lunar Fish Producers Organisation Ltd
4.	Ally Dingwall	Sainsburys	23.	David Anderson	Aberdeen Fish Producers Organisation Ltd
5.	Ian Gatt	Scottish Pelagic Fishermen's Association	24.	Bertie Armstrong	Scottish Fishermen's Federation
6.	Mike Short	Food and Drink Federation	25.	Malcolm Morrison	Scottish Fishermen's Federation
7.	Brian Young	British Frozen Food Federation	26.	Kenny Coull	Scottish Fishermen's Federation
8.	Mike Mitchell	Young's	27.	Jennifer Mouat	Scottish White Fish Producers Association
9.	Steve Norton	Grimsby Fish Merchants Association Ltd	28.	Alex Wiseman	Scottish Pelagic Fishermans Association
10.	Will Clark	Wilsea Ltd / Scottish Seafood Association	29.	Tom Bryan-Brown	Mallaig and North West Fishermans Association
11.	Dale Rodmell	National Federation of Fishermen's Organisations	30.	Simon Collins	Shetland Fishermans Association
12.	Elizabeth Bourke	National Federation of Fishermen's Organisations	31.	Fiona Matheson	Orkney Fishermans Association
13.	Tony Delahunty	National Federation of Fishermen's Organisations	32.	Sandy Ritchie	Anglo Scottish Fishermans Association
14.	Steve Parker	South West Fisheries Committee	Other		
15.	Paul Gilson	South East Fisheries Committee	33.	Mick Bacon	Seafish Industry Authority
16.	Ned Clark	North East Fisheries Committee	34.	Richard Caslake	Seafish Industry Authority
17.	Stewart Harper	North Atlantic Fish Producers Organisation	35.	Bill Turrell	Marine Scotland - Science
18.	Jon Harman	Alaska Seafood Marketing Institute	36.	Karen Galloway	KAGC Ltd
19.	Alex Olsen	Espersen	37.	Richard Ballantyne	British Ports Association
			38.	Mike Davies	Department of Transport
			39.	Chris Wilcock	Scottish Government

Annex 4: UK seafood industry – functions, activity and systems

By the term ‘seafood product’ we mean *any aquatic food product (fish, molluscs, crustaceans, echinoderms and other forms of marine and freshwater life) regarded as food for human consumption or feed for animal consumption.*

The basic industry functions underpinning seafood products are described below.

- **Stocks** – This function covers the geographical location and ecological context for the fish source (e.g. Barents Sea, North Atlantic, or North Sea). This function also concerns the biological condition of the fish stock and fish abundance (whether the stock is under fished, fully fished or overfished).
- **Capture / production** – This function covers both wild capture and production of aquatic organisms.
 - o In fish capture this concerns all activities associated with the harvesting of wild aquatic organisms, including steaming to / from fishing grounds, fishing those grounds (including capture method). It also concerns landing and auctioning which includes port harbour facilities, landing, chilled / frozen storage, auctioning and fish market facilities. It also includes intermediaries (agents / sub-agents / merchants / importers) involved in connecting material with downstream stakeholders. Intermediaries are concerned with collecting fish at the landing points or with pre-processing (such as sorting sizes and quality) and connecting with processors, or purchasing the product with the aim of selling on directly to retail, food service, and wholesaler outlets.
 - o In fish production this concerns farming, harvesting and slaughtering of aquatic organisms for food or feed. Fish production relies on inputs from wild capture (as above), or alternatively from broodstock cultivation, hatching and nurseries (the husbandry of sexually mature aquatic organisms kept for the purpose of controlled reproduction including younger specimens destined to be used for the same purpose).
- **Transport and distribution** – This function concerns the movement of seafood products between stages of production. This includes transport mode (road, rail, sea, air), route (local, short haul, long haul) and associated transport and warehousing facilities. Also includes chilled / frozen storage.
- **Importing, processing and storage** – This function concerns the receiving, preparation, preservation and packing of seafood products. Primary processing involves cleaning and packing and preliminary transformation of material such as cutting, filleting, heading and gutting (in relation to finfish) and picking, trimming, shucking, peeling, and washing (in the case of shellfish). Additional, secondary processing, involves the likes of freezing, brining, smoking, marinating, canning, deboning, breading, battering, and cooking / ready meals. Processing activity includes chilled / frozen storage.
- **Market / sales outlet** – This function covers export, retail, food service, wholesale and feed suppliers:
 - o *Export.* This concerns product transported to international markets, with exporters controlling the movement of the product through international borders.
 - o *Retail.* This concerns outlets selling the products to the final consumer destined for in-home consumption, namely fishmongers, retail chains (including multiple retailers) and individual grocery stores.
 - o *Food Service.* This concerns all outlets destined for out-of-home consumption, namely restaurants, hotels, fast food outlets (including fish and chip shops) and institutional outlets (schools, hospitals, prisons, etc).
 - o *Wholesale.* This concerns all outlets that aggregate and supply processed primary products direct to retail or food service. Wholesale outlets can range from small operations (such as inland wholesale fish markets, or wholesale merchants supply smaller retail and food service outlets) to large operations (such as wholesale / importing companies supplying catering companies in food service).
 - o *Feed supplier.* This concerns outlets for seafood products destined for animal consumption (either aquatic- or land-based production). Products supplied can either be waste products (from processing operations), or whole fish products (species unfit for human consumption).

- **Consumption** – This function concerns out-of-home and in-home consumption which involves chilled / frozen storage, cleaning, cooking, and eating. Many of the activities within out-of-home consumption are supported under food service activity.
- **Waste** – This function concerns the collection / treatment of waste products (including packaging) to landfill, incineration recycling, or composting.

Although the seafood industry is diverse, complex and dynamic, basic industry functions interrelate – as seafood systems – in ways that reveal general patterns regardless of product and regional location. A synthesis of system based concepts provides a potentially useful system framework. Systems based concepts from an environmental perspective include the product life-cycle, and from an economic perspective, the industry value chain. Definitions, descriptions, and concepts are drawn from a number of relevant publications (British Standards Institution, 2012; United Nations Environment Programme; Seafish).

UK seafood industry – main systems, functions and activities (Source: Seafish, Defra 2010b)

System	Broad species grouping	Species	Species distribution (and main producing countries)	Source method	Capture method	Transportation	Format and processed form
Domestic	Whitefish	Cod, haddock, whiting, monkfish, sole, plaice	UK waters / NE Atlantic (UK)	Capture	Whitefish and flatfish (bottom trawl)	Road, container	Fresh – whole, fillets / loins, smoked, prepared
Domestic	Whitefish	Cod, haddock, pollock	UK waters / NE Atlantic (UK)	Capture	Whitefish (gillnets) Whitefish (minority line-caught)	Road, container	Fresh – whole, fillets / loins, smoked, prepared whole, fillets / loins, smoked, prepared
Domestic	Whitefish	Sole, plaice, rays	UK waters / NE Atlantic (UK)	Capture	Flatfish and rays (beam trawl)	Road, container	Fresh – whole, fillets / loins, prepared
Domestic	Pelagic	Herring, mackerel, sardine / pilchard, blue whiting	UK waters / NE Atlantic (UK)	Capture	Small pelagic (purse seine and mid-water trawl)	Road, container	Fresh / frozen (including frozen at sea) – whole, fillets / loins, smoked, fishmeal, preserved, aqua feed
Domestic	Pelagic	Mackerel	UK waters / NE Atlantic (UK)	Capture	Small pelagic (line caught)	Road, container	Fresh – whole, fillets / loins, smoked, prepared
Domestic	Shellfish	Crabs, lobsters, Nephrops, whelks	UK waters / Eastern Atlantic (UK)	Capture	Crustaceans (pots)	Road, air freight	Live Fresh / frozen – whole, prepared
Domestic	Shellfish	Nephrops	UK waters / NE Atlantic (UK)	Capture	Prawn (trawl)	Road	Live Fresh / frozen – whole, shelled, preserved
Domestic	Shellfish	Mussels, scallops	UK waters / Eastern Atlantic (UK)	Capture	Molluscs (dredged)	Road, air freight	Live Fresh / frozen – preserved
Domestic	Shellfish	Mussels, oysters	UK waters / NE Atlantic (UK)	Aquaculture	Molluscs (rope grown / longlines) Molluscs (bottom grown)	Road, container, air freight	Live Fresh – preserved
Domestic	Salmonids	Atlantic salmon, Rainbow trout (NE Atlantic small pelagic, waste and some imported fisheries (anchovy, sardine) input as feed)	UK waters / NE Atlantic (UK)	Aquaculture	Marine cage farming Freshwater ponds / raceways	Road, container, air freight	Fresh / frozen – whole, fillets / loins, prepared, smoked Fresh / frozen – fillets / loins smoked, prepared

System	Broad species grouping	Species	Species distribution (and main producing countries)	Source method	Capture method	Transportation	Format and processed form
International	Whitefish	Cod, haddock, hake, halibut, plaice	NE Atlantic / Barents sea (Norway, Russia, Iceland)	Capture	Demersal fish (bottom trawl)	Road, container, air freight	Fresh / Frozen – fillets / loins, smoked, prepared
International	Whitefish	Alaska pollock	North Pacific / Bering sea (USA)	Capture	Whitefish (pelagic trawl)	Road, container	Frozen – fillets / loins, smoked, prepared
International	Pelagic	Anchovy, sardine / pilchard	Eastern Atlantic (Spain, Morocco) Eastern Pacific (Peru)	Capture	Small-pelagics (purse seine)	Road, container	Fishmeal, fish oil, canned, aqua feed
International	Pelagic	Tunas (yellowfin, albacore, skipjack, swordfish)	Indian ocean (Spain / France / Sri Lanka) Pacific ocean (Philippines / Mexico) Atlantic ocean (Spain / France / Ghana)	Capture	Tunas (long line) Tunas (purse seine) Tunas (pole and line / handline)	Air freight, container	Fresh / frozen – whole, fillets / loins, preserved preserved whole, fillets / loins, preserved
International	Shellfish	Northern / cold-water prawn	North Atlantic (Denmark / Greenland / Iceland / Norway / Canada)	Capture	Prawn (trawl)	Road, container	Frozen – whole, shelled, preserved
International	Salmonids	Pacific salmon	Pacific ocean (USA / Canada / Russia)	Capture	Salmon (nets)	Road, container	Frozen – whole fillets / loins, smoked, prepared
International	Cephalopods	Squid, octopus, cuttlefish	Mixed (Eastern Pacific, Mediterranean, North and South Atlantic, Indian ocean)	Capture	Cephalopods (jigging, trawl in North Atlantic)	Road, container	Frozen – prepared, brined
International	Whitefish	Pangasius	South East Asia (Vietnam)	Aquaculture	Freshwater pond culture	Road, container	Frozen – whole, fillets / loins, prepared
International	Shellfish	Warm-water prawn	South East Asia (Indonesia / India / Thailand), Central America (Ecuador / Honduras)	Aquaculture	Shrimp farming (intensive > extensive)	Road, container	Frozen – whole, shelled, preserved
International	Salmonids	Atlantic salmon	NE Atlantic (Norway / Faroes), Eastern Pacific (Chile)	Aquaculture	Marine cage farming	Road, container	Frozen – whole, fillets / loins, prepared, smoked frozen – fillets / loins smoked, prepared

Annex 5: Example mechanisms potentially supporting seafood adaptation responses

The UK seafood industry operating within the international system is likely to have a strategic interest in the work of, and adaptation actions taken by, third country and international fisheries management bodies. In some instances, the UK industry may be reliant on the timeliness and effectiveness of third party adaptation actions. It is beyond the scope of this study to examine the views, intentions and actions with respect to climate change adaptation of all relevant 'influencers' on international fisheries and trade in seafood but the following account provides indicative examples.

Shelton (2014) compiled profiles of current and recent climate change adaptation activities in the fisheries sector internationally which has been published by Food and Agricultural Organization of the United Nations (FAO). These examples provide an insight into the types of adaptation activities and programmes being undertaken and by whom. Whilst the majority relate to aquaculture or to small fishing community adaptations, those potentially of more relevance to UK seafood importers, albeit indirectly, include:

- *Pacific Islands multi-country 'vessel day scheme for tuna'* – aimed at limiting number of vessel days; targeting migratory species limits; influencing fishing capacity and helping to maintain Pacific tuna populations. The scheme permits some flexibility given east-west variations in tuna locations during ENSO events, and it is argued this type of flexibility may be beneficial long term with climate-induced changes in variation.
- *Pacific Islands, multi-country programme: PACC (Pacific Adaptation to Climate Change)* – aid for the implementation of long term adaptation strategies to increase resilience in key development sectors including but not limited to fisheries (e.g. water resources, food production and security, and coastal zone management).
- *Mexico (Gulf and Pacific offshore):* enhancement to accuracy and frequency of marine and coastal weather forecasts to protect fishers at sea and permit better operational planning.

- *Seychelles:* introduction of ecosystem-based adaptation to climate change, including construction / rehabilitation of fringing coral reefs: also, building local capacity via local management coordinating bodies to oversee assessment, implementation and monitoring of activities.

Although many are presently concerned with sustainability of fisheries rather than climate change *sensu stricto*, all Regional Fisheries Management Organisations (RFMOs) are likely to have a key role to play in considering, designing and implementing adaptation actions. As an example, the Scientific Committee of the Western and Central Pacific Fisheries Commission in 2012 discussed a programme to progress adaptation to climate variability and change in the regional tuna fisheries (Evans et al, 2012). This considered the establishment of a multi-agency collaboration to: (a) enhance national and international policy advice and technical support to “*maintain a healthy Pacific Ocean that sustains catches of tuna*” under climate variation and longer-term change; and (b) build capacity for prioritising and implementing adaptations to maintain the socio-economic benefits of Pacific Ocean tuna fisheries to Pacific Island communities.

Its specific objectives included enhancing the capacity of Pacific Island Countries and Territories (PICTs) and regional organisations to identify adaptation strategies to minimise negative impacts and to maximise opportunities. The following programme outputs are envisaged: (i) improved climate change risk profiles for inclusion in resource management plans; (ii) improved regional and national projections under a range of climate change and socioeconomic scenarios in order to inform appropriate national and regional management strategies; (iii) tools to use in prioritising and optimising adaptation strategies for development of climate policies for national, regional and international negotiations; and (iv) enhanced capacity for PICT fishery resource managers to participate in regional and national negotiations on climate change adaptations relating to tuna fisheries.

The Fisheries and Aquaculture Department of the FAO has defined a set of priority adaptation actions for international fisheries which include: the development and application of data and knowledge for impact assessment and adaptation; support and improvement of governance for climate change adaptation; building of livelihood resilience to climate

change; targeted approaches for conservation and sustainable management of biodiversity; the identification, support and application of innovative technologies; and improved disaster risk management.

The FAO works with the Global Partnership for Climate, Fisheries and Aquaculture (PaCFA) to raise awareness on these issues and to promote a coordinated response from the fisheries sector to climate change. This includes the promotion of *“a strategic approach to maintain or enhance the health and resilience of global oceans and waters, and strengthening the capacity of dependent people and communities, integrating these closely into broader development strategies”*¹.

ICES (the International Council for the Exploration of the Sea) has an expert working group on climate variability and change. With PICES (the North Pacific Marine Science Organization)², ICES also leads the *‘Strategic Initiative on Climate Change Impacts on Marine Ecosystems’* (SICCME)³, a programme to coordinate northern hemisphere efforts to understand, estimate and predict the impacts of climate change on marine ecosystems. SICCME maintains links to other international bodies including: European Commission, Regional Seas Conventions, Intergovernmental Panel on Climate Change (IPCC), FAO, the Intergovernmental Oceanic Commission (IOC), World Bank and large marine science programmes (e.g. IMBER – Integrated Biogeochemistry and Ecosystem Research in global changes in ocean systems⁴).

The Commonwealth Secretariat⁵ provides guidance on policy making, technical assistance and advisory services to 53 Commonwealth member countries, including on sustainable resource management and economic development. Examples of its funding initiatives include assisting:

- Mauritius and Seychelles to secure joint rights to manage 400,000 square kilometres of additional seabed (continental shelf) beyond the 200 nautical mile exclusive economic zones of the two member countries. This has led to the establishment of the world’s first Joint Management Zone covering such an area, together with a Joint Commission to coordinate and manage the exploration, conservation and development of the living and non-living resources of the seabed in the area.

- The Organisation of Eastern Caribbean States (OECS) to develop and implement a regional ocean policy, the first of its kind in the Caribbean.

The International Cold Water Prawn Forum has climate change issues on the agenda of its annual conferences. The 2014 conference in Paris included a paper (Aschan, 2014) on the current status and outlook for prawn stocks and the fishery in the North Atlantic. The 2013 ICWPF conference in London included a paper (Wassmann, 2013) on climate change and its challenges for cold-water prawn in the Arctic.

Campaigning organisations also have influence on marine and fisheries policy and management. For example, Greenpeace and others are campaigning to create ‘ocean sanctuaries’. Together with Pew, RSPB, the Zoological Society of London, and Blue Marine, as well as Fish Fight campaigner Hugh Fearnley-Whittingstall, Greenpeace has lobbied the UK government over protecting the waters around the Pitcairn Islands, a UK Overseas Territory in the South Pacific, and creating the world’s biggest marine reserve. In 2015, the UK government agreed to establish an MPA around Pitcairn. When taking all 14 of its Overseas Territories into account, the UK is responsible for the fifth largest area of ocean in the world, measuring 6.8 million square kilometres, c. 30 times the size of the UK itself. Some 94% of the UK’s biodiversity exists in these Territories⁶.

1 See: <http://www.fao.org/fishery/topic/166281/en>

2 <https://www.pices.int>

3 <http://www.ices.dk/community/groups/Pages/SICCME.aspx>

4 See <http://www.imber.info/index.php/Science/National-Network/UK> for further information, including IMER activity in the UK.

5 <http://thecommonwealth.org/our-work/economic-development>

6 <http://www.greatbritishoceans.org/March-Budget.pdf>

Annex 6: Climate change implications for wild capture fisheries – selected references.

DOMESTIC

This annex provides further information on the main implications for domestic wild capture fisheries described in Chapter 3. Key references are provided for users wishing to explore these issues in more detail.

1. Changing catch potential. With regards to the fisheries resource itself, warming in UK waters is expected to lead to further declines in traditional cold-water species (e.g. cod and haddock), whilst warm-water species become more abundant (e.g. John Dory, squid, anchovy and red mullet). Changing catch potential has important implications for quota allocation as species move across international boundaries. Changes in mackerel distribution in the NE Atlantic have led to a series of disagreements between the EU and Iceland and the Faroes which have still not been resolved.

In addition to broad changes in species distribution and migration patterns, timing of spawning, growth rates and year-class strength are all likely to be affected by changing climate. For example, spawning in cod and sole has changed over recent decades with knock on effects for mismatch with prey availability. A trend towards smaller average body size could be linked to climatic warming whilst impacts on year-class strength (recruitment) could be a key impact of climate change.

For shellfish, in addition to changes distribution and fish biology described above, regional scale increases (or decreases) in the prevalence of harmful algal blooms, pests and disease, jellyfish and non-natives could have important consequences, both positive and negative. In the longer-term, ocean acidification could impact on shell-forming organisms to the detriment of the shellfisheries and could have knock-on implications for wider food web dynamics.

Key references

Defra (2013) Economics of Climate Resilience: Natural Environment – Sea Fish CA0401. February 2013. Frontier Economics Ltd for Department for Environment, Food and Rural Affairs (Defra), UK. 101pp.

This report was specially commissioned by Defra and the Devolved Administrations to look at the economic implications of climate change impacts on fisheries. It looks across a range of economically important cold and warm-water fish species from all types of capture fisheries and estimates both direct consequences (e.g. from changing catch potential) and indirect consequences (such as changes in fuel costs associated with fishing for fish species which may be becoming more or less distant from UK ports).

Simpson, S.D., Blanchard, J.L. and Genner, M.J. (2013) Impacts of climate change on fish, MCCIP Science Review, 113-124, doi:10.14465/2013.arc13.113-124.

This review commissioned as part of the 2013 MCCIP report card provides a detailed overview of changes in both commercial and non-commercial fish species. The review principally focusses upon whitefish and pelagic species and as well as covering changing distributions of warm vs cold adapted species, it provides a more detailed look at specific aspects of fish biology thought to be sensitive to climate change such as phenological changes (i.e. changing in timing of life cycle events) plus changes in fish growth and overall body size.

2. Impacts on offshore operations and assets.

Any increase in storm intensity and frequency could increase the risk of damage to boats, especially smaller vessels, and potentially put lives at risk. The increased vulnerability of small boats, as well as beach landing sites, has been demonstrated with modern high-sea vessels able to operate at much higher wind thresholds than smaller vessels.

Deployment and performance of gear is also adversely affected in stormy conditions for a wide range of gear types across whitefish, pelagic and capture fisheries. Stormy conditions make it difficult to deploy gear, and once it is deployed then there is the risk of damage or loss of equipment. For pelagic capture the gears are typically large and spread out spatially which makes them vulnerable to motion through changes in sea state. For bottom and beam trawling for whitefish and shellfish, operating thresholds can typically be lower and bouncing of gear can affect performance in stormy conditions.

The 'catchability' of some target species is affected by both stormy conditions and temperature regimes due to effects on fish depth and visibility (e.g. for line fisheries).

Key references

Pinnegar, J., Engelhard, G. and Jones, M.C. (submitted) *Climate Change Impacts on North Sea Fisheries for the North Sea Region Climate Change Assessment (NOSSCA)*.

This review includes sections on catchability of commercial species as well as vessel stability and performance. Impacts of storms on vessel operations, as well landing sites and fishing gears are reviewed. The effects of stormy conditions on water clarity and catch rates are also discussed.

Cheung, W.W.L, Pinnegar, J., Merino, G., Jones, M.C. and Barange, M. (2012). *Review of climate change impacts on marine fisheries in the UK and Ireland. Aquatic Conserv. Mar. Freshw. Ecosyst.*, 22, 368-388.

This review, specially commissioned by MCCIP as part of their report on UK fish, fisheries and aquaculture takes a broad overview of the fisheries industry as a whole, rather than just focus on changes in fish distributions. It includes a section on impacts on fishing operations which considers effects on gear types and the catchability of different fish species as a consequence of climate change, as well as the effects of storminess on operations.

3. Impacts on onshore operations and assets. Sea level rise and surge events, as well as extreme storms and waves could damage, or cause widespread disruption to onshore operations and assets. This includes damage to port and harbour assets (including boats), and local housing and amenities.

The risk of coastal flooding to residential properties around the UK as a consequence of climate change is expected to increase significantly over the coming decades. When combined with increased population pressure at the coast, as well as social deprivation in many traditional fishing communities then local populations in fishing communities are clearly vulnerable.

Fish processing plants (some of which are close to ports and harbours) could also be affected. Specifically, extreme events could lead to storm damage and flooding of sites.

Impacts on transport routes (e.g. roads and ferries) and loss of electricity supply at ports and harbours and processing sites could also be important issues. For example in Scotland, ferries are an important transport route for fish which are vulnerable to extreme weather events.

At the local level, changes in terrestrial rainfall could increase flood threats to onshore operations. Extreme events could also disrupt onshore operations through loss of days at sea. For example, the winter storms of 2013 / 14 meant that boats were in port, especially in the SW of England, for long periods of time.

Key references

Wright, P. (2013) *Impacts of climate change on ports and shipping, MCCIP Science Review 2013*, 263-270, doi:10.14465/2013.arc28.263-270.

This review commissioned as part of the 2013 MCCIP report card provides a broad overview of the impacts of climate change on ports and shipping. It provides a high level overview of the findings of all of the port authority ARP reports published to date, and considers both terrestrial and atmospheric impacts (fluvial flooding, wind damage, etc) on port operations, as well as impacts from tidal flooding.

Associated British Ports (ABP) *Adaptation Reporting Power Report (2011) for Humber, Hull, Immingham and Southampton Harbour Authorities*. 60pp.

This report covers the four harbour authorities (of the 21 they own) that ABP were directed to report on. The key climate change risks that were considered likely to impact on the harbour functions were related to sea level rise / flooding, temperature changes, and storm events.

The key risks identified were related to engineering and VTS functions and the projected impacts associated with sea level rise and flooding, temperature increases and storminess.

Given that the Seafish ARP review includes port and harbour functions, the research conducted by ABP (as well as the other port authorities) has proved invaluable in assessing the range of risks (and proposed responses) for this report.

INTERNATIONAL

This annex provides further information on the main implications for international wild capture fisheries described in Chapter 3. Selected references are provided for users wishing to explore these issues in more detail.

(Note: the sources referred to here are in addition to those referenced in the various case studies within the report.)

1. Changing catch potential: climate change is causing broad changes in species distribution and migration patterns: timing of spawning, growth rates and year-class strength are all likely to be affected by changing climate.

For shellfish, in addition regional scale increases (or decreases) in the occurrence of harmful algal blooms, pests and disease, jellyfish and non-natives, and ocean acidification may all have important impacts on stocks and catch potential, either positive and negative.

Selected references:

Brander (2010) *Impacts of climate change on fisheries. Journal of Marine Systems 79, 389-402.*

The paper notes that the impacts on fisheries are due to a range of direct and indirect effects associated with physical and chemical factors, which include e.g. temperature, winds, vertical mixing, salinity, oxygen, pH. These directly affect the physiology, development rates, reproduction, behaviour and survival of individuals. Indirect effects act through ecosystem processes and through changes in the production of food or in the characteristics of competitors, predators and pathogens.

Whilst acknowledging that current knowledge is incomplete, the author argues that it provides an adequate basis for improving the management of fisheries and associated ecosystems, and for adapting to climate change. In terms of the latter, Brander argues that for adaptation to climate change future monitoring and research must be closely linked to '*responsive, flexible and reflexive management systems*'.

On the specific issue of sea ice cover, the author argues that reduction of sea ice in the Arctic due to warming will allow light to penetrate in new areas and therefore increase the productive area. However, the retreat of the highly productive marginal sea-ice zone will disrupt the existing food web. In the 'new' ice-free areas production is likely to be limited by nutrient supply due to the increased freshwater input.

Perry R.I (2011) *Potential impacts of climate change on marine wild capture fisheries: an update. The Journal of Agricultural Science 149, pp. 63-75.*

This paper reviews the evidence since 2007 including models that predict shifts in fish distributions of 45–60 km per decade, with 0.80

of species moving poleward. It notes that, with a high CO₂ emissions scenario, there may be little overall change in the global maximum potential fisheries catch (31%) but that there may be high spatial variability: decreases of 40% are projected for the tropics, with increases of 30–70% for higher latitudes. Countries in the tropics appear to be most vulnerable to the impacts of climate change on fisheries production.

Although the author considers that good observations of the impacts of climate change exist for high latitude, coral reef and North Atlantic systems, significant knowledge gaps include a comprehensive / co-ordinated global network of observations to help distinguish climate change from variability, and increased detail in the structure and processes of models. The challenge is reduce the uncertainties of climate impacts models, enhance understanding of the synergy between multiple stressors and include humans factors into coupled models and socio-economic analyses, in particular at regional and local scales.

Anon (undated) *Climate variability and fisheries: Collapse of Anchovy Fisheries and the expansion of Sardines in upwelling regions.* <http://www.pfeg.noaa.gov/research/climatemarine/cmffish/cmffishery4>.

The source reports that these species dominate the ocean in highly productive upwelling regions along the eastern edge of the oceans off California, Peru, Canary Islands, and South Africa. They also occur in other nutrient enriched areas such as off Japan and Argentina. It indicates that over the past 100 years conditions did not remain favourable for any of these populations for more than 30 years.

It is reported that sardine are more tropical than anchovy and expand their range poleward in warmer periods. By contrast, anchovy do not migrate far seasonally and do not expand far enough poleward during warm regimes to avoid the increased temperatures; they tend to recover during cooler periods. It is argued that global warming may not produce a proportional shift poleward for all species, but may instead favour the dominance of warmer adapted species over a larger area. The change in locations of the fish populations can have important economic consequences when the fish move out of the territorial waters on a country.

Determining how changes in these fisheries over time are impacted by climate variability and potentially by climate change remains a key research objective.

Anon (2014c) *Atlantic HMS management-based needs and priorities*. Report of the Highly Migratory Species Management Division, National Marine Fisheries Service, Maryland, USA.

This sets out key research needs that directly support Atlantic HMS management, including of bluefin, bigeye, albacore, yellowfin and skipjack tunas; swordfish; billfish (blue marlin, white marlin, roundscale spearfish, longbill spearfish, and sailfish); and sharks. The report identifies as a medium priority for addressing longer-term needs the following: “*Examine the influence of climate change on range, migration, nursery / pupping grounds, and prey species for HMS in general.*” This is indicative of the role of research in supporting the design of adaptation actions.

Bell J., Ganachaud A., Gehrke P., Hobday A., Hoegh-Guldberg O., Johnson J., le Borgne R., Lohodey P., Lough J., Pickering T., Pratchett M., Sikivou M., Waycott M. (2013) *Vulnerability of fisheries and aquaculture to climate change in Pacific Island countries and territories*. FAO/ Secretariat of the Pacific Community Workshop, 5–8 June 2012, Noumea, New Caledonia. FAO Fisheries and Aquaculture Proceedings No. 28. Rome.

The report discusses the vulnerability of the tuna and coastal fisheries in the region. It also presents projections for surface climate and the ocean derived from the Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model data set used for the IPCC’s 4th Assessment Report. It includes projections of sea surface temperature, ocean acidification, sea level rise and intensity of tropical storms for the Pacific, providing confidence levels for each projection. These projections are made alongside the expected continuing variability in El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) events.

Cheung W.W.L., Lam V.W.Y., Sarmientoz J.I., Kearney K., Watson R., Zeller D. and Pauly D. (2010) *Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change*. *Global Change Biology* 16, 24-35.

This paper provides model-based projections of changes in global catch potential for 1066 species of exploited marine fish and invertebrates from 2005 to 2055 under different climate change scenarios. It suggests that climate change may have a large impact on the distribution of maximum catch potential – used as a proxy for potential fisheries productivity – in this timescale. Redistribution of catch potential is driven by

projected shifts in species’ distribution ranges and by the change in total primary production within the species’ exploited ranges. The results indicate that climate change may lead to large-scale redistribution of with an average of 30–70% increase global catch potential in high-latitude regions and a drop of up to 40% in the tropics. The paper also spells out the various uncertainties associated with the projections.

Cheung, W.W.L., Watson, R. and Pauly, D. (2013) *Signature of ocean warming in global fisheries catch*. *Nature* 497, pp. 365–368.

The authors note that marine fishes and invertebrates respond to ocean warming through distribution shifts, generally to higher latitudes and deeper waters: as a result it is anticipated that fisheries should be affected by ‘tropicalisation’ of catch i.e. an increasing dominance of warm-water species. They report on an index, termed the ‘mean temperature of the catch’ (MTC) that is calculated from the average inferred temperature preference of exploited species weighted by their annual catch. Evidence is presented to show that ocean warming has already affected global fisheries in the past forty years.

HELCOM (2010) *Ecosystem Health of the Baltic Sea 2003–2007: HELCOM Initial Holistic Assessment*. *Baltic Sea Environment Procedures*. No. 122. <http://www.helcom.fi/Lists/Publications/BSEP122.pdf>

This paper provides an assessment of the environmental status of the Baltic Sea, one of the world’s largest semi-detached bodies of brackish water. Commercial fisheries in the open Baltic concentrate on several regulated species: cod, herring, sprat, salmon, flounder, plaice and eel. The regional characteristics of the Baltic are such that the sea is largely land locked with very limited water exchange, making it susceptible to environmental impacts.

The report highlights that eutrophication, caused by nutrient pollution, is a major concern in most areas with the impact, among others, of fostering algal blooms and depleting oxygen. Important nutrient inputs (phosphorus and nitrogen) to the Baltic originate from waterborne sources, particularly agricultural sources. The five largest sources of phosphorus and nitrogen are the rivers Vistula, Neva, Oder, Daugava and Nemunas (the drainage basins of which include Poland, Latvia, Lithuania, Germany, Czech Republic, Slovakia, Russia, Belarus and Ukraine).

Climate change is recognised as an additional challenge over and above anthropogenic pressures on the Baltic Sea basin. Precipitation is projected to increase and this, combined with increasing winter temperatures, may lead to increased winter runoff and leaching of nutrients.

Noted within the report is the important requirement to reduce all anthropogenic pressures and notably reducing nutrient inputs.

Secretariat of the Convention on Biological Diversity (2014) *An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity* (Eds: S. Hennige, J.M. Roberts and P. Williamson). Montreal, Technical Series No. 75, 99 pp.

The report notes that ocean acidification has increased by around 26% since pre-industrial times. It contends that: “*It is now nearly inevitable that within 50 to 100 years, continued anthropogenic carbon dioxide emissions will further increase ocean acidity to levels that will have widespread impacts, mostly deleterious, on marine organisms and ecosystems, and the goods and services they provide*”, with marine calcifying organisms at particular risk.

The report discusses: natural temporal and spatial variability in seawater pH; natural biological variability in organisms’ responses to pH changes; the evidence that surface waters in polar seas and upwelling regions are increasingly at risk of becoming undersaturated with respect to calcium carbonate; international collaboration to improve monitoring of ocean acidification; impacts of ocean acidification upon early life stages of a number of organisms; ocean acidification altering sensory systems and behaviour in fish and some invertebrates; impacts on corals, molluscs and echinoderms including reduction in growth and survival rates; tolerance of or benefits for many seaweed (macroalgae) and seagrass species from future ocean acidification; potential benefits to many phytoplankton could potentially benefit from future ocean acidification, etc. The authors indicate that acidification may interact with many other changes in the marine environment, at local and global scales. They suggest that the ‘multiple stressors’ will include changes in temperature, nutrients and oxygen levels.

(The report notes that ocean acidification is apparently already impacting aquaculture in the north-west United States of America, further decreasing the pH of upwelled water,

which has a naturally low saturation state for calcium carbonate. Monitoring and management measures are being taken to mitigate high mortalities in oyster hatcheries.)

2. Impacts on offshore operations and assets. Increasing intensity and / or frequency of storms may increase the risk of damage to boats and risk lives, especially where smaller vessels are involved. Deployment and performance of gear may also be affected adversely in more stormy conditions.

Selected references:

Haynie, A.C. and Pfeiffer, L. (2013) *Climatic and economic drivers of the Bering Sea walleye pollock (*Theragra chalcogramma*) fishery: implications for the future. Canadian Journal of Fisheries and Aquatic Sciences*, 2013, 70(6): 841-853.

This paper uses retrospective data from the Bering Sea walleye pollock catcher–processor fishery to model the impact of climate on spatial and temporal variation in catch and fishing locations and to draw inferences about harvester behaviour in a warmer climate. One key factor in the models is the IPCC-based prediction of a 40% decrease in sea ice by 2050, resulting in warmer Bering Sea temperatures.

The authors argue that the economic drivers of a fishery, and its management structure, are complex, vary on a local level, and are impacted by climate factors in many ways. Therefore, when predicting how climate will affect a fishery, it is important to consider the characteristics of the ocean dynamics, the region, the species, the harvesting fleet, and the management structure that likely to be unique to particular fisheries. The authors argue that not giving sufficient concern to these local factors, which global-scale modelling cannot do, may lead to inaccurate predictions of fishery adaptation.

Leurig, S. (2011) *Climate change risk disclosure by insurers: evaluating insurer responses to the NAIC Climate Disclosure Survey. CERES Report*. <http://www.ceres.org/resources/reports/naic-climate-disclosure/view>

Climate change is altering the insurance industry’s global business environment and the risk models on which it depends. After being accustomed to operating in a relatively stable global climate, the report indicates that insurers are facing more volatile weather patterns driven by rising temperatures caused by human activities. The US National Association of Insurance Commissioners

(NAIC) has noted what is regarded as a fast-emerging threat that will have broad impacts across the industry, adversely affecting its ability to price physical risks, creating potentially major new liabilities and threatening the performance of its investment portfolios.

There is a broad consensus among insurers that climate change will have an effect on extreme weather events, including important issues for marine insurers. However, the insurance industry is largely focused at present on the implications of climate change for hurricanes and other coastal events.

3. Impacts on onshore operations and assets.

Climate change may have consequences for the resilience and siting of onshore operations, ports / harbours and other assets. Sea level rise and surge events, extreme storms and waves may cause damage or disruption. Processing plants at coastal locations could also be affected by extreme events.

Selected references:

Brecht H., Dasgupta S., Laplante B., Murray S. and Wheeler, D (2012) Sea-Level Rise and Storm Surges: High Stakes for a Small Number of Developing Countries. *Journal of Environment and Development* 2.1 pp. 120-138.

This paper discusses the consequences of climate changes during the 21st century that are associated with larger cyclonic storm surges. Notwithstanding any global trend, it notes that impacts will vary due to local conditions: *“As conditions worsen, variations in coastal morphology will magnify the effects in some areas, while largely insulating others”*. The article examines the implications for 31 developing countries and 393 of their cyclone-vulnerable coastal cities with populations greater than 100,000.

Anon (2011a) *Mauritius Environment Outlook Report*. Ministry of Environment and Sustainable Development, Government of Mauritius.

According to this report, in Mauritius the impacts of climate change are already apparent through rising sea levels, beach erosion, an increase in frequency and intensity of extreme weather events, as well as recurrent floods and droughts. The main areas of economic and environmental vulnerability to climate change include tourism, agriculture, fisheries, health and freshwater. The coastal zone faces pressure with impacts on strategic infrastructure, especially during cyclones and sea surges. It predicts that as the El Niño phenomenon becomes more frequent, intense

and of longer duration, the size and location of fish stocks and fish migration patterns will be affected, providing illustrations of historic changes.

Dasgupta S., Laplante B., Meisner, C., Wheeler D. and Yan J. (2007) *The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis*. World Bank Policy Research Working Paper 4136.

In terms of adaptation responses to sea-level rise as a result of climate change, the World Bank source advises that for precautionary planning purposes, a sea-level rise (SLR) in the range of 1m – 3m this century should be regarded as realistic: unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets might produce a 5m SLR.

Hanson, S., Nicholls R., Ranger N., Hallegatte S., Corfee-Morlot J., Herweijer C. and Chateau J. (2011) *A global ranking of port cities with high exposure to climate extremes. Climatic Change* 104, pp.89-111.

This paper estimates the exposure of the world's large port cities to coastal flooding due to sea-level rise and storm surge now and in the 2070s, taking into account scenarios of socio-economic and climate changes. The analysis suggests that about 40m people (0.6% of the global population or roughly 1 in 10 of the total port city population in the cities considered) are currently exposed to a 1 in 100 year coastal flood event. By the 2070s, total population exposed may be greater by a factor of three due to the combined effects of sea-level rise, subsidence, population growth and urbanisation. Although not specifically discussing the threats to fishing ports and harbours, the projections made for major ports are indicative of the threat level of relevance to the fishing industry internationally.

4. Socio-economic impacts: climate change has the potential to impact (negatively but sometimes positively) social and economic conditions of regions and countries. The resulting impact will be due in large part to consequences linked to climate drivers but also to the capacity of communities and economies to adapt.

Selected references

PWC (2013) *International threats and opportunities of climate change for the UK*. PWC contribution to the UK Government's National Adaptation Programme.

The report assesses the implications of climate change effects that occur overseas for UK interests, including industry and investors / owners of overseas assets. The main threats identified were: (i) damages to physical and financial assets from extreme weather; (ii) increased frequency and urgency of humanitarian assistance; (iii) increased volatility in food prices and political or policy reactions affecting availability of food supplies; and (iv) increased demand for UK Government services by overseas territories and citizens abroad. Among the threats and opportunities referred to are: impacts on coral reefs; locational changes in fisheries productivity; risks of damage by extreme events; and opportunities due to the loss of Arctic ice.

The study examined a number of 'themes' that may be impacted by climate change viz. business (trade and investment); infrastructure (in particular, energy); food; health and wellbeing, and foreign policy. In its assessment, PWC uses a 'Medium Emissions Scenario' i.e. one aligned with the 2 degree C target whilst noting that lack of progress to date in limiting CO2 emissions may make this temperature target difficult to achieve i.e. more severe impacts may be experienced.

The PWC report identifies as a threat to the UK the impact of climate change on fishing and its role in the economy of smaller tropical and sub-tropical islands. It also notes opportunities for the UK from the opening up of new routes to shipping following the loss of Arctic ice, albeit not specifically linked to fishing or the import of fish products.

By the 2020s the report also indicates climate change impacts on fisheries off the southern coasts of Africa; and off Australia and New Zealand due to changes in southern ocean circulation; changes in the location of fish stocks in the south-east Pacific (off the South American continent); and off North America, it points to an expected decline in cool water fisheries and gains in warm-water fisheries. By the 2050s, it predicts negative impacts on fisheries due to changes in the coastal environment in southern Africa which continue into the 2080s. However, the implication of the report is that this list of climate effects should not be seen as particular threats or opportunities for the UK. There is a caveat here: the report's authors note that in their high level summaries of projected impacts internationally, where no information is presented this indicates a lack of evidence in an area rather than necessarily the lack of climate change impacts.

The PWC report refers to threats and opportunities arising from the effects of climate change directly on the UK ('domestic' impacts) viz. opportunities from changes in fish catch latitude / centre of gravity (referring specifically to plaice and sole) and threats from similar changes affecting cod and haddock. More generally in terms of domestic effects, it points to threats from a decline in productivity of 'cold-water' fish and shellfish stocks. Whilst no comparable threats or opportunities for the UK are identified due to climate change effects being experienced overseas, the authors do advise that: *"There are likely to be large impacts on the world's coral reefs by the 2020s, alongside impacts on many other species of animals and plants and a variety of habitats. Fisheries are expected to be severely impacted in many areas."*

Allison E.H., Perry A.L., Badjeck M-C., Adger N.W., Brown K., Conway D., Halls A.S., Pilling G.M., Reynolds J.D., Andrew N.L and Dulvy N.K. (2009) *Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries, Blackwell Publishing Ltd.*

The authors compare the 'vulnerability' of 132 national economies to potential climate change impacts on their capture fisheries using an 'indicator-based approach'. In this, vulnerability is due to the combined effect of predicted warming, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities. The precise impacts and direction of climate-driven change for particular fish stocks and fisheries are uncertain. Countries in Central and Western Africa (e.g. Malawi, Guinea, Senegal, and Uganda), Peru and Colombia in north-western South America, and four tropical Asian countries (Bangladesh, Cambodia, Pakistan, and Yemen) are identified as most vulnerable.

Daw, T.; Adger, W.N.; Brown, K.; Badjeck, M.-C. (2009) *Climate change and capture fisheries: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto and T. Bahri (eds). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp.107-150.*

The paper discusses three relevant concepts: vulnerability, adaptation and adaptive capacity. It sets out a range of generalised options for adaptation to climate impacts, including reactive and anticipatory actions by individuals or public institutions. These include: abandoning fisheries for alternative occupations; developing

insurance and warning systems; changing fishing operations; ensuring governance regimes are flexible enough to account for changes in stock distribution and abundance.

The authors argue that: *“the variety of different impact mechanisms, complex interactions between social, ecological and economic systems, and the possibility of sudden and surprising changes make future effects of climate change on fisheries difficult to predict.”* In this context they state: *“Investments in generic adaptive capacity and resilient fisheries systems seem to be a good strategy to support future adaptations which are not currently foreseen. Better managed fisheries with flexible, equitable institutions are expected to have greater adaptive capacity.”*

The paper also discusses the Peruvian anchoveta fisheries and its extreme variability because of population fluctuations induced by warm modes of the El Niño-Southern Oscillation (ENSO). These events reduce upwelling along the Peruvian coast affecting adversely the process that provides nutrients for the anchovies.

The authors note that annual catches in the Peruvian fishery have fluctuated between 1.7 and 11.3 million tonnes within the past decade in response to El Niño climate disruptions. Because Peru is the main producer of fishmeal and fish oil, fluctuations of anchovy stocks have an impact at national level and on the global aquaculture feed market. However, the adverse impact on the industrial fishery sector due to reduced stock of anchovies and sardines in the eastern Pacific upwelling areas, has historically been beneficial to the Baltic sprat fishery, a competing species for fishmeal production, which secures higher prices.

The impact of climate change on the variability of the ENSO is a key issue for the long term management of the anchoveta fisheries. The authors indicate that climate change is likely to increase the frequency of ENSO events, with changes in timing and latitude of upwelling.

Johnson, T. (undated) *Fisheries adaptations to climate change*. Report by the Alaska Sea Grant Marine Advisory Program. http://seagrants.noaa.gov/Portals/O/Documents/what_we_do/climate/AK%20SG%20Fisheries%20Adaptations%20to%20Climate%20Change.pdf

The paper sets out the climate effects related to fish population biology and to fishermen and fishing communities. On fish biology, the range of effects identified include: changes in primary productivity (positive and negative); changes in species composition and abundances

within regions; changes in ocean currents and water column mixing which alter larval dispersal and food availability, with, typically, warm water increasing stratification and decreasing productivity; altered trophic level interactions, causing decreases (or increases) in abundance of valued species and their predators and competitors; redistribution of stocks and species, commonly from lower latitude warmer and shallower nearshore waters to higher latitudes with deeper and cooler temperature waters; introduction or survival of invasive species; harmful algal blooms and bacterial / viral diseases; increased areas of oxygen-minimum zones ('dead zones'); changes in the timing of ecological events; elevated sea level which damages particular habitats; changes to run-off which affects coastal habitats; lower pH of seawater (ocean acidification); potential increase in pollution effects, including eutrophication and ultraviolet radiation absorption.

On fishermen, businesses and communities, the range of effects identified include: communities can include: changes in fisheries productivity which demand expensive adaptations by harvesters, processors, and dependent communities (e.g. bigger, more sophisticated vessels to operate in more distant locations; processing facilities in new locations); increased frequency and severity of storms or weather, resulting in sea conditions unsuitable to fishing and / or well as causing onshore damage through flooding, erosion and storm damage; sea level rise that floods communities or valuable habitat; storms or flooding that disrupt supply chains, transportation of supplies and products, and costs to businesses; decrease in food security.

The paper discusses climate change as it may impact the Alaska fisheries and adaptation responses. This includes discussion of the effects on the Alaska pollock fisheries, an important source of UK imports. The author notes that in the Bering Sea the abundance and bloom timing of ice-dependent phytoplankton influence the recruitment strength of each year class of several important commercial species, in particular walleye pollock: especially warm conditions tend to be unfavourable to strong recruitment to this fishery. The author also notes that the pollock fisheries have large trawlers that are 'highly mobile' i.e. able to expand their range of operations if target fish stocks shift to cooler northern waters.

Annex 7: Industry case studies (domestic and international)

DOMESTIC

1. Climate change (temperature change) and wild capture fish and shellfish stocks

What is the issue?

Changing climatic conditions have been linked to changes in the abundance and distribution of commercial fish stocks of relevance to the domestic system. In some cases this is leading to new (e.g. boarfish) or enhanced opportunities to exploit 'warm-water' commercial stocks (e.g. squid, John Dory, seabass, red mullet and anchovy), whilst more traditional 'cold-water' stocks become increasingly threatened (e.g. cod and haddock).

Example(s):

- A recent expansion in the abundance of boarfish (which only Denmark, Ireland and UK have quota for) could be linked to climate change leading to new commercial opportunities. For example, Ireland has now opened markets to China.
- Off north-east Scotland, where most squid is found, more boats are now trawling for squid than the region's traditional target species, such as haddock and cod.

Key references:

Defra (2013) *Economics of Climate Resilience: Natural Environment - Sea Fish CA0401*. February 2013. Frontier Economics Ltd for Department for Environment, Food and Rural Affairs (Defra), UK. 101pp.

Pinnegar, J.K., Cheung, W.W.L., Jones, M., Merino, G., Turrell, B. and Reid, D. (2013) *Impacts of climate change on fisheries*. MCCIP Science Review 2013, 302-317, doi:10.14465/2013.arc32.302-317.

Simpson, S.D., Blanchard, J.L. and Genner, M.J. (2013) *Impacts of climate change on fish*, MCCIP Science Review, 113-124, doi:10.14465/2013.arc13.113-124.

2. Climate change (temperature change), changing fish distributions and their implications for quota management

What is the issue?

The impact of climate change on fish species distribution has the potential to lead to international disagreements as stocks move across international boundaries.

There are not only issues with non-EU countries declaring quota, but also the mal-adaptation of EU quota systems under 'relative stability' which lacks the flexibility to respond to geographical shifts of fish species.

Example(s):

- Recent disagreements over mackerel quotas when the species had suddenly attained high abundance in Icelandic and Faroese territorial waters. This development requires a broadening of the parties involved in the quota agreement for mackerel but as yet this remains unresolved. It is not clear if mackerel are spreading out or shifting distribution (by 2014 mackerel had reached as far as Greenland), but either way it is important to understand the role of climate change given the political implications for quota allocations.

Key references:

Pinnegar, J.K., Cheung, W.W.L., Jones, M., Merino, G., Turrell, B. and Reid, D. (2013) *Impacts of climate change on fisheries*. MCCIP Science Review 2013, 302-317, doi:10.14465/2013.arc32.302-317.

Cheung, W.W.L., Pinnegar, J., Merino, G., Jones, M.C. and Barange, M. (2012). *Review of climate change impacts on marine fisheries in the UK and Ireland*. Aquatic Conserv. Mar. Freshw. Ecosyst., 22, 368-388.

3. Climate change (increased storminess) and impacts on onshore and offshore operations

What is the issue?

Changes in the frequency and intensity of storms have the potential to cause major disruption to both onshore and offshore operations. On land, port and harbour infrastructure, as well as day-to-day operations, can be adversely affected by storms, as can processing plants and transport routes to market. At sea, the ability to go out to fish, especially for smaller vessels, is an issue, as is the safe deployment and performance of gear.

Example(s):

- Recent storms have led to substantial physical damage to port infrastructure (e.g. the lighthouse and other properties at Fraserburgh, as well as over-topping of sea defences at Peterhead, damaging equipment and housing). The port authority at Peterhead is already investing in higher sea walls.

- The winter of 2013-14 was extremely stormy, especially in south of the UK, which meant boats were stuck in port for long periods.
- In the pelagic sector storminess and waves are already seen to be making an impact. Waves are threatening crew on the existing deck where fish is being pumped aboard from alongside. A number of vessels have built a raised deck and placed the pump higher so that crew members are away from swells (and clear of danger). New build vessels are relocating the pump to the stern i.e. pumping fish from aft as this is safer than pumping from alongside.
- *Vulnerability of early life stages of fish* (eggs, larvae) to change in pH as well as changes in the plankton community reducing survival in the early life stages due to effects on food quality and quantity, timing (match / mismatch in timings of food supply and demand) and predation.
- *Vulnerability of shellfish* – as an example, evidence of the seasonal upwelling of acidic waters onto the continental shelf in the California Current region adversely affecting oyster hatcheries on the coasts of Washington and Oregon. These oyster hatcheries have suffered high larval mortalities (up to 80%) since 2006, threatening the viability of the industry.

Key references:

Wright, P. (2013) *Impacts of climate change on ports and shipping*, MCCIP Science Review 2013, 263-270, doi:10.14465/2013.arc28.263-270.

Pinnegar, J., Watt, T. and Kennedy, K. (2012) *CCRA Risk Assessment for the Marine and Fisheries Sector*. UK 2012 Climate Change Risk Assessment: Defra, London. 204pp.

Roberts, Stephen (2009). *'Britain's most hazardous occupation: Commercial fishing'*. Accident Analysis and Prevention 42: 44-49. doi:10.1016/j.aap.2009.06.031.

INTERNATIONAL

4. Climate change (acidification and deoxygenation) and its consequences for marine fisheries

What is the issue?

Ocean acidification, the result of increasing carbon dioxide uptake by ocean waters from the air, is now widely regarded as a threat to the future of commercially important fish and shellfish stocks. The ocean's pH has already fallen by 0.1 since pre-industrial times, a c.30% increase in acidity: if CO₂ emissions continue rising at the current rate an additional pH drop of 0.3 by 2100 is projected. Researchers point to a range of biological and commercial consequences, some of which are already in evidence:

- *Adverse effects on some marine ecosystems* – in a future with lower pH and higher CO₂ in combination with a rising temperature e.g. (a) evidence from fish habitats associated with the cold-water coral systems of Western Norway of an adverse impact on recruitment to fish stocks; (b) evidence from coral reefs globally of rapidly declining ecosystems and risk of collapse of some related coastal fisheries.

Regarding corals, if CO₂ emissions continue rising at the current rate, coral reef erosion is likely to outpace reef building before the end of this century. Coral bleaching as a result of rising temperatures is also expected to increase, with resulting loss of support and habitat for fisheries.

Example(s):

On upwelling of more acidic waters, whilst some authors regard the precise role of climate change here as uncertain, others argue that additional acidification due to anthropogenic CO₂ is already having a biological impact, noting carbonate saturation values offshore western USA already at levels projected for elsewhere 50-100 years in the future. Local oyster hatcheries are now adapting their working practices to avoid using very low pH seawater, either by re-circulating seawater or by treating their water during upwelling events.

Researchers in Norway (Fossa et al) indicate that increased acidification is likely to become especially marked in Arctic and sub-Arctic waters. Emphasising the importance of recruitment as a factor in stock assessment and its vulnerability to acidification, these authors refer to case studies (Northern Cod, Norwegian Spring Spawn Herring) to demonstrate that stock collapse is usually the result of a combination of unfavourable environmental conditions (affecting recruitment) and overfishing (mismanagement). Some species may be indirectly impacted through changes in the food chain and habitat e.g. haddock which feed on echinoderms. However, some commercially important species may adapt or be naturally resilient e.g. the mussel *Mytilus edulis* is reportedly thriving in the naturally CO₂-enriched waters of Kiel Fjord, Germany.

Key references:

Fossa, J.H., Bellerby, R, and Jakobson, T (undated) *Consequences of Ocean Acidification for Fisheries*. Presentation for the Special Committee on Oceanic Research, International Council for Science (ICSU). www.scor-int.org/High_CO2_II/Presentations/Fossa.pdf

IPCC, 2014: *Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Secretariat of the Convention on Biological Diversity (2014). *An Updated Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity* (Eds: S. Hennige, J.M. Roberts and P. Williamson). Montreal, Technical Series No. 75, 99 pages.

5. Climate change (temperature change) and cold-water prawns

What is the issue?

Cold-water prawns are among UK's favourite seafood. The Arctic and North Atlantic oceans are the key sources of cold-water prawns. UK consumption includes imports mostly from Denmark and Canada. This commercial fishery has been subject to substantial change recently: West Greenland's quota was reduced for the 2015 season by 14% relative to 2014. There has been a worldwide decline in cold-water prawn stocks in 2015.

Aschan (2014) discussed the global decline in cold-water prawn stocks at the International Cold Water Prawn Forum's (ICPWF) industry meeting in Paris. The presentation considered causal links to larger and expanding cod stocks, predation by young cod reducing shrimp recruitment to the fishery, and emerging mismatches in time and space of processes in the marine ecosystem resulting in recruitment failure. Temperature increase is regarded as the most likely main underlying reason for decline, due to direct and indirect effects. Aschen notes that although temperatures will rise, natural oscillation will hide

this fact in the short term in some areas. However, the consequences for cold-water species such as *Pandalus borealis* may be dramatic.

Example(s):

The Arctic Ocean is experiencing a measurable and dramatic decrease in sea ice, estimated to be greater than 5% reduction per decade. It is forecast that the entire sea ice of the Arctic will be lost during the summer months in a few decades. In a presentation on the impact of climate change on cold-water prawns at the ICWPF's London conference in 2013, Wassmann notes that as a consequence of climate change: "A new, ice-free, stratified and completely unknown ecosystem will arise".

Its characteristics will include the following:

- At the end of this century, prawns (and other fish species) will feed over a larger area as compared to today.
- Climate change may favour cold-water prawn in new productive regions, whilst more southerly areas may lose out.
- Like other bottom-dwelling forms, prawns depend on primary production and what is 'left over' in the upper water column and sinks to the bottom.

Although not feasible yet to estimate the scale of the cold-water prawn resource from primary production forecasts only, it may be possible to indicate where prawn stocks will be located in future decades e.g. north of Svalbard due to better feeding grounds and in extensive new feeding grounds across the Kara Sea and along the outer Siberian shelf, whereas the Barents Sea may have smaller quantities than now, in particular in the south.

The availability of the Barents Sea stock is expected to fall as it moves east out of 'shared' waters into Russian waters. According to the Wassmann: "*Russia is the big climate winner in the Arctic Ocean*". By 2100 Russia may see a 55% increase in stocks. From an industry perspective, the author recommends looking into the option of gaining better access to Russian territorial waters and/or quotas, or to investing in Russian cold-water prawn interests.

Key references:

Aschan, M (2014) *Current status and outlook for stocks and fishery of Pandalus borealis in the North Atlantic*. Presentation to the International Cold Water Prawn Forum Industry Meeting, Paris.

<http://icwpcf.com/wp-content/uploads/2014/11/1-Michaela-Aschan-2014.pdf>

<http://www.seafoodnews.com/Story/957763/West-Greenlands-coldwater-shrimp-quota-slashed-14-percent-for-2015-fishery>

Wassmann, P. (2013) *How will climate change affect the Cold Water Prawn?* Presentation to the International Cold Water Prawn Forum, London.

6. Climate change (temperature change, acidification and deoxygenation) and tuna fisheries

What is the issue?

Tuna is among the top ten most popular fish eaten in the UK, much of it imported from Mauritius and the Seychelles. However, tuna is a highly migratory species, swimming through international waters and waters belonging to many countries. Countries with an interest in sharing these resources join together in treaties to create regional fisheries management organisations: these RFMOs are responsible for setting catch limits, monitoring the health of stocks and regulating the right to fish. Growing evidence of climate-related changes in the distribution of commercial fish stocks challenges the present fishery and ecosystem management arrangements of RFMOs. Shifting stocks may lead to conflicts between industrial foreign fleets and national ones restricted to their Exclusive Economic Zone (EEZ). Similar problems could also occur on sub-national scales between local jurisdictions, traditionally managed areas or territorial rights systems.

Example(s):

Changes in temperature, oxygen levels and food availability in the ocean are all likely to alter the distribution and abundance of top predator species such as tuna in the Pacific and Indian Oceans: in general, stocks in both oceans are predicted to shift eastwards.

The impact of climate on the tuna fishery is under consideration by the Mauritius government given likely modifications to fisheries productivity and availability. Its Environment Outlook report expresses concern that as the El Niño phenomenon becomes more frequent, intense and of longer duration, the size and location of fish stocks and fish migration patterns will be affected.

Based on SEAPODYM (Spatial Ecosystem and Population Dynamics Model) the distribution of skipjack tuna in the Pacific is projected to extend further eastward over time, with catches eventually decreasing in the west. The stock of bigeye tuna is expected to decrease across the region.

Preliminary analyses for albacore suggests that it will contract in range and decline in biomass as oxygen levels are affected by climate change. Model projections are now available up to 2100.

Early responses to these issues are evident by international fisheries bodies. For example, at the meeting of its scientific committee in 2012 (in Busan, South Korea), the Western and Central Pacific Fisheries Commission discussed adaptation to climate variability and change affecting the tuna fisheries. It identified the importance of improving models, forecasts and projections of tuna stocks in order to assess the full socio-economic implications of changes in tuna catches and adjust adaptation plans with the aim of minimising threats and maximising opportunities. Areas requiring enhanced knowledge are: modelling the climate system, particularly future projections of El Niño / Southern Oscillation (ENSO) patterns; physiology, biology and ecology of tunas; description of food webs; and improving quality and spatial resolution of fisheries catch data and developing a better understanding of the behaviour of fishing fleets.

Key references:

Anon. (2011a) *Mauritius Environment Outlook Report*. Ministry of Environment and Sustainable Development, Government of Mauritius.

Evans et al (2012) *Progressing adaptation to climate variability and change in Western and Central Pacific Ocean tuna fisheries*. Scientific Committee (Eighth Regular Session), Western and Central Pacific Fisheries Commission.

Johnson et al (2013) *Priority adaptations to climate change for Pacific fisheries and aquaculture: reducing risks and capitalizing on opportunities*. FAO/Secretariat of the Pacific Community Workshop, 5–8 June 2012, Noumea, New Caledonia. FAO Fisheries and Aquaculture Proceedings No. 28. Rome.

Lehodey et al 2011. *Vulnerability of oceanic fisheries in the tropical Pacific to climate change*. In J.D. Bell, J.E. Johnson and A.J. Hobday, eds. *Vulnerability of tropical Pacific fisheries and aquaculture to climate change*, pp. 433-492. Noumea, New Caledonia, Secretariat of the Pacific Community.

MacKenzie et al (2014) *A cascade of warming impacts brings bluefin tuna to Greenland waters*. *Global Change Biology* 20.8.

Annex 8: Detailed overview of key risks and associated climate driver(s)

In this section, for each of the key risks, threats and opportunities highlighted, more detail is provided on:

- The range of impacts identified (including citations to key sources of evidence used).
- Views expressed by industry stakeholders.
- Rationale for scoring as a high risk, threat / opportunity.

For more detail on scoring and evidence used in across all of the issues considered for the domestic and international systems please refer to the matrix and the full 'domestic' and 'international' reference list in Annex 10.

DOMESTIC

Part 1. Offshore: fishery resources and offshore operations

Whitefish

a) Fishery resources

i. Alterations in species phenology [life-cycle events] due to air or sea temperature change.

Range of impacts identified (threats only): There is evidence that the timing of spawning of sole has retreated by 1.5 weeks / decade since the 1970s and that changed in Cod since 1960s have affected mis-match of timing with zooplankton prey. Key sources: Pinnegar et al. (2013); Simpson et al. (2013).

UK industry views: Broadly considered as a wider fish biology, although issues around cod and prey species were noted.

Rationale for scoring as a high risk: Where spawning is too early or too late to capitalise on available food resources, annual recruitment can be strongly affected.

ii. Impacts on 'choke' species (linked to landing obligations) due to air or sea temperature change.

Range of impacts identified (threats only): Species redistribution will have impacts on choke species (the species that stops you from fishing when its quota runs out in a multi-species fishery). This is a potentially damaging situation whereby a lack of quota for one particular species may

prevent you from risking going to sea and fishing in case you catch that species that you now can't discard under EU landing obligations. Key sources: Seafish (2014); Baudron and Fernandes (2014).

UK industry views: The issue of Hake being a choke species was raised given how abundant is has become and the inflexibility around TACs was highlighted as a major issue.

Rationale for scoring as a high risk: There is considerable concern that choke species causing socio-economic impacts both directly on the fishermen and the communities they support, but also on the markets these vessels supply.

iii. Changes to the growth rate of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): Starting to see some changes now with regard to optimum temperature and growth, but this will become more apparent in coming decades. Likely that some species such as sole will benefit, whilst others such as cod will be detrimentally affected. There is evidence that some whitefish species (e.g. haddock, plaice and sole) grow faster in warmer conditions due to an increase in metabolic rate. However, this can lead to a significant overall reduction in body size as fish mature earlier. For anchovy, one consequence of summer warming, documented for the southern North Sea, may be a spatial and temporal expansion in favourable growth habitats. Key sources: Pinnegar et al. (2013); Simpson et al. (2013).

UK industry views: Changes in growth rate could mean that NE Scotland is famed for (small haddocks) may be lost and the customer case eroded. If changes led to larger fish sizes, the onshore industry could find itself in competition with high volume supplies from overseas (e.g. Iceland and Norway). It was also recognised that not only does warming increase fish breathing and metabolism, but the rate of contaminant build up in fish could increase.

Rationale for scoring as a high risk: Links between climate warming and impacts on growth rates and maturation are important through their effects on fish size distributions, especially where we are seeing significant reductions in fish size.

iv. Changes to the distribution of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): For whitefish, the southern boundary of traditional cold-water catch species (e.g. Cod and haddock) has retreated northwards

with declining yields. Other species such as Hake are becoming more abundant and other species moving in a less consistent manner (e.g. Sole towards eastern channel and Plaice northwest into the central north sea). Key sources: Pinnegar et al. (2013); Baudron and Fernandes (2014);

UK industry views: The decline of cod was widely noted, as was the recent increase in Hake, which appears to have been significant.

Rationale for scoring as a high risk:

Understanding, and responding to, the changing distribution of target species is perhaps the most fundamental issue of concern for the industry with respect to climate change impacts.

v. Changes to the year-class strength of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities):

The link between water temperature and recruitment success (year class strength) is well established. For whitefish, traditional cold-water species such as cod are suffering from poor recruitment success with warming, especially in the North Sea although yields of warm-water species such as bass have been increasing. Key sources: Pinnegar et al. (submitted); Simpson et al. (2013).

UK industry views: Changes in year-class strength widely noted as part of the wider issue of fish biology. The increasing abundance of seabass around the UK was raised as an issue.

Rationale for scoring as a high risk: Given the known sensitivity of recruitment of commercial fish to sea temperature, and the critical importance this has on stock levels then this has to be considered an important issue.

vi. Migration patterns of target species (timing and routes) due to air or sea temperature change.

Range of impacts identified (threats and opportunities):

Habitat suitability changes linked to sea temperature appear to have affected the migration of sole and plaice from the Dutch coast. Delayed migration to offshore waters in warmer years has been identified in flounder in the English Channel. These movements could have both negative and positive effects. Key sources: Simpson et al. (2013).

UK industry views: Changes in migration patterns were noted as part of the wider issue of fish biology.

Rationale for scoring as a high risk: This is an important issue as changes in migration affect

the 'catchability' of individuals to fishing gears. Populations may move away from (or towards) the area where fishing fleets operate and / or where spatial restrictions on fishing are in place.

b) Offshore operations

i. Physical working conditions for staff due to increased storminess and waves.

Range of impacts identified (threats): Risk of physical injury or death from collision with equipment on board or drowning at sea. Any change in wave and wind conditions would have a direct effect on safety at sea. Key sources: Pinnegar et al. (submitted); Roberts (2009).

UK industry views: Waves are threatening crew on existing decks where fish is being pumped from alongside. Risks are seen as generally higher for the smaller inshore vessels that are out more regularly compared to larger vessels, such as those that predominate in the pelagic fleet which don't need to go out so much. Inshore vessels can also be 'over-extended' into offshore waters thereby compromising the basic safety of the crew.

Rationale for scoring as a high risk: The high risk score given reflects the high risk nature of the industry (The most recent figures show that a total of 117 deaths were identified for seafarers in the UK fleet in the years from 1996 to 2005 ncbi.nlm.nih.gov-maritime report). Risk should be considered higher for smaller whitefish and shellfish capture vessels than the pelagic fleet.

ii. Deployment / performance of gear due to increased storminess and waves.

Range of impacts identified (threats): Stormy conditions make it difficult to deploy gear, and once it is deployed then there is the risk of damage or loss of equipment. The types of gear identified as being at highest risk are gillnets, line capture and bottom and beam trawling for whitefish. For beam trawling, the operating thresholds are typically lower and bouncing of gear can affect performance. Key sources: Pinnegar et al. (submitted); Westlund et al. (2007).

UK industry views: There are good examples of gear loss in winter storms and in terms of deployment there are some moves towards pumping fish on board at the stern rather than alongside as this is safer.

Rationale for scoring as a high risk: Given the wide ranging examples provided by industry stakeholders and the direct relationship between sea state and deployment of gear this issue is highlighted as a high risk. As with physical working conditions for staff, risk should be considered higher for smaller whitefish and shellfish capture vessels than the pelagic fleet.

iii. Damage to fleet due to increased storminess and waves.

Range of impacts identified (threats): Physical damage to the structure of the boat as a result of storm conditions. Key sources: Pinnegar et al. (submitted); Westlund et al. (2007).

UK industry views: The smaller inshore fleet which are out more regularly are likely to be more vulnerable than larger, more stable vessels that are not out at sea as much. Smaller vessels are likely to be most vulnerable to changes in storms and sea state.

Rationale for scoring as a high risk: Whitefish and shellfish vessels are typically smaller than the pelagic fleet and go out more of the year.

Pelagic

a) Fishery resources

i. Changes to the migration patterns of target species (timing and routes) due to air or sea temperature change.

Range of impacts identified: Sea temperature have a strong effect on migration behaviours of pelagic fish. For example, warmer temperatures appear to be causing an earlier migration in western mackerel stocks, and leading to eggs found further north in warmer years. Key sources: Simpson et al. (2013).

UK industry views: The redistribution of mackerel stocks is resulting in huge governance issues.

Rationale for scoring as a high risk: The impact of climate change on fish species distribution has the potential to lead to international disagreements as stocks (e.g. mackerel) move across international boundaries. The current quota system also lacks the flexibility to respond to these changes.

ii. Alterations in species phenology [life-cycle events] due to air or sea temperature change.

Range of impacts identified (threats): Impacts on pelagic species such as herring and horse

mackerel have been identified. Key sources: Pinnegar et al. (2013); Simpson et al. (2013)

UK industry views: Broadly considered as a wider fish biology.

Rationale for scoring as a high risk: Where spawning is too early or too late to capitalise on available food resources, annual recruitment can be strongly affected.

iii. Changes to the catchability of target species due to increased storminess and waves; air or sea temperature change.

Range of impacts identified (threats): Temperature and the depth of the thermocline have been demonstrated to be important controls on the presence and abundance of herring in the North Sea. The thermocline can also break down as a result of storms and turbid conditions. Also impacts around turbidity and visibility for line fisheries. Key sources: Pinnegar et al. (submitted).

UK industry views: No views expressed.

Rationale for scoring as a high risk Considered a key risk if catchability is to become adversely affected.

iv. Changes to the growth rate of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): Starting to see some changes now with regard to optimum temperature and growth, but this will become more apparent in coming decades. Likely that some species such as sole will benefit, whilst others such as cod will be detrimentally affected. There is evidence that some pelagic species (e.g. whiting and herring) grow faster in warmer conditions due to an increase in metabolic rate. However, this can lead to a significant overall reduction in body size as fish mature earlier. For anchovy, one consequence of summer warming, documented for the southern North Sea, may be a spatial and temporal expansion in favourable growth habitats. Key sources: Simpson et al. (2013); Baudron et al. (2014).

UK industry views: It was recognised that not only does warming increase fish breathing and metabolism, but the rate of contaminant build up in fish could increase.

Rationale for scoring as a high risk: Links between climate warming and impacts on growth rates and maturation are important through their effects on fish size distributions, especially where we are seeing significant reductions in fish size.

v. Changes to the distribution of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): For pelagic species, the 'centre of gravity' of species has moved more quickly than whitefish species and over larger distances. There are winners and losers again, anchovy is increasing, whilst mackerel is spreading out further. Key sources: Pinnegar et al. (submitted); Simpson et al. (2013).

UK industry views: For pelagic species, the spreading of mackerel stocks is widely noted and a westward shift in herring over recent years.

Rationale for scoring as a high risk: Understanding, and responding to, the changing distribution of target species is perhaps the most fundamental issue of concern for the industry with respect to climate change impacts.

vi. Changes to the year-class strength of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): The link between water temperature and recruitment success (year class strength) is well established. There will be winners and losers. Atlantic mackerel recruitment is known to be strongly affected by temperature and has been declining in the North Sea over recent decades. Key sources: Pinnegar et al. (2012); CCRA (2012).

UK industry views: Changes in year-class strength widely noted as part of the wider issue of fish biology. The changes in mackerel around the UK was noted.

Rationale for scoring as a high risk: Given the known sensitivity of recruitment of commercial fish and shellfish to sea temperature, and the critical importance this has on stock levels then this has to be considered an important issue.

b) Offshore operations

i) Physical working conditions for staff due to increased storminess and waves.

Range of impacts identified (threats): Risk of physical injury or death from collision with equipment on board or drowning at sea. Any change in wave and wind conditions would have a direct effect on safety at sea. Key sources: Pinnegar et al. (submitted); Roberts (2009).

UK industry views: Waves are threatening crew on existing decks where fish is being pumped from alongside. Whilst risks are lower than for the

smaller inshore vessels that are more common in the whitefish and shellfish fleet, but still need to be considered.

Rationale for scoring as a high risk: The high risk score given reflects the high risk nature of the industry. Risk should be considered higher for smaller whitefish and shellfish capture vessels than the pelagic fleet.

ii) Deployment / performance of gear due to increased storminess and waves.

Range of impacts identified (threats): Stormy conditions make it difficult to deploy gear, and once it is deployed then there is the risk of damage or loss of equipment. The types of gear identified as being at highest risk are mid-water trawl, purse-seines and line capture. For pelagic capture the gears are typically large and spread out spatially which makes them vulnerable to motion through changes in sea state. Key sources: Pinnegar et al. (submitted); Westlund et al. (2007).

UK industry views: There are good examples of gear loss in winter storms and in terms of deployment there are some moves towards pumping fish on board at the stern rather than alongside as this is safer.

Rationale for scoring as a high risk: Given the wide ranging examples provided by industry stakeholders and the direct relationship between sea state and deployment of gear this issue is highlighted as a high risk.

Shellfish

a) Fishery resources:

i. Presence of Harmful Algal Blooms (HABs) due to air or sea temperature change; increased storminess and waves; changes in rainfall / run-off.

Range of impacts identified (threats): Changes in the distribution and abundance of harmful algal blooms is affected by changes in temperature, storminess and run-off. Key sources: Pinnegar et al. (2012); Bresnan et al. (2013).

UK industry views: Not specifically referenced in discussions but shellfish farmers were less represented than whitefish and pelagic fishermen.

Rationale for scoring as a high risk: Although the incidence of HABs is variable over space and time, it will be important to try and understand the impacts of climate change on HABs. Whilst these

changes mean that HABs could decrease in some areas, the economic consequences of closures of shellfish harvesting areas would mean negative consequences are more severe than any positive effects of reduced HABs.

ii. Presence of pests or disease due to changes in rainfall / run-off.

Range of impacts identified (threats): Of particular interest here is norovirus which can be linked to storm overflows causing untreated sewage to enter shellfish harvesting waters, resulting in high concentrations of norovirus. This is then transmitted to humans through consumption of oysters and mussels harvested in these waters which can subsequently lead to secondary infections as it is highly contagious. Key sources: Pinnegar et al. (2012); Baker-Austin et al. (2013).

UK industry views: The need to consider the impacts on pollution was highlighted as an issue that needs to be considered, particularly in relation to sewage overflows and water quality in shellfish growing areas.

Rationale for scoring as a high risk: Population pressure and climate change could increase the risk of sewer overflows (and hence the incidence of norovirus) in the future.

iii. Changes to the year-class strength of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): The link between water temperature and recruitment success (year class strength) is well established. There will be winners and losers, for example Isle of Man scallop recruitment appears to be positive related to sea temperature and links to climate warming with Nephrops have been suggested. Edible crab could be negatively affected. Key sources: Cheung et al (2012); Pinnegar et al. (2013).

UK industry views: Changes in year-class strength widely noted as part of the wider issue of fish biology.

Rationale for scoring as a high risk: Given the known sensitivity of recruitment of commercial fish and shellfish to sea temperature, and the critical importance this has on stock levels then this has to be considered an important issue.

iv. Presence of non-natives / jellyfish due to air or sea temperature change.

Range of impacts identified (threats and opportunities): Impacts could be both positive and negative as some species are commercially exploitable (albeit to the detriment of native species) like pacific oyster, as well as razor and manila clams. Other species that are becoming established with climate change are negative like the slipper limpet and rapa whelk, as well as the carpet sea squirt which can foul shellfish equipment and support structures. Key sources: Cook et al. (2013).

UK industry views: Impacts of non-natives are already apparent with the establishment of pacific oysters. Jellyfish appear to be a big issue in some years but not others, although they do seem to like warm waters (e.g. high prevalence in Gulf Stream waters around the UK).

Rationale for scoring as a high risk: Non-natives have an important impact on the relative abundance and distribution of commercial exploitable shellfish and as climate change facilitates the movement of non-natives around the British Isles this is likely to be important well into the future. Jellyfish are relatively understudied but could have important links to climate change and shellfish.

v. Changes to the distribution of target species due to air or sea temperature change.

Range of impacts identified (opportunity): There are strong indications that squid are becoming more abundant in response to climate change. Impacts on other species (such as Nephrops) are less conclusive and more research is needed in these areas. Key sources: Pinnegar et al. (2013); Cheung et al. (2012).

UK industry views: We have all seen changes in distribution of target species (e.g. the Wash was a pink shrimp fishery, now it is a brown shrimp fishery). Squid are also being worked much further north than they used to be.

Rationale for scoring as a high opportunity: Off North-east Scotland, More boats are actively trawling for squid than traditional capture species such as cod and haddock.

vi. Changes to the growth rate of target species due to air or sea temperature change.

Range of impacts identified (threats and opportunities): Similar to recruitment, changes in growth rate are starting to be linked to changes we are seeing now with positive links to scallops, spider crab and possibly Nephrops being suggested, with some negative impacts on

other species such as edible crabs in some areas. Key sources: Pinnegar et al. (2013); Cheung et al. (2012).

UK industry views: Changes in growth rate widely noted as part of the wider issue of fish biology.

Rationale for scoring as a high risk: Like recruitment, growth rate is linked to temperature which could be an issue for the industry.

b) Offshore operations

i. Physical working conditions for staff due to increased storminess and waves.

Range of impacts identified (threats): Risk of physical injury or death from collision with equipment on board or drowning at sea. Any change in wave and wind conditions would have a direct effect on safety at sea. Key sources: Pinnegar et al. (submitted); Roberts (2009).

UK industry views: Waves are threatening crew on existing decks where fish is being pumped from alongside. Risks are seen as generally higher for the smaller inshore vessels that are out more regularly compared to larger vessels. Inshore vessels can also be 'over-extended' into offshore waters thereby compromising the basic safety of the crew.

Rationale for scoring as a high risk: The high risk score given reflects the high risk nature of the industry. Risk should be considered higher for smaller whitefish and shellfish capture vessels than the pelagic fleet.

ii. Deployment / performance of gear due to increased storminess and waves.

Range of impacts identified (threats): Stormy conditions make it difficult to deploy gear, and once it is deployed then there is the risk of damage or loss of equipment. The types of gear identified as being at highest risk are trawls and dredging. For bottom trawling, the operating thresholds are typically lower and bouncing of gear can affect performance. Key sources: Pinnegar et al. (submitted); Westlund et al. (2007).

UK industry views: The smaller inshore fleet which are out more regularly are likely to be more vulnerable than larger, more stable vessels that are not out at sea as much. There are good examples of gear loss in winter storms.

Rationale for scoring as a high risk: Given the wide ranging examples provided by industry stakeholders and the direct relationship between sea state and deployment of gear this issue is highlighted as a high risk. As with physical

working conditions for staff, risk should be considered higher for smaller whitefish and shellfish capture vessels than the pelagic fleet.

iii. Damage to fleet due to increased storminess and waves.

Range of impacts identified (threats): Physical damage to the structure of the boat as a result of storm conditions. Key sources: Pinnegar et al. (submitted); Westlund et al. (2007).

UK industry views: The smaller inshore fleet which are out more regularly are likely to be more vulnerable than larger, more stable vessels that are not out at sea as much. Smaller vessels are likely to be most vulnerable to changes in storms and sea state.

Rationale for scoring as a high risk: Whitefish and shellfish vessels are typically smaller than the pelagic fleet and go out more of the year.

Part 2. Onshore: onshore operations

a) Ports and harbours

i. Damage to site infrastructure due to sea level rise and extreme water levels; increased storminess and waves; increased rainfall / runoff.

Range of impacts identified (threats): For sea level rise, timing of impact reflects consideration in port ARP reports (ABP; Milford Haven, Felixstowe) that mid-century is likely time when this would become an issue for sites. This could have important consequences (e.g. flooding of infrastructure, cutting off power) and was highlighted as a medium to high risk in the Felixstowe ARP report. Important consequences identified across the port ARP reports include overtopping of sea defences, damage to seawalls, damage to physical infrastructure, loss of equipment (e.g. fish boxes), all of which could have significant cost implications, as well as disruption to operations or even temporary closure of the port. Changes in storminess would affect a wide range of issues such as power outages, pilotage / cranes, general repairs and VTS. Regarded as one of highest scoring risks in both ABP ARP reports and the Felixstowe ARP report. There is a medium risk from damage to infrastructure through terrestrial flooding. According to the Felixstowe ARP, whilst this would be expected to have less impact than overtopping of quay by extreme water levels, impacts could become apparent sooner. Key sources: ABP (2011); Felixstowe (2011); Milford Haven (2011).

UK industry views: Considerable damage from storms and waves have been experienced in recent years, resulting in significant port and onshore damage. This includes at large ports such as Fraserburgh (e.g. December 2012) and across numerous smaller ports (especially in the south west) during the stormy winter season of 2013 / 14. Flooding of onshore facilities from high rainfall is also an issue (e.g. at Eyemouth harbour).

Rationale for scoring as a high risk: The high risk score reflects the importance afforded to this issue from other relevant ARP reports (e.g. those produced by ABP; Milford Haven, Felixstowe) and recent experience of significant impacts experienced by the industry (this relates to all the climate drivers). Consideration will also need to be given to differences in vulnerability between small and large ports to these impacts.

ii. Damage to boats within ports / harbours due to increased storminess and waves.

Range of impacts identified (threats): Important consequences identified include boats breaking loose from their moorings and being damaged (with knock-on effects for insurance premiums), disruption to operations and loss of income. Key sources: ABP (2011); Felixstowe (2011); Milford Haven (2011).

UK industry views: Damage to vessels should be considered as important an issue as damage to port infrastructure. Damage to boats in port could be critical and one off big storms could lead to considerable damage.

Rationale for scoring as a high risk: The high risk score reflects the importance afforded to this issue from other relevant ARP reports (e.g. those produced by ABP; Milford Haven, Felixstowe) and the high number of stakeholders commenting on the potential importance of this as an issue for the industry.

iii. Integrity of electricity supply due to increased rainfall / runoff.

Range of impacts identified (threats): Important consequences identified include power supplies disrupted due to offsite disruption to the network, flooding of sub-stations, high voltage power supplies to cranes cut off. Key sources: ABP (2011); Felixstowe (2011); Milford Haven (2011).

UK industry views: The integrity of electricity supplies was highlighted as being an important consideration.

Rationale for scoring as a high risk: The high risk score reflects the importance afforded to this issue from other relevant ARP reports (e.g. those produced by ABP; Milford Haven, Felixstowe) and the high number of stakeholders commenting on the potential importance of this as an issue for the industry.

b) Employment and fishing communities

i. Integrity of housing and local amenities due to sea level rise and extreme water levels; increased storminess and waves.

Range of impacts identified (threats): Impacts of coastal flooding and storms include those affecting local amenities for the industry including damage to net stores, markets, etc as well as housing. Key sources: Pinnegar et al. (2012); Zsomboky et al. (2011); Joseph Rowntree Foundation (2011).

UK industry views: Although not widely cited given the indirect nature of the risk, recent impacts on local housing and amenities were documented at large fishing ports (e.g. around Peterhead) which had led to difficulties in both obtaining insurance and selling properties.

Rationale for scoring as a high risk: The 2012 UK Climate Change Risk Assessment suggests that the number of residential properties at significant risk of coastal flooding will increase substantially in the future in response to climate change. The risk is greatest around the Humber. For storms and waves, the risk reflects impacts on port and harbour infrastructure. If impacts occur around areas of coastal deprivation, this would increase vulnerability.

ii. Days at sea due to increased storminess and waves.

Range of impacts identified (threats): Boats are tied up in harbours for prolonged periods of time affecting revenues, prices and profits. Key sources: Pinnegar et al. (submitted).

UK industry views: During the stormy 2013 / 14 winter fishing vessels were tied up for many months at a time. Smaller ships are more affected by high winds speeds than larger boats and there are issues with beach landings for coastal fisheries if the sea and swell conditions are too

rough for launching or landing. This is less of an issue for larger vessels in the pelagic fleet that are more stable and don't have to go out in all conditions. The smaller, inshore fleet is most likely to be vulnerable to these disruptions. Where small vessels are used to transport fishermen to larger vessels then storms may prevent fishermen leaving the shore in the first place.

Rationale for scoring as a high risk: The winter of 2013 / 14 showed how much the fleet can be disrupted (for example some boats were tied up for many months on end in the south-west) suggesting there are significant implications for livelihoods, at least for the more vulnerable inshore fleet with smaller sized vessels.

c) Transportation of catch

i. Disruption to ferry service due to increased storminess and waves.

Range of impacts identified (threats): Important consequences identified include disruptions to ferry services between Scottish islands and between the UK and the mainland. Key sources: Coll et al. (2013).

UK industry views: In some places, e.g. Shetland and Orkneys, the industry is completely reliant on these services for the transportation of catch. Disruptions to ferry routes are almost of particular importance to the south-west of England where a lot of material is transported to the continent on articulated lorries and channel ferries.

Rationale for scoring as a high risk: The high risk score reflects the importance that disruptions to ferry services can have on the transportation of catch within the UK as well as to the continental markets.

d) Processing of catch

i. Damage to site infrastructure due to sea level rise and extreme water levels; increased storminess and waves; increased rainfall / runoff.

Range of impacts identified (threats): Important consequences identified include damage to physical infrastructure, loss of equipment, damage to stock as well as disruption to operations or temporary closure of site.

UK industry views: Whilst there was less direct experience of impacts on infrastructure when compared to ports and harbours, where

operations are in close proximity then it is assumed the level of damage to infrastructure would be similar in nature.

Rationale for scoring as a high risk: The high risk score reflects the importance afforded to impacts for port and harbour infrastructure and in other relevant ARP reports (e.g. those produced by ABP; Milford Haven, Felixstowe) and the perceived importance of impacts by the industry.

ii. Integrity of electricity supply due to increased rainfall / runoff.

Range of impacts identified (threats): Important consequences identified include power supplies disrupted due to offsite disruption to the network, flooding of sub-stations, high voltage power supplies to crane cut off.

UK industry views: The integrity of electricity supplies is highlighted as being an important consideration for disrupting processing activities.

Rationale for scoring as a high risk: The high risk score reflects the importance afforded to this issue for port and harbour operations and from other relevant ARP reports (e.g. those produced by ABP; Milford Haven, Felixstowe) and the high number of stakeholders commenting on the potential importance of this as an issue for the processing industry.

INTERNATIONAL

The key risks to the international system, highlighted in Chapter 4, are now discussed further. In particular, the inputs from industry are reported. Also set out briefly below is the rationale for the risk scoring based on both primary and secondary sources of evidence.

Part 1 Offshore: fishery resources and offshore operations

This section considers the effects of climate change on the marine ecosystem and how this impacts upon fishery resources. It also considers climate change effects on the ability to operate offshore i.e. the ability to catch in an efficient, effective and safe manner. The implications for international fisheries overall are discussed first and subsequently specific fishery resource issues for whitefish, pelagic and shellfish are considered in turn.

The potential effects of climate change on the international system include both threats and opportunities: with respect to fishery resources, at a national or regional level there are likely to be winners and losers. Impacts will arise mostly from increasing air / sea temperature, ocean acidification, spread in the extent of 'dead zones' and, for operations at sea in particular, increased storminess and waves. Locally, coastal fisheries may be impacted by greater freshwater run-off.

On fishery resources, the projected effects of climate change are expected to overlie and may exacerbate other changes. These other factors are likely to include over-fishing as well as the known variability with the oceans including notably the variability of the El Niño Southern Oscillation (ENSO) in the Pacific.

Moreover, fishery resources and supply is impacted upon not only by the complex interaction between natural and anthropogenic-driven climate effects but also on the resilience and capacity to adapt of national economies and their indigenous fisheries. Moreover, there is an acknowledgement of increasing uncertainty when seeking to link projected climate change effects with ecosystem change and with downstream socio-economic outcomes.

Whitefish

a) Fishery resources

Range of potential impacts identified. As with the domestic system, whitefish stocks internationally are likely to be impacted by changes in year-class strength of target species, growth rate, species phenology and presence of invasive species as a consequence of climate change. The nature, timing and scale of impacts due to these factors are likely to vary internationally by geography and stock: the present research is not designed to ascertain threats and opportunities associated with fish biology and species developments at a comparable level of detail to target species in the domestic system.

Locally, fisheries may also be impacted by increased freshwater run-off which pushes stocks offshore at or beyond the operating limits of smaller vessels.

Whitefish species are also expected to be impacted by changes to sea temperature in a warming world. At a regional scale and of relevance to UK importers, the key impacts are

those expressed in projections of substantial shifts in commercially targeted species and catch potential. The international literature reports projections on:

- Migration of species towards higher latitudes, with:
 - o opportunities from increased catch potential in higher latitudes, and
 - o threats from reduced catch potential in lower latitudes.
- Retreat of Arctic sea-ice:
 - o bringing opportunities from the opening up of new fishing grounds.

UK industry views. For UK stakeholders with an interest in whitefish imports from the international system, these factors are most relevant to the extent that they impact on the security and cost of supplies over time. Security issues may be impacted by issues around ease of trade in supplies from different EEZs. Cost of supplies may be impacted upon by changes in competition in the international market for particular species as a stock's location and / or productivity changes.

In more detail, UK industry stakeholders offered the following views on threats and opportunities associated with whitefish from within the international system:

- The changes may lead to the introduction of new species or increased stocks of existing species in Arctic and sub-Arctic areas – the commercial value of these will need to be assessed (e.g. *“what value is there in the forecast increase in polar cod?”*)
 - o To establish whether the fish can be commercially fished, it is important to assess if they are economic to process, meet consumer tastes, have suitable large biomass, and are suitable substitutes for existing supplies.
- In the context of distributional shifts, as well as considering the market for new species it will be important not to over-exploit declining fisheries.
- Where there are major geographic shifts in stock, increased use of processing at sea could be one coping strategy for vessels accessing more distant grounds. One contributor referred to the Alaskan pollock fishery: *“Presently much is frozen at sea (headed and gutted). This may then be sent to China, defrosted and reprocessed for onwards sale in Europe.*

A potential option is to invest capability for frozen at sea graded fillets and sell these direct to market.”

- o contributors point to demonstrable resilience and adaptability of the Alaskan fisheries.
- Shifts in distribution will challenge fisheries governance and quota arrangements: one contributor noted concerns that *“there could be incentives for existing stakeholders to take as much fish as possible before a fish resource disappears. This would reduce the fish stock for new stakeholders in those jurisdictions towards which fish are migrating.”*

Rationale for scoring. Evidence for climate change driven by increasing air / sea temperature and its impact upon species distribution and the retreat of Arctic ice is provided with a high degree of confidence (e.g. see IPCC, 2014 and Brander, 2010).

On this basis, a high score for the threats to and opportunities for the international system overall can be justified. However, for those UK industry stakeholders that are import-reliant, the level of threat or opportunity, and nature of appropriate responses (see later) need to be qualified based on the industry views summarised above.

Pelagic

a) Fishery resources

For the international system overall, the principal climate driver is change in sea temperature which is expected to cause changes in species distribution and fisheries productivity. However, as with the domestic system, individual species and fisheries may also be impacted by changes to year-class strength (including larval survival) and alterations in species phenology. Nearshore pelagic fisheries may be impacted by increased run-off.

Range of potential impacts identified. There is expected to be substantial impact on tuna fisheries, notably in the distribution of tuna stocks in the Pacific and Indian oceans. However, the nature of the change is expected to vary between different species of tuna (see Annex 7). Shifts in distribution will challenge fisheries governance arrangements where there are substantial movements of stock across international boundaries.

The other major threat to pelagic stocks within the international system is to the anchovy and sardine fisheries off the Pacific coast of South America. This is of global significance as the fisheries

offshore Chile and Peru are the major source of anchovies which in turn are a key source of feed for the aquaculture industry. However, historically these fisheries are known to have varied widely in terms of stock levels and productivity. There remains a scientific debate over the extent to which the threat to them comes from natural fluctuations in coastal upwelling at the Pacific margin alone (linked to the ENSO) or from this phenomenon exacerbated by climate change.

The impact of climate change on mackerel in the North Atlantic is discussed in the context of the domestic system.

UK industry views. For UK stakeholders with an interest in importing pelagic fish from the international system, these factors are most relevant to the extent that they impact on the security and cost of supplies over time. In the case of tuna, this is a relatively high value, traded species in the international market and UK importers can to a large degree operate flexibly to buy supplies from whatever sources are available. Whilst the impact on climate change on tuna is expected to be shifts in distribution, the threat to the main anchovy fishery is one of substantial reduction in productivity or collapse. This is likely to reduce capacity to supply within the international market and place greater demands on other sources of anchovy internationally with possible consequences for market prices.

In more detail, UK industry stakeholders offered the views on threats and opportunities associated with pelagics from within the international system reported below:

- There is already a good level of awareness and understanding of the shifting stock distributions (of whatever cause) amongst Regional Fisheries Management Organisations (RFMOs) within the international system as they are dealing with highly migratory species – more so than in fisheries management of the North Atlantic.
- It is relevant for all fisheries management bodies to take on board and assess critically the projected effects and consequences of climate change and to build appropriate responses into their forward plans.
- In terms of the anchovy and sardine fisheries in off the Pacific coast of South America, monitoring already occurs in relation to El Nino (when the upwelling of nutrients is

disturbed and this disrupts the fishery). The importance of considering climate change is to determine the likelihood of a more permanent shift in species distribution. As one industry contributor noted, this could make the present the fleet and processing facilities unviable: it is argued that *“with a dependence on fresh anchovy, a long distance fleet is not feasible and feedplant supplies would decline”*.

Rationale for scoring. Evidence for climate change driven by increasing air / sea temperature and its impact upon the distribution of tuna is provided with a high degree of confidence (e.g. see IPCC, 2014 and Bell et al, 2013). The threat to the anchovy fishery is regarded as severe although the appropriate level of attribution to climate change is less clear cut (e.g. see Pörtner et al, 2014).

On this basis, a high score for the risks to the international system overall can be justified. However, for those UK industry stakeholders that are import-reliant, the level of threat and nature of appropriate responses (see later) need to be qualified based on the industry views summarised above. In particular, importers are confident in their flexibility to source supplies of tuna from wherever they are made available.

Shellfish

a) Fishery resources

For shellfish in the international system a number of climate drivers are likely to in play viz. rise in air / sea temperature, increased storminess, ocean acidification and greater rainfall / run-off.

Range of potential impacts identified. As with the domestic system, shellfish resources internationally are likely to be affected adversely by increased presence of pests and diseases and an increased in harmful algal blooms (HABs). Increased rainfall / runoff may pollute coastal fisheries. The distribution and abundance of HABs is affected by changes in temperature, storminess and run-off.

Also, changes may occur in year-class strength or growth rate of target species, distribution of target species and introduction of non-native species, each of which may have adverse effects or bring opportunities in specific instances. The main climate driver in play here is change in sea temperature.

The nature, timing and scale of impacts due to these factors are likely to vary by geography and species. Although the present research is not designed to determine the extent of all such threats and opportunities at a comparable level of detail to target species and stocks in the domestic system, it is appropriate to comment further on two issues.

The adverse effect of increased ocean acidification on invertebrates is already being felt and projected to continue in coral ecosystems. These in turn are especially important habitats for fish in the tropics. Corals are also impacted adversely by 'bleaching' which is due to stress induced by changes in conditions such as temperature, light or nutrients (which results in them expelling the symbiotic algae living in their tissues, causing them to turn white).

Of shellfish fisheries in the international system, the cold-water prawn fisheries of the North Atlantic is of particular importance to the UK, with Canada and Denmark being key countries from which imports are sourced. Increased acidification is a particular threat to the health of this fishery and changes to sea temperature are likely to impact its geographic distribution directly or its productivity indirectly as a result of the impact of temperature on cod stocks with which prawn appears to have an inverse relationship (see below).

UK industry views. For UK stakeholders with an interest in importing shellfish from the international system, these factors are most relevant to the extent that they impact on the security and cost of supplies over time. Potentially the greatest and most direct concern with the effects of climate change in terms of UK importers is in relation to cold-water prawn, its availability and price, and its quality.

In more detail, UK industry stakeholders offered the following views on threats and opportunities associated with shellfish fisheries within the international system:

- If cold-water prawn stocks shift further north over time it may be harder for vessels to catch as the stock may be under ice or under another jurisdiction.
- Because of climate change and other factors there is already a change in when young are produced with the result their survival rates are decreasing. However, it is acknowledged

that as these changes oscillate the longer term effects of a change in temperature may be hidden. According to one stakeholder the concern is that: *“some stocks may get a short term increase but then suddenly a crash in CWP occurs akin to Grand Banks cod.”*

- In the Barents Sea / North Atlantic, there is an inverse relationship between the cod and prawn stocks: as cod increases, prawn decreases. One contributor recalls that a decline in prawn was seen in offshore Canadian waters as cod stocks were high, followed by an increase in inshore Canadian prawn stocks as cod was reduced off Canada.
 - o The role of climate change amongst other natural variables seems more difficult to discern with certainty: one contributor notes that in the Canadian waters of the North West Atlantic, there is confidence in following advice from the International Council for the Exploration of the Sea (ICES) as it is seen to have been appropriate historically in leading to the return of cod on the Grand Banks.
- The significance of changes in cold-water prawn goes beyond (just) commercial implications. As one industry expert noted: *“CWP are so far down the food web (with zooplankton) they are like a leading indicator”* of change in the marine ecosystem.
- The industry, through the Cold Water Prawn Forum (CPF), is already aware of the effects of climate change but its challenge is to convert this into action: for example *“what can we do about acidification?”*

Rationale for scoring. Evidence for climate change driven by increasing air / sea temperature, increased storminess, ocean acidification and increased rainfall / run-off is reported with a high degree of confidence (e.g. see IPCC, 2014 and Pörtner et al, 2014).

On this basis, a high score for the risks to the international system overall can be justified. However, for those UK industry stakeholders that are import-reliant, the level of threat and nature of appropriate responses (see later) need to be qualified based on the industry views summarised above. As with other fisheries, the prime commercial concern of importers, at least over the short to medium term, is with any threat of wholesale collapse to a particular fishery where no accessible, affordable substitute source is readily available. For UK shellfish importers, one stock (s) 'to watch' at present would appear to be that of cold-water prawn.

Offshore operations

Range of potential impacts identified. In principle, for wild capture operations generally the potential consequences may include: (a) fleets having to adjust to operating in more distant grounds as stocks migrate, with implications for example for sea-worthiness of smaller vessels (whitefish and shellfish vessels are typically smaller than those in the pelagic fleet and operate at sea for more of the year); (b) implications for the deepwater fleet, for example through demand for more offshore processing / freezing capacity if spending longer at sea to fish more distant grounds, operating in more hazardous sea conditions, with implications for safety and for 'downtime'; (c) adjusting catching methods to cope with stocks at deeper levels; and (d) diversifying to work with different or multiple species.

One widely reported effect of climate change on international fisheries is shifts in the distribution of species and in catch potential. As well as impacting upon the location of fishing grounds and knock-on effects on national economies reliant on existing wild capture fisheries, substantial geographic shifts in species and stocks will challenge international fisheries governance regimes and may cause international dispute.

There may also be broader implications for food security of climate change impact on fisheries distribution and productivity.

UK industry views. For UK importers, the potential impacts arising from climate change are relevant to the extent that they affect the nature, price and continuity of supplies.

On these specific issues, research with industry stakeholders elicited the following views:

- Consideration is being given by the industry internationally to investing in vessels that can withstand storms. According to one contributor, *“Russians are buying up Norwegian vessels that come on the market with the understanding these will have a 15-year lifespan. Norwegians meanwhile are building new boats.”* More generally, it is argued for example that Icelandic, Norwegian and Russian fleets in the North Atlantic and Arctic, being already familiar with severe conditions, are well placed to adapt if required. In any event, fleets have already changed considerably from the years in which fishermen manually hauled fish and were

exposed: modern deepwater vessels have more enclosure, and in the case of factory ships the crew works below deck.

- Notwithstanding any increased threat to vessels and fishing gear at sea due to climate change, the industry must always strive to use the best gear, best methods and have concern for ethical practice.

In short, the overall view on risks to operating conditions at sea with increased storminess and waves are not rated as having major consequences for current deepwater fleets and more broadly, not considered a major concern for UK importers for the foreseeable future.

On the broader matter of food security, UK industry stakeholders offered the following views:

- From a UK importers' perspective, maintaining flexibility and a spread of suppliers makes business sense going forward.
- Notwithstanding this, access to risk assessments for particular sources in the face of climate change will be useful for strategic business planning for certain companies, especially larger firms with integrated supply chains.
- Threats to fishery productivity in lower latitudes may catalyse further investment overseas in order to diversify into aquaculture – one contributor pointed to Thailand as an example of where this has been accomplished.

Rationale for scoring. The evidence from the international literature provides projections for the intensity and frequency of storms due to climate change and considers the implications for offshore operations (see e.g. Cochrane et al, 2009; OECD, 2010; and Leurig, 2011).

On this basis, a high score for the risk to the international system overall can be justified. However, for UK industry stakeholders the level of risk to them and the nature of the appropriate responses (see later) must be qualified based on the industry views summarised above.

Part 2 Onshore: Onshore operations

Range of potential impacts identified. The potential effects of climate change on onshore operations within the international system are likely to be adverse. Impacts may arise from progressive sea-level rise; from such a rise reaching key 'threshold' levels in particular locations; from more intense storms and storm surges; from temperature change; and from increased rainfall and run-off events.

The extent of these impacts will vary with geography e.g. longer term projections of sea level rise due to climate change will be moderated in places by isostasy i.e. it is relative sea-level rise that is key at a regional level; mid latitude regions in the Pacific and Indian oceans are likely to experience the worst effects of the increased intensity of tropical storms that are projected; the loss of Arctic ice arising from temperature changes; the impact of increased rainfall and intense run-off events will depend on local drainage conditions.

In principle, for the wild capture seafood industry, these climate change effects may impact onshore operations in a number of ways: damage to ports / harbours and / or longer term decline in their operational effectiveness; damage to vessels and gear within harbours; the opening of new navigation and international maritime transport routes in the Arctic (Beniston, 2010; Anon, 2014a; IPCC, 2014); damage to facilities such as processing plant located at coastal sites; damage to other infrastructure (e.g. transport, energy) on which the local seafood industry relies.

UK industry views. Amongst UK seafood industry stakeholders, views of the significance of these potential threats to onshore operations depend on several factors: (i) the nature of the supply chain of individual companies – whether integrated or not; (ii) the extent to which the imported species is traded internationally and can be sourced from different places i.e. importers are not wholly dependent on sourcing from a narrow geographical area; (iii) the capacity of the threatened location to respond and repair.

On these specific issues, research with industry stakeholders elicited the following views:

- Threats of extreme events damaging vessels in port should be given as much consideration as threats to ports / harbours themselves – among other things, this leads to operational downtime and has implications for insurance premiums.

- Extreme events can threaten onshore infrastructure at overseas locations.
- However, most large importers have flexibility / contingency plans as they recognise these types of disruption to supply can happen. These are likely to be sufficient in most circumstances. So long as the target species remains available from somewhere, most UK importers and their business customers will react and adapt.

The UK seafood industry may have a specific interest where it has invested for the longer term in facilities at particular overseas location and / or where there could be a substantial disruption to supplies. In these situations, there is merit in the relevant firms being more aware and gaining early warning of adverse impacts of climate change that may occur over (say) the next 10 years. This is especially relevant for UK interests in the development of new coastal facilities ('new builds') in support of the industry. There is a recognition that the present state and likely resilience of infrastructure and facilities at overseas locations is highly variable. One contributor advised that whilst generally conditions are poorer in equatorial regions, there are exceptions – *"Sri Lanka has very good facilities having seen improvements made through third party investments"*.

On resilience, it is argued that such onshore threats would be rated as low priority in a place such as Alaska. An industry informant notes: *"Where there is damage to infrastructure the response in Alaska would be swift. For example, in the 1960s an earthquake and subsequent tsunami wiped out all onshore facilities in Kodiak, yet six months later processing activity was back in action. Another example was the deliberate beaching and converting of a World War II liberty ship (the 'Star of Kodiak' operated by Trident Seafoods) in order to create a processing facility and subsequent onshore infrastructure"*.

One respondent from a large import-dependent UK business illustrated further some of the issues involved: *"For Skipjack tuna, for example, we have several sources. This type of flexibility works for us except in the relatively rare situations of having a very discrete source fishery, or where all fisheries are affected at the same time. When the tsunami affected the Indian ocean, its tuna fishery took a number of months to get back up and running"*.

Rationale for scoring. The evidence from the international literature provides projections for the longer term rise in global sea level, increasing intensity of storms and increased rainfall / run-off due to climate change. Projections on sea-level, storminess and run-off are provided by with a high degree of confidence (see IPCC, 2014: Michel, 2012: and Cochrane et al, 2009).

On this basis, a high score for the risk to the international system overall can be justified. However, for UK industry stakeholders the level of risk to them and the nature of appropriate responses (see later) must be qualified based on the industry views summarised above. It appears that larger importers at least are confident in their existing capacity to react and adapt as required in many if not all circumstances, at least when looking ahead over the short to medium term.

Annex 9: Potential seafood industry adaptation responses drawn from the literature

Potential seafood industry adaptation responses based on the literature are provided here for both

domestic and international systems. The following adaptation responses were not captured directly from stakeholder sources but should be considered based on relevant literature and experiential knowledge of the industry.

Table A9.1 DOMESTIC Adaptation responses – suggestions drawn from the research evidence for future consideration

		System	Adaptation response	Owner	Scale of resource			
					Minor	Moderate	Significant	Major
Speed of response (inertia)	Underway	Fishery	Research: explore climate variability and fish stocks	UK / EU research community				
		Fishery	Research: explore fish response to climate change	UK / EU research community				
		Fishery	Research: provide seasonal to decadal forecasts on marine climate	Met Office / CEFAS				
		Fishery	Set TACs based on medium term forecasts	ICES				
		Fishery	Change gear type to exploit target species increasing in abundance	Industry				
		Fishery	Deal with choke species	Industry				
		Fishery	Consider climate change impacts in fisheries (EU fisheries policy)	EU / Govt / scientists / industry				
		Communities	Research: vulnerability studies	Joseph Rowntree Foundation				
	Immediate (<2 years)	Fishery	Improve consumer education to reflect changing species	Govt / Trade Associations / retailers				
		Fishery	Use economic incentives to support switching gear / target species	Govt / Trade Associations / retailers				
	Short term (2-5 years)	Fishery	Research: explore impacts of, and response to climate change	EU / Govt / scientists / industry				
		Offshore	Safety review into staff working conditions to reduce risk to staff	Industry with support from trade associations				
		Offshore	Safety review into working practices and safety limits on gear use	Industry with support from trade associations				
		Ports	Incorporate climate change into company risk register	Port / harbour authorities				
		Ports	Monitor risk of extreme water levels and analyse tide gauges	Relevant FRM delivery bodies				
		Ports	Review the design and service life of major structural assets	Port / harbour authorities				
		Ports	Research: explore climate impacts on insurance and customers	Relevant FRM delivery bodies				
		Ports	Review flood plan to protect electricity substations from flooding	Electricity suppliers				
		Communities	Support income diversification of crew	Industry				
		Medium term (5-15 years)	Fishery	Invest in gear to take advantage of abundant new species	Industry			
Ports	Ensure integrity and security of storage sites		Port / harbour authorities					
Ports	Review / adapt site drainage to improve surface water run-off		Relevant FRM delivery bodies					
Long term (>15 years)	Fishery	Review closed areas if protected species are moving out	EU / Govt / scientists / industry					
	Ports	Consider moving mooring locations to reduce exposure	Port / harbour authorities					
	Ports	Protect electricity supply e.g. move to underground cables	Electricity suppliers					
	Ports	Invest in new quay designs that follow best practice and standards	Port / harbour authorities					

DOMESTIC

Offshore: Fishery resources – Whitefish, pelagic and shellfish capture fisheries

- **Research:** There is a long history of academic research on links between climate variability and fish stocks, particularly in the North Sea.
- **Research:** The academic research literature is growing with regards to fish responses to climate change, with more papers being published in the last few years than were in the past couple of decades.
- **Research:** There is a growing body of work in the UK, notably by the Met Office, looking to provide seasonal to decadal forecasts of marine climate. If these prove to be of sufficient skill they could help fishermen plan for the season ahead.
- **Setting TACs:** International Council for the Exploration of the Seas (ICES) set total allowable catches (TACs) every year based on a medium term forecast.
- **Changing gear type:** Changes in gear type to exploit target species that are increasing in abundance (e.g. squid off NE Scotland).
- **Dealing with choke species:** The industry is already having to learn to cope with choke species (e.g. hake) that may be becoming more abundant as a result of climate change.
- **EU fisheries policy:** A new EU Common Fisheries Policy (CFP) has come into force which is supposed to take greater account of climate change impacts.
- **Education:** Improve education to encourage consumers to adopt changing domestic fish species.
- **Switch gear / target species:** Economic incentives to switch target species or use other gear.
- **Research:** More research on:
 - The impacts of temperature change on the growth rate of key target species.
 - The response of specific high value fisheries (especially nephrops) to climate change impacts.
 - Separating out pressures on the marine environment coming from climate change versus fishing pressures so that correct management decisions can be taken.
- The social and economic consequences of climate change.
- The influence of climate change on primary productivity in climate models, which is highly sensitive and has a big influence on food web dynamics.
- The relationship between temperature and recruitment, and the exploration of whether seasonal forecasting can be used to inform fisheries management.
- Impacts on the fish processing sector.
- Vulnerability studies for small vessel operators.
- **Gear investment:** Further investment in gear to take advantage of increasing abundance of warm-water species.
- **Review closed areas:** Review fishery closure areas (and move them) if the species they are protecting are moving away from those areas (e.g. as has happened with the North Sea Plaice Box).

Offshore: offshore operations

- **Safety review:** Review limits of safe working conditions and measures in place to reduce risk to staff.
- **Safety review:** Review working practices and safety limits in place for operating gear.

Onshore: onshore operations

- **Risk register:** Incorporate climate change into the company risk register for the port / harbour authority.
- **Monitoring risk:** Monitoring extreme water levels and analyse tide gauges.
- **Asset review:** Review the design and service life of major structural assets (e.g. quays, buildings, cranes).
- **Costing risk:** Increase understanding of climate impacts on insurance policies and customer confidence.
- **Flood planning:** Review flood plan to protect against flooding of electricity sub-stations.
- **Integrity of storage:** Make sure storage sites are secure.

- **Adapt site drainage:** Review / adapt site drainage to improve surface water run-off.
- **Mooring location:** Consider moving mooring locations to reduce exposure.
- **Protecting electricity supply:** Move to underground electricity cables to reduce risk of damage.
- **Structural engineering:** New quay designs to follow best practice and legislated standards.
- **Vulnerability studies on coastal communities and social deprivation** have been published (e.g. the Joseph Rowntree foundation).
- **Income diversification:** Diversification of income for crew (e.g. to supporting recreational angling).
- Become fully informed on climate change and keep up to date on research developments.
- Undertake vulnerability assessments to determine where problems or opportunities may occur.
- ‘Look beyond the headlines’ – explore less obvious ways in which climate change could affect daily operations and long-term viability.
- Look for ways to spread risk.
- Develop strategies for increasing resilience to environmental change (e.g. flexible operations, diversification of products and / or income sources) and, where possible, for exploiting new opportunities.

INTERNATIONAL

The table below brings together adaptation responses for the international system based on evidence from three illustrative sources: (i) a general review of typical adaptation responses internationally prepared by Shelton (2014); (ii) a report on climate change implications for one important fishery viz. Alaska (Johnson, undated); and (iii) a report on the cost of adaptation by Sumaila and Cheung (2010) for the World Bank.

Given the scale and diversity of wild capture fisheries internationally and the importance of ensuring any investment in adaptation is suitably contextualised, the content of the table should be taken as indicative rather than comprehensive or wholly representative of what may be required by stakeholders in particular fisheries. The table’s content supplements the information on adaptation actions discussed elsewhere in this report.

In the Alaskan context, Johnson (op. cit.) notes that most public sector (‘planned, top-down’) adaptation programmes are addressing resource depletion more directly than climate change: they focus on promoting biological resilience, stock rebuilding and reducing overcapacity in the fishing fleets. By contrast, the author refers to private sector adaptation measures as ‘mainly reactive’ and ‘bottom-up’) Johnson discusses how Alaska’s fishermen and fishing-dependent communities can adapt. The following steps are proposed:

Johnson (op. cit.) argues that for the Alaska fisheries, the norms with respect to vessels, gear, target species and products, seasonal work patterns, and fishing industry ‘lifestyle’ may need to change over time.

Sumaila and Cheung (op. cit.) in the context of assessing the overall cost of adaptation examine experience to date of adaptation in the wild capture fisheries industry. The authors point to a record of continuous adaptation by the private sector because of declining fish stocks over time.

Offshore: Fishery resources – Whitefish, pelagic and shellfish capture fisheries

- **Reduce external stressors on natural systems** (Shelton, op. cit.).
- **Identify and protect valuable areas** (Shelton, op. cit.). This could include spawning grounds and reefs.
- **Enhanced monitoring and learning from the past** to provide information to feed into adaptive management as well as contribute to understanding what impacts are occurring. Also identification of useful information and where to obtain it e.g. future fish production projections, decision-making tools under uncertainty (Shelton, op. cit.).
- **Improve climate research, monitoring, and forecasting** (Johnson on Alaskan fisheries).
- **Improve communication and information sharing on climate change and fisheries adaptation** to improve collaboration (Johnson on Alaskan fisheries).
- **Establish marine reserves** and other schemes for improving fish stock resilience and rebuilding (Johnson on Alaskan fisheries).

Table A9.2 Adaptation responses – suggestions drawn from the research evidence for future consideration

		System	Adaptation response	Owner	Scale of resource			
					Minor	Moderate	Significant	Major
Speed of response (inertia)	Immediate (<2 years)	Fishery	Enhanced monitoring and learning from the past	Industry / Govt / scientists				
		Fishery	Improve operational efficiencies	Industry				
	Short term (2-5 years)	Offshore	Invest in enhanced early warning and forecasting systems	Industry / Govt / scientists				
		Offshore	Address 'ghost fishing'	Industry				
		Ports	Ensure adequate onshore storage facilities for boats and gear	Port / harbour authorities				
		Socio-Ec	Establish programmes to encourage and assist in diversifying livelihoods	Govt				
		Socio-Ec	Engage in other non-fishing livelihood activities, such as aquaculture and shipping	Industry				
		Medium term (5-15 years)	Fishery	Identify and protect valuable areas	Govt			
	Fishery		Improve climate research, monitoring, and forecasting	Industry / Govt / scientists				
	Fishery		Establish marine reserves	Govt				
	Fishery		Form national and regional strategies to prevent habitat destruction	Govt				
	Fishery		Embed the ecosystem approach to fisheries (EAF) management	Industry / Govt / scientists				
	Fishery		Develop pilot projects intended to foster resource protection and fisheries adaptation	Govt / industry				
	Offshore		Invest in measures to improve safety at sea	Industry				
	Offshore		Reduce overcapacity through permit or vessel buybacks, subsidy reductions	Govt				
	Offshore		Purchase larger, more sophisticated vessels with multi-fisheries capabilities	Industry				
	Offshore		Acquire bigger vessels and sophisticated gear	Industry				
	Offshore		Maintain multiple licenses or permits	Govt / industry				
	Ports		Spatial planning	Port / harbour authorities				
	Ports		Invest in safer harbours and landings	Port / harbour authorities				
	Processing		Development of flexible fish product processing capacity	Industry				
	Socio-Ec		Policy and management considerations in the context of induced socio-economic changes	Govt				
	Socio-Ec		Mainstream fisheries into national climate and food security policy-making	Govt				
	Socio-Ec		Capacity building with civil society, NGOs and Government	Govt / industry				
	Socio-Ec		Spread risk through insurance, cooperatives, and alternative forms of financing	Industry				
	Socio-Ec		Invest in the development of the fish farming sector	Industry / Govt				
	Socio-Ec		Develop and implement disaster risk management (DRM) policies	Govt / industry				
	Long term (>15 years)	Fishery	Reduce external stressors on natural systems	Govt / industry				
		Onshore	Develop IFQs-individual quota management schemes	Govt / industry				
		Socio-Ec	Public sector adaptation responses	Govt				
Socio-Ec		Use of innovative financial mechanisms	Govt / industry					
Socio-Ec		Link local, national and regional policies and programmes	Govt					
Socio-Ec		Alter international trade practices	Govt / industry					

- **Form national and regional strategies to prevent habitat destruction** (Johnson on Alaskan fisheries).
- **Embed the ecosystem approach to fisheries (EAF) management** (Johnson on Alaskan fisheries) – encompassing the marine environment and target commercial fish stocks: ensuring adaptive fishery management.
- **Develop pilot projects intended to foster resource protection and fisheries adaptation** (Johnson on Alaskan fisheries).

Offshore: offshore operations

- **Invest in measures to improve safety at sea** in response to more severe weather events (Shelton, op.cit.). For example through investing in larger vessels (Shelton, op. cit.), the author argues that if these vessels were capable of accessing seasonal pelagic species and small enough to also fish for demersal species in other seasons, safety during harvesting would be increased and year-round harvesting options made available.
- Invest in enhanced early warning and forecasting systems for severe weather events (Shelton, op. cit.)
- **Address ‘ghost fishing’** – as storm severity increases, this will result in more gear, such as lobster traps, being lost leading to mortality and habitat damage (Shelton, op. cit.)
The author refers to the use of biodegradable escape panels.
- **Reduce overcapacity through permit or vessel buybacks, subsidy reductions,** and other means (Johnson on Alaskan fisheries).
- **Develop IFQs-individual quota management schemes** (Johnson on Alaskan fisheries).
- **Purchase larger, more sophisticated vessels with multi-fisheries capabilities** (Johnson on Alaskan fisheries) in order to travel farther, to different locations that offer better fishing opportunities, diversify fishing activities, and exploit a wider range of species and stocks.
- **Acquire bigger vessels and sophisticated gear** that allow fishers to stay out fishing for longer (Sumaila and Cheung, 2010).

- **Maintain multiple licenses or permits** to allow shifting from one target species to another (Johnson on Alaskan fisheries).
- **Improve operational efficiencies,** such as fuel efficiency and improved product handling, storage, and preservation (Johnson on Alaskan fisheries). Also relevant onshore.

Onshore: onshore operations

- **Spatial planning** – including the need to think long term about requirements for current coastal activities to shift landwards as shorelines retreat over time.
- **Invest in safer harbours and landings** (Shelton, op. cit.) Part of a wider theme of improving resilience.
- **Ensure adequate onshore storage facilities for boats and gear** to prevent loss or damage from storms and extreme events (Shelton, op. cit.).
- **Development of flexible fish product processing capacity** for utilising ‘emergent’ resources (Johnson on Alaskan fisheries).

Socio-economic conditions

- **Policy and management considerations in the context of induced socio-economic changes** as existing fisheries become less profitable and new ones become available (Shelton, op. cit.). This refers to the FAO Code of Conduct for Responsible Fisheries, precautionary principles, adaptive and ecosystem management.
- **Mainstream fisheries into national climate and food security policy-making** – integrating the fisheries sector fully into climate change adaptation and food security policies at the national level (Shelton, op. cit.).
- **Public sector adaptation responses** include: (a) fisheries buybacks, (b) individual transferable quotas, and (c) livelihood diversification measures (Sumaila and Cheung, 2010).
- **Capacity building** – with civil society, non-governmental organisations (NGOs) and government organisations included in climate change planning, not just technically focused departments (Shelton, op. cit.).
- **Use of innovative financial mechanisms** e.g. insurance, at national and international levels and other instruments to create effective incentives / disincentives (Shelton, op. cit.).

- **Spread risk through insurance, cooperatives, and alternative forms of financing** (Johnson on Alaskan fisheries).
- **Link local, national and regional policies and programmes** and work across both spatial and sectoral frameworks, plans and programmes (Shelton, op. cit.).
- Some countries (e.g. members of the European Union and the United States) buy fishing access rights from mainly developing countries as an adaptation measure to keep their fishing capacity busy and supply fish to meet the growing demand at home (Sumaila and Cheung, 2010).
- **Invest in the development of the fish farming sector** as a means for countries to adapt to declining marine fishing opportunities ((Sumaila and Cheung, 2010).
- **Alter international trade practices** – where these may work against increasing economic diversification of production and exports of high-value-added processed products (Shelton, op. cit.).
- **Establish programmes to encourage and assist in diversifying livelihoods** (Johnson on Alaskan fisheries) - including investment in marine tourism and aquaculture development. Diversifying incomes into non-fishing activities.
- **Engage in other non-fishing livelihood activities, such as aquaculture and shipping** as fish stocks decline, so fishers in both developed and developing countries diversify their income (Sumaila and Cheung, 2010).
- **Develop and implement disaster risk management (DRM) policies** (Johnson on Alaskan fisheries).

Notes

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Seafish

18 Logie Mill, Logie Green Road,
Edinburgh, UK. EH7 4HS

t: +44 (0) 131 524 8697
f: +44 (0) 131 558 1442
e: seafish@seafish.co.uk
w: www.seafish.org

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