Climate change adaptation in the UK (wild capture) seafood industry 2018.

A Seafish/MCCIP Watching brief report. Spring 2019.

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Introduction

- Climate change is a strategic challenge across all UK sectors (including UK seafood). In late 2015, Seafish together with the Marine Climate Change Impacts Partnership (MCCIP) published a review of climate change adaptation for UK domestic and international (wild capture) seafood. This contributed to the UK Government, 'Adaptation Reporting Powers' commitment on climate change, requiring that certain industries or organisations report to parliament every five years.

- The Seafish review concluded that climate change was a challenge for UK seafood, but that industry considers it a 'low priority' relative to other risks. As such a watching brief is to be maintained on climate change developments and their impacts on UK industry. Specifically, seeking regular feedback from industry stakeholders on climate change, impacts and adaptation actions. The findings to be incorporated into Seafish annual horizon reporting.

- This watching brief report considers recent advances in understanding and industry experience of climate change drivers and impacts. Advances in understanding draws on new scientific evidence collated through the MCCIP initiative, experience of these drivers is captured through semi-structured interviews with 13 UK industry stakeholders. Findings are provided for domestic and international seafood, and, where appropriate, by major fish species grouping concerned. This report provides a 'light touch' overview and is indicative only.

2

Scientific evidence

Advances in understanding climate change drivers and impacts

2.1 Physical climate change drivers (sea level rise, temperature, storms and waves, ocean acidification and de-oxygenation, changes in terrestrial rainfall).

In 2017/2018 the winter (DJFM) North Atlantic Oscillation (NAO) index was near neutral, ending a run of four consecutive winters with strong positive index. When the NAO index is positive, there is an increased chance that seasonal temperatures will be higher than normal in northern Europe. During positive phases of the NAO, winds from the west dominate, bringing with them warm air, while the position of the jetstream enables stronger and more frequent storms to travel across the Atlantic supporting mild and stormy conditions for the UK. By contrast when the NAO is negative, winds from the east and north-east are more frequent, bringing with them cold air, while the adjusted position of the jet stream leads to weaker and less frequent storms.

According to the UK Met Office, 2018 was warmer than average for the UK, although not as warm as 2017. May, June, July and December were all much warmer than average. Notable extreme events during the year included a spell of severe winter weather ('The Beast from the East') in late February and early March. The Met Office issued two Red Warnings, and this was the most significant spell of snow and low temperatures in the UK since 2010. High pressure dominated throughout the summer – the warmest for the UK since 2006, the driest since 2003 and the sunniest since 1995. Some rain gauges in southern England recorded more than 50 consecutive dry days and temperatures exceeded 30 °C fairly widely on 15 days during July and August. Nine named storms affected the UK during 2018. Storm Ali in mid-September brought very strong winds to the north and was one of the most notable early autumn storms of recent decades (https://www.metoffice.gov.uk/climate/uk/summaries/2018/annual).

The provisional UK mean temperature for 2018 was 9.5 °C, which is 0.6 °C above the 1981-2010 long-term average, ranking as the seventh warmest year in the historical UK series from 1910. All top-ten warmest years in this series have occurred this century. Summer 2018 was equal-warmest in the UK series, with 1976, 2003 and 2006. The provisional UK rainfall total for 2018 was 1064mm, 92% of the 1981-2010 average, making this a dry year overall although not exceptionally so. Parts of northern Scotland received only 75% of average rainfall. Southern England recorded its driest June since 1925. (https://www.metoffice.gov.uk/climate/uk/summaries/2018/annual).

Sea surface temperatures (SST) in the southern North Sea started the year (2018) with slightly positive anomalies, but were followed by an unusual intensive cooling to negative anomalies in March and April. This drop was followed by an extraordinarily rapid temperature rise from March to July - never witnessed during the past 50 years. The July average temperature of 16.3 °C was the second highest July average recorded during the last 50 years. The annual area-averaged North Sea SST of 10.7 °C was slightly above the climatological mean (ICES, 2019).

[1]. http://www.seafish.org/media/1476673/climate_change_report_-_lr.pdf

[2]. See MCCIP (2017). Marine Climate Change Impacts: 10 years' experience of science to policy reporting. (Eds. Frost M, Baxter J, Buckley P, Dye S and Stoker B) Summary Report, MCCIP, Lowestoft, 12pp.

2.2 Implications (changing catch potential, impacts on offshore operations and assets, impacts on onshore operations and assets).

2.2.1 Domestic system

During February 2018, massive numbers of starfish, crab, mussels and lobsters were washed up on the North Sea coast of the UK, following freezing weather and storms. Animals were piled up along the Holderness coast in Yorkshire and similar mass mortality events were reported in Kent and Norfolk. This followed a sudden 3°C drop in seawater temperature between 26th February and 4th March. Beginning on 22 February 2018, Great Britain and Ireland were affected by a cold snap, dubbed the 'Beast from the East' by the media and officially named Anticyclone Hartmut, which brought widespread unusually low temperatures and heavy snowfall to large areas. All the organisms piled up on the shores were dead, except some commercial-sized lobsters. Yorkshire Wildlife Trust worked alongside local fishers to rescue the surviving lobsters.

An estimated 25,000 lobsters were transported to merchants tanks in Bridlington. The aim was to put the lobsters back in the sea when the weather improved (on 5th March). Such 'cold-snap' events have become relatively rare in recent years, given that winters have tended toward being warmer (on average) than was the case in the past.

Previous cold-snap events such as the 'big freeze' in 1963 witnessed large-scale fish and shellfish die-offs, especially of warm-water species such as sole (Woodhead, 1964), and they remind us that, even though temperatures are generally warming around the UK, cold periods will still occur. On the whole however, 2018 has been identified as the 7th warmest year on record for the UK despite the very cold conditions experienced in February (https://www.metoffice.gov.uk/climate/uk/summaries/2018/annual).

In 2018 both commercial and recreational fishers continued to see large numbers of Atlantic bluefin tuna Thunnus thynnus, especially off Devon and Cornwall but also in the North Sea (see Watching brief, 2017). Faillettaz et al (2019) reviewed the changing abundance and distribution of bluefin tuna in the Atlantic Ocean over the last 200 years and suggested that the disappearance and reappearance of bluefin tuna in northern European waters can be explained by patterns of hydroclimatic variability and in particular the Atlantic Multidecadal Oscillation (AMO).

A major focus of previous scientific reports has been the impact of climate on fish recruitment (i.e. the number of juvenile fish reaching an age or size whereby they can be caught by the fishery). Capuzzo et al. (2018) reported a significant decline in primary production in the North Sea during the past 25 years, thought to be influenced by sea surface warming and reduced riverine nutrient inputs. In turn, significant correlations were found between observed changes in primary production and the dynamics of higher trophic levels including (small) copepods and a standardized index of fish recruitment, averaged over seven stocks of high commercial significance (cod, haddock (Melanogrammus aeglefinnus), whiting (Merlangius merlangus), Norway pout, herring, sprat (Sprattus sprattus) and sandeel (Ammodytes marinus)).

According to the most recent stock assessments for cod, stocks around the UK were heavily overfished in the early-mid 2000s when populations were at their lowest ever recorded value. However, since this period, fishing mortality has been significantly reduced through vessel decommissioning schemes and statutory effort controls. Spawning stock biomass in the North Sea has recovered to a level (118,387 tonnes in 2018) above its precautionary reference limit, but this recovery has been slower than originally anticipated. In the Irish and Celtic Seas, as well as the west of Scotland, cod stocks are still at low levels, despite the very dramatic and deliberate reduction in fishing mortality. This is largely a reflection of continued poor recruitment in all UK cod stocks, at least partially related to prevailing climatic conditions since the mid-1990s. However, Brander (2018) warned against overemphasizing the role of climate. He noted that the average sea surface temperature for the North Sea over the period 2000–2015 increased by >1 °C relative to the 1961–1990 baseline and, contrary to the projection of Drinkwater (2005), the cod stock doubled in biomass (rather than declining).

Free et al. (2019) modelled the influence of warming on the productivity of 235 commercial marine fish in 38 ecoregions. Some populations responded significantly positively (n = 9 populations) and others responded significantly negatively (n = 19 populations) to warming. Hindcasts indicate that the maximum sustainable yield of the evaluated populations decreased by 4.1% from 1930 to 2010, with five ecoregions experiencing losses of 15 to 35%. Notably, populations in the North Sea and Celtic-Biscay shelf (i.e. around the British Isles) were among the most negatively impacted worldwide. The authors found that exploitation history and temperature change interacted to determine the vulnerability of populations to warming. Populations that had experienced intense and prolonged overfishing were more likely to be negatively influenced by warming, especially when they had also experienced rapid warming (>0.2°C per decade).

In recent years hundreds of papers have been published focussing on the impacts of ocean acidification (OA) on marine organisms. However, there is still a lack of conclusive evidence as to what the possible consequences for commercial fish and shellfish might be and, consequently, the impacts on fisheries and aquaculture are largely unknown.

Opinions voiced in the literature range from complete catastrophe for global fisheries (e.g. Colt and Knapp, 2016) to very modest impacts. Mangi et al. (2018) provided a review of relevant (2005–2016) laboratory experiments conducted on commercial shellfish species (mainly crustaceans and molluscs) with a particular focus on those of interest in the UK. This review only considered studies that simulated pH changes of less than 0.4 pH units (considered a realistic pH scenario for the year 2100 around the British Isles). The various meta-analyses that have been completed in recent years (by Kroeker et al. 2013; Hendriks et al. 2010; and Kroeker et al. 2010) have all indicated that crustaceans (crabs, lobsters and shrimps) are more robust to simulated pH changes than molluscs (bivalves and gastropods). The effect size at different pH values were subsequently used to calculate anticipated financial losses in 2100, under a medium and high emission scenario. Results showed the total loss to the UK economy from both shellfish production and shellfish consumption, ranging from £23–£88 million at 2013 levels. In addition, there are regional variations due to different patterns of shellfish wild-capture fisheries and aquaculture practiced, and the sensitivities of species to OA. Wales will be the most heavily impacted largely because of the importance of mollusc fisheries. Predicted losses for other devolved nations are less, largely because wild-capture fisheries and aquaculture are more reliant on crustaceans (especially Nephrops norvegicus) rather than molluscs, and crustaceans are known to be more robust (Styf et al. 2013).

Responses to OA are particularly uncertain in fin-fish. Although several studies have noted that early life stages (eggs and young larvae) of fish may be sensitive to the direct effect of OA (e.g. Franke and Clemmesen, 2011; Frommel et al., 2012), the results appear to depend on the particular fish species and habitat of the stock (e.g. Pimentel et al., 2016).

Rather confusingly, negative impacts of OA on larval growth, development, metabolism and survival have all been documented, but so have positive, indirect food web impacts of OA on survival and growth of Atlantic herring larvae in a semi-wild, mesocosm study (Sswat et al., 2017). Stiasny et al. (2019) documented divergent responses of Atlantic cod larvae to ocean acidification and food limitation. Stiasny et al. (2018) presented the first data on the effects of parental acclimation to elevated aquatic CO2 on larval survival, a fundamental parameter determining population recruitment.

In the past few years major advances have been made with regard to the ability to provide future projections for climate change impacts on fish and fisheries. This progress has been made on two separate fronts: (1) providing forecasts' at the seasonal to decadal time horizon, and (2) providing long-term projections of species distribution, fish stock productivity and hence consequences for fishing fleets and the economy. The ICES Working Group on Seasonal-to-Decadal Prediction of Marine Ecosystems (WGS2D) is a new group that aims to provide predictions on near-term timescales in order to support marine resource management and business planning (ICES, 2018). Several 'products' from this group are of utility for fisheries in the UK. In June 2017 WGS2D issued its first forecast for blue whiting Micromesistius poutassou spawning habitat in the North Atlantic (subsequent forecasts were issued in August 2018 and January 2019). The group suggested that this forecast should be used as a broad-scale indicator of the expected spawning distribution of blue whiting in the upcoming spawning season (see Figure 2). Similar short-term forecasts have also been issued for bluefin tuna feeding habitat in the North Atlantic. http://www.fishforecasts.dtu.dk/forecasts.

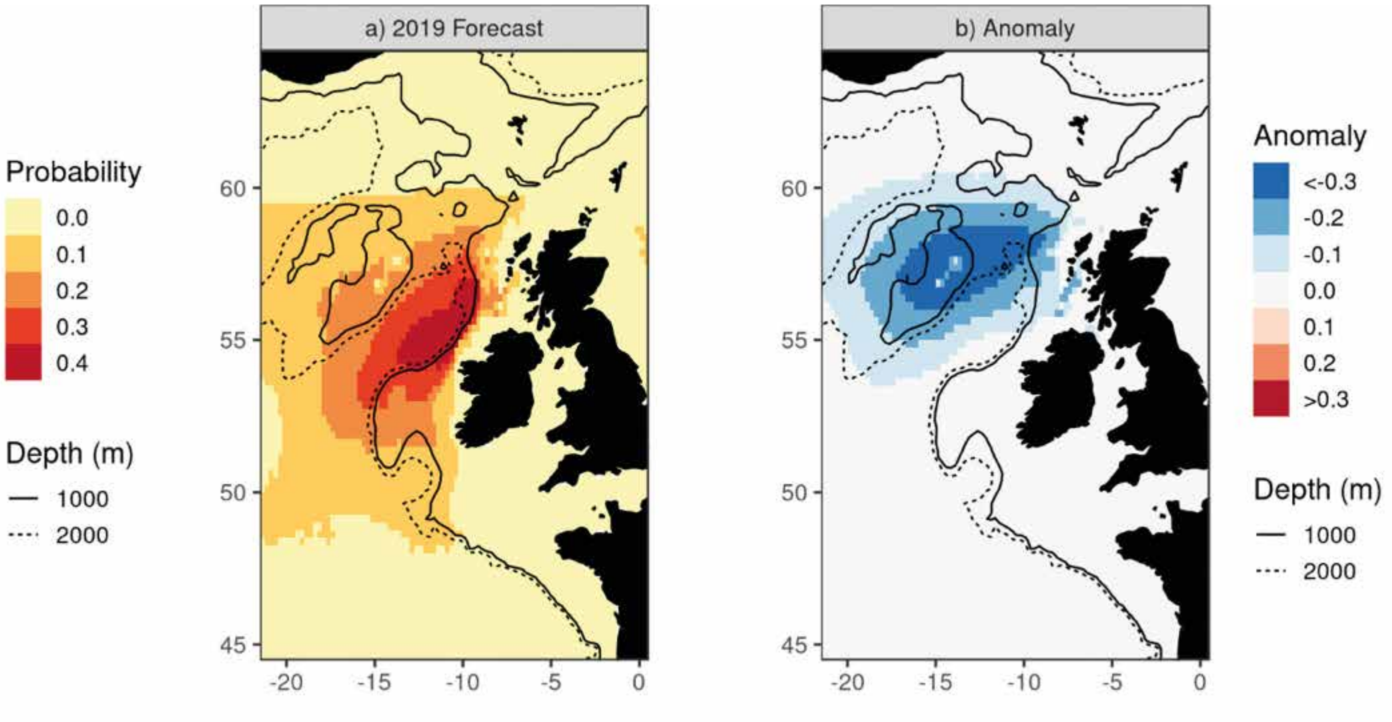

Figure 2. Forecast spawning distribution for blue whiting in March 2019. Distribution is represented here as the probability of observing blue whiting larvae in a single haul performed by the Continuous Plankton Recorder and is plotted as a) the value and b) the anomaly relative to the climatological probability (1960-2010).

Changing storminess poses a direct risk to fisheries: storms disrupt fishing effort and pose a physical threat to fishers, their vessels and gear, as well as to fishing communities and their infrastructure on land (Sainsbury et al., 2018). Fishing remains the most dangerous occupation in the UK: the fatal accident rate is 115 times higher than that in the general workforce and much of this is related to operating in poor weather conditions. Uncertainty in projections of past and future storminess from global and regional climate models remains high as a result of widespread variation in analytical methods, poor historic observational data and the challenge of distinguishing externally forced climate changes from natural internal climate variability.

At present, confidence in the wind and storm projections from Global Climate Models (GCMs) and down-scaled Regional Climate Models (RCMs) is relatively low, with some models suggesting that northwest Europe will experience fewer (though more intense) storms in the future, whereas other models suggest an increase in storm frequency. Assessing the vulnerability of fisheries to changing storminess is essential for prioritizing limited adaptation resources and informing adaptation strategies. Sainsbury et al. (2018) provided a 'research roadmap' to better understand the impact of changing storminess on fisheries, arguing that the potentially catastrophic impacts of changing storminess for global fisheries over relatively short timescales mean that enhanced integration across disciplines is urgently needed to address this challenge.

The new 'EU landing obligation' will be introduced gradually between 2015 and 2019 for all commercial fisheries (species under TACs, or under minimum landing sizes). The obligation stipulates that once the least plentiful quota species in a mixed fishery is exhausted, the whole fishery must cease operation. Baudron and Fernandez (2015) have argued that many commercial fish stocks are beginning to recover under more sustainable exploitation regimes and, in some cases, as a result of favourable climatic conditions. For example northern hake (Merluccius merluccius), a warm-water species, has recolonized the northern North Sea from which they had largely been absent for over 50 years (Staby et al., 2018). These shifts in distribution, whether driven by climate change or not, have implications for the management of other stocks. Notably, if discards are banned as part of management revisions, the relatively low quota for hake in the region could be a limiting factor (a 'choke stock') that may potentially result in the premature closure of the entire demersal mixed fishery, jeopardizing livelihoods of commercial fishermen, especially in Scotland (Baudron and Fernandez, 2015). In addition, Cormon et al. (2016) have suggested that this spatial shift in hake distribution could modify predator–prey interactions, and that indirect impacts may materialize through competition with other resident predators.

Distribution shifts in commercial species necessitates adaptive management and governance structures that allow flexible access to quota based on updated information that reflects current and anticipated future distribution and places less emphasis on historical patterns and allocations (Pinsky et al. 2018). In Europe, 28 countries are subject to the provisions of the EU Common Fisheries Policy (CFP) (all member states are subject, but only 23 of the EU 28 are coastal states).

Within the CFP, Total Allowable Catches (TACs) are shared between EU member nations through pre-agreed 'Relative stability' arrangements and fishers are able to operate anywhere in community waters where they have quota allocation. These arrangements were based on Member State catches during a historical reference period and give each Member State a fixed percentage share of the total stock in perpetuity (Morin, 2000). For many stocks, this historical reference period coincided with the relatively cold 1970s–1980s (usually 1973–1978). Climate change has since shifted the geographical distribution of many commercial species such that the national shares may no longer make sense in terms of geographic proximity, i.e. the fish for which a country has quota may be now be distributed a long distance from the ports where the vessels are based. The necessity for additional agreements will be greatly increased once the United Kingdom leaves the EU Common Fisheries Policy (CFP) and EU vessels will no longer have the automatic right to fish in UK waters or vice versa (Phillipson and Symes, 2018). Historic 'relative stability' arrangements may need to be revisited (and revised on a more regular basis) so that they better reflect the current distribution of fish resources, and the access-rights available to the different fleets (Phillipson and Symes, 2018).

Gaines et al. (2018) considered how improvements in fishery management can potentially offset the negative consequences of climate change. The authors found that success hinges on the current status of stocks. The poor current status of many stocks combined with potentially maladaptive responses to range shifts could reduce future global fisheries yields and profits even more severely than previous estimates had suggested. Reforming fisheries in ways that jointly fix current inefficiencies, adapt to fisheries productivity changes, and proactively create effective transboundary institutions could lead to a future with higher profits and yields compared to what is produced today.

2.2.2. International system

From a scientific perspective, one of the most important publications to appear in 2018 was the FAO Technical Report, number 627 titled "Impacts of climate change on fisheries and aquaculture" (FAO 2018). This report provides a global synthesis of knowledge as well as a catalogue of adaptation and mitigation measures that have been tried worldwide in the wild-capture fisheries sector.

This report is arranged as a series of geographical chapters, including one focussing on the 'North Atlantic and Atlantic Arctic' (Peck and Pinnegar 2018). In addition, Chapter 4 provides projected changes in fisheries catch potential for each nation state under two climate change scenarios in the twenty-first century – see Fig 3 (Cheung et al. 2018).

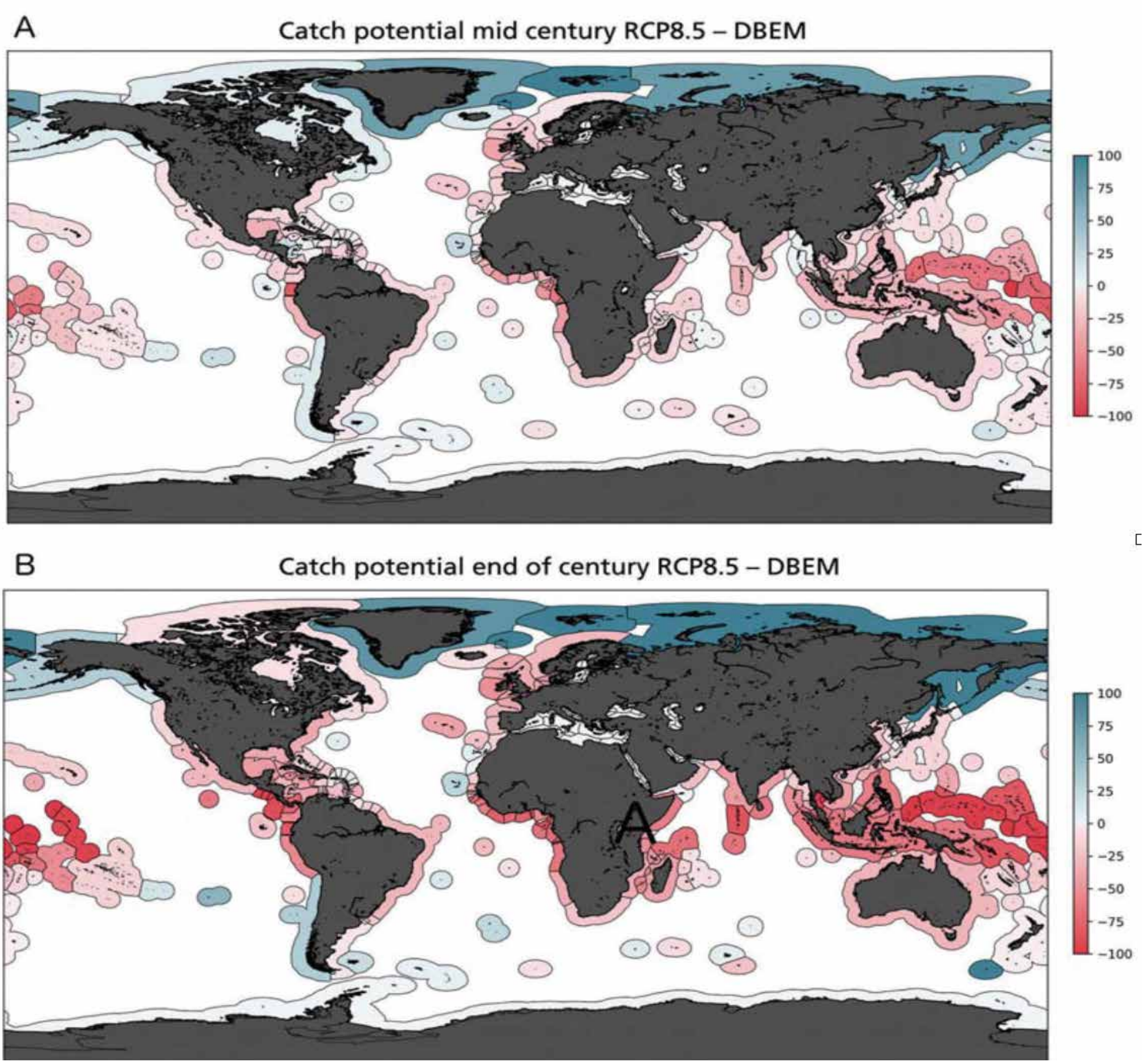

Figure 3. Projected changes in maximum catch potential (%) under RCP8.5 by 2050 (A: 2046 to 2055) and 2095 (B: 2091 to 2100) for the DBEM projections (from Cheung et al. 2018).

For the United Kingdom a decline in catch potential of -17.88% by 2050 and -34.52% by 2100 is suggested, assuming a high-emissions (RCP 8.5) scenario. By contrast, more northerly countries and territories are anticipated to benefit from climate change, with the catch potential of Jan Mayen Island (Norway) anticipated to increase by 777% by the end of the century, and Greenland by 81%. Averaged across the two climate-LMR models, EEZs that show the largest decrease (less than -40 percent) by the end of the century are in tropical countries, mostly in the South Pacific regions. These tropical countries include Nauru, Kiribati, Tuvalu, Ecuador, Palau, Micronesia (Federated States of) and Tokelau. However, in the mid-century timescale, in addition to tropical EEZs, potential catches in EEZs in the temperate Northeast Atlantic were also projected to decrease substantially (about -30 percent) (Cheung et al. 2018).

With regard to large pelagics, virtually all tuna landed into the UK, and available to consumers is from abroad (MMO 2018). In 2017 for example, the largest tuna exporters to the UK were the Seychelles, followed by Ghana, Ecuador, Mauritius, and the Philippines. Globally, sudden shifts in tuna distributions related to warming and other climatic events (e.g. ENSO), has resulted in significant losses of revenue and economic impacts for many vulnerable countries. Some Small Island states (e.g. Kiribati, Tokelau, Tuvalu, Federated States of Micronesia) derive more than 40% of government revenues from granting tuna fishing licences to companies based in Europe. Monllor-Hurtado et al (2017) suggested that tuna distributions are highly conditioned by sea temperature, and that for this reason they may be a good indicator of the effect of climate change on global fisheries.

The El Niño/Southern Oscillation (ENSO) has a major influence on climate patterns in various parts of the world. This naturally occurring phenomenon involves fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere. In the past, major ENSO events have caused horizontal and/or vertical displacement of tuna stocks across the Indian and Pacific Oceans, such that fishing fleets have also needed to relocate in order to maintain catch rates (Miller 2007). Scientific progress on the understanding and modelling of this phenomenon has improved prediction skills to within a range of one to nine months in advance. The WMO analysis estimated the chance of a fully-fledged El Niño event between December 2018 and February 2019 at 75-80%, with a 60% chance of it continuing to April 2019.

With regard to whitefish, the UK is a net importer of cod and haddock. In 2017 the largest exporter of cod to the UK was Iceland, followed by Norway, Denmark/Greenland and Faeroe Islands. Barents Sea cod recruitment is known to be heavily influenced by temperature. Due to a favourable climate as well as lower fishing pressure in recent years, the Northeast Arctic cod stock reached record levels in 2013 (spawning stock biomass 2.7 million tonnes), in contrast to elsewhere in the NE Atlantic (such as the North Sea, Celtic Sea and West of Scotland), where populations have remained low. According to ICES, the spawning stock biomass (SSB) for northeast Arctic (Barents Sea) cod remained high in 2018 (1.5 million tonnes), as did the cod stock biomass around Iceland (SSB 651,600 tonnes). Haddock imports accounted for 61 per cent of the total supply, mostly from Norway and Iceland (MMO 2018). According to ICES, haddock stock biomass in subareas 1 and 2 (Northeast Arctic) remained high but was declining (251,205 tonnes) in 2018, having witnessed an all-time peak in 2014 (SSB 675,563 tonnes). Stock biomasses have somewhat recovered around Iceland (to 128,766 tonnes).

Climatic events over the Barents Sea during 2018 were reported by (ICES, 2018) , Southeasterly winds prevailed in January–March 2018 and westerly winds – during the rest of the year. The number of days with winds more than 15 m/s was higher than usual most of the year. In some months, the storm activity attained a record high since 1981. Ice conditions in the Barents Sea in 2018 developed as in low-ice years. In January and February, the ice coverage (expressed as a percentage of the sea area) was respectively 20 and 17% lower than the long-term average (1981–2010) and close to that in 2017. Overall, the 2018 annual mean ice coverage of the Barents Sea was 13% lower than average as it was in 2017. Sea surface temperature (SST) averaged over the southwestern (71–74°N, 20–40°E) and southeastern (69–73°N, 42–55°E) Barents Sea showed positive SST anomalies (relative to the base period of 1982–2010). Bottom temperature was in general 0.8°C above average (1931–2010) in most of the Barents Sea (ICES, 2019). In the past decades, the area of Atlantic waters has increased in the Barents Sea, whereas the area of Arctic waters has decreased (ICES, 2019).

According to a recent report by the Arctic Monitoring and Assessment Programme (AMAP, 2018), but drawing on work by Koenigstein et al (2018), if climate change isn't addressed, the northeast Arctic cod stock in the Barents Sea is projected to first rise and then crash, possibly to almost zero before the end of the century,. This study is the first to take both ocean acidification and warming into account. It found that larval mortality rates were 75% higher when exposed to the combined pressures of the two factors – both of which are caused by carbon emissions – than to heating alone. As a result, fish numbers, catches and revenues will decline faster than previously estimated. A temperature rise of up to 4.5°C is suggested to be beneficial to the cod, and result in a projected worth of 255 million Norwegian kroner per year (£23m). But beyond this point, the larvae rapidly start to die off. At 6°C of warming (equivalent to less than 3°C for the rest of the world), they completely disappear (AMAP, 2018).

3

Industry experience of climate change impacts and relevant responses

Industry experience of climate change within domestic and international systems is described by major fish species grouping.

Note: Stakeholders urged caution in attributing impacts directly to climate change drivers. Other drivers of relevance include social (e.g. fisheries management) and environmental (biological and oceanic cycles) drivers, so the link between climate change drivers and impact should be considered indicative only.

3.1 Domestic (see tables 3.1 and 3.2 in Annex 1)

More widely, and anecdotally, there is commentary about seasons seeming to have shifted in relation to the time of year: Autumn is no longer September, but now November/December; Spring is no longer March but May/June; Winter is no longer December but March/April.

Whitefish

- 'Temperature change':
  - Potentially playing a role in North sea fish distribution. There was a notable lack of cod for the first 6-8 months of the year. Cod availability centred on Shetland and the northern sector (seeming to concentrate on feed) with very little in mid or southern North sea. The implications of delays in supply meant plenty of quota was left, raising the prospect that boom and bust cycles of quota return, erratic supplies and price/market crises; arresting investment in the onshore sector. Coupled with investment in the fleet, a lack of processing critical mass could make supplies even more erratic. Anecdotally there appears to be more unusual whitefish species in northern Scotland e.g. Dory's and Mullets
  - Higher summer temperatures contributing to poor sales of whitefish (e.g. products not suited to barbecues).

- 'Temperature change' and 'Increased storminess and waves':
  - Contributing to poor weather conditions (e.g. the 'Beast from the East' in spring 2018) which, whilst not affecting catching did disrupt onshore logistics and product deliveries.

Pelagic

- 'Temperature change':
  - Affecting the variability and unpredictability of fish migration. Mackerel slower to begin their migration during the 2018 winter fishery, the North sea summer herring fishery started almost a month later than normal.
  - Higher summer temperatures contributing to demand for fresh herring and mackerel (e.g. for barbecues); higher costs for freezing down product from higher ambient temperature.

Shellfish

- 'Temperature change' and 'Increased storminess and waves':
  - The cold winter and 'Beast from the East' was felt to have made a significant difference to fishing; affecting the accessibility of shellfish (if too cold, shellfish just shut down) and slowing the fleet. As temperatures rose later in the year shellfish became more active and more shellfish were landed.

Progress against adaptation responses

Notable responses in:

- Fisheries management include developing closer science-industry collaboration and engaged research helping to advance a 'more robust strategic fisheries knowledge base'. Examples include:
    - A general shift in how scientific research is being conducted, with more engaged research. Some parts of the industry now employ their own scientists, including the Scottish Pelagic Fishermen's Association (SPFA), Scottish Fishermen's Organisation (SFO), and Scottish White Fish Producers Association (SWFPA). A range of scientific projects are now underway and, in some cases, this is supported by a developing network of Norwegian, Dutch, Danish and British industrial scientists. Projects include self-sampling programmes (SPFA), and on board observer programmes (SFF).
    - Ongoing Fisheries Innovation Scotland (FIS) / Marine Alliance for Science and Technology Scotland (MASTS) initiatives. FIS commissioned Aberdeen University to explore the current state of knowledge related to climate change impacts on fish distribution. A workshop held in Aberdeen, brought in global experts to consider this issue and the broader topic of innovation in the use of fish distribution data, and a review of the approaches taken by three countries (Australia, UK, and US) towards adaptation planning within the fishing industry.
- Quota management, and ensuring quota swaps / transfers operate efficiently is under discussion, propelled by Brexit, between industry, government and POs (both domestic and international swaps).

- Fishing operations includes enhancing operational safety through:
    - The deployment of Personal Flotation Devices (PFDs), including providing personal locater beacons. PFDs now been deployed right across the UK, ongoing safety@sea training through Seafish.
    - The continuing trend in new pelagic vessel build that incorporates additional decks/pumping from stern – improving safety and allowing continued working in poor weather. Most of the new whitefish vessels (pair trawlers and seiners) are hauling and shooting from the stern, seemingly following the pelagic lead.

- Processing and markets for the longer term development of markets for available domestic seafood are considered weak. However, initiatives concerned with communicating the availability of domestic seafood continue to progress. This includes the Seafood 2040 initiative in England (operationalised in 2018) and the continuing "Connect Local" initiative in Scotland (providing a framework for selling Scottish material locally, and at a Scotland and UK level - bringing supply chain stakeholders together, funding for collaborative initiatives etc).

3.2 International (see tables 3.3 and 3.4 in Annex 1)

Whitefish
Notable drivers experienced include:
- 'Temperature change':
  - Anecdotally, this is affecting fish distribution in the Barents Sea/Arctic with cod and haddock stocks moving northwards, and impacting on fishing patterns and catch potential of target species.
  - Higher temperatures have resulted in a lot of softer fish, causing problems in production lines as soft flesh fragments and this blocks machinery. Examples include imports of plaice which, this year, were soft and thin (with warmer temperatures the fish had stopped eating and gone straight into roe production).

Pelagic
No notable drivers identified.

Shellfish
Notable drivers experienced include:
- 'Temperature change' and 'acidification':
  - Ice break-up in the Arctic, more –-and larger sized - icebergs off Newfoundland, and ice melt affecting water composition. Changes in ice coverage affecting level of sunlight and the appearance of algal blooms in areas where these have not previously appeared. These drivers (alongside cod predation) are believed to affect catch potential of target species (cold water prawn) in the North Atlantic and Western Atlantic.

Progress against adaptation responses

Notable responses in:
- Fisheries management include management regimes embracing the concept of climate change adaptation through the upholding of the recent negotiated agreement between Government/industry/NGO stakeholders concerning international access and governance rights in the Svalbard area of the Arctic. The Svalbard initiative is continuing, with the fishing practice moratorium monitored by VMS and fish projections being confirmed. Greenpeace has replicated their Arctic initiative in the Antarctic, pressing for restrictions on Krill.

- Processing and markets, in improving resilience, highlights the growing interest in cold storage by large whitefish processors in Grimsby. This is an attempt to smooth supplies in response to volatile conditions; driven primarily by Brexit but applicable to climate change volatility.

4

Conclusion

- Notable advances have been made in the evidence base, particularly the publication of the FAO report ‘Impacts of climate change on fisheries and aquaculture’. Projected changes in catch potential could prove useful discussion points for industry and business planning.

- A range of impacts continue to be experienced, with ‘temperature change’ and ‘storminess’ climate change drivers particularly notable in the UK domestic system.

- A range of practical actions, prompted by climate change or by other drivers (e.g. the Brexit process), continues to make a contribution to adaptation responses. These include science-industry collaboration in fisheries management, quota management, and enhancing operational safety in fishing operations.

5

Annex

Table 3.1
Table 3.2
Table 3.3
Table 3.4
Consultees
References

Table 3.1 Summary of key domestic offshore and onshore threats (red dots) and opportunities (green dots)

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

Table 3.2 Adaptation responses for the 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				
	Underway	Fishery	Development of training and education modules for fishermen	Fishing into the Future (with Seafish)				
	Underway	Operations	Enhance operational safety (raised decks)	Industry				
	Underway	Operations	Enhance operational safety (Personal Flotation Devices)	The Fishing Industry Safety Group				
	Underway	Operations	Enhance operational safety (Safety at Sea training)	Seafish-approved training providers				
	Underway	Ports	Build port resilience	Port / harbour authorities / Department of Transport				
	Underway	Processing	Develop markets for available domestic seafood	Seafood Scotland				
	Immediate (<2 years)	Ports	Ensure berth allocations for vulnerable vessels	Port / harbour authorities		■		
	Immediate (<2 years)	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		■	■	
	Short term (2-5 years)	Fishery	Ensure quota swaps / transfers	Industry		■		
	Short term (2-5 years)	Operations	Keep a watching brief on climate change and potential responses	Industry trade associations	■			
	Short term (2-5 years)	Ports	Improving port risk management	Port / harbour authorities	■	■		
	Short term (2-5 years)	Transport	Assess vulnerability of freight ferries	Government			■	
	Short term (2-5 years)	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			■	
	Medium term (5-15 years)	Fishery	Review of domestic quota allocation	EU / UK Govt / Fisheries scientists / industry			■	■
	Medium term (5-15 years)	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				■
	Long term (>15 years)	Operations	Assess vulnerability of fleets across the EU	EU research				■
	Long term (>15 years)	Processing	Re-locate processing sites inland	Processors and planning inspectorate				■

Table 3.3 Summary of key international offshore and onshore threats (red dots) and opportunities (green dots)

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			🔴	🔴	

Table 3.4 Adaptation responses for the International system

Speed of response (inertia)		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)		-					

Consultees

1. David Anderson, Aberdeen Fish Producers Organisation.
2. Will Clark, Wilsea Ltd.
3. Karen Galloway, Xenosophy Ltd.
4. Ian Gatt, Scottish Pelagic Fishermen's Association.
5. Cameron Moffat, Young's Seafood Ltd.
6. Malcolm Morrison, Scottish Fishermen's Federation.
7. Alex Olsen, Espersen.
8. Dale Rodmell, National Federation of Fishermen's Organisations.
9. John Rutherford, Frozen At Sea Fillets Association.
10. Robert Stevenson, Lunar Fish Producers Organisation Ltd.

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