



Climate-related impacts on fisheries management and governance in the North East Atlantic

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Executive Summary

Climate change is a present and growing threat, creating significant shifts in the range, distribution, and productivity of key commercial species. Existing institutions in the North East Atlantic region are straining to deal with these challenges, particularly under rigid rules and governance structures that make adaptive management difficult to achieve. Tensions have already arisen from the changing distribution of fish stocks, threatening the long-term conservation of fish species and the socioeconomic benefits derived from their use. Disputes over how to share fishery resources that are moving across geo-political boundaries have led to conflicts and overfishing and this is a problem that promises to become more acute as climate change takes hold.

At the same time, full implementation of the EU-wide landing obligation - which requires the elimination of discards of species managed by quota - is colliding with the rigidity of the EU's fixed relative stability key. The combination of accelerated climate impacts within a rigid fisheries governance system are compounding to create a new set of challenges that have the potential to create the 'perfect storm' and compromise the ecological and socio-economic integrity of the region. In a shifting, dynamic, and warming ecosystem, is the current governance and management system flexible enough to ensure that climate change does not lead to chronic misalignment between EU and coastal state quota allocations and the portfolio of fish available to catch? While our institutions do not yet seem fully prepared to adapt to the layering complexities of the region, they can, and must, be brought up to date so that conflicts, overfishing, and illegal discarding can be averted. With new tools and adaptive management and governance, we have the capacity to meet this challenge.

Europe has access to world class fishery science and management expertise – an excellent foundation from which to build innovative new approaches, or unearth existing tools, to construct a stable and sustainable future under climate change. This inspired Environmental Defense Fund (EDF) to join forces with the International Council for the Exploration of the Seas (ICES) to bring together relevant scientific and governance expertise to delve into the challenges at hand. The frames of 'science', 'management' and 'governance' were used to examine the existing landscape, and explore avenues for future action.

“Crucially, the groups found that we already know enough to start making changes today, and we have tools at our fingertips to achieve positive outcomes.”

What we know

Fish stocks are shifting rapidly as a result of climate change. Research shows that system-level shifts are already underway, and change is accelerating rapidly, affecting the range, distribution, abundance and productivity of key species. We can't predict exactly which stocks will rise, fall or relocate, but we can paint broad scenarios to help managers plan for different possibilities.

Scientific and management institutions are not yet fully prepared for the changes under way and still to come. The long time periods and geographic ranges at which climate change takes place are often in direct conflict with the protocols and rules that guide traditional fisheries management systems. Both science and management institutions must work together to ensure scientific assessments are carried out at the most appropriate geographic and temporal scales so that they are equipped to address the transboundary nature of fish.

The EU's relative stability key has remained virtually unchanged while fish populations continue to move northwards. Matching catches to quota will therefore be increasingly important, particularly as the EU's landing obligation comes into full effect. Without forging solutions to reduce the increasing lack of alignment between catch (based on total mortality) and quota, EU fishermen will face pressure to either 'tie up' or continue to discard illegally, risking overfishing.

International agreements governing shared stocks are not keeping pace with changes in the water, with even well-defined international fisheries agreements not resilient to unanticipated change, nor ready to adapt when political interests override sustainability. There are lessons that can be learned, such as the 'mackerel wars' earlier this decade, which aptly demonstrate the risks of mis-management of shifting stocks, and the complex dynamics between different coastal states when there is perceived injustice within the system. This case study can help to signpost areas for innovation and improvement as we move forward.

We are experiencing a political moment of change. Political shifts in the region – the UK's planned exit from the EU – are creating a rare window where coastal states and institutions are alive to the idea of a significant change in the way governance operates in the North East Atlantic. This is a chance to move beyond business as usual in order to realise the greatest economic, social and environmental value from shifting ecosystems thereby addressing the pressing challenges linked to climate change and how fisheries will be managed in the future.

How we can move forward

Inclusivity in decision-making and trust in science is vital. Greater dialogue is required between all fisheries stakeholders. In the context of climate science and adaptive fishery management, science and policy need to work more closely to ensure that adequate and appropriate data is gathered and used effectively to co-define the questions underpinning research and management decision-making. Uncertainty in climate projections from climate models and a dearth of understanding between disciplines contributes to a lack of trust in the system and further hinders the ability for policy-makers to take precautionary management decisions. A collaborative dialogue and more inclusive decision-making process is needed to build trust in the science, even when models are not able to provide easy 'answers' to the complex challenges ahead.

Re-invigorated regional institutions can help to lead change. The North East Atlantic Fisheries Commission (NEAFC) has already begun a re-evaluation of their management and governance systems; we can encourage and accelerate this effort, to serve a stronger governance role at a scale that better accommodates climate-induced shifts. Regional and bi-lateral arrangements for stock sharing need a fresh approach that reflects the shifting governance of the region. The advice function of Advisory Councils and regional groups (Scheveningen, Baltfish) should also be more transparent and channel scientific input to the highest levels.

A shift towards ecosystem-based approaches can support resilient, flexible management. A broader, flexible view of management – which can adapt to a changing ecosystem – is ‘ecosystem-based fisheries management’ (EBFM). This approach is based on the simultaneous management of multiple interacting stocks in the context of global and ecosystem-scale drivers. EBFM presents new challenges to science, but is seen as the natural evolution of current single-stock management, which is not holistic enough to encompass the range of dynamic shifts expected in the region.

We can achieve adaptive, flexible fisheries management and governance through uptake of a range of regionally-appropriate tools and approaches already at hand. Whilst the shift to more adaptive, flexible fisheries management is significant and challenging, nations must embrace a more adaptive approach to achieve resilient fisheries and durable management systems. Fortunately there are a number of tools and approaches managers, scientists and fishers can apply to support the attainment of sustainable, resilient fisheries. These should be explored to support the process towards more adaptive, flexible fisheries management and governance.

Next steps

With such a strong consensus that climate change has wide-ranging and potentially harmful implications for European fisheries under the existing framework, continued action in this area is critical. With the knowledge base established through this workshop, Environmental Defense Fund will seek on-going dialogue with science and policy actors, as well as continued outreach to industry, to stimulate further discussion and seek consensus about how to build a more resilient future for the North East Atlantic: one that embraces climate-proofing policies to achieve a more adaptive fisheries management and governance framework for the region.



Section 1 & 2: Introduction & Workshop Rationale

Europe¹ is host to complex, highly developed fisheries governance and management systems. The complexity of such systems are being challenged by climate-related impacts where shifts in geographic distribution and range of fish stocks are now observed clearly in European waters (Lam et al. 2016). Recent research indicates that climate change may affect all fish species in the world's oceans to some degree, but that these effects vary tremendously from one species to another. Some stocks may become more productive while others may decline. In terms of geographic shifts, it is predicted that widely distributed stocks are likely to shift poleward in response to increasing temperatures. These changes will challenge existing management and governance systems as species move in and out of traditional management zones in search of more favorable conditions. It could also lead to competition for resources and a decline in the stock biomass as countries dispute previous stock sharing agreements, or target stocks in new management areas without appropriate fisheries management plans in place (Gaines et al., 2017, in review). This could lead to exploitation rates higher than recommended scientifically determined levels.

Europe offers a pertinent case study in this regard. As a result of management reforms, a number of stocks are on a trajectory towards recovery, yet climate-driven impacts are unfolding quickly - creating management challenges for the region. The International Council for the Exploration of the Seas

¹ Europe in the context of this paper includes all EU Member States, UK, Norway, Iceland, Faroe Islands, and Greenland

² WKFISHDISH: <http://ices.dk/news-and-events/news-archive/news/Pages/Substantial-changes-in-fish-distribution-identified-by-ICES.aspx>

(ICES) recently documented shifts for 16 of 21 key EU commercial species, eight of which were found to have moved outside their historic ICES areas, as evidenced in the recent WKFISHDISH report². With this degree of fish stock movement, challenges and potential conflict among fish sharing nations are likely to increase. Research undertaken by EU-funded projects such as Climefish³ and SICCME⁴ are all shedding light on important climate-related impacts, bringing clarity and prominence to the issue.

How we manage fisheries in the face of climate change must therefore be swiftly brought to centre stage. Global climate and fisheries modelling indicate that the type of management response to climate-related impacts on fisheries may have a larger effect on fish stocks than the impact of climate change itself⁵ (Gaines *et al.*, 2017 in review). This finding underscores the importance of building management and governance systems that are capable of adapting to change as it occurs. Failure to do so will increase the risks to stock health and contribute to the depletion of fishery resources with negative consequences for fishery-dependent communities and associated industries.

Workshop Rationale

Given the impact climate change is having on the distribution and range of fish stocks in the region, and the associated management and governance challenges that these changes present, Environmental Defense Fund (EDF) set out to explore these core issues, and possible solutions to them, through a two-day collaborative workshop titled: '***Climate-related Impacts on Fisheries Management and Governance in the North East Atlantic Region***'. The workshop, held on the 30th and 31st of August 2017, was hosted by the International Council for the Exploration of the Seas (ICES) at their headquarters in Copenhagen, Denmark. Twenty-five participants from the region were in attendance representing a cross-section of disciplines covering fisheries and climate science, management, and governance (Annex A contains a full participant list).

The workshop sought to:

- Provide a common grounding on the latest research and trends relating to changes in fish stock distribution and productivity as a result of climate change, and to discuss these changes as they relate to the North East Atlantic region.
- Examine the role of science in identifying climate-related risks and impacts, and assess the current science-policy interface.
- Consider possible implications of climate-related impacts on fisheries management and governance in Europe and the wider North East Atlantic region now and in the future.
- Explore possible tools and approaches that can best manage fisheries in the face of these impacts.

³ <http://climefish.eu/>

⁴ ICES PICES Strategic Initiative on Climate Change Impacts on Marine Ecosystems: <http://www.ices.dk/community/groups/Pages/SICCME.aspx>

⁵ These findings were presented to the American Advancement of the Association of Science (AAAS) meeting in February 2017: <https://aaas.confex.com/aaas/2017/webprogram/Session15365.html>

These objectives were developed to deliver the following outcomes:

- A shared understanding of the possible approaches and tools to address climate-related impacts on European fisheries and options for alternative management approaches.
- More open and fluid dialogue between science and policy experts, with lasting connections made between the fisheries science and policy communities.
- This report, detailing the discussions and findings of the workshop and identifying overarching themes, as well as possible next steps for advancing research and building future partnerships.

Participants were invited to present their latest work on the impacts of climate change in Northern European Fisheries helping to provide a common grounding from which to explore issues in more detail. The lenses of ‘science’, ‘management’ and ‘governance’ were used to examine climate-related challenges, as well as potential, regionally-appropriate solutions.

While this report does not identify any specific policy recommendations, it does compile and highlight key policy-relevant observations assembled over the course of the two-day workshop. Presentations are publicly available and can be found here: <https://goo.gl/bBjDvY>

Additionally, further links to relevant participant research are listed in Annex A, opposite the relevant participant’s name.

Section 3: The Roles of Science, Management and Governance

While we are starting to see the Common Fisheries Policy (CFP) bearing fruit through key policies that bring total allowable catch (TAC) in line with scientific advice, there is an ever-growing misalignment between quota allocation and stock availability under the existing fixed EU relative stability key (Baudron and Fernandes, 2015). In recent years, this has been exacerbated by the northward trajectory of stocks as a consequence of climate change (Poloczanka et al., 2013) with the current misalignment between TAC allocations and catch being brought into sharper focus because of the EU landing obligation, which has eliminated industry's previous option of discarding commercial species.

Brexit introduces a further layer of complexity, with the future of negotiations (and therefore future fish allocations and governance for the region) still very much up in the air. There will likely be ramifications of this shifting governance landscape on other bilateral and multi-lateral fisheries agreements in the region, which will require strong governance to ensure fisheries are exploited sustainably during any geo-political transition. In this moment of political and biological flux, an opportunity for increased collaboration and innovation exists.

On the basis of this information, we set out to explore:

- (1) what the latest **scientific** research is revealing about the effects of climate change on fisheries, and;
- (2) how those findings are – or are not – currently taken into account by **institutional** bodies through their **management** strategies.

Science

Best available research and data to provide information on the life history and state of fish stocks used to inform fisheries management decisions.

Bridging the gap between science and policy

Science is improving our shared understanding about the impacts of climate change on fish stocks. Workshop participants, however, provided views around the ways in which fishery managers are posing questions about climate impacts to scientists, and the ways in which scientists are responding. Effective, two-way communication between scientists and policy-makers has long been a challenge within Europe. Tackling the gaps in communication between these groups will only become more important as climate change takes hold.

Different perspectives were presented on the shortcomings of both science and management; however, there was general agreement that science and policy must be intertwined through a coherent

framework in which there is direct interaction and continual dialogue between scientists and policy actors. Despite the fact that science is considered to help reduce uncertainty in policy decisions to some degree, challenges remain. In particular it was noted that uncertainty in projections from climate models contributes to a lack of confidence (from policy-makers) in the results, especially over longer time horizons. This makes lobbying for more precautionary management approaches, or the direct incorporation of climate impacts into policy decisions, more challenging. A more inclusive decision-making process may help build greater trust in the science and deliver stronger, workable solutions.

“It was noted that uncertainty in projections from climate models contributes to a lack of confidence (from policy-makers) in the results, especially over longer time horizons.”

In terms of EU fishery management, concern was raised that — despite significant improvements to stock assessments — predicting changes with precision and accuracy is still not always possible in an evolving complex marine environment. This makes management based on fishing mortality rates (F) and maximum sustainable yields (MSY), which are estimated from models that assume equilibrium conditions, difficult given the dynamic nature of multi-species fisheries. Currently, advice from scientific assessments are applicable within a given timeframe which is compatible with the metrics used to determine the advice. After a stipulated timeframe a new assessment should be conducted to update the metrics or reference points used. Multiannual Plans (MAPs) that assign F values into law present a challenge to this approach, especially with respect to climate change, which can result in changes in stock productivity. This presents a clash between science and policy/law where legal requirements may take years to adjust against a continually changing and dynamic environment where stock productivity and abundance changes can be rapid. This type of scenario can lead to



Across the two day workshop delegates took part in a number of lively discussions on issues surrounding fisheries management and science.

undesirable effects on socioeconomic conditions, as well as conservation of the resource. Management should ideally be able to respond to these natural fluctuations with the ability to update F values as conditions change. Therefore, managing fishing mortality rates (or biomass) based on relative reference points that are re-evaluated regularly would be a more robust option than scribing values into law. Another option is using relative reference points within the legislation (i.e. similar to ICCAT with the estimated recent F being expressed as a proportion of the F_{msy} reference point) which would be a more flexible approach than is currently the case.

Additionally, greater scientific input into the decision-making process could help embed science more effectively into the management framework. It was suggested that the

decision making process in the European Union could be improved by ensuring representation of the scientific community on the EU Advisory Councils and at the Member State high level group⁶.

At the international level, it was noted that governance could be strengthened to ensure that climate and fisheries science advice and policy can be developed at the most appropriate biological scale for a particular fishery.

“Legal requirements may take years to adjust against a continually changing and dynamic environment where stock productivity and abundance changes can be rapid.”

Importantly, participants noted overall that a caveat to these considerations is that better science does not necessarily lead to better decision-making and that more can, and should, be done to improve the communication and trust between the two disciplines. Approaches to improve this relationship were discussed but that overall there must be improvements in the way decision-making and planning is communicated to fishery managers so that advice is presented in a more simplified and easy to understand.

Scientific modelling

The need for greater knowledge on the spatial distribution of stocks (and structure of that distribution) was highlighted, including more accurate short and long-term forecasting and modelling of current trends and projected changes in productivity. A ‘gap analysis’ could help identify what is missing in current models and determine how scientists can map anticipated changes, and at what level (e.g., ecosystem or stock level). For example, a better understanding from science on where fisheries are likely to be more or less productive would help managers in determining the socio-economic and environmental/ecosystem implications of climate-related shifts in production and abundance.

Specifically, the need for model improvements, such as the use of ‘decision-support tools’ (DSTs) was highlighted as an area for further discussion. DSTs are techniques or tools that analyse or help to narrow the field of choice. They may be represented by paradigm models that help users evaluate different situations, or simulation models that can enable answers to ‘what if’ questions. For example, the MareFrame⁷ DST has been developed to support implementation of the Ecosystem Approach to Fisheries Management in the EU.

While there is notable value in the use of decision tools to aid constructive dialogue on key issues, their real-world application in helping to inform actual decisions, particularly those made at the

⁶ Regionalisation is built on co-operation among Member States for the development of joint recommendations for management. To facilitate this process, Member State Fisheries Director Groups have been formed for the North Sea and Baltic, known as BALTIFISH and the Scheveningen group, respectively. While these groups are not formalised, they have developed into effective co-operation mechanisms among Member States and are often referred to as High-Level Groups.

⁷ MareFrame is a EC-funded project which encourages a more widespread use of the ecosystem-based approaches to fisheries management: <http://mareframe-fp7.org/>

international level, was queried. Currently it is unclear where in the region these techniques could be applied. It was felt that in their current form, DSTs operate more like ‘discussion-support tools’ that create dialogue, rather than facilitate decisions. Scenario-based approaches were also highlighted and discussed for exploring possible futures (Mullon et al., 2016; Fernandes et al., 2017). These kind of approaches have been used in European projects such as Meece⁸ or EURO-BASIN⁹ and are being further developed in current projects such as Cere¹⁰ and in global efforts such as FISH-MIP¹¹.

Operating at the relevant scale

Environmental changes are occurring across large temporal and spatial scales, demanding an international perspective from scientists and policy makers. The long time periods and geographic ranges at which climate change takes place is often in direct conflict with traditional fisheries management systems, such as the annual TAC setting process according to traditional management areas. As changes to fish stock abundance and distribution take hold as a result of climate change, these management areas are no longer synced with where the fish are located and routine assessment surveys may require adjustments to cover a larger or altered geographic scope. By aligning management decisions according to the most appropriate scale (both temporal and spatial), managers will be better equipped to address the transboundary nature of fish. Scientific and socio-economic models will also need to be adjusted to account for new species interactions.

“Environmental changes are occurring across large temporal and spatial scales, demanding an international perspective from scientists and policy.”



Science is helping policy makers make more informed decisions about the state of the current North Sea herring stock.

⁸ MEECE is a European FP7 Integrated Project which increased ecosystem modelling predictive capacities by gathering experts in the field to develop and create model based tools to support understanding of European marine ecosystems: <http://www.meece.eu/drivers/climate.html>

⁹ EURO-BASIN is the European branch of the International BASIN Program (**B**asin-scale **A**nalysis, **S**ynthesis & **I**ntegration) focusing on climate and human forcing ecosystem impacts on living resources in the North Atlantic: <http://www.euro-basin.eu/>

¹⁰ Ceres tackles sustainability challenges, including climate change, water scarcity and pollution, and human rights abuses: <https://www.ceres.org/our-work/climate-change>

¹¹ A network of more than 40 global and regional marine ecosystem modellers bringing together disparate marine ecosystem models to forecast long-term impacts of climate change on fisheries and marine ecosystems: <https://www.isimip.org/gettingstarted/marine-ecosystems-fisheries/>

Work is already occurring to this end, illustrated by the recent research taken forward on the West of Scotland North Sea herring stock where an industry-led survey is helping make more informed assessments about the stock by getting the scale of assessment right. Fishermen are working in partnership with scientists to provide scientific support to the fishery management process. While it was believed by fishermen and scientists that the southern and northern areas contained different stocks, this could not be validated. The study — a collaboration between Marine Scotland, the Scottish Fishermen’s Federation, IMARES Netherlands, Thuenen Institute Germany, Marine Institute Ireland, University College Dublin, the Killybegs Fishermen’s Organisation, amongst others — helped support the evaluation of two different stocks by setting the scientific assessment at the most appropriate scale, and in partnership with industry, to inform the process¹². Conducting assessments like this one, at the most appropriate ecological level and with the active involvement of the industry, will contribute to better-informed decision making and future management.

Embedding science in the management process

The current *modus operandi* between fishery managers and other stakeholders (particularly scientists) may be creating institutional barriers to the effective uptake and application of scientific advice. The example of the Advisory Councils (ACs) was highlighted; it was felt that while AC advice is developed and channeled through the regional high-level groups, there is a lack of transparency in the way this advice is incorporated into joint recommendations, which are subsequently adopted by the European Commission, European Council and European Parliament¹³. On a more international level, forums such as the Regional Fisheries Management Organisations (RFMOs) were also considered to not adequately address the international dimensions of management, including the incorporation of scientific advice or stakeholder views.

The ‘mackerel wars’ are a case in point. An agreement existed between coastal states for the management of the mackerel stock and the allocation of the TAC (outside of the North East Atlantic Fisheries Commission – NEAFC – framework). Iceland and the Faroe Islands argued for a greater share of the TAC given the increased abundance of the stock within their EEZs, which they attributed to climate change, but the EU and Norway were unwilling to give up their quotas, resulting in the management and TAC-sharing arrangement breaking down with Iceland and the Faroes setting their own quotas unilaterally¹⁴ (Bazilchuk, 2010; Astthorsson et al. 2012, Jansen et al 2016). This meant that the total ‘quota’ for the stock exceeded the scientifically prescribed TAC limit. This example demonstrates that even well-defined agreements are not resilient

“Even well-defined agreements are not resilient to unanticipated change, nor are they readily adaptable when political interests override.”

¹² <http://www.spsg.co.uk/herring-survey-pioneers-new-approach-to-support-fisheries-management/>

¹³ <http://nffo.org.uk/news/regionalisation-of-the-cfp-taking-stock.html>

¹⁴ Quotas set by a country without previous consultation or negotiation with others. In fisheries, setting a unilateral quota could have the impact of exceeding the recommended amount of scientifically advised TAC if the sum of the individual TACs exceeds the recommended TAC.

to unanticipated change, nor are they readily adaptable when political interests override sustainability. Notably, the scientific advice that the total catch would constitute overfishing was not sufficient to yield concessions by either side. A more effective mechanism is needed to help avoid future conflicts and enable the consideration of cross-sector views, whilst ensuring that coastal states' quotas and catches do not exceed scientific advice.

NEAFC are currently developing recommendations for contracting parties in relation to allocation criteria and for the coastal state agreements. These initiatives should continue to be developed, with a view to ensuring quota can be allocated according to the criteria developed. The existing fast-track dispute settlement mechanism (which was introduced in 2004 to strengthen decision-making but has not been used) could also be employed to help arbitrate matters relating to TAC setting and quota allocations (Dankel *et al.*, 2015).

Improvements in communication

As touched on above, there was a strong desire for constructive dialogue between scientists and policy makers, with a general recognition that current EU-funded programmes have a responsibility to improve communications and narrow the knowledge divide between disciplines. This is happening to a certain degree through programmes such as ICES WKFISHDISH, CERES, and ClimeFish but more needs to be done to move away from the practice of calling on science to deliver an 'answer' after policy makers pose a question. This expectation is too simplistic and neglects the fundamental ethos that science is not just about *delivering* an answer to a specific question but about *discovering* and *exploring* an answer, together with the relevant experts. Scientific information could also be presented in a simpler format so it is more easily understood by policy makers. This might be achieved by simplifying scientific language so that advice is presented in a more user-friendly format.



A series of expert presentations helped set the scene and shape the afternoon's activities.

Real-time monitoring, use of industry data, speeding up the scientific process

The current drawn-out process for making TAC-setting decisions is particularly unhelpful in the context of climate change because stock changes are occurring rapidly within shifting environmental conditions. More responsive methods are required to produce robust science that feeds into the advisory process; real-time data sampling and advice, supplemented by effective monitoring, could help bring science more in line with decision-makers' needs. While this is already taking place for certain species and fisheries (e.g. sandeel and anchovy), the same is needed for other stocks, particularly those that are changing rapidly in range and productivity levels.

Industry should also be brought into the process to improve the speed of decisions. This could involve some form of payment by industry or cost recovery by managers, so that not all science needs are covered by public funds. This approach is currently occurring in several of the larger European pelagic fishing fleets (e.g., Scottish herring vessels) and has been established practice in other parts of the world, like New Zealand, for quite some time. While it was considered that industry would be receptive to funding more responsive, rapid science (particularly given fishers are experiencing first-hand impacts from climate change on their fishing grounds), this would need to be validated by exchanges with fishers on this subject. Transitioning to more responsive science may require the implementation of real-time monitoring systems (such as on-board cameras) and barriers to this – including low



Gear selectivity was highlighted as an option to help build more robust science to incorporate into the advisory process.

levels of willingness within some segments of industry – remain. The workshop highlighted other options, such as improvements in gear selectivity and avoidance mechanisms, greater efficiency within the existing methods for quota transfer, and ad-hoc adjustments to the current relative stability key. These are discussed in greater detail in Section 4.

It was further noted that a collaborative effort should be undertaken to incorporate reliable industry data into the current scientific assessment process, with suitable safeguards to ensure public confidence in the data and decision making. There are a myriad of real-time tools - such as on-board

cameras, vessel monitoring systems¹⁵ (VMS), catch-apps, and other satellite technologies - which need further analysis in terms of their uptake to improve knowledge around spawning aggregations, sensitive features, vulnerable species, and ensuring TAC limits are strictly adhered to. The challenge here is reflecting on the most appropriate tools in a given fishery and how these different data streams can be incorporated into management decisions, such as limits on catch and real-time closures.

Management

The combination of policy, law and agreements set at the local, national and international level to hold fisheries accountable and ensure adherence to scientific limits.

Building resilience

Resilience means that when a shock to a system occurs, the system will have the ability to recover or adapt. Resilience in a climate and fisheries context can be twofold: 1) the natural system's ability to withstand, recover from, or adapt to environmental change without suffering long-term significant negative impacts, and 2) the ability of the socioeconomic environment to withstand and/or adapt to these changes. Management can implement measures that foster resilience and the more adaptive – i.e., flexible to change - management is, the more resilient the fisheries will become.

Resilient management can be fostered through the adoption of approaches that incorporate risk and uncertainty. Risk-averse policies, such as precautionary harvest control rules, can help ensure that fish stocks are resilient to system shocks effectively creating a stock 'buffer'. Similarly, policies which enable fishing activity to shift between different strategies and species, can help to make coastal communities resilient, even while the mix of available species on which they depend changes.

Fostering resilience also requires systems to recognise that while participating coastal states should be striving for the same sustainability goal, the socio-economic needs of neighbouring states are different. Management systems should be designed with this in mind. Ultimately, there is no one-size-fits-all approach; however, a coherent overarching framework in which to operate is vital. This ensures that any flexibilities in management are supported by shared objectives that are robust and safeguards the continued sustainability of fish stocks across borders.

Existing management and the need for a more 'adaptive', ecosystem-based framework

To build resilience into the system, there must be a good understanding of the existing management picture, as well as where changes may be needed to increase flexibility to ensure sustainability of

¹⁵ VMS is a satellite-based monitoring system which at regular intervals provides data to the fisheries authorities on the location, course and speed of vessels.

the stocks. The current shifts in the distribution of European fish stocks present a dilemma under the existing management framework; while improvements in abundance and recovery of stocks is providing a sense of optimism, there is a growing misalignment between quota allocations with catches, given the varied distribution of stocks over time against a rigid allocation key.

It was queried whether the relative stability key is actually still achieving its stated objective - to protect local fishing communities through predictable access to fishing. Addressing the mismatch between quota allocations and catches was therefore viewed as a critical element to 'get right' within the management framework, particularly if we are to continue on a positive trajectory for recovery of stocks. One idea is to look at examples where there are big differences between TAC allocations and catches and evaluate how to more effectively bring these in line. Key questions to consider include: (1) how might allocation keys better reflect the new reality of rapid distributional change, and (2) through what mechanism might a constructive dialogue take place?

Another approach that can help foster climate resilience is by establishing a more responsive and adaptive management system: one that is capable of deploying fishery management measures in response to rapid changes in the biological, environmental, political, and social landscape. Best practice examples in fisheries around the world could help provide insights into how other countries and regional management bodies have applied adaptive frameworks with success (see adaptive management text box below).

Adaptive Management in Australian Fisheries

Adaptive management was adopted by the Australian Fisheries Management Authority (AFMA) as a way to combat climate impacts and build resilience in their fisheries. Most of Australia's federally-managed fisheries include harvest strategies that set out management actions needed to achieve defined biological and economic objectives for fish stocks. The inclusion of control rules in management plans helped set the level of fishing activity, and monitoring and assessment processes helped inform the setting and progress of the harvest strategy objectives. Management Strategy Evaluation (MSE) is used to conduct evaluation of the entire management cycle in developing harvest strategies. The continual review of management outputs and outcomes allows for adjustments in response to new information. Additionally, cost recovery can allow for new research to address emerging questions. This process was viewed by practitioners as a way to build adaptive capacity, reduce vulnerability and increase socio-ecological resilience while promoting sustainable fisheries. *Ogier et al. (2016), p. 84, 86, 90.*

This approach can be particularly transformative for fisheries that are rebounding, as in Europe, where more healthy and productive stocks enable managers to take forward reforms that further improve upon the current system.

Within an appropriately designed adaptive management framework are tools and approaches that can work at various management scales. For example, responsive harvest control rules that incorporate

precautionary thresholds - based on environmental trigger points - may help keep stocks at sustainable levels and curtail fishing effort when adverse environmental conditions are detected. Adaptive management can also aid in the move towards Ecosystem-Based Fisheries Management (EBFM). Given the ecosystem-wide impacts of climate change, single species management is likely to be insufficient to encompass and respond to these changes. A management perspective that sets goals within the context of broader ecosystem conditions – and focuses science and decision making to support those goals – will be much more able to meet the challenges posed by climate change. More detail on EBFM is provided in Section 4.

Implementing more responsive and adaptive management of quota within this framework will require understanding of how the current allocation scheme is applied at both the regional and international levels. This could also include how TACs and quotas are allocated, either according to historic track record (as used by the relative stability key) or according to zonal attachment¹⁶ (as used in the EU-Norway agreement) to develop quota allocations for shared stocks (including the use of ‘cod equivalents’¹⁷ to determine relative values of different species for quota swaps). Fishing dependency of coastal communities could be another factor entering into play in terms of allocation options. More on quota transfer as a tool to build adaptive fisheries is discussed in Section 4.

Overall, taking a more streamlined, less bureaucratic, stakeholder and community-led approach – characterised by flexibility and responsiveness – was seen as the future for resilient fisheries. Adaptive management was discussed as a framework that can help achieve this greater resilience and improve the management of European fisheries.

“Overall, taking a more streamlined, less bureaucratic, stakeholder and community-led approach – characterised by flexibility and responsiveness – was seen as the future for resilient fisheries.”

Bio-economic and climate modelling

The coupling of bio-economic and climate models can be particularly instructive in understanding how to generate benefits through adjustments to management decisions. They can demonstrate that greater harvests, increased levels of biomass, and improved profits are possible under a management framework that is responsive to both range and productivity shifts resulting from climate change versus one that does not account for such changes (e.g., Gaines et al., 2017 in review). Considered together, these models can also illustrate that the negative impacts from climate change can be offset by getting the management framework right.

¹⁶ A method of allocation where TACs are shared according to the proportion of the stock located in each nation’s waters

¹⁷ A key to establish the relative value of different species, based on their market price compared to the market price of cod. The cod equivalents key used in EU-Norway quota swaps was established in the 1970s and has not been updated, despite changes in the prices of different species relative to cod.

The effects of species distribution shifts on socio-economic outcomes has also been explored on a regional scale, using a high resolution climate model and relatively fine-scale fisheries independent survey data on the US North East Shelf (Kleisner *et al.*, 2017). This analysis illustrates how stocks are shifting into and out of management areas, and the potential for negative socio-economic impacts as stocks shift away from traditional fishing grounds, with positive impacts if management allows for the sustainable exploitation of new stocks. While these climate models can provide a picture of the potential availability of thermal habitat, it was acknowledged that there is still much uncertainty around climate projections and models are not able to provide absolute estimates of biomass change or range shifts. Ultimately, however, modelling changes in species' thermal habitats can provide indicators of climate risk and be useful to managers. Additionally, being able to map these distribution shifts provides a means of more easily communicating these changes to managers and other stakeholders.

Ecosystem-level scientific information

As touched on above, successful fishery management will require more holistic consideration of the broader ecosystem's effects on fisheries in the face of climate change. Doing so will require complementary scientific information that provides advice to enable informed decision-making at the appropriate scale. Managers and scientists must work together to identify the type of scientific information and advice needed to support appropriate fishery goals in light of the broad-scale changes to the ecosystem that will occur with climate change. For instance, given the impact of very large fish stocks on other species in the ecosystem, single stock assessments are not always able to respond to the complexities of multi-stock fisheries. The effects of large stocks on smaller stocks can be profound due to food web interactions. The intersection of climate change and fisheries may exacerbate these profound impacts in ways that are not yet fully understood.

One approach to begin closing this information gap is the development of spatially-explicit multi-species models and tools that can be conceptualised for different species interactions and their interplay within the management system. Climate change impacts can be incorporated into these models in order to further inform multi-species stock dynamics as a result of a fluctuating environment.

The degree to which an ecosystem model, or models with environmental variables, can predict climate change impacts on multiple stock dynamics, needs further research and analysis. There is an inherent degree of uncertainty in these more complex models, which raises issues around the acceptance and adoption of management approaches that are otherwise informed by these models. However, as discussed previously, transitioning to an EBFM framework should ultimately lead to improvements in both the science and the management system in ways that help foster goal attainment in light of broad ecosystem-level change that will occur with a changing climate. It is also worth noting that, within a northern European context, stocks are in a relatively good state of health

“Transitioning to an EBFM framework should ultimately lead to improvements in both the science and the management system in ways that help foster goal attainment in light of broad ecosystem-level change resulting from climate change impacts.”

and more is known about them than in other ocean regions, meaning the ability to reform existing models and assessment approaches presents less risk of undermining this positive trajectory.

Industry contribution to science and management

While industry were not directly represented at the workshop, several participants were former professional fishers who provided insights from an industry perspective. Fishers were broadly considered to hold a wealth of knowledge that should and must be tapped into by scientists and managers in order that science can more accurately reflect what is being observed on the fishing grounds. This requires greater collaborative working to ensure that fishers can derive tangible benefits from their contribution, and eventually see their data used in the assessment and management process. This is already occurring locally to some degree (see above example on West of Scotland herring). However, more national and international input of industry knowledge is required, particularly where stocks are moving into and out of management areas. Finding ways to incorporate industry-supported data within the system is no doubt challenging, but will help to achieve more responsive management through the generation of high quality, real-time data.

“Fishers were broadly considered to hold a wealth of knowledge that should and must be tapped into by scientists and managers in order that science can more accurately reflect what is being observed on the fishing grounds.”

In addition to contributing to science, industry also has a role to play in making the existing management framework more workable and able to deliver on its objectives. Fleet adaptation, such as improvements to quota transfer and gear selectivity, must be catered for when designing appropriate



More national and international input of industry data is required so scientists and managers can more accurately reflect what is being observed on the fishing grounds.

management systems so that industry is able to effectively respond to changes in the system. Contributing to the dialogue on finding ways to alleviate choke scenarios and effectively implementing the landing obligation is already happening and is an essential component of adapting to change. However, fishers should have access to more fluent swapping of quota between Member States and between the EU and other coastal states, which would further help alleviate choke and discarding issues. Greater transparency in the existing quota system would help, as well as identifying possible ‘swap partners’ for different species.

The use of the existing framework to set up priority quota exchanges could take place, as well as one-off adjustments to the relative stability key including, where required, adaptation of the management areas, to alleviate any mis-match in quota and catch. For example, setting up a one-off bilateral exchange to alleviate haddock as a choke species for Spain in Area VII, or a one-off adjustment to the relative stability key for hake that separates northern and southern stocks to account for the increased presence of hake in northern waters.

Governance

The compilation of institutions, actors, rules, science, policy and law that make up a legal and guiding framework for fisheries in the North East Atlantic region.

Existing institutional framework

Climate-related impacts are no doubt gaining traction within the region's governance discourse; for example, the European Commission is working to build 'climate-proofing' policies - requiring that the CFP take account of climate change to promote more resilient, adaptable fisheries management systems for Europe¹⁸. Getting the institutional and governance system right is critical so that the pillars of management and science can be effectively nested within a governance framework that meets the needs outlined above. Changes to institutional structures do not occur quickly but it is necessary to elevate the dialogue now so that institutional adaptation is able to occur. Additionally, it was remarked that key actors (including but not limited to scientists, fishers, and managers) should be aspirational about what they want for the future, as well as what the ideal institutions are to tackle the challenges ahead.

The need for new – versus newly-invigorated – institutions

While there was recognition that effective management and institutional frameworks are needed, the idea of simply creating one or more new institutions to deal with the changing fisheries landscape was generally not supported, noting that new institutions do not necessarily equate to improvements.

The group recognised that flaws in fisheries management are not solely or necessarily due to data gaps in science; some may be a product of poor institutional or governance systems that are not (or are no longer) suited to the changing circumstances. It was noted that the existing institutional framework cannot effectively respond to the changing nature of politics and environment, meaning coastal states (and their institutions) are not equipped to deal with challenges such as the movement of species into and out of management areas (and any associated impacts that this may have on fishing patterns).

Refreshing the current institutional arrangements to better equip managers to deal with systemic 'shocks', whether climatic or otherwise, was felt to be a sensible step forward. Bringing key players

¹⁸ The EU Strategy on Adaptation to Climate Change (Action 6), 2013. https://ec.europa.eu/clima/sites/clima/files/docs/eu_strategy_en.pdf

together to review existing institutional arrangements, including current allocations among coastal states, current bilateral and multilateral stock sharing arrangements, and the potential for improved dispute resolution mechanisms, were considered necessary in helping ‘climate-proof’ fisheries governance for the region.

The role of the North East Atlantic Fisheries Commission (NEAFC) as a governing institution

NEAFC is a regional fisheries management organisation with international legal competence to manage fisheries in the North East Atlantic. Its management role is mainly on the high seas, but measures can apply to areas within national jurisdiction where the relevant coastal state suggests such an arrangement (Asmundsson & Corcoran, 2016). The Contracting Parties to NEAFC are Denmark (with respect to the Faroe Islands and Greenland), the European Union, Iceland, Norway and the Russian Federation. Cooperating non-contracting parties are Bahamas, Canada, Liberia, New Zealand and St Kitts and St Nevis¹⁹. Most of the waters within the NEAFC Convention Area are under the fisheries jurisdiction of the Contracting Parties, but there are four large areas of international waters, which make up the NEAFC Regulatory Area.

NEAFC was highlighted in discussions as a possible institution to take on the umbrella role of fisheries management for the region. Effective and overarching leadership is required, in coordination with respective national fishery management goals and objectives, in order to deal with the challenges posed by climate impacts at this level. However, reservations were expressed as to whether NEAFC — in its current form — is equipped to coordinate coastal states through taking on such a region-wide governance role. For example, the existing ‘fast track’ dispute resolution mechanism adopted by NEAFC in 2004 has yet to be put to the test despite conflicts that have arisen between signatories in the intervening years, especially for mackerel. The UK most likely joining NEAFC as an independent coastal state in the wake of Brexit may provide a timely window for review.



NEAFC was highlighted in discussions as a possible institution to take on the umbrella role of fisheries management for the region.

Regional Fisheries Management Organisations (RFMO) like NEAFC could develop mechanisms to improve their responsiveness to fisheries challenges: such as a function enabling them to take action when members fail to agree on management of shared stocks through coastal states’ agreements. Whether NEAFC might improve in this area was a topic of discussion, and may be limited to those

¹⁹ NEAFC website, https://www.neafc.org/managing_fisheries/measures/ra_map, 5 October 2017.

stocks that straddle international waters or include a minimum number of NEAFC members. Reviewing how other RFMOs operate when conflict arises, and under what conditions, could help broaden knowledge on how international fisheries conflicts can be resolved.

Regardless as to whether NEAFC should have an enhanced role in managing fisheries of the region, the benefits to refreshing or reforming this existing, well-positioned institution rather than creating a new one, was a repeated point of discussion. Lessons can also be learnt from the NEAFC collaboration with The Oslo-Paris Commission for the Protection of the Marine Environment in the North East Atlantic (OSPAR) through the development of their Collective Agreement,²⁰ which set out roles and responsibilities between the two institutions within the region aimed at enhancing effective conservation. It was noted that NEAFC has also demonstrated exemplary leadership in being the first RFMO to conduct an independent performance review²¹, and could further develop this leading position by taking a role in ensuring that coastal states' agreements for the management of shared stocks function effectively.

European Commission and the Member State high level groups

The high level regional groups have an important role in proposing regional management plans and technical measures (with the advice of the Advisory Councils) to the Commission. While they serve an important function in bringing fishery directors from relevant Member States together, questions around their lack of stakeholder input and transparency were raised. The current set up — where Advisory Councils discuss fisheries issues and submit advice to the high-level groups (which were thought to sometimes take non-transparent decisions separate from scientific and other stakeholders) — could benefit from review during a possible future CFP reform round, if not before. More integrated dialogue between the high level groups and the ACs is needed to achieve genuine bottom-up decision making.

Conversely, some noted that the system is generally heading in the right direction (with different high-level groups and Advisory Councils demonstrating varying degrees of integration and success) and that, with a bit of fine-tuning, the necessary elements could be in place to improve their ability to adopt and implement needed management plans and technical measures.

²⁰ The growing importance of fisheries to issues of biodiversity (both in terms of habitat protection and bycatch of non-target species), and vice versa, led NEAFC and OSPAR to develop a bilateral Memorandum of Understanding, which later developed into the (potentially multilateral) Collective Arrangement; see https://www.neafc.org/system/files/opsar_mou.pdf

²¹ A more recent performance review highlights both NEAFC's strengths and its challenges; see PERFORMANCE REVIEWS BY REGIONAL FISHERY BODIES: INTRODUCTION, SUMMARIES, SYNTHESIS AND BEST PRACTICES, Volume I: CCAMLR, CCSBT, ICCAT, IOTC, NAFO, NASCO, NEAFC, 40-42. <http://www.fao.org/docrep/015/i2637e/i2637e00.pdf>

Section 4: Frameworks, Tools and Approaches for Future Fisheries Management in the Region

Certain management tools already exist which hold great promise for helping to mitigate or navigate the effects of climate change on ecosystems and associated fisheries. Any of these tools deployed to provide more robust, climate-ready advice for fisheries should be used within a cohesive, adaptive management framework. To be effective, fishery managers should be familiar with these tools and have the ability to deploy them promptly. This is often a challenge, especially in systems where silos exist and communication is limited. This once more underscores the need to effectively connect science, management and policy to ensure knowledge, ideas and established best practice can be shared and acted upon.

The full consideration, uptake and application of different tools and approaches can be encouraged or stifled by particular conditions in the existing system. These barriers and enabling conditions are useful to tease out and we provide some thoughts on these in Annex B of this report.

The following section outlines some of the specific management tools discussed at the workshop in developing more adaptive management frameworks. Some of these tools already exist but further consideration on how they may be refined and applied in a European context is worth pursuing.

(1) Adaptive, Ecosystem-Based Fishery Management (EBFM)

As identified earlier within this report an adaptive EBFM approach holds potential to incorporate complex interactions and information to help managers make decisions in a rational, structured way. This can be particularly useful when considering the uncertain and unfolding effects of climate change.

To help frame possible solutions to challenges in the region there must be a structure that enables managers to engage in a continuous cycle of goal setting, science development, specification of fishery management measures, and evaluation of fishery performance against goals for the fishery. This approach can help foster the development of holistic goals that are appropriate given the degree of ecosystem level change that will occur. It can also help to enable the incorporation of information which may be new or unfamiliar, along with the utilisation of decision-making support tools. Such additional steps include (but are not necessarily limited to):

- Incorporation of ecosystem-level information within scientific and management advice;

- Taking into account the effect of fishery management measures on the broader socio-ecological system, and vice versa; and
- The use of decision support tools to help focus policy decisions through a lens of risk and uncertainty.

By adopting and implementing adaptive EBFM management frameworks, it is more likely that fishery managers will be able to better handle unforeseen events as they unfold, and to make more calculated decisions that anticipate and mitigate climate change effects on fisheries.



Dr. Mark Dickey-Collas, the ecosystem approach coordinator in the secretariat of ICES, presents his work on EBFM to the workshop.

(2) EBFM-specific management tools

To help foster the uptake and implementation of adaptive EBFM systems, specific management tools can be deployed by fishery managers to respond to climate-related challenges. The development of new tools should be simultaneously encouraged as a way to achieve more resilient fisheries that foster a process toward attaining EBFM.

Several management measures and approaches are already available to help managers deal with the effects of climate change on fisheries. These can broadly be categorised as:

- a) target reference points, stock level indicators, and harvest control rules;
- b) bioeconomic tools;
- c) decision-support tools;
- d) social resilience or socio-economic tools.

Below we present the different tools discussed during the workshop:

a) Target reference points, stock level indicators and harvest control rules

Target reference points (TRPs) are goals for a certain stock size or fishing rate. In the European context they refer to fishing mortality and fishing rates that provide a desired yield, as opposed to other parts of the world where TRPs may focus on biomass levels. Policy makers often orient these fishery management goals around fishing rates that achieve MSY. However, alternative TRPs may be more robust to climate change effects than those aiming at MSY. The “pretty good yield” approach outlined by Hilborn (2010) argues that desired fishery outcomes can be attained if fisheries provide something close to the MSY. If stocks are maintained at relatively high levels of abundance (such as 50% of the



Workshop delegates broke out into small working groups to discuss the different management tools that can help to mitigate or navigate the effects of climate change on ecosystems and associated fisheries.

unfished level) yields to the fishery are generally not greatly affected. Keeping biomass levels higher than that which generates MSY can be a hedge against climate-related uncertainty and variability. This approach, and others like it, appear to hold promise for dealing with climate-related risks²².

Stock level indicators ICES uses stock level indicators rather than assessments for data limited stocks (i.e. categories 4 through 6). While already in use, more extensive use of stock-level indicators, potentially even for data-rich stocks during the interim between formal stock assessments, can inform more rapid identification of changes in stock abundance and status. In turn, having more frequent information can potentially allow for management interventions if it appears there are significant changes in stock abundance. Inversely, if stock level indicators suggest an assessed stock has not undergone any meaningful change in abundance, limited scientific resources could be redirected to a different species that may be in more need of attention.

Harvest Control Rules (HCRs) are management actions that are taken in response to changes in stock abundance or status. These actions can be tailored in such a way as to make fisheries more adaptive under climate change, especially when it comes to changes in productivity. Often productivity changes in a stock are not identified by fishery scientists until well after these productivity changes have occurred. If productivity is declining, and fishery scientists have recommended harvest levels based on higher assumed rates of productivity, then the result is likely to be a fishery that unknowingly engages in overfishing, resulting in a decline in stock size. HCRs that are appropriately specified can buffer against this possibility, provided that the HCR is “ramped” in the sense it scales up and down in accordance with stock abundance. Often, stock abundance is easier to measure than productivity, so as long as there is an indicator of abundance readily or frequently available. A ramped HCR that scales harvest

²² While this approach is already built into the EU MAPs, further exploration and honing of these approaches in the context of climate change would be worthwhile.

rates according to abundance will increase or decrease fishing pressure in accordance commensurate with that abundance. If these abundance changes are due to productivity changes, then the HCR will effectively be adapting the fishery to climate-induced productivity change.

b) Bio-economic tools

A recently completed effort coupling a climate velocity model with a bio-economic model provided valuable insights regarding climate-related fishery challenges on a global scale (Gaines et al. 2017, in review). Developing a similar model that is scaled to the North East Atlantic region could provide similar insights regarding future climate impacts on fish stocks and the consequences of different fishery management responses. Such an effort could help to focus policy reform efforts and guide future research in the region.

International coalitions²³ will be necessary for managing problems posed by shifting stocks. Game theory analytics and other similar forms of analysis can help inform the building of these coalitions as well as provide a better understanding of the impacts on different countries as fish stocks move in and out of ICES management areas and across Coastal State EEZs. One technique that has helped construct collective management agreements in Europe and other parts of the world is Game Theory. It is a bio-economic tool that has been used to deal with different sources of conflict and can be applied to conflict that may arise due to climate change. Several scenarios in which game theory could usefully be applied include:

1. New coalitions (when a new stock moves into a different EEZ and choices must be made as to how to manage the new stock in a different zone²⁴);
2. Adapt existing coalitions (when a stock expands geographically and existing agreements need to be revised to avert conflict);
3. Partial coalitions (if parties cannot agree and not all relevant Coastal States are party to a shared stock agreement²⁵).

Understanding how to develop successful coalitions will become increasingly relevant to North East Atlantic fisheries as stocks continue moving and parties attempt to avoid disputes.

Participants noted that game theory analyses can be very sensitive to uncertainty. However, even in the face of this uncertainty, these analyses offer insights on how certain actions by one party lead to reactions by another. This perception can help identify different incentive mechanisms to foster coalition formation, and can aid in the review and strengthening of existing coalitions.

²³ International coalitions refer to an agreement or partnership among nations for collectively managing a resource that is shared by those countries.

²⁴ A recent announcement by Norway to propose a joint EU, Norway, UK Fisheries Commission is an example of forming new coalitions that support new legal and institutional structures: <https://www.politico.eu/pro/politico-pro-morning-agri-and-food-presented-by-ecpa-norway-fish-talks-agri-food-summit-tuna-quota/>

²⁵ Recent ICCAT discussions led to a re-negotiation of tuna sharing agreements in order to allow for new coalition members, and ensure total catch adherence to a desired TAC.

Game Theory in Practice

The Parties to the Nauru Agreement (PNA) is an example of coalition formation to attain desired conservation and economic goals. Pacific island nations comprising the PNA collectively represent 85% of the historic catch of skipjack tuna. These island nations have been able to leverage their collective position to ensure stock abundance goals are met, and to generate relatively large royalties from vessels desiring to fish in their EEZs. Understanding whether a coalition of nations is large enough to attain desired conservation goals while returning economic benefits to member countries is one way in which game theoretic analytics can be used to help inform the development of robust management institutions.

One of the main sources of uncertainty in game theoretic analyses is often the inability to include all relevant factors. For instance, in the case of international fisheries, factors other than the allocation and access to a fishery resource often play a large part in negotiations over the sharing of that resource. Trade, political negotiations, and geographic access (rather than just harvest) also need to be taken into account.

c) Decision-Support Tools (DSTs)

DSTs can be described as instructive tools to help managers, scientists, and fishers understand possible outcomes under varying scenarios and conditions. In the context of climate change, DSTs can be particularly useful when considering climate-related risks and uncertainty and the management thereof. By developing a DST that clearly articulates the difference between varying management outcomes in terms of their risk profiles, managers could make better, more informed, decisions.

One form of DST familiar to fishery scientists and managers is the Management Strategy Evaluation (MSE) approach. They involve “using simulation to compare the relative effectiveness for achieving management objectives of different combinations of data collection schemes, methods of analysis and subsequent processes leading to management actions” (Punt et al. 2016). The application of DSTs are becoming more widely used in the fisheries management community. A recent Mareframe conference set out the application and uptake of DSTs across Europe. Case studies can be found here: <http://mareframe.mapix.com/>

d) Socio-economic tools

Climate change will have varying effects on people and places. Understanding who will benefit and who will be disadvantaged, and how fisheries are prosecuted as climate change takes hold, will go a long way to determining how individual communities fare and how fish resources fare. Various socioeconomic analytical approaches have been deployed for assessing factors like the dependence of communities on fisheries, and their vulnerability to change – especially fisheries-related change. Coupled ecological-economic optimisation models, in particular resolving age-structured populations, are able to

address climate change by using environmentally-sensitive stock-recruitment functions, for example. Furthermore, they are able to simulate the effects of changes in economic driving forces (e.g. fuel costs, prices), which might be of comparable importance, so that changes in optimal fishing strategies under global change scenarios (climate and economic) can be computed. This will facilitate the visualisation and communication of trade-offs, which are important for policy and decision making.



Active participation was encouraged over the two day workshop, delegates shown here discussing their ideas for future fisheries management in the region.

By using socio-economic models to inform our understanding on the dependence of communities on fisheries (as well as their vulnerabilities), the underlying motivations of fishers - and related stakeholders - can be better understood, as well as the type of reforms that may be appropriate to relevant groups and communities. Developing measures that take these factors into account while helping them adapt to climate change effects can reduce any social disruption that may be caused as a result of climate-related impacts on fisheries.

(3) Cod Equivalents or development of some other ‘paper/online’ currency to facilitate quota transfers

The development of some form of ‘quota currency’ was raised as a possible approach to enable fishers to keep more of what they catch and/or resolve catch/quota misalignments. The development of a currency could vary between the different coastal states but could be applicable in the first instance to fisheries where normal market conditions are already in place with strong institutional structures to support setting different values to key species. Such a scheme could enable fishers to acquire quota for fish they are targeting and might be based on the existing ‘cod equivalents’ key which is used to determine relative values of different species for quota swaps.

There could be challenges with the development of such an approach - particularly any new currency mechanism - and the following issues were identified during the workshop:

- a) Challenges in achieving a level playing field due to different quota management rules and trading cultures within each Member State and within the coastal states;
- b) Small-scale and artisanal fishermen may not be as well suited to this mechanism if methods are not devised that cater for their needs. It is also difficult to interpret the potential impact without full analysis;
- c) How to make a ‘common currency’ with fluctuations in market prices, and different values of different species (including fluctuating differences in values);
- d) The development of any type of currency to facilitate transfers must be approached carefully so as to fully consider the ecological, economic and social outcomes that might result from such an approach.

(4) Bilateral/multilateral cooperation at EU level to enable more fluent swapping of quota with more flexible management arrangements

There are existing tools for quota swapping which could be expanded upon to address the need for more fluid quota transfers. Specific stocks that pose a significant choke risk could form the basis for an exchange of this nature. The Commission could assist in convening two or more Member States in need of exchange of quota, with a view to establishing a precedent for further exchanges as needed.

(5) Quota Management/catch balancing tools

Balancing catch against quota allocation is an essential component of robust fisheries management and this is particularly relevant in the European context where stocks straddle national and international management areas. We touched upon a variety of ways that the current institutional arrangements might be altered to enable better adaptation to climate-related impacts across the different governance levels, such as:

- Refinements to the roles of existing institutions like NEAFC (see above)
- Mechanisms to periodically revisit stock sharing arrangements
- Enhanced dispute resolution mechanisms among coastal states

A number of these ideas are explored in more depth in a follow up paper on governance mechanisms arising from the workshop²⁶.

(6) Use of different units of stock allocation when dividing among EU Member States and between the EU and other nations

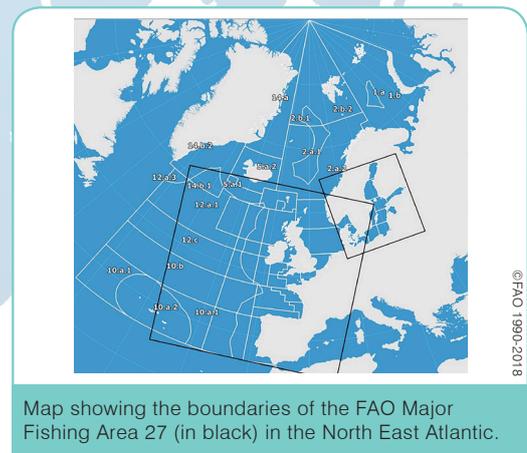
One method to allow for added flexibility when dealing with changing abundance and mixture of stocks, while still recognising important social values, is to allocate different types of fishery units; for example, allocating a “fishery portfolio” (such as groundfish, or pelagics), rather than the allocation of individual fish stocks at either an EU or coastal state level. It would work by assigning a percentage of a fishery, such as groundfish, but then each year would be allocated an amount of individual groundfish species that is based on the species abundance mix that is present in adjacent waters. Thus, while the overall share of the groundfish fishery would be constant, the amount and type of groundfish allocated would change each year based on prevailing conditions. This approach could be piloted on a national level to begin with, and while complex to enact on a larger scale, this same approach could be considered at an EU or international level when setting TACs between relevant coastal states.

²⁶ See recent ABPmer report for EDF on building fisheries resilience in the North East Atlantic: ABPmer, 2018. *Building Resilience of fisheries Governance in the North East Atlantic (in review)*.

Section 5: Condensing Workshop Themes and Next Steps

While the workshop did not aim to draw conclusions or consensus recommendations, it did set out to synthesise themes and highlight more generally that the current science and policy infrastructure ‘housing’ fisheries management and governance is in need of a more adaptive and ecosystem-focused framework. It achieved this by identifying some of the most complex challenges that climate change effects will have on fish stocks and fisheries in the North East Atlantic region by bringing together relevant experts. More importantly, it tasked participants to consider potential solutions to overcoming these challenges.

Discussions highlighted the well-documented northwards trajectory of stocks as a result of changes to environmental conditions and how this is creating a growing misalignment between fixed quota allocation and catches. The ability to discard catches for which there is no quota will be prohibited once the landing obligation is fully implemented in 2019 and this will bring into full view the growing disconnect between quota allocation and catches.



Overall, we heard that while the challenge posed by climate change is large, the results of this workshop show that there are things that can be done to mitigate – and potentially even take advantage of – the changes to fisheries that climate change will bring. What is more is that we know enough now about

“The results of this workshop show that there are things that can be done to mitigate – and potentially even take advantage of – the changes to fisheries that climate change will bring.”

the effects of climate change, and how to deal with it, to begin taking action. The more quickly we can explore these new tools and approaches, and adapt them for implementation in the region, the more likely it is we can avoid any undesirable consequences.

A suite of tools and approaches were identified that are responsive to climate change effects. Implementing these tools within an adaptive, ecosystem-based framework may provide the greatest opportunity for effective and appropriate deployment. In addition, developing decision support tools that explicitly incorporate risk and uncertainty can guide policy decisions that are robust in the face of significant and inherent uncertainty associated with climate change impacts.

While a myriad of themes and tools were discussed, the common theme connecting the threads was the need to provide sufficient flexibility to adapt to shifting stocks, and the multitude of additional

effects we have not yet identified. Given the scale of these challenges, such conversations need to rise to the level of national administrations, international forums (such as RFMOs) and other institutions with the perspective necessary to manage stocks that cross political boundaries. Without modifying current stock-sharing mechanisms and adopting appropriate tools, the significant risks and uncertainty to Europe's fishing future will continue to plague managers and fishermen with the likelihood of fisheries disputes occurring in the region.

The need for adaptation is clear, and the sense of urgency among stakeholders is mounting. Indeed, Europe offers a prime test case for dealing with the nexus of climate change and fisheries. While these challenges are complex, they are not insurmountable; the desire on the part of all participants to make the system more resilient and responsive to external shocks, was evident throughout the workshop.

To make this happen there should be a thorough evaluation of the existing suite of institutions so that management approaches can be effectively joined up across Member States and between Member States and Coastal States, particularly where stocks are shared. The suite of tools discussed in the



A group picture of the workshop Steering Committee, speakers and participants who contributed their time, energy and expertise to making this workshop a success.

“Without modifying current stock-sharing mechanisms and adopting appropriate tools, the significant risks and uncertainty to Europe’s fishing future will continue to plague managers and fishermen with the likelihood of fisheries disputes occurring in the region.”

workshop are a good starting point to get the process going, but all participants saw the need for further elaboration and debate.

Finally, further research and the development of these tools must be underpinned by sufficient funding and taken forward through strong partnerships to benefit from collective expertise. Building on the collaborative efforts of this workshop will be an important

next step, with further research and collaboration incorporating industry interests and relevant coastal state administrations. Only through strong, well-funded partnerships can climate-related impacts on fisheries in the North-East Atlantic receive the attention merited – prompting the development of urgently needed solutions.

Annex A: Participant List

Name	Organisation	Relevant research
ALAN BAUDRON	University of Aberdeen	ClimeFish http://climefish.eu/ MareFrame http://mareframe-fp7.org/
BRIAN MACKENZIE	DTU AQUA National Institute of Aquatic Resources	
ERIN PRIDDLE	Environmental Defense Fund Europe	
FRANCO BIAGI	European Commission	
HARRIET YATES SMITH	Mindfully Wired Communications	
HELEN TAKADE-HEUMACHER	Environmental Defense Fund	
IRATXE RUBIO	University of Vigo	https://futureoceanslab.org/
JESSICA LANDMAN	Environmental Defense Fund Europe	
JOHANNA FERETTI	Thuenen Institute for Baltic Sea Fisheries	
JÓNAS R. VIÐARSSON	Matís	http://climefish.eu/ http://mareframe-fp7.org/ http://www.discardless.eu/ http://www.saf21.eu/ https://www.farfish.eu/ http://ecofishman.eu/
JORN SCHMIDT	University Kiel	www.preface.w.uib.no
JOSE FERNANDES	AZTI	
KATRINA RYAN	Mindfully Wired Communications	
KRISTIN KLEISNER	Environmental Defense Fund	https://www.nefsc.noaa.gov/press_release/pr2017/scispot/ss1705/ http://www.oceanhealthindex.org/
MARK DICKEY-COLLAS	ICES	
MERRICK BURDEN	Environmental Defense Fund	http://www.nrcresearchpress.com/doi/abs/10.1139/F10-118#.WIOxYFWnHIU
MIKE FITZPATRICK	Marine Natural Resource Governance	
MOGENS SCHOU	AquaMind	https://ec.europa.eu/research/scar/pdf/scar_fish_report_11_2013.pdf
MYRON PECK	University of Hamburg	ceresproject.eu
POUL DEGNBOL	Aalborg University	
SCOTT LARGE	ICES	
SUZANNAH WALMSLEY	ABPmer	www.abpmer.co.uk/experience/fisheries-and-aquaculture-experience/
UNN LAKSA	Syntesa	

Annex B: Enablers and Barriers

Barriers	Enablers
Advice can be too slow to take meaningful management decisions. Advisory process is tedious and long-winded but need more rapid, responsive decisions.	Starting to transition towards real-time data, need to scale up pilots to programmes.
Lack of certainty in FISHDISH process, leading to no change in status quo.	Commission believe in funding climate research, supporting other projects in future and learning from previous ones.
Rigid management system, dated relative stability key not reflective of current stock distributions.	Relative stability objective to protect local communities; therefore using this objective there is justification to re-evaluate key and whether it is achieving its stated purpose.
EU projects like ClimeFish are great but decision-support tools are not able to inform decisions in reality and are therefore blocking uptake at policy level.	Shifts in governance for the region provide a 'window' to explore adaptive management and reform existing institutions so they effectively feed in science and policy into higher level thinking. Currently no fixed way to establish agreements to need to act on this dynamic political 'moment' to ensure adaptive strategies prevail.
Poor governance to set up needed bilateral/multi-lateral transactions for quota swaps to reduce discarding and ensure quota can be swapped/traded in to cover catches.	Potential to develop mechanisms to facilitate quota swaps and trades
Reliability of data - stocks moving in and out of management areas but science not keeping pace or informing management effectively.	
Lack of industry buy-in to scientific process, not enough use of industry data to feed stock assessments - all contribute to poor uptake in real-time data efforts.	
Breaking up ownership of fish quota and moving to a more equitable system that provides broader access, particularly for small scale fishermen	System is set up to enable more effective quota transfer, just need to tweak around the edges and gain political will to make change
Political inertia for change risking the closure of fisheries due to high levels of choke species due to misalignment of catch with quota allocations.	

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