MASTS Fisheries – Interaction with Policy Symposium

0930-1630 on Tuesday 7th February 2023

Lyell Centre, Heriot Watt University, Currie, EH14 4AS

This event provided the opportunity to showcase to Marine Scotland Policy colleagues, the scope and research expertise relevant to fisheries across the MASTS community. The symposium was designed to allow a broad selection of research to be highlighted through a series of brief presentations and time for questions and discussion. Policy colleagues were invited to participate in a facilitated open discussion to explore how the research community can engage and help to better inform policy.

The facilitator for this event was Kara Brydson, Executive Director at Fisheries Innovation & Sustainability.

Marine Scotland's strategic agenda is driven by the actions contained within the Fisheries Management (FFM) Strategy and the Blue Economy vision and associated outcomes. There are several gaps in knowledge and understanding, along with items that will require further development to inform our policy development both now and in the future. Key areas of interest include (but aren't limited to):

- Future proofing policies and horizon scanning for new technology and practices, including general improvements to the Scottish fisheries management approach
- Climate change adaptation and mitigation throughout the supply chain
- Resilience and diversification within the fishing industry, including in relation to labour, succession planning and equalities
- Fishing interactions in the marine space, particularly in relation to competing sectors (e.g. renewables), conflict between fishing methods, and the spatial squeeze e.g. because of new environmental management measures.
- Building the evidence base for stocks, including where these might support a shift in management e.g. TACs for non-TAC species
- Considering incentive-based fisheries management options in a Scottish context
- Wider ecosystem interactions and impacts, including cumulative impacts of fishing on the marine environment and how these can be mitigated.

The format for the symposium was as follows:

09:30-09:45	Arrival tea/coffee
09:45-10:00	Welcome, Introductions and Scene setting
10:00-11:10	Presentations and discussion - session 1
11:10-11:30	Coffee/Tea Break
11:30-12:40	Presentation and discussion - session 2
12:40–13:15	Lunch
13:15-14:15	Presentation and discussion - session 3

14:15-14:35 Coffee/Tea Break

14:35-15:35 Presentation and discussion - session 4

15:35-16:15 Feedback from MS and open discussion re ways that the fisheries research community can better help to inform policy.

16:15-16:30 Closing remarks and next steps

Session 1 (view abstracts here and presentations here)

- Coby Needle (Marine Scotland Science) – brief outline of fisheries work happening in Marine Scotland Science
- Tara Marshall (University of Aberdeen) - Climate change impacts on fish in UK waters
- Natasha Walker-Milne (University of Glasgow) - Fish nursery habitat in Scotland
- Clive Fox (SAMS-UHI) – The Scottish Razor Clam fishery
- Ieuan Jones (Aberdeen University) – Tropicalization of the North Sea - *Online presentation*
- Blair Easton (St Abbs Marine Station) – Crab Fisheries in the Berwickshire Marine Reserve
- Tully Osmond (Edinburgh Napier University) - The influence of parasitic interactions in Scotland's fishing industry

Session 2 (view abstracts here and presentations here)

- Ingrid Kelling (Heriot Watt University) – Introduction to the Global Centre for Social Sustainability in Seafood Supply (GC4S) - *Online presentation*
- Ian Napier (UHI) - Fisheries management, fisheries policy and associated issues, and their interactions with the fishing industry.
- Elena Balestri (Scottish Fishermen's Federation) - Bridging the gaps between the fishing industry and Science
- Rachel Shucksmith (UHI) - Best practice and potential barriers to a just energy transition for fisheries and dependent communities
- Paul Fernandes (Heriot Watt University) - Sustainable management of marine resources, with a focus on marine technology
- Mark James (St Andrews University) - Technology, processes, and systems to support fisheries management.

Session 3 (view abstracts here and presentations here)

- Mike Heath (Strathclyde University) - StrathE2E – a strategic tool for scoping an ecosystem approach to fisheries management.
- Emma Tyldesley (Strathclyde University) - Developing the ecosystem-based Likely Suspects Framework (LSF) programme for salmon
- Neda Trifanova (University of Aberdeen) – An ecosystem modelling and assessment framework for decision processes seeking to integrate new uses into marine ecosystems.
- Jack Laverick (Strathclyde University) - The StrathE2E online app – real-time game play for ecosystem fisheries management
- Douglas Speirs (Strathclyde University) - StrathSpace – Spatial Modelling of Fish Stocks *Online presentation*

Session 4 (view abstracts here and presentations here)

- Niall Fallon (Marine Scotland Science) - Investigating Environmental Impacts of the Scottish Nephrops Fleet: Current and Future Fisheries Management Scenarios
- Ana Adao (Strathclyde University) – State of the cod population in the Clyde and evaluation of the impact of discards by the Nephrops fishery
- Simon Northridge (St Andrews University) – The UK Bycatch Monitoring Programme
- Robin Cook (Strathclyde University) - The impact of seals on whitefish stocks in the West of Scotland
- Tara Marshall (Aberdeen University) – BATmap - A pioneering approach for reducing unwanted bycatch and discards.

SESSION 1 Abstracts and contact details.

Tara Marshall (University of Aberdeen) - **Climate change impacts on fish in UK waters**

As co-lead of ongoing MCCIP review of climate change impacts on fish in UK waters I will speak to this topic by reviewing the nature of impacts as well as broader implications for fisheries. I also work on GHG emissions of different fleets with a view to developing suitable mitigation priorities.

Natasha Walker-Milne (University of Glasgow) - **Fish nursery habitat in Scotland**

The team at Glasgow have been working on fish nursery habitat in Scotland for the last 10 years, in collaboration with Nature Scot, Marine Scotland Science and the University of Strathclyde. Our work has focussed mainly on the South Arran Nature Conservation MPA, though recent work in collaboration with SRUC extends these studies to Loch Eriboll and the Wester Ross MPA. Our main method is the use of Stereo Baited Underwater Video systems (SBRUVs). Our work has demonstrated the importance of seabed biodiversity, substratum type and seascape configuration in the presence, abundance, and growth of juvenile gadoids. Our seascape models create highly detailed seabed maps from BRUV imagery, allowing seabed patch type, size, and shape to be determined. The incorporation of seascape information into the design of spatial measures for fisheries and conservation will allow better targeting of protection and restoration efforts. This work is relevant to fisheries spatial management, as well as the HPMA programme.

Clive Fox (SAMS-UHI) – **The Scottish Razor Clam fishery**

The Scottish Government has authorised a scientific trial electrofishery for razor clams which is taking place within designated areas of the Scottish coast. I will briefly introduce this fishery which is mainly export focussed and worth around £4-7 million per annum (over last 5 yrs). Although less economically important than other shellfish such as crabs, lobsters, and prawns, it is an important source of local employment and presents a diversification option. Because fishing with electricity is controversial to some stakeholders, the aim of the trial is to collect sufficient scientific evidence to establish whether this form of fishing can be sustainable in the longer term from stock and

environmental perspectives. This includes setting of appropriate catch limits given that the fishing technique also appears to be efficient. Since 2016, SAMS has been working closely with Marine Scotland Science to assist with collection of the scientific data. This has included developing and deploying a towed-video survey method to generate fishery independent estimates of razor clam abundance and size profiles and I will present results from some of the surveys conducted in Largo Bay and the Aryshire coast. We also have a joint PhD student who is working on updating length:age relationships for different grounds and conducting experiments on physiological recovery of other typical animals found on these grounds after exposure to electrofishing. The survey and ageing data in particular are contributing to length-based stock assessments being undertaken by MSS. To date this work has been funded from the EMFF, Scottish Marine Fund and SUPER DTP partnership bringing additional resources to those allocated from within Marine Scotland Science. An additional benefit is the collaborative science-industry relationships developed as working razor-clam vessels are used to conduct the video surveys, which also draw on the local knowledge of the skippers. Biologically we know very little about razor clam reproduction and recruitment dynamics which does present a risk for long-term sustainability of the stocks. Ideally the major grounds should be re-surveyed every few years to enable detection of stock depletion ahead of declines in commercial catch rates and improve understanding of recruitment dynamics. However, funding remains a challenge and in particular the lack of flexibility in timing of SMF grants has caused difficulties with scheduling fieldwork. If Policy were able to address this issue it would be extremely helpful for this collaborative research moving forward.

Ieuan Jones (Aberdeen University) – **Tropicalization of the North Sea** - Online presentation

Tropicalization, the increase of biodiversity due to species from warmer climates expanding poleward, is a documented response to climate change and has occurred in the fish community of the North Sea. Since 1991, the number of Lusitanian species (warm water species) found per haul in the North Sea International Bottom Trawl Survey has increased, causing the overall number of species found per haul to increase with it. These shifts towards increased numbers of warm species could lead to changes in the size-structure of fish communities in the North Sea since warm water species are generally thought to be smaller and faster growing than species from cooler waters. This is important for the fish community but also has the potential to impact measures of Good Environmental Status (GES).

Size-based indicators have been used to monitor the fish community with regard to achieving goals for GES. The Large Fish Indicator (LFI), the proportion of large fish in the community, fish Typical Length (TyL), the weighted average fish length, and Mean Max Length (MML) have been used to monitor GES for the fish community. Between 1980-2000 the LFI showed significant declines but has since begun to recover. However, if Lusitanian species are generally smaller, their increases could reduce the sensitivity of the LFI and TyL to recovery in size. Equally, increasing temperatures could prevent further recovery of large individuals since these generally come from the cold water species community.

Here we propose that thermal affinity, species affinity for colder or warmer waters, should be taken into account when measuring trends in the size-based indicators to account for changes which may be driven by climate change.

LFI of both the Lusitanian (warm) and Boreal (cold) communities declined from 1980-2000, and both showed recovery post 2005. Lusitanian LFI was generally lower than Boreal LFI, though it has

increased beyond the reference levels set in 1983 and the gap between the two has reduced due to poor Boreal LFI in 2019-2020. TyL and MML was also higher for the Boreal community in the reference year at the beginning of the study period. However, declines in Boreal TyL and MML were greater with much less sign of recovery since the early 2000s. Equally, the gap between Lusitanian and Boreal TyL and MML has reduced substantially.

These results suggest that since the Boreal community was larger in the reference years which set the targets for GES that increases in Lusitanian species could have negative impacts for achieving these targets. However, the convergence of the Lusitanian and Boreal community, alongside limited Boreal recovery may suggest that climate change has impacted the Boreal community's ability to recover to previously observed sizes. This is important for policy because it has implications for the way we measure GES for fish communities under climate change and the ability to reach targets. Targets may need to be more dynamic and consider the different impacts on size structure within the community.

Blair Easton (St Abbs Marine Station) – **Crab Fisheries in the Berwickshire Marine Reserve**

The Berwickshire Marine Reserve, formally known as the St Abbs and Eyemouth Voluntary Reserve, covers an open sea area of 10.3km². Within this area, static gear fishing is the most common fishing practice which is supported by around 62 active fishing vessels (<10m vessel length) fishing within six nautical miles. The prevalence of static gear fishing occurs from the statutory static gear reserve which designates a 26km² area of which no mobile form of fishing are prohibited, this includes dredging and trawling as examples. All designations stated are situated within the Berwickshire and North Northumberland Coast European Marine Site, which is a special area of conservation under the habitats directive (Conservation (Natural Habitats &c.) Regulations 1994). The location of the marine station is situated between Berwickshire and Northumberland, both of which have separate management plans for the commercially important species *C.pagurus* and *H.gammarus*. Anecdotal data shows that fishermen are landing *C.pagurus* and *H.gammarus* across the border as the minimum conservation reference sizes are different from Scotland to England. Having no physical border provides more options for fishermen to increase their yield from lower effort, but in doing so could be effecting the local stocks detrimentally as they are removing reproductive individuals that could help feed into the local population. Studies have been developed to understand the sustainability of both species by providing a baseline understanding of the current distribution of the species, the fishing effort applied by the local fishermen, the sexual maturity of the *C.pagurus*, and the population dynamics of the juvenile *C.pagurus* which aim to inform local management plans and strategies. At present, the research conducted at the marine station has included a mark/recapture study in which we mapped the distribution of both species along the Berwickshire coastline and found that some individuals travelled as far as Fife (~45km distance) over a month, showing great migrational movements; fishing effort has been recorded from a small number of local inshore fishermen to understand their current fishing activity and how this changes over an annual period which highlighted the increase and decrease of presence for these species seasonally; understanding the juvenile population (in this case *C.pagurus*) we can understand how the fished population will be replenished, we surveyed locations along the Berwickshire coastline to see how the numbers and sex ratio of this species varied over an annual period and whether this related to the seasonal migrations of *C.pagurus* from inshore to offshore brooding grounds. Lastly, assessing the size at which *C.pagurus* from Berwickshire and Northumberland became sexually mature we could highlight regional variation and whether the separate minimum conservation reference sizes were appropriate or would a harmonious MCRS benefit both regions due to the close proximity of both

locations. Further research is planned in the region to assess the potting density in the marine reserve, the fishing pressure of the region and also in situ underwater observations of static gear to assess the inter and intra behavioural interactions of this species which could affect fishermen's catch.

Tully Osmond (Edinburgh Napier University) - **The influence of parasitic interactions in Scotland's fishing industry**

Scotland's fishing industry is largest in the UK and one of the most productive fisheries in Europe. Annually, over one quarter of the total landings sold by the Scottish fishing fleet is caught from the west coast of Scotland, in 2020 these landings were valued at £142,476,000, thus the ecosystem has a high socioeconomic value to fragile coastal communities. As Scotland looks towards a move to ecosystem-based management for its fisheries it's important to consider the influence of parasitic interactions. Parasites can induce a variety of effects on individual hosts, such as reduced fitness, or broader impacts on host populations that can cascade through ecosystems, such as castration. Consequently, without incorporating parasites into marine policy and management plans significant aspects of natural ecosystem dynamics will be missed. This study aims to identify new ways to include parasites within food web models exemplified using Scotland's west coast, which covers the ICES fisheries management area 6a. The study is focusing on the metazoan parasites of four of Scotland's most commercially valuable species; mackerel (*Scomber scombrus*), herring (Clupea harengus), anglerfish/monkfish (*Lophius piscatorius*) and whiting (*Merlangius merlangus*). Fish dissections and a detailed literature review are being used to identify the main metazoan parasites that could be influencing Scottish fisheries and could potentially be detrimental to stock recovery. This talk summarises the study's methods, data collected hitherto, and outlines ways in which the study will be useful to policy makers. Currently, there is a lack of legislation surrounding marine parasites in Scottish policy, as most of the current legislation is heavily linked to the aquaculture industry. We will discuss how this study and parasite research in general could aid in policy decision making concerning stock management of commercially valuable species in Scotland.

Recent studies have suggested that marine parasites are on the rise. Due to increasing temperatures in the marine environment the composition of the parasitic fauna of marine animals is being altered. For example, Anisakis nematodes are becoming more prevalent worldwide, because their eggs can now persist for longer providing an extended hatching period. One common host species of Anisakis nematodes is mackerel, which is Scotland's most valuable commercial species, with £210 million worth landed in 2021. It is therefore crucial to understand these changes and make appropriate adjustments within fisheries policy. To ensure food safety and to prevent increases in zoonoses from fish consumption, policy will potentially have to be modified accordingly alongside fish processing facilities with associated costs. Furthermore, marine parasites can be used as biological tags for stock discrimination, currently Scotland uses genetic sampling for stock assessments of pelagic species, a prominent example being herring. A possible cost-effective alternative could be utilising parasites as biological tags to trace recruitment migrations of herring. Parasitism incorporates complex lifecycles with characteristics that are informative and useful for environmental management, subsequently parasites can be used as bioindicators for pollution and ecosystem health. The talk will demonstrate that by incorporating parasites further into Scottish marine policy it will assist Scotland in fulfilling its Blue Economy Vision.

SESSION 2 Abstracts and contact details.

Ingrid Kelling (Heriot Watt University) – **Introduction to the Global Centre for Social Sustainability in Seafood Supply** (GC4S) - *Online presentation*

The Global Centre for Social Sustainability in Seafood Supply (GC4S) is a new research centre based at Heriot-Watt University that provides research that challenges system inequities in seafood supply. It provides the critical approaches – including interdisciplinary, innovative research and multi-stakeholder collaborative processes – that challenge systemic inequity and injustice in food value chains.

Ian Napier (UHI) - **Fisheries management, fisheries policy and associated issues, and their interactions with the fishing industry**.

The principal focus of my research activity is on fisheries management, fisheries policy and associated issues, and their interactions with the fishing industry. I have gained a deep knowledge and understanding of the fishing industry, especially in Shetland, through a close working relationship over more than 25 years.

Specific areas of work and interest in relation to the fishing industry include:

- analysis of fisheries data, including fishermen's data, knowledge and information.

- evaluation of the effects of fisheries management measures.

- the management and utilisation of quotas.

- analysis of fisheries policy and development of policy and management proposals.

- provision of scientific advice to the industry on issues including stock assessments, management advice, and so on.

- the economic and social contribution of fishing to communities.

- the history and development of the fishing industry.

Amongst other things, this work has shown:

- the extent of fishermen's knowledge about fish stocks and the broader marine environment which is currently largely untapped by scientists and policy makers.

- the complexity of the behaviour of individual fishermen and of the industry collectively in response to fisheries management measures and other changes that affect the industry.

A key message from this work is that fishermen and the fishing industry collectively may respond to fisheries management measures in ways that are different and more complex and sophisticated than may be assumed or expected.

Elena Balestri (Scottish Fishermen's Federation) - **Bridging the gaps between the fishing industry and Science.**

Science Policy Officer for the Scottish Fishermen's Federation, I am involved in several initiatives and processes with the main aim of bridging the gaps between fishing industry and Science (ICES, Universities, MSS) and Governmental agencies (MS, NatureScot, JNCC, Defra). I am also in charge of the Independent Fisheries Science Support Scheme (IFSSS) that includes an Observers' scheme, a

pilot on Co-sampling and collaboration with various strands of data collection for Industry/Science related initiatives).

Rachel Shucksmith (UHI) - **Best practice and potential barriers to a just energy transition for fisheries and dependent communities**

The use of the marine environment has grown rapidly since the 1950s, where historically fisheries and navigation enjoyed near exclusive use. As human uses of marine space have expanded (e.g. marine renewables, oil and gas, aquaculture etc.), developing frameworks which effectively manage environmental impacts as well as conflicts between new and existing users has proved to be challenging. While national and international legislation and regulation has led to some improvement in how environmental impacts such as water quality are managed, conflicts between users poses a different type of challenge, sometimes termed 'wicked problems'. Challenges faced by decision makers include how to make trade-offs between wider societal aims and values such as decarbonising energy creation via offshore renewable energy, with the impacts on existing users such as fisheries and navigation, as well as onshore communities. These challenges are difficult to legislate or regulate for, however recognition of wicked problems can allow focus to shift towards solutions.

The Just Transition to low carbon energy production and the protection of important many habitats are creating a shift in how marine spaces are being managed. In order that this shift is 'fair' for fishers and onshore communities the concept of energy justice allows reflection on existing processes across the three tenants of justice: procedural, distributive and recognitional justice. Here we examine current best practice as well as potential barriers to a just energy transition for fisheries and dependent communities.

Paul Fernandes (Heriot Watt University) - **Sustainable management of marine resources, with a focus on marine technology**

Paul Fernandes' research group at Heriot Watt University focusses on the sustainable management of marine resources, with a focus on marine technology. Having worked at Marine Scotland Science for over 17 years, latterly as head of the Sea Fisheries group, much of this work centres around Scotland fish and fisheries. His principal area of expertise is in surveying fish, with expertise and extensive experience in acoustic surveys, trawl surveys, stock assessment and working with industry. In this presentation he will start by showing how acoustic surveys are used to estimate the abundance and distribution of fish. Reference is made to past work on herring and sprat; existing projects relating to studying fish around oil and gas structures (NERC INSITE); offshore renewables (NERC ECOWIND); and future work on mackerel surveys. This not only includes developments in fisheries acoustics, an area pioneered by the Marine Laboratory Aberdeen, but also developments in the platforms that these acoustic and other sensors can be mounted on, pointing to a future of low cost, low carbon and low risk (human safety) marine sampling.

In 2005, whilst still at MSS, he setup the anglerfish trawl surveys in collaboration with the fishing industry. These are used to this day to provide catch advice, but do not yet contribute to a full analytical assessment. This can lead to some uncertainty in the advice and in stakeholders' perception of stock status (e.g. MCS good fish guide). He will provide an update on recent research to improve the estimates of anglerfish abundance leading to a full analytical assessment.

After spending several years studying bycatch and discards in the Scottish trawl fisheries, he will talk about Smartrawl. Smartrawl is a technological solution to this long-standing problem. It consists of a stereo camera, mounted close to the cod-end of a trawl, a controlling computer, and a gate. As fish and other animals pass by the camera images are taken, and the computer uses artificial intelligence algorithms to detect the object, size it and determine its species. Depending on what is programmed into the system, a command is then sent to open or close the gate if the object is wanted (caught) or not (released). Components of the system have been developed over the past 5 years, including extensive work on AI. A recent proposal has been submitted to integrate these components into a working whole system.

Finally, he will talk about a few other areas of work which may be of interest, including a collaboration with the Rowett Institute of Human Nutrition thinking about smarter ways of utilising our valuable fish resources, work on Irish Sea cod to understand its demise (with parallels with west of Scotland cod), and future ambitions to develop marine technology at Heriot Watt University.

Mark James (St Andrews University) - **Technology, processes, and systems to support fisheries management.**

There is a need to develop and deploy technology, processes and systems that will support the acquisition of fisheries data to inform more effective, efficient, and timely fisheries management. The Coastal Resources Management Group (CRMG) at St Andrews has been involved in several initiatives, some in collaboration with Marine Scotland, focusing on this area of work with respect to the inshore fishing sector.

The vessel tracking system, including a suite of data analysis tools to provide highly spatially and temporally resolved metrics of fishing effort has been developed and deployed over the last two years in the Outer Hebrides (OH). A Catch App has been developed and is to be trialled in the OH in 2023. The purpose of the App is to encourage fishers to record both catch and retained figures which can be related to fishing effort derived from the tracking system to provide more spatially and temporally resolved catch and landings per unit effort (C/LPUE). These developments are also now being applied in a recently funded OWEC project looking at the impacts of fisheries displacement caused by offshore wind development.

Further development of an automated, species, sex and size measuring system (AS3ID) is taking place under the EU EveryFish project. The device is designed to rapidly record and process 3D point cloud data of crabs and lobsters to provide metrics that can be fed into stock assessment models. The capacity to collect these data cost effectively through more regular fisheries dependent and independent surveys which could engage fishers in data collection, will allow more timely and regionally targets stock assessments to inform management of the fishery.

Using a range of low-cost open-source electronics and sensors the CRMG are also developing an environmental data logger capable of collecting coastal sea data from fishing gear deployments – this includes high resolution depth, temperature, downwelling light and salinity measurements that can be uploaded to an online database automatically via the mobile telephone network. Comparing these data to catch data could help to inform management and more efficient fishing practices.

Using a recently developed inertial movement module (IMM), the CRMG are exploring ways to monitor the configuration of creel lines with a view to understanding the entanglement risks posed by these lines to protected endangered and threatened species. A spinoff of this research has been

the potential to use the IMM to monitor the stability of small-scale fishing vessels and to use high resolution vessel movement data to refine models of gear deployment and recovery. Further uses of the IMM are being explored in developing world artisanal fisheries including spear fishers and those involved in seashore gleaning.

Critical to the work outlined above has been working in close collaboration with the fishing sector and individual fishers who have provided advise and support in the development and deployment of the various technologies. Use of these innovations opens up new opportunities for co-management and access to data that can be of direct utility in operational, management and regulatory contexts.

SESSION 3 Abstracts and contact details.

Mike Heath (Strathclyde University) - **StrathE2E – a strategic tool for scoping an ecosystem approach to fisheries management.**

Scotland's Fisheries Management Strategy 2020-2030 Delivery Plan - Action 11 – describes an ambition to deliver an ecosystem-based approach to fisheries management. According to FAO Technical Guidelines this involves moving towards a state where fisheries are living within the capacity of the ecosystem to support them. It is not necessarily the case that managing every stock to its MSY while implementing Marine Protected Areas to limit direct impacts on sensitive habitats and species means that we are delivering on this aim. An ecosystem approach should involve a higher-level setting of objectives for the overall status or health of the whole ecosystem, defined by e.g. the balance between the various interconnected elements of the food web – and incorporating these into fisheries management policy.

Scotland needs access to tools for scoping the integration of fisheries policy with ecosystem health. These include numerical models than can simulate the biomass and structure of the whole ecosystem under broad-scale scenarios of fishing (e.g. the balance between pelagic and demersal fisheries) alongside other human activities and climate change. At the University of Strathclyde we have developed the StrathE2E food web and fisheries model for just such broad-brush strategic analyses. The model is available as a computer programming package, and an online app (https://outreach.mathstat.strath.ac.uk/apps/StrathE2EApp/). For Scottish waters, we already have implementations for the North Sea, west of Scotland, and the Firth of Clyde. In this presentation I will briefly outline what StrathE2E is, what it can do, and illustrate its capabilities with some examples of fisheries management scenario experiments. Ultimately, a policy decision on where to strike the balance between fisheries extraction and ecosystem health is a societal and political choice involving many strands of evidence. StrathE2E could be one of the scientific tools to help provide some of these strands of support for Marine Scotland.

Emma Tyldesley (Strathclyde University) - **Developing the ecosystem-based Likely Suspects Framework (LSF) programme for salmon.**

Atlantic salmon (*Salmo salar*) is an important species experiencing population decline across its range, driven largely by reduced marine survival (ICES, 2020). The mechanisms are not fully understood and require ongoing cooperative scientific work to support salmon conservation and management.

The University of Strathclyde is working with the Missing Salmon Alliance (https://missingsalmonalliance.org/) on developing the ecosystem-based Likely Suspects Framework (LSF) programme for salmon. This programme will assist conservation efforts by mobilising knowledge, targeting research on mortality in different phases of the life cycle and developing new management support tools (Bull et al., 2022).

Data mobilisation for the LSF centres on the Salmon Ecosystem Data Hub (SalHub), an interface for indexing data relevant to the salmon life cycle (Diack et al., 2022). Data are categorised by life stage, geographical domain and type of physical or biological variable. The data held in SalHub have been used to develop a mortality modelling framework for salmon throughout their freshwater and marine phases. The framework models growth and mortality at each life stage. It is being designed to be modular, allowing inclusion of new knowledge and detail as appropriate for specific research or management questions. It can be parameterised for a particular river or used more generically for hypothesis testing of the effectiveness of freshwater management actions when considering responses across the whole life cycle.

A current LSF implementation case study is focusing on mortality during the early marine phase from river emigration to the end of the first winter at sea. The work uses freshwater and marine data to assess marine survival indicators. Current work focusing on energy within the food web has shown that food availability for forage fish (the main prey of salmon) has steeply declined over the past few decades and is significantly correlated with marine survival (Tyldesley et al., 2022, in prep).

We are also conducting detailed research on migration pathways from UK rivers. The migration of juvenile salmon once they enter the marine phase is simulated using particle tracking modelling driven by the MSS-hosted Scottish Shelf Waters Reanalysis Service hindcast model. The focus is on the effects of environmental variability on migration pathways and possible consequences for salmon survival. The work has the potential to inform management decisions in the coastal and offshore zones. For example, how long do salmon remain in coastal waters, and what is the overlap with pressures such as renewable energy and fish farming?

The ongoing assimilation of this knowledge is to be made accessible via the development of a Salmon Management Decision Support Tool, an online interface running the mortality framework model. It is a tool for assessing management options for general or specific river systems, allowing salmon managers and decision-makers to explore the impacts of management interventions or long-term shifts in conditions (e.g. due to climate change).

Neda Trifanova (University of Aberdeen) – **An ecosystem modelling and assessment framework for decision processes seeking to integrate new uses into marine ecosystems**.

An abrupt step-change in the use of shallow seas around the globe is underway, specifically by the addition of large-scale offshore renewable energy (ORE) developments. The UK is the current global leader in offshore wind with 10.4 gigawatts (GW) installed and a commitment to increase its capacity to 50 GW by 2030. To get to this goal so rapidly there has been a dramatic shift in policy to cut approval times for new offshore windfarms from 4 years to 1. Therefore, decarbonising the UK energy supply through increases in offshore wind will require an extremely rapid increase in the use of information on the nexus of the implications of trade-offs between both direct and indirect environmental effects, as well as spatial conflicts with other marine uses like food production (fisheries) and marine protected areas (MPAs).

The interlinked effects of changes from the introduction of structures, extraction of energy and displacement of fishing actives on the physical environment up through the entire marine ecosystem are needed to provide accurate estimates of changes to biodiversity, ecosystem services and calculations of increases or decreases in natural capital. To ensure the minimization of negative impacts and secure wider environmental benefits, such as biodiversity enhancement, an ecosystem approach that assesses the changes is essential.

We present an ecosystem modelling and assessment framework that captures evidence-based impacts of climate change and marine uses (ORE developments, fisheries, MPAs) on ecosystems, natural capital assets, ecosystem services delivery, and socio-economic impacts. In contrast to "static" frameworks, our proposed approach provides a data-driven dynamic holistic assessment, allowing for the multiplicity of interactions amongst different ecosystem components (e.g., physical environment through to plankton, zooplankton, fish, seabirds, and marine mammals) across different spatial scales and using prior information on changes over time, incorporating climate change trends. The proposed assessment framework measures whole ecosystem as well as population (species/functional group) level change, and assesses changes in ecosystem goods and services, and socio-economic value in response to ORE deployment scenarios as well as climate change. This approach will provide objective information for decision processes seeking to integrate new uses into marine ecosystems.

An example of a specific case study that will be explored is the "costing" of fisheries displacement from ORE developments. A choice of scenarios framed around climate change (e.g., "business-as-usual") and fisheries (e.g., increase vs decrease in spatial fishing pressure due to displacement) will be co-designed and framed with input from the fishing industry, ORE developers and statutory groups (e.g., Marine Scotland Science). Through the scenario analysis, outputs in a range of ecological (e.g., stock biomass in kilograms) and monetary (e.g., Gross Value Added) metrics at a local, regional, and national level and their changes over time will be produced. Such outputs will allow the exploration of fish population trends in combination with risk maps of ecosystem-level, natural capital, and socio-economic change. These outputs will provide strategic advice and policy support on the balance of benefits and trade-offs between marine uses to deliver long-term environmental and energy sustainability and economic benefits.

Jack Laverick (Strathclyde University) - **The StrathE2E online app – real-time game play for ecosystem fisheries management**

Developing policy is an iterative process. New proposals for meeting defined objectives require a period of evaluation before a decision can be made on their effectiveness. Mathematical modelling is a cost-effective tool for providing initial assessments, however, complex models which aim to capture many interacting processes can be slow to run and difficult to use for non-specialists. The result is a game of postal chess, where exploration of the model system by policy experts requires repeated requests to the modellers. This friction can undermine the communication between policymakers and scientists, and the timely delivery of insight.

I will present the interactive web interface (https://outreach.mathstat.strath.ac.uk/apps/StrathE2EApp/) for StrathE2E, an ecosystem model for fisheries management developed at the university of Strathclyde. The app is fast enough to allow attendees at a meeting to run multiple "what if" experiments then and there. This allows model

results to become part of a naturally flowing conversation, answering questions as they arise and inspiring new ideas to explore.

StrathE2E is capable of exploring the trade offs between food provisioning and conservation targets, representing an interconnected food web and multiple fishing fleets. We have implementations for the North Sea, west of Scotland, and the firth of Clyde which are of direct relevance to the management of Scottish fisheries. We are also expanding this list of implementations to other regions around the UK and Atlantic, from as far North as the Barents Sea, down to South Africa. I will demonstrate how the app can be used to explore the impacts of fisheries management on the wider ecosystem, and what this could mean for the catch of exploited stocks in Scottish waters.

Douglas Speirs (Strathclyde University) - **StrathSpace – Spatial Modelling of Fish Stocks** *Online presentation*

Fish stocks do not respect national boundaries or, frequently, even fisheries management areas. For highly migratory internationally shared stocks this can lead to major disputes regarding quota allocations. Over time, changes in distributions and migration routes can lead to mismatches between abundances of fish and distributions of quota. Such issues were a well-documented consequence of the inflexible 'relative stability' protocol for distributing quota between EU Member States at the heart of the CFP. There was much discussion during the Brexit process of an alternative 'zonal attachment' concept for apportioning quota. As a now independent coastal state the UK still aspires to a zonal attachment scheme for negotiating quotas, though the current Trade and Cooperation Agreement is closer to relative stability. Nevertheless, Scotland has "agreed with other UK Fisheries Administrations to apportion and allocate quota based on a mix of historic track record and zonal attachment" (Scotland's Fisheries Management Strategy 2020-2030, Action 3).

Despite the increasing interest in zonal attachment there is no universally accepted definition of the term. Complications include seasonal migrations, different life history stages occurring in different zones, and temporal changes in abundance. At a minimum, the degree of zonal attachment needs to be re-assessed regularly, but even this does not address management planning for longer-term changes in stocks such as those driven by climate change. Scotland therefore has a need for national capability in tools for modelling the spatial population dynamics of fish stocks. In this presentation I will briefly outline one such tool - the StrathSpace modelling approach - and its capabilities. I will illustrate the outputs using examples from an implementation for blue whiting (a wide-ranging migratory stock), and the glacial lanternfish (an abundant but currently unexploited deep-water fish that is currently the subject of trial fisheries as part of an EU programme on mesopelagic fisheries).

SESSION 4 Abstracts and contact details.

Niall Fallon (Marine Scotland Science) **- Investigating Environmental Impacts of the Scottish Nephrops Fleet: Current and Future Fisheries Management Scenarios**

The Scottish Government (SG) is committed to ensuring the sustainability of Scotland's marine resources, including commercial fisheries. Through the Future of Fisheries Management discussion paper, the SG opened a dialogue with fisheries stakeholders to inform the development of Scottish Fisheries in a manner which ensures their long-term sustainability. The Scottish Nephrops fleet consists of two distinct components: i) vessels deploying static creel and ii) vessels using mobile

trawl gears. Stakeholders are engaged in an ongoing and wide-ranging discussion around the sustainability of each fleet component, considering the economic potential, selectivity, and environmental impacts of each approach.

To that end and following the publication of a policy brief which modelled changes in fleet composition based on optimal economic scenarios, the SG highlighted the need to investigate the environmental impacts of the Nephrops fishery, and of potential changes to fleet composition in terms of the relative effort of each fleet component. The brief concluded that there is significant potential for the Scottish Nephrops fishery to increase gross value added through redistribution of access to fishing grounds. There exists a detailed breakdown of how this would affect the operation of the components of the fleet, but it does not account for how an increase in one method or another might affect Nephrops stock productivity or the benthic environment. For instance, there may be an obvious economic gain from increasing the landings of large individuals selected by creel fishing, but it is unclear whether a significant increase in the removals of those individuals from the stock is actually sustainable.

Innovative modelling approaches are being explored to describe the relationship between Nephrops population dynamics and the activity of each component of the Nephrops fleet, taking the North Minch stock as a case study. The effects of potential or proposed Nephrops fleet configurations on Nephrops stock demographics, and the sustainability of Nephrops fisheries, can then be explored through forward simulations. A concurrent literature review will provide an assessment of the impact of Nephrops fishing methods on the wider marine environment, investigating potential environmental impacts of the proposed fleet configuration scenarios, and recommending mitigation measures to negative impacts where possible. The project as a whole aims to inform scientific advice that is complementary to the existing socioeconomic research, with the intention of providing policymakers and managers with a more holistic evidence base in support of decision making. The MASTS Fisheries Policy-Science Interaction event is an ideal opportunity to ensure that project outputs appropriately address the needs of policy colleagues.

Ana Adao (Strathclyde University) – **State of the cod population in the Clyde and evaluation of the impact of discards by the Nephrops fishery**

The Firth of Clyde is one of the main fishing grounds of the Scottish Nephrops (or Norway lobster) trawl fishery which has a significant whitefish bycatch. Landings of whitefish species such as cod and whiting declined steeply over the 1980-90's until the directed fishery was no longer economically viable in early 2000's. There are still no signs of cod stock recovery in the Clyde, despite the implementation of a Statutory Instrument (SI) since 2001 that closed a specific area of the Clyde to directed fishing for 11 weeks each year (the "cod box" closure). A recent alteration to this legislative instrument to prevent any disturbance in spawning grounds means that no fishing activity is allowed to take place in the "cod box" between February and April, excluding the Nephrops fisheries (both trawlers and other gears) during this season.

This work provides updated abundance estimates of cod in the Clyde that can be used as a scientific basis to inform fisheries management measures such as the "cod box" closure. First, quantities of cod, haddock and whiting discarded by the Nephrops fishery in the Clyde were estimated with a new statistical methodology. Second, we developed an age-structured stock assessment model that uses scientific survey data and commercial fisheries discards data. The model has been applied to the three main species of whitefish in the Clyde. The results of this work have been used to assess the

state of the cod population in the Clyde and evaluate the impact of discards by the Nephrops trawlers on the total cod stock biomass. Future projections under different scenarios to simulate recovery conditions for the whitefish stocks in the Clyde will be investigated.

Simon Northridge (St Andrews University) – **The UK Bycatch Monitoring Programme**

The Scottish Oceans Institute has been running an on-board observer scheme to explore the bycatch of protected species in certain key fisheries since 1996, known now as the UK Bycatch Monitoring Programme (BMP). The aims are to provide annual bycatch estimates for selected species of concern, to place these estimates in a population conservation context, to explore the reasons why bycatch occurs and to develop suitable mitigation measures if these are deemed necessary. Many protected or sensitive species are only very rarely reported caught in fishing operations, yet we still need to consider the overall fleet level impact that such catches might have at a population level. However, broader policy drivers suggest that the bycatch of any non-target species (and especially those of mammals and birds) should be minimised or eliminated. To date, estimates of bycatch have focused on marine mammals and seabirds, though data on fish are also collected.

We place observers on board commercial fishing vessels with the voluntary agreement of skippers and owners, with the aim of collecting data that provides an impartial and independent evidence base on one of the potential environmental impacts of fishing activity. This work has helped a number of fisheries attain MSC certification, but also allows governments and their agencies track progress toward Good Environmental Status in the marine environment or "ecologically diverse and dynamic ocean and seas which are clean, healthy and productive". The BMP also helps fulfil a number of international commitments under global and regional bodies (IWC, OSPAR, ASCOBANS, and formerly EU fisheries policies). Most recently, our current contract with Defra and Marine Scotland is structured around a consortium of science and industry partners.

We have developed statistical tools to explore the factors underpinning bycatch of certain species, and to look for trends in bycatch rates. We have developed a good understanding of where, why and how bycatch of certain species occurs, though there is much still to learn in this regard. In a few instances where concerns have been raised, we have engaged with industry to develop mitigation measures to reduce the bycatch of particular species. Initially this was focused on reducing the bycatch of porpoises in gillnet fisheries (only a minor issue in Scotland), first demonstrated in an EU funded projects in 1997 with the use of acoustic deterrent devices, and later implemented with a novel deterrent device in 2011 under a Fisheries Challenge Fund project. A second example was the reduction of bycatch of common dolphins in a midwater trawl fishery for bass, operated by Scottish vessels in English waters, using a bycatch reduction device (sorting grid) and later an acoustic deterrent approach. We are currently working with the Scottish hake longline fleet to help them reduce fulmar bycatch with a suite of potential mitigation measures.

Our role is therefore not just to troubleshoot for particular issues of concern relate to bycatch, but also to provide industry, government, eNGOs, welfare groups and fish consumers with information about the level of environmental impact of specific fisheries.

Robin Cook (Strathclyde University) - **The impact of seals on whitefish stocks in the West of Scotland**

Much of the annual cycle of fisheries management revolves around stock assessments supported by ICES. These work well for principal stocks where annual catch advice is required for management purposes. When advice on less routine issues is required, annual ICES assessments may not be sufficient. This may apply to issues such as the interaction between fisheries and seals, evaluation of the discards and mitigation measures and the assessment of stocks not normally assessed within the ICES system. Work in recent years at Strathclyde has developed models the assessment impact of seals on whitefish stocks in the West of Scotland (ICES 6a). While subject to uncertainty, these analyses suggest seals may be impairing cod recovery. In relation to discards we have done analyses of discards of all species by fleet in conjunction with Marine Scotland Science to illustrate the effects of changing fleet gear selection characteristics or catch limits on discards. This work has also been extended to show how different discarding scenarios may affect the ecosystem. More recently our work has focussed on assessing fish stocks in the Clyde and the impact of discards from the Nephrops fishery on cod stock recovery. It appears that fishing mortality caused by this fleet is sufficient to supress recovery of both cod and whiting.

Tara Marshall (Aberdeen University) – BATmap - **A pioneering approach for reducing unwanted bycatch and discards.**

BATmap is an award-winning collaboration between Scottish skippers, producer organisations and scientists to develop and deploy state-of-the-art technology to avoid unwanted catches of cod and spurdog.

Skippers on the west coast of Scotland are now using a bespoke software system to record hauls of these unwanted species in 'real-time'. If catches are higher than an agreed threshold, an automatic alert is triggered informing other participating vessels so they can avoid these areas.

Policy Attendees

Marine Scotland Policy

Jim Watson – Head of Domestic Fisheries Management

Jane Macphearson – Head of Fisheries Management Strategy

Malcolm MacLeod – Head of Access to Sea Fisheries

Oana Racu – Fisheries Management Strategy

Ashleigh Meikle – Head of Fisheries Interactions in the Marine Environment

Stuart Bell – Inshore Fisheries Management

Ellen Huis - Head of Inshore Modernisation

Chloe Aird – Inshore Fisheries Management

Marine Scotland Science

Coby Needle

Findlay Burns

Liz Clarke

Jessica Craig

Helen Holah

Niall Fallon

Bee Berx

Marine Analytical Unit

Kay Barclay

Annabel Arbuthnott

Amy McQueen

Gavin Brown