Supplementary material for Quo Vadimus:

Including ecological, economic, social and institutional considerations when setting targets and limits for multispecies fisheries

Anna Rindorf, Catherine M. Dichmont, James Thorson, Anthony Charles, Lotte Worsøe Clausen, Poul Degnbol, Dorleta Garcia, Niels T. Hintzen, Alexander Kempf, Phillip Levin, Pamela Mace, Christos Maravelias, Coilín Minto, John Mumford, Sean Pascoe, Raul Prellezo, André E. Punt, David Reid, Christine Röckmann, Robert L. Stephenson, Olivier Thebaud, George Tserpes and Rüdiger Voss

Contents

Overview of symposium contributions

Table S1. Overview of contributions presented at the symposium. Abstracts are given in the supplementary material. Numbers under 'Addressing topic' refer to: (1) ecological, economic, social and governance sustainability in fisheries management, (2) internally consistent targets and limits for management, (3) addressing uncertainty and variability and (4) effective governance.

Authors	Title	Addressing topic	Reference
Drakou and Pendleton	A conceptual model to assess and map "extra-local benefits" from fisheries at a global level	1+2	Supplementary material
Dedman *et al.*	Using spatial management to achieve Bpa targets for vulnerable Irish Sea skates	1+2	Deadman *et al*., this issue
Dolder *et al.*	DAMARA: Science to support management decisions for the multi-fleet multi-stock fisheries of the Celtic Sea	1+2	Supplementary material
Gaichas *et al.*	Combining stock, multispecies, and ecosystem level status determination criteria: what tradeoffs can we expect?	1+2	Gaichas *et al*., this issue
Garcia *et al.*	Could multistock reference points mitigate the impact of landing obligation in the economic performance of the fleets? The case study of Spanish Demersal fleets operating in Iberian Waters	1+2	Garcia *et al*., this issue
Hamon *et al.*	Accounting for socio-economic constraints to define the path to sustainability: European examples	1+2	Supplementary material
Henriquez *et al.*	Rebuilding Patagonian toothfish off Southern Chile: evaluating trade-offs via closed-loop	1+2	Supplementary material

	harvest strategy simulations		
Hintzen *et al.*	Lost in translation: Increased complexity in management results in lost pelagic catch opportunities	1+2	Supplementary material
Hoff and Frost	Trade-offs between Maximum Sustainable and Maximum Economic Yield in the North Sea Demersal Fishery'	1+2	Supplementary material
Kempf *et al.*	The MSY concept in a multi-objective fisheries environment – lessons learned from the North Sea	1+2	Kempf *et al.* 2016
Levontin *et al.*	On the role of visualization in the management of fisheries	1+2	Supplementary material
Mace	The journey to set targets and limits in fisheries management	1+2	Supplementary material
Mahevas *et al.*	Beyond the single species Maximum Sustainable Yield approach : a mutiple species and multiple fleets approach using the ISIS-fish simulation tool.	1+2	Supplementary material
Mumford *et al.*	A framework for managing fisheries with multiple economic, ecosystem and social objectives	1+2	Supplementary material
Northridge	How metier and vessel size class may influence accident and fatality rates at sea	1+2	Supplementary material
Pascoe	Australian experiences with modelling multiple management objectives in fisheries	1+2	Pascoe *et al*., this issue
Punt	Strategic Management Decision Making in a Complex World: Quantifying, Understanding and Using Trade-offs	1+2	Punt, this issue

Rindorf *et al.* (a)	What is it we want to maximise and sustain in Maximum Sustainable Yield?	1+2	Rindorf *et al*., 2016, submitted to Marine policy
Rindorf *et al.* (b)	Are 'pretty good yield' ranges precautionary?	1+2	Rindorf *et al*. b, this issue
Rindorf *et al.* (c)	Food for thought: Pretty good multispecies yield.	1+2	Rindorf *et al*. c, this issue
Sampedro *et al.*	Stakeholder engagement in the management strategies for Atlantic Iberian waters: from the identification of priorities to the evaluation of a Multiannual Management Plan	1+2	Sampedro *et al*., this issue
Smout *et al*.	Beyond the Target Species: Future Consequences of MSY under different scenarios of change	1+2	Supplementary material
Tserpes *et al*.	Management of multispecies demersal fisheries in the Mediterranean	1+2	Supplementary material
Ulrich *et al.*	Achieving Mixed-fisheries and multispecies MSY in the North Sea demersal fisheries	1+2	Ulrich *et al*., this issue
Vinther *et al*.	MSY ranges in a multispecies stochastic model environment	1+2	Supplementary material
Bastardie *et al.*	Effects of recent changes in stock conditions and mixing on sustainability and economic viability of the fishery - The Danish fisheries for Baltic cod	3	Bastardie *et al*., this issue
Cadigan and Wang	Local Sensitivity of Fisheries Management Target and Limit Reference Points	3	Supplementary material
Cadigan *et al.*	Stochastic maximum sustainable yield reference points for Northern cod, including	3	Supplementary material

	variable natural mortality rates and a spatial stock-recruit model		
Cubillos and Curin-Osorio	Equilibirium properties of the Ricker stock-recruitment model and their relationships with spawning-per-recruit at zero fishing mortality and recruitment regime.	3	Supplementary material
Cubillos *et al.*	Evaluation of the target fishing mortality utilized for the sustainability of the austral sardine (*Sprattus fuegensis*) fishery in Patagonian waters of Chile.	3	Supplementary material
Duplisea	Long-lived species with highly variable recruitment may require unique fishery management objectives and management strategies: the Laurentian Channel (Canada) deepwater redfish, Sebastes mentella, stock	3	Supplementary material
Hidalgo *et al.*	Spatiotemporal variation of fish size spectra across geographic and bathymetric gradients: an Atlantic - Mediterranean comparison	3	Supplementary material
Licandeo *et al.*	Evaluation of harvest control rules under changes of fish productivity using a closed-loop simulation	3	Supplementary material
Minto	Challenges in tracking stock productivity and relaying to ground control	3	Supplementary material
Patterson	Decadal changes in reference points for stocks of EU interest in the northeast Atlantic	3	Supplementary material
Quaas *et al.*	It's the economy, stupid! Projecting the fate of fish populations using ecological-economic modeling	3	Supplementary material

Reeves and Thorpe	Multi-species and multi-models; accepting imperfection in an uncertain world.	3	Supplementary material
Stäbler *et al.*	Detecting ecosystem signals of technological creep and density-dependent changes in catchability and their impact on policy exploration with an ecosystem model of the southern North Sea	3	Supplementary material
Thorson *et al.*	Detecting shifts in productive habitat and overfishing limits using spatial state-space surplus production models	3	Supplementary material
Worsøe *et al.*	What is MSY when stock productivity shifts? A worked example from the North Sea	3	Supplementary material
Bailey	Incorporating Societal Concerns into Science: Lessons learned from Inter- and Transdisciplinary Research	4	Supplementary material
Charles	Fishery Targets and Limits: Of What? By Whom? Governance and Institutional Considerations	4	Supplementary material
Degnbol	Linking targets and limits to practical management	4	Supplementary material
Geers *et al.*	Global Comparisons of Fisheries Expansion, Overfishing and Recovery and the Influence of Catch Limits	4	Supplementary material
Knigge	#CFPreality? Implementation of MSY objectives in the reformed EU Common Fisheries Policy	4	Supplementary material
Linnane *et al.*	Adaptive management response to a spatially confined rock lobster (*Jasus edwardsii*)	4	McGarvey *et al.*, this issue

	fishery in South Australia.		
Payá	Implementation of target and limits in Chilean fisheries management: Tier system, BRP, drastic quotas reductions and mitigation plans.	4	Supplementary material
Rindorf and Fisher	Ups and downs in the cooperation between Danish fishers and scientists	4	Supplementary material
Stephenson	Fisheries Science and management in a societal setting: Obtaining and maintaining Social License	4	Supplementary material
Veitch *et al.*	Three steps for getting EU fisheries management to reflect scientific advice and societal priorities.	4	Supplementary material
Voss *et al.*	Social-economic drivers in (political) TAC setting decisions	4	Supplementary material

Symposium Programme

ICES SYMPOSIUM

TARGETS AND LIMITS FOR LONG TERM FISHERIES MANAGEMENT

Date:
27-30 October 2015

Venue:
N.J.V. Athens Plaza Hotel, Athens, Greece

The Myfish project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 289257.

ICES SYMPOSIUM

TARGETS AND LIMITS FOR LONG TERM FISHERIES MANAGEMENT

Symposium Programme

Introduction and Welcome

Welcome to our joint ICES/Myfish symposium on "Targets and limits for long term fisheries management"! We are proud to welcome stakeholders, managers and scientific experts from across the world to an excellent selection of talks showing best quality scientific approaches to management advice and implementation under potentially conflicting objectives.

Substantial challenges remain in the implementation of the Maximum Sustainable Yield (MSY) approach to fisheries, particularly where objectives are in conflict, such as is the case in mixed fisheries, areas where prey and predators are both exploited, forage fish fisheries, divergence between e.g. Maximum Economic Yield (MEY) and MSY, where ecosystem goals are mutually inconsistent and in the implementation of the approaches in management plans. Together these challenges form a societal need for learning from experience in other areas and fields, discussions and the creation of new ideas to bring this important area forwards.

The symposium takes a global approach to these topics under a series of themes:

- Identifying trade-offs and conflicting objectives, and identifying approaches to inform and resolve these.
- The role of targets and limits in a variable world
- Economically and socially feasible management tools
- Practical implementation of targets and limits in management

We present to you a mixture of scientific oral and poster presentations and interactive sessions focusing on implementation of targets and limits in practical fisheries management.

We hope you will enjoy the symposium!

The symposium organising committee

Anna Rindorf, Denmark

Cathy Dichmont, Australia

James Thorson, US

Christos Maravelias, Greece

The symposium is coorganised by ICES and the EU-FP7 project Myfish – Maximising yield of fisheries while balancing ecosystem, economic and social concerns.

ICES SYMPOSIUM

TARGETS AND LIMITS FOR LONG TERM FISHERIES MANAGEMENT

Symposium Programme

Project

Background and Aims

Background

Targets and limits for long term fisheries management are at the core of fisheries research. Guidelines for setting targets and limits have varied from focusing on defining targets to obtain the largest sustainable yield formalised in the 1950s, to focusing on defining limits to avoid stock collapse in the 1980s and 1990s. Recent research has centred on the Ecosystem Approach to Fisheries Management as well as on defining targets to obtain the largest yield while also ensuring sustainability in a changing ecosystem and socioeconomic context.

The original derivation of MSY as a target was based on assumptions of constancy in vital rates such as growth, maturation, natural mortality and stock-recruitment relationships. Fisheries were examined individually, ignoring any interaction in the fishing process and maximising the weight or value of landings. Over time, it became clear that these assumptions are rarely fulfilled and that maximising landings in tonnes or even value is unlikely to ensure the maximum value of fisheries to industry or society in general. This value will be affected not only by variation and trend in the underlying biological processes but also by conditions such as the value of landings, the operational costs of fisheries, the demand for labour and conditions in the surrounding society. This broader definition of what we seek to maximise and sustain has forced fisheries scientists to consider how advice on the setting of targets for ecosystems rather than single species should be formulated, how conflicts between different objectives are identified, illustrated and communicated, how the variability in the systems affects results and how such complicated information is received and implemented in management.

Aims

The symposium will provide an opportunity to discuss and review the latest progress on how targets for fisheries management are set, what aspects of yield (such as landings or economic yield) can feasibly be maximised under management, how limits to ecosystem, economic and social sustainability should be defined, the identification of conflicting objectives and trade-offs and suggestions for decision making, the role of targets and limits in a changing world, economically and socially feasible management tools and implementation of fisheries targets and limits in practice. By targeting a global international audience, the symposium will promote the exchange of knowledge on these topics both within ICES and between ICES and other international organisations such as FAO and PICES.

Sessions

SESSION 1: Introductory Session

The journey to set targets and limits in fisheries management.

Session contents
The main part of this session focuses on the history of the MSY concept and the journey of setting targets and limits on world's fisheries and its implication for today's fisheries management.

Keynote speakers: Poul Degnbol (AAU) and Pamela Mace (MPI, NZ)

SESSION 2: Science and Management in a Societal Setting

Conveners: Barrie Deas (NFFO), Robert Stephenson (DFO Canada/UNB) and Anna Rindorf (DTU Aqua)

Session contents
This session concentrates on how science is brought to reflect societal priorities, how management is brought to reflect scientific advice in practice and how adaptive management can be implemented in slowly reacting legislative systems. This session initiates the scientific sessions to ensure that application in practice is brought into focus before hearing the scientific presentations as society and implementation is a top priority of the work presented. The session is subdivided into three smaller interactive sessions, each of which is initiated with short talks to spark discussion. These short talks are meant to spark discussion and are elevator talks or pecha-kucha talks rather than longer scientific talks. Each session has an appointed facilitator and rapporteur who together will write a synthesis based on all presentations in their subsession and the subsequent discussion. The sessions will end with group summaries presented in plenary and a panel discussion with the facilitators in each group.

Barrie Deas
Barrie Deas has been Chief Executive of the National Federation of Fishermen's Organisation (NFFO) since 1995. He is Chairman of the North Sea Advisory Council's Demersal Working Group, a member of the Executive Committee of the North West Waters Advisory Council and a vice-president of Europeche.

Robert Stephenson
Robert Stephenson has been a research scientist with the Canadian Department of Fisheries and Oceans (DFO, St. Andrews Biological Station) since 1984, and is currently Visiting Research Professor at the University of New Brunswick (UNB). He is Principal Investigator of the Canadian Fisheries Research Network – a Natural Sciences and Engineering Research Council (NSERC)-funded network that is linking academics, industry and government in collaborative fisheries research across Canada. Stephenson has worked extensively on the ecology, assessment, and management of Atlantic herring, and more broadly on issues related to fisheries resource evaluation and Fisheries Management Science. Current research interests include the integration of ecological, economic social and institutional aspects of management, development of integrated coastal zone management, implementation of the ecosystem approach (particularly in fisheries and aquaculture), and development of policies and strategies for sustainability of marine activities.

Anna Rindorf
Anna Rindorf works on investigating and modelling predator-prey interactions, growth, survival and spatial distribution of commercially exploited fish stocks in the North Sea, on estimating management reference points to ensure MSY and precautionarity and on the quantification of trade offs between different ecosystem considerations and the use of trade off information in management. She coordinates the FP7 project Myfish and is head of the Technical University of Denmark (DTU) section on Ecosystem Based Marine Management. Read more about Anna Rindorf here:
www.dtu.dk/english/Service/Phonebook/Person?id=39786&tab=1

Sessions

SESSION 3: Identifying Trade-offs and Conflicting Objectives

Conveners: Rudi Voss (CAU) and Phil Levin (NOAA)

Session contents

This session will focus on case studies as examples of the application of tools to identify trade-offs between ecological, economic and social objectives in various fisheries around the world. These are envisaged to span case studies on selection of indicators to quantify trade-offs in specific ecosystems, as well as model simulations to explore and evaluate trade-off situations in selected case study ecosystems or fisheries. The aim is to provide concrete examples of how trade-offs are identified and explored, with the aim of providing sound scientific advice that can be incorporated into the decision making process (Session 4). We encourage cross-disciplinary studies.

Rudi Voss

Rudi Voss has his main scientific interest in analysing the population dynamics of harvested species in their ecosystem context. Rudi realised early that trying to understand the interplay of species ecology, human use, food web interactions, as well as feedbacks requires an interdisciplinary approach. Accordingly, he started a fruitful inter-disciplinary collaboration during his PhD thesis. Realizing that the human impact has the potential to rule out all other factors, Rudi increasingly incorporated management questions, e.g. multi-species assessment, trade-offs, and fisheries advice, in his work. Ultimately, he had to realise that in a market economy economic incentives determine how resources are used. Furthermore, unlike ecology, economics provides sound methods to operationalise normative societal objectives such as welfare and sustainability. Therefore, Rudi was grateful for the opportunity to join a newly established inter-disciplinary working group on resource economics at Kiel University in 2008. While being able to keep up biological research regarding key population parameters within the cluster, he could more and more include the human aspect, as driven by economic considerations and needs. Rudi contributed significantly to several national and international research project, with a main focus on the Baltic Sea. He also coordinated the field activities in the GLOBEC Germany project. Find out more about Rudi here: **www.eree.uni-kiel.de/de/mitarbeiterinnen-mitarbeiter/dr.-ruediger-voss**

Phillip Levin

Dr Phillip Levin is a community ecologist and conservation biologist with an interest in bridging the gaps between theory and practice in conservation biology and fisheries science, and developing modelling and statistical approaches to inform ecosystem-based management of marine systems. The main focus of his current work is on developing scientific tools to inform Ecosystem-based Management in the United States (and beyond). Levin has led the development of new analytical tools for characterizing ecosystem health and forecasting the cumulative effects of fisheries management and coastal zone management and climate change on living marine resources. Phillip Levin is a Senior Scientist and leads the Ecosystem Science Programme and the Nearshore Ecology Team at National Oceanic and Atmospheric Administration (NOAA) Fisheries' Northwest Fisheries Science Center in Seattle, WA, USA. Read more about Phillip Levin here: **www.nwfsc.noaa.gov/contact/display_staffprofile.cfm?staffid=389**

Sessions

SESSION 4: Incorporating Knowledge on Trade-Offs and Conflicting Objectives into Decision Making

Conveners: Cathy Dichmont (CSIRO) and Niels Hintzen (IMARES)

Session contents

This session will focus on approaches to incorporating scientific advice on trade-offs and conflicting objectives into decision-making. Of importance are implemented examples that can be applied by other fisheries as well as techniques used to convey complex information from scientists to managers and other stakeholders. As a result, both successes and failures are equally important. Furthermore, the session will include case studies that articulate how scientifically based decision-making has been supported while still articulating uncertainty, trade-offs and conflicts and those that place these conflicting objectives into broad contexts (whether over species and ecosystem, or across the whole socio-ecological system).

Cathy Dichmont

Cathy Dichmont has a national and international reputation in stock assessment, modelling natural systems, natural resource management, shared fisheries stocks, and management strategy evaluation (MSE) and has led numerous collaborative and multi-disciplinary projects. She has more 20 years of experience in temperate and tropical marine ecosystems at international and regional levels. She was a key contributor to bio-economic modelling that rejuvenated prawn fishing in the Gulf of Carpentaria, received the CSIRO Medal for Research Achievement and leads the Resource Use and Assessment Research Stream in the CSIRO Wealth from Oceans Flagship. Read more about Cathy Dichmont here:
www.csiro.au/Organisation-Structure/Divisions/Marine--Atmospheric-Research/CathyDichmont.aspx

Niels Hintzen

Niels Hintzen works with translating results from data analyses to mathematical models, performing statistical analyses and using this to simulate future management scenarios. He is lead scientist on assessments of herring stocks in Europe and horse mackerel in the South Pacific and he currently chairs the ICES working group on herring assessment. Read more about Niels Hintzen here:
www.wageningenur.nl/en/Persons/Niels-Hintzen.htm

Sessions

SESSION 5: Targets and Limits in a Variable World

Conveners: James Thorson (NOAA) and Olivier Thébaud (Ifremer)

Session contents

Making tactical and strategic decisions based using predictions of conceptual and mathematical models of increasing complexity generally requires that processes either remain constant over time or develop in a predictable way. However, there is increasing evidence that populations, ecosystems, and human systems change over time and not always in the way we expect. Methods for detecting variation over time in individual processes (e.g., expected recruitment during different ecosystem regimes, or changes in fisher behaviour after management changes) are developing rapidly, but covariation among processes and synchrony in changes among different ecosystem components are important topics of further research. There are also many unresolved questions regarding which processes can be predicted accurately at different time scales, and what level of predictive precision is necessary when informing management. Perhaps more importantly, there is relatively little synthesis regarding how changes in human behaviour arise from and impact upon fisheries management actions and changes in biological processes.

James Thorson

Jim Thorson conducts research regarding state-of-the-art analytic approaches to theoretical and applied questions in marine population ecology. He also participates in stock assessments as a member of the FRAM division, while conducting cooperative research with other divisions at the NWFSC. Current projects include 1) a semi-parametric model for surplus production; 2) meta-analyses of rockfish natural mortality, recruitment for West Coast groundfishes, and weight-at-length parameters globally; and 3) alternative approaches to assessing the status of species using only catch data.

http://sites.google.com/site/thorsonresearch

Olivier Thébaud

Olivier Thébaud is a resource and environmental economist. His research focuses on the development of decision-support approaches and tools for the management of coastal and marine resources, including ecological-economic modelling, and the economics of ecosystem-based approaches to natural resources management. Key areas of application include the regulation of commercial and recreational fisheries, aquaculture, multiple ecosystem uses and coastal hazards, as well as biodiversity conservation policies including Marine Protected Areas. He currently leads the Economics Unit of the French Marine Research Institute Ifremer, and the joint Ifremer-UBO research group AMURE. He is also an adjunct professor with the Queensland University of Technology (Brisbane, Australia).

Sessions

SESSION 6: Practical Implementation of Targets and Limits: Institutional Frameworks which Deliver

Conveners: Petter Holm (UiT) and Ernesto Penas-Lado (EC)

Session contents

This session invites case studies on the institutional challenges encountered in practical implementation of targets and limits on different scales and using management measures under different conditions. Descriptions of cases where adaptive management has been implemented in practice and the consequences in terms of process and outcome are also welcomed as well as studies of the implementation at a range of different scales from local fisheries to large marine regions. Further, studies of the effect on societal settings on the decision and implementation of targets and limits by management institutions are encouraged. The session complements Session 2 by allowing longer presentations on specific topics related to practical implementation of targets and limits in institutional frameworks.

Petter Holm

Petter Holm has a social science background and is working on fisheries governance issues. He has a broad research interest, ranging from the organisation of the fishing industry, the societal status of fishers and fish workers in different countries, and institutional change processes. A main focus of his work is on knowledge processes relating to policy making in the fisheries. In particular, he has been interested in the generation and use of scientific advice, and the condition under which such advice can be legitimate and effective. He has been involved in a number of interdisciplinary EU research on fisheries governance, including the Seventh Framework Programme (FP7) projects GAPII and Ecofishman. Petter Holm currently works as a professor at the Norwegian College of Fishery Science, UiT – The Arctic University of Tromsø, Norway.

Ernesto Penas-Lado

Penas Lado is originally from Spain where he obtained a diploma in Biological Sciences at the University of Alcala of Madrid. Later he did a PhD in marine ecosystem modelling in the USA. His career at the European Commission/Directorate-General for Fisheries began in 1986 but he took a three-year break to complete his functions of Director General for Fisheries and Aquaculture for the Galician Regional Government in Spain. Back at the European Commission/Directorate-General from Maritime Affairs and Fisheries, his responsibilities included negotiations in the Regional Fisheries Management Organisations, then he occupied the post of Head of the Unit “Conservation Policy”, and finally “Common fisheries policy and aquaculture”. In 2009, he was appointed Director of the Directorate “Baltic Sea, North Sea and Landlocked Member States” and from mid-2010 he has been occupying the post of Director in the Directorate MARE-A “Policy Development and Co-ordination” In this capacity, he has been responsible for the recent reform of the Common Fisheries Policy.

Keynote Talks

Pamela Mace

Pamela Mace is the Principal Adviser Fisheries Science at the New Zealand Ministry for Primary Industries. Her key responsibilities are to ensure the scientific integrity of the Ministry's fisheries research, stock assessment and environmental assessment programs. She has worked extensively in the United States, Canada, and New Zealand, as well as in Europe and Australia. Her research interests include the national and international development of biological reference points and harvest control rules for fisheries, ecosystem approaches, development of criteria for defining species at risk, and fish stock assessments.

Read more about Pamela Mace here: **www.scientists.org.nz/member/pamela-mace**

Keynote Title: The Journey To Set Targets And Limits In Fisheries Management

Defining and implementing targets and limits for our world's wild fisheries has been instrumental in ending overfishing and rebuilding depleted fish stocks, particularly in the last two decades. Here I document and explore the early and recent evolution of target and limit reference points and their role in promoting ecologically sustainable fisheries, as well as the areas where we need to continue our efforts. There has been substantial progress in recent times, but there is still much that needs to be accomplished, and many challenges for the future.

Along the way, there have been numerous critiques of reference points including estimation problems, their appropriateness, difficulties effectively implementing reference point-based harvest strategies, and multispecies, ecosystem, economic and social issues. The concept of MSY has, and still does, come in for a disproportionate amount of criticism. An epitaph for the concept was written almost 40 years ago, but MSY didn't die because it is enshrined in UNCLOS and many national legislations, and no operationally superior construct has gained prominence. However, its interpretation has continued to evolve over the years and many alternative, often related, fisheries management targets have subsequently been developed. Limit reference points are a more recent innovation and it is interesting that some former targets are evolving to become limits.

Despite problems, the pervasiveness and effectiveness of reference points in fisheries science and management is currently stronger than ever. I argue that in many cases this has resulted because of the changing emphasis from target reference points to limit reference points. Reference points that are defined as limits to be avoided with high probability are usually taken more seriously – in the sense that they are treated less flexibly – than targets that are to be achieved on average. These are also arguably more relevant for multispecies, ecosystem, economic and social issues. More importantly, targets and limits have new-found importance due to much stronger legislation, policy statements, and binding international declarations with time-bound deadlines for implementation.

Keynote time: Tuesday 9.10

Poul Degnbol

Poul Degnbol is adjunct professor at the Institute for Innovative Fisheries Management, Aalborg University, Denmark. An ecologist by training he has through his career worked with marine management issues in Europe, Africa and Asia as researcher, research director, adviser and through capacity development projects. His recent positions include: being Head of Advisory Programme in the International Council for the Exploration of the Sea (ICES) with a charge to ensure that best available science is operationalised in response to questions from competent authorities regarding the marine environment and fisheries; being Scientific Adviser in the European Commission with responsibility for developing the Green Paper prior to the most recent reform of the Common Fisheries Policy; and being Director for Institute for Fisheries Management and Coastal Community Development, Denmark, a research institute focusing on institutional aspects of marine policy and management.

Keynote Title: Linking Targets And Limits To Practical Management

The MSY concept and its associated targets and limits have risen to become a core guideline for policy while it

Keynote Talks

was developed and first implemented at a time, when both fisheries science and fisheries policy were embedded in understandings of nature and society which were very different from those industry stakeholders, civil society, policy makers and scientists deal with today. The presentation will discuss the tensions which arise when concepts, policies an institutions with different historical roots and representing different interests are brought together to find practical solutions to targets and limits in today's policy landscape. On this basis, key shortcomings of some current fisheries management institutions will be identified and potential remedies discussed. The presentation will close with a discussion of the responsibilities of marine scientists as agents for change of practical management in their roles as scientists and as advisers.

Keynote time: **Tuesday 9.40**

Sean Pascoe

Dr Sean Pascoe has 30 years of experience in the field of fisheries economics. Prior to joining CSIRO in August 2006 as Economist for the Marine and Atmospheric Research Division (now the Oceans and Atmosphere Flagship), Dr Pascoe was Professor of Natural Resource Economics and Director of the Centre for the Economics and Management of Aquatic Resource, University of Portsmouth, UK. Much of his research experience has involved the development of bioeconomic models for a range of fisheries around the world. He has also worked extensively in the area of capacity and efficiency analysis in fisheries. Dr Pascoe has also undertaken extensive work on fisheries management policies, and has worked with the European Commission, OECD and FAO on the development of management policies and guidelines. He is also currently an Adjunct Professor in the School of Economics and Finance, Queensland University of Technology (QUT), where he supervises a number of research students. To date, he has produced over 200 papers and reports, including over 100 refereed journal articles. Read more about Sean Pascoe here: **http://people.csiro.au/P/S/Sean-Pascoe**

Keynote Title: **Australian Experiences With Modelling Multiple Management Objectives In Fisheries**

Australian federally managed fisheries were amongst the first in the world to embrace a management objective of maximising net economic returns as the primary objective of fisheries management. This followed many years of campaigning from scientists and industry. More recently, the "social" agenda has also increasingly been promoted in fisheries management. This has been largely taken up by the Australian States, with many having a loosely defined social as well as economic objective as part of their management objectives. Although not formally part of the federal management framework, social aspects of management have also been considered. Incorporating social and economic relationships, together with sustainability objectives into models to provide management advice creates a number of challenges. Several different approaches have been used, some as part of the formal management strategy evaluation process and others as more exploratory approaches. In this talk, I outline the general challenges around incorporating multiple objectives into models for management advice. I present three case study fisheries where different approaches have been used to include social, economic and ecological considerations – the so-called triple bottom line.

Keynote time: **Tuesday 15.10**

André Punt

André E. Punt is a Professor in the School of Aquatic and Fishery Sciences at the University Washington, Seattle, USA and currently the Director of the School. Dr Punt has been involved in stock assessment and fisheries management for over 25 years and has been recognised for his contributions in this area with awards from CSIRO, the University of Washington, the Australian Society for Fish Biology, and the American Fisheries Society. The research undertaken by Dr Punt and the MPAM (Marine Population and Management) group at the University of Washington relates broadly to the development and application of fisheries stock assessment techniques, bioeconomic modelling, and the evaluation of the performance of stock assessment methods and harvest control rules using the Management Strategy Evaluation approach. Dr Punt has conducted stock assessments for a wide range of species, ranging from anchovies and sardines, to groundfish, tunas, and cetaceans and has published over 250 papers in peer-reviewed literature, along with over 400 technical reports. He was recently a member of a National Research Council panel on evaluating the effectiveness of fish stock rebuilding in the United States. Dr Punt is currently a member of the Scientific and Statistical Committee of the Pacific Fishery

Keynote Talks

Management Council, the advisory committee for Center for the Advancement of Population Assessment Methodology, the Crab Plan Team of the North Pacific Fishery Management Council, and the Scientific Committee of the International Whaling Commission. Read more about André Punt here **http://fish.washington.edu/people/punt/**

Keynote Title: Strategic Management Decision Making in a Complex World: Quantifying, Understanding and Using Trade-offs

Use of Management Strategy Evaluation (MSE) techniques to inform strategic decision making is now standard in fisheries management, and is increasingly being recommended for use in terrestrial systems. The technical aspects of MSE, including how to design the operating models that represent the managed system and how to simulate future use of management strategies, are well understood and can be readily applied, especially for single-species targeted fisheries. However, MSE evaluations seldom identify strategies that will satisfy all of the objectives of the decision makers simultaneously, i.e. each strategy will achieve a different trade-off amongst the objectives. We examine the basis for identifying management objectives and representing them mathematically, as well as how the trade-offs can be illustrated to the various audiences who provide input into decision making. To the extent feasible, how the trade-offs were accounted for in decision making is also outlined. The approaches and experiences are illustrated using case studies on sardine from Australia and the west coast of North America, commercial and aboriginal harvesting of baleen whales, and other examples of single- and multi-species fisheries. The case studies are restricted to where a management strategy, or at least a harvest control rule, is formally adopted. The examples highlight the wide variety of types of objectives that can be considered in an MSE, but that traditional single-species considerations continue to dominate decision making. The desirability and consequences of minimum performance standards ('satisficing') as well as the difficulties assigning plausibility ranks to alternative states of nature are found to be amongst the major challenges to effective provision of strategic advice on trade-offs among management strategies.

Keynote time: Wednesday 14.00

Cóilín Minto

Cóilín's research focuses on coupling biological and ecological mechanisms with tailored statistical methodologies at individual, population and community levels. Broad research interests include applications and developments of EM algorithms, detection of structural breaks in multivariate time series, analysis of technical measure trials to address European landings obligation requirements, coupled bio-economic modelling for decision support, monitoring programme design, and data-poor assessment methods.

Cóilín is a Senior Researcher in Quantitative Ecology and Biostatistics at the Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology, Galway, Ireland.

Keynote Title and abstract: Challenges in tracking stock productivity and relaying to ground control

That fish population productivity varies in time and space is hardly new – it was a central focus in the founding of modern fisheries science. Practically, however, the assumption of unchanging productivity has been useful, as it provided static targets and limits to management ground control, thus orienting the fishery mission. In the production of these static reference points, violations of model fit were often treated as post-hoc problems to be corrected for while inference focussed on the static form. This missed that the dominant feature of the data can be the violation (e.g., ubiquitous autocorrelation of residuals) and ignoring those patterns in favour of the static form misses the nature of the target.

What is relatively new, is an ability to track changes in productivity using time-varying forms of the methods underlying the static approach. In particular, here I highlight Peterman's productivity method which uses time-varying parameter estimation methods originating in signal processing to couple biological theory with observation. In an analogous approach to projectile tracking in space, where the laws of motion are coupled with antennae observations to provide an update of position, the time-varying parameter method projects the population forward under biological theory (of increasing complexity) and updates the predictions by noisy observations. This dynamic parameter evolution allows for translation into dynamic reference points to be relayed to ground control.

Broad challenges of why versus how productivity has changed remain. Technical challenges in this new moving arena

Keynote Talks

include: non-linear estimation, the form of the parameter evolution, distinguishing sources of error (e.g., process error from structural breaks), and lags in catching up with productivity. These and some potential solutions are reviewed. For ground-control, challenges including moving targets and accommodating various missions, some of which have set out already, are discussed.

Keynote time: **Thursday 10.20**

Anthony Charles

Anthony Charles is a professor at Saint Mary's University (Halifax, Nova Scotia, Canada) with a joint appointment in the School of the Environment and the Sobey School of Business. He is a Pew Fellow in Marine Conservation, and specialises in interdisciplinary analysis of fisheries, coastal and marine issues. Particular areas of emphasis include community-based conservation and resource management, small-scale fisheries, integrated ocean and coastal management, the ecosystem approach, marine protected areas, indicator frameworks, and the development of management measures for sustainability and resilience. He serves as an advisor to fisheries organisations in Atlantic Canada, and internationally he works on fisheries, ocean and coastal management in Asia, Latin America and the Caribbean, as well as with FAO and OECD. Read more about Anthony Charles here: **www.dal.ca/faculty/science/marine-affairs-program/faculty-staff/our-faculty/dr--anthony--tony--charles.html**

Keynote Title: **Fishery Targets and Limits: Of What? By Whom? Governance and Institutional Considerations**

This presentation reflects on personal experience, as well as drawing on analysis in the recent book Governance of Marine Fisheries and Biodiversity Conservation, to examine governance and institutional issues relating to fishery targets and limits. Using a framework of two conflicting streams of governance – one emphasising fishery resource use, the other marine conservation – the presentation explores what targets and limits are to be considered, and who should develop and utilise them. Most examples of full implementation of targets and limits are found in situations where only biological (or sometimes also economic) objectives are considered. What are the pros and cons of the common absence of targets and limits relating to social (and often economic) objectives? In terms of process, should the setting of fishery targets and limits be a 'people process' and with what level of participation? On the other hand, is it, at present, largely a 'technical exercise'? What is the right process to be followed in design and implementation of targets and limits, and how does this depend on societal settings and management institutions?

Keynote Time: **Friday 9.10**

Postcard Reflections

During the symposium, we will engage in presentations, discussions and reflections in plenary and in groups. In addition to this, we would like to know which observations, statements or conclusions you found to be the most significant in each session. These reflections will be collected by Reflection Postcards which we will distribute for you to fill out at the end of each session. The reflections will subsequently be typed anonymously and used in the synthesis work to provide us with the main lessons learned by all participants. We hope you will take a few minutes to help us in this effort!

Scientific Programme

Monday October 26th 2015		
16.00-18.00	**Registration -** Conference room Pacific at Hotel NJV Athens	
19.00	**Cocktail event -** Winebar By the Glass	
Tuesday October 27th 2015		
8.00	**Registration and coffee -** Conference room Pacific at Hotel NJV Athens	
Session 1: Introductory session		
9.00	Welcome	Anna Rindorf
9.10	**Keynote:** The journey to set targets and limits in fisheries management	Pamela Mace
9.40	**Keynote:** Linking targets and limits to practical management	Poul Degnbol
Session 2: Science and management in a societal setting		Conveners: Barrie Deas, Robert Stevenson, Anna Rindorf
10.10	Presentation of the session aim and structure	Barrie Deas
10.20	Fisheries Science and management in a societal setting: Obtaining and maintaining Social License	Robert Stephenson
11.20	**Coffee**	
11.50	Incorporating Societal Concerns into Science: Lessons learned from Inter- and Transdisciplinary Research	Jennifer L. Bailey
13.00	**Lunch**	
14.00	Ups and downs in the cooperation between Danish fishers and scientists	Anna Rindorf, Kenn Skau Fisher
14.50	Postcard session	Anna Rindorf
Session 3: Identifying trade-offs and conflicting objectives		Conveners: Phillip Levin, Rudi Voss
15.00	Presentation of the session aim and structure	Phillip Levin
15.10	**Keynote:** Australian experiences with modelling multiple management objectives in fisheries	Sean Pascoe
15.40	A conceptual model to assess and map “extra-local benefits” from fisheries at a global level	Evangelia Drakou
16.00	**Coffee**	
16.30	Are ‘pretty good yield’ ranges precautionary?	Anna Rindorf
16.50	Combining stock, multispecies, and ecosystem level status determination criteria: what tradeoffs can we expect?	Sarah Gaichas
17.10	Management of multispecies demersal fisheries in the Mediterranean	George Tserpes
17.30	Stakeholder engagement in the management strategies for Atlantic Iberian waters: from the identification of priorities to the evaluation of a Multiannual Management Plan	Paz Sampedro
18.00	End of presentation programme	
20.00	**Symposium dinner -** Restaurant Dionysos Zonars	

Scientific Programme

Wednesday October 28th 2015		Speaker
Session 3: Identifying trade-offs and conflicting objectives (Continued from Tuesday)		
9.00	MSY ranges in a multispecies stochastic model environment	Morten Vinther
9.20	The MSY concept in a multi-objective fisheries environment – lessons learned from the North Sea	Alexander Kempf
9.40	Lost in translation: Increased complexity in management results in lost pelagic catch opportunities	Niels Hintzen
10.00	Beyond the single species Maximum Sustainable Yield approach: a mutiple species and multiple fleets approach using the ISIS-fish simulation tool.	Stephanie Mahevas
10.20	Rebuilding Patagonian toothfish off Southern Chile: evaluating trade-offs via closed-loop harvest strategy simulations	Vania Henriquez (Poster)
10.45	Beyond the Target Species: Future Consequences of MSY under different scenarios of change	Sophie Smout (Poster)
10.50	**Coffee**	
11.20	Group consultations on general lessons learned	
12.35	Postcard session	Anna Rindorf
Session 4: Incorporating knowledge on trade-offs and conflicting objectives into decision making		Conveners: Cathy Dichmont, Niels Hintzen
12.45	Presentation of the session aim and structure	Cathy Dichmont
13.00	**Lunch**	
14.00	**Keynote:** Strategic Management Decision Making in a Complex World: Quantifying, Understanding and Using Trade-offs	André E. Punt
14.30	What is it we want to maximise and sustain in Maximum Sustainable Yield?	Anna Rindorf
14.50	On the role of visualization in the management of fisheries	Polina Levontin
15.10	A framework for managing fisheries with multiple economic, ecosystem and social objectives	John Mumford
15.30	**Coffee**	
16.00	Discussion of the proposed framework: Would this suit other (non-tested) cases?	John Mumford
16.40	Accounting for socio-economic constraints to define the path to sustainability: European examples	Katell G. Hamon
17.00	DAMARA: Science to support management decisions for the multi-fleet multi-stock fisheries of the Celtic Sea	Paul Dolder
17.20	Afternoon food for thought: Options under the European Horizon 2020 programme	Nikos Zampoukas
17.40	End of presentation programme	
20.00	Poster session and idea fair for the European Horizon 2020 programme	

Scientific Programme

Thursday October 29th 2015		Speaker
Session 4: Incorporating knowledge on trade-offs and conflicting objectives into decision making *(Continued from Wednesday)*		Conveners: Cathy Dichmont (CSIRO), Niels Hintzen (DLO/ IMARES)
9.00	Achieving Mixed-fisheries and multispecies MSY in the North Sea demersal fisheries	Clara Ulrich
9.20	How metier and vessel size class may influence accident and fatality rates at sea (Poster presentation)	Simon Northridge
9.25	Group consultations on session conclusions/topics	
10.00	Postcard session	Anna Rindorf
Session 5: Targets and limits in a variable world		James Thorson, Olivier Thebaud
10.10	Presentation of the session aim and structure	James Thorson
10.20	**Keynote:** Challenges in tracking stock productivity and relaying to ground control	Coílín Minto
10.50	What is MSY when stock productivity shifts? A worked example from the North Sea	Lotte Worsøe Clausen
11.10	**Coffee**	
11.40	Stochastic maximum sustainable yield reference points for Northern cod, including variable natural mortality rates and a spatial stock-recruit model	Noel Cadigan
12.00	Decadal changes in reference points for stocks of EU interest in the northeast Atlantic	Kenneth Patterson
12.20	Evaluation of the target fishing mortality utilized for the sustainability of the austral sardine (*Sprattus fuegensis*) fishery in Patagonian waters of Chile.	Luis A. Cubillos
12.40	Local Sensitivity of Fisheries Management Target and Limit Reference Points	Noel Cadigan (Poster)
12.45	Evaluation of harvest control rules under changes of fish productivity using a closed-loop simulation	Roberto Licandeo (Poster)
12.50	Equilibirium properties of the Ricker stock-recruitment model and their relationships with spawning-per-recruit at zero fishing mortality and recruitment regime.	Luis A. Cubillos (Poster)
13.00	**Lunch**	
14.00	Spatiotemporal variation of fish size spectra across geographic and bathymetric gradients: an Atlantic - Mediterranean comparison	Manuel Hidalgo
14.20	Effects of recent changes in stock conditions and mixing on sustainability and economic viability of the fishery - The Danish fisheries for Baltic cod	Francois Bastardie
14.40	Multi-species and multi-models; accepting imperfection in an uncertain world.	Stuart Reeves
15.00	Detecting shifts in productive habitat and overfishing limits using spatial state-space surplus production models	James T. Thorson
15.20	**Coffee**	
15.50	It's the economy, stupid! Projecting the fate of fish populations using ecological-economic modelling	Jörn Schmidt

Scientific Programme

16.10	Detecting ecosystem signals of technological creep and density-dependent changes in catchability and their impact on policy exploration with an ecosystem model of the southern North Sea	Moritz Stäbler
16.30	Could multistock reference points mitigate the impact of landing obligation in the economic performance of the fleets? The case study of Spanish Demersal fleets operating in Iberian Waters	Raul Prellezo
16.50	Final group consultations	
17.40	Postcard session	Anna Rindorf
17.45	How to write your contributions to the ICES Journal of Fisheries Science	Howard Browman
18.00	End of programme	Anna Rindorf

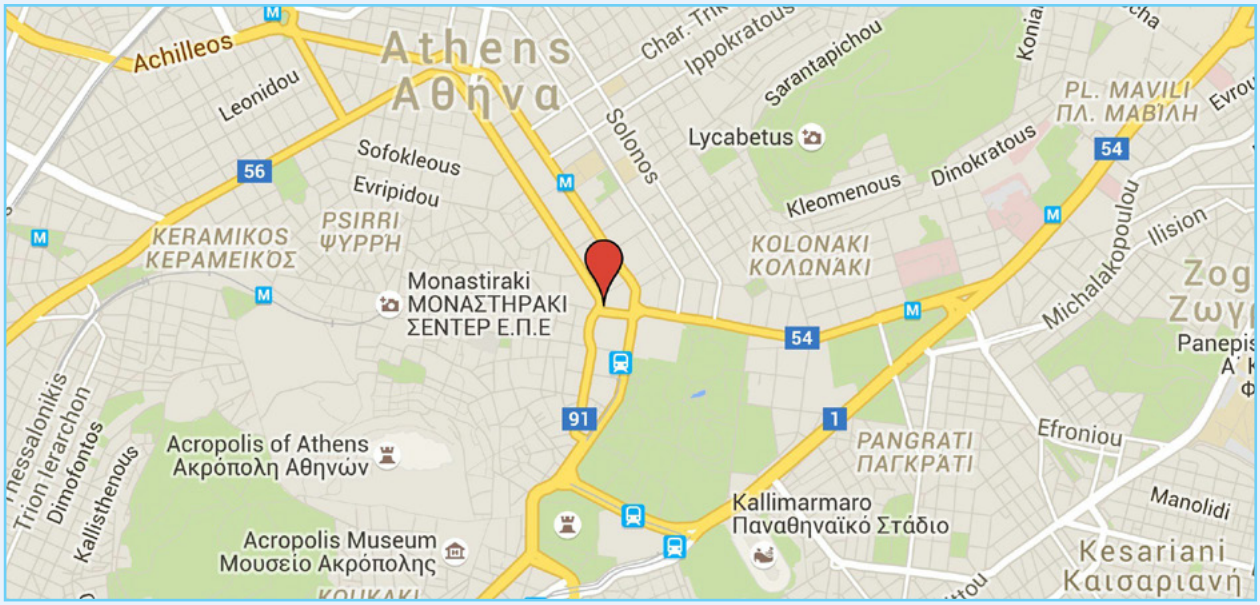
Friday October 30th 2015		**Speaker**
Session 6: Practical implementation of targets and limits: institutional frameworks which deliver		Conveners: Petter Holm, Ernesto Penas-Lado
9.00	Presentation of the session aim and structure	Petter Holm
9.10	**Keynote:** Fisheries targets and limits: Of what? By whom? Governance and institutional considerations	Anthony Charles
9.50	Global Comparisons of Fisheries Expansion, Overfishing and Recovery and the Influence of Catch Limits	Tess Geers
10.10	Incorporating social and cultural objectives in fisheries policy: The case of small-scale fisheries of the English Channel and Southern North Sea	Julie Urquhart
10.30	Using spatial management to achieve Bpa targets for vulnerable Irish Sea skates	Simon Dedman
10.50	Adaptive management response to a spatially confined rock lobster (*Jasus edwardsii*) fishery in South Australia.	Adrian Linnane
11.10	**Coffee**	
11.40	Implementation of target and limits in Chilean fisheries management: Tier system, BRP, drastic quotas reductions and mitigation plans.	Ignacio Payá
12.00	Social-economic drivers in (political) TAC setting decisions	Rudi Voss
12.20	#CFPreality? Implementation of MSY objectives in the reformed EU Common Fisheries Policy	Markus Knigge
12.40	Three steps for getting EU fisheries management to reflect scientific advice and societal priorities	Liane Veitch
13.00	**Lunch**	
14.00	Session conclusions/group consultations	Petter Holm, Ernesto Penas-Lado
14.45	Postcard session	Anna Rindorf
14.50	Symposium impressions and award presentation	Anna Rindorf
15.00	End of programme	Anna Rindorf

Social Programme

Monday October 26th 2015

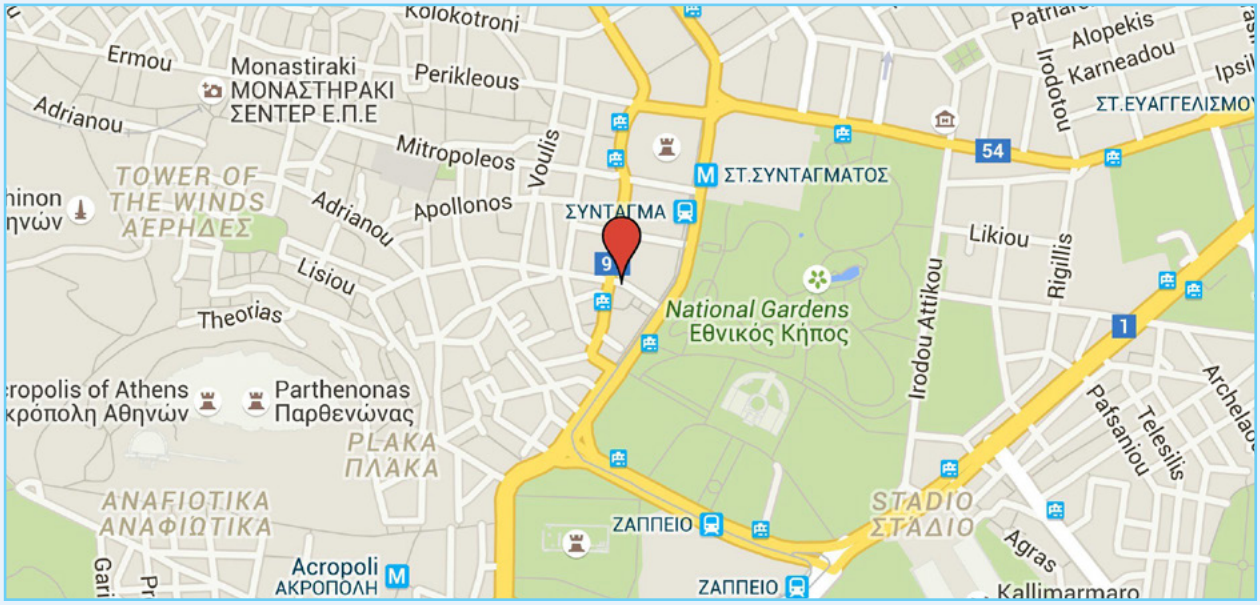
16.00-18.00 | **Registration – conference room Pacific at Hotel NVJ Athens**

NJV Athens Plaza Hotel Varnikos S.A – 2, Vasileos Georgiou A, Constitution Square (Syntagma Square) 105 64 Athens, Greece



19.00 | **Cocktail event – By the Glass**

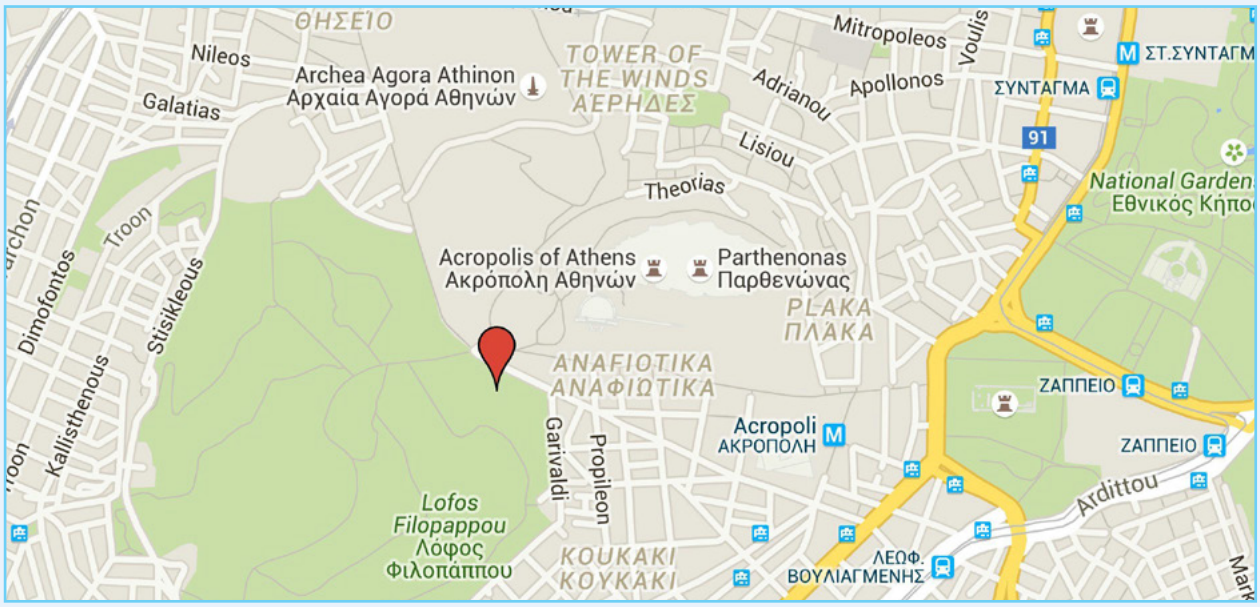
Winebar “By the Glass”, 3 George Souris Str, Syntagma, Athens



Social Programme

Tuesday October 27th 2015	
8.00-9.00	Registration and coffee – Conference room Pacific at Hotel NVJ Athens
20.00	Symposium Dinner at restaurant Dionysos Zonars

Restaurant Dionysos Zonars, 43 Str. Rovertou Galli, Acropolis, Athens



Participant List

First name	Last name	Organisation/Institute/Company	Country	Email
Gustaf	Almqvist	Stockholm University	Sweden	gustaf.almqvist@su.se
Michael	Andersen	Danish Fishermen Producer Organisation	Denmark	ma@dkfisk.dk
Jennifer	Bailey	Department of Sociology and Political Science, Norwegian University of Science and Technology	Norway	jennifer.bailey@svt.ntnu.no
Francois	Bastardie	DTU Aqua	Denmark	fba@aqua.dtu.dk
Howard	Browman	Institute of Marine Research	Norway	howard.browman@imr.no
Noel	Cadigan	Marine Institute of Memorial University of Newfoundland	Canada	noel.cadigan@mi.mun.ca
Cristian	Canales Ramirez	Instituto de Fomento Pesquero	Chile	cristian.canales@ifop.cl
Natacha	Carvalho	JRC	Italy	natacha.carvalho@jrc.ec.europa.eu
Anthony	Charles	Saint Mary's University	Canada	tony.charles@smu.ca
Luis	Cubillos	Universidad de Concepción	Chile	lucubillos@udec.cl
Barrie	Deas	National Federation of Fishermen's Organisations	USA	bdeas@nffo.org.uk
Simon	Dedman	Galway-Mayo Institute of Technology	Ireland	simondedman@gmail.com
Poul	Degnbol	ICES	Denmark	poul@degnbol.net
Cathy	Dichmont	CSIRO	Australia	cathy.dichmont@csiro.au
Mark	Dickey-Collas	ICES	Denmark	mark.dickey-collas@ices.dk
Anne	Doeksen	North Sea Foundation	The Netherlands	a.doeksen@noordzee.nl
Paul	Dolder	CEFAS	UK	paul.dolder@cefas.co.uk
Evangelia	Drakou	University of West Brittany	France	evangelia.drakou@univ-brest.fr
Carian	Emeka	Ministry of Economic Affairs - The Netherlands	The Netherlands	c.cemeka@minez.nl
Kenn Skau	Fischer	North Sea Advisory Council (NSAC)	Denmark	ksf@dkfisk.dk
Judith	Fuchs	AquaTT	Ireland	judith@aquatt.ie
Sarah	Gaichas	NOAA NMFS Northeast Fisheries Science Center	USA	Sarah.Gaichas@noaa.gov
Tess	Geers	Oceana	USA	tgeers@oceana.org
Claudia	Günther	Institute for Hydrobiology and Fishery Science	Germany	claudia.guenther@uni-hamburg.de
Katell	Hamon	LEI-Wageningen UR	The Netherlands	katell.hamon@wur.nl
Emma	Hatfield	European Commission. DG MARE	Belgium	emma.hatfield@ec.europa.eu
Vania	Henriquez	Universidad de Concepción	Chile	vaniahenriquezt@gmail.com
Manuel	Hidalgo	Spanish Institute of Oceanography (IEO)	Spain	jm.hidalgo@ba.ieo.es

Participant List

First name	Last name	Organisation/Institute/Company	Country	Email
Julie	Hills	Fisheries Science - MPI New Zealand	New Zealand	Julie.Hills@mpi.govt.nz
Niels	Hintzen	IMARES, part of Wageningen UR	The Netherlands	niels.hintzen@wur.nl
Petter	Holm	Norwegian College of Fishery Science, University of Tromso	Norway	petter.holm@uit.no
Christopher	Hopkins	AquaMarine Advisers	Sweden	chris.hopkins@aquamarine.se
Jan	Horbowy	National Marine Fisheries Research Institute	Poland	horbowy@mir.gdynia.pl
Reine J.	Johansson	Baltic Sea Advisory Council	Denmark	rj.j@pelagic.se
Alexander	Kempf	Thünen Insitut für Seefischerei	Germany	alexander.kempf@ti.bund.de
Markus	Knigge	The Pew Charitable Trusts	Germany	mknigge-consultant@pewtrusts.org
Phillip	Levin	NOAA Fisheries	USA	phil.levin@noaa.gov
Polina	Levontin	Imperial College	UK	polina.levontin02@imperial.ac.uk
Tristram	Lewis	Funding FISH		tris@fundingfish.eu
Roberto	Licandeo	UBC/Institute for the Oceans and Fisheries	Canada	robertolicandeo@gmail.com
Adrian	Linnane	SARDI Aquatic Sciences	Australia	adrian.linnane@sa.gov.au
Pamela	Mace	New Zealand Ministry for Primary Industries	New Zealand	Pamela.Mace@mpi.govt.nz
Stephanie	Mahevas	IFREMER	France	Stephanie.Mahevas@ifremer.fr
Christos	Maravelias	HCMR	Greece	cmaravel@hcmr.gr
Geert	Meun	VisNed	The Netherlands	gmeun@visned.nl
Cóilín	Minto	Galway-Mayo Institute of Technology	Ireland	Coilin.Minto@gmit.ie
Cristina	Morgado	ICES Secretariat	Denmark	Cristina@ices.dk
John	Mumford	Imperial College London	UK	j.mumford@imperial.ac.uk
Shuya	Nakatsuka	National Research Institute of Far Seas Fisheries	Japan	snakatsuka@affrc.go.jp
Richard	Nash	Institute of Marine Research	Norway	richard.nash@imr.no
Verena	Ohms	Pelagic Advisory Council	The Netherlands	v.ohms@pelagic-ac.org
Michael	Park	SWFPA	UK	mike@swfpa.com
Norah	Parke	Killybegs Fishermen's organisation Ltd	Ireland	norahparke@gmail.com
Sean	Pascoe	CSIRO Oceans and Atmosphere	Australia	sean.pascoe@csiro.au
Kenneth	Patterson	European Commission	Belgium	kenneth.patterson@ec.europa.eu
Ignacio Sergio	Payá Contreras	INSTITUTO DE FOMENTO PESQUERO	Chile	ignacio.paya@ifop.cl

Participant List

First name	Last name	Organisation/Institute/Company	Country	Email
Ernesto	Penas Lado	European Commission	Belgium	ernesto.penas-lado@ec.europa.eu
Raul	Prellezo	FUNDACION AZTI	Spain	rprellezo@azti.es
Andre	Punt	University of Washington	USA	aepunt@uw.edu
Stuart	Reeves	Cefas	UK	stuart.reeves@cefas.co.uk
David	Reid	Marine Institute	Ireland	David.Reid@Marine.ie
Anna	Rindorf	DTU Aqua	Denmark	ar@aqua.dtu.dk
Maria Paz	Sampedro	Instituto Español de Oceanografía	Spain	paz.sampedro@co.ieo.es
Jörn	Schmidt	Kiel University	Germany	jschmidt@economics.uni-kiel.de
Sheku	Sei	Statistics, Reserch and Policy Unit, Ministry of Fisheries and Marine Resources	Sierra Leone	seisheku@yahoo.com
Sophie	Smout	SMRU, St Andrews University	UK	scs10@st-andrews.ac.uk
Claus Reedtz	Sparrevohn	Danish Pelagic Producers Organisation	Denmark	crs@pelagisk.dk
Moritz	Stäbler	TI Institute of Sea Fisheries & University of Hamburg	Germany	moritz.staebler@ti.bund.de
Robert	Stephenson	Canadian Fisheries Research Network (UNB & DFO)	Canada	robert.stephenson@dfo-mpo.gc.ca
Olivier	Thebaud	IFREMER	France	olivier.thebaud@ifremer.fr
Robert	Thorpe	CEFAS	UK	robert.thorpe@cefas.co.uk
James	Thorson	Fisheries Resource Analysis and Monitoring Division, Northwest Fisheries Science Center, NMFS, NOAA	USA	James.Thorson@noaa.gov
George	Tserpes	HCMR	Greece	gtserpes@hcmr.gr
Clara	Ulrich	DTU Aqua	Denmark	clu@aqua.dtu.dk
Olga	van Der Valk	DLO	The Netherlands	olga.vandervalk@wur.nl
Liane	Veitch	ClientEarth	UK	lveitch@clientearth.org
Morten	Vinther	DTU Aqua	Denmark	mv@aqua.dtu.dk
Lis	Vinther Elmsted	DTU Aqua	Denmark	lvi@aqua.dtu.dk
Rudi	Voss	University of Kiel, Dep. of Economics	Germany	voss@economics.uni-kiel.de
Lotte	Worsøe Clausen	DTU Aqua	Denmark	law@aqua.dtu.dk
Nikos	Zampoukas	European Commission, DG Research & Innovation	Belgium	nikos.zampoukas@ec.europa.eu

Publication of Proceedings

ICES Journal of Marine Science has agreed to publish a special volume of articles based on a selection of presentations (oral as well as posters) given at the symposium. In addition to the presentations, key note speakers and conveners are requested to provide manuscripts based on their presentations. The ICES journal is ideally suited for this task through its wide scope, encompassing papers from ecosystem studies, environmental effects on fished stocks, as well as economic and social studies related to fisheries.

Manuscripts to be considered for publication to special the volume can be submitted from January 1st 2015 until 1 February 2016. Accepted manuscripts will be available online once they have completed the regular process for papers in the ICES Journal of Marine Science. The symposium issue is expected to be published in January 2017. All manuscripts are required to conform to normal standards for publication in ICES Journal of Marine Science.

Sponsors

The Myfish project received funding from the European Union's Seventh Framework Programme (FP7 /2007-2013) under grant agreement no 289257. The Myfish project is organising and co-financing this event.

The Myfish Project

The European Common Fisheries Policy has made a commitment to direct management of fish stocks towards achieving Maximum Sustainable Yield (MSY) by 2015. Attaining this goal is difficult because achieving MSY for an individual stock may hamper the achievement of MSY for other stocks and compromise ecological, environmental, economic, or social aims. The objective of the Myfish project is to face these difficulties and provide definitions of MSY variants, evaluations of the effect and desirability of attaining these variants, and an operational framework for their implementation. This is achieved through cases addressing single species, mixed species, pelagic, and demersal fisheries across Europe. Social aspects are integrated throughout the project by active involvement of stakeholders in the definition and evaluation of MSY variants. The project gathers 31 national fisheries institutes, universities and SMEs across all RAC regions in a consortium coordinated by DTU Aqua. The institutes cover a broad range of knowledge, from more traditional fields in fisheries science and fisheries management to expertise in bycatch of sensitive species, effects of fishing on environment and sea bottom, resource and environment economics, to social science and industry involvement. The project was initiated in 2012 and ends in 2016.

Myfish decomposes MSY into three aspects: What to maximise (MSY variants), what to sustain (constraints to sustainability) and how to manage fisheries aiming for MSY (management measures). The project was initiated with a workshop aiming to determine which variants are acceptable and feasible in practical management in each of five European regions: the Baltic Sea, the Mediterranean, the North Sea, the Western Waters and Widely Ranging Stocks. The results showed that the variant 'Maximise inclusive governance' had a 'very good' performance in all groups, making this the top ranked variant together with variants of MSY and MEY. Ensuring precautionarity was an important aspect in all areas. As a result, Myfish has continued to produce test cases for how the inclusive governance process can be conducted in practice while adhering to the precautionary and MSY principles. The work has involved various aspects of scientific modelling to predict what aiming for different MSY variants such as MSY in tonnes or value of landings would mean to the yield, the status of stocks and the status of other factors such as other ecosystem components and income associated with fishing, visualisation and elicitation of responses to different scenarios.

Over the past two years, the project participants have made a dedicated effort to provide the scientific input needed by the European Commission to construct Multiannual Management Plans aiming at MSY using a series of descriptions of the consequences of aiming at different MSY variants. For example, aiming at MSY for all species individually will lead to choke species problems as the fishing effort required to reach MSY of the most sensitive species is much less than that required to achieve MSY of more robust species. This issue has become increasingly relevant with the gradual implementation of the landing obligations for a number of species. The efforts have included discussions with stakeholders in all regions about the pros and cons of aiming for different scenarios.

More details about the project can be found at our website, **www.myfishproject.eu.**

Follow the symposium on Twitter:
@myfishproject #icesmyfish

The Myfish project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 289257.

Designed by AquaTT

Abstract Booklet

ICES SYMPOSIUM

TARGETS AND LIMITS FOR LONG TERM FISHERIES MANAGEMENT

Date:
27-30 October 2015

Venue:
N.J.V. Athens Plaza Hotel, Athens, Greece

ICES CIEM myfish

DTU

hcmr ΕΛΚΕΘΕ

myfish

Maximising yield of fisheries while balancing ecosystem, economic and social concerns

ICES SYMPOSIUM

TARGETS AND LIMITS FOR LONG TERM FISHERIES MANAGEMENT

Table of Contents

Session 1: Introductory Session

Linking targets and limits to practical management

Poul Degnbol

The maximum sustainable yield (MSY) concept and its associated targets and limits have risen to become a core guideline for policy while it was developed and first implemented at a time, when both fisheries science and fisheries policy were embedded in understandings of nature and society which were very different from those industry stakeholders, civil society, policy makers and scientists deal with today. The presentation will discuss the tensions which arise when concepts, policies an institutions with different historical roots and representing different interests are brought together to find practical solutions to targets and limits in today's policy landscape. On this basis, key shortcomings of some current fisheries management institutions will be identified and potential remedies discussed. The presentation will close with a discussion of the responsibilities of marine scientists as agents for change of practical management in their roles as scientists and as advisers.

The journey to set targets and limits in fisheries management

Pamela Mace

Defining and implementing targets and limits for our world's wild fisheries has been instrumental in ending overfishing and rebuilding depleted fish stocks, particularly in the last two decades. Here I document and explore the early and recent evolution of target and limit reference points and their role in promoting ecologically sustainable fisheries, as well as the areas where we need to continue our efforts. There has been substantial progress in recent times, but there is still much that needs to be accomplished, and many challenges for the future.

Along the way, there have been numerous critiques of reference points including estimation problems, their appropriateness, difficulties effectively implementing reference point-based harvest strategies, and multispecies, ecosystem, economic and social issues. The concept of maximum sustainable yield (MSY) has, and still does, come in for a disproportionate amount of criticism. An epitaph for the concept was written almost 40 years ago, but MSY didn't die because it is enshrined in UNCLOS and many national legislations, and no operationally superior construct has gained prominence. However, its interpretation has continued to evolve over the years and many alternative, often related, fisheries management targets have subsequently been developed. Limit reference points are a more recent innovation and it is interesting that some former targets are evolving to become limits.

Despite problems, the pervasiveness and effectiveness of reference points in fisheries science and management is currently stronger than ever. I argue that in many cases this has resulted because of the changing emphasis from target reference points to limit reference points. Reference points that are defined as limits to be avoided with high probability are usually taken more seriously – in the sense that they are treated less flexibly – than targets that are to be achieved on average. These are also arguably more relevant for multispecies, ecosystem, economic and social issues. More importantly, targets and limits have new-found importance due to much stronger legislation, policy statements, and binding international declarations with time-bound deadlines for implementation.

Session 2: Fisheries Science and Management in a Societal Setting

Fisheries Science and management in a societal setting: Obtaining and maintaining Social License

Robert Stephenson

Successful fisheries science and management (including the implementation of limits and targets) requires societal acceptance, or 'social license'. While there has been considerable attention to relevance, legitimacy and credibility of parts of the process (especially in the generation of scientific advice), there has been insufficient attention to societal perception, engagement and support of the management system generally. Lack of social acceptance is capable of undermining science advice and management, even of what were previously considered credible and respected institutions. There is no agreed recipe for obtaining or maintaining social license. A review of the literature from fisheries and other sectors including aquaculture, oil & gas, mining, forestry and agriculture, suggests that social license is dynamic and non-permanent, requires ongoing approval from a broad continuum of stakeholders and community, requires trust that is derived from legitimacy credibility and process, and benefits greatly from participation. This presentation examines recent trends and anticipated evolution in management planning and of third party certification with the objective of defining and overcoming key gaps related to social license. In many jurisdictions, there seems to be a lack of appreciation that policy reflects societal priorities (perceived policy gap), or that management is achieving desired objectives (implementation gap). This is complicated by the need for more diverse and explicit objectives (including ecological, social, economic and institutional/governance goals), the obvious conflicts and trade-offs required with diverse objectives, difficulty in establishing participatory governance processes with better defined decision-support frameworks, and an ongoing problem of engagement and communication.

Incorporating Societal Concerns into Science: Lessons learned from Inter- and Transdisciplinary Research

Jennifer L. Bailey

While good basic scientific research as determined by strictly scientific criteria will always be important, there is also increasing pressure for such science to be "policy relevant". This means that at least some scientific work must be formulated with a variety of societal concerns in mind. Beyond the increasing management and policy requirements for such work, there are other practical reasons for incorporating such concerns. The concerns of stakeholders (including managers) may not coincide with those of natural scientists or even social scientists. Yet, adequate responses to the broad spectrum of stakeholder concerns may be a key determinant in the fashioning of policy that is considered legitimate by stakeholders. Legitimacy in turn, is frequently a key driver of commitment to a regulatory regime. In addition, a research-funding environment increasingly geared to policy relevance means that even basic science must increasingly be justified according to its policy usefulness, calling upon the applicant to position the value of the proposed work in the hierarchy of dominant societal concerns. This paper reviews the experiences of two multi-disciplinary Norwegian Research Council projects (CINTERA, focusing on eutrophication and aquaculture; and JANUS, focusing on the increase in jellyfish in the Trondheimsfjord of Norway) for lessons learned about how to bring societal objectives into science. Among other things, it highlights the importance of fashioning research projects in concert with stakeholders and the importance of indicator development and other policy objectives in driving the incorporation of societal priorities into science.

Ups and downs in the cooperation between Danish fishers and scientists

Anna Rindorf and Kenn Skau Fisher

Danish fishers and fishermen's organisations have a long-lasting cooperation with fisheries scientists. The cooperation expanded greatly in the mid 1990s and was initiated in 'win-win' topics, e.g. areas where a clear benefit was likely to be the result. Here we briefly present examples of three win-win topics: the self-sampling programme conducted by Danish fishers to improve the knowledge of sandeel biology, cooperation on changes in the spatial distribution of North Sea cod and experiments with pingers to deter harbour porpoise bycatch. In all these topics, the cooperation has led to a better understanding on the scientific side of the way fisheries operate and the way management can sensibly be formulated, a better understanding on the fisheries side of the scientific process required to change management and on both sides, an increased knowledge of each-others motives and incentives. However, after an initial euphoric phase, the examples have been characterised by a general disillusioned phase. The disillusioning seemed to be fuelled by differences in expectations to the outcome and the tendency to make changes in the conditions facing the stock and fishery the responsibility of the other party. Though the journey has contained both ups and downs, the final result was substantial benefits to both the scientists, fishers and the general community. Science has gained by getting a better knowledge of the ecosystem and stocks in it, fishers have gained from this improved knowledge and the general community has gained by getting greater benefits from the fishery including more environmentally friendly activities. Future cooperation should investigate the importance of how and why topics are chosen, be specific about the potential changes to management resulting from the cooperation and work on how the resilience of the cooperation to outside events can be increased.

Session 3: Identifying Trade-offs and Conflicting Objectives

A conceptual model to assess and map "extra-local benefits" from fisheries at a global level

Evangelia G Drakou and Linwood Pendleton

Our oceans, from the coasts to the deep sea, generate benefits that contribute to human well-being directly or indirectly through food provision, coastal protection, recreation or regulating functions. The benefits generated from fisheries are among the most well assessed ecosystem benefits of the marine environment. Yet, the increasing exploitation of our oceans continues to alter these ecosystems, causing conflicts among social, ecological and economic benefits that these ecosystems can provide to the local and global population. Maps are a strong tool that can be used to communicate the exploitation of these benefits and the impact they have on the natural environment, to policy makers and influence the decision making process for the management of these ecosystems. Within the Mapping Ocean Wealth project, we built a conceptual model to better assess and map ecosystem service (ES) flows for marine ecosystems. We applied our conceptual model to assess and map the South Pacific tuna fisheries that benefit a consumer population that resides mostly in Europe and the USA. We called these benefits "extra-local" as they are enjoyed far from the ecosystem of their provision. The generated maps show the flow of benefits enjoyed from the Pacific tuna fisheries globally. The maps highlight the need to take into account the supply and demand for these fisheries beyond the local level and to look at the global impact these ecosystems have. Within our mapping and modeling exercise we also identified data gaps and areas of uncertainty that could lead the way for future research on this topic.

Are 'pretty good yield' ranges precautionary?

Anna Rindorf, Massimiliano Cardinale, Samuel Shephard, José A. A. De Oliveira, Einar Jorleifsson, Alexander Kempf, Anna Luzenczyk, Colin Millar, David Miller, Coby Needle, John Simmonds, Willy Vanhee and Morten Vinther

Pretty Good Yield (PGY) is a sustainable fish stock yield corresponding to obtaining no less than a specified (large) percentage of the Maximum Sustainable Yield (MSY). It has been argued in literature that a PGY of 80% can be obtained over a broad range of stock sizes, and that the range is not sensitive to basic life history parameters such as natural mortality, growth rate, or age at maturity. We investigated 19 European fish stocks to test the hypothesis that PGY yield ranges are inherently precautionary. An FMSY range was calculated for each stock as the range of fishing mortalities (F) that lead to an average catch of at least 95% of MSY (a more precautionary range than PGY=80%). Moreover, a precautionary reference point for each stock (FP.05) was defined as the F resulting in a 5% probability of the spawning stock biomass (SSB) falling below an agreed lower biomass limit (Blim) in long-term simulations. For the majority of the analysed stocks, the upper bound of the FMSY range exceeded the estimated FP.05. However, species with larger asymptotic length were more likely to have FMSY ranges falling within precautionary limits. Our study shows that FMSY is generally precautionary for teleost fish species in Northern European waters whereas the upper part of the range providing 95% of MSY is not precautionary for small and medium sized fish.

Combining stock, multispecies, and ecosystem level status determination criteria: what tradeoffs can we expect?

Sarah Gaichas, Michael J Fogarty, Geret DePiper, Gavin Fay, Robert Gamble, Sean Lucey and Laurel Smith

We explore alternative status determination criteria and reference points that could simplify fisheries management using a multispecies/ecosystem-based management procedure. There are four components to the management procedure: 1. a limit on total removals for the ecosystem; 2. an allocation of the total removals limit to aggregate species groups; 3. minimum stock size thresholds for individual species; and 4. guidance for optimising the species mix (within aggregates) based on bio-economic portfolio analysis. In this procedure, fishing mortality threshold criteria are applied only to aggregates of species at the ecosystem and group level, but minimum biomass threshold criteria apply at the species/stock level. Previous work using multispecies production models identified conditions where conservation and yield objectives could be balanced: aggregations of species with similar life histories, species interactions, and responses to environmental forcing supported the highest yields while minimising risks that individual stocks dropped below biomass thresholds. Here, we use a more complex size structured multispecies, multifleet simulation model to explore the performance of the management procedure. Different species aggregation rules were applied (taxonomic, habitat, etc) to form alternative groupings, and yield curves for the aggregate groups were constructed by sequentially increasing effort in each of the fleets (alone and simultaneously), while recruitment for each species varied stochastically around a function based on spawning stock biomass. The performance of individual species and each aggregate type was then compared with respect to yield and biomass objectives. Our results evaluate the tradeoffs between management simplicity, yield, and biomass status for the 10 species in the system.

Management of multispecies demersal fisheries in the Mediterranean

George Tserpes, Gorka Merino, Christos Maravelias, Nikolaos Nikolioudakis, Natacha Carvalho and Antoni Quetglas

Mediterranean demersal fisheries are typically multispecific, with a large variety of gears being used to exploit over a hundred of commercial fish species. Fisheries are managed through input control measures based on MSY targets established through the EU CFP. However, the multispecies nature of fisheries makes it rather impossible to achieve MSY targets across all stocks simultaneously; thus the identification of appropriate management actions is a challenging issue. The present work examines the medium-term effects of different management schemes and targets on the demersal fisheries of two Mediterranean regions from both the eastern (Aegean Sea) and western (Balearic Islands) basins. The management schemes include effort/capacity reductions and gear selectivity improvements, while the examined targets concern both biological (MSY) and economic yields (MEY). Two different model frameworks have been employed and based on both biological and fisheries data, the medium-term impact of the examined scenarios on the exploited stocks has been assessed, considering also the viability of fisheries in terms of economic performance. The developed frameworks can be easily adapted to other areas in order to contribute to the sustainable exploitation of multispecies fisheries that are managed through input control.

Stakeholder engagement in the management strategies for Atlantic Iberian waters: from the identification of priorities to the evaluation of a Multiannual Management Plan

Paz Sampedro, Dorleta García, Raúl Prellezo, José María da Rocha and Santiago Cerviño

The fishing exploitation in the Cantabrian Sea-Northwestern fishing ground is mainly performed by a multi-fleet and mixed-species fishery. The development of an optimal management strategy for the fishery resources must incorporate the nature of their fleets and, together with the environmental aspects, the economic and social concerns. This work analyses how alternative management strategies were formulated and evaluated the multi-fleet and multi-species bio-economic model FLBEIA and how the stakeholders' participatory process was built. Based on the stakeholders' knowledge and their social and economic priorities alternative scenarios of management were defined and the posterior evaluation of their results verified the feasibility of their compliance. The results indicate that after restoring the fish stocks to healthy levels, the maximisation of revenues and the stability of catches in time are the principal causes of concern. Also, mackerel was identified in the model results and by the stakeholders as a choke species for both artisanal and industrial fleets. The increase of fishing opportunities of mackerel in this area would ensure the economic sustainable of some fleets but it would be incompatible with the principle of "relative stability" from the EU CFP. An important conclusion of this work is that participation of the stakeholders from the beginning of model configuration and the inclusion of their insights in the evaluation seem to be an adequate framework to validate and legitimate the model, to identify the conflicts between user groups objectives and to facilitate the fishery management compliance.

MSY ranges in a multispecies stochastic model environment

Morten Vinther, Anna Rindorf and Alexander Kempf

The Stochastic Multi-Species North Sea model (SMS) is a model of biological interaction and a size dependent food selection of 23 interacting stocks. Parameters are estimated by maximum likelihood from observations of catch at age, survey catch rates and stomach contents. The model was used to forecast future stock sizes and yield for a large set of combinations fishing mortality for different species. The results show that the variation in predation mortality in many cases is a far more important factor than the variation in fishing mortality on the specific stock: where top predatory fish tend to have a reasonable relationship between fishing pressure and yield regardless of changes in other stocks, this is not the case for prey fish. The interactions introduce significant trade offs between exploitation of top predators and fish lower in the food chain. Lightly exploiting top predators severely decreases the yield of mid-level predators as well as forage fish, consistent with trophic cascades. Further, light exploitation of top-predators may lead to cases where middle level predator stocks are unable to reach precautionary biomass levels due to the combined effect of an increase in exploited predators such as cod and other predators which have recently increased such as gurnards and grey seals. These trade offs present policy decisions on where to aim for in the MSY-region of 'pretty good yield' as decisions on one stock may have severe implications for other stocks and different methods to visualise these trade offs have been attempted. Further, the potential use of F-MSY ranges was investigated.

The MSY concept in a multi-objective fisheries environment – lessons learned from the North Sea

Alexander Kempf, John Mumford, Polina Levontin, Adrian Leach, Ayoe Hoff, Katell G. Hamon, Heleen Bartelings, Morten Vinther, Moritz Staebler, Jan Jaap Poos, Sophie Smout, Hans Frost, Sander van den Burg, Clara Ulrich and Anna Rindorf

One of the most important goals in current fisheries management is to maintain or restore stocks to levels that produce the maximum sustainable yield (MSY). However, in areas like the North Sea the implementation of the MSY concept is difficult because of a multi-dimensional trade-off space caused by many interacting species, mixed fisheries and multiple management objectives. Our study gives insights on how inclusive governance and appropriate tools can help in such difficult political processes to reach consensus and how science can be used to make informed decisions inside a multi-dimensional trade-off space. The premise is that MSY is a concept that needs adaptation, not wholesale replacement. The approach chosen involved a process of consulting and discussing options with stakeholders as well as scenario modelling of preferred options with bio-economic, multi-species and ecosystem models. Although addressing trade-offs is complicated, it could be demonstrated that the current approach of treating each stock separately and ignoring trade-offs may result in unacceptable ecosystem, economic or social effects. Overall, a “pretty good yield concept” was favoured by stakeholders over trying to reach the absolute sustainable maximum in yield or profit. To treat FMSY no longer as point estimate but to estimate sustainable ranges leading to “pretty good yield” was seen as promising way forward to avoid unacceptable outcomes when trying to reach the impossible, namely to fish all stocks simultaneously at FMSY.

Lost in translation: Increased complexity in management results in lost pelagic catch opportunities

Niels Hintzen, Martin Pastoors, Claus Reedtz Sparrevohn, Anna Rindorf, Anne Cooper and Lotte Worsoe Clausen

Management plans were initially designed to improve sustainable management in the long term, with the beneficial side effects of providing transparent outlook on catch opportunities and reducing negotiations over TACs. Within the development of a management plan, choices have to be made to balance short versus long term gains, stability in catch opportunity and the desired abundance of fish left in the sea. In the herring and sprat fishery in the North Sea and IIIa, addressing these trade-offs resulted in adding additional rules to the North Sea herring management plan, apart from the agreed target set according to the relationship between Spawning Stock Biomass and fishing mortality. This is because juveniles of the North Sea herring stock were susceptible in the sprat fishery in the North Sea and herring fishery in the Skagerrak / Kattegat region. Although these additional rules did ensure the sustainable exploitation of North Sea herring to a certain extent, they did not balance catch opportunity allocation by member state. Thus, in 2015 additional rules were added to both herring stocks management plans to address this problem. The resulting management plan however is complex and murky, with unpredictable outcomes if one alters management on one of the three stocks. In this study we show that with a simpler management plan design, the sustainability roots are still adhered, and the overall outtake of fish is higher. Though, member state allocations do shift with distinct ‘winners’ and ‘losers’.

Beyond the single species Maximum Sustainable Yield approach: a multiple species and multiple fleets approach using the ISIS-fish simulation tool

Stéphanie Mahevas, Sigrid Lehuta and Pascal Laffargue

The complexity of interactions between exploited species within their environment and the dynamic adaptation of fishermen in reaction to management and resource fluctuations result in the inability to simultaneously exploit all stocks at their Maximum Sustainable Yield. The challenges posed by the new Common Fisheries Policy in terms of data limited stocks and landing obligation together with the ambition of the Marine Strategy Framework Directive to reach the good ecological status require exploring innovative scenarios. These have to take explicit account of multiple species interactions and of fisheries impact on habitat for balancing biological and economic interests of fisheries. The need for taking into account spatial heterogeneities and technical interactions to provide a realistic assessment of alternative management scenarios in the context of mixed fisheries led us to use the ISIS-Fish simulation model. This model allows us to describe explicitly the spatial dynamics of mixed fisheries including dynamic fishermen behaviour, heterogeneity of access to resources and the dynamics of benthic habitats. Exploratory simulation experiments were first run to test for the existence of multi-species MSY within the hake-nephrops- sole fishery in the Bay of Biscay. A management strategy evaluation was then carried out where TAC setting rules (harvest control rules based on more or less rich data approaches) were considered with landing obligation, biological safeguards and deminimis. Finally MSY ranges scenarios were compared to the baseline scenarios. All scenarios were evaluated regarding impact on stocks and fleets as well as spatial impact on sea bed including uncertainty analysis.

Rebuilding Patagonian toothfish off Southern Chile: evaluating trade-offs via closed-loop harvest strategy simulations

Vania Henriquez, Luis Cubillos and Sean Cox

Management strategy simulation is a useful tool for evaluating expected performance of management procedures (MPs) against economic and conservation objectives. Successful MPs are necessary not only for conservation of exploited stocks, but also for strengthening economic resilience of fisheries. We used management strategy simulations to explore MP candidates aimed at rebuilding the Patagonian toothfish stock from Southern Chile and to examine trade-offs between fishery viability and fish conservation. The Patagonian toothfish fishery supports one of the most lucrative fisheries in Antarctic and Sub - Antarctic waters off the southern cone of South America. The harvest control rules (HCR) components of simulated management procedures consisted of (1) a rebuilding target (TSSB) corresponding to BMSY or a 0.45B0 proxy; (2) limits (LSSB) corresponding to multiples of BMSY or B0 (e.g. 0.5BMSY); and (3) target fishing mortality rates corresponding to multiples of FMSY or FSPR45%. We used a surplus production model in simulated stock assessments to estimate annual exploitable biomass along with the harvest control rule components given above. Ten MPs were tested against an age-structured operating model that mimicked the Patagonian toothfish population and fishery over the period 1989 to 2012. The best MPs included HCRs with (i) LSSB = 0.5BMSY, TSSB = BMSY, and FMSY, (ii) LSSB = 0.2B0, TSSB = 0.45B0, and 0.5Fspr45%, and (iii) constant FMSY. The best MPs demonstrate that Patagonian toothfish could recover from its current over-fished state to levels greater than 0.25B0 within the years 2022 to 2038; however, such recovery would cost at least 36-40% reduction in annual catch (> 400 tonnes).

Beyond the Target Species: Future Consequences of MSY under different scenarios of change

Sophie Smout, Alex Kempf, Ayoe Hoff, Katell Hamon, Moritz Stabler, Anna Rindorf and Simon Northridge

Traditional MSY approaches focus on the management of single fish stocks, aiming to optimise sustainable biomass production. More sophisticated variants may consider different objectives such as maximisation of economic profit. MSY-type models developed for the North Sea adjust the allocation of effort in different fleets and métiers in order to achieve optimal results. Such models can be run to investigate the potential impacts on MSY fishing of different future scenarios such as increased fuel costs and changes in primary production. Changes in fishing effort that are finely tuned to optimise the harvest of a commercial species under different circumstances may impact other species in the ecosystem including some that are also commercial, and others (Protected Endangered and Threatens Species or PETS) that are of importance for biodiversity conservation and ecosystem function. Important PETS in the North Sea include seals, harbor porpoise, and elasmobranch species such as common skate. Bycatch rates for PETS (numbers or biomass for a given level of fishing effort in a given métier) can be estimated from observer data, including those from dedicated PET observer schemes and discard sampling schemes. An MSY or MEY model optimised under a given scenario gives a time-series of projected future effort in different fleets and métiers. Numbers of by-caught animals associated with these projected levels of effort can then be calculated from the empirically-derived by-catch rates. By comparing these estimates across the different scenarios, and by comparing with historical rates, contrasts in the level of will be presented. Population-level risks will be estimated either by heuristic metrics for data-poor species (such as elasmobranchs) or by more detailed population modeling with specific management goals for species such as harbor porpoise and grey seals.

Session 4: Incorporating knowledge on trade-offs and conflicting objectives into decision making

Strategic Management Decision Making in a Complex World: Quantifying, Understanding and Using Trade-offs

André E. Punt

Use of Management Strategy Evaluation (MSE) techniques to inform strategic decision making is now standard in fisheries management, and is increasingly being recommended for use in terrestrial systems. The technical aspects of MSE, including how to design the operating models that represent the managed system and how to simulate future use of management strategies, are well understood and can be readily applied, especially for single-species targeted fisheries. However, MSE evaluations seldom identify strategies that will satisfy all of the objectives of the decision makers simultaneously, i.e. each strategy will achieve a different trade-off amongst the objectives. We examine the basis for identifying management objectives and representing them mathematically, as well as how the trade-offs can be illustrated to the various audiences who provide input into decision making. To the extent feasible, how the trade-offs were accounted for in decision making is also outlined. The approaches and experiences are illustrated using case studies on sardine from Australia and the west coast of North America, commercial and aboriginal harvesting of baleen whales, and other examples of single- and multi-species fisheries. The case studies are restricted to where a management strategy, or at least a harvest control rule, is formally adopted. The examples highlight the wide variety of types of objectives that can be considered in an MSE, but that traditional single-species considerations continue to dominate decision making. The desirability and consequences of minimum performance standards ('satisficing') as well as the difficulties assigning plausibility ranks to alternative states of nature are found to be amongst the major challenges to effective provision of strategic advice on trade-offs among management strategies.

What is it we want to maximise and sustain in Maximum Sustainable Yield?

Anna Rindorf, John Mumford, Lotte Worsøe Clausen, Louize Hill, Niels Hintzen, Ellen Hoefnagel, John Holt, Alexander Kempf, Adrian Leach, Polina Levontin, Pamela Mace, Steve Mackinson, Christian Olesen, Clive Potter, Raúl Prellezo, Axel Rossberg, George Tserpes, Rudiger Voss and Dave Reid

Trade-offs between catches of different species and between long term average yield and stability produce a situation where maximising long term average yield in tonnes of each species separately may not be the most desirable aim for fisheries management. Working with stakeholders, We investigated whether a wider interpretation of MSY capable of addressing the shortcomings of the current strict definitions of MSY as maximum tonnes taken on an individual species basis can be attained. We approached this through a three-year interactive process involving scientists, industry, NGOs and managers in five different European regions. All regions showed a pronounced preference for being inclusive in the setting of targets and for introducing constraints to ensure ecosystem sustainability, However, the preferences for other targets varied between regions according to whether fish stocks and fisheries were considered as isolated or interlinked and according to the conditions in the surrounding societies. Regions which considered fish stocks or fisheries as interlinked showed a low preference for interpreting MSY as the total summed catch of all species. Northern regions tended to focus less on employment and more on economic factors such as rent return than southern regions. Beyond maximising inclusive governance, targets aiming at maximising some form of social yield rather than biomass or economic yield were seen as not being operational and hence received a low preference. Options for maximising yield in weight or value received higher scores. Over the three years of the study, a procedure to operationalise inclusive governance in scientific advice emerged. Ranges providing outcomes close to MSY were defined to provide room for trade-off of different considerations in a more adaptable way than through automatic maximisation of different versions of yield.

On the role of visualization in the management of fisheries

Polina Levontin, John D. Mumford, Adrian W. Leach, Paul Baranowski, Laurence T. Kell and John Holt

Environmental change has focused the attention of scientists, policy makers and the wider public on risk and uncertainty in interactions between people and the environment. Governance in fisheries has shifted to become more open to stakeholder participation and more inclusive in its remit, which is no longer limited to ensuring a Maximum Sustainable Yield from a single stock but considers species and habitat interactions, as well as social and economic issues. The increase in scope, complexity and awareness of uncertainty in fisheries management has brought methodological and institutional changes globally. Progress towards comprehensive, explicit and participatory risk management in fisheries depends on effective communication. We present examples from outside the field of various visualisation techniques that have potential for wide applications within fisheries. We tested some of these visualisation methods within stakeholder workshops and used feedback to make improvements. We experiment with new formats and discuss way of presenting results of management strategy evaluations that might be more effective as forms of communication than those currently in use.

A framework for managing fisheries with multiple economic, ecosystem and social objectives

John D. Mumford, Anna Rindorf, David Reid, Axel Rossberg, Christine Röckmann, Alexander Kempf, George Tserpes, Christos Maravelias, Christopher C.E. Hopkins and Maria Hadjimichael

The maximisation of sustainable “yield” (MSY) is an immediately appealing concept which seems to hold promises of long-term fisheries value. However, practical implementation has led to substantial criticism of MSY as a management goal, in part because of the focus on yield as the single management dimension. Here, we address this criticism by determining general guidelines which can be used by European policy-makers in the implementation of fisheries management based on multiple objectives. General guidelines are produced on the type of systems for which MSY variants are likely to be appropriate and relevant, along with an evaluation of applicable model types for different systems depending on complexity, uncertainty and data availability. The resulting guidelines are organized in a framework to support the implementation of MSY and variants in a wider range of European Union (EU) fisheries. Fisheries reviews identified examples of current good practice in several fisheries outside the EU, broadly in relation to science, governance and rights. Well-communicated, comprehensive policies employing science in structured systems, with predictable staged rules, durable ownership and co-management are examples of practices that appear to give good outcomes. These examples provided guidance on the design of inclusive multi-dimensional fisheries management through the application of the proposed framework. The framework describes a good practice approach to new multi-dimensional fisheries management cases. This includes sixteen steps in problem framing, agreeing options, addressing potential stakeholder outcomes resulting from implementation and evaluation to ensure a relevant and effective plan for governance and management is developed. Stakeholder participation is an essential element in the process. The framework has been validated in part through application of the process to a series of regional case studies with mixed groups of stakeholders.

Accounting for socio-economic constraints to define the path to sustainability: European examples

Katell G. Hamon, Heleen Bartelings, Jose Maria Da Rocha, Dorletta Garcia, Ayoe Hoff, Alexander Kempf, Stephanie Mahevas, Christos Maravelias, Gorka Merino, George Tserpes, Clara Ulrich, Rudi Voss

One objective of the EU project Myfish, involved identifying the trade-offs between the ecological, economic and social aspects of sustainability of fisheries. Once the sustainability objectives and associated targets are defined, managers must still decide of the pace to reach them. While it is recognised that acting fast is more likely to lead to environmental sustainability, this can have undesirable economic consequences for the fleets dependent on the managed resource and deeply affect local communities. To account for the socio-economic dimensions of fisheries, constraints can be and have been set to the speed at which the target must be reached. This can for example be defined as a maximum variability of quota or effort limit between consecutive years. Here, examples ranging from the Baltic Sea, the North Sea, the Bay of Biscay to the Mediterranean Sea illustrate how the socio-economic dimensions can be integrated in bio-economic models to define acceptable paths to the targeted sustainability level. A set of common indicators is used to measure the performances of different harvest control rules in the case studies.

DAMARA: Science to support management decisions for the multi-fleet multi-stock fisheries of the Celtic Sea

Paul Dolder, Cóilín Minto, Marianne Robert, Simon Mardle, Dorleta Garcia, David Goldsborough, Norman Graham

Reforms to Europe's Common Fisheries Policy place regionally based Multi-Annual Plans at the centre of delivering biologically and economically sustainable fisheries. Plans require fishing levels to be consistent with MSY for all stocks, which is a challenge in multi-stock multi-fleet fisheries where biological and technical interactions persist. The combination of approaches for managing fishing pressure through input and output controls, (e.g. TACs, effort, selectivity or spatio-temporal measures) has consequence for all stocks and the fisheries that depend on them. Trade-offs are complex, fleet specific and driven by differing multi-sectoral priorities with consequences for the economic viability of fleets in the short term and long term. DAMARA (DemersAl Mixed fishery Analysis tool for Regional Advice) is a Decision Support Tool (DST) designed to support regional stakeholders in evaluating trade-offs between management choices that are consistent with the CFP's biological, economic and social goals. It combines a fully coupled bio-economic model (FLBEIA; the Fisheries Library Bioeconomic Impact Assessment in R) with a user-friendly interface (based around Shiny), the design of which has been driven by the stakeholders. The DST can be used by stakeholders to compare scenarios to achieve specific targets and assess the biological and economic implications (at multiple levels from country to given fleet segments) of choosing different paths to these goals. Uncertainty in model parameters can be incorporated in the simulations, with the model built around a modular framework allowing more detailed consideration of aspects of the fishery of concern (e.g. recruitment dynamics, price dynamics, fleet structure, effort distribution etc..). DAMARA shows science, industry and authorities jointly developing a DST that uses the best available information to compare trade-offs between management choices. The model has been developed to be generic and could in future also be applied to other regional seas.

Achieving Mixed-fisheries and multispecies MSY in the North Sea demersal fisheriesto sustainability: European examples

Clara Ulrich, Paul Dolder, Ernesto Jardim, Steven Holmes, Alexander Kempf, Lars Olof Mortensen, Jan-Jaap Poos, Anna Rindorf, Youen Vermard

There are concerns about attaining the desired objectives stated in the Common Fishery Policy (CFP) and Marine Strategy Framework Directive (MSFD) in complex and dynamic fisheries targeting multiple species, and in particular about the applicability of Maximum Sustainable Yield (MSY) in mixed fisheries. These concerns apply to a large extent to the North Sea, where the diversity of species and fisheries induce numerous biological and technical interactions. In contrast to many other systems, the North Sea is data rich and well-studied. Interactions are routinely monitored and quantified, allowing for new approaches to emerge. The dynamic nature of the biological system can be addressed through defining MSY as a desirable area of "Pretty Good Yield" rather than a single species point estimate for each stock. Using the FCube fleet-based mixed-fisheries model we demonstrate how the North Sea demersal fisheries system can reach this multidimensional 'space of opportunity' within a short time period, through the use of flexible TAC management that can minimise mixed-fisheries conflicts and improve regional governance, while maintaining viable economic outcomes. We also emphasise the positive changes which have already been attained along this path in recent years.

How metier and vessel size class may influence accident and fatality rates at sea

Simon Northridge

Although it is widely recognised that the fishing industry has one of the highest accident and fatality rates of any occupation, accident rates are rarely if ever considered when making fishery management decisions. Accident rates are not even considered in European fisheries management policy. Fishing vessels accidents are reported in detail by most EU member states and many of these are available online. In this study the available records have been synthesised and accident rates compared between fishing methods and length classes. In order to standardise these rates, the number of days at sea by fishing gear type and by vessel length class have been used to highlight fishing methods and vessel length classes that appear to be most dangerous. Results suggest that (for the UK at least) static net and potting vessels, and vessels of less than 12m in length have a lower accident rate (number of vessel accidents and number if human fatalities) per day at sea than certain other gear and length classes. Specifically, the most accident prone sectors are the over 20m vessel length class and vessels using Nephrops trawls and dredges. The reasons for these differences are speculated upon, though further research into the causes may help elucidate why some sectors are more accident prone than others. These results provide another possible consideration when allocating effort among vessel sectors.

Session 5: Targets and Limits in a Variable World

What is MSY when stock productivity shifts? A worked example from the North Sea

Lotte Worsøe Clausen, Anna Rindorf, Mikael van Deurs, Morten Vinther, Mark Dickey-Collas and Niels Hintzen

Pelagic fish support large scale fisheries and are key components of large marine ecosystems across the world. Their productivity is often highly variable with dominance alternating between different components. The North Sea Large Marine Ecosystem is characterised by long term sustained high volume commercial fisheries on all major small pelagic fish species. Here we investigate the temporal development in the productivity of the four key planktivorous fish species in the North Sea; herring, sprat, Norway pout and sandeel. Productivity changes are determined by analysing time series of recruitment success, mean length of juvenile and older fish, and natural mortality is estimated using data from stock assessment, survey catches and commercial samples of the four species. Using time series analysis, we detect consistent temporal shifts across species related to changes in their main food supply measured from the abundance of copepods in CPR data. Estimating Maximum Sustainable Yield of the four species in the periods between these transitions reveals important changes to the yield and the composition of the catches. This will impact both the ecosystem and the dependent commercial fisheries industry.

Stochastic maximum sustainable yield reference points for Northern cod, including variable natural mortality rates and a spatial stock-recruit model

Noel Cadigan, Jon Fisher and Joanne Morgan

Northern cod (Gadus morhua) off southern Labrador and eastern Newfoundland is an iconic Canadian stock with a varied past. It collapsed in the late 1980's and early 1990's and a moratorium on commercial fishing is still in place. This stock has changed dramatically in size and spatial distribution which makes its stock assessment and determination of maximum sustainable yield (MSY) reference points more complicated. A new integrated state-space assessment model has been developed for this stock that addresses issues related to uncertain catch statistics, variable natural mortality rates (M's), and changes in survey catchability. This model integrates much of the relevant productivity information for this stock. We use the results of this model and a novel spatial stock-recruit model to calculate stochastic MSY reference points that include expected future levels and variability in M and recruitment.

Decadal changes in reference points for stocks of EU interest in the northeast Atlantic

Kenneth Patterson

MSY targets have been adopted as objectives for the Common Fisheries Policy, and monitoring of stock development over time with respect to MSY reference points provides managers with a measure of the success of policy implementation. However, these are moving targets: from 2003 until 2013 Fmsy values as advised by ICES for the principal fish stocks in European waters increased on average by 29%. An attempt is made to ascribe the drivers for Fmsy increases among factors such as management-driven effects (reduced fishing mortality and selection at older ages), data-driven changes concerning somatic growth (e.g. density dependence of growth rates), and changes to methodological assumptions in the provision of advice. Initial results suggest that of 17 stocks where Fmsy estimates increased, 9 showed faster growth, 5 were assessed with higher values of natural mortality, and 5 showed indications of increased selection at older ages. However, 6 stocks with higher Fmsy estimates in 2013 appeared to show slower growth, unchanged M and no increase in age-related selectivity and so the increase in estimated yield-per-recruit may be due to structural issues. Some inferences for monitoring policy implementation can be drawn.

Local Sensitivity of Fisheries Management Target and Limit Reference Points

Noel Cadigan and Shijia Wang

Reference points and harvest control rules are important for good fisheries management. However, they can have substantial economic and social implications for fishing industries and communities, especially via ecolabeling of the sustainability of fisheries. Reliable and useful reference points should be reasonably stable over time and robust to uncertainty. For this purpose it is first useful to understand which of the reproduction, growth and mortality processes that are involved in the calculation of the reference points are more influential. We derive equations that describe how per-recruit and maximum sustainable yield reference points are influenced by changes to productivity inputs. Our results provide a theoretical basis to understand the reliability and robustness of these references points.

Evaluation of harvest control rules under changes of fish productivity using a closed-loop simulation

Roberto Licandeo, Divya Varkey and Carl Walters

Reference points and harvest control rules (HCRs) based on maximum sustainable yield assume stationary environmental conditions. Nevertheless, regime shifts can produce changes in fish productivity and could necessitate a change in the harvest policy. Regime shifts may alter the stock-recruitment relationship through changes in either "carrying capacity" or juvenile survivorship (or both), i.e., regime shift in beta (beta-rg) or alpha (alpha-rg), respectively. We explored HCR performance under these two non-stationary conditions. An age-structured model based on Jack Mackerel (*Trachurus murphyi*) life-history was used to simulate the population dynamics. We simulated persistent changes in productivity under a beta-rg or alpha-rg and the HCR performance was examined using a closed-loop simulation. Auto-correlated errors over time in the stock assessment were simulated using Kalman filtering. We used a generic HCR: quota = qslope*(Bhat-Bmin) to characterise "fixed exploitation rate" or a "fixed escapement" harvest policy (Bmin [optimum escapement] = 0 implies a fixed exploitation rate rule; Bmin > 0 and qslope = 1 implies a fixed escapement rule). We found that the control rule form was related to the stock depletion and the state of the system (i.e., if the current regime shift represented a period of low productivity compared to the historical assessment period). For example, when depletion was high (low stock levels) and the regime shift caused a decline in productivity, the best strategy was the "fixed escapement" (with qslope > 0) policy irrespective of whether the regime shift was manifest through a change in carrying capacity or juvenile survivorship or whether the performance metric was to maximise total catch or sum of log catches (ie., a risk-averse utility function). In general, at lower levels of depletion (higher stock levels), "fixed exploitation" was the best strategy for maximising the long term yield. Further, the beta-rg produces more average long term yield than alpha-rg irrespective of the performance metric and and the state of the system.

Equilibrium properties of the Ricker stock-recruitment model and their relationships with spawning-per-recruit at zero fishing mortality and recruitment regime

Luis A. Cubillos and Sandra Curin-Osorio

In assessing environmental impact on long-term reference points, the S-R question should be attacked from a different perspective from the traditional statistical analysis of fitting. S-R parameters should be estimated from equilibrium S-R properties of models, and from equilibrium relationships by combining S-R parameters with spawning biomass-per-recruit (SPR) and yield-per-recruit (YPR) analyses. YPR and SPR are equilibrium cohort-based models, and there is a correspondence with S-R models in terms of equilibrium properties of the models. The relationships can be achieved by reformulating the S-R models in terms of the unexploited spawning biomass (S0). In this paper, the equilibrium properties of the Ricker S-R model was analysed and the relationship between these properties with spawning biomass per recruit were established. It is demonstrated that the slope of the Ricker S-R model is related to the unexploited SPR, and that the productivity parameter is determined only by an absolute estimate of the unexploited spawning biomass (S0). Once the relationships were established, the impact on long-term yield of fish and biological reference points were analysed by taking into account changes in the unexploited spawning biomass as induced by environmental changes producing recruitment regimes.

Evaluation of the target fishing mortality utilized for the sustainability of the austral sardine (*Sprattus fuegensis*) fishery in Patagonian waters of Chile

Luis A. Cubillos, Sandra Curin-Osorio and Sergio Neira

The austral sardine (*Sprattus fuegensis*) is the main fish resource of a small-scale fishery operating in the Patagonian waters of Chile (41°30'S-46°00'S). The landings have fluctuated between 14,344 and 48,589 tons between 2006 and 2014. The stock assessment of the austral sardine utilises a separable catch-at-length model and a total allowable catch is estimated according to a target fishing mortality at 60% of the unexploited spawning stock biomass per recruit (F60%). The austral sardine is a forage species in the Chilean Patagonia and the stock size is dependent on incoming recruitment. The objective was to evaluate the performance of the current target for fishery sustainability. A simulation–estimation framework was used to examine the performance of three fishing mortality targets (F=M, F55% and F60%). An Ecopath with Ecosim model projected the biomass of the austral sardine during 20 years under the previous fishing mortality rates and used as input to an age-structured operative model (OM). The OM simulated projections during 20 years under different structural scenarios for the population dynamics, i.e. the stock-recruitment model and natural mortality, as well as process and observation errors. The results showed that the F60% target had a good performance only when the underlying population dynamics followed a Ricker stock-recruitment model. The ratio between the projected spawning stock biomass and the unexploited spawning stock biomass (SSBi/SSB0) was slightly above the target of 60%. The F55% was not able to identify an overexploited status because the SSBi/SSB0 was lower than 55% during the projected period. A more precautionary fishing mortality target is suggested for the austral sardine fishery sustainability. In addition the target fishing mortality should be computed each year due to changes in selectivity due to interannual recruitment fluctuations.

Spatiotemporal variation of fish size spectra across geographic and bathymetric gradients: an Atlantic - Mediterranean comparison

Manuel Hidalgo, Antoni Quetglas, Marina Delgado, Antonio Esteban, Luis Gil de Sola, Francesc Ordines, Lucia Rueda, Antonio Punzón and Enric Massutí

Detecting the spatial and temporal scales of variation of fish community dynamics is one of the main challenges when moving from populations to community level processes. Size spectra of fish communities are among the most robust size-based metrics to characterise fish communities and to assess potential effects of fishing on communities and ecosystems. However, it is still a challenge to evaluate how the relative contribution of size-selective removal of predators and the release of preys affect size-spectra at temporal and spatial scales. In addition, few studies focus on the relevance of the spatial variance of the slope, rather than mean values, as an indicator of the spatial heterogeneity of the community. We use information of trawl surveys to compare five contrasting ecosystems around Spain, two in the Atlantic and three in the Mediterranean coast. For each ecosystem, we calculate spatial and temporal variation of the mean slope of size spectra and its coefficient of variation for distinct bathymetric communities. Estimates were compared with the relative biomass of preys and predators to assess the relevance of drivers shaping both strength of the slope and its variability. Results evidence both general and contrasting patterns in the size-spectra, as well as in the relative contribution of the drivers, across geographic and bathymetric gradients. In all the systems, mean biomass of small-sized individuals drives short-term temporal variation of the mean slope, while mean biomass of large-sized fish constraints the long-term pattern of size spectra as well as the variability (i.e., coefficient of variation). Our study also reveals certain spatial segregation of the influence small-sized and large-sized components of the spectra in some areas. We discuss how the relationship between mean and variance of spectra may help to understand the context-dependent characteristics of each ecosystem and contribute to delineate outputs and input controls helpful for fisheries management.

Effects of recent changes in stock conditions and mixing on sustainability and economic viability of the fishery - The Danish fisheries for Baltic cod

Francois Bastardie, J. Rasmus Nielsen, Anna Rindorf and Margit Eero

Recent changes in stock conditions and stock mixing between both the Baltic Sea cod stocks jeopardise the reliability of the stock assessments and put the economy of the fisheries at risk. Focusing on the Danish fisheries, we used an individual-vessel based bio-economic modelling approach (www.displace-project.org) to assess how far a change in the population structure (growth, recruitment and East-West migration) would affect the economy of the fisheries at stake under the current MSY management plan and which fleet segments/activities are more likely to be adversely affected. The model reproduces the harvesting dynamics using information about fishing ground preferences and experienced vessel-specific catch rates. The assessment computes the daily decision-making of the fishing vessels and the individual or overall economic and stock status indicators together with the size-based spatial distribution dynamics of the cod stocks. In this application, scenario testing applies on Danish vessels (>12 m) conducting the Baltic Sea cod fisheries by altering the spatial distribution of effort and associated costs. The stock mixing was a determining/crucial factor affecting the profit of various fishing communities and the efficiency in energy use by affecting the stock abundances and spatial dynamics, while growth and recruitment affects the size composition of the landings, and decrease the final profit estimates from the landings originating from different visited areas. This modelling study contributes to the evaluation of the effect of different recommendations on sustainability and economic viability of the fishery.

Multi-species and multi-models; accepting imperfection in an uncertain world

Stuart A. Reeves, Robert B. Thorpe

The incorporation of information on multi-species interactions into fisheries assessments and advice is a well-established research topic in European fisheries science. The inclusion of such ideas within the recently reformed EU Common Fisheries Policy has acted as a spur for renewed interest in the topic. Accounting for multiple stocks and their interactions within a single model adds considerable complexity to the assessment process, both in the nature of the system being modelled and in the structure of the models in use. This added complexity makes the estimation and handling of uncertainty a particularly important part of the process. In this study we employ an ensemble of size-structured multi-species models to perform stock projections to investigate interaction strengths and yield trade-offs for 21 North Sea stocks. Comparisons within the ensemble enable us to examine the sensitivity of results to assumptions about parameter settings, while comparison with published results from comparable projections using other multi-species models illustrates the effect of assumptions about model structure. Our results indicate that estimated interaction strengths and yield trade-offs are sensitive to both parameter and structural uncertainty. Given our findings, we recommend that multi-species modelling would benefit from the use of a multi-model approach which would enable the uncertainties to be considered explicitly. However, the results also have implications for single species models and for how information on multi-species interactions is used in scientific advice on fisheries management, and our study also explores these issues.

Detecting shifts in productive habitat and overfishing limits using spatial state-space surplus production models

James T. Thorson, Jason Jannot, Kayleigh Somers

Global climate change, ocean acidification, and industrial fishing impact demographic rates of individual fish populations, and also affect population interactions and marine community structure. Population and community changes could potentially shift the spatial distribution of fish populations, as well as change which parts of the distribution are more or less productive. Meanwhile, fisheries managers worldwide are expected to assess status and determine fishing targets and limits for an increasing proportion of marine species. Therefore, there is need for rapid, widely applicable methods to estimate fishing limits that vary spatially and over time. Here, we present a spatial state-space surplus production model that uses recent advances in geostatistical methods to estimate spatial variation in population density, fishing intensity, and overfishing limits. This model uses finite-element analysis techniques to account for advective-diffusive movement of individual fish, and fits directly to each individual survey and fishery tow. In this talk, we evaluate the spatial surplus production model using a simulation experiment, and demonstrate that it can precisely estimate the magnitude of spatial and spatiotemporal variation as well as the strength of density-dependent population regulation. We also demonstrate the method using 10 years of data for big skate in the California Current, including catch and effort from a bottom trawl survey and spatial fishing effort data from the fishery logbooks. We compare estimates of coastwide overfishing limits with a previous data-poor assessment technique (Fmsy/M). Based on these results, we argue that spatial models of population dynamics are a useful first-step to screen for shifts in spatial distribution, and can be used to inform changes in spatial fisheries management actions over time.

It's the economy, stupid! Projecting the fate of fish populations using ecological-economic modelling

Martin F. Quaas, Thorsten B. H. Reusch, Jörn O. Schmidt, Olli Tahvonen, Rudi Voss

Four fish species are among the most important on the world market: cod, salmon, tuna, and sea bass. While the supply of North American and European markets for two of these species – Atlantic salmon and European sea bass – mainly comes from fish farming, Atlantic cod and tunas are mainly caught from wild stocks. We address the question what will be the status of these wild stocks in the mid-term future, in the year 2048, to be specific. Whereas effects of climate change and ecological driving forces on fish stocks have already gained a lot of attention, our prime interest is in studying the effects of changing economic drivers, as well as the impact of variable management effectiveness. Using a process-based ecological-economic multi-species optimisation model, we assess the future stock status under different scenarios of change. We simulate (i) technological progress in fishing, (ii) increasing demand for fish, and (iii) increasing supply of farmed fish, as well as the interplay of these driving forces under different scenarios of (limited) fishery management effectiveness. We find that economic change has a substantial effect on the stocks. Increasing aquaculture production can dampen the fishing pressure on wild stocks, but this effect is likely to be overwhelmed by increasing demand and technological progress, both increasing fishing pressure. The only solution to avoid collapse of the majority of stocks is institutional change to improve management effectiveness significantly above the current state. We conclude that full recognition of economic drivers of change will be needed to successfully develop an integrated ecosystem management, and to sustain the wild fish stocks until 2048 and beyond.

Detecting ecosystem signals of technological creep and density-dependent changes in catchability and their impact on policy exploration with an ecosystem model of the southern North Sea

Moritz Stäbler, Alexander Kempf, Marc Hufnagl, Axel Temming

Amongst the key benefits that multispecies and ecosystem models provide in support of strategic decisions in fisheries management is their capability to account for fishing effects on not only target, but also bycatch species simultaneously. As for bycatch, fishing mortality rates (F) are unknown and F-related fishing targets not established, the use of ecosystem models for policy exploration often relies on fishing efforts as a lever. That requires the model to make assumptions about how effort translates to respective Fs of the species included in the model. These assumptions affect how the model is fitted to historic records of its state variables (biomasses, catches, efforts, Fs…), the so called hindcast, which again has consequences on resulting population dynamics of the groups modelled and their reaction to exploratory fishing regimes. In vivo, two factors should shape the response of F to nominal fishing effort: technological development, which constantly increases the vessels' effectiveness; and density-dependent catchability, according which stocks can contract and remain available to the fishery at high density despite their abundance being in decline. Explicit knowledge of both factors bears the potential to better understand past dynamics of stocks and system and to improve, if not even the forecasting power of ecosystem models, at least our understanding of their uncertainties. We established estimates of significance and extent of both technological development in the fleets and density-dependent changes in catchability of target and non-target species of the southern North Sea. We then identified how inclusion of both factors in an ecosystem model of the southern North Sea affects hindcast simulations and fishing policy explorations, both input (effort) and output (Fmsy) controlled.

Could multistock reference points mitigate the impact of landing obligation in the economic performance of the fleets? The case study of Spanish Demersal fleets operating in Iberian Waters

Dorleta Garcia, Raul Prellezo, Paz Sampedro, Jose Castro, Jose Maria DaRocha and Santiago Cerviño

In this study we evaluated the economic impact of the Landing Obligation (LO) policy in the Spanish demersal fleet operating in the Iberian Sea region. We used a multistock and multifleet simulation model to combine the LO policy with a multiannual management plan based on a maximum sustainable yield (MSY) framework. We used two different sets of MSY reference points, the MSY reference points defined by ICES and a vector of reference points calculated simultaneously using a bio-economic optimisation model. Furthermore, we used two different fleet dynamics models, in one of the models the effort distribution among metiers was maintained constant and in a second one we studied the adaptability of the fleet through the redistribution of total effort among metiers according to a profit maximisation strategy. In both approaches, selection patterns at metier level were maintained constant. However in the second approach since the effort distribution along metiers varied, the overall selection pattern also changed. We found that the impact of LO differed from fleet to fleet and it was highly dependent on the fleet dynamics used. While some fleets where negatively affected in the whole simulation period others were benefited from the implementation of the policy. The multistock reference point did not have the expected outcome and it only served to mitigate the effect of LO in some specific cases.

Session 6: Practical Implementation of Targets and Limits: institutional Frameworks which Deliver

Global Comparisons of Fisheries Expansion, Overfishing and Recovery with Implications for National Fisheries Policy

Tess M. Geers, Margot L. Stiles and Michael F. Hirshfield

Following peak catches, most countries' fisheries are expected to follow one of three patterns: maintaining high catch levels (sustainable exploitation); crashing and then maintaining low catch levels (sustainable overexploitation); or crashing and then recovering to medium-high levels of catches. We group countries using time series clustering analysis on aggregated landings data for individual countries. We then look at these patterns in the context of implementation of national fisheries policies to determine how these national policies correspond to countries' trajectories of fisheries development and recovery. Limits implemented near the time of peak catches or during fisheries expansion may be successful in preventing crashes; whereas limits implemented after a major decline in landings and without rebuilding targets are likely to result in continued low catch levels rather than recovery.

Although these overall patterns may mask concerns with individual fisheries (e.g., serial depletion), they can nevertheless provide some guidance to countries seeking to develop and prioritise new fisheries policies as well as insight into the importance of timing in setting targets and limits. For example, countries whose fisheries are still expanding or whose catches have recently peaked may be able to prevent the latter two scenarios by rapidly implementing precautionary, science-based catch limits thereby allowing them to maintain high levels of landings. Fisheries managers may also find these classifications useful for more strategic sharing of information and lessons learned between countries at similar stages or with similar histories of exploitation.

Using spatial management to achieve Bpa targets for vulnerable Irish Sea skates

Simon Dedman, Samuel Shephard and David G. Reid

Skates and rays in the Irish Sea include data poor exploited stocks, and several PET species. We have used survey data and discard records to develop Fmsy and Bpa proxies for these populations. More recent work applies innovative modeling of survey catch and environmental factors such as depth, substrate and flow, to map skate and ray abundance hotspots. Together these approaches allow us to estimate (i) the proportion of population biomass of given Irish Sea elasmobranch species that must be conserved annually to meet PA or MSY thresholds, i.e. escapement, and (ii) the spatial distribution of biomass across the area. This information is combined with international fishing effort data (VMS) to identify the location and size of habitat areas where management could protect the escapement PA biomass while minimizing disruption to fishing activity and the displacement of effort. We propose a target-based a priori rationale for the size and location of protected areas for Irish Sea skates and rays.

Adaptive management response to a spatially confined rock lobster (Jasus edwardsii) fishery in South Australia

Adrian Linnane, Richard McGarvey, Janet Matthews and Annabel Jones

The Northern Zone rock lobster fishery of South Australia is extensive, covering approximately 207,000 km^2. The fishery is managed under transferable quotas, with a single total allowable commercial catch (TACC) of 323 tonnes. Despite its size, the majority of the annual TACC is taken within inshore grounds (<60 m depth) in the eastern region of the fishery. This trend is largely driven by overseas market demands for lobsters of a particular size and colour, specific to shallow-water areas. The confined nature of fishing behaviour under the TACC system has led to concerns of localised spatial depletion and the need for adaptive management response. One option identified was the potential for sub-zonal TACC areas based on regional estimates of legal-sized biomass. GROTAG estimates of yearly average growth highlighted spatial variation in growth between regions with deep-water females, in particular, growing far more slowly than inshore area counterparts. Using a fishery model that uses weights-at-age, catches by weight and by number landed, and fishing effort as input, we estimated harvestable biomass for three sub-zones (inner, deep-water and west coast) within the fishery. The current harvest strategy for the Northern Zone fishery uses the relationship between biomass and catch rate to set annual TACCs based on sustainable and economically optimal levels of exploitation rate. Using the spatial biomass estimates, appropriate target, trigger and limit reference points were developed for two sub-zonal management areas. Overall, the work acts as a case study for lobster fisheries working over broad geographical regions and highlights specific requirements where management options are being considered at finer spatial scales in response to external influences on fishery characteristics

Implementation of target and limits in Chilean fisheries management: Tier system, BRP, drastic quotas reductions and mitigation plans

Ignacio Payá

The aim of the New Chilean Fishery Act 2012 (CFA) is to keep fisheries at their maximum sustainable yield (MSY). CFA creates Scientific and Technical Committees (STC) and Management Committees (MC). STC must set MSY, Biological Reference Points (BRP) and ranges (80-100%) of catch quotas. The government cannot set quotas beyond quota ranges. MC should define the management or recovery plans. In order to implement the CFA, the Chilean Fisheries Research Institute (IFOP) conducted a project to review MSY estimations that routinely were done by IFOP for 28 stocks (pelagic and demersal fish and crustaceans). W. Clark, M. Dorn, M. Dunn, C. Fernandez, M. Haddon, N. Kleir, M. Sissenwine and S. Zou were contracted as MSY experts. Three workshops were done with participations of local scientists, MSY experts, STC and others stakeholders. The tier system to estimate MSY was reviewed and the methods for estimating target and limits by tier were established. Nine stocks were found underexploited (F<Fmsy and B>Bmsy), 11 overexploited (F>Fmsy or B<Bmsy) and eight depleted (B<Blimit). Additionally, CFA stablishes that fishing mortality produced by quota (F_quota) cannot surpass Fmsy in every year (Fquota<=Fmsy). With this restriction and the results of MSY project, STC reduced drastically the annual quotas for overexploited stocks. In several important fisheries, the quotas were half reduced in just one year. Entrepreneurs and fishermen complained against STC for not taking into account social and economic impacts, unaware that STC cannot set F_quota >Fmsy. To mitigate these impacts, the government implemented a US$5 million plan for helping circa 3600 artisanal fishermen, however some fishermen protests still remain. During 2015, management plans should be developed by MC and consulted with STC. The Government also applies several others actions, for example, reductions in bird mortality, discard reductions and banning of trawling on vulnerable ecosystem as seamounts.

Social-economic drivers in (political) TAC setting decisions

Rudi Voss, Julia Hoffmann, Marcos Llope, Jörn O. Schmidt, Christian Möllmann, Lorena Fricke, Martin F. Quaas

Sustainable use of marine resources, as targeted by Ecosystem-Based Fishery Management (EBFM), is a highly ranked policy goal. However, many marine fish stocks are still overused, challenging sustainability goals. Reasons for this policy failure are disputed and they might be manifold, including economic, institutional, and social drivers. Here, we use Generalised Additive Models (GAMs) to empirically determine and quantify the importance of interacting ecological, economic, and social drivers in a political decision making process, i.e. the setting of annual Total Allowable Catch (TAC) limits. GAMs allow non linear relationships between response and explanatory variables and due to their flexibility have successfully been applied to investigate ecosystem dynamics. Here, we use this modeling approach in a novel way to quantify social-economic-ecological feed-backs on policy decisions. European fisheries policy agreed in most cases to TACs higher than scientifically advised. We recorded this deviation for all managed European fish stocks for the time-series 1987-2014. Additionally, we make use of available time-series of socio-economic and ecological variables potentially influencing the decision, including national unemployment rates, stock status, economic growth rates, and employment in fisheries. We show that political decisions on TACs are not only driven by scientific advice on the ecological state of the stock, but that socio-economic variables have a significant effect on TACs – however not related to sound scientific advice. We conclude that scientific advice for a successful implementation of EBMF will have to address socio-economic driving forces more explicitly.

#CFPreality? Implementation of MSY objectives in the reformed EU Common Fisheries Policy

Markus Knigge

The European Common Fisheries Policy has recently been revised to include clear and time bound objectives to achieve Maximum Sustainable Yield (MSY) exploitation rates in view of restoring and maintaining populations of harvested species above biomass levels capable of producing the MSY. However, the CFP's MSY objectives are not yet fully implemented: European Commission official documents use less ambitious language, multi-annual plan proposals include exploitation limits that exceed MSY levels, and there seems to be resistance by several stakeholders to measure progress towards restoring and maintaining populations of harvested species above Bmsy levels – one of the key ambitions of the CFP. Also, during the time when the reform process was carried out and ambitious MSY targets were negotiated, fishing opportunities were persistently set higher than scientific advice. More importantly, in the last two years the trend to reduce the level of overfishing that was achieved in the previous 10 years was actually reversed. This presentation will illustrate signs of lack of CFP implementation and make concrete proposals how to fully implement the MSY concept in the EU context.

Three steps for getting EU fisheries management to reflect scientific advice and societal priorities

Liane Veitch, Heather Hamilton, Sandy Luk, Flaminia Tacconi

When the reformed EU Common Fisheries Policy (CFP) came into force on 1 January 2014, one of the most significant changes it included was a much stronger legal requirement for EU decision-makers to set fishing levels consistent with a level of exploitation that aims to restore and maintain fish stocks above levels capable of producing maximum sustainable yield (Article 2(2) of the CFP). We have identified three conditions that will have to be fulfilled to ensure this requirement is met. Firstly, the request for scientific advice that the European Commission sends to ICES must be framed in a way that is consistent with the requirements stipulated in the CFP. Secondly, the scientific advice that is developed must reflect these legislative requirements and be meaningful to end-users (e.g. the European Commission, the Council of Ministers and the European Parliament, as well as wider stakeholders). Finally, the text of the delegated and implementing measures (e.g. multiannual plans, the TAC and Quota Regulations) must appropriately reflect the scientific advice requested and translate it effectively into management. Although these conditions reflect the processes that the CFP should have been following for years now, in practice this has not always happened: the Commission's instructions to ICES are sometimes unclear, the Commission's proposals for fishing opportunities have been above the levels in ICES' advice, and the Council's decisions on TAC and Quota Regulations have even further exceeded ICES' advice. This is illegal and it is important that the EU institutions improve their role in this process. They must become legally compliant so that the objectives of the CFP – our clearest reflection of societal priorities for fisheries – are achieved "on the water".

The symposium is coorganised by ICES and the EU-FP7 project Myfish – Maximising yield of fisheries while balancing ecosystem, economic and social concerns.

Designed by **AquaTT**

The Myfish project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 289257.