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Ocean sustainability under global change

TOP PRIORITIES FOR NORWEGIAN RESEARCH AND PROSPECTS FOR COLLABORATION

Results from the IMBER - Future Earth Norway workshop
1–2 September 2016, Bergen, Norway

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Foto:

www.imr.no

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Summary and key messages

In September 2016, the Integrated Marine Biochemistry and Ecosystem Research Project (IMBER, a Future Earth Core Research Project) and Future Earth Norway collaborated to convene a workshop to explore the top priorities for Norwegian marine research on ocean sustainability and prospects for collaboration with global initiatives, including Future Earth´s Oceans Knowledge-Action Network,[1] over the next decade.

Addressing the complex sustainability issues facing the oceans requires the cooperation of a diverse range of academic disciplines (natural and social sciences, the humanities) as well as a multitude of actors from the public and private sector. More collaborative, disciplinary, interdisciplinary and integrated research is needed. We were therefore proud to welcome a diverse group of high-level representatives from key organizations across Norway and Europe, including the FAO[2], IOC[3], IMR[4] and the Norwegian Department of Fisheries, Industry and Trade, with expertise in marine science, social science, economics, and global, national and local natural resource management.

The meeting focused primarily on humans and their interactions with the oceans. There was a common experience that barriers exist that are currently hampering transdisciplinary collaborations. Discussing those barriers emerged as one of the most important issues in the meeting. With such a varied mix of expertise, and the tight timeframe, group discussions and outcomes centered more around enabling interdisciplinary and transdisciplinary cooperation in marine research, rather than delving into specific aspects of oceanographic science. Nevertheless, much valuable information from a range of expert perspectives can be found in the following report, including the summaries of the various presentations. The presentations are available for download at: www.futureearth.org/norway/results-imber-fen-wshop-2016

A series of presentations set the global and local context and then the following gaps in marine research were discussed:

- Agreeing on a definition of a sustainable ocean
- Appreciating different values
- Acknowledging the limitations of models
- Gaps in knowledge due to management scales and lack of resources
- Incorporating different forms of knowledge
- Dealing with uncertainties
- Recognizing the power of normative goal setting
- Lack of successful interdisciplinary and transdisciplinary marine research
- The need for common platforms
- Society´s ownership of the ocean

[1] http://www.futureearth.org/future-earth-oceans
[2] Food and Agriculture Organization
[3] Intergovernmental Oceanographic Commission of UNESCO
[4] Institute of Marine Research, Bergen

In the next session, the participants split into four groups to discuss some of the knowledge and collaborations needed over the next decade in relation to specific aspects of marine research. These are listed in the table below:

Topic 1: Global marine ecosystem assessments and their role in regional management	**Topic 2: Regional decision making perspective**	**Topic 3: Socio-ecological research servicing policy needs**	**Topic 4: Modelling and scenarios**
Overcoming problems concerning the scale of assessments	Scales of marine governance	Applying a systems approach at the local level	Know your audience
Choosing the methodology	Providing knowledge for regional and local managers	Answering the right questions and having the right objectives	Strengthening the connection between modellers and biologists/ecologists
Bridging issues around scale and culture	Researchers collaborating with the community to highlight the value of the oceans, including leveraging citizen science	Building the profile of ecosystem service valuations, and recognise the process is iterative	Visualize! It makes ecosystems easier to understand
		Educating for the future	We need more consideration on how to communicate uncertainty in the models

After further group work, the participants arrived at the following recommendations. More details can be found under each point within the report (p. 29).

What research needs to be done?

- Improving integrated ecosystem assessments
- Assess and give guidance on how institutions should evolve in the next decade
- More research is needed into the trade-offs
- Create scenarios and visualizations
- Improve how we deal with uncertainties

What could the marine research community do?

- Focus more on solutions-oriented science
- Integrate, where relevant
- Work towards a common language and value-setting
- Self-reflect
- Try to catalyse long term inter- and trans-disciplinary research
- In relation to global assessments, support regional agencies to have a more proactive outreach component and make sure that a wider community of marine scientists become involved in the assessment work
- When publishing articles, state how the article links to current policy and management issues

Introduction

The oceans and seas are of vital importance for nature and human life. They are globally connected ecosystems and highly dynamic environments of physical, chemical, and biological interaction. Coastal and nearshore areas provide services essential for life and the history, culture and livelihoods of people across the globe. However, oceans face multiple challenges from climate change, overfishing, acidification, pollution and de-oxygenation. The United Nations´ Sustainable Development Goals have an entire goal, Goal 14, focusing on healthy oceans and the diverse and vital roles they play in society, biodiversity and climate regulation.

Healthy oceans are vital for Norway; essentially a coastal country responsible for managing and utilizing resources from an ocean area seven times greater than its land area. In addition, its oceans are among the most productive in the world. Norway is the world's second largest exporter of fish and fish products and most of the population lives on the coast. Ensuring sustainable, productive and healthy oceans and coasts is therefore of the utmost importance.

Research has an important role to play in providing our policy makers and communities with the knowledge base required to secure or achieve sustainable oceans, including research on the structure and functioning of linked ocean and human systems, on interactions of different drivers of change, on thresholds, and on social-ecological dynamics.

The Integrated Marine Biochemistry and Ecosystem Research Project (IMBER) and Future Earth Norway collaborated to convene this workshop to identify gaps, discuss the knowledge and collaborations needed, prioritize research goals and actions for the next decade and explore how the Norwegian marine research community could interact with global initiatives such as the FAO, the IOC, IMBER, and Future Earth´s Oceans Knowledge-Action Network.

Addressing complex environmental issues and securing or transitioning towards marine sustainability, requires the cooperation of a diverse range of disciplines across the natural and social sciences as well as the humanities. More collaborative, disciplinary, interdisciplinary and integrated research is needed, including co-producing and providing evidence-based knowledge and guidance for policy-makers, managers and marine-related communities. We were therefore proud to convene a group of high-level speakers and participants from a range of sectors across Norway and Europe, with expertise in marine science, social science, economics, and global, national and local natural resource management (see Participants List). We would like to thank all the participants for their time and engagement.

The meeting focused primarily on humans and their interactions with the oceans. There was a common experience that barriers exist that are currently hampering transdisciplinary collaborations. Discussing those barriers emerged as one of the most important issues in the

meeting. With such a varied mix of expertise, and the tight timeframe, group discussions and outcomes centered more around enabling interdisciplinary and transdisciplinary cooperation in marine research, rather than delving into specific aspects of oceanographic science. Nevertheless, much valuable information from a range of expert perspectives can be found in the following report, including the summaries of the various presentations. The presentations are available for download at: www.futureearth.org/norway/results-imber-fen-wshop-2016

This workshop was kindly funded by the Norwegian Research Council, Future Earth Norway, IMBER and IMR.

Participants

Full list of participants. Some participants had to leave after Day 1.

First name	Surname	Title	Affiliation
Annette	Samuelsen	Group Leader – Ocean Modeling Group	Nansen Environmental and Remote Sensing Center
Carol	Robinson	Reader, School of Environmental Sciences/Chair IMBER Scientific Steering Committee	University of East Anglia/IMBER
Cecilie	Hansen	Researcher. Exploring the combined effect of climate and fisheries scenarios in the Barents Sea with an end-to-end model (Atlantis)	Institute of Marine Research
Cecilie	Mauritzen	Research Director for Water and Climate	Norwegian Institute for Water Research
Christian	Wexels Riser	Special Advisor	The Research Council of Norway
Dorothy	Dankel	Researcher, Department of Biology. Projects: Reflexive Systems Biology, ADMAR, REGIMES, Salmosterile, Aquafly	University of Bergen
Elisabeth	Gabrielsen	Deputy Director of Department for Fisheries and Aquaculture & Director of Section for Fisheries Management	Norwegian Ministry of Trade, Industry and Fisheries
Erik	Pihl	Research Liaison (Stockholm)	Future Earth
Gabriella	Bianchi	Researcher	IMR (former FAO Fisheries and Aquaculture Director)
Gro I.	van der Meeren	Executive Director	IMBER/ Institute of Marine Research
Henrik	Österblom	Deputy Science Director	Stockholm Resilience Centre
Jason	Whittington	Researcher & Scientific Director of the Nordic Centre of Excellence NorMER	Centre for Ecological and Evolutionary Synthesis – University of Oslo
Jeppe	Kolding	Professor, Department of Biology	University of Bergen
Jerry	Tjiputra	Principal Researcher, Biogeochemistry	Uni Research, Bjerknes Centre

Karen	O´Brien	Professor, Department of Sociology and Human Geography/Science Committee Member Future Earth	University of Oslo/Future Earth
Kristin	Magnussen	Senior Environmental Economist (PhD)	Vista Analyse
Leif Kristoffer	Sandal	Professor of Applied Mathematics and Management Science	NHH Norwegian School of Economics
Leonie	Goodwin	Project Coordinator	Future Earth Norway
Lisa	Maddison	Deputy Director	IMBER
Manuel	Barange	Director of the Fisheries and Aquaculture Policy and Resources Division (FIA)	Food and Agriculture Organization (FAO)
Mette	Skern-Mauritzen	Researcher on Ecosystem Processes	Institute of Marine Research
Morten D	Skogen	Senior Scientist in Oceanography and Climate. Projects DEECON & EcoFish	Institute of Marine Research
Olav Sigurd	Kjesbu	Director of Hjort Centre and Adjunct professor: CEES, University of Oslo	IMR/Hjort Centre for Marine Ecosystem Dynamics
Ole Arve	Misund	Director General	National Institute of Nutrition and Seafood Research
Peter	Haugan	Professor at the Geophysical Institute, University of Bergen and Chair of IOC	Intergovernmental Oceanographic Commission (IOC) of UNESCO/University of Bergen/IMR
Sturla	Kvamsdal	Researcher. Project EINSAM (Ecosystem-Economic Interactions in the Norwegian Sea) & ARC-Change (Arctic Marine Resources under Climate Change)	SNF - Centre for Applied Research at Norwegian School of Economics
Svein	Sundby	Research Scientist in Oceanography and Climate/IMBER SSC Member	Institute of Marine Research/IMBER
Thomas	Kiland-Langeland	Senior Adviser	County Office, Aust- and Vest-Agder
Tor	Eldevik	Professor, Geophysical Institute. Large-sale oceanography / decadal climate dynamics	UiB / Bjerknes Centre
Wendy	Broadgate	Global Hub Director (Sweden)	Future Earth
Åsmund	Bjordal	Director of the Center for Development Cooperation in Fisheries	Institute of Marine Research

Program

Thursday 1 September 2016

09:00	Welcome, introduction, the meeting objectives and practical details	Geir Lasse Taranger, IMR Research Director; Gro I. van der Meeren, IMBER Exec Officer
	Tour de table: Introductions	
	Future Earth and Future Earth-Norway: An introduction	Wendy Broadgate, Future Earth Global Hub (Sweden); Leonie Goodwin, Future Earth Norway
	Introducing IMBER: Towards sustainable oceans	Carol Robinson, Chair of IMBER Scientific Steering Committee
	Changes in marine ecosystems: current knowledge	Svein Sundby, IMR & IMBER SSC member
	The state of global fisheries: socio-ecological research needs to service policy demands for the 21st century	Manuel Barange, FAO - Fisheries and Aquaculture
	Moving out of the comfort zone - how do we understand and address global challenges?	Henrik Österblom, Stockholm Resilience Centre
	Diving Deeper: What do we really mean by integrated research on oceans?	Karen O'Brien, University of Oslo
11:40	**Panel discussion: The current status and gaps in marine science in Norway** Moderator: Svein Sundby Scene-setting plenary presentations: 1. Ocean sustainability under global change: where do the humanities fit in? - Dorothy Dankel, University of Bergen 2. Linking marine ecosystem knowledge to economic development - Kristin Magnussen, Vista Analyse 3. Projecting/predicting changes in marine ecosystems - Morten Skogen, IMR	
14:00	**Group discussions: Filling the gaps - What knowledge needs to be produced for society in the next 10 years? What links and collaborations are required?** Topic 1: Global marine ecosystem assessments and their role in regional management - Peter Haugan, Intergovernmental Oceanographic Commission Topic 2: Regional decision making perspective - Thomas Kiland-Langeland, County Office, Aust- and Vest-Agder Topic 3: Socio-ecological research servicing policy needs – management plans - Gro I. van der Meeren, IMBER and IMR Topic 4: Modelling and scenarios e.g. the Atlantis model case study - Cecilie Hansen, IMR The four speakers each addressed the plenary for 5 minutes. Meeting participants then split into 4 groups to discuss a topic for 25 minutes. After 25 minutes, each group circulated to a new topic until all groups discussed all topics.	

16:30	Plenary - report back from the topic groups	

Friday 2 September 2016

09:00	Plenary: Summary and integration of Day 1 Tour de Table: "What´s been missing for you so far?"	Led by Gro I. van der Meeren & Carol Robinson
	Break out groups: Prioritize research goals and actions for the next decade Group 1: Global settings Group 2: National and local settings	Group 1 Leaders: Lisa Maddison, Svein Sundby, Morten Skogen and Cecilie Hansen Group 2 Leaders: Gro I. van der Meeren, Carol Robinson, Dorothy Dankel
11:30	Plenary: Groups report back and discuss of priorities list and conclusions	Moderator: Carol Robinson
	Tour de Table: "What will I take home from this workshop?"	Moderators: Carol Robinson & Gro I. van der Meeren

Welcome

Representing the host institutions, the Research Director from the Institute of Marine Research, Geir Lasse Taranger, and the Executive Director of IMBER, Gro I. van der Meeren, opened the workshop and outlined the programme. Taranger highlighted the importance of considering the impact of social and political issues in marine science and touched on some recent, high-profile Norwegian aquaculture examples e.g. accurately estimating herring stock numbers and the lack of expansion in the salmon industry over the last four years.

Setting the scene: The global context

The first series of presentations placed the meeting´s objectives within the global context and provided an update on the current state of research, needs and policy making at the intergovernmental level.

Referring to The Great Acceleration graphics,[5] Wendy Broadgate, Future Earth´s Global Hub Director (Sweden), [6] discussed some of the critical pressures and impacts on global oceans. Future Earth´s new Oceans Knowledge Action-Network[7] seeks to address these challenges through solutions-oriented research. It will engage with stakeholders from a diverse range of sectors and regions to work towards international, more integrated and more fit-for-purpose research. The Oceans group is currently setting its research agenda and preparing a Collaborative Research Action for the Belmont Forum. It will further develop its scientific agenda at a meeting in Kiel, Germany, in early December 2016.

[5] Presentation title: Future Earth: An introduction
[6] Steffen W., W. Broadgate, L. Deutsch, O. Gaffney, C. Ludwig (2015) *The Anthropocene Review* 2: 1, 81-98.
[7] http://www.futureearth.org/future-earth-oceans

Carol Robinson, Chair of IMBER´s Scientific Steering Committee,[8] highlighted some of IMBER´s recent and forthcoming activities including a conference on marine socio-ecological systems, regime shifts and ocean governance in October 2015; an interactive summer school for 65 international students in August 2016 based around predicting the socio-ecological impacts of global change; and releasing its 2016-2025 Science Plan and Implementation Strategy.

Ongoing interdisciplinary projects within the IMBER regional programmes and working groups include assessing the resilience and adaptive capacity of Arctic marine systems under a changing climate, building scenarios for the sustainability of global oceanic ecosystems and fisheries, developing a web-based support tool to help decision makers, researchers and stakeholders decide how to respond to complex situations involving interactions and feedbacks between natural, social and governing systems and the stressors that affect them, and continuing work with CCAMLR[9] to ensure that scientific results are translated appropriately into messages that resonate with policy makers.

Svein Sundby, Research Scientist in Oceanography and Climate at IMR and IMBER Scientific Steering Committee member,[10] reminded the participants of some of the challenges facing marine ecosystems due to climate change by summarising recent research on the changes in marine ecosystems, with a focus on the Arctic and high-latitudes. Marine ecosystems respond very differently to climate change compared with terrestrial ecosystems. And even among the marine ecosystems of the world´s oceans, considerable diversity in responses can be observed, with high-latitude marine ecosystems demonstrating the strongest thermal response to climate change.

A significant knowledge gap still exists around how wind will change in response to climate change: an essential element in nutrient supply. Sundby concluded by discussing his recent research comparing the impacts of temperature changes on various fish stocks in the NE Arctic, Atlantic, and Barents Sea, in particular the effect on species numbers and location.[11,12]

The next three presentations considered the role of marine science and how it could evolve to better serve stakeholders´ needs including intergovernmental organizations, business and society.

[8] Presentation title: Integrated Marine Biogeochemistry and Ecosystem Research (IMBER): Ocean sustainability under global change for the benefit of society

[9] Commission for the Conservation of Antarctic Marine Living Resources

[10] Presentation title: Changes in marine ecosystems: current knowledge

[11] Sundby, S. and Nakken, K. (2008) Spatial shifts in spawning habitats of Arcto-Norwegian cod related to multidecadal climate oscillations and climate change. *ICES Journal of Marine Science: Journal du Conseil*, 65, doi:10.1093/icesjms/fsn085

[12] Hollowed, A.B., and Sundby, S. (2014) Change is coming to the northern oceans. Perspectives. *Science* 344 (6188): 1084-1085. 6 June 2014. doi: 10.1126/science.1251166

Manuel Barange, Director of the FAO´s Fisheries and Aquaculture Policy and Resources Division,[13] gave an update on the state of global fisheries according to FAO´s research and how socio-ecological research could better service policy demands. Recent FAO studies indicate 31.3% of global oceans are overfished, 10.5% are underfished, and 58.1% sustainably fished, with a continued trend to overfishing observed. Barange spoke of the importance of considering every fishery a story in itself and how this enables one to bring in powerful narratives. Using this approach, resource management problems become less about true and false and more about better and worse. In this context, science is no better placed to set objectives and trade-offs than other knowledge contributors e.g. NGOs, locals, and local resource managers.

At FAO´s recent FishAdapt conference in Bangkok (8-10 August 2016), scientists, development professionals and natural resource managers working in the context of fisheries, aquaculture, rural development and related fields, identified the following top research needs:

- Increase forecasting capacity (not scaremongering capacity). For instance, there have been very few studies predicting global fisheries in the future.
- Increase vulnerability assessments (can we forecast vulnerability?)
- Develop sectoral, cross-sectoral adaptation strategies (short and long-term)
- Increase focus on gender issues - not just for equity reasons but as a lens to adaptation strategies
- Develop institutional capacity
- Build resilience into management strategies
- Improve post-harvest use and reduce loss
- Increase focus on small scale fisheries and Small Island Developing States (SIDS), small-scale fisheries

Barange introduced this slide on scenarios (Fig. 1).

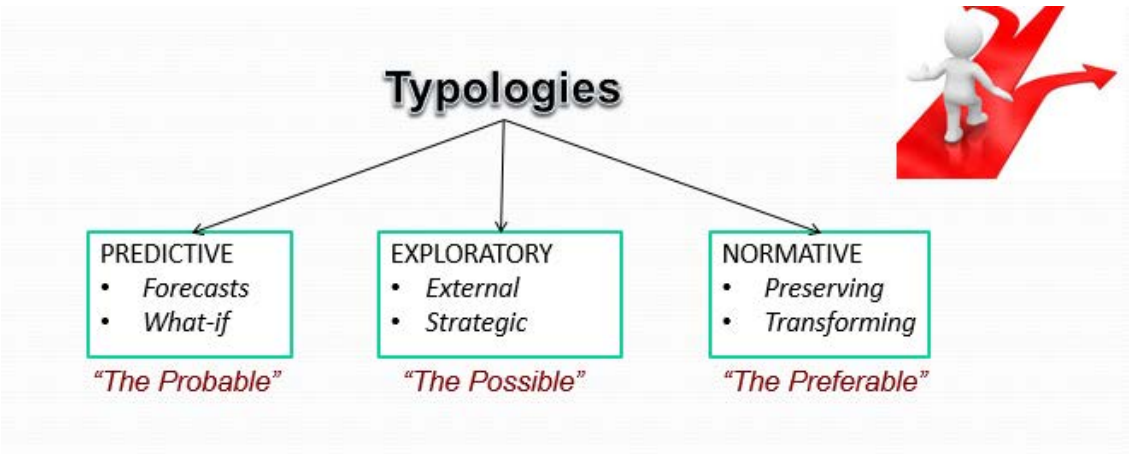

Figure 1. Different types of scenarios (Predictive, Exploratory, and Normative)[14]

[13] Presentation title: The state of global fisheries: socio-ecological research needs to service policy demands for the 21st century
[14] Börjeson, L. et al. (2006) *Futures* 38 and Payne et al. (2015) *ICES J. Mar. Sci*.

When providing research or analysis, it´s important to clarify which scenario (Predictive, Exploratory, or Normative) is being used and why. Often researchers mix the three, while they have different assumptions and expectations. Predictive scenarios focus on obtaining the most accurate outcome based on the most likely conditions; Exploratory scenarios provide outcomes for a number of conditions, regardless of their likelihood. Normative scenarios can be useful to explore how to achieve specific future expectations. The three scenario types are summarized as delivering: the Probable (predictive), the Possible (exploratory), and the Preferred (normative).

Henrik Österblom, Deputy Science Director at the Stockholm Resilience Centre,[15] presented key points from a paper he recently co-authored (Österblom et al., 2016)[16] which discusses some of the new frontiers and challenges for marine ecosystem science in the coming decades. While understanding interacting drivers of change, identifying thresholds in ecosystems, and investigating social-ecological dynamics represent particularly interesting frontiers for marine ecosystem scientists, there is an urgent need to address some more critical issues, namely modelling the Anthropocene, operationalizing resilience, and understanding social-ecological dynamics across scales.

In his experience working on multi-stakeholder projects, including recent work with top global seafood operators,[17] this dive into unknown waters requires researchers to adopt a number of strategies to be successful. Firstly, actively prepare for the unexpected. Secondly, cross boundaries and collaborate to increase depth and width of knowledge but beware of the associated transaction costs. When working in this way researchers must invest a lot, it takes a long time to work well together. And lastly, as researchers we must acknowledge and understand our cognitive limitations and the fact that much of the time in transdisciplinary collaboration we don´t have a map telling us where to go.

Karen O'Brien from the University of Oslo and Future Earth´s Science Committee,[18] echoed Henrik Österblom´s talk by highlighting calls from the global funding and intergovernmental community (e.g. Belmont Forum and the UN SDGs) for integrated cross-sectoral and cross-scale research involving relevant stakeholders. She highlighted how the predominant Earth Systems Science view of the way humanity interacts with the environment has been shifting from a traditional conceptual model placing humans in a small box on the side of the system,[19] to one that acknowledges the presence and power of values, paradigms, beliefs and assumptions about humans´ capacity to change. An approach that truly integrates the human and social dimensions recognizes differing time horizons,

[15] Presentation title: Moving out of the comfort zone - how do we understand and address global challenges?
[16] Österblom, H., Crona, B.I., Folke, C. et al. (2016) Marine Science on and Intertwined Planet, *Ecosystems*, doi:10.1007/s10021-016-9998-6
[17] Österblom et al. (2015) Transnational Corporations as 'Keystone Actors' in Marine Ecosystems, *PLOS One*, http://dx.doi.org/10.1371/journal.pone.0127533
[18] Presentation title: Diving deeper: What do we really mean by integrated research on oceans?
[19] Bretherton Diagram, Conceptual Model of Earth System process operating on timescales of decades to centuries from a presentation by Bromley et al. on Earth System Science (2004) http://www.una.edu/faculty/gggaston/Classes/HandP/ess_bretherton_diagram.ppt, accessed 07/11/16.

different assumptions about the future, and the role of power and politics in facilitating or impeding systemic change.

O´Brien emphasized that there are different perspectives and ways of knowing about the world, which can be summarized as: Experience, Behaviour, Systems, and Culture.[20] Each of these perspectives influences change processes and all need to be integrated to understand and effect change. Future Earth´s new cross-cutting Transformation´s Knowledge-Action Network[21] provides an unprecedented opportunity for creating an integrated global change research initiative, in that it aims to reflect on change itself and how the global change research community can work more closely with society to generate transformations to sustainability.

The current status and gaps in cross-sectoral marine science

Before moving to a panel discussion, three presentations set the scene and provided varied disciplinary perspectives on the status and gaps in current marine science.

Gaps in research on marine science-policy interfaces

Dorothy Dankel, from the University of Bergen,[22] observed there is a gap in interdisciplinary research on marine science-policy interfaces and contexts (including institutional cultures) and this may be hampering our ability to leverage research into action.

The need for translation and interpretation between the science and policy domains can make solving problems more complex. For example, science must interpret queries into scientific problems, and in that process it´s likely the key problem may not be being addressed or it may be interpreted differently by the different parties.

Pseudoscience is another trap in the world of science that may sometimes result in uncertainty being over or under estimated to yield results that advance model proponents´ preferences. The standards of quality for models must be high, lest model use falls into disrepute and models are rejected altogether (Saltelli & Funtowicz, 2014).[23] Such a tendency was highlighted in a recent and on-going Norwegian example - "Sildekrigen" (or Herring war) - in which some of the pelagic (herring, mackerel and blue whiting) fishermen firmly disagree with the annual herring assessment (and scientifically-advised quotas through participation in ICES[24]). They have been publicly discrediting the stock assessment model for

[20] O´Brien, K. and Hochachka, G. (2010). Integral Adaptation to Climate Change. *Journal of Integral Theory and Practice*, 5(1): 89–102.
[21] http://www.futureearth.org/future-earth-transformations
[22] Presentation title: Ocean sustainability under global change: where do the humanities fit in?"
[23] Saltelli, A., Funtowicz, S. (2014) When all models are wrong: More stringent quality criteria are needed for models used at the science-policy interface, Issues in Science and Technology, Winter 2014, 79-85. http://www.andreasaltelli.eu/file/repository/IST_saltelli_1_.pdf
[24] The International Council for the Exploration of the Sea

herring.[25,26] This case has put stock assessment models, their inherent uncertainty and the credibility, legitimacy and saliency of these models, and IMR as a public national institute in an uncharted and uncomfortable place. Dankel suggested that in such situations, bringing in social science and humanities research is useful in helping researchers and fishermen reflect on their methodological approaches and how to communicate them for a more nuanced contextual understanding of the boundaries and cultures of science and policy and the public.[27]

Valuation of marine resources based on the ecosystem services approach

Kristin Magnussen, Senior Environmental Economist at the consultancy Vista Analyse, [28] gave an update on the status of the ecosystems services approach and how it is currently the dominant approach in valuing marine ecosystems. However, despite the popularity of this approach, many gaps still exist and the following research and knowledge is needed:

- Obtain assessments of values (monetary and non-monetary) of all ecosystem services. A lot is known about the provisioning ecosystem services, e.g. commercial fisheries, but little about most of the other ecosystem services: regulating, cultural and supporting
- Link ecosystem status and functions to ecosystem service flows and the long-term values of these flows and the effects on human welfare
- Link drivers of change to changes in ecosystems and hence ecosystem services and human welfare
- Link instruments and measures to changes in drivers, ecosystems and ecosystem services and human welfare

In recent years, there have been several initiatives for marine ecosystem services assessment and valuation in Norway:

- NOU 2013:10 - The Goods from Nature (on Values of Ecosystem Services)[29]
- Management plans for Oceans (ES assessment started with the plan for the Barents Sea and Lofoten)[30]
- Valuations of deep sea coral reefs - UiT and NMBU[31]
- Valuation of lost welfare due to oil spills from shipping accidents - Vista Analyse and IMR, NINA, DNV GL and international experts[32]

[25] Per Anders Todal (2016) Sildekrigen, Forskerforum website (published 29 August 2016, accessed 31 October 2016) http://www.forskerforum.no/sildekrigen/

[26] Dankel, D. (2015) Fisheries quota advice for management: Significant scripts and significant digits. Presentation at the European Commission– Joint Research Centre workshop: Significant Digits: Responsible Use of Quantitative Information. http://webcast.clevercast.eu/jrc/significant-digits-responsible-use-quantitative-information-part-3

[27] Pereira, A. G., Ravetz, J. & Saltelli, A. (2015) Responsible use of quantitative information: inspirational workshop 2. Published by European Commission & Joint Research Centre. http://bookshop.europa.eu/is-bin/INTERSHOP.enfinity/WFS/EU-Bookshop-Site/en_GB/-/EUR/ViewPublication-Start?PublicationKey=KJ0415970

[28] Presentation title: Linking marine ecosystem knowledge to economic development

[29] https://www.regjeringen.no/en/dokumenter/nou-2013-10/id734440/

[30] http://www.imr.no/filarkiv/2010/05/sernummer1a_2010_web.pdf/en

[31] https://uit.no/prosjekter/prosjektsub?sub_id=350821&p_document_id=349718

[32] www.vista-analyse.no/site/assets/files/5593/va-rapport_2016-22_velferdstap_ved_oljeutslipp_fra_skip.pdf

- The ongoing "Coast Benefit" – an NFR 2016-2019 study on values of Ecosystem Services in Coastal Zone Management[33]

Despite these initiatives, some of the larger gaps still remaining include:

- There are currently only valuation studies for a few of the marine ecosystem services. More are needed, especially for cultural and to some degree regulating services. Surprisingly little is known about recreation use and values for instance. Non-use values are also important, and little is known about these.
- In valuation studies for monetary and non-monetary estimates, we need to improve the methods for non-priced goods and services and how they should be included.
- Research into and development of best practice for value transfer for marine ecosystem services.
- Bioeconomic modelling of marine resources.
- Research on policy instruments and measures and their consequences and effects on marine ecosystem services.

Using models to predict and project changes in primary production under global change

Dr. Morten Skogen, Senior Scientist at IMR,[34] discussed recent changes in phytoplankton production and predicted future changes according to climate models. Changes in phytoplankton production are significant because changes at the lower trophic levels will impact the higher trophic levels. The models predict large shifts in phytoplankton production by 2100, but the sign (increase/decrease) is uncertain. Control factors regulating phytoplankton production are light and wind; however, the inability to accurately model cloud cover or wind currently hampers attempts to model nutrient distributions and transports. Uncertainties include scenario uncertainty (i.e. the unknown future socio-economic landscape), model uncertainty (i.e. inaccuracies in the model), internal variability (i.e. difficulty detecting a clear climate change signal until it averages out). While model and internal variability uncertainty decrease with lead time, scenario uncertainty increases. Models currently occupy a key role in predictions and projections because it is assumed that despite their limitations, they are the only tool that can integrate all the existing knowledge and help us describe future trends.

Plenary discussion on status and gaps

The morning´s plenary speakers then formed a panel moderated by Svein Sundby to further discuss the status and gaps in current marine research. The key points emerging from the discussion are summarised below:

Agreeing on a definition of a sustainable ocean

We are all working towards clean and rich oceans; however, what constitutes a clean and rich ocean differs widely across the world and within each country. Could we arrive at a

[33] http://www.forskningsradet.no/prognett-miljoforsk/Nyheter/Fem_prosjekter_far_stotte_til_kystsoneforskning/1254014748457&lang=no

[34] Presentation title: Projecting/predicting changes in marine ecosystems

minimum we consider clean or sustainable? Deciding on this and advising society what it should do to obtain these goals would be a complex challenge, not least because of the different attitudes around how we utilize the ocean in different regions and communities.

Appreciating different values

Following on from the point above, as researchers we aim to understand and quantify the capacity of the oceans and predict future trends, yet there is so much uncertainty and different ideas about utilizing the ocean and sustainable oceans. A lot of conflict arises around values, and researchers need to be more transparent about the values underpinning their research.

Acknowledging the limitations of models

Although they are critical tools, we need to be more aware of the limitations of models. It´s common in the natural sciences to use complex ecosystem models, such as end-to-end (E2E) models as a way of linking "everything". However, not everything can be put into numbers and models embed many values e.g. what is the minimum we consider clean, sustainable?

Gaps in knowledge due to management scales and lack of resources

Local managers often have weak or missing information at the local scale. In Norway, for example, living marine resources are often managed at the national level and are often based on assessed stock size regionally, nationally or even internationally. In a recent example, IMR mapped seagrass beds and coastal cod - but only selected areas along the Norwegian coast were covered because the time and costs involved were too high to cover the entire coastline. Thus, many local coastlines were not mapped. In another example, integrated ecosystem assessments developed by ICES were developed with virtually no input from managers.

We are dealing with very complex issues and for this research to be relevant to managers, we need them to be more involved than they have been. There is an urgent need to bridge management and research in a different way. This requires management to have the will and capacity to do so.

Incorporating different forms of knowledge

It important to recognise that often in a local setting, quantitative data and models do not give more legitimacy than experiential information from locals. The post-normal science[35,36,37] toolbox recognises this and acknowledges that all actors have legitimate opinions and information when it comes to knowledge generation.

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[35] Funtowicz, S. O. and Ravetz, J. R. (1991) "A New Scientific Methodology for Global Environmental Issues", in Costanza, R. (ed.), Ecological Economics: The Science and Management of Sustainability: 137–152. New York: Columbia University Press.

[36] Funtowicz, S. O. and Ravetz, J. R. (1992) "Three types of risk assessment and the emergence of postnormal science", in Krimsky, S. and Golding, D. (eds.), Social theories of risk: 251–273. Westport, Connecticut: Greenwood.

[37] Funtowicz, S. and Ravetz, J. (1993) "Science for the post-normal age", *Futures*, 31(7): 735-755.

In a recent Norwegian example, the municipality of Tvedestrand implemented a local management programme in an attempt to improve on local coastal management in the municipality. Locals were asked what they caught and where. This information was added to IMR´s mapping and consequently locally selected Marine Protected Areas (MPAs) were established.[38]

Dealing with uncertainties

There are, and will continue to be, a lot of uncertainties and assumptions in marine research: in data collected from the oceans, in the analyses and models, and in the interpretations. For instance, understanding and quantifying sustainable carrying capacities and advising society on how to use oceans sustainably are key research aims, but in order to do this, many assumptions are made. Equiping society to make decisions under uncertainty requires more understanding and research. In addition, better methods are needed to communicate uncertainties. Creating "what if" science-based scenarios was suggested as just one possible way to improve our handling of and ability to communicate uncertainties.

Recognizing the power of normative goal setting

Most of the time current marine research employs predictive or exploratory scenarios i.e. forecasts and strategies, yet normative (preferable scenarios), can be very powerful for objective setting and creating a common language. Normative scenarios were used in the Global Energy Assessment[39], which started off by asking stakeholders "where do we want to be in the future?" and "what would it take to get there?" The goals and science came after the agreed vision. A lot of normative scenarios are also used in the agricultural world. So, could the same open, inclusive, visioning approach to developing goals be used to work towards sustainable oceans and seas? In marine science, scenarios tend to be quite opaque, i.e. it´s not clear whose perspective the scenarios are coming from.

Lack of successful interdisciplinary and transdisciplinary marine research

There was generally a consensus on the need for more integration between socio-economic, socio-ecological and natural science researchers if the research sector truly wants to provide policy-makers with sufficient information and understanding to develop regulations and procedures for long-term sustainable marine management. In fact, a large part of the panel discussion focused on how to enable successful interdisciplinary and transdisciplinary research (not so common in Norway), as this was seen by many as one of the most promising way to achieve sustainable use and management of marine resources in the future.

The discussion circled around the barriers prohibiting functional and truly interdisciplinary collaboration and how to overcome them. A bottom-up design developed by the scientists

[38] Celius, H. (2014) Forvaltning av marine ressurser I kystsonen I Tvedestrand.En utforskende studie av aktører og berørte parter innvolvering I prosesser not et lokalt tilpasset forvaltningsregime. Master thesis, The Arctic University of Norway, August 2014: 79 pp. (in Norwegian).

[39] GEA (2012): Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria. http://www.globalenergyassessment.org/

might be required to force different disciplines together, as the institutions, universities and applied science alike are slow to change. Other strategies to achieve connections and create interdisciplinary networks were also discussed.

Manuel Barange stressed that while there is undoubtedly a need to work together across disciplines, being clear on the problem first is critical. As a very first step, co-creation of the problem's frame is crucial. Once a problem or question has been co-defined by the relevant scientists and stakeholder, the players who can help solve it can be brought together, rather than working across disciplines just for the sake of it.

Some participants have tried cross-disciplinary, inter-disciplinary and trans-disciplinary projects and felt that researchers needed more concrete guidance on successful approaches - there is a lack of basic understanding of the interdisciplinary processes. Calls to adopt this approach, often imply we know what the questions are. But so much is still unknown, so some participants asked how do we do inter- and trans-disciplinary research when we don´t know what the questions are?

Dorothy Dankel touched on some ways to bring in the ethical, legal and social perspectives of an issue (e.g. embedding social science PhDs in labs to analyse the way researchers work and help them reflect on their approach) and build trust (e.g. "Walkshops" as outlined by Wickson, Strand et al. (2015)[40]). Some participants said it would be useful to build on presently available examples of "best practices" around how to cooperate.

Language is very relevant. Communication can be difficult between disciplines, even within the same discipline. One way to overcome this would be to involve people who study language, cultures, institutions in your work processes e.g. someone with a linguistic or cultural science background could observe your scientific meetings. They could reveal valuable insights into how participants are communicating and working with each other.

Successful interdisciplinary collaboration depends on finding a common language, developing trust, and agreeing on working methods – all of which take time. In order to tackle big problems continuity between projects is needed. Under the current system, PhDs are often funded more easily than post-docs or projects. But PhD students only work for 3 years. Such short-term engagements don´t provide the necessary long-term investment

[40] Wickson, F., et al. (2015). "The Walkshop Approach to Science and Technology Ethics." *Science and Engineering Ethics* 21(1): 241-264. Abstract: In research and teaching on ethical aspects of emerging sciences and technologies, the structure of working environments, spaces and relationships play a significant role. Many of the routines and standard practices of academic life, however, do little to actively explore and experiment with these elements. They do even less to address the importance of contextual and embodied dimensions of thinking. To engage these dimensions, we have benefitted significantly from practices that take us out of seminar rooms, offices and laboratories as well as beyond traditional ways of working and interacting. We have called one such practice the 'walkshop'. Through walkshops, we have spent several days walking together with our colleagues and students in open outdoor spaces, keeping a sustained intellectual discussion on ethical aspects of science, technology and innovation while moving through these landscapes. For us, this has generated useful opportunities to escape established hierarchies, roles and patterns of thought and to rethink conceptual and philosophical issues from new perspectives, under new attitudes and with renewed energy. In this paper we wish to highlight the potential benefits of the walkshop approach by sharing some of our experiences and describing how we have prepared for and carried out these events. We share this information in the hope that we may encourage others to both experiment with the walkshop approach and exchange information on their own innovative processes for research and teaching in science and engineering ethics.

needed to develop interdisciplinary research. The Norwegian Research Council does offer some funding for interdisciplinary research programmes, however it is usually aimed at relatively small projects, compared to the high costs involved in marine research. This results in project leaders not having the financial resources to bring a variety of researchers from different disciplines on board in a meaningful way.

The European Centre for Environment and Human Health,[41,42] part of the University of Exeter Medical School, is a good example of an institution adopting an integrated approach to the environment and its impacts on humans with some of its focus being on marine research. The connections among different disciplinary circles in marine science and medical science help create salient knowledge that is communicated out to the local society in Cornwall and more broadly to British society at the national level. This example illustrates the step from inter-disciplinary to trans-disciplinary where other institutions, other than academic institutions, are involved in problem-framing and communication.[43]

The need for common platforms

Institutions in the 21st century are being challenged, but for now many still remain very solid and siloed. There is an urgent need to start working across sectors and institutional barriers (physical and systemic) are hampering progress. There is currently a lack of fora to initiate interdisciplinary scientific collaborations. Future Earth´s Oceans Knowledge-Action Network aims to foster cross-sectoral collaboration and link groups and initiatives, with one of the overarching goals being to provide insight into the targets underpinning Sustainable Development Goal 14 on oceans.

Society´s ownership of the ocean

Participants discussed ways to increase societies' ownership of the ocean. How can people come to understand and appreciate the importance of maintaining clean and rich oceans? Does ocean literacy need to be improved? Two projects that demonstrate success in communicating the value of oceans to communities were discussed:

1. The Blue Gym[44] links blue space environments to positive human health and well-being outcomes and explores whether the public could be encouraged to preserve and protect these environments via pro-marine behaviours (e.g. sustainable fish choice,

[41] http://www.ecehh.org/

[42] Video: Introducing the European Centre for Environment & Human Health (2011) via Vimeo: https://vimeo.com/35625519, accessed 07/11/16.

[43] Two further references that provide methodologies for approaching transdisciplinary work include:

1. Diaz S. et al. (2015) A Rosetta Stone for Nature's Benefits to People, *PLOS Biology*. Available at: http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002040.
   This paper can be thought of as a kind of "Rosetta Stone" that highlights commonalities between diverse value sets and seeks to facilitate crossdisciplinary and crosscultural understanding.
2. The IMBER Human Dimensions Working Group, I-ADApT (Assessment based on Description and responses, and Appraisal for a Typology): http://www.imber.info/en/projects/imber/science/working-groups-1/human-dimensions-working-group-hdwg/i-mber-adapt.
   I-ADApT is a decision support tool designed to respond to the challenges of global change. It is based on case studies, where action was taken in response to an environmental or other impact resulting from global change.

[44] White, M. P. et al. (2016) The 'Blue Gym': What can blue space do for you and what can you do for blue space? *Journal of the Marine Biological Association of the United Kingdom*, 96: 1 (Oceans and Human Health). 5-12. DOI: https://doi.org/10.1017/S0025315415002209

reduction of plastic use, avoidance of littering). The findings highlight the importance of understanding public awareness, values and attitudes and the power of visualization in communicating marine sustainability issues.

2. GRID-Arendal in Norway often collaborates with municipalities, universities to make its marine science available to the public. They have worked on several communications projects with local stakeholders, with very positive results.

Also, linked to this, it was noted that Norway has surprisingly few science writers or other communicators that prioritize the marine environment despite the fact it has such strong interests in the ocean.

Filling the gaps: What knowledge and collaborations are needed in the next 10 years?

The next session aimed to address the knowledge and collaborations required with a specific focus on four topics: global and regional management scales, socio-ecological research, and the use of modelling and scenarios. Summaries of the introductions and key discussion points are provided below:

Topic 1: Global marine ecosystem assessments and their role in regional management

Introduction by Peter Haugan, Chair of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, Professor at the Geophysical Institute, University of Bergen, and Research Director II at Institute of Marine Research

The following assessments have been published by the UN in recent years:

- The First Cycle of the World Ocean Assessment (WOA)[45,46]
- The Transboundary Water Assessment (TWAP)[47,48]

The first WOA has been completed recently following earlier decisions by the UN General Assembly with the intention to continue producing such reports periodically (the so-called Regular Process). The TWAP website states that the UNEP/GEF/IOC TWAP LME reports "are being used by the GEF[49] to help set science-based priorities for financial resource allocation and the institutional arrangements for conducting periodic future assessments of the ocean. As well, the work provides an access point for other policy

[45] WOA 2009 - https://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html
[46] Assessment of Assessments 2009 and The First Cycle of Regular Process 2015 (WOA-1: First Cycle of Regular Process - http://www.un.org/depts/los/global_reporting/WOA_RegProcess.htm). The World Ocean Assessment methodology has a decadal history.
[47] The Transboundary Water Assessment (UNEP TWAP) - http://www.geftwap.org/
[48] The Open Ocean and Large Marine Ecosystem (LME) 2016 The methodologies for TWAP LME and Open Ocean were published in 2011
[49] Global Environment Facility

makers and international organizations, to be guided by these results for pertinent decision-making."

Lessons learned from the First Cycle of the Regular Process (World Ocean Assessment-I) [50]
After the World Ocean Assessment-1: First Cycle of Regular Process in 2015, the IOC has reflected on some of the lessons learned in the process, finding that while a WOA report may be valuable in terms of depicting global ocean processes, the level of information at the regional level may not be robust enough to support decision making. (The IOC is the United Nations´ body for ocean science, ocean observatories, ocean data and information exchange, and ocean services such as tsunami warning systems.)

It is suggested that a possible option for the future could be to develop a dual approach, have the WOA focusing on marine environmental processes of a global nature whilst providing regions with the capacity to define the scope of the regional inputs based on their priority considerations. The implementation of regional workshops in the second cycle could be a mechanism for scoping regional priorities.

The consistent assessment of trends in various regions of the world and over various time scales may require the definition of baseline indicators that are harmonised and inter-comparable across regions, and would allow for integration. A basis for this could be the Transboundary Water Assessment Programme led by IOC and UNEP which provides baseline indicators for all LMEs[51] and open ocean areas. But the investment for developing a robust and globally applicable methodology, including the definition of common standards to measure these processes, should not be underestimated.

There are examples of methodology failure, for example, in the UNEP/GEF/IOC TWAP LME report on fisheries scores. The score for the Barents Sea and Norwegian Sea was removed due to major flaws in the analyses due to the use of aged or misrepresenting data and incapability of globally uniform ecosystem assessment approaches to deal with the very different physical and biological characteristics of each ecosystem.

The contrasting results between global and regional assessments are an issue, as is the influence of global assessments. It has to be recognized that only a few groups have been doing such global assessment work up to now. The methods selected and the resulting conclusions may relate to the conviction and values of the individual scientists and related to available funding for the work. Constructively criticizing and further developing global assessments with contributions from regional experts is difficult and no established routine currently exists.

[50] IOC input to World Ocean Assessment Ad Hoc Working Group "consideration of lessons learned" August 2016. http://www.un.org/Depts/los/global_reporting/lessons_learned_submission.htm
[51] Large Marine Ecosystems

Suggested knowledge and collaborations

Overcoming problems concerning the scale of assessments

Global assessments are not always appropriate for different regions (e.g. evaluation methods should differ for the North Sea vs the Barents Sea). Could assessments still be done based on local knowledge but using predesigned categories?

Could global assessments be based on the regional mechanisms and collaborative processes that already exist? The quality of the assessment would be different, however, because the level of expertise and quality of data would vary between regions and make comparison difficult. Regional organizations could be used such as ICES[52], PICES[53], NAFO[54], CCAMLR[55], various Large Marine Ecosystem intergovernmental organizations and regional seas programs. GEO[56] also does assessments. The FAO, for example, suggest using regional LME expertise to produce global assessments. The UNEP Regional Seas Programme[57] or IOC regional bodies e.g. could take charge.

Policy makers have expressed the need to harmonize the assessments. Could all the assessments be harmonized with the indicators linked to targets decided at the global level?

Choosing the methodology

There are pros and cons with each suggested methodological approach i.e. meticulous peer-review vs a quicker process. Competing expert groups could be invited to come up with different assessments rather than forcing consensus, e.g. the IPCC approach vs a more free-flowing approach. Several methods are used for large marine ecosystem assessments, for example the GEF´s analysis of LMEs.

In contrast to past assessments, e.g. the IOC could work to bring more people into the process, more competing approaches that could introduce new methodologies. Importantly, building transparency and engagement and an understanding of how and on what basis decisions have been made is critical for building trust among stakeholders. There will always be a plurality of expectations to navigate and reaching agreement will always be difficult. There is a need to more clearly recognize this and consider that science is normative and the way questions are asked is important.

Some participants suggested the IOC could call a conference on improved methodology to engage stakeholders.

[52] International Council for the Exploration of the Sea
[53] The North Pacific Marine Science Organization - https://www.pices.int/
[54] Northwest Atlantic Fisheries Organization - http://www.nafo.int/
[55] Commission for the Conservation of Antarctic Marine Living Resources - https://www.ccamlr.org/
[56] Group on Earth Observations - http://www.earthobservations.org/index.php
[57] http://www.unep.org/regionalseas/

Bridging issues around scale and culture

It´s important to recognize that on a global scale, many countries do not have the capacity to question the regional results. The methodology in the reports needs to be improved around e.g. trophic levels, advection, selecting the right data. Regional Fisheries Management Organizations (RFMOs) exist in most places and could be included in the preparation of the assessments. Still, assessments need to include a quality flag.

With the suggested approach of using local experts from RFMOs, the experts would be nominated from similar institutions. However, it is important to consider that this can lead to prejudices and conscious biases because all the contributing experts would come from similar cultures. (A problem that was already present in the previous assessment groups, which included hardly any scientists from governmental institutions). In addition, regional organizations are often sectoral. One solution to this could be to collaborate across sectors, as OSPAR-ICES[58] does.

Topic 2: Regional decision making perspective

Introduction by Thomas Kiland-Langeland, County Office, Aust and Vest Agder

In Norway, ocean and coastal resource management occurs at the regional and national level, with the result being that the local level doesn´t have a lot of influence in this area. In other sectors, decision-making has been moving down to the local level, but not so much in oceans and coasts. The municipalities have responsibility for the area management in the coastal zone out to one nautical mile off the baselines and counties are responsible for the mineral resources in these areas. Because local politicians often lack knowledge about ecosystems, fish resources, and the processes taking place, they tend to focus their attention elsewhere.

Using the example of climate change, local politicians are gradually giving more attention to the issue and are acquiring more knowledge around the challenges. But generally, local politicians know very little about the consequences of climate change to the marine environment and their coastal zones. As climate change effects on marine ecology are expected to increase, local politicians should acquire more information on how this will affect their coastal zones. Only then will they be able to adapt their fields of management to the changing marine environment and maybe contribute to reducing the negative effects.

Suggested knowledge and collaborations

Scales of marine governance

The classic local vs. central conflict exists in Norway. The responsible municipality´s need to set local regulations, is hampered by overarching national and international regulations. Experiences in other countries could provide some insight into different approaches e.g.

[58] Oslo and Paris Conventions – OSPAR protects and conserves the marine environment of the North-East Atlantic http://www.ospar.org/

other EU countries, North America or the Baltic Sea, where the nutrient load model allows nutrient load levels to be decided locally but sea basin-wide limits apply.

Providing knowledge for regional and local managers

There are huge gaps between the available scientific knowledge and the information local managers have. Regional and local managers need more robust information to be able to perform knowledge-based management in the coastal zone. Researchers can help by collaborating and pulling together the knowledge they have, and combining that with local knowledge. With sufficient understanding and knowledge, cross-sectoral decisions on how to solve problems could be made. However, to fully achieve this, a common understanding of the values involved, not only the economic values but also the non-monetary values of the ecosystem is needed. Further, the current state of the ecosystem must be determined to quantify the value of the ecosystem. An upcoming White Paper[59] on biodiversity in Norway is a step in this direction and an expert committee aim to make clear the criteria for Good Ecologic Status (GES) and suggest indicators to measure the state and trends in different ecosystems, including the open seas by 1st June 2017.[60]

Researchers collaborating with the community to highlight the value of the oceans, including leveraging citizen science

Projects where researchers connect with local citizens and other community stakeholders can play an important role in highlighting the value of oceans. The MPA process in the Tvedestrand region was one such project in Norway, in which local knowledge was combined with academic research on the region.[61] to answer basic questions such as "What is the seascape like in this area?" and "What´s living there?". The collaboration between scientists, local policy makers, managers and citizens resulted in improved knowledge and understanding of the life and structures in the coastal waters.

In developing the national plans for the development of marine national parks and species specific protection areas, significant local engagement is needed. Increased knowledge of a region can often lead to local citizens and policy makers changing their views around values such as protection, use and keep the status quo.

Marine management always needs new and updated information and a lot of valuable information can come from local stakeholders. In addition to the Tvedestrand MPA process mentioned above, a lobster protection area project in the Skagerrak area[62] is another successful Norwegian example. Local decision makers and other local stakeholders worked with scientists to map and prepare plans for coastal marine protected areas with a view to

[59] Stortingsmeldingen om naturmangfold (Meld. St. 14 (2015–2016) Natur for livet — Norsk handlingsplan for naturmangfold.
[60] https://www.regjeringen.no/no/aktuelt/ekspertrad-for-okologisk-tilstand-er-opprettet/id2510493/
[61] Celius, H. (2014) Forvaltning av marine ressurser I kystsonen I Tvedestrand.En utforskende studie av aktører og berørte parter innvolvering I prosesser not et lokalt tilpasset forvaltningsregime. Master thesis, The Arctic University of Norway, August 2014: 79 pp. (in Norwegian)
[62] Moland, E. et al. (2013) Lobster and cod benefit from small-scale northern marine protected areas: inference from an empirical before–after control-impact study. *Proc R Soc B* 280: 20122679. http://dx.doi.org/10.1098/rspb.2012.2679

protecting the local stocks of lobsters, cod and sea trout. The county did not have knowledge about the stock sizes but local communities knew the local distribution of the species. They provided more information than the scientists could have collected within their timeframe and budget. The Marine Protected Area (MPA) was established where there was a good balance between the lowest conflict and species that were interesting for a specific reason.

Some key reasons for this project´s success were:

- There was a good correlation between the researchers´ needs and the locals´ interests
- When people experience "ownership", whether they be local policy makers or citizens, they tend to respond in a more positive way
- The locals were integrated into the project from the start - from knowledge generation through to the decision making. Participatory approaches tend to give better results. If people are involved in decisions, they will accept outcomes more readily.

One unsolved problem is to decide who should pay for collaboration with citizens and stakeholders. So far co-funding by the municipality, county and government has covered the costs. The County Governor in Aust and Vest Agder is presently spending 200k NOK (US$ 24.5k) to reward local communities for removing invasive Pacific Oysters.

Topic 3: Socio-ecological research servicing policy needs – management plans

Introduction by Gro I. van der Meeren, Executive Director, IMBER

According to Link & Mundy (2016), the Ecosystem Approach to Management and Integrated Ecosystem Assessments[63] may be comprised of the following steps:

1. Identify the ecosystem
2. Describe the ecosystem
3. Set ecological objectives
4. Value the ecosystem
5. Manage the human activities

Points 1 to 4 comprise the system of knowledge. Point 5 involves the regulatory process.

A lot more work is needed on point 4, valuing marine ecosystems. For instance, we have quite a lot of information on the value of fish stocks but little on the lower trophic levels such as plankton. This field of trophic level interaction research needs to be continued, by known values and inferred values and known, albeit uncertain interactions. And we still don´t know enough about the impacts and consequences of human activities on marine ecosystems to enable us to manage human activities in a fully informed way.

Based on what researchers know, many different stakeholders need more knowledge (e.g. resource managers, policy makers, local governments) to achieve sufficient understanding to

[63] Jason S. Link, Phil Mundy, NOAA-National Marine Fisheries Service, PAME Conference Fairbanks August 2016, Ecosystem Approach to Management and Integrated Ecosystem Assessments.

make well-informed decisions. It is equally important for scientists to understand what is important for the stakeholders.

The global IMBER project is one of several projects looking at the development of a socio-ecological framework to unravel marine impacts of climate on human communities. IMBER's motivation stems from the recognition that humans not only influence ocean systems, but also depend on ocean systems for goods and services (Fig 2). The IMBER Human Dimensions Working Group's goal is to promote an understanding of the multiple feedbacks between human and ocean systems, and to clarify what human institutions can do, either to mitigate anthropogenic perturbations of the ocean system, or to adapt to such changes.

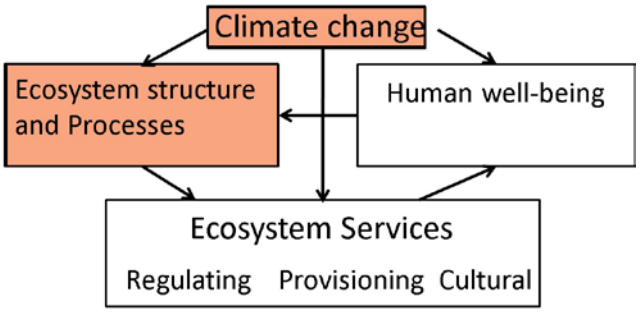

Figure 2. A framework to unravel the marine impacts of climate change interactions with human communities.[64]

The Arctic Council working group AMAP uses a similar approach. At the AMAP conference in Fairbanks, Alaska, USA (August 2016), an Inuit case was presented that explained how this native culture looked at the sustainable use of Arctic resources. In the Alaskan Food Security Conceptual Framework, human food security sits at the middle of everything encircled by layers of environmental health (Fig 3).

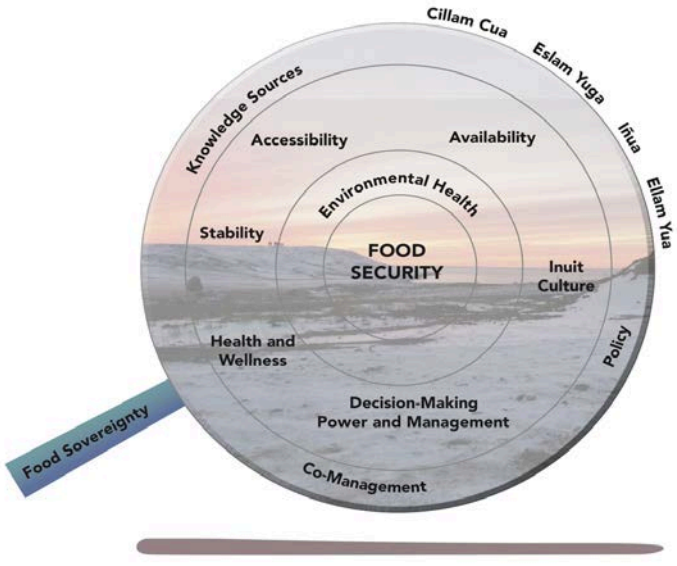

Figure 3. The Alaskan Inuit Food Security Conceptual Framework.[65]

[64] Marianne Falardeau, Audrey Rochon, Elena Bennett, Dept. of Natural Resource Sciences, McGill Univ., Quebec, Canada. PAME Conference Fairbanks August 2016. Ecosystem Approach to Management and Integrated Ecosystem Assessment, with kind permission from the author.

[65] Inuit Circumpolar Council-Alaska (2015), Alaskan Food Security Conceptual Framework: How to Assess the Artic From an Inuit Perspective. Technical Report, Anchorage, AK. Borrowed with kind permissions from a presentation by Carolina Behe 2016, at the PAME conference Ecosystem Approach to Management and Integrated Ecosystem Assessments, Fairbanks, Alaska, August 2016.

Suggested knowledge and collaborations

Applying a systems approach at the local level

Understanding and analysing a socio-ecological system requires one to ask clear questions e.g. Who are the actors? What are the sustainability issues behind this policy objective? What is really making the system non-sustainable, for example is it a location of extreme poverty? If the drivers are towards non-sustainability then it isn´t wise to use a model, but rather different research or interventions such as development and aid. In this way, the overall system analysis is not based on advanced modelling but on addressing issues locally and the agenda is set by the local context.

Answering the right questions and having the right objectives

Ensuring research is relevant and solutions-focused is critical in the coming decades. Collaborating with relevant locals from the outset of a socio-ecological research project is likely to result in more relevant and solutions-focused research. Such a participatory approach can help bring out a broader range of key issues, clarify objectives, set priorities and enable researchers to create clear questions with a clear picture of who the results are for. (But what to do if the objectives are not well chosen?)

Building the profile of ecosystem service valuations, and recognise the process is iterative

The value of ecosystem services are not reliably accounted for in the national accounts and budget; for this reason, it´s difficult for management and policy makers to deal with them. There is a still a long way to go before the value of marine ecosystem services are adequately accounted for. Could selecting a common concept, e.g. ecosystem services, help natural and social scientists, economists and lawyers transgress their different cultures and languages and connect and form a common engaging language? Further, the ecosystem services approach could be highlighted as a means to connect science and policy.

Ecosystems´ status, our knowledge and levels of information, as well as societal needs change over time, and will speed up as we experience more rapid global change. The science/policy interface needs to be more flexible and allow for processes to change over time, to be iterative and refined. In addition, respect for the differences in valuation approaches and approaches to the issues in marine science, management and social benefit from marine ecosystems is important.

Educating for the future

Marine research education within universities needs to combine different discipline types e.g. social science, natural science, economics, governance, etc. In addition, global initiatives such as IMBER and Future Earth, can help build awareness within tertiary institutions on the value of such cross-disciplinary training e.g. along the lines of the IMBER´s ClimEco summer schools.

Topic 4: Modelling and scenarios

Introduction by Cecilie Hansen, Researcher, Institute of Marine Research

In terms of modelling, Cecilie asked where are we going and what does society need? She gave three current but very different examples of models, ranging from the simple to the very complex, all attempting to make marine ecosystems and ocean dynamics visible. Right now, society needs more information on:

- Food availability and security
- Information about sustainable harvests
- Information on causes and effects including sudden shifts and consequences
- Pollution and variability – information on who the winners and losers are

And modellers need more guidance on how to handle tradeoffs and the consequences arising from communicating their research.

But, at what level do we need that information and how can we find the answers? Is it in more observations, experiments and process studies; more models; more money; other models or better models; more and better interaction between modellers and biologists, politicians, and fishermen; easy access to model results (but who will use them?); better communication e.g. getting the science out to those that need it (but who are they and what are their needs)?

Suggested knowledge and collaborations

Know your audience

If we want models to be more readily used to inform management and influence current approaches, then one possible method is for modellers to include these stakeholders in shaping and contributing to the model. Another approach could be a cross-sectoral visioning process bringing in different stakeholder scenarios. Decisions on definitions, expressions and baselines and the scientific approach could be agreed upon before commencing to choose the models. This approach could help ensure we have the right questions and aims for the models. It may also help to allay doubts around the legitimacy of the models and ensure the final model was not too specific to address the issues being reviewed.

Strengthening the connection between modellers and biologists/ecologists

The bridge between modellers and biologists and ecologists is not strong and is challenging to build, but we should start by including each other in the process of building the model. This may reduce some of the uncertainty in models, as well as increase common understanding of each other's expertise. Traditionally, ecologists have had no inherent interest in providing relevant models for economic analysis. But being open for collaboration may improve models and help make them more useful for policy makers and managers.

Visualize! It makes ecosystems easier to understand

The structure and processes in the sea are more difficult for society to visualise than terrestrial ecosystems. Designed correctly, models can help improve citizen understanding and help communities appreciate trade-offs when there are competing aspects of a situation to decide on. Combining models and computer games could be a way to help people understand the complexity of the decision-making involved. One example, Ecopath[66] is a free ecological/ecosystem modeling software suite (it was noted that games must have very impressive graphics in order to satisfy audiences these days).

We need more consideration on how to communicate uncertainty in the models

Users and stakeholders find it difficult to handle uncertainty and chaotic models. This can lead to skepticism, a view that research is chaotic and ultimately to confusion and conflict, as in the Norwegian Sea herring stock assessment case in 2013-16. [67] Modellers have grown up in a culture of being very careful with making conclusions because they appreciate the value other people put on them. So how can we articulate the uncertainties better? This is difficult, but no excuse for ignoring the problems. When chaotic models are used, a question that should be raised is "How relevant is the mean path?" "Are there tail paths that may dominate in terms of benefits or costs?" Critical evaluation, including critical questions on the use of models and modelled results will be necessary to improve the common understanding of the value of models.

Further, can we compare levels of uncertainty in existing management models with 'new' ecosystem-system-based models?

Recommendations for the future

Finally, the participants were asked to consider:

1. What research needs to be done?
2. What could the marine research community do?

A number of important points emerged from the workshop discussions. Although not listed in any order, the following points were recognized as important recommendations for improving the prospects for collaboration and interdisciplinary research and for reducing the barriers that are currently hampering integrated research in the marine research community.

[66] http://ecopath.org/

[67] Per Anders Todal (2016) Sildekrigen, Forskerforum website (published 29 August 2016, accessed 31 October 2016) http://www.forskerforum.no/sildekrigen/

What research needs to be done:

Improving integrated ecosystem assessments

- Improve the methods and make integrated ecosystem assessments more relevant.
- Part of the value of global assessments lies in the possibility of comparing ecosystems; however, current assessments are often based on indicators without understanding contexts or regions (e.g. the differences between the Norwegian Sea and the Barents Sea). Indicators need to be understood and applicable and relevant to the marine system being assessed.
- Interdisciplinary and integrated understanding and cooperation will be needed to do this.
- How general can we be when talking about the global compared with the regional? Could we create templates that give guidance around how general assessment needs can be applied to different contexts and regions.
- Much of the work being done is not well linked to the SDGs at present.

Assess and give guidance on how institutions should evolve in the next decade

- Analyse where they are now, where should they be now, and in the future to meet societal needs, locally and nationally.
- How they can best face the future challenges?
- What kind of institution is better for achieving different objectives? Is the Norwegian structure optimal?
- How do they need to change to be innovative and address long-term complex problems?
- Collaboration with social scientists is critical to provide insight into what might be needed.

More research is needed into the trade-offs

- What tradeoffs will decision-makers and society be prepared to accept in the future?
- Identify relevant decision-makers (e.g. ministries, departments) and work with them to identify these.
- More in-depth discussion and new ways of collaborating productively around tradeoffs is needed.

Create scenarios and visualizations

- Visualize a future that understands the compromises and trade-offs needed.
- Undertake more scenario-based work. Important for researchers to be clear whether they are employing predictive, explorative or normative typologies (see M Barange´s presentation).
- The kind of objective setting required by normative scenarios can lead to a common language. Work with stakeholders to define and decide on the objectives for some normative scenarios.
- Improving ecosystem service valuations could be an effective way to show the value of ecosystems to governments, decision makers and society. We need:
    - Baselines e.g. biological reference point setting for stocks, pollution, ecosystem processes, trophic cascades, etc. that can be used for planning and management.
    - Future projections
    - Forecasting

Improve how we deal with uncertainties

- More work is needed on defining, understanding, communicating and incorporating uncertainties from a range of perspectives, e.g. economic, biological, into management approaches.
- Could frameworks for Management Strategy Evaluations (MSEs) that aid managers to take various uncertainties into account be developed?

What could the marine research community do?

Focus more on solutions-oriented science

- Society needs solutions. Apocalyptic projections and scaring is not helpful.
- Should the research community adopt a more engineering-type approach?
- Foster an attitude that incorporates an understanding and acceptance of the uncertainties as they stand at that time and try to work together with others from that point.

Integrate, where relevant

- Look at the problem and consider who needs to come together to solve it. Use what is needed to answer the questions you have rather than thinking "I must be interdisciplinary or transdisciplinary, so I need a social scientist and an economist and a …".

- Interscientific education would be valuable, to allow students improved integrated insights by allocate time to study topics and literature "outside" their chosen field of expert topic. This will enable them to understand and talk to experts in other fields. Such insights is lacking in many expert scientists in Norway at present.

Work towards a common language and value-setting

- The research community needs to work on developing language that connects more successfully with policy makers and management.
- Perhaps capacity building and training is needed to do this.
- Where relevant, invite different stakeholders to workshops and meetings.
- Establish regular meetings for researchers and marine managers in Norway. Bring the community together e.g. researchers and management through meetings and dialogues. e.g. specific workshops - walkshops or even sailshops.

Self-reflect

- Related to the above point, we could involve people who study language, cultures, and institutions in our work processes. This could be someone with linguistic or cultural science expertise who could observe inter- and trans-disciplinary meetings and provide insights into our communication and working styles.

Try to catalyse long term inter- and trans-disciplinary research

- To tackle big problems we need continuity between projects. Novel findings are good but continuity is also valuable. Often PhDs are funded more easily than post-docs or projects and PhDs only work on a project for 3 years.
- Through establishing Centres of Excellence that would do integrated work on complex issues.

In relation to global assessments,

- Support regional agencies to have a more proactive outreach component.
- Make sure that a wider community of marine scientists become involved in the assessment work.

When publishing articles, state how the article links to current policy and management issues

- Natural scientists publishing articles could briefly outline how their article is related to current policy and management practice. This would help show relevance and is something economists frequently do.

Barriers to progress

The participants discussed some of the barriers that currently prevent progress. These strong barriers, mean that the possibility for more integration between sectors, research fields and people is limited.

Differences in culture and language between researchers and government or private sector decision-makers

- Managers are often reluctant to join projects (researchers should try inviting them) and the differences in language and culture (e.g. use of and understanding of terms, and opinion on value setting) were perceived to be the greatest cause of reluctance.

Time and funding

- Acceptance within academia and other research institutions, that allocation of sufficient time is needed for integrated science.
- Funding must be available for inter-disciplinary projects.