Maritimes Region Workshop Report: Incorporating an Ecosystem Approach into Science Advice for Fisheries (April 3 to 7 2017)

Alida Bundy, Tana Worcester and the Maritimes Region Ecosystem-Based Fisheries Management Working Group

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ABSTRACT

Incorporating an Ecosystem Approach into DFO's Science Advice, including taking into account climate change, has been identified as a priority for DFO. The Maritimes Region Ecosystem Based Fisheries Management Working Group held a Workshop on "Incorporating an Ecosystem Approach into Science Advice For Fisheries" to summarise the state of EBFM in the Maritimes Region, to provide hands-on learning experience for stock assessment scientists, to discuss the opportunities and challenges related to implementing EBFM in the Maritimes Region, and to develop an implementation plan. Participants also discussed the relationship between new State of the Ocean (SOTO) reporting, Ecosystem Stressors and Climate Change programs, which are current priorities in the department regionally and nationally, and EBFM. This report provides an account of the workshop, including its main conclusions, and paves the way to reinvigorate the EBFM discussion, providing concrete recommendations for progress.

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RÉSUMÉ

Intégrer une approche écosystémique aux avis scientifiques de Pêches et Océans Canada qui tient notamment compte du changement climatique a été désigné en tant que priorité du Ministère. Le groupe de travail de la région des Maritimes sur la gestion écosystémique des pêches (GEP) a organisé un atelier intitulé *Intégration d'une approche écosystémique aux avis scientifiques destinés aux pêches* pour résumer l'état de la GEP dans la région des Maritimes, fournir aux scientifiques une expérience d'apprentissage pratique de l'évaluation des stocks, discuter des défis et possibilités liés à la mise en œuvre de la GEP dans la région des Maritimes et préparer un plan de mise en œuvre. Les participants ont aussi discuté de la relation entre l'établissement de rapports basés sur l'état des océans, les programmes d'agents de stress écosystémiques et de changement climatique – qui sont des priorités actuelles du Ministère sur le plan régional et national –, et la gestion écosystémique des pêches. Le présent rapport donne un compte rendu de l'atelier, avec les constatations et recommandations principales qui en ont découlé et prépare le terrain pour donner un nouvel élan à la discussion sur la gestion écosystémique des pêches, en fournissant des recommandations concrètes pour l'avancement.

INTRODUCTION

The 2017 Mandate Letter for the Minister of Fisheries, Oceans and the Canadian Coast Guard identified the following as a priority for DFO: "use scientific evidence and the precautionary principle, and take into account climate change, when making decisions affecting fish stocks and ecosystem management.

Incorporating an Ecosystem Approach into Science Advice for Fisheries has also been identified as a priority under the new "Ecosystem and Fisheries Research and Monitoring" theme of the new Science funding. Furthermore, for addressing the potential impacts of climate change on fisheries, an Ecosystem Approach is required. In order to address this priority in a structured, coherent and pro-active manner, the Maritimes Region formed an "Ecosystem Approach for Science Advice for Fisheries" Working Group (Appendix 1) with representation from Scientists and Managers of the Science Divisions at the Bedford Institute of Oceanography (BIO) and St. Andrews Biological Station (SABS). The first objective of the working group was to establish the status of an Ecosystem Approach in the Maritimes and then to develop an implementation plan for Ecosystem Based Fisheries Management (EBFM) in the Maritimes Region.

The Working Group thus planned this workshop on "Incorporating an Ecosystem Approach into Science Advice for Fisheries" with the following objectives:

- Build expertise in incorporating Ecosystem Approach into single species stock assessments.
- Critically evaluate where Maritimes Region single species stock assessments are with respect to an EBFM.
- Scope out opportunities for incorporating an EBFM for individual species and groups of species in the Maritimes Region, as appropriate.
- Put fisheries stock assessment advice in an ecosystem context.
- Discuss bottom-up and top-down effects on species production.
- Identify data gaps/requirements and actions to mitigate them.
- Develop a plan to make progress with an Ecosystem Approach in the short, medium and long-term, and determine what tools and actions would be appropriate.
- Ensure proposed approaches will be appropriate and useful for management decisions.

The workshop was designed to summarise the state of EBFM in the Maritimes Region, to provide hands-on learning experience for stock assessment scientists, to discuss the opportunities and challenges to implementing EBFM in the Maritimes Region and to develop an implementation plan. It also addresses the State Of The Ocean (SOTO) reporting, Ecosystem Stressors and Climate change, which are current priorities in the department regionally and nationally. The workshop, therefore, consisted of a combination of presentations, four working groups focussed on methods to incorporate an Ecosystem Approach into Science Advice for Fisheries and discussion sessions to move our thinking and actions forward (see Agenda, Appendix 2). Although the workshop was focused on the Maritimes Region, participants included representatives from the Gulf, Newfoundland and Pacific Regions and from Ottawa (Appendix 3).

This workshop report provides the following sections:

1. Workshop organisation
2. Implementation plan for EBFM.
3. Summary of workshop discussion sessions
4. Appendices
    - Apendix 1. Maritimes Region Working Group (WG) members
    - Apendix 2. AGENDA
    - Apendix 3. Workshop Participants
    - Apendix 4. WG Descriptions
    - Apendix 5. Status of incorporating an Ecosystem Approach into science advice for fisheries:
        - i. Maritimes Region
        - ii. Gulf Region
        - iii. Newfoundland Region
    - Apendix 6. WG Reports
        - WG 1 Report: Incorporating Ecosystem Indicators into Stock Assessments
        - WG 2 Report: Spatial Modelling
        - WG3 Report: Incorporating an Ecosystem Approach in Groundfish Stock Assessment
        - WG 4 Report: Ecosystem Assessment and Report Card

A note on terminology
Numerous terms, acronyms and definitions exist for an ecosystem approach. We focussed on an Ecosystem Approach to fisheries in this workshop and use the term ecosystem-based fisheries management (**EBFM**) to encompass incorporating an ecosystem approach into science advice for fisheries.

WORKSHOP ORGANISATION

The workshop took place over five days, from Monday afternoon (April 3 2017) to Friday mid-day (April 7 2017, see Agenda, Appendix 2). The first afternoon and following morning plenary sessions took place at BIO, providing the opportunity for all BIO staff to attend presentations. Thereafter, the meeting was held off-site at Oakwood House, Dartmouth, providing a retreat like atmosphere with space for separate working groups. The detailed Agenda is provided in Appendix 2 and Figure 1 summarises the structure of the workshop. Descriptions and outlines of the four working groups are provided in Appendix 4.

Time	Mon	Tue	Wed	Thu	Fri
Venue:	BIO	BIO (am) & Oakwood house (pm)	Oakwood House, Dartmouth	Oakwood House, Dartmouth	Oakwood House, Dartmouth
9:00 AM		Plenary session at the Lewis King Boardroom, Bedford Institute of Oceanography	Plenary session	**WG2, WG3 & WG4:** cont'd	WG final overarching reports
10:00 AM					Plenary session: strategic planning a
11:00 AM			WG reports & discussion		
12:00 PM		Lunch			**12:00 Workshop end**
1:00 PM	**1:30 workshop begins**	Working Groups (WG) Oakwood House, Dartmouth	**WG1, WG2** and **WG3** cont'd (last session of **WG1**)	WG reports & discussion	
1:30 PM	Introductions/objectives				
2:00 PM	Plenary session at the Needler Boardroom, Bedford Institute of Oceanography			Plenary session & Discussion #4	
3:00 PM			**WG2** and **WG3** cont'd First day of **WG4**.		
4:00 PM					
5:00 PM	End				

Figure 1. Structure of the Workshop

The objective of the first two plenary sessions was to provide an overview of progress in EBFM in Canada and elsewhere, an overview of current ecosystem understanding of the Scotian Shelf based on Research Vessel Survey trends and ecological indicators, and to discuss EAF/EBFM/EBM with respect to resource management needs, climate change, ecosystem stressors and recent DFO initiatives such as SOTO, a recent Technical Expertise in Stock Assessment (TESA) workshop (Incorporating an Ecosystem Approach into single-species stock assessments: Edwards et al. 2017) and Management Strategy Evaluation (MSE: internal DFO discussion paper by Kronlund and Shelton, Nov 2016).

The objective of the third plenary session was to focus on data availability and access, the “data wrangling” R tool developed in the Maritimes Region and the Federal Geospatial Platform.

The four working groups (WG) took place from Tuesday to Thursday, with short plenary sessions for reporting back and sharing progress with the rest of the workshop participants:

- WG 1: Incorporating ecosystem indicators into stock assessments
  Group leads: Adam Cook, Catalina Gomez, and Catriona Regnier-McKellar
- WG 2: Spatial modeling
  Group leads: Brad Hubley, Jamie Tam and Ryan Stanley
- WG 3: Incorporating Ecosystem Approach to ground fish stock assessment -
  Group leads: David Keith and Doug Swain
- WG 4: Ecosystem Assessment and Report Card
  Group leads: Alida Bundy, Catherine Johnson and Andrea Moore

The final two plenary sessions were discussion sessions focussed on developing an implementation plan for EBFM.

IMPLEMENTATION PLAN FOR EBFM

The workshop culminated in the development of an implementation plan for EBFM (Table 1), based on the material presented and discussed during the workshop. The implementation plan is focussed on the Maritimes Region, but has National aspects and is likely applicable to all regions.

For EBFM to be successful, different levels of DFO Management and Science need to be involved. Therefore, the implementation plan is designed to be inclusive and specifically targets key groups, that is, National Headquarters (NHQ), Stock assessment, Ecosystem Monitoring Programs, Ecosystem Research Scientists, SOTO, Canadian Science Advisory Secretariat (CSAS), Resource Management/Ecosystem Management, Data Managers, Regional Director of Science (RDS)/Division Managers/Section Heads.

The implementation plan (Table 1) describes the” Expectations/Roles” of each key group, the “Challenges/ Opportunities” they face, and then suggests “Next Steps”. The summary below focusses on “Next Steps”.

NATIONAL HEADQUARTERS (NHQ)

DFO’s Sustainable Fisheries Framework “provides the foundation of an ecosystem-based and precautionary approach to fisheries management in Canada”[1]. However,

[1] http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/overview-cadre-eng.htm

further guidelines need to be developed for successful implementation, i.e. how to provide ecosystem-based advice for fisheries. There have been attempts in the past to develop a national framework for an Ecosystem Approach (e.g. national meetings in 2013 and 2015). In order to provide strategic Science direction with respect to EBFM, it was recommended that next steps include revisiting the documentation of past EBFM work, then consolidating and developing this into a coherent National guidance/framework document for EBFM. It was further recommended that a National Ecosystem WG be created to discuss lessons learned from ongoing regional EBFM efforts, develop national guidelines and a national community of practice, make recommendations on next steps, and report on progress.

STOCK ASSESSMENT

This is where the majority of EBFM takes place, although there is considerable variation in the extent to which an Ecosystem Approach is used (see Regional overviews in Appendix 5 and "Summary of Workshop Discussion Sessions" below). There are four main challenges to EBFM at the bench level: resources, expertise, bycatch data (see Summary of Workshop Discussion Sessions-Bycatch), and perceived expectations (i.e. single species stock assessment people do not have "incorporate EBFM into stock assessment" on their workplan). These are major challenges, perhaps in all regions. Addressing limited resources requires a multi-tiered approach including creating opportunities for collaboration and sharing of experiences, ensuring greater efficiency of resources, triaging the assessment frameworks to which an EBFM will be applied, taking a team approach with some quantitative and ecosystem scientists contributing to multiple assessments, and making annual reporting requirements easier by agreeing on specific indicators and working with Data Managers to streamline process (see below). To address the broader considerations of an EBFM approach, additional personnel and expertise would facilitate progress. TESA is developing technical expertise, with one workshop to date dedicated to this topic (Edwards et al. 2017). To facilitate EBFM, guidelines could be developed for what is expected in a framework meeting. This could include the following: bycatch, habitat suitability (spatial component, see Appendix 6: WG2 report and Summary of Workshop Discussion Sessions), time varying mortality and/o recruitment (see Appendix 6: WG3 report and Summary of Workshop Discussion Sessions), identification of strong environmental drivers, identification of interactions with other species, and climate change [life history stages]. For data rich stocks, TESA has developed a guidance document: "Issues to consider when thinking of incorporating ecosystem factors in single-species stock assessments" (Edwards et al. 2017, Appendix E). Access to environmental data and MPA planning layers is also required.

ECOSYSTEM MONITORING PROGRAMS

These programs have a key role in providing information for EBFM. There are already good existing relationships between oceanographers and the stock assessment process, with presentation of oceanographic information to stock assessment meetings. This process needs to be streamlined since oceanographers cannot attend every stock assessment meeting (see also Summary of Workshop Discussion Sessions - Multispecies Assessments below, where the idea of conducting multiple assessments is discussed). Further, direct links to stock assessments should be made when making oceanographic/ecosystem presentations. Generation of new indices are required that (a) are useful across multiple stocks/needs such as climate change indices, including thermal habitat suitability index (climate change), and (b) indices specific to certain stock(s). A regular monitoring program needs to be developed for the coastal zone, with an associated reporting mechanism, as recommended in a recent report (DiBacco et al. 2016). Fisheries Report Cards (Zador et al. 2016) could be used as a means to include ecosystem issues. We need to be able to assemble data from diverse sources quickly and efficiently, and re-use data and data products already developed.

ECOSYSTEM RESEARCH PEOPLE (including oceanographers)

This group should also have a key role in providing information for, and contributing to, EBFM***.*** The main challenges for this group are to include contributing to EBFM in work planning and to tie ecosystem research more clearly to the stock assessment process. Next steps include circulating the functional organisation chart (who is doing what) and an inventory of ecosystem-based projects, as well as further development and application of ecosystem indicators and conceptual models. We need more collaboration among these researchers, regionally and nationally.

STATE OF THE OCEAN (SOTO)

This is a National process with regional application. The Department has been tasked with developing State of the Ocean Reports as part of an annual process that will inform Canadians about the current status and potential state of Canada's oceans (see SOTO section in Appendix 6: WG4 report). Main next steps are communication and planning for the upcoming State of the Atlantic Ocean Report (due 2017-2018 fiscal year).

EBFM can contribute to SOTO reporting by providing a synthetic perspective on the status and trends of fisheries in Atlantic Canada. Incorporating environmental components with species trends and species interactions can lead to clearer and more comprehensive messaging that is easier to communicate and more meaningful to Canadians. Specific examples of EBFM can also be used as case studies to showcase the extent and importance of collaboration among researchers in different fields.

CSAS

As the organiser of stock assessment meetings, CSAS has a key role in helping to implement an EBFM, including providing connections between the different stock assessments (see Integrated Fisheries Management Plan discussion below), and adding key identified linkages, issues and ecosystem requirements to the terms of reference for CSAS meetings. The clearer the expectations of the CSAS process are, the more likely they are to be met.

RESOURCE MANAGEMENT/ ECOSYSTEM MANAGEMENT

The role of resource and ecosystem managers is to identify emerging priorities and liaise with stakeholders, and to create opportunities to explore longer-term ecosystem impacts and engage in more strategic discussion in the context of EBFM. There are many existing ecosystem objectives, but how do we make them operational? Which should be prioritised for management to act on? This requires on-going discussion.

DATA MANAGERS

Data and data access issues were raised throughout the workshop. The role of data managers is to provide frameworks for data organization, to provide tools to access data, help link fisheries datasets with non-fisheries datasets and to communicate what information is available and how to access it. In the Maritimes Region's Population Ecology Division, this is facilitated through the "data wrangling" tool. However, additional effort is required by Managers to ensure people post key data products for others to access, make use of Federal Geospatial Platform and the Marine Spatial Data Initiative (MSDI) to make use of data inventories, and to implement a data management work planning template. Note that data storage, access and collection can vary widely among regions.

MANAGERS (RDS/Division Managers/Section Heads)

EBFM requires support from Regional management, particularly in terms of resource allocation and strategic direction. This needs to be made more explicit and incorporated into work planning for staff of all Divisions, where appropriate. Immediate next steps include discussion by senior science managers of action items from this workshop, as well as to facilitate and support specific EBFM projects.

Table 1. Implementation plan for EBFM

Group	Expectations / Roles	Challenges / Opportunities	Next Steps
NHQ	Clearly articulate expectations and program resources/requirements Contribute to development of guidance material Foster receptivity of EFM/P&E to EBFM - Key messages Foster communication on meetings/workshops/projects - Communicating results Communicating direction	Dealing with difference in regional capacity and regional datasets (explaining the differences) Breadth and depth of expertise across the country 2015 National EBFM Workshop to build on Timing is good. Industry notices.	Revisit existing EBFM documentation - Policy documents - Internal workshop documentation - Maritimes Region EBFM Framework - Focus on implementation - Consolidation may help minimize inconsistencies National Ecosystem WG - Role could be to address suggestions above - Make recommendation on how to proceed (implementation) - Senior Science Managers (e.g. SEC) to create a national EBFM working group - Develop a national research plan to be implemented by FSERP and other funding Continue to review what's happening in other jurisdictions

Group	Expectations / Roles	Challenges / Opportunities	Next Steps
Stock Assessment	Stock Assessment Cycle (operational) - Report on agreed to indices - Bycatch, habitat ** need to do a better job at this (cumulative) Framework Cycle (strategic) - Explore linkages between target species and its environment - Explore mechanisms - Thinking long-term - Climate change Data Collection - Collecting species information along with habitat information - Food habits program – diet information will be used more effectively	Challenges: Constrained by assessment cycle. No time. Small teams (need to be efficient with our resources) Inconsistent access/experience with exploring ecosystem linkages Challenges with accessing bycatch information outside of PED control – look for ways to centralize / increase access to this (privacy issues) Finding quantitative people (loss of experience through retirements) Opportunities: • New people with new ideas/skills • Opportunities for Funding	Create opportunities for collaboration and sharing of experiences Make annual reporting requirements easier so that more time can be dedicated to pursuing key research questions Ongoing training R Technical WG Identify key issues, drivers, and connections. Role of report cards.
Ecosystem Monitoring Programs , e.g. AZMP and Oceanographers	Collect quality data - Enhance seasonal and spatial coverage Generate indices - Explore indices of particular relevance for commercial species - Existing presentations on interactions that could be referenced	Oceanographers cannot attend every stock assessment meeting. Need to resolve roles on this.	Incorporation of new data streams Expand monitoring into the coastal zone / linkages with existing coastal monitoring / inshore needs to create its own reporting mechanism How to simplify the presentation of the contextual information for presentation – figure out the timing of the presentation (when it can be used effectively, i.e. at

Group	Expectations / Roles	Challenges / Opportunities	Next Steps
	Communicate indices - Presenting/explaining information at AZMP/SOTO/stock assessments		framework). How much information is taken up?
Ecosystem Research People	Ecosystem indicator development approaches Multi-species and ecosystem analysis and modelling Building and documenting evidence for ecosystem linkages (repository of all knowledge) Conceptual models Development of climate change indices in general - Development of thermal suitability habitat index over time (climate change)	Identify individuals with relevant expertise Project-based opportunities	Circulate the functional organisational chart Inventory of ecosystem-based projects Tie projects to work planning, e.g. environmental analysis to stock assessment frameworks
SOTO	Coordinate input of various science disciplines into the State of the Ocean report Produce report for public consumption, i.e. tell our stories Ensure linkages between	National WG has been meeting (has staff) Some regions don't have specific staff dedicated to this task (Quebec)	Atlantic WG that will meet in May Develop document template, workplan (1 year first, then a 4-year workplan) and strategy Get to know Andrea Moore (Maritimes SOTO). Email communication on the program and expectations.

Group	Expectations / Roles	Challenges / Opportunities	Next Steps
	human activities and ecosystem impacts		Present at branch All staff meeting?
CSAS	Maintain the multi-year assessment schedule Organize the meetings Clear templates and articulation of expectations - Standardized TOR - Framework guidance	Public expectations for increased/more consistent reporting (increasing translation requirements) Timelines are hard to achieve. Translation of metadata / documentation.	Better follow up with research / analysis recommendations. - Linkages to program planning and resourcing. - Tracking. Add key identified linkages / issues to TOR for the next meeting. Provide connections between the different stock assessments.
Resource Management/ Ecosystem Management	Identify emerging priorities Articulate available/current management measures Liaison with stakeholders. Objectives – share the socio-economic objectives in the IFMPs / network objectives		Create opportunities to explore longer-term ecosystem impacts, measures, and objectives with further strategic discussion required. There are a lot of possible EBFM objectives, and there have been many initiatives and workshop to develop these objectives. There is a need for ongoing prioritization of these objectives for regional action.
Data Managers	Provide frameworks for data organization Provide tools to manage and access data Help link datasets – fisheries with non-fisheries Communicate what	Opportunity to use GitHub for sharing of code and methods Data storage is being made available Challenge: time consuming to do proper documentation, but there are benefits.	Encourage people to version/post key data products Make use of FGP/MSDI – Investigate how FGP/MSDI could be used to facilitate EBFM work Make use of data inventories Implement data management work planning

Group	Expectations / Roles	Challenges / Opportunities	Next Steps
	information is available and how to access it		template Risk analysis / prioritization. The importance of proper data publication and documentation needs to be communicated, and there needs to be a shift in culture related to this. - Ongoing data management workshops and communication needed.
Regional Managers (RDS/ Division Managers/ Section Heads)	Provide resources Identify opportunities for funding Help Science to be more strategic Direct work-planning. Set aside time to allow people to work on this.	Roles of research scientists is different between Divisions (strong ties to providing advice) Working with the people and resources we have. Time of change.	Encourage people to attend AZMP summary meetings. BMC to discuss action items. Facilitating and supporting specific projects. Focus.

SUMMARY OF WORKSHOP DISCUSSION SESSIONS

FISHERIES

Fisheries Management (FM) Perspective

The value of Maritimes fisheries is around $1.3 billion, of which around $1 billion is from the American lobster (*Homarus americanus*), scallop (*Plactopecten magellanicus*), and snow crab (*Chionoecetes opilio*) fisheries. FM is concerned about ocean acidification and how to manage for potential impacts on invertebrate fisheries. Better information is required. The following considerations were raised during the discussion:

- Marine Stewardship Council (MSC) certification: 12 fisheries are currently undergoing MSC, and they are being assessed for ecosystem impacts, so this contributes to an Ecosystem Approach.
- The Sustainable Fisheries Framework contains elements of an Ecosystem Approach. FM is not doing anything beyond this. Can we use existing policy to address an Ecosystem Approach?
- Science needs to better understand FM needs, and FM needs to understand how to frame questions that can be answered scientifically.

Integrated Fisheries Management Plans (IFMPs)

Currently, IFMPs do not facilitate evaluation of trade-offs across stocks/objectives; there is no mechanism for integrating across the various IFMPs. In the Maritimes Region, the IFMPs do include ecosystem considerations, modelled after the Maritimes EAM Framework (internal document). In Newfoundland and Labrador Region, there are competing objectives between shrimp (*Pandalus borealis*) and Atlantic cod (*Gadus morhua*). The Guidance Document that has been developed by Maritimes Region to describe what is expected within a stock assessment framework includes EBFM considerations, such as fisheries footprint, fisheries impacts on habitat, trophic interactions, etc. Addressing climate change may be a catalyst for assessing multiple stocks and exploring trade-offs since species will be differentially affected by climate change.

Harvest Control Rules (HCRs)

How specific can we be with HCRs given contextual and environmental indicators? A national discussion on this subject would be helpful.

Single Species Assessments

Framework assessments can be used as an opportunity to explore links between species' productivity and external drivers and/or ecosystem conditions. There are an increasing number of ways to include environmental/mortality parameters into single species stock assessments (see Regional Reports on Incorporating an Ecosystem Approach into Science Advice for Fisheries, WGs 1-3 Reports). These include:

- Incorporate contextual indicators into stock assessments (see Appendix 6: WG1 Report)

- Having many indicators helps to see what the big picture is all about – major/general trends.
- Use the individual indicators to determine when there is a mismatch/departure with/from the general trends.
- Connection between indicator trends and mechanisms responsible for those trends.
- Indicators are developed through exploratory analysis, and relationships between species and their environment.
- Framework for the selection of indicators and general processes.

- Identify key drivers of stock productivity and incorporate into assessment model
- Incorporate habitat suitability modelling (see Appendix 6: WG2 Report).
- Incorporating time varying terms into population productivity (see Appendix: 6: WG3 Report).

Management Strategy Evaluation (MSE)
Prior to adopting a MSE, we need to define the decision context and assess what types of management procedures are possible. There is growing interest in MSE, but experiences in the Pacific Region and elsewhere indicate that it is not necessarily the optimal approach for every situation and the use of MSE should be assessed on a case by case basis. MSE requires objectives, and for it to be successful, it needs a firm commitment from Management, Industry and Science. For example, Management and Industry need to agree on the objectives. The MSE process can be time consuming, involving many parties, and can be difficult to implement. We need to evaluate how we provide advice. Is there a simpler way to do MSE? Note that there is a National process underway (internal DFO discussion paper by Kronlund and Shelton, Nov 2016).

Bycatch
Knowledge of fisheries bycatch is an essential element of EBFM (Gilman et al. 2017). However, observer coverage is limited in the Maritimes Region and the extent to which it is possible to follow bycatch in the Maritimes is questionable. There is inconsistency in bycatch reporting. How effective is the bycatch policy? Do we have any fisheries with good bycatch data in the Maritimes? The scallop fishery might be one example. Note that there are privacy issues to displaying some of the data and that there are not enough observers in the Maritimes (George's Bank is the best covered area). Questions: where do we have the best information, what do we do with it, how does it change things, what is the risk?

DEVELOPING AN ECOSYSTEM APPROACH

Groundfish Updates

Maritimes Region conducted a Groundfish Update review in December 2016 that included updates of all primary groundfish stocks. However, despite an overview of the Atlantic Zone Monitoring Program (AZMP) report and overview of ecological indicators, the links between groundfish stock, environmental indicators and ecological indicators were not discussed due to time constraints. Several suggestions were made to improve this process:

- Groundfish assessment scientists and ecosystem scientists need to discuss what should be included well in advance of the Groundfish Update meeting.
- A conceptual model was suggested to help link scientists and resource managers and centralize knowledge, data, links between species and indicators, and to identify gaps.
- This process is modular but linked, i.e. not all groundfish need to be considered at once, but linkages between them (shared habitat, predators, prey, drivers, fisheries) must be considered.
- Each assessment may only use a few of the suite of potential indicators
- Use the ecosystem analysis to set the terms of reference for a stock assessment
- Where do we focus our attention? For which stocks is this most important?
- Triage stocks we are dealing with based on the strength of the signal
- Need to look at the functional group level
- Evaluate correlation between RV survey trends and other survey indices
- Explore trends and magnitude of indices

Multispecies Assessments

There are different ways to approach multi-species assessments including multiple single species assessments (assessment of different species at the same time), minimum realistic models (e.g. herring, plus key predators and prey) and total catch ceilings. All have heuristic value and decisions can be made afterwards concerning whether to act upon the information.

Multiple single species assessments

The Maritimes Region held a groundfish update meeting December 2016 that included information about the environment, lower trophic levels and ecological indicators. However, there was not opportunity to integrate these into the stock assessments, or to discuss stock assessments collectively. Improvements will be made to the 2017 groundfish update review to try to address these issues.

Minimum Realistic Models (MRM)

These may not be the main assessment model but may be informative. For instance, a Multi-Species Virtual Population Analysis (MSVPA) for southwest Nova herring was developed and presented at the 2011 herring assessment (Guénette and Stephenson 2012), but it suffered from the same retrospective problems as the other analytical models for this herring stock and was not used for advice (DFO 2011, Power et al. 2012). Further, a cod/capelin/seal MRM was developed for 2J3KL in Newfoundland and Labrador regions and presented at assessment but not used for advice.

Total catch ceilings (Total Allowable Catch: TACs)

These can operate at the total catch level or functional group (e.g. groundfish, forage fish) level, and are usually based on some type of ecosystem or functional group model. In addition, these assessments can use aggregate biomass models (e.g. production models/biomass dynamic modes, Ecopath with Ecosim, Ecosystem Production Unit models) for total TAC or TAC for mixed fisheries. In Alaska, for example, there is not a thorough model but good rationale based on logic. In addition, NAFO roadmap calls for total catch ceilings. There are additional examples in other regions such as Pacific.

- For Mixed Groundfish Fisheries there is a suite of tools that are already available:
    - Simple multi-species model to explore how 2-3 species interact, look at impacts of differential fishing pressure on them
    - Dynamic Factor and other types of multi-variate analysis
    - Equation-free models can also be used (see TESA Proceedings, Edwards et al. 2017)
    - Estimate total allowable catch for Mixed Groundfish Fisheries (see above)
    - Use survey indices - look for common trends (Dynamic Factor Analysis)
    - Exploratory approach to improve understanding of what's going on

These tools could be applied to Scotia-Fundy Groundfish. The current challenge is that assessments are conducted for only a few of the stocks but there is a possibility to start a dialogue towards pursuing groundfish multispecies assessments.

- Need to look at groundfish and invertebrates systems since there may be trade-offs between them.
- Currently we are not providing advice on many secondary species (e.g. flounder and sculpin, see Appendix 5. Status of incorporating an Ecosystem Approach into science advice for fisheries) in the Maritimes Region. How can this be improved? There could be interest in looking at catch caps for secondary groundfish species.
- Redfish have increased in abundance in recent years and questions/considerations are being raised concerning management and an Ecosystem Approach:
    - If we increase the fishing effort on Redfish, would this have impacts on other fisheries?
    - What are the potential bycatch issues if this fishery increases?
    - It will be a new fishery in some areas
    - Need observer trips (see Gaps section below). Could include as condition of license?
    - Opportunity for an Ecosystem Approach to an expanding fishery?

- The experience in Pacific Region with respect to Pacific MSC groundfish certification is that guidelines are becoming stricter. Industry has been a driver of change to meet these guidelines. The following considerations were highlighted:
  - Stock assessments to be done for all non-target bycatch species
  - Minimum acceptable assessment, i.e. what are the minimum standards? They are working on defining this.
  - Data-Limited Methods Toolkit (DLM tool) probability of violating reference points (see TESA Proceedings, Edwards et al. 2016)

Indicator Frameworks

- An Indicator Selection Guidance Framework has been developed to select a suite of ecological indicators for the Scotian Shelf Bioregion (Bundy et al. in press).
- The Indicator Selection Guidance Framework can be applied to other regions/areas/ecosystems.

EBFM

- To what extent can we use existing policies to move EBFM forward?
- EBFM includes social and economic information. How are decisions made? How are social and economic information included in decision making? This leads into an **institutional** and **governance** discussion, which is also linked to the combining IFMPs discussion. How do we deal with competing management objectives?
- NAFO EBFM Road Map is developing a tiered process to define sustainable exploitation levels, and it is in the process of defining ecosystem units that can be used for implementing an Ecosystem Approach to fisheries.

Transitioning to EBFM

Newfoundland and Labrador Region has a Working Group with Resource Managers (seven science staff and a number of Resource Managers) that recognizes the following points:

- Integrated advice is the only way forward (recognition from Resource Managers)
- Assessments start with expanded single species models as the basis for projections of future states based on dominant drivers
- There are efforts underway trying to partition stock productivity in terms of growth/recruitment versus losses to predation and exploitation
- Resource Managers produced a discussion paper on this
- Have significantly reduced shrimp TAC and snow crab TAC in 2017.

Transitioning to EBFM also involved getting ahead of the peer-review process (six months ahead of time) to:

- Avoid hitting resource management and industry at the wrong time
- Prepare them earlier
- Review and anticipate alternative scenarios of ecosystem and environmental change to future productivity independently of stock assessment process (what-if scenarios)
- Need to educate stakeholders about broadening of the approach
-

Considerations for the Maritimes Region:

- Develop multispecies IFMPs
- Build on Ecosystem Research Initiative conclusions (White et al. 2013)
- People are oversubscribed – how can we fit in more? How to make the process more efficient?

Conceptual Models

The introduction of conceptual models was new to some attendees, but they have been used and developed internationally and form a core part of the IEA process in the US (Levin et al. 2014). They are relatively simple models of the system that can be drawn on paper or quantified using computer algorithms. Ideally, they should include natural, social and governing components, and may span the marine–land interface. They can also be developed in a modular or hierarchical fashion, with ecological, social and governing components developed separately, then subsequently combined. Examples of both are provided by the US conceptual model of the Georges Bank system developed for the ICES WGNARS working group and the US conceptual models developed for the Californian Current system (ICES 2016). Conceptual models provide snapshots of system understanding and can be used as communication tools, to centralize knowledge, data and to identify gaps, and to support other modeling work through qualitative analyses and semi-quantitative analyses. Development of conceptual models involves engaging with experts and stakeholders in a multidisciplinary team. The process can be time consuming but can also result in greater mutual understanding of different perspective, issues, challenges and trade-offs. They may also be used to explore whether, in addition to stock reference points, there are additional ecosystem properties that we should be reporting on (cf. Auditor General's report). However, due to the time commitments required to develop conceptual models, it is not clear at this stage whether or how they will be used in the Maritimes Region.

Habitat Suitability Modelling (HSM)

HSM has multiple potential applications (see Appendix 6: WG2 Report), for example:

- Evaluating how habitat suitability (e.g. thermal habitat) will change with climate change.
- for stock assessments
    - use a combination of presence/absence data and environmental data to define suitable habitat
    - need spatial distribution of fishing as an indicator

  - map cumulative impacts of fishing
- Potential Habitat Indicators
  - Water mass indicators
  - Benthic habitat quality
  - Scallop survey (over 800 sets)
- Use an HSM approach for southwest Nova Scotian Atlantic herring? Is there time before the forthcoming framework? Is there adequate data to do this? (The southwest Nova Atlantic herring stock is the only quota managed Atlantic herring stock and the RV Survey is not used as an index of abundance for its assessment).
- Propose a R Technical Working Group to explore different spatiotemporal approaches to HSM

Ecosystem Boundaries and Spatial Structure

Ecosystems have spatial structure that needs to be recognised prior to conducting ecosystem assessment and reporting, i.e. the appropriate scale for the assessment needs to be identified. The appropriate scale is related to the objectives of the assessment and ecosystem properties such as structure, functioning and main drivers. In the Maritimes Region, NAFO Divisions have been used as proxies for ecosystem units, but in reality, these were designed around groundfish management and do not reflect broader ecosystem considerations. Several analyses have been conducted to explore and describe the ecosystem(s) of the Scotian Shelf bioregion and there is some coherence among them. For example, the division between the eastern and western Scotian Shelf is placed east of the NAFO 4WX Division Line. The Working Group recommended the following:

- To develop a structured approach to describe our ecosystems: bioregions/Ecosystem Production Units/Ecoregion (cf NAFO WG)
- A workshop (CSAS process) is required to agree on what the (fuzzy) boundaries of the ecosystem units should be
- Ideally there should be consistency among regions on how we define ecosystems and their boundaries, e.g.
  - Bioregion
  - Ecological Production Units (very large units)
  - Ecoregions within those with more fluid definitions
- We need to consistently report at these spatial scales
- We need consistency among regions on how we do this
- We need to link this to the use of ecological indicators to report at these scales.

Ecosystem Assessments and Report Cards

A suite of indicators is required to capture ecosystem properties and the environmental and anthropogenic drivers of the system. Indicators should address management objectives (see Appendix 6: WG4 Report). The Maritimes Region has developed a framework for selecting and use of indicators (see Bundy et al. in press). Indicators should be used to measure or evaluate specific objectives. We need to examine major changes, what has happened in the last five years, and overall long term trends. It is also important to integrate across indicators to communicate with Management and Industry. For this, methods of communication are important, and ecosystem report cards are one option (see Appendix 6: WG4 Report). How are management decisions made based on ecosystem report cards? In Alaska, the ecosystem report cards were used it to adjust the Pollock TAC.

Climate change

Fishing still remains an important source of mortality for fish stocks in Maritimes Region. Given capacity that we have, what can we do? Incorporating climate change necessitates an Ecosystem Approach. How far into the future does/can Resource Managers look? Year to year questions do not change too much, but we should aim to include longer term planning into IFMP and management decisions such as projections of stock productivity and distribution with respect to climate change. It is also important to consider evidence of persistent plankton community change

DATA

Data and Data Access

*The "*mar.datawrangling" is a "suite of tools for extracting, filtering and aggregating data from the Maritimes fisheries science databases". It is an R package, but can be installed from GitHub.com instead of cran. It does not require user to be an R expert, but some basic knowledge is required. The group recognized the importance of making sure data is available. In Maritimes Region, this includes:

- Access to Jae Choi's environmental layers (these were developed for the snow crab assessment and included variables derived from bathymetry (depth, slope and curvature), substrate grain size, and bottom temperature interpolations (Climatological mean, sd, min and max as well as annual values).
- Marine Protected Area planning layers
- Use of data inventories

GitHub and the R Technical Working Group

One of the outcomes of this workshop resulted in the assemblage of the R technical working group for an Ecosystem Approach. The objectives of this working group are:

- To capitalize from the existing expertise in R to enhance its use and to facilitate collaboration across regions and divisions at DFO. This will be accomplished by developing regional workshops for new and experienced users
- To enhance open and reproducible science with R by building and sharing an inventory of R code, tools, and associated workflows available *via* GitHub

- Support potential upcoming CSAS processes by implementing analysis on selected stocks and/or species at risk. This objective will be accomplished *via* the technical working subgroups (e.g. spatial modelling sub-group at BIO).
- Present advancements of the R group and thus request feedback from other scientists and managers to frame other analysis questions/priorities (e.g. what species or species groups should be a priority for a given sub-group to focus effort at the short, medium and long term)

Data Gaps

- Bycatch - lack of data; low confidence in the data; risk of not collecting bycatch data
- Coastal System (less than 100m depth)
- Spatial distribution, abundance and diversity of non-commercial benthos across the Scotian Shelf
- Seasonal abundance and distribution information
- Cumulative fishing pressure
- Invasive species
- Noise (Ocean Protection Plan)
- Inshore/offshore linkages (including energy transport, e.g., nutrient movement between the inshore and offshore environments)

Process Gaps

- Analysis of bycatch information in stock assessments
- Multiple species IFMPs
- Multiple fisheries assessments
- No National Fisheries Database (cf ICES) – do we need one?
- How do we move forward to make data collection more similar across Regions?
- Basic research targeted to gaps in understanding that contirbute to decision-making

CONCLUSIONS

This workshop has highlighted the following:

- Progress is being made in advancing EBFM in the Maritimes and other Regions.
- This is largely due to individual effort and expertise.
- There are challenges with respect to lack of time and resources.
- Data, monitoring programs and data analysis tools are in place, although there are gaps, including gaps in integrated data management planning for EBFM.
- There is currently no mechanism to integrate across stock assessments/IFMPs and explore trade-offs, but, in a world of competing ocean uses, this will become increasingly necessary.
- For EBFM to be successful, different levels of DFO Management and Science need to be involved.
- Science, Oceans Management and Resource Management appear to be willing to work together on this.

- Science staff is looking for concrete guidance or direction from NHQ or Regional Management on next steps for EBFM.
- With the dual challenges of climate change and MSC/consumer requirements, EBFM is essential.

The Implementation Plan (Table 1) provides a roadmap for EBFM, but it requires all the players to participate and be involved. Critically, if we want to avoid approaching this in a piecemeal fashion, National Guidance and a framework document for EBFM is required. This workshop paves the way to reinvigorate this discussion, providing concrete recommendations for progress.

APPENDICES

APPENDIX 1. MARITIMES REGION EBFM WG MEMBERS

Alida Bundy (co-Chair)
Don Clark
Kirsten Clark
Adam Cook
Catalina Gomez
Nell den Heyer
Brad Hubley
Catherine Johnson
David Keith
Catriona Regnier-McKellar
Andrea Moore
Nancy Shackell
Kent Smedbol
Jamie Tam
Yanjun Wang
Tana Worcester (co-Chair)

APPENDIX 2. AGENDA

Monday April 3rd (1:30 pm – 5:00 pm)
1:30 Objectives of the workshop and plan for the next 4 days
Presenters: Alida Bundy and Tana Worcester (10 mins)
1:40 Introduction of meeting participants (10 mins)
1:50 Review of EAF/EBFM to inform Maritimes Region EAF/EBFM planning
Presenter: Alida Bundy (30 min)
2:20 Trending Now: Climate change fits in the oceanographic drivers part of an Ecosystem Approach to Management
Presenter: Nancy Shackell (15 min)
2:40 Presentation from Fisheries Manager on EAF from RM perspective and identification of challenges and opportunities
Presenter: Carl MacDonald (20 min)
3:20 Discussion (1): Ecosystem based Science advice for Resource Management: challenges, needs and opportunities
4:20 National and regional ecosystem reporting (SOTO)
Presenter: Andrea Moore (15 min)
4:35 Conceptual models: lessons learned from a worked example
Presenter: Jamie Tam (10 mins)

Tuesday April 4th (9.00 am – 5:00 pm)
9:00 Overview of the state of the environment
Presenter: Catherine Johnson and Emmanuel Devred (20 min)
9:20 RV Survey Trends Update
Presenter: Catriona Regnier-McKellar (10 min)
9:30 Selection and evaluation of indicators for ecosystem assessment of the Scotian Shelf
Presenter: Catalina Gomez (15 min)
9:45 Review of Technical Expertise in Stock Assessment (TESA) workshop "Incorporating an Ecosystem Approach into single-species stock assessments"
Presenter: Brad Hubley (10 mins)
9:55 Progress made on Management Strategy Evaluation (MSE)
Presenters: Tana Worcester and Yanjun Wang (15 mins)
10:30 Overview of stock assessments in the Maritimes Region: movement toward on an Ecosystem Approach to providing science advice for fisheries management
Presenter: Adam Cook (15 mins)
10:45 Incorporating an Ecosystem Approach into science advice for fisheries in the southern Gulf of St. Lawrence
Presenter: Hugues Benoit (15 mins)
11:00 Incorporation of the effects of environmental and trophic interactions on stock productivity in Newfoundland and Labrador region region: work to date and plans for the near future
Presenter: Pierre Pepin (15 mins)

11:15 Summary of single species assessments from Groundfish update review
Presenter: Tana Worcester (15 mins)

11: 30 Discussion (2): Positioning the groundfish assessments in an ecosystem context. What do assessment leads think are the most important ecosystem considerations?
1:00 pm Working Groups (WG): Introductions from WG leads (5 minutes)

> WG 1: Incorporating ecosystem indicators into stock assessments
> *Group leads: Adam Cook, Catalina Gomez and Catriona Regnier-McKellar*
> WG 2: Spatial modeling
> *Group leads: Brad Hubley and Jamie Tam*
> WG 3: Incorporating Ecosystem Approach to ground fish stock assessment
> *Group leads: David Keith and Doug Swain*
> WG 4: Ecosystem Assessment and Report Card
> *Group leads: Alida Bundy, Catherine Johnson* and Andrea Moore

Wednesday April 5th (9.00 am – 5:00 pm)
9:00 Wrangling Data from Maritimes Fisheries Science Databases
Presenter: Mike McMahon (1 h)
10:00 Discussion (3): Data Availability and Access:
- Are there particular data products that can be useful?
- Federal Geospatial Platform
- Identify data gaps/requirements and actions to mitigate them

11:20 WG Reports (10 mins for each group) followed by discussion
1:00 pm WG continued

Thursday April 6th (9:00 am – 5:00 pm)
9:00 am WG continued
1:00 pm WG Reports (10 mins for each group) followed by discussion
2:00 pm Discussion (4):
- Conceptual models for moving towards EAFM (Sara Quigley and Tana Worcester)
- Conceptual models (follow up from Jamie Tam's conceptual model presentation)
- Where do secondary species fit it (species with good data, species with less)?
- Discussion of assessing species together. How?
- Trophic linkages and relationship between species

Friday April 7th (9.00 am – 12 m)
9:00 WG final overarching reports/summary/path forward
10:00 Discussion (5):
- Strategic planning (Planning committee: Tana, Alida, Adam, Brad, Dave Keith, Nell, Kent)
- Develop plans for single species (EAF)
- Develop a vision for what science advice for fisheries would look like
- Develop a plan to make progress with an Ecosystem Approach in the short, medium

and long term, moving towards EBFM
- Identify tools and skill sets
- Relationship with other programs, e.g. Marine Protected Area network planning, Ocean Protection Plan, SARA

APPENDIX 3. WORKSHOP PARTICIPANTS

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APPENDIX 4. Working Group (WG) Descriptions

WG 1: Incorporating ecosystem indicators into stock assessments

Group leads: Adam Cook, Catalina Gomez and Catriona Regnier-McKellar

Objectives: In this working group we will describe and estimate indicators based on stratified random trawl, fishery logbook and at-sea sampling data. In particular we will explore abundance, distribution and size based metrics, as well as species - environmental habitat associations (e.g. Perry and Smith 1994 CJFAS), among others. We will also examine methods for combining indicators to describe overall patterns of the system.

Part 1: Example on the use of indicators in an Ecosystem Approach to stock assessments will be presented and described. Details on the estimation of fishery dependent/independent indicators and environmental correlates will be presented. Multivariate and graphical analyses of the contextual indicators will be used to investigate coherence among indicators trends over time. Participants have the option to bring their own data sets to apply concepts/tools from the workshop to their own stocks.

Part 2: Exploration of the indicatorSpaceTime function, developed to extract ecosystem indicators derived from DFO's RV survey and commercial fisheries landings. Indicator extraction will be explored at different spatial scales.

WG 2: Spatial modeling

Group leads: Brad Hubley, Jamie Tam and Ryan Stanley

Objectives: To incorporate environmental/ecosystem data into a single species stock assessment using a spatial approach. Most environmental data such as depth, temperature, substrate and species distribution is spatial in nature. Survey data for single species stock assessments are also collected across space and time but space is rarely considered in most assessments. Leveraging spatial environmental data would allow us to better estimate species distribution and abundance patterns, understand how fishing patterns affect different components of the stock and produce better science advice. We already do this informally in the CSAS process but in this workshop we can begin to explore how to do it explicitly by incorporating available environmental and ecosystem data sources.

WG 3: Incorporating an Ecosystem Approach to ground fish stock assessment

Group leads: Dave Keith and Doug Swain

The objectives of this working group were to: a: explore methods for incorporating an Ecosystem Approach into groundfish stock assessments for models of varying complexity, b: investigate effects of ecosystem variables on these assessments, and, c: discuss ways to overcome impediments to incorporating Ecosystem Approaches into current assessments.

The methods used will incorporate ecosystem effects on natural mortality, recruitment, and growth into relatively simple stage (delay difference) and more complex age (statistical catch at age, VPA) based models.

The Group leads will present case studies on incorporating ecosystem effects into stock assessments using both simple and complex models. Two general approaches will be examined: 1) allowing components of productivity (e.g. natural mortality) to vary over time in assessment models, and 2) incorporating functional relationships between components of productivity and specific ecosystem factors (e.g. temperature, prey or predator abundance) within assessment models. The group will discuss these approaches and will attempt to apply these and other approaches using fish stock and environmental data provided by participants. Data requirements for the different modelling approaches are described below. To get the most out of this workshop you should be familiar with population modeling and have experience with R. ADMB and/or WinBUGS/JAGS experience is also an asset.

WG 4: Ecosystem Assessments and Report Card
Group leads: *Alida Bundy, Catherine Johnson, and Andrea Moore*

Commercial fish species live in a complex environment and may be affected by a triad of drivers including environmental, trophic and anthropogenic pressures. Monitoring and understanding changes in large scale ecosystem drivers and multi-scale community responses allows us to place single species stock assessments in the context of their wider environment and ecosystem to inform fisheries and oceans management. An ecosystem assessment should include the drivers of change, which can include natural and anthropogenic drivers and the ecosystem properties of interest. Ideally, the assessment should encompass information from the whole ecosystem, from primary production to top predators, including habitat. State of the Oceans (SOTO) reporting requires this ecosystem –level data integration to develop indicators that reflect trends on bioregional and ocean-level scales.

The objectives of this workshop are to:

- explore and assemble available data to develop indicators for ecosystem assessment
- identify and discuss existing indicators and information gaps
- identify and discuss tools and methods of communication for this purpose.

We will build on, and extend, the work of the AZMP program and SPERA Ecosystem Indicators project to provide information for fisheries management, oceans management and SOTO reporting at regional and sub-regional scales: Scotian Shelf (4VWX), eastern Scotian Shelf (4VW) and western Scotian Shelf (4X).

APPENDIX 5. STATUS OF INCORPORATING AN ECOSYSTEM APPROACH INTO SCIENCE ADVICE FOR FISHERIES

(i) Maritimes Region

Overview of Stock Assessments in the Maritimes Region: Movement Towards an Ecosystem Approach to Providing Science Advice for Fisheries Management
Adam Cook, Brad Hubley, David Keith

In the Maritimes Region, exploited marine resources were divided into primary and secondary stocks in 2012 in order to prioritise resources and improve stock assessment advice in key areas. Primary stock were defined on the basis of criteria such as landings ($ or t), international importance, Food, Social and Ceremonial (FSC), importance as a recreational fishery, regional/national priority, and whether it has a key ecological role. For full details see supplementary material section below. Primary stocks are listed in Table 2, which are regularly assessed, have IFMPS and reference points (DFO 2012). There are also over 50 secondary stocks, which are not further considered in this overview.

In the Maritimes Region, most framework assessments for primary species (Table 2) address an Ecosystem Approach to fisheries to some degree, which varies from a mere mention to incorporation of environmental drivers into the assessment model. Indeed, the TOR for each stock assessment meeting specifies that this information should be included either qualitatively or quantitatively. In the following a summary of the stock assessments conducted by the Maritimes Region with a brief statement of the ecosystem information and Ecosystem Approaches to providing stock assessment advice currently used. Additionally, research programs to improve ecosystem integration are indicated.

Marine Mammals

The marine mammal stock assessments led out of the Maritimes region is the grey seal assessment; however, the group participates in other national stock assessment processes. The grey seal assessment incorporates the relationship of sea-ice coverages and seal pup mortality which are included in the risk assessment when providing advice. Research programs are directed toward understanding the trophic interactions and impacts of seals within the ecosystem and exploring sex-specific diet and foraging distribution.

Groundfish

The groundfish assessments cover a number of species including specific stocks of Atlantic cod, Haddock, Atlantic halibut, Pollock, Redfish, Spiny dogfish, Silver hake, and Yellowtail flounder. In many of these assessments ecosystem attributes are incorporated as descriptive measures of change or for overall information. Specifically, temporal changes in habitat associations (Perry and Smith 1994), and productivity

parameters of growth, maturity, condition and recruitment are described. Typically, the predator-prey relationships are well defined.
Two stock assessments have been incorporating time-variant natural mortality to describe some of the changes in stock productivity, such as Georges Bank Cod and 4VsW Cod.

Several research projects are underway for specific stocks to improve our understanding of spatial and temporal dynamics. Specifically, directed research with Atlantic halibut has examined spatial and temporal productivity measures, tagging studies and movement.

Diadromous Species

The diadromous stock assessments in the Maritimes region have included a number of status reports and Recovery Potential Assessments. Many of the regional Atlantic salmon stocks have been assessed as RPAs with incorporation of freshwater and marine threats into the risk assessments for recovery. The integration of ecosystem information for Striped bass and American eels has largely been descriptive with the integration of research studies as they become available. Striped bass assessments have explored the incorporation of temperature – year class strength relationship whereas eel work has largely been directed toward exploring the delivery mechanisms of glass eels (new recruits) to freshwater environs.

Small Pelagics

The main small pelagic species that is currently assessed in the Maritimes region is Atlantic herring. There is currently no working assessment model, and thus no formal integration of ecosystem attributes into stock assessment advice. There has been a number of recent research projects that have the potential to improve the understanding of ecosystem impacts on herring productivity which include the development of a multispecies virtual population analysis (MSVPA) to estimate predation mortality and a tagging program to examine migration rates (DFO 2011).

Molluscs

Surf clam

The surf clam assessment incorporates regular monitoring of bottom impacts with high resolution data of effort in time and space from vessel monitoring systems on industry fishing vessels. Models have been developed to identifying suitable clam habitat through VMS proxy (led by DFO) and high resolution multibeam bathymetry and backscatter (led by industry).

Scallop

The Scallop Unit uses analytical models for 8 specific scallop populations. These assessments currently incorporate a varying amount of ecosystem information. Sea scallop has a strong association with bottom type and the Scallop Unit has utilized acoustic mapping to develop Habitat Suitability maps for sea scallop which have been incorporated into an assessment model. The sea scallop team is involved in research to further develop habitat based approaches. In addition, research is being conducted to investigate the impact of the plankton community on scallop population dynamics and the Scallop Unit is working to help clarify the primary drivers of spatio-temporal variability in sea scallop life history (Figure 2).

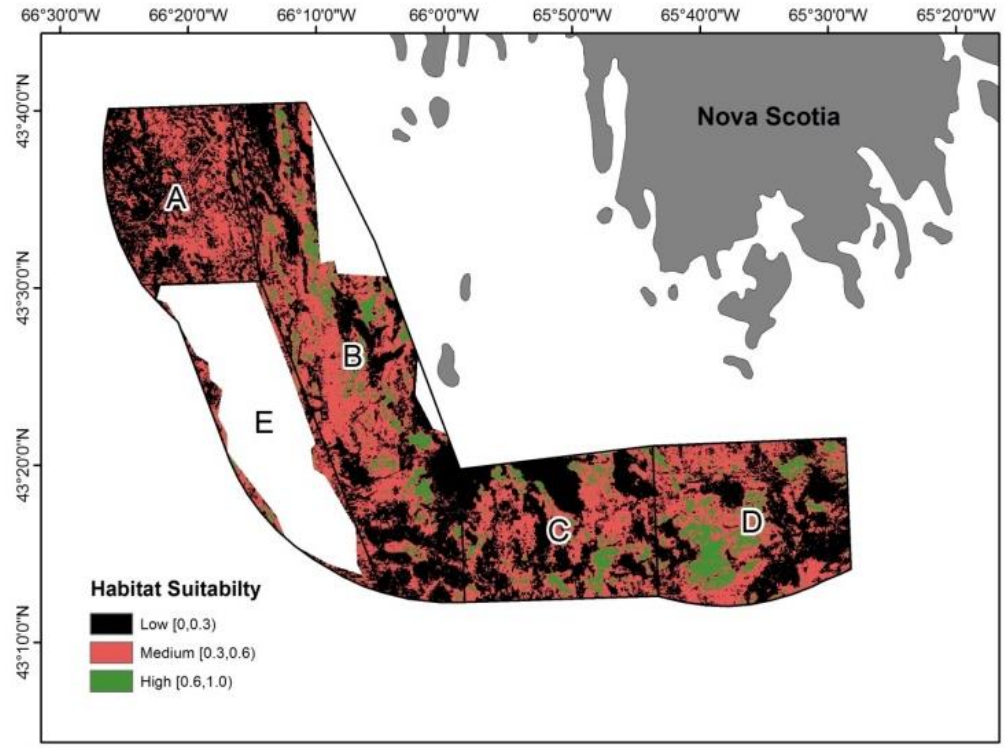

Figure 2. Scallop habitat suitability map from the MaxENT Species Distribution Model binned by Low [0, 0.3), Medium [0.3, 0.6] and High [0.6, 1.0] categories of habitat suitability probabilities for SFA 29 West

Crustaceans

Northern Shrimp

Northern Shrimp incorporates a traffic light approach into stock assessment advice in a semi-quantitative manner. The indicators in the traffic light include environmental metrics (temperature), survey biomasses and distribution, abundance of predators and competitors, and the size distribution of the shrimp population (Figure 3). The ecosystem and secondary sources of information are translated into science advice if the stock is within the cautious zone as the rate of decrease of the removal reference can be flexible based on the status of indicators other than total biomass (Figure 4).

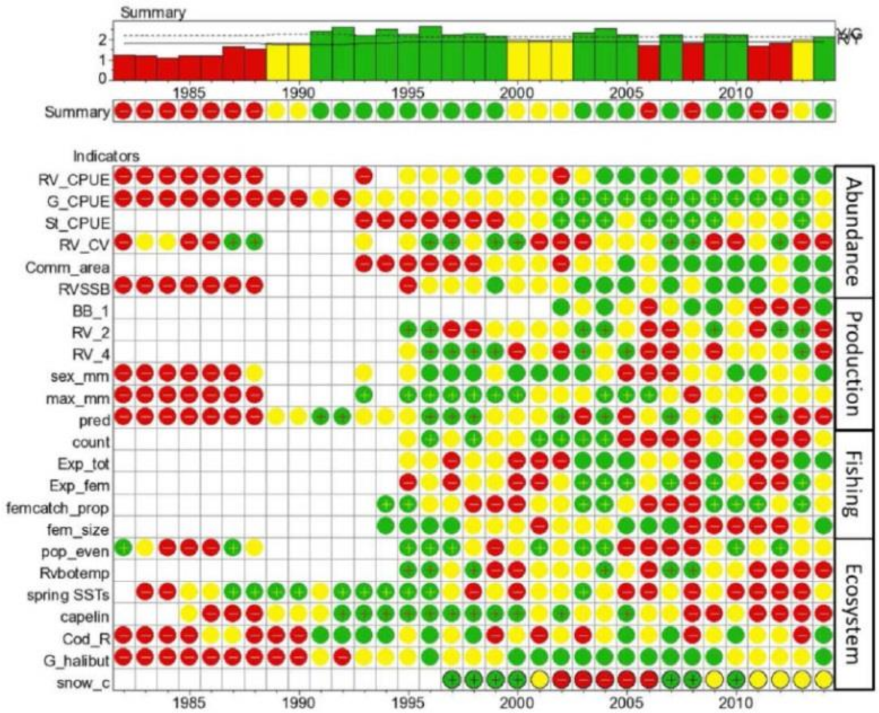

Figure 3. Results of the Traffic Light Approach, 2015 (DFO 2015)

Northern Shrimp - PA

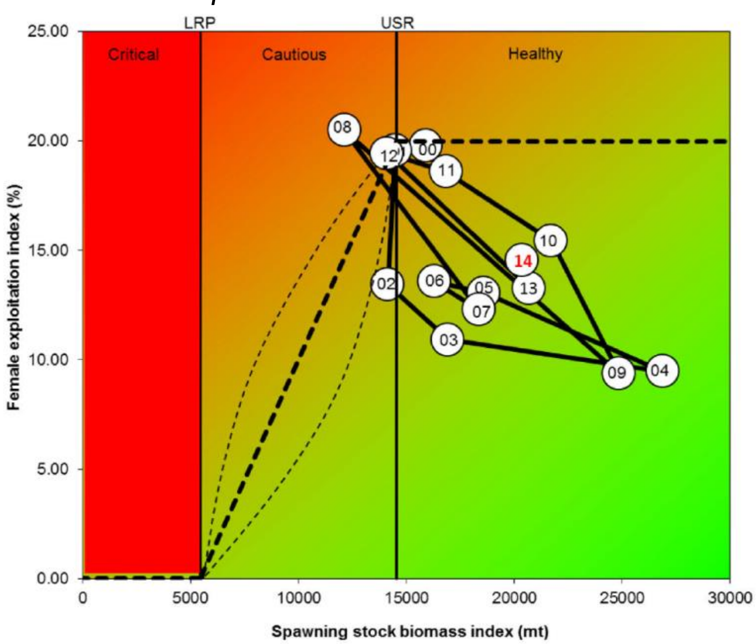

Figure 4. Phase plot of stock status in relation to upper stock and limit reference points, USR and LRP respectively. The removal reference (dashed line) decreases in the cautious zone, but can fall within the concave and convex lines based on signals from the traffic light and secondary indicators.

Snow Crab

The snow crab assessment is the most advanced in terms of the Ecosystem Approach (Choi et al. 2012). The assessment produces an annual index of abundance which incorporates the effects of various ecosystem components on both the likelihood of supporting snow crab (habitat) and the abundance of snow crab when present. Ecosystem factors that directly go into the models include monthly estimates of bottom temperature, depth, slope, curvature, substrate, and principle component analysis of the species composition from various surveys. Other considerations are also presented for a wider context of the overall ecosystem of the Scotia Shelf.

Lobster

Inshore and offshore lobster stocks incorporate ecosystem attributes into their stock assessments. In the inshore lobster, bottom temperatures are included in catch rate models to account for some of the interannual variability in catch rates based on thermally mediated behaviour rather than standing stock abundance. The offshore lobster stock uses a range of data sources in a qualitative approach of incorporating ecosystem attributes into stock assessment advice. Figure 5 shows the time series of PCA anomalies for indicators of abundance, distribution, size, temperature, predators, and climate forcing. The indicators are ranked according to the PCA scores to show the coherence of changes in anomalies over time. This information is taken qualitatively into account when stock advice is provided, and provides the basis for discussion about ecosystem attributes.

Figure 5. Anomaly plot of PCA scores for contextual indicators for offshore lobster in the Maritimes Region (Cook et al. 2017). Colours represent the time series of PCA anomaly, green positive and red negative.

Conclusions

There is progress towards EAF in the Maritimes with most frameworks containing some aspects of EAF. Progress is most advanced for invertebrates where a detailed spatial modelling approach that includes environmental parameters has been developed, and an indicator approach that incorporates broader ecosystem properties has been developed. However, there is much less progress for other primary stocks including groundfish, small pelagics, pelagics, and diadromous species. Predation has largely been ignored, although there has been ecosystem modelling efforts to explore mortality (e.g. MSVPA in Guénette and Stephenson 2012; EwE in Araújo and Bundy 2012) outside of the stock assessment process. Further, there is on-going research exploring ecosystem drivers, ecosystem structure and functioning, ecosystem indicators and the ecosystem impacts of fishing that can contribute to the stock assessment process. Sharing code via GitHub has helped progress.

Table 2. List of primary species in the Maritimes Region

Primary species groups	Primary Species
Marine Mammals	Grey seals
Groundfish	Cod, Atl. Halibut, Sp. Dogfish, haddock, pollock, silver hake, yellowtail fl., redfish
Large pelagics / Sharks	Swordfish, bluefin tuna, blue shark, porbeagle shark
Small Pelagics	Herring
Diadromous	Salmon, gaspereau, eels & elvers, striped bass
Molluscs	Scallops (inshore and offshore), Surf clam
Crustaceans	Lobster (13 LFAs), Snow crab (3 CFAs), Shrimp

Supplementary Material

Priority Setting Protocol for Fishery Assessment and Management: Primary and Secondary Stocks in the Maritimes Region (2012)

Concept or context

This protocol provides a mechanism for discussing priorities and allocation of fishery assessment and management resources within and outside of the Department of Fisheries and Oceans (DFO). It will provide guidance on post-Larocque fishery advice, a common list for checklists, reference points, multi-year assessments, Integrated Fishery Management Plans, and permit a rebalancing of work in order to provide the best level of service where it is most needed.

Questions and decisions for Science and Fishery Management are becoming more complex. Our client base is expanding and becoming more knowledgeable. We are being asked to consider species interactions, as well as ecosystem structure and functioning in our decisions. Resources directed to single species stock assessment science and management requires a protocol for making defensible trade-offs for the projects that DFO can complete.

A change in DFO policy emphasizing species interactions and ecosystem structure in fishery decision making began with the 2001 Dunsmuir Conference. The Maritimes Region subsequently adopted an Ecosystem Approach to Management (EAM) and in 2009 conducted pilot assessments using this approach. This emphasis on the Ecosystem Approach has moved human and financial resources from single species stock assessments to ecosystem-based programs. Cost-saving measures implemented across DFO have also reduced the resources directed to single species stock assessments. There has been no coincident restructuring of the way in which priorities are set for fishery science and fishery management in response to this re-allocation of resources. As a result, Science and Fishery Management staff are over-committed and client service with respect to decision-making on single species is at risk of failing to detect and react to changes in stock status necessary to ensure long-term sustainability. Meaningful implementation of the Ecosystem Approach to Management is also at risk because stock surveys and assessments are fundamental input requirements to the EAM.

A protocol describing priority stocks for fishery assessment and management departmental resource allocation is presented with an overall objective of better alignment between the science provided and the resulting management strategy. This protocol separates stocks into Primary and Secondary categories that define the difference in the DFO response to requests for advice and allocation of departmental human and financial resources.

For example, dividing stocks into Primary and Secondary categories provides a means to designate which stocks will:

1. have a completed sustainability checklist for the next three years;
2. have a full Integrated Fisheries Management Plan;
3. have reference points developed as a matter of priority and peer-reviewed during RAP processes; and
4. be priorities for science resources looking forward, with reduced resources, rather than as a result of historical science effort.

Principles and criteria for inclusion as a Primary stock

Table 3 and Table 4 provides a list of the Primary and Secondary stocks based on the principles and criteria below.

Any of the following economic, social, policy, and scientific principles and criteria:

Principles:

1. Appreciable landings in the Maritimes Region
2. Appreciable landed value in the Maritimes Region
3. Subject of international agreements
4. Important Food, Social, or Ceremonial (FSC) stock
5. Important recreational stock
6. Designated a regional or national priority
7. Harvested and plays a key ecological role

Criteria:

1. Landings >2000 t
2. Value >$2 million per annum
3. International agreement requiring Canadian science or management
4. A keystone stock or ecologically and biologically significant stock

These principles and criteria were chosen to cover the range of considerations commonly taken into account when prioritizing single species stock assessment science and management in the Maritimes Region.

The levels with respect to landing tonnage and economic value reflect the need to establish a cut-off point, while at the same time recognizing that a completely non-arbitrary method of fixing these levels does not exist. As a result, they reflect the judgement that 2000 tonnes is an appreciable amount of biomass to remove from the system and that a $2 million fishery is one that makes an appreciable overall contribution to the Maritimes Region fishery economy.

DFO is open to adding or altering the principles and criteria defining Primary and Secondary stocks. However, this protocol describes the maximum current work capacity and equivalent work would have to be removed to create capacity for new issues. The intent is that these criteria will serve as a basis for discussions and decisions regarding any movement of stocks between Primary and Secondary lists during the proposed 3-year review period (see below).

Services provided

Table 5 below provides a summary of the services provided for Primary and Secondary stocks. Important policy and procedural differences are highlighted below.

Stock assessment: The amount of dedicated DFO financial and human resources allocated to each stock is a major consequence of defining a stock as Primary versus Secondary. In general, if work is required to provide advice on Secondary stocks for fisheries management, including analyses and interpretation of data, these resources would come from the relevant fishing industry. Ideally, this work would commence after consultation with DFO experts on methodology and reporting standards. Advice for Primary and Secondary stocks would be provided through a science review process conducted under the CSAS. For review of Secondary stocks, DFO staff would function primarily as reviewers of the work. Alternatively, advice could be provided through an ecosystem analysis vetted through the CSAS process. This advice would have more DFO ecosystem science staff than stock assessment staff involvement. The relative merits of which process would be used in a given situation would be made on a case-by-case basis.

Eco-certification: The difference between Primary and Secondary stocks with respect to eco-certification is minimal. The Maritimes Regional policy with respect to eco-certification indicates that work related to eco-certification would occur if it is part of an existing work plan. Given that DFO financial and human resources will be allocated to Primary stocks, it is more likely that eco-certification work would be a part of a Primary stock work plan than a Secondary stock work plan. This likelihood is particularly applicable to work that is considered by DFO to be part of the mandate for Primary stocks, but not Secondary stocks, such as, reference points and fishery checklist completion. However, items that do not fit these criteria are unlikely to be in work plans for either Primary or Secondary stocks. In cases where the work required is not part of a DFO work plan, there would be no subsidizing of the work using DFO financial or human resources.

Species at risk (SARA): The categorization of stocks into Primary and Secondary stocks based on the above criteria does not apply to stocks when they are in the SARA process. The timelines and prioritization for SARA deliverables are set by the national Species at Risk Program (SARP) for species submitted by COSEWIC. Once the species have been selected for funding, all species have equal priority under SARA. If a Recovery Potential Assessment (RPA) or pre-COSEWIC assessment is required for either a Primary or a Secondary stock for which DFO Science has a species lead, it would be conducted by that person. When human resources are insufficient, either due to lack of expertise within DFO Science (e.g. no species lead) or due to prior work commitments, Species-at-Risk funding would be requested by Science to contract the necessary science work, as this work would be considered incremental to core activities.

It is expected that RPAs would identify key research priorities for a listed species that would then be used to help prioritize future requests for SARA funding related to Recovery Strategies or Action Plans.

General principles

A consequence of this protocol is that non-DFO science will be more prevalent with respect to the science advice for fishery management than in the past. As identified above, the CSAS process would be used to review DFO and non-DFO science advice. To ensure a consistent approach under both advice scenarios, the general principles guiding the provision and review of science advice for departmental management actions would apply. Chief among these are the *Principles and Guidelines for the Effective Use of Science and Technology Advice in Government Decision Making* (i.e. SAGE Guidelines).

These principles are:
1. Early Issue Identification
2. Inclusiveness
3. Sound Science and Sound Advice
4. Uncertainty and Risk
5. Transparency and Openness
6. Review

Process for review

The assignment of stocks to the Primary or Secondary list will be reviewed every three years. Three years provides time to develop and complete any existing plans for scientific and management projects.

The list currently matches maximum capacity; thus, even if a Secondary stock attains one of the criteria listed, it will not automatically move into the Primary stock list. A stock or combination of stocks with similar workload requirements would have to be removed.

The review will be completed by Science and Fishery Management staff and then brought to the Maritimes Region Operations Committee before adoption and engagement outside the Region occurs.

Stakeholder engagement

The Fishery Roundtable will be used to engage stakeholders for stocks represented by Roundtable attendance. For other stocks, advisory committees will be used for stakeholder engagement.

Aboriginal engagement
Aboriginal Affairs in discussion with Area Aboriginal Co-ordinators and Policy and Economics will determine the most appropriate method for engaging Aboriginal peoples with consideration for the Aboriginal Duty to Consult.

Other region and national engagement
The National Science Directors Committee (NSDC) will be used to engage the National and other regional Science sectors. The Fisheries Management Oversight Committee (FMOC) will be used to engage the National and other regional Fisheries Management sectors.

Conclusion
The proposed protocol will require increased planning among Science, Fisheries Management, and the fishing industry. This planning will vary depending on industry and DFO capacity and will evolve as the protocol is implemented. Publication and presentation of work plans will be required to ensure that relevant parties understand the work plan content and any incremental work requirements. Trade-offs will need to occur to accommodate ad hoc advice requests and will need to be minimized to maintain stability in Science and Fisheries Management work planning and industry harvesting plans. This protocol will provide a publicly available mechanism for discussion of priorities and allocation of resources within and outside of DFO for the purpose of providing fishery science advice and management within an ecosystem context.

Table 3. List of Primary stocks[2]

Group	Species/ Species Group	Stock list[1]	Principles (P) & Criteria (C) Applicable
Groundfish	Atlantic Cod	4Vn (WAIT)	P6,7; C4
		4VsW (WAIT)	P6,7; C4
		4X5Y (WAIT)	P6,7; C4
		5Z (WAIT)	P3,6,7; C3,4
	Atlantic Halibut	3NOPs4VWX+5	P2; C2
	Spiny Dogfish	(WAIT)	P7; C4
	Haddock	4X5Y	P1; C1
		5Z	P1,2,3; C1,2,3
	Pollock	4Xopqrs5 (western comp)	P1; C1
	Silver Hake	4VWX	P1,2,3; C1,2,3
	Yellowtail Flounder	5Z	P3; C3
	Redfish	Unit 3 (WAIT)	P1,2; C1,2
Small Pelagics	Herring	4VWX	P1,2,6,7; C1,2,4
		5Y5Z	P6,7; C4
Crustaceans	Lobster Inshore	LFA 27-32, 33	P1,2,4,6; C1,2

[2] Species at risk status in parentheses (END=endangered; THE=threatened; SC=special concern; WAIT=waiting decision; NL=not listed).

Group	Species/ Species Group	Stock list[1]	Principles (P) & Criteria (C) Applicable
		LFA 34	P1,2,4,6; C1,2
		LFA 35-38	P1,2,4,6; C1,2
	Lobster Offshore	LFA 41	P2,6; C2
	Snow Crab	ENS-N	P2; C2
		ENS-S	P1,2; C1,2
		4X	P6
	Shrimp	SFA 13-15	P1,2,7; C1,2,4
Molluscs	Scallop Inshore	SFA 28 (Bay of Fundy)	P2; C2
		SFA 29W	P2; C2
	Scallop Offshore	26: German, Browns	P2; C2
		27: Georges	P1,2; C1,2
	Surf Clam	Banquereau	P1,2; C1,2
		Grand Bank	P1,2; C1,2
Large Pelagics and Sharks	Swordfish		P2,3,7; C2,3,4
	Bluefin tuna	(WAIT)	P2,3,5,6,7; C2,3,4
	Blue Shark	(WAIT)	P3,5,7; C3,4
	Porbeagle	(NL)	P2,3,7; C2,3,4
Marine Mammals	Grey seals		P6,7; C4
Diadromous	Salmon	Inner Bay of Fundy (END)	P3,4,5,6; C3
		Outer Bay of Fundy (WAIT)	P3,4,5,6; C3
		Southern Uplands (WAIT)	P3,4,5,6; C3
		Eastern Cape Breton (WAIT)	P3,4,5,6; C3
	Gaspereau		P2,4; C2
	Eel & elvers	WAIT	P2,4,6; C2
	Striped Bass	WAIT	P2,4; C2

Table 4. List of Secondary stocks

Groundfish
1. Flounders (excluding 5Z YTF, but including other YTF, witch, American Plaice (WAIT), winter flounder)
2. Greenland Halibut
3. Haddock 4TVW (could be included with 4X5Y haddock as ecological)
4. Pollock 4VWXmn (eastern component)
5. Hagfish
6. Groundfish stock not otherwise noted (e.g. cusk (WAIT), Atlantic wolfish (SC), white hake, sculpin)
7. Skates (Winter (NL),
Small pelagics
8. Capelin
9. Herring 4Vn (Local stocks, e.g. Glace Bay, Bras d'Or Lakes and does not include 4T herring migrating to 4Vn)
10. Mackerel
Large pelagics and sharks
11. Albacore
12. Bigeye tuna
13. Yellowfin tuna
14. Basking (WAIT)
15. Greenland
16. Black dogfish
17. Shortfin Mako (WAIT)
18. White shark (END)
Diadromous
19. Atlantic sturgeon (WAIT)
20. Shad
21. Short nose sturgeon (SC)
22. Smelt (Lake Utopia Rainbow Smelt, small bodied, END; large bodied=WAIT)
23. Whitefish (END)
24. Atlantic tomcod
Crustaceans
25. Inshore crabs (Jonah and rock)
26. Red crab
27. Shrimp SFA 16
Molluscs
28. Propeller clams
29. Razor clams
30. Soft-shelled clams
31. Quahogs

32. Scallop SFA 29 East	
33. Scallop SFA 10-12 (St. Pierre Bank)	
34. Scallop SFA 25 (Eastern Scotian Shelf)	
35. Periwinkle	
36. Oyster	
Cephalopods	
37. Squid	
Echinoderms	
38. Urchins	
39. Sea cucumber	
Marine plants	
40. Marine plants (e.g. rockweed, Irish moss)	
Bycatch from fisheries for targeted species	
41. Right Whale (END)	
42. Harbour porpoise (THE)	
43. Mahi mahi	
44. Loggerhead sea turtles (WAIT)	
45. Leatherback sea turtles (END)	
46. Seabirds	
47. Northern Bottlenose Whale (END)	
48. Sowerbys Beaked Whale (SC)	
Fisheries in developing phase (1 or 2)	
49. Whelks	
50. Bloodworms	
51. Any new/developing/experimental/exploratory fishery	

Table 5. Summary of characteristics and services provided for Primary and Secondary stocks

	Primary	Secondary
Science and stock assessment	Has a peer-reviewed stock assessment or Management Strategy Evaluation (MSE) at regular intervals. Assessment based on a population model or an empirical data analysis. Has dedicated science resources to undertake data collection, analysis, monitoring/research, and provision of advice.	Science survey, industry survey results, fishery-dependent information or habitat information (e.g. benthic classification) as the basis for management advice. Old assessment or other published information may exist. Advice provided through a Special Science Response or other science review process.
Species at risk assessments	Primary and Secondary categorization does not apply to SARA stocks. Once the species have been prioritized and selected for funding by the National SARP, all species have equal priority under SARA. If a Recovery Potential Assessment (RPA) or pre-COSEWIC assessment is required for either a Primary or a Secondary stock either DFO Science will lead or the work will be contracted with SARP funding. SARP funding would support required research.	
Eco-certification	If awarded certification, DFO Science staff would complete the work needed to maintain certification/respond to conditions if part of an existing work plan. Work outside the work plan is considered to be incremental to DFO core activities.	No additional work would be subsidized to support eco-certification, with the exception of those activities done for ordinary administration of the fishery.
Bycatch	Primary stocks that are caught as bycatch in any other fishery will be tracked by DFO with analysis as required. Total bycatch of primary stocks is summed over all other fisheries in the primary stock assessment.	Secondary stocks that are caught in other fisheries will have information reported where available. For secondary stocks, total bycatch will be estimated wherever possible.
Resource Management	Has a Resource Management advisor responsible for planning and management. Routine Advisory Committee process.	On RM 'watch list' with limited day-to-day activity. Limited consultation efforts.
Checklist	Yes (if a targeted fishery)	No
Management Plan	Managed with a full IFMP, compliant with the template	No full IFMP, but would have a briefer version describing key management controls.
Precautionary Approach	First priority for PA Reference Points and HCR development and implementation	Second priority for development and implementation of PA and HCR (empirically-based only)

(ii) Gulf Region

Incorporating an Ecosystem Approach into science advice for fisheries in the southern Gulf of St. Lawrence
Hugues Benoît, Doug Swain, Gerald Chaput et al.

Science advice in the Gulf region is provided on a regular and ongoing basis for a number of groundfish stocks, Atlantic herring, Atlantic salmon, snow crab and Atlantic lobster. Other stocks are assessed on an infrequent and often irregular basis such as gaspereau, scallops and rock crab. Of the ongoing assessments, those for groundfish (all species) and herring are based on analytical models, while those for salmon and snow crab are based on statistical models. Recovery potential assessments for groundfish led by the Gulf region have also all employed analytical models.

At the most basic level, environmental effects on growth and condition are inherently incorporated in the science advice for all stocks, as annual measurements are used as input to the advice. The same is true for data on maturation for some stocks. While not required for the provision of ongoing science advice, targeted research is often carried out to try and understand the causes of changes in these characteristics.

The most prominent manner in which environmental effects are explicitly incorporated into stock assessment and advice is by the use of population models with time-varying components of productivity. For stocks that are assessed using biomass-dynamic models, such as witch flounder, this is accomplished by allowing the intrinsic rate of population increase to vary in time (DFO, 2017a). For stocks that are assessed using age- or length-disaggregated models (e.g. statistical catch-at-age or catch-at-length, virtual population analysis), this is accomplished by allowing estimated recruitment to vary randomly over time and for natural mortality to vary smoothly over time using a random-walk approach (e.g. Atlantic cod, white hake, American plaice; Swain et al. 2015a, 2016; Ricard et al. 2016) or to vary over time blocks (e.g. yellowtail flounder; Surette and Swain 2016). These types of models have dramatically reduced the incidence of retrospective patterns which had previously hindered a number of the assessments. Furthermore, these models have been validated using simulations and self-tests (e.g. Swain and Benoît, 2015). Projections from these models for science advice have generally used population parameters from the most recent years, thereby increasing the likelihood that projections will reflect prevailing environmental conditions. Alternatively, auto-regressive models for the productivity parameters could also be used for projections where there are important trends in these parameters.

The advantages of using models with time-varying productivity components to incorporate environmental effects are three-fold. First, there is no need to specifically identify the causal factor and its relationship to productivity, which could otherwise severely constrain model dynamics and therefore conclusions. Second, these models account for the cumulative and interacting effects of multiple factors operating on the same component of productivity. Third, the models accommodate possible time-varying forms of the causal relationships between ecosystem factors and population productivity. The principal disadvantage of the approach is that it does not directly identify causal factors. Understanding why productivity has changed would clarify management options and may also improve population projections. Consequently models incorporating time-varying productivity are viewed an important first step in understanding ecosystem impacts, and follow-up targeted research is advisable. Important increases in natural mortality for adults have been estimated for a large number of groundfish stocks in the southern Gulf, notably cod, American plaice, white hake, winter flounder, yellowtail flounder, and three skates (winter, smooth and thorny) (Swain and Benoît, 2015). Follow-up research and a weight-of-evidence approach suggest that predation by grey seals has contributed strongly to these increases as a predation-driven Allee effect (e.g. Benoît et al. 2011a,b; Swain et al. 2011, 2015b).

These results motivated the development of population models for cod and winter skate that explicitly incorporate grey seal predation and which are presently being finalized. In contrast to the random-walk approach, these models require defining a certain form or parameters for a functional response and, for cod, requires assumptions (model priors) for time-varying natural mortality components due to factors other than seal predation, such as poor condition and unreported catch.

Environmental changes can affect not only the demographic rates and biological characteristics of fish populations, but also their spatio-temporal distribution. This in turn can lead to changes to the catchabililty of fish to surveys and the fisheries. It is therefore possible to account for such environmental effects by modelling time-varying catchabilities in population models. While catchability to surveys and fisheries is likely to vary for reasons unrelated to the environment, notably due to density-dependent changes in distribution and changes in fishing patterns or characteristic, using time-varying parameters will account for these effects as well environmental ones. Models with time varying catchability have been tested and adopted for southern Gulf of St. Lawrence spring and fall spawning herring stock assessments (Swain, 2016).

For other stocks, environmental relationships are routinely reported or have been investigated, but are not used specifically in the provision of scientific advice. A notable example is snow crab, which is a stenothermic species with a preference for colder water temperatures. The available thermal habitat is reported annually but is not used in the tactical management of the stock because the functional relationship between thermal habitat and crab dynamics has yet to be established (Chassé et al. 2015; DFO, 2017b). However, the amount of habitat is projected to become limited under climate change, with anticipated effects on population dynamics. The thermal habitat index may become important for longer term strategic fishery planning. Another example pertains to Atlantic salmon in the Miramichi river, where correlations have been established between return rates for salmon adopting a specific reproductive strategy and the availability of forage fish in the southern Gulf (Chaput and Benoît, 2012). While this correlation is interesting, considerable work remains to establish whether the relationship is causal and to determine if it can be used in refining or forecasting return rates.

Finally, a number of indicators of ecosystem change in the southern Gulf of St. Lawrence have been developed, generally using data from the multispecies trawl survey. While these indicators are not used in the provision of scientific advice, they have been important components of reporting on the state of the ecosystem (Dufour et al. 2010; Benoît et al. 2012) and have been used to support conclusions about important changes age- and size-dependent mortality patterns in the marine fish community (Benoît and Swain, 2011; Swain and Benoît, 2015) and climate related changes in community composition (e.g. Benoît and Swain, 2008; Benoît et al. 2012). In summary, including time-varying productivity components in assessment models for finfish is the principal manner in which ecosystem effects are included in Gulf region assessments and science advice. This is viewed as a key first step, following which research can focus on enhancing understanding and on explicitly/parametrically modelling the effects. While other environmental indices are reported on or have been studied, these do not currently directly inform the advice.

(iii) Newfoundland and Labrador Region

Incorporation of the effects of environmental and trophic interactions on stock productivity in NL region: work to date and plans for the near future –

Pierre Pepin, Northwest Atlantic Fisheries Centre, St. John's, NL

Moving from a single species to an Ecosystem Approach to the provision of advice is a key regional priority for Newfoundland and Labrador (NL). Motivation in development of the action plan for the region has been strongly based on development of NAFO's roadmap toward an Ecosystem Approach to management (EAM). NAFO's strategy relies on a tiered approach based on understanding the underlying patterns of variability in environmental conditions and key functional processes and interactions among trophic levels. Knowledge of ecosystem productivity and energy flow represents the foundational element (Tier 1) that could serve to establish total catch ceilings while Tier 2 considers more detailed representation of multispecies and environmental effects that can serve to inform expectations of stock productivity in single species stock assessments (Tier 3). Examination and development of management advice could then be based on modulating the signals of various ecosystem components to gain an understanding of the consequences of management decisions and ecosystem change on population abundance and trajectories across managed species and trophic levels.

The approach being developed in NL region is based on a pragmatic perspective that EAM is a long-term goal. Our first consideration is to start extending our knowledge of the factors that have been demonstrated to affect single species or stocks. The rationale is that the NL Ecosystem is a relatively simple ecosystem: each trophic level is dominated by small number of taxa and there have been strong environmental signals. This combination of features facilitates the understanding and detection of the impacts of environmental and trophic interactions on individual populations. There have been major changes in overall abundance of demersal, pelagic and invertebrate stocks that have led to important changes in community structure, and environmental conditions have cycled from above average temperatures to the coldest conditions on record, which were followed by a steady rise to the warmest conditions on record. The pathway of effects projections based on such drivers can be done over short (annual) or medium term (3-5 years) periods, depending on the lag of the impact on population productivity, with reasonable levels of certainty because of the high degree of serial correlation in environmental and ecosystem conditions.

Development of an EAM in the NL region is based on creating a Regional WG of Science and Resource Management (RM) sectors. Buy-in from RM of integrated (ecosystem level) advice is the only way forward because of the need to adapt management systems to a changing approach in Science recommendations. The approach starts with extended single-species models, either empirical or mechanistic, as a basis for projections of future states (1-3 years) based on dominant drivers. The goal is to explore the uncertainty in our ability to make projections, based on statistical error and underlying environmental variability. This will involve trying to partition stock productivity in terms of growth/recruitment versus losses to predation and exploitation based on our knowledge of NL Ecosystem dynamics. Involvement of the RM sector also involves getting ahead of the peer-review process. In the past, the primary focus has been on determining current state to determine acceptable an exploitation rate that will maintain stock productivity in the near future. Adapting to new information can have abrupt consequences to nature of advice relative to previous cycles which can result in a negative reaction from the policy sector and stakeholders. The process should review (and anticipate) alternative scenarios of ecosystem and environmental change on future productivity independently of the stock assessment process in order to provide RM and Policy sectors with time to consider impacts of what we know/expect/dread before we get confirmation. It is also critical to start educating stakeholders of potential broadening to the EAM and discuss the consequences for decision making, policy development and long term prospects.

There are five fundamental findings that are to serve as the basis for the gradual building of an EAM on research outcomes: [1] productivity of a major shrimp stock (SFA6) is strongly influenced by the timing of the spring phytoplankton bloom (physically driven) and losses to predators (DFO 2017c); [2] Capelin abundance is strongly linked to the timing of ice retreat (Buren et al. 2014) and we know that predation pressure (ecosystem dependency) on the stock is substantial; [3] Snow crab landings are strongly linked to the availability of suitable thermal habitats; the impact of predation by groundfish is probably becoming increasingly important (Dawe et al. 2012, Mullowney et al. 2014); [4] Productivity of the northern cod stock is strongly related to the impact of exploitation and the availability of capelin (Buren et al. 2014); and [5] Reproduction of harp seals is strongly affected by the availability of capelin and the extent and quality of sea ice (Stenson et al. 2016). In order to move toward increased integration, the Regional WG will develop an hierarchy of single-species extended models based on empirical and mechanistic descriptions of the influence of environmental and/or trophic interactions to apply in “what-if” scenarios and to understand the degree of uncertainty in projections. In addition, a suite of minimum regional trophic models that aim to understand the effects of changes in environmental conditions, trophic interactions and anthropogenic effects on ecosystem productivity will be developed. The focus will be on Newfoundland Shelf and Grand Bank ecosystems to assess impact of changes in trophic interactions among planktivores, benthivores and piscivores (including seals) and how these are affected by management actions (vs environment [no control]). To deal with uncertainty, we will attempt to gain increased knowledge of prey-predator relationships with increased collections of stomach samples; investigate how to deal with habitat heterogeneity (structure), changes in response to ecosystem state, and spatial management initiatives; and focus on gaining greater understanding on drivers of lower trophic level productivity as limiting factors to overall ecosystem productivity.

APPENDIX 6. Working Group Reports

WG 1 Report: Incorporating Ecosystem Indicators Into Stock Assessments

Indicators represent key attributes in a system, they allow changes to be measured, they provide the basis to assess the status and trends in the condition of the system or of an element within the system, and they are essential to support an Ecosystem Approach (EA) into Science Advice for Fisheries. Participants in WG1 discussed that the first step in the process of selecting indicators for an EA consists of differentiating between two key considerations:

1. Painting the general picture of the ecosystem; and/or,
2. Identifying drivers that are directly impacting a given stock

In addition, the group identified the following three considerations to improve the process of identifying and incorporating key indicators into stock assessments.

1. *How do we find important links between physical, chemical, and biological indicators of the system? Connecting data and scientists across divisions*

One of the main goals of an Ecosystem Approach is to find links between ecosystem indicators and stock assessment measures, as well as describing the mechanisms that are causing changes in the system and the stocks. Finding links requires that data and analytical tools are documented and shared easily across divisions. For example, information for describing general information of the system is derived from initiatives such as the Atlantic Zone Monitoring Program (AZMP) in eastern Canada, which since 1998 has provided basic information on the variability in physical, chemical, and biological properties of the Northwest Atlantic continental shelf on annual and interannual scales (http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html). The agenda of the Groundfish Update review held at BIO on December 2016, for example, included an overview of the AZMP report aiming at providing ecosystem context. The agenda also included an overview of multi-species indicators derived from the RV survey and commercial fisheries landings database. All of this information was presented at the beginning of the Groundfish Update review, but there was no time throughout the review to discuss its implications or links between all indicators discussed. The group therefore recommended that there should be time specifically allocated to discuss key indicators that may be relevant for a particular stock prior to assessment updates and reviews (i.e. finding time outside CSAS processes to build upon ideas). The following activities are examples of strategies identified by the group that can link indicators as well as scientists horizontally across the organization (i.e. OESD and PED):

- Attendance of stock assessment groups to the annual overviews of the AZMP programme;

- Developing conceptual models as part of stock assessment overviews with the aim of incorporating information of the stock with other physical, chemical, and biological indicators; this can be accomplished in a practical way by focusing on a particular piece(s) of the system that we understand in detail. Conceptual models can help linking not only indicators but also scientists across science divisions; and,

- R Technical Working Group can consolidate a network of R users, key to strengthening science in the context of EA, through innovation, collaboration, and peer-support across science divisions.

2. *Identify what spatial and temporal scales matter for your questions/assessment*

The biological structure is different to the management structure of the stocks, therefore it is essential to reconcile between spatial areas identified in stock assessments with stock boundaries. For this process, there is an urgent need to continue incorporating spatial analyses into stock assessments (this is discussed in WG2; and will be implemented via the R technical working group). Spatial considerations should also be considered for multi-species indicators to help to define important trophic links between species. These multi-species assessments could, for example, enhance the RV survey trend report by reporting multi-species indicators at different and more relevant spatial scales derived from species assemblage's analysis.
Biological systems act at different scales than management systems. Identifying temporal scales that matter for biological and management systems can aide the process of differentiating between:

- short–term decisions (e.g. next year: influence Total Allowable Catch); *vs*

- mid-term decisions (e.g. 3 to 5 years); *vs*

- long-term decisions (e.g. next decade: not too long of a time-lag to consider introducing or not more fishing licenses); *vs*

- super long-term considerations/projections (e.g. 50 years; can potential strategies be identified to take into account the effects of pressures such as climate change, which cannot be regulated on a short-term fisheries management timescale?).

In a decision-making context, these considerations are fundamental to distinguish between "manageable" and "unmanageable" indicators. Manageable indicators are those that managers can regulate via TACs, moratoria, closed areas or other strategies. Unmanageable indicators provide vital understanding of the system and stock measures (e.g. SST), and should be taken into consideration to adjust the manageable indicators.
Ultimately, going back to the basic biological/ecological information of a given stock can give an insight of what time-lags and spatial scales matter for a given stock (e.g. what is

the life-cycle? Where do they spawn?). These considerations can also be examined in retrospective using historical information.

3. *Incorporating productivity as an indicator*

Productivity is the amount of new organic matter produced per biomass unit, with dimensions per unit time (Garcia et al. 2012). Productivity may be a noisy signal but may have stronger linkages with ecosystem responses compared with other indicators such as abundance.

Final considerations discussed during WG1 highlighted the importance of delivering sound science by making sure that we will produce and share quality information. Open source data and code (under the Federal Geospatial Platform and Open Government initiatives) will be critical steps to achieve that goal.

WG 2 Report: Spatial Modelling

The objective of this working group was to consider approaches to incorporate environmental and-or ecosystem data into a single species stock assessment using a spatial approach. Survey data for single species stock assessments are collected across space and time, however the spatial attributes of this data are rarely considered in stock assessments. Leveraging spatial environmental would permit a better estimation of the spatial characteristics of abundance and distribution overall, leaning on predictive species habitat modelling. With these models we can better understand how fishing influences different components of the stock and in turn produce better science advice. We already do this informally in the CSAS process, but in this workshop we can begin to explore how to do it explicitly by incorporating available environmental and ecosystem data sources (Table 6).

Table 6. Shows how increasing complexity of spatial approaches can feed into management advice at various stages.

Spatial approaches	**Feed into Management Advice**
Species distribution models	quantify available habitat
Habitat suitability models	quantify available habitat, explicitly spatial
Spatial Abundance models	quantify abundance and distribution, construct an abundance index that can feed into a fisheries model
Spatial-temporal population dynamics	explicit incorporation of spatial abundance and distribution patterns into a fisheries model

We began by working with simple species distribution and habitat suitability models (HSM) using the *dismo* R package (Climate Envelop Model Booth 2014 Diversity and Distributions 20:1-9). The *Bioclim* algorithm has been extensively used for species distribution modeling. *Bioclim* is the classic ’climate-envelope-model’. Although it generally does not perform as well as some other modeling methods (Elith et al. 2006) and is unsuited for predicting climate change effects (Hijmans and Graham, 2006). It is still used, however, among other reasons because the algorithm is easy to understand and thus useful in teaching species distribution modeling.
The *Bioclim* algorithm computes the similarity of a location by comparing the values of environmental variables at any location to a percentile distribution of the values at known locations of occurrence (’training sites’). The closer to the 50th percentile (the median), the more suitable the location is. The tails of the distribution are not distinguished, that is, 10 percentile is treated as equivalent to 90 percentile.

In this R implementation, percentile scores are between 0 and 1, but predicted values larger than 0.5 are subtracted from 1. Then, the minimum percentile score across all the environmental variables is computed (i.e. this is like Liebig’s law of the minimum, except that high values can also be limiting factors). The final value is subtracted from 1 and multiplied with 2 so that the results are between 0 and 1. The reason for this transformation is that the results become more like that of other distribution modeling methods and are thus easier to interpret. The value 1 will rarely be observed as it would require a location that has the median value of the training data for all the variables considered. The value 0 is very common as it is assigned to all cells with a value of an environmental variable that is outside the percentile distribution (the range of the training data) for at least one of the variables. In the predict function, you can choose to ignore one of the tails of the distribution

We tried this approach on available species abundance and environmental data. The environmental data that was used was originally derived as part of the snowcrab assessment (Hubley et al. 2017) and included variables derived from bathymetry (depth, slope and curvature), substrate grain size, and bottom temperature interpolations (Climatological mean, sd, min and max as well as annual values). Species abundance data came largely from the DFO ecosystem survey (lobster, scallop, halibut and silver hake), data from the scallop survey and clam fishery were also used.

Bioclim results were compared with a generalized additive model (GAM) approach which allows for space to be explicitly incorporated into the model (Figure 6).

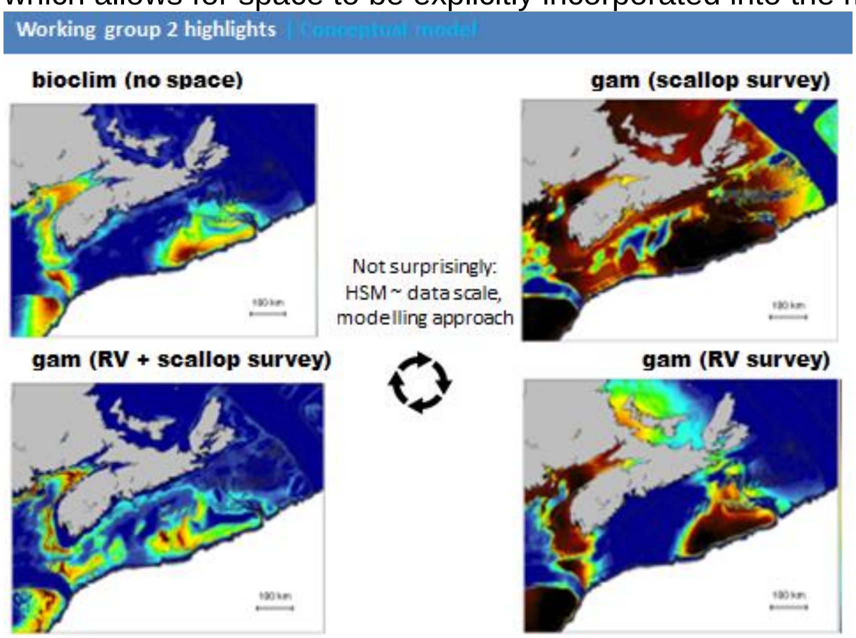

Figure 6. Example outputs from HSM modelling scenarios using sea scallop as an example species.

HSMs besides quantifying suitable habitat can be used to stratify abundance indices that can then be fed into a traditional approach to fisheries management. The next level of complexity which we did not workshop at the meeting would involve developing a spatial abundance model to quantify abundance and distribution. By combining a prediction surface for habitat and abundance (non-zero data) habitat is then used as weights for non-zero biomass to get final estimate of fishable biomass. This resulting index which incorporates the continuity of the habitat suitability can also then be fed into a traditional approach to fisheries management. Spatial-temporal population dynamics represent a further level of complexity where biomass dynamics are modelled spatially and are explicitly tied to the specific habitat. This approach is currently challenging to achieve for a meaningful resolution. That being said HSMs represent valuable information that should be developed and included in stock assessments that seek to incorporate the ecosystem more fully than is currently being done.

Participants were provided the opportunity to actively participate in HSM model development, using species distribution (American lobster, sea scallop, Atlantic halibut, and silver hake) and environmental data, in conjunction with R code provided by working group leaders (B. Hubley and J. Tam). The working group discussed approaches to spatially integrate habitat suitability information among species. It was decided that HSMs could be used to develop a spatial representation of ecosystem (multi-species) resilience or susceptibility to marine climate change. To accomplish this, it was proposed that change could be projected as spatial anomalies (Figure 7), detailing stability, gains or losses in suitability between baseline (i.e. contemporary climatology and distribution) and forecasted (i.e. baseline model and climatology advanced from baseline period) model output, summed across species and space. The working group collaboratively applied this approach in R using available distributional (lobster, scallop, halibut, hake) and environmental data (baseline – 1999:2004 and future – 2009:2014). This preliminary analysis was presented during the workshop summary with specific discussion on potential applications and limitations of the approach.

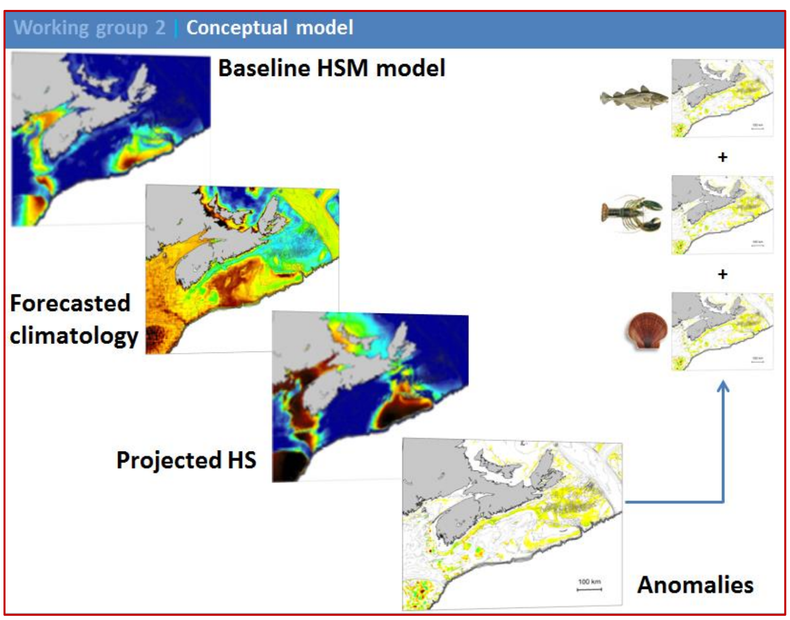

Figure 7. Conceptual approach to integrate HSMs among species towards an index detailing the ecosystem susceptibility to marine climate change.

WG3 Report: Incorporating an Ecosystem Approach In Groundfish Stock Assessment

The objectives of this working group were to: a: explore methods for incorporating an Ecosystem Approach into groundfish stock assessments for models of varying complexity, b: investigate effects of ecosystem variables on these assessments, and c: discuss ways to overcome impediments to incorporating Ecosystem Approaches into current assessments. The methods used incorporated ecosystem effects on natural mortality, recruitment, and growth into relatively simple stage (delay difference) and more complex age (statistical catch at age, VPA) based models.

Approaches

The majority of the workgroup focused on the more complex age based models as it was found that these models had more scope for the incorporation of an Ecosystem Approach than the simple stage based models. Two approaches were compared within the age based models:

1. Time-varying natural mortality (productivity). Causal factors do not need to be identified with this approach and it can account for complex interacting effects.
2. Incorporating ecosystem effects using functional relationships. Results in a deeper understanding of the causes of productivity change, clarifies management options, and can improve population projections

The project objectives determine which of these approaches is most suitable. When the objective is operational (e.g. annual stock assessments) approach 1 is preferred. This approach can account for all ecosystem factors which influence natural mortality, including cumulative effects and interactions, without explicitly having to identify these factors and their functional relationships to components of productivity. It is also straightforward to validate the results via simulation.
Approach 2 would generally be preferred when the project objectives are strategic (e.g. research focusing on the causal factors that influence natural mortality variability). The goal with this approach is to better understand how specific ecosystem factors are influencing productivity by explicitly including them in the modelling itself. This can help to clarify the impact of specific ecosystem factors on the population which in turn can clarify appropriate management options and could improve the predictive ability of the model.

Tracking these changes in productivity is also critical when considering reference points. Reference points are often set as fixed values based on past population behaviour; typically, there is an underlying assumption of stationarity in natural mortality. The reference points set in this way are not appropriate when natural mortality is non-stationary; in general more flexibility in how reference points are adopted and utilized is necessary to account for the variability in productivity that is observed in these populations.

Simple vs Complex Models

The group also explored the utility of including ecosystem information into the growth, mortality, and, to a lesser extent, the recruitment components of a delay difference model. The simpler delay difference models work well when there is some index of natural mortality. Without such an index a good estimate of average natural mortality is needed or the model will provide biased estimates of biomass and other parameters. The model is not able to estimate natural mortality or a time trend in natural mortality without some informative priors. An ecosystem based index of natural mortality would be a candidate for incorporating ecosystem information into an assessment to help estimate variation in natural mortality (e.g. a predator index, temperature, etc.). Similarly, an ecosystem based index of recruitment could also be of benefit when a reliable estimate of recruit stage abundance is not available.
For the growth component of the model it was shown that environmental indices could have some benefit for projecting the future state of a population (i.e. predicting the biomass in the following year) if an index was available which was a good predictor for growth rates. Otherwise, unless growth was poorly measured, in which case a delay-difference model would likely be a poor model choice, there was minimal benefit to using an Ecosystem Approach for the growth component of a delay difference model. The delay-difference models used in this workgroup were not spatially explicit and were based on annual time-steps. The development of delay-difference models with finer spatial or temporal resolutions will likely require ecosystem indicators since the cost of traditional sampling methods to parameterize these models would often be prohibitive. For example, using depth, bottom type, and an existing plankton index to estimate spatio-temporal variability in growth could be used in place of a monthly survey if a causal relationship between growth and these variables is established. The ecosystem indicators would need to be available at a similar (or finer) scale to that of the model.

WG 4 Report: Ecosystem Assessment and Report Card

The objectives of WG 4 were to:

i. explore and assemble available data to develop indicators for ecosystem assessment
ii. identify and discuss existing indicators and information gaps
iii. identify and discuss tools and methods of communication for this purpose.

The WG discussion was split into two sessions:

Gathering the Elements
- What ecosystem drivers and properties do we want to represent with indicators?
- What data do we have for the Maritimes Region?

Developing the Assessment/Report Card
- Examples of ecosystem assessments and report cards
- Communication and Interpretation
- Placing single species in an ecosystem context (link back to WG1)

Discussion Part 1: Gathering the elements

Ecosystems have spatial structure which needs to be recognised prior to conducting an ecosystem assessment, i.e. the appropriate scale for the assessment needs to be identified. The appropriate scale is related to the objectives of the assessment <u>and</u> ecosystem properties such as structure, functioning and main drivers. In the Maritimes Region, NAFO Division are commonly used as proxies for ecosystem units, but in reality, these were designed around groundfish management and do not reflect broader ecosystem considerations. Several analyses have been conducted to explore and describe the ecosystem(s) of the Scotian Shelf bioregion and there is some coherence among them. For example, the division between the eastern and western Scotian Shelf is placed east of the NAFO 4WX Division Line.

The WG recommended the following:
- A structured approach is required to describe our ecosystems:
- bioregions/EPUs/Ecoregion (cf NAFA WG)
- A workshop (CSAS process) is required to agree on what the (fuzzy) boundaries of the ecosystem units should be
- We need to consistently report at these spatial scales
- Ideally there should be consistency among regions on how we define ecosystems and their boundaries.

What ecosystem drivers and properties do we want to represent with indicators?
Conceptual models can be very useful to synthesize thinking and understanding of how the different components of marine ecosystems interact. They can be developed

hierarchically to represent different components of the ecosystem with increased detail. For example, Figure 8 is focussed on the main physical and human drivers of the Scotian Shelf Bioregion. The biotic components are represented simply by functional groups. The intention is to build on this conceptual model and to add detail, such as invasive species and habitat and to explore how these systems will change due to pressures and climate change.

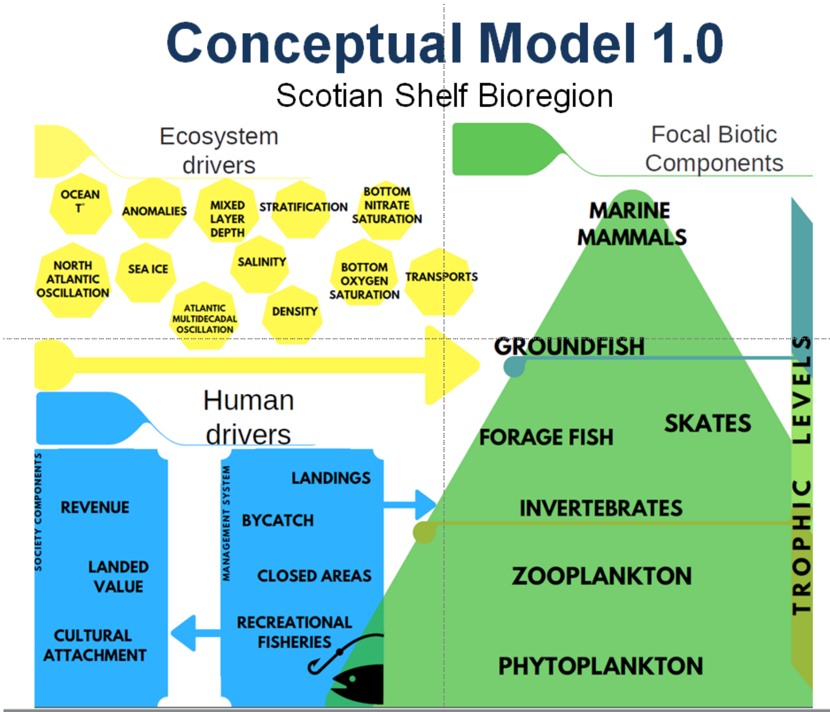

Figure 8. Conceptual diagram of the types of drivers that affect the Scotian Shelf Bioregion. Credit: Catalina Gomez.

What data do we have for the Maritimes Region?

There are multiple data sources in the Maritimes Region, including the following:

- Data – AZMP,RS data, RV Survey, Other survey data, Catch Data – see Data Compilation and Survey Report
- Industry Surveys - Snow crab survey, ITQ/Lobster survey, Halibut survey, 4Vn Sentinel, Shrimp Survey, Scallop Survey, Inshore Lobster Bay Settlement Survey, Clam Survey, FSRS Lobster Recruitment trap Survey, Grey Seals. Other
- Other Surveys such as Herring Acoustic Survey, Larval Herring Survey, BT Passamaquoddy Bay (Musquash Monitoring), Other?
- Environmental data layers developed by Jae Choi (for snow crab assessment)

However, there are also substantial data gaps:

- Coastal Data Gap
    - Distinguish between inshore and shelf (cf., SPERA project Kenchington and Wong)
    - Inshore/offshore energy transport

- Lobster and inshore herring relevant for the inshore/offshore linkages
- Habitat
- Benthos – we should put the RV survey to better use and identify more benthic species (cf., SPERA project Kenchington)

Methodological and Other Gaps:

- Habitat is missing from a lot of EBFM discussions.
    - Habitat Suitability Modelling (see also WG2):
        - Habitat functional group modelling – cluster analysis of environmental parameters to define suitable habitat
        - Need spatial distribution of fishing pressure as an indicator
        - Cumulative fishing pressure
- Invasive Species – how do we know when they are established? In Newfoundland and Labrador region for Aquatic Invasive Species to be established they need several consecutive warmer years

Discussion Part 2: Developing the Assessment and Report Cards

Several options of ecosystem assessments and report cards/visualisation method were presented and discussed, and the following conclusions reached:

Data Display

- Simpler is better
- Principal Component Analysis useful to simplify multiple indicators as it reduces the dimensionality of the problem and produce key signals from principal components. Use correlation matrix rather than co-variance matrix since this can deal with missing data.
- Anomaly plots are also useful as they place everything on the same scale and cumulative anomaly plots show overall signal and what is driving it (e.g. see Figure 3.1.5.3 in https://archive.nafo.int/open/sc/2015/scs15-19.pdf)
- Information and the audience:
    - What is the information that you want to present?
    - Who do you want to present it to?
    - What message are we trying to convey?
    - What is presented as contextual information for stock assessment people? Start with overview, and then look at indicators that will be relevant for the specific question(s).
    - What are the specific indicators of use to the single stocks (WG1)?

Report Cards

Several examples of report cards where shown, including one from the eastern Scotian Shelf, adapted from the NOAA (US) report card approach.

Question as to how ecosystem report cards and included into science advice for fisheries. How is a management decision made?

- In Alaska where the report card was developed, a detailed ecosystem assessment and “hot topic” report is also produced to provide context for ecosystem-based fisheries management. See https://access.afsc.noaa.gov/reem/ecoweb/Index.php?ID=0 for more information.
- NAFO is planning to develop 2 page ecosystem report cards for each stock in each production unit. This is at the research stage.
- Note that there is a link here to the complaint in the OCEANA report about the lack of consistency in stock assessments across Canada.

The **SAR** approach: need to show the **state** of the ecosystem, the **action** required, and the **risk** associated with it.

- Will managers take action and the ecosystem level?
- TAC decisions are already been made for invertebrate fisheries such as snow crab and shrimp in the Maritimes Region based on environmental parameters

State Of The Ocean (SOTO) Reporting

This year (2017/2018) the Department has been tasked with developing a State of the Atlantic Ocean Report as part of an annual process that will inform Canadians about the current status and potential state of Canada’s oceans.

- Goal is a consistent approach across all regions (nationally and among the Atlantic regions; however, process will be learned from and modified each year)

- Workplan governed by SEC, next meeting in June
    - 1 year workplan - produce a public report (~10 pages) based on existing information (side product is technical document useful internally)
    - 4 year workplan (2021/2022) – Focus will shift as process develops, goal to get to a better place

- Participation is required as this is a Treasury Board submission

- What can we generate this year?
    - Report card on status and trends of existing stocks? What is missing?
    - Functional groups or other groupings (warm water/cold water species) may be used as in Newfoundland and Labrador region. A small number would be preferable to assist interpretation and make messaging clear.

- Indicators of fish body condition in Maritimes region although this is not available in Newfoundland and Labrador region as fish length measuremnst are not available.
- Flagship species -- cod, lobster, halibut, seals, snow crab
- *Calanus* story is a good one (whales, lobster gear)

- Need a set of sensible indicators. What is the key message? Management action needed?

- Atlantic Zone workshop in May (national WG) to discuss next steps in collecting and coordinating science information.

- Lead scientists will be contacted with further information as meetings progress

REFERENCES

Araújo J., Bundy A. (2011) Description of three Ecopath with Ecosim ecosystem models developed for the Bay of Fundy, Western Scotian Shelf and NAFO Division 4X. Can Tech Rep Fish Aquat Sci:189.

Benoît, H.P., and Swain, D.P. (2008). Impacts of environmental change and direct and indirect harvesting effects on the dynamics of a marine fish community. Can. J. Fish. Aquat. Sci. 65: 2088-2104.

Benoît, H.P., and Swain, D.P. (2011). Changes in size-dependent mortality in the southern Gulf of St. Lawrence marine fish community. DFO Can. Sci. Adv. Sec. Res. Doc. 2011/039. iv + 22 p.

Benoît, H.P., Swain, D.P., Hammill, M.O. (2011a). A risk analysis of the potential effects of selective and non-selective reductions in grey seal abundance on the population status of two species at risk of extirpation, white hake and winter skate in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/033. iv + 30 p.

Benoît, H.P., Swain, D.P., Bowen, W.D., Breed, G. A., Hammill, M.O., and Harvey, V. (2011b). Evaluating the potential for grey seal predation to explain elevated natural mortality in three fish species in the southern Gulf of St. Lawrence? Mar. Ecol. Prog. Ser. 442:149-167.

Benoît, H.P., Gagné, J.A., Savenkoff, C., Ouellet, P., and Bourassa M.-N. (eds.). 2012. State-of-the-Ocean Report for the Gulf of St. Lawrence Integrated Management (GOSLIM) Area. Can. Manuscr. Rep. Fish. Aquat. Sci. 2986: viii + 73 pp.

Buren AD, Koen-Alonso M, Pepin P, Mowbray F, Nakashima B, Stenson G, Ollerhead N, Montevecchi WA (2014) Bottom-Up Regulation of Capelin, a Keystone Forage Species. Plos One 9

Chaput, G. and Benoît, H.P. (2012). Evidence for bottom-up trophic effects on return rates to a second spawning for Atlantic Salmon (*Salmo salar*) from the Miramichi River, Canada. ICES J. Mar. Sci. 69: 1656–1667.

Chassé, J., Galbraith, P.S., Lambert, N., Moriyasu, M., Wade, E., Marcil, J., and Pettipas, R.G. (2015). Environmental conditions in the southern Gulf of St. Lawrence relevant to snow crab. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/009. v + 28 p.

Dawe EG, Koen-Alonso M, Chabot D, Stansbury D, Mullowney D (2012) Trophic interactions between key predatory fishes and crustaceans: comparison of two Northwest Atlantic systems during a period of ecosystem change. Marine Ecology Progress Series 469:233-248

DFO (2011). Proceedings of the Maritimes Region Science Advisory Process on the Assessment Framework for Southwest Nova Scotia/Bay of Fundy Herring; 24-28 January 2011. Can Tech Rep Fish Aquat Sci:28.

DFO (2015). Assessment of Northern Shrimp on the Eastern Scotian Shelf (SFAs 13-15). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/004.

DFO (2017a). Stock assessment of Witch Flounder (*Glyptocephalus cynoglossus*) in the Gulf of St. Lawrence (NAFO Divs. 4RST) to 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/036.

DFO (2017b). Assessment of snow crab (*Chionoecetes opilio*) in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) to 2016 and advice for the 2017 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/004.

DFO (2017c). An assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4– 6 and of Striped Shrimp (*Pandalus montagui*) in Shrimp Fishing Area 4 in 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/012, 26p.

DiBacco, C., Johnson, C.L., Moore, A.M., and Scriven, D.R. (2016). Recommendations for a DFO Maritimes Coastal Monitoring Program. Can. Tech. Rep. Fish. Aquat. Sci. 3185: viii + 29 p.

Dufour, R. and 13 other co-authors. (2010). Ecosystem status and trends report: Estuary and Gulf of St. Lawrence ecozone. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/030. v + 187 p.

Edwards, A.M., Haigh, R., Tallman, R., Swain, D.P., Carruthers, T.R., Cleary, J.S., Stenson, G. and Doniol-Valcroze, T. (2017). Proceedings of the Technical Expertise in Stock Assessment (TESA) National Workshop on 'Incorporating an ecosystem approach into single-species stock assessments' 21-25 November 2016, Nanaimo, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 3213: vi + 53 p.

Garcia, S. M., Kolding, J., Rice, J., Rochet, M. J., Zhou, S., Arimoto, T., Beyer, J. E., Bundy, A., et al. (2012). Reconsidering the consequences of selective fisheries. Science, 335: 1045–1047.

Gilman E, Weijerman M, Suuronen P. Ecological data from observer programmes underpin ecosystem-based fisheries management. 2017. ICES Journal of Marine Science, 74 (6): 1481–1495. https://doi.org/10.1093/icesjms/fsx032.

Guénette, S., and Stephenson, R.L. (2012). Accounting for predators in ecosystem-based management of herring fisheries of the western Scotian Shelf, Canada. In Global Progress in Ecosystem-Based Fisheries Management. Edited by G.H. Kruse, H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, and C.I. Zhang. Alaska Sea Grant, University of Alaska, Fairbanks, Alaska. pp. 105-128.

ICES. (2016). Final Report of the Working Group on the Northwest Atlantic Regional Sea (WGNARS), 21-24 March 2016, Falmouth, USA. ICES CM 2016/SSGIEA:03. 42 pp

Levin, P. S., Kelble, C. R., Shuford, R., Ainsworth, C., deReynier, Y., Dunsmore, R., Fogarty, M. J., Holsman, K., Howell, E., Monaco, M., Oakes, S., and Werner, F. (2014). Guidance for implementation of integrated ecosystem assessments: a US perspective. – ICES Journal of Marine Science, 71: 1198–1204.

Mullowney DRJ, Dawe EG, Colbourne EB, Rose GA (2014) A review of factors contributing to the decline of Newfoundland and Labrador snow crab (*Chionoecetes opilio*). Reviews in Fish Biology and Fisheries 24:639-657

Power, M.J., Knox, D., MacIntyre, A., Melvin, G.D., and Singh, R. (2013). 2011 Evaluation of 4VWX Herring. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/085. iv + 85 p.

Ricard, D., Morin, R., Swain, D.P., and Surette, T. (2016). Assessment of the southern Gulf of St. Lawrence (NAFO Division 4T) stock of American plaice (*Hippoglossoides platessoides*), March 2016. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/057. ix + 43 p.

Surette, T., and Swain, D.P. (2016). The Status of Yellowtail Flounder in NAFO Division 4T to 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/058. x + 74 p.

Stenson GB, Buren AD, Koen-Alonso M (2016) The impact of changing climate and abundance on reproduction in an ice-dependent species, the Northwest Atlantic harp seal, *Pagophilus groenlandicus*. ICES J Mar Sci 73:250-262

Swain, D.P. 2016. Population modelling results for the assessment of Atlantic herring (*Clupea harengus*) stocks in the southern Gulf of St. Lawrence (NAFO Division 4T) to 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/061. xi + 53 p.

Swain, D.P., and Benoît, H.P. (2015). Extreme increases in natural mortality prevent recovery of collapsed fish stocks in the southern Gulf of St. Lawrence. Mar. Ecol. Prog. Ser. 519: 165-182.

Swain, D. P., Benoît, H. P., Hammill, M. O., McClelland, G., and Aubry, É. (2011). Alternative hypotheses for causes of the elevated natural mortality of cod (*Gadus morhua*) in the southern Gulf of St. Lawrence: the weight of evidence. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/036. iv + 33 p.

Swain, D.P., Savoie, L., Cox, S.P., and Aubry, E. (2015a). Assessment of the southern Gulf of St. Lawrence Atlantic cod (*Gadus morhua*) stock of NAFO Div. 4T and 4Vn (November to April), March 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/080. xiv + 137 p.

Swain, D.P, Benoît, H.P, and Hammill, M.O. (2015b). Spatial distribution of fishes in a Northwest Atlantic ecosystem in relation to risk of predation by a marine mammal. J. Anim. Ecol. 84:1286-1298.

Swain, D.P., Savoie, L., and Cox, S.P. (2016). Recovery potential assessment of the Southern Gulf of St. Lawrence Designatable Unit of White Hake (*Urophycis tenuis* Mitchill), January 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/045. vii + 109 p.

White, A.L., R.I. Perry, M.A. Koops, R.G. Randall, A. Bundy, P. Lawton, M. Koen-Alonso, D. Masson, P.S. Galbraith, M. Lebeuf, M. Lanteigne, and C. Hoover. (2013). A National Synthesis of the Fisheries and Oceans Canada Ecosystem Research Initiative. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/027. v + 31 p.

Zador, S. G., Holsman, K. K., Aydin, K. Y., and Gaichas, S. K. 2016. Ecosystem considerations in Alaska: the value of qualitative assessments. ICES Journal of Marine Science, doi:10.1093/icesjms/fsw144.