xii) Progress on the "Roadmap for EAF" (Item 13)

Fisheries Commission requested Scientific Council to report on the progress of the "Roadmap for developing an Ecosystem Approach to Fisheries for NAFO" regarding:

a) The general progress of the Roadmap;

b) Further developments on the stock interactions studies between cod, redfish and shrimp in the Flemish Cap by applying multi species models and by quantifying potential yield and biomass tradeoffs with different fishing mortalities in the multispecies context. The predation of cod over cod juveniles should be taken into account

c) Developments on stock interaction studies for the Grand Banks (NAFO Divisions 3KL and 3NO). The spatial overlap between these stocks should be considered.

Scientific Council responded:

a) The "Roadmap" lays out the organizing framework to develop an EAF. It is a framework that includes both Scientific Council and Fisheries Commission. Scientific Council has made progress on many aspects of the Roadmap, although there are still gaps that need to be addressed (see Table 2). Required inputs from Fisheries Commission include 'goal setting' (e.g. defining explicit ecosystem objectives, developing governance mechanisms to discuss/set multispecies objectives), and 'monitoring' (e.g. developing mechanisms to ensure the availability of catch information for both commercial and non-commercial species); 'risk assessment' would also require important input from Fisheries Commission.

Limited human resources and funding support impose limits to the pace at which many of the studies required to support the roadmap can be carried out

b) Studies estimating cod consumption of shrimp, redfish and cod (i.e. cannibalism) and redfish consumption of shrimp in the Flemish Cap reinforced the notion that strong trophic interactions between these species exist. Additional work on multispecies modeling incorporated these results and showed that model outcomes were similar in trend to work reported by Scientific Council in 2012. Further work is required to provide the required quantitative advice.

c) A variety of studies (e.g. analysis of ecosystem trends, diet studies, ecological modeling) are ongoing.

a) The "Roadmap for developing an Ecosystem Approach to Fisheries for NAFO" (hereafter referred to as "Roadmap") was initially conceived in 2010 as a conceptual foundation from where Scientific Council could discuss and propose a way forward for an ecosystem approach to fisheries for NAFO. The Roadmap is not a fixed plan; as its name indicates, it is a guiding set of ideas whose details evolve as it is developed and implemented. Limited human resources and funding support impose limits to the pace at which many of the studies required to support the roadmap can be carried out.

The Roadmap was originally developed around the concept of Integrated Ecosystem Assessments (IEA), and its core premises are: a) the approach has to be objective-driven, b) it should consider long-term ecosystem sustainability, c) it has to be a place-based framework, and d) trade-offs have to be explicitly addressed.

In terms of setting sustainable exploitation levels, the overall framework can be summarized as a 3-tiered hierarchy. The first tier defines fishery production potential at the ecosystem level, taking into account environmental conditions and ecosystem state. This allows a first order consideration for the potential influence of large scale climate/ecological forcing on fishery production, as well as explicitly considering the basic limitation imposed by primary production on ecosystem productivity. The second tier utilizes multispecies assessments to allocate fisheries production among a set of commercial species, taking into account species interactions as well as considerations on the resilience and stability of the exploited assemblage. This tier explicitly considers the trade-offs among fisheries, and allows identifying exploitation rates which are consistent with multispecies sustainability. The third tier involves single-species stock assessment, where the exploitation rates derived from tiers 1 and 2 can be further examined to ensure single-species sustainability. This hierarchical sequence allows considering the sustainability of the exploitation at the ecosystem, multispecies assemblage, and single stock level.

The current representation of the Roadmap (Fig. 8) provides an operational perspective of how the EAF could be implemented in a possible work-flow process. This schematic incorporates the hierarchical approach to define exploitation rates, and integrates the impacts on benthic communities (e.g. VMEs) associated with the different fisheries that take place within the ecosystem.

Although significant progress has been made since the original proposal of the Roadmap, there is still a fair amount of work that remains to be done (Table 2). Fully addressing Fisheries Commission Request 13a requires input not just from Scientific Council, but also from Fisheries Commission. Summarizing the progress on the Roadmap should not be limited to the work done by Scientific Council and its WGs, it should also include the work that Fisheries Commission and its WGs have done. Some of the most important components of the Roadmap (Fig. 8) that requires input from Fisheries Commission includes 'goal setting' (e.g. defining explicit ecosystem objectives, developing governance mechanisms to discuss/set multispecies objectives), and 'monitoring' (e.g. developing mechanisms to ensure the availability of catch information for both commercial and non-commercial species); although 'risk assessment' would also require important input from Fisheries Commission. Table 2 provides a summary of the progress to date following the structure described in Fig. 8.

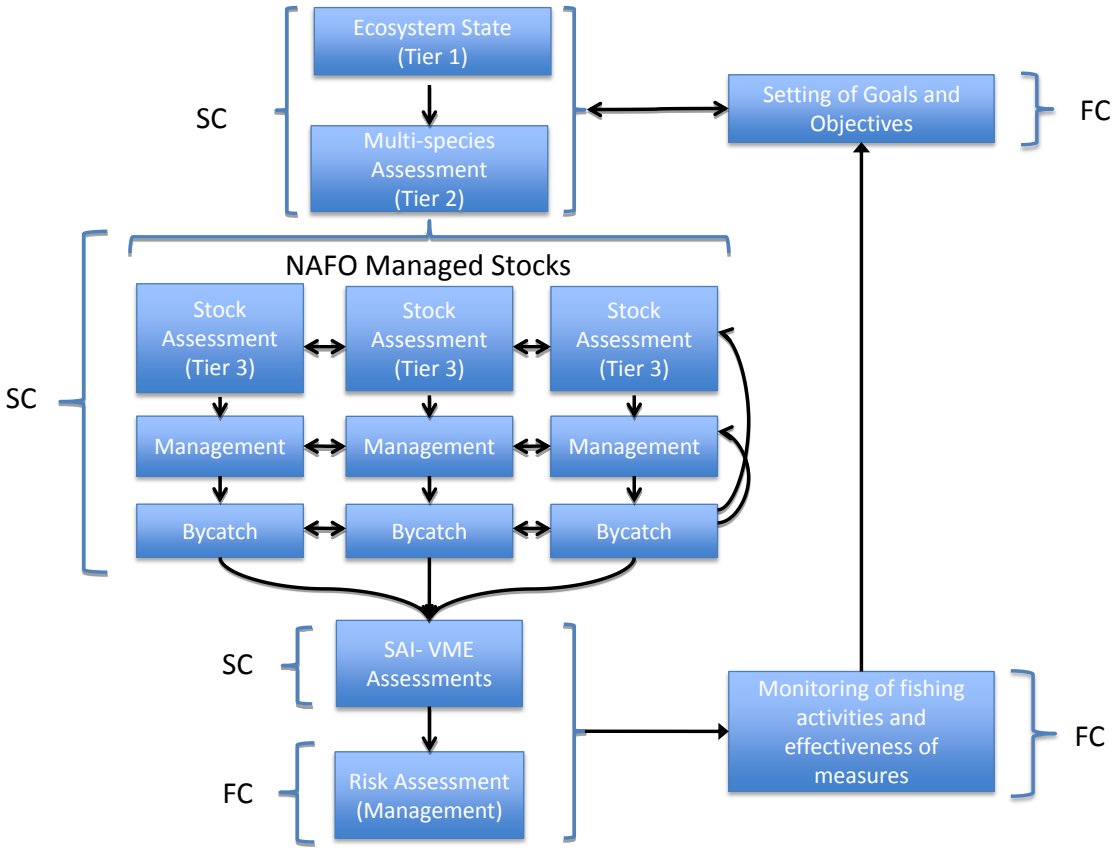

Fig. 8. Current working template of the Roadmap.

b) Studies on food consumption by cod, and redfish in the Flemish Cap were carried out. In these studies, emphasis was put on estimating cod consumption of shrimp, redfish and cod (i.e. cannibalism), and on the estimation of redfish consumption of shrimp. These consumption analyses reinforced the notion of strong trophic interactions between these three species in the Flemish Cap. Beyond their stand-alone usefulness, and their role in defining possible scenarios for natural mortality in stock-assessment, these consumption estimates were also incorporated into the ongoing multispecies modeling exercise for the Flemish Cap.

The multispecies modeling work was advanced by exploring the impact of different catchability considerations on both qualitative and quantitative model behavior. Current results indicate that the qualitative behavior of the model is robust to catchability assumptions, but quantitative estimates are not. Therefore, further work is required before the quantitative answers required can be provided.

c) Studies on species interactions and ecosystem trends in the Grand Banks are ongoing. Between 2007 and 2012, the Ecosystem Research Initiative of Fisheries and Oceans Canada supported a research program on the Newfoundland-Labrador marine ecosystem (the ERI-NEREUS program). ERI-NEREUS, together with other dedicated research efforts like NEREIDA, was instrumental in the development of the Roadmap. These studies explored, for example, trends in fish functional groups, the role of fishing pressure and environmental drivers on common trends in core groundfishes, diets of core groundfish (cod, Greenland halibut, American plaice, yellowtail flounder, and redfish) and pelagic (capelin, sandlance, and Arctic cod) fishes, as well as exploring bottom-up (climate, food availability) and top-down (predation, impact of fishing) effects on key species. Many of these results have been presented at SC and SC WGEAFM meetings, and even though the ERI-NEREUS program has already ended, there are ongoing efforts aimed at continuing some of this work in support of both, the Roadmap and DFO efforts towards developing ecosystem approaches. This ongoing work also includes estimations of food consumption for fish stocks in the Grand Banks, as well as the development of minimum-realistic multispecies models. Results from these research activities are being tabled at SC as they become available, but the complexity of the Grand Bank ecosystem, together with limited human resources and funding support, necessarily impose limits to the pace at which many of these studies can be carried out.

Table 2. Summary of progress on the development and implementation of the Roadmap to date. Information is schematically summarized following the steps (boxes) as described in Figure 1. For each component (box), a brief description of the task associated with it, the progress to date, the work that still needs to be done, and some issues deemed critical are provided. In many cases, other NAFO bodies are expected to have relevant information that could add to the progress summarized here by Scientific Council.

Roadmap Component	Progress to date	Work to be done	Critical issues
Goal Setting			
• Defining ecosystem level objectives for NAFO fisheries.	Initial discussions on the implications of species interactions in setting TAC for species in the Flemish Cap. Acknowledgement of the role of trophic interactions in the context of management of fisheries directed to these spp.	Development of governance mechanisms to discuss and set multispecies objectives	Lack of explicit objectives
	[more to be added by FC, and SC-FC WGs]	[more to be added by FC, and SC-FC WGs]	[more to be added by FC, and SC-FC WGs]
Ecosystem State			
• Defining spatial management units	Ecoregion analyses for Newfoundland and Labrador, Flemish Cap, Atlantic US, and partially on Scotian shelf.	Integrate ecoregion analysis across NAFO convention area	Consideration of the broader set of climate change impacts

Roadmap Component	Progress to date	Work to be done	Critical issues
• Exploring temporal variability of units	Some candidate ecosystem-level management units identified.	Correspondence between stock boundaries and candidate ecosystem management units	Better integration of environmental and oceanographic information (e.g. STACFEN work)
• Defining productivity state and its variability	Preliminary Fisheries Production Potential models for Newfoundland and Labrador, Flemish Cap, and Scotian Shelf; studies on this topic are also available for the Atlantic US.	Consideration of different scales and how to integrate them	Incorporation of northern NAFO divisions (0 and 1)
	Preliminary Aggregate Biomass Production models for Newfoundland and Labrador, Flemish Cap; studies on this topic are also available for Scotian Shelf and Atlantic US.	Identification of ranges of variability in the past compared to present.	Incorporation of oceanic waters (i.e. open ocean ecosystems)
	Initial studies linking elements of productivity and environmental drivers in Newfoundland and Labrador, and Flemish Cap; studies on this topic are also available for Scotian Shelf and Atlantic US.	Improved Fisheries Production Potential and Aggregate Biomass models	More comprehensive consideration of top predators (seabirds, sharks, seals, and cetaceans)
		Integrate environmental drivers into models of ecosystem productivity.	Developing more specific/functional connections and collaborations with ICES Working Group on the Northwest Atlantic Regional Sea (WGNARS)
Multispecies assessment			
• Description of species interactions and trends	Studies of food habits in Flemish Cap and Newfoundland and Labrador; studies on this topic are also available for Scotian Shelf and Atlantic US	Improving multispecies modelling for Flemish Cap	Considerations of environmental drivers and species interactions on reproductive potential (e.g. integration of the NAFO SC WGRP work)

Roadmap Component	Progress to date	Work to be done	Critical issues
• Quantification of diets and predation	Preliminary modelling of key species in the Flemish Cap.	Developing preliminary multispecies models for Newfoundland and Labrador	Enhanced participation and incorporation of information from Scotian Shelf and US
• Understanding the role of environmental drivers in ecosystem structure and dynamics	Testing specific hypothesis of bottom-up and top-down regulation in Newfoundland and Labrador	Improved characterization of diets and its variability in space and time	Developing more specific/functional connections and collaborations with ICES Working Group on the Northwest Atlantic Regional Sea (WGNARS)
• Understanding the response of food webs to anthropogenic impacts	Studies of common trends among multiple stocks in Flemish Cap, and Newfoundland and Labrador; studies on this topic are also available for Scotian Shelf and Atlantic US.	Improved/additional estimation of consumption/predation for key stocks	
• Definition of multispecies reference points	Estimation of consumption/predation for some stocks	Improved understanding of the linkage between lower trophic level characteristics and dynamics and fish production.	
• Provision of advice on candidate TAC based on multispecies considerations		Study the role of environmental drivers in the regulation and structure of food webs.	
Stock Assessment			
• Stock identification	Current single-species assessments	Development and/or improvement of assessment models.	Reliable estimates of fishery catches and stock indicators for their use in stock and ecosystem assessments
• Assessment of the status of the stock	Some shrimp assessments include predation	Inclusion of predation in more assessments.	Improve integration between stock-assessments and ecosystem analyses.
• Consideration of processes/environmental drivers affecting recruitment, growth, maturation and spatial distribution.	Redfish assessment has considered the impact of predation in setting natural mortality.		

Roadmap Component	Progress to date	Work to be done	Critical issues
• Consideration of sources of mortality at the stock level			
Management			
• Provision of advice on stock-specific TAC with multispecies considerations	Provision of current TAC advice on NAFO stocks	Development of rebuilding plans for more stocks.	Definition of explicit management objectives for each stock
• Definition of stock-level reference points	Precautionary approach framework and reference points for some stocks	Further development of reference points.	Consideration of stock specific management objectives in the context of ecosystem objectives
• Development and implementation of harvest control rules, stock-specific management strategy evaluation frameworks and rebuilding plans	Management strategy evaluation approach for Greenland halibut	Revision of the precautionary approach framework	
	Rebuilding plans for some stocks are under development	Complete rebuilding plans (including harvest control rules) Develop mechanisms to links and evaluate TAC from multispecies candidates.	
	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]
By-catch			
• Evaluation of by-catch of commercial and non-commercial species (including VME-defining spp).	Compilation of available information of bycatch by fishery for commercial spp.	Incorporation of non-commercial spp (including VME-defining spp)	Lack of full catch information for both commercial and non-commercial spp, including VME-defining spp, on a tow-by-tow basis
• Reporting of bycatch for use in all assessments (stocks, ecosystems, and SAI-vmes)	Suite of management measures associated with by-catch (e.g. Limits of spp under moratoria in directed fisheries)	Improve reliability of catch information	

Roadmap Component	Progress to date	Work to be done	Critical issues
• Development and implementation of measures to control by-catch levels.	Adoption of the catch reporting tow-by-tow	Link tow position with catch information (e.g. Full use of vms data for scientific analysis) Develop comprehensive approach to report bycatch across fisheries and make available to NAFO bodies for their inclusion in analyses.	
	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]
Assessment of Significant Adverse Impacts (SAI) on VMEs			
• What the nature of the VME is.	Identification and mapping of VME elements and indicator species.	Assess VME resilience.	Lack of full catch information for both commercial and non-commercial species, including VME-defining species, on a tow-by-tow basis
• What the nature of the pressure is.	Identification and review of impacts on seabed.	Integration of macro and megafauna data layers.	Understanding the functional relationships between VMEs and fisheries yields.
• What the impact is, as a combination of the nature of the VME and pressure.	Assessment of distribution and intensity of fishing activity (including initial evaluation of cumulative pressure from fishing), taking into account the type of fishery, gear employed, etc.	Determine the status of vmes as essential fish habitats.	Determining what proportion of vmes is optimal in a given fishery (i.e. How much VME we need to protect).
• Analysis of fishing impacts on benthic ecosystems	Modelling VME indicator species by-catch	Assessment of current closures for the protection of high concentrations of vme-indicator species by 2014.	How vme closures relate to other human activities, and how these interactions may affect fisheries and fisheries resources.
	Modelling VME presence.	Fisheries assessments regarding their impacts on VMEs (i.e. First assessments by 2016).	

Roadmap Component	Progress to date	Work to be done	Critical issues
	Evaluating criteria for VME indicator species.	Use the tools developed for VMEs to assess fishing impacts on benthic ecosystems at large.	
Risk Assessment			
• Assess the likelihood of significance adverse impacts on VMEs, in the context of current activities and objectives.	Development of selected VME-indicator spp maps, showing the risk of bottom fishing impacts.	Continue the development and implementation of management measures to minimize or prevent SAI on VME s	Develop, design, and implement a strategy to assess risk at the ecosystem level.
• Assess the likelihood of fisheries having significant adverse impacts on ecosystem structure and function.	Implementation of closed areas for the protection of high concentration of selected VME -indicator spp.	Develop guideline to ensure consistent application of risk assessment criteria in the context of current activities and objectives.	Ensure full interaction between all NAFO bodies to define risks in a manner that is acceptable and properly understood by all.
• Development and implementation of management actions in response to the outcomes of risk assessments.	Implementation of closed areas for the protection of physical VME elements		
	Implementation of encounter protocols for selected VME-indicator spp		
	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]
Monitoring			
• Collection, analysis, and interpretation of data pertaining to ecosystem status and human activities relevant to the NAFO convention objectives.	RV surveys (stock status, ecosystem interactions, etc)	Improve/enhance collection of scientific information on non-commercial spp in RV surveys	Lack of full catch information for both commercial and non-commercial spp, including VME-defining spp, on a tow-by-tow basis
• Use of available data to track the effectiveness of management measures	VMS (fishing footprint, intensity of fishing, compliance of management regulations)	Improve reliability of catch information from commercial fleets	Basic scientific information lacking in some areas (e.g. Seamounts, northern areas)

Roadmap Component	Progress to date	Work to be done	Critical issues
	NAFO and scientific observer programs	Link tow position with catch information (e.g. Full use of VMS data for scientific analysis)	Basic scientific data are very limited for some ecosystem components (e.g. Epipelagic and bathypelagic zones).
		Develop and integrated way to summarize and track fleet composition and activities.	
	[more to be added by FC, and SC-FC WGs]	[more to be added by FC, and SC-FC wgs]	[more to be added by FC, and SC-FC wgs]