Participatory modelling of the lobster fishery's social-ecological system with commercial harvesters in the Maritimes Region

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By

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ABSTRACT

Tam, J.C., Parlee, C. E., Pourfaraj, V., Campbell-Miller, J., Cook, A. M., Sonnenberg, M., Morse, B., Armsworthy, S., Denton, C., Element, G., Howse, V., Zisserson, B. 2025. Participatory modelling of the lobster fishery's social-ecological system with commercial harvesters in the Maritimes Region. Can. Tech. Rep. Fish. Aquat. Sci. 3725: v + 51 p. https://doi.org/10.60825/4zv2-8609

Participatory modelling is an approach for developing research and providing scientific support for decision-making. This approach actively involves the collaboration between rightsholders, stakeholders, experts, and community members. It aims to incorporate diverse perspectives, local knowledge, and insights from various participants to create models that reflect a contextually relevant and comprehensive understanding of a complex system. The Blue Economy Lobster Team held a participatory modelling workshop on May 24, 2023, with a harvester association and commercial harvesters in Grand Manan (Lobster Fishing Area 38). The workshop aimed to refine a conceptual model of the American Lobster fishery previously developed by a multidisciplinary team of DFO staff with input from a lobster fishing association members and harvesters. Here we provide documentation of the pilot workshop, along with insights and lessons learned from the process. Contributing participants were able to collaborate and refine a conceptual model. Through the process, participants developed a shared understanding surrounding the benefits, issues, and challenges of the lobster fishery. Ultimately, this experience demonstrated that new tools such as conceptual modelling can be useful in improving the understanding of social-ecological systems that impact fisheries and can ultimately provide transparency in the provision of science.

RÉSUMÉ

Tam, J.C., Parlee, C. E., Pourfaraj, V., Campbell-Miller, J., Cook, A. M., Sonnenberg, M., Morse, B., Armsworthy, S., Denton, C., Element, G., Howse, V., Zisserson, B. 2025. Participatory modelling of the lobster fishery's social-ecological system with commercial harvesters in the Maritimes Region. Can. Tech. Rep. Fish. Aquat. Sci. 3725: v + 51 p. https://doi.org/10.60825/4zv2-8609

La modélisation participative est une approche utilisée pour développer des recherches et fournir un appui scientifique à la prise de décision. Cette approche implique activement la collaboration entre les détenteurs de droits, les parties prenantes, les experts et les membres de la communauté. Elle vise à intégrer des perspectives diverses, des savoirs locaux et les connaissances de différents participants afin de créer des modèles reflétant une compréhension contextuelle et complète d'un système complexe L'équipe « Économie bleue – Homard » a organisé un atelier de modélisation participative le 24 mai 2023, avec une association de pêcheurs et des pêcheurs commerciaux à Grand Manan (Zone de pêche au homard 38). L'atelier avait pour objectif de raffiner un modèle conceptuel de la pêche au homard d'Amérique précédemment élaboré par une équipe multidisciplinaire du MPO, avec la participation de membres d'une association de pêcheurs de homard et de pêcheurs eux-mêmes. Nous présentons ici la documentation de cet atelier pilote, ainsi que les enseignements et les leçons tirés du processus. Les participants ont pu collaborer et améliorer un modèle conceptuel. Au cours de ce processus, ils ont développé une compréhension commune des avantages, des enjeux et des défis liés à la pêche au homard. En fin de compte, cette expérience a démontré que de nouveaux outils, comme la modélisation conceptuelle, peuvent être utiles pour améliorer la compréhension des systèmes socioécologiques qui influencent les pêches et peuvent, en fin de compte, renforcer la transparence dans la production de connaissances scientifiques.

Introduction

Fisheries are often composed of a variety of interacting factors that make up a complex system, including stock status, stock productivity, climate, habitat, fishing activities, and benefits to coastal communities. Ecosystem Approaches aim to incorporate scientific information of different types to manage resources and associated Social-Ecological Systems (SES; Ostrom 2009) in a flexible and adaptive manner while meeting societal and ecological objectives (McLeod et al. 2005; Link and Browman 2017; Tam et al. 2024). Social-ecological systems that support Ecosystem approaches are representations of combined social-cultural, economic, ecological, and governance components that reflect the complexity of a system (Pourfaraj et al. 2022b). With SESs being central to Ecosystem Approach principles, the tools and methods used to tailor a conceptual model of the SES are important to meet specific management objectives. Thus, the development of an SES is dependent on the information pathways to deliver scientific advice for decision-making (e.g., setting a harvest control rule, ecosystem-level reporting), and the beneficiaries of such scientific advice (rightsholders, stakeholders, and resource managers).

The lobster fishery is culturally and economically important in the Maritimes Region. In 2023, it was estimated to contribute over $1.76 B in Atlantic Canada (DFO 2025). It is a fishery that is managed and assessed by management units or Lobster Fishing Areas (LFAs; DFO 2023) which have been defined based on historical boundaries, not biological stocks (Campbell-Miller et al. 2024). Assessments are indicator-based, using catch per unit effort (CPUE; kg/trap haul) as the main indicator to determine stock status in many areas. Relying primarily on biological or simple CPUE indicators does not incorporate the complexity of the ecosystem perspective on the lobster fishery (e.g., including changes to harvester behaviour or impacts of climate change to scientific advice). Thus, moving to a more holistic approach to providing stock advice requires a fundamental change which relies on describing the information pathways reflecting the wide range of impacts on, and complexities of, the social-ecological system that ultimately impacts the fisheries and stocks.

One of the methods that can help to improve understanding and incorporate ecosystem information into scientific processes is conceptual models or qualitative models (Melbourne-Thomas et al. 2012; Reum et al. 2021; ICES 2022; Tam et al. 2025). Such models, when used to represent SESs can incorporate varying information types (qualitative, fuzzy, quantitative) into representative models that include indicators and drivers as model components. Such models can be a practical way to include multiple types of knowledge (beyond science-based knowledge) into scientific processes (Table 1). Thus, model components with quantitative information such as fisheries landings can be explored alongside those that are more qualitative, such as sustainable livelihoods. Initial drafts of such models have already been created for lobster in the Maritimes Region (Pourfaraj et al. 2022b, 2022a)

Table 1. Definitions of knowledge types (adapted from (Berkes et al. 2007; Garcia-Quijano 2007; Berkström et al. 2019; Alexander et al. 2019).

Term	Definition	Information types
Local Ecological Knowledge (LEK)	Knowledge, beliefs, practices, and understandings that people in a specific local community have about their environment, ecosystems, and natural resources. It is the knowledge that is developed over one's lifetime by interacting with people living in close proximity to and their natural surroundings. LEK is often unique to a particular culture, region, or community and is grounded in the experiences and observations of local people.	Ecological processes Resource management Weather and climate Medicinal and cultural uses Biodiversity and species identification Adaptation strategies
Traditional Ecological Knowledge (TEK)	Accumulated knowledge, practices, beliefs, and insights that Indigenous and local communities have developed over generations through their interactions with the environment.	Local spatial context Inter-generational Cultural significance
Experiential Knowledge (EK)	Knowledge that is gained through direct personal experience, observation, and interaction with the world. It is knowledge that is acquired through sensory perception, experimentation, and practical engagement with various phenomena. Experiential knowledge is valuable because it is grounded in personal involvement and engagement with the real world.	Everyday life Skill development Professional expertise Physical world understanding Cultural practices
Science-Based Knowledge	An evolving body of knowledge that tends to favor objectivity, reductionism, repeatability, and peer-review. It is grounded in empirical evidence, rigorous research, and systematic inquiry.	Empirical evidence Objectivity Systematic inquiry Repeatability Peer review

What is participatory modelling and how is it useful to support operational Ecosystem Approaches to Fisheries Management (EAFM)?

Participatory approaches are ways of gathering data and producing knowledge that are conducted via a collective process as opposed to individual/isolated ones. The purpose of participatory approaches is to promote an action or some form of change in the *status quo* (Bennett et al. 2017; Maund et al. 2022). There is evidence for increasing use of participatory and collaborative approaches in governance, policy development, and decision-making by employing suitable tools and methods (Benson and Stephenson 2018; Mukherjee et al. 2018). Among Ecosystem Approaches (e.g. that support EAFM), multispecies Management Strategy Evaluation (MSE) and Integrated Ecosystem Assessment (IEA) are some of the processes that have identified the need for adopting more participatory approaches to promote collaboration and transparency when dealing with complex resource management issues, ultimately paving the way for operational Ecosystem Based Management (DePiper et al. 2017). When done effectively, participatory approaches encourage an open discussion, help to build rapport, and enhance the relationship between the researchers and other knowledge holders (e.g., rightsholders, stakeholders) (Mukherjee et al. 2018).

Participatory modeling (or collaborative modeling) is defined as engaging with stakeholders to gather data and their knowledge of the topic while applying a purposeful learning process to co-create a shared representation of scientific research. Knowledge types such as Local Ecological Knowledge (LEK), Traditional Ecological Knowledge (TEK), or Experiential Knowledge (EK) have crucial roles in participatory modelling in that they help to build the contextual understanding, improve model validity, and help to overcome data gaps. While the process of creating conceptual models to represent the SES of the lobster fishery in the Maritimes Region has already begun (Pourfaraj et al. 2022a, b), the next step in the process requires engaging harvesters to develop a realistic and comprehensive model for operational use at the stock level, in this case the LFA.

When considering the engagement with harvesters for participatory modelling, it is important to assess the level of participation that is required or desired for a given scientific advice process. In the case of lobster science in the Maritimes Region, the goal is to achieve **partnership** in relation to stakeholder participation in this process (Figure 1). Partnership is defined as citizens (or in this case primary stakeholders, harvesters with extensive expertise) having decision-making responsibilities shared with DFO scientists with regards to the co-creation of research. This differs from higher levels of citizen power (Delegation and Citizen Control) in that the majority or totality of decision-making power with regards to this conceptual model is not just with the stakeholders, or DFO Science. In contrast, degrees of tokenism and non-participation (Figure 1) are actively avoided by the DFO scientists in the participatory modelling process.

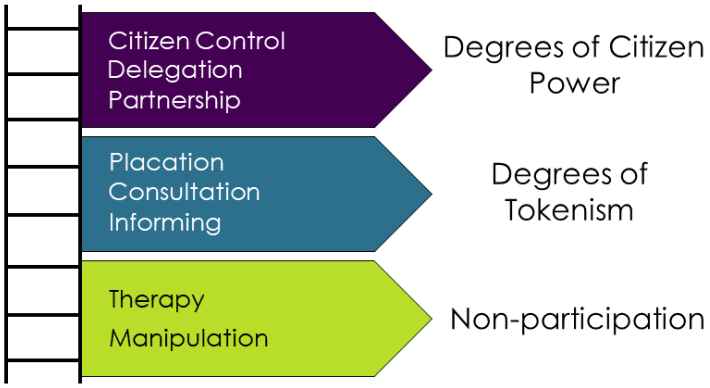

Figure 1. A ladder of citizen participation in governance depicts participation ranging from low to high, including components of Degrees of Citizen Power, Degrees of Tokenism, and Non-participation. Adapted from Arnstein (1969). Note that the term "Consultation" in this graphic does not refer to the legal "duty to consult" as defined by various Supreme Court of Canada judgements.

To move toward partnership and in accordance with Arnstein's ladder of citizen participation (Figure 1), a transdisciplinary approach was used. Transdisciplinary approaches differ from multidisciplinary approaches as they include not only members from multiple academic disciplines (e.g., social sciences, history, biology, ecology) but also engage rightsholders or stakeholders in the development of scientific research (Klein 1990; Huutoniemi et al. 2010; Haapasaari et al. 2012; Turgeon et al. 2018). This ensures transparency and inclusion regarding the development of scientific advice for decision making, ultimately achieving greater citizen participation. Transdisciplinarity has 3 common characteristics: i) new knowledge is created by integrating existing knowledge from various sources (e.g. experience, observation, trainee), perspectives and cultures, ii) this knowledge, known as transformative knowledge,

supports society to transform towards a more sustainable future, iii) science combines abstract knowledge with case specific knowledge and thus becomes part of a social learning process (Grünhagen et al. 2022).

Through this pilot project, the existing conceptual model developed by Pourfaraj et al. (2022a, b) was refined with subject-matter experts and harvester input using transdisciplinary participatory modelling approaches. Researchers built upon the existing relationship between DFO scientists and lobster harvesters to help create a collaborative environment. They engaged with stakeholders in LFA 38 (Grand Manan, NB) through an in-person workshop and follow-up (hybrid) conversations.

The objectives of this workshop were to:

1) Bring new types of information and knowledge into lobster science including social-cultural, economic, ecological, and governance through the co-creation of research.
2) Improve understanding of how different elements of the lobster fishery are interconnected, including validating anecdotal and assumed relationships in the conceptual model.
3) Increase engagement with harvesters regarding the development of scientific advice, promote positive partnerships in the co-development of research, strengthen trust, and improve transparency.
4) Develop a flexible methodology for DFO scientists to engage in participatory modelling with rightsholders and stakeholders.

Methods

Contributing participants

Initial engagements for the participatory modelling workshop relied on the previous work by Parlee et al. (Parlee et al. 2023) and past Science Meetings (DFO 2022a). The focal stakeholders in this participatory modelling workshop were commercial harvester groups and harvesters. Future iterations of such work would include other rightsholder and stakeholder groups. Below is a list of the research participants.

The Blue Economy Lobster Team (BELT) are the multidisciplinary research team at DFO-Maritimes:

Adam M. Cook, Population Ecologist and lead of the Lobster Unit
Jill Campbell-Miller, Historian
Courtenay E. Parlee, interdisciplinary Anthropologist and Sociologist
Vahab Pourfaraj, Biologist and Ecologist
Jamie C. Tam, Ecosystem Scientist

Stakeholder contributors from Grand Manan Fishermen's Association (GMFA; LFA 38) in the participatory modelling research:

Melanie Sonnenberg, GMFA
Bonnie Morse, GMFA
Brian Guptill, harvester LFA 38
Adam Parker, harvester LFA 38

Keith Morse, harvester LFA 38
Theron Ingalls, harvester LFA 38
Randy Parker, harvester LFA 38
Allen Green, harvester LFA 38

Subject-matter experts from the Lobster Ecology and Assessment Team (LEAT) at DFO-Maritimes that also contributed:

Shelley Armsworthy, Senior Technician
Cheryl Denton, Senior Technician
Geraint Element, Biologist
Victoria Howse, Senior Biologist
Sean (Ross) Mckinnon, Technician
Ben Zisserson, Senior Biologist

Contributors from Policy and Economics at DFO-Maritimes:

Mike Campbell, Senior Economist

Ethical Review

The BELT utilized a suite of tools and employed approaches to facilitate the development of this conceptual model. Preliminary stages and processes are documented in previous technical reports (see (Pourfaraj et al. 2022a, 2022b; Parlee et al. 2023). One major consideration prior to conducting this research was ensuring that the methodology used in all stages, including engagement, data gathering, and publication, met the requirements of ethical research involving humans. Though not standard practice within DFO, the BELT presented their research proposal including a Survey on Fishing Practices to the Ethics Board of Public Health Agency of Canada prior the development of the research. Details of the ethics approval as well as approaches and methods utilized in the Survey on Fishing Practices and components of this research can be found in Parlee et al. (2023).

The researchers determined that the main component of this research pilot project, participatory modelling, did not require ethics approval, as the stakeholders involved (harvesters) co-created the research and modelling during the workshop and follow-up conversations, and thus are not research subjects, but subject matter experts involved in the research.

A secondary component of this research was participant observation, which met ethical requirements through Health Canada (Parlee et al. 2023). Participant observation is a qualitative data collection method whereby the researcher immerses themselves in a group and takes systematic notes on themes raised by participants (including the researchers) and their interactions. See details below in the *Participant Observation* section.

Preliminary model review

The initial conceptual model was developed through a series of iterative methods that were selected based on the context of the fishery. This included existing policies regarding the lobster fishery in the Maritimes region, the existing relationships and past interactions between DFO and lobster harvesters in the region, the scientific methods currently used to assess lobster stocks, and the social-cultural and economic importance of various aspects of the lobster fishery. The conceptual model consists of model elements that represent components of the lobster fishery, and connections that represent positive or negative linkages between the model elements (directional, but not quantitative). The first iteration of conceptual model called, "the interactional map of the social-ecological system" (IMSES) for the lobster fishery in the Maritimes region was first developed through a workshop with subject-matter experts from DFO and Academia (details can be found in Pourfaraj et al. 2022a). Further work to refine the IMSES was done by the Blue Economy Lobster Team to ensure that the model components capture the most important aspects of the lobster fishery, and the dynamic relationships (the positive or negative relationships) between model components (details can be found in Pourfaraj et al. 2022b).

There were multiple significant economic elements in the conceptual model of the social-ecological system. After several rounds of iterations, compartmentalization, and the development of a literature review to support linkages the BELT felt the need to utilize the expertise of an economist to explicitly review the respective linkages and ensure that the major economic elements of the system were captured. During a meeting with the economist at DFO Maritimes, new elements were identified. **Revenue** was added to the model (Figure 2) and was defined as the profit obtained by license holders (previously captured by profitability and viability). The new element was also linked to components of the commercial lobster fishery including lobster market price and lobster stock abundance. Partnership, distribution of benefits, and market price were among the topics that were scrutinized, and their respective relationships validated through a review of academic literature.

The model also benefited from the expertise of Lobster Ecology and Assessment Team (LEAT) throughout the development process. More specifically, a modelling workshop was held with LEAT members prior to introducing the conceptual models in general and the model of the system specifically to harvesters of LFA 38 (GMFA; Grand Manan, NB). There were a few reasons for holding this workshop: the preexisting relationship between some LEAT members and lobster harvesters in that community and their collaboration experiences in multiple science projects helped provide additional information and insight to the model. This conversation resulted in tailoring the subsequent meeting with GMFA (and the harvesters they represent) and facilitated a more efficient engagement to receive their perspectives on the key elements of the system. It was identified during this meeting that **in-migration** of workers during the fishing season (e.g., deck hands/crew, fish plant workers) and **out-migration** of community members seeking jobs outside of the fishing industry (e.g., oil and gas) might play a significant role in the community in LFA 38 (Figure 2).

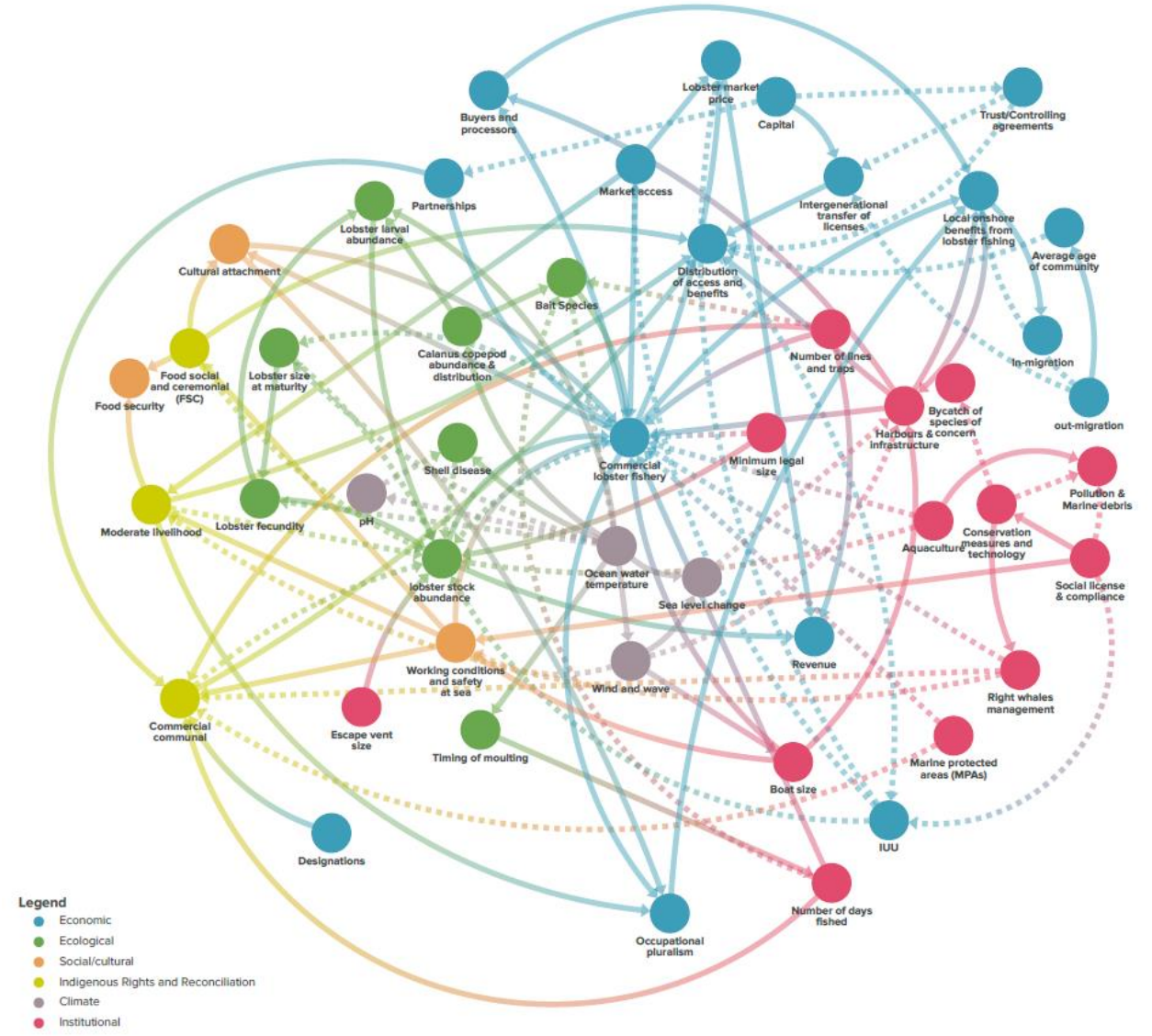

*Figure 2. Interactional Map of the Social Ecological System (IMSES) or conceptual model after review by Michael Campbell (Economist) and LEAT. Notable changes from previous iterations of the IMSES from Pourfaraj et al. (2022b) are the inclusion of **revenue**, **in-migration**, and **out-migration** as model components. Circles are model elements linked to sub models by colour, solid arrows represent positive relationships, while dotted arrows represent negative relationships.*

Initial engagement for the participatory modelling workshop

Previous Ecosystem Based Management efforts by DFO-Maritimes included the Eastern Scotian Shelf Integrated Ocean Management (ESSIM) Plan (DFO 2007). The ESSIM strategic plan included a Stakeholder Advisory Council (SAC), comprising approximately 30 stakeholder members (Sector Representatives). The SAC's general role was to provide "regular communications and two-way information sharing between its members and the broader communities of interest that they represent". Other multi-sector, multi-stakeholder engagement includes the Blue Economy Strategy "what we heard"

Report (DFO 2022b), and the Fish and Fish Habitat Protection Program engagement platform (DFO 2024). While those types of engagements have targeted higher level strategic planning for governments, more recent efforts attempt to involve two-way communication with the communities they impact (Zellner and Campbell 2015; Gray et al. 2018). Thus, the BELT developed a community-level, participatory approach for engagement to examine a fishery in the context of Ecosystem Approaches to management. The BELT was mindful of similar participatory engagement processes done on fisheries from the northeast US and Irish Sea regions and considered the outcomes for developing approaches that work for the specific context of the lobster fishery in LFA 38 (Gaichas et al. 2018; Pedreschi et al. 2021; Bentley et al. 2021).

Here the BELT based the engagement for the participatory modelling workshop on pre-established relationships from Parlee et al. (2023) and Science Meetings with Lobster harvesters and harvester groups. As a participatory effort, the BELT did a preliminary scan of the differing LFAs and approached two harvester groups who had participated in the pilot SSH research project (Parlee et al. 2023). The participatory modelling workshop was communicated as a practical way to bring the social and ecological aspects of the lobster fishery together. It is acknowledged that there are rightsholder groups and other stakeholders that may also have interest in contributing to the participatory model, but due to the timeframe and deadline of the BELT project, and a history of positive engagement between DFO-Science in the Maritimes Region and LFA 38, this area was selected for this pilot research effort.

Response to initial engagement from GFMA and harvesters

There was interest and willingness by GFMA and LFA 38 harvesters to participate in the pilot participatory modelling workshop. They expressed interest in clarifying the ways through which the fishery impacts could be documented and analyzed for the coastal community related to LFA 38. The GMFA confirmed that there would be interest and participation by members and harvesters that would require half a day of time. There was a desire from participants to contribute to research on the SES for lobster and to also have a wider breadth of understanding of modelling techniques that would be useful for lobster research.

The participatory modelling workshop

Location

The workshop took place in Grand Manan on May 24, 2023, at St. Paul's Anglican Church and ran for approximately 3 hours.

Video and introductory presentation

To streamline the workshop and to maintain focus on the workshop objectives, the participatory modelling workshop began with an introductory presentation by BELT (S1). This included a video on conceptual mapping developed by Dr. Debbi Pedreschi derived from work of the ICES Workshop on Common Conceptual Mapping Methodologies (ICES 2022). The introductory presentation included information about who each of the BELT members are and their expertise, objectives and goals of the workshop, some preliminary results from the lobster harvester survey (Parlee et al. 2023), the software used for the participatory modelling (Kumu), and a brief agenda for the workshop. The purpose of the introductory presentation was to methodically introduce the participatory modelling process as none of the participants had experience working with conceptual models.

In addition to the presentation, handouts were provided with the table of the model components and the conceptual map (S2). These were useful for each participant to be able to take notes. The BELT also encouraged workshop participants to take a copy of the handouts and to communicate with us through email if they had any new ideas with regards to the IMSES in the future.

Figure 3. Photo from the participatory modelling workshop in Grand Manan (LFA 38), May 24, 2023. Image shows participants working together to refine the IMSES.

Participatory modelling

Throughout the workshop, the participants were active and engaged in the process. The BELT had initially prepared some opening questions, but they were unnecessary as the participants were very open to sharing their thoughts and opinions. The workshop progressed with only a little structure, primarily open discussions attempting to focus on changes to the IMSES, while also listening and asking questions for clarification. Notes were taken throughout the workshop by the BELT members and were used to confirm that consensus had been reached, and to fill in the descriptions of the model element and connection tables. When consensus was reached about the addition or change to a model element or connection, it was added in real time to the model using the Kumu software.

Participant observation

Participant observation is a data-gathering method, separate from minutes or notes, that requires researchers to be immersed in a setting to hear, see, and experience the reality as participants do. During participant observation of an activity the researcher takes detailed notes if the activity permits it, and if not, notes are recorded afterwards. Notes include themes that arise during conversation, physical and emotional reactions and items/issues to follow up with in subsequent interactions. All participants, including researchers, are observed in this process. Participant observation is an ongoing and iterative process that requires reflection, and action from the researchers. Combined with other forms of data collection, it can provide additional insight into whether key objectives are being met. Furthermore, participatory observation can help to identify emerging themes that may warrant further investigation or clarification.

The purpose of the participant observation in this case was to build the foundation for future work with the IMSES. Information collected iteratively across multiple meetings were used to determine and validate objectives of the fishery and to maintain a record of the relationships developed during these meetings. It is important to note that all participants were observed during the workshops including the BELT.

Follow up virtual meetings

Two follow-up meetings were organized after the participatory modelling workshop, both virtual. One was held June 13th, 2023, and another was held on July 6th, 2023. The first meeting's objectives were to discuss social-cultural components for the IMSES. It was identified that the IMSES has little information with regards to social-cultural model elements, and there was interest in determining if there were additional model components that would reflect social-cultural aspects of the lobster fishery. The second meeting objectives were to 1) discuss the aesthetics of the IMSES to explore customizations and improve the communication capability of the conceptual model, 2) review new components based on the previous two meetings, and 3) continue discussions on the social-cultural dimensions of the model.

Outcomes/Results

Additional elements and connections were added over the course of the participatory workshop and follow-up virtual meetings (Figure 4).

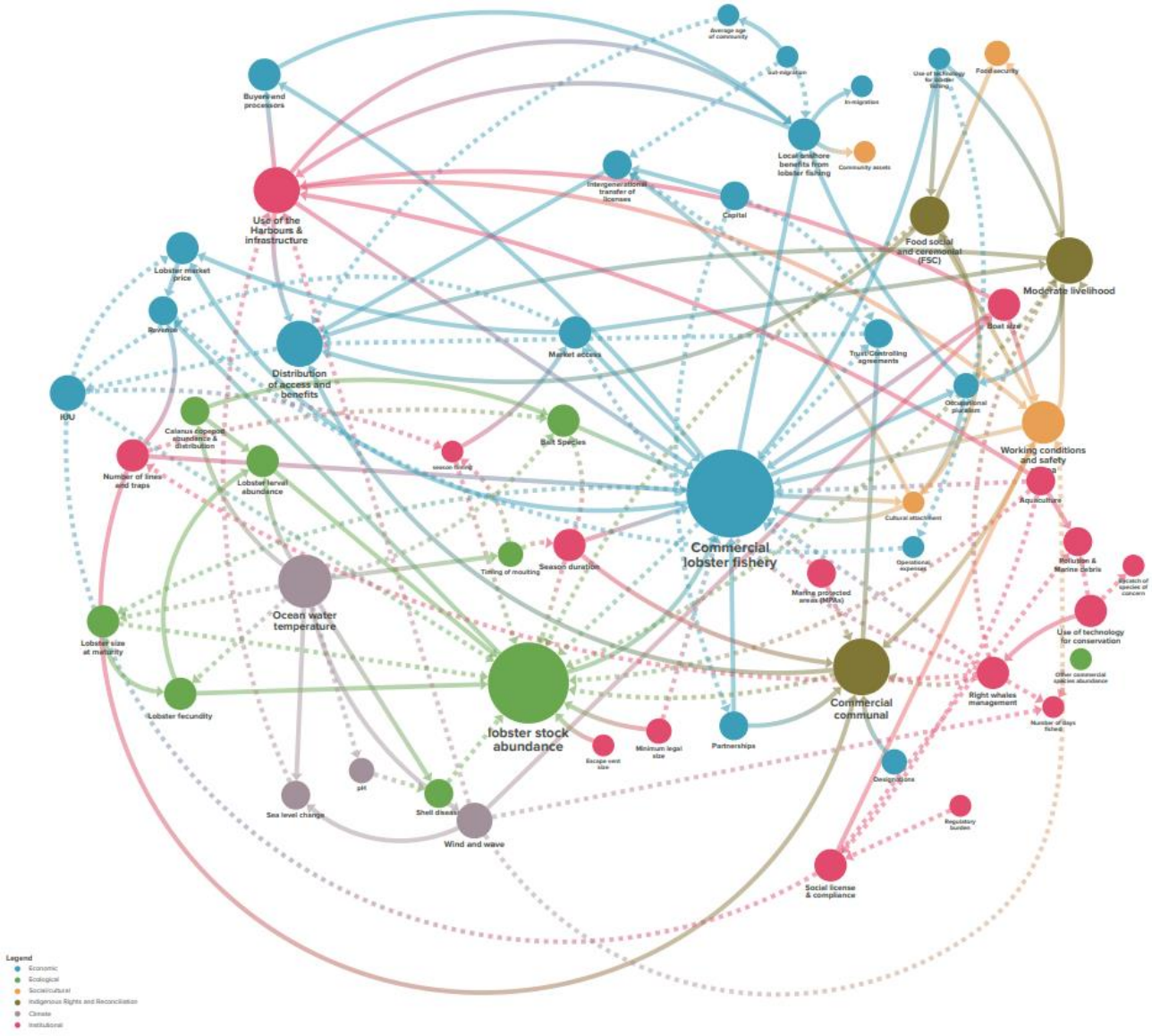

Figure 4. IMSES with additional information from the participatory modelling workshop in LFA 38. Differing sizes of the model element symbol (circle) reflects the number of connections from the model element (outdegrees).

Additional Elements to IMSES from the participatory modelling workshop:

Regulatory burden: The number of regulations required to commercially fish for lobsters in LFA 38.

Operational expenses: Costs of fuel and equipment.

Other commercial species abundance: Where lobster harvester might hold a license to fish a separate species (groundfish and scallop). Currently the fishery on Grand Manan is very focused on the lobster fishery.

Season timing: When during the year the season occurred. Moving towards September from the spring fishery would be an increase in season timing, while away from September would be considered a decrease. Harvesters noted this as an important and sensitive time for the lobster life cycle.

Season duration: The total length of the season. This was distinguished from the number of days fished because it was identified that the duration of the season was longer than the number of days fished as poor weather or other factors could affect the total number of days fished, but not the season duration.

Number of days fished: Due to the addition of Season duration, this element's definition changed slightly to reflect the total number of days fished by a harvester (i.e. the number of days hauling traps), not the total available number of days fished.

Additional Elements to IMSES from the follow-up virtual meetings:

Community assets: This reflects social and recreational benefits to the community through the lobster fishery. Parks at school grounds, paved parking lots, social venues, hockey rinks, etc. are aspects of the community that fluctuate with the lobster fishery in LFA 38.

Use of technology for conservation: split from Conservation measures and technology, to reflect technology that is adopted specifically to meet conservation objectives (e.g., avoiding bycatch, whale entanglement).

Technology for lobster fishing: split from Conservation measures and technology to reflect technology that is adopted for lobster fishing (e.g., sonar).

Additional connections with the IMSES from the participatory modelling workshop include:

Aquaculture > Use of harbours and infrastructure: It was noted that the increase in aquaculture (Atlantic salmon) in LFA 38 has caused overcrowding at the harbour. The need for aquaculture sites to have boats for maintenance and feeding has increased use of the harbour.

Operation expenses > Revenue: Increasing operational expenses can decrease revenue.

Right whale management > Market access: During times of closures due to the presence of at-risk whales in the LFA might reduce the access to lobster markets.

Right whale management > Number of lines and traps: During times of closures due to the presence of at-risk whales in the LFA might reduce the total number of lines and traps that are out.

Right whale management > Revenue: During times of closures due to the presence of at-risk whales in the LFA might reduce overall revenue.

Timing of molting > Season duration: If molting of the lobsters changes that would impact the duration of the season, as the season specifically avoids molt times for lobsters.

Additional connections in the IMSES from the follow-up virtual meetings:

Cultural attachment > intergenerational transfer of license: Lobster fishing as a traditional occupation. Many lobster fishing families have children that would like to fish as a way of life, and harvesters noted that being brought up within an atmosphere that promotes cultural attachment to the fishery (e.g. going on board the boat as a child, helping out family members with fishing work) is more likely to result in a child ultimately pursuing a lobster license as an adult.

Aesthetic changes were incorporated to include making the size of the symbol (circles) in the model proportional to the number of connections coming out of the model element (outdegrees). This reflects the level of impact the model element has on the overall model.

The conversations that occurred during the in-person and virtual meetings provided more context for inclusion of elements and connections based on professional/experiential/traditional knowledge. For example, additional understanding of community well-being was a major discussion topic. Community well-being is reflected by assets and cultural attachment in LFA 38. Community health overall is greater when lobster fishing is good, investments in communities are possible (e.g., fundraising, increased extracurricular activities for children, parks).

The final revised model was shared with participants, this included a kumu model (online, free access) and instructions on how to access and use kumu.

Discussion

Through this pilot project, participatory modelling has been a successful approach to understanding the interacting elements within the lobster SES. These participatory approaches allowed for the incorporation of diverse perspectives, local knowledge, and insight from various participants to co-create models that are contextually relevant, more comprehensive, and reflect complex systems, issues, or challenges. This project was highly successful because it delivered on several objectives:

1. *Bring new types of information and knowledge into lobster science including social-cultural, economic, ecological, and governance through the co-creation of researc*h.

LEK, TEK, and EK from the contributing participants enhanced the existing conceptual model. While most of the participants had a depth of knowledge regarding the ecological components of the lobster fishery, the knowledge derived from co-creation of the conceptual model improved representation of the

social-cultural, economic, and governance elements. Through sharing unique perspectives, insights, and local knowledge, the model became a more accurate representation of the lobster fishery for LFA 38. The participatory model can be integrated into CSAS Assessment Frameworks to develop research plans as the basis for understanding how the indicators used in lobster assessments are interconnected, and to identify gaps in knowledge.

2. *Improve understanding of how different elements of the lobster fishery are interconnected, including validating anecdotal and assumed relationships in the conceptual model.*

Examination of the connections between model elements during the participatory modelling workshop allowed the BELT to ask questions to validate assumed relationships (that are widely accepted, but have no specific data associated with them) in the conceptual model. Because a consensus was required before the addition of a new model element or connection, a shared understanding needed to be reached before any changes to the IMSES were made. This shared understanding not only helps scientists to develop and deliver scientific advice, it also can help to improve the adaptive capacity of communities, and their ability to adjust, cope with, and recover from various stressors and changes related to the lobster fishery.

3. *Increase engagement with harvesters regarding the development of scientific advice, promote positive partnerships in the co-development of research, strengthen trust, and improve transparency*.

The process of co-creating research fosters a shared ownership of science and empowerment. Such positive engagements among participants can help to strengthen trust. This process was also transparent, with all participants, including the researchers, openly discussing and sharing information, assumptions, and uncertainties. Importantly, all participants had an opportunity to share their knowledge and experience, and to reject components or ask for changes to the model to reflect their understanding of the fishery. Conversation provided consensus about these changes or alterations.

In a typical science presentation forum, focus is placed on “experts” (often scientists) that present information to the audience. This typical format allows for limited opportunity for feedback or sharing. In contrast, the participatory modelling process applied here allowed for more open discussions, while also acknowledging all participants' expertise. Information was sought from the harvesters (experts on the lobster fishery), and the scientists were then tasked with interpreting and incorporating these views into the SES model. Discussion among all participants ensured that consensus views were incorporated into the model.

4. *Develop a flexible methodology for DFO scientists to engage in participatory modelling with rightsholders and stakeholders.*

This participatory modelling approach is designed to be adaptable and flexible, with the ability to reproduce similar models for other fisheries, or other regulatory processes. The participatory models can serve as tools to support decision making by providing insight into potential outcomes, risks, tradeoffs, and implications of different management scenarios.

Future iterations of the conceptual model can be used as a platform to integrate multiple models (e.g. climate model with ecological model), used to explore impacts of SES drivers on model components, or used as the foundational model for a risk assessment (Gaichas et al. 2018; Pittman et al. 2020; Reum et al. 2021; Tam et al. 2025). The current example of a participatory process for conceptual model refinement provides a way to ensure that perspectives from stakeholders or rightsholders can also be included and considered.

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Supplementary Materials

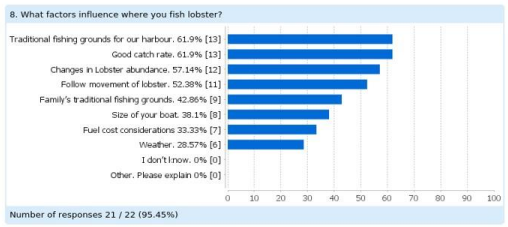
S1. Introductory slides from the participatory modelling workshop in LFA 38, May 24, 2023.

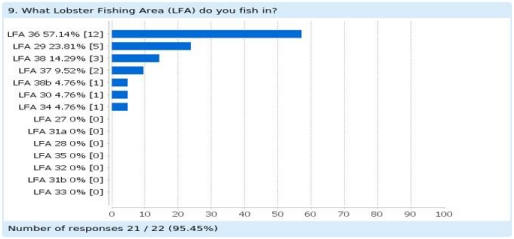
Who we are

- What is our goal?
  - **To bring new types of information into lobster science.**
  - Social-cultural, economic, environmental, governance.
  - Understand how the aspects of the lobster fishery are interconnected.

- Blue Economy Lobster Team
  - Courtenay Parlee, Anthropologist and Sociologist
  - Jill Campbell-Miller, Historian
  - Vahab Pourfaraj, Aquatic biologist
  - Jamie Tam, Ecosystem Scientists
  - Adam Cook, Population Ecologist

2 8/3/2023


8. What factors influence where you fish lobster?
Traditional fishing grounds for our harbour. 61.9% [13]
Good catch rate. 61.9% [13]
Changes in Lobster abundance. 57.14% [12]
Follow movement of lobster. 52.38% [11]
Family's traditional fishing grounds. 42.86% [9]
Size of your boat. 38.1% [8]
Fuel cost considerations 33.33% [7]
Weather. 28.57% [6]
I don't know. 0% [0]
Other. Please explain 0% [0]
0 10 20 30 40 50 60 70 80 90 100
Number of responses 21 / 22 (95.45%)


9. What Lobster Fishing Area (LFA) do you fish in?
LFA 36 57.14% [12]
LFA 29 23.81% [5]
LFA 38 14.29% [3]
LFA 37 9.52% [2]
LFA 38b 4.76% [1]
LFA 30 4.76% [1]
LFA 34 4.76% [1]
LFA 27 0% [0]
LFA 31a 0% [0]
LFA 28 0% [0]
LFA 35 0% [0]
LFA 32 0% [0]
LFA 31b 0% [0]
LFA 33 0% [0]
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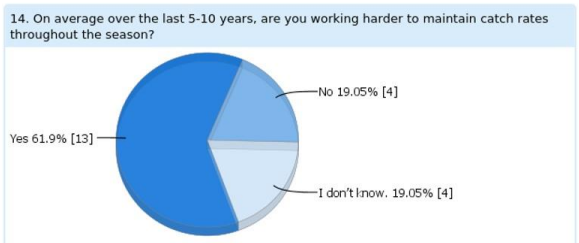
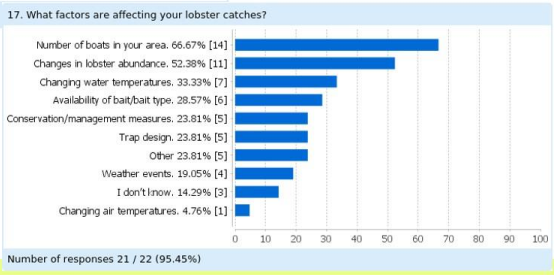
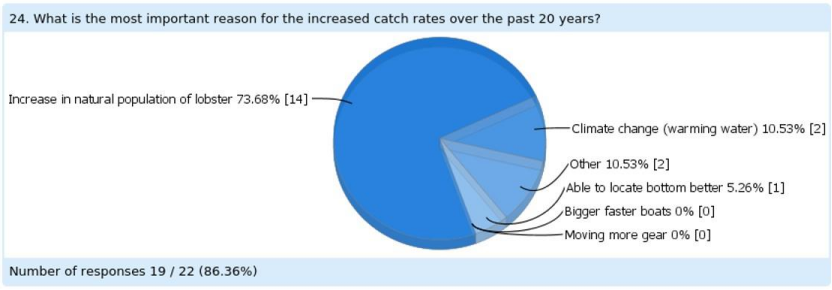
Number of responses 21 / 22 (95.45%)


14. On average over the last 5-10 years, are you working harder to maintain catch rates throughout the season?
No 19.05% [4]
Yes 61.9% [13]
I don't know. 19.05% [4]
Number of responses 21 / 22 (95.45%)


17. What factors are affecting your lobster catches?
Number of boats in your area. 66.67% [14]
Changes in lobster abundance. 52.38% [11]
Changing water temperatures. 33.33% [7]
Availability of bait/bait type. 28.57% [6]
Conservation/management measures. 23.81% [5]
Trap design. 23.81% [5]
Other 23.81% [5]
Weather events. 19.05% [4]
I don't know. 14.29% [3]
Changing air temperatures. 4.76% [1]
0 10 20 30 40 50 60 70 80 90 100
Number of responses 21 / 22 (95.45%)


24. What is the most important reason for the increased catch rates over the past 20 years?
Increase in natural population of lobster 73.68% [14]
Climate change (warming water) 10.53% [2]
Other 10.53% [2]
Able to locate bottom better 5.26% [1]
Bigger faster boats 0% [0]
Moving more gear 0% [0]
Number of responses 19 / 22 (86.36%)

Introduction to Conceptual Modelling

- In 2022, the International Council for the Exploration of the Seas, developed a workshop for conceptual mapping methods.
- Developed a short video for the ICES Annual Science Conference to explain what conceptual mapping/modelling is and how it can be useful for resource management and fisheries.
  - Powtoon - Pedreschi_CCMM2022

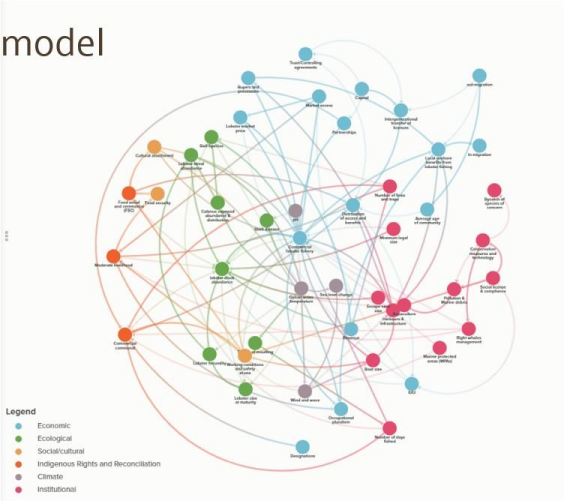
History of the Lobster IMSES

- First Workshop within DFO to develop and organize preliminary information.
- Refined by the Blue Economy Lobster Team.
- Refined by DFO economist.
- Refined by you.

What do we hope to achieve with the IMSES?

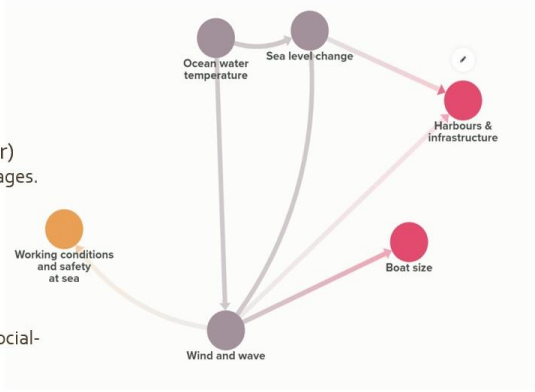
- Better understand your concerns and priorities.
- Include your perspectives into lobster science.
- Develop new ways to produce science at DFO.
  - Can be used to help strategic planning for the lobster fishery.
  - Considering the big picture, include interactions.
- Conceptual models are a great way to gain a common understanding of the social-ecological system and management processes.
  - More informed communication and conversations internally and externally.

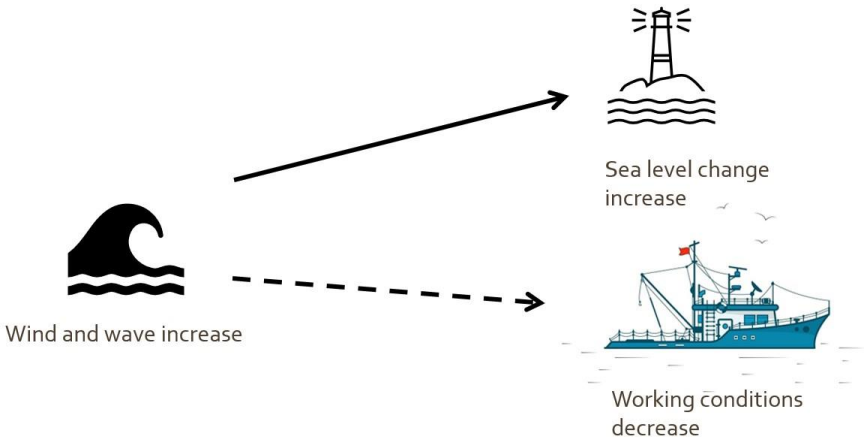
The base model

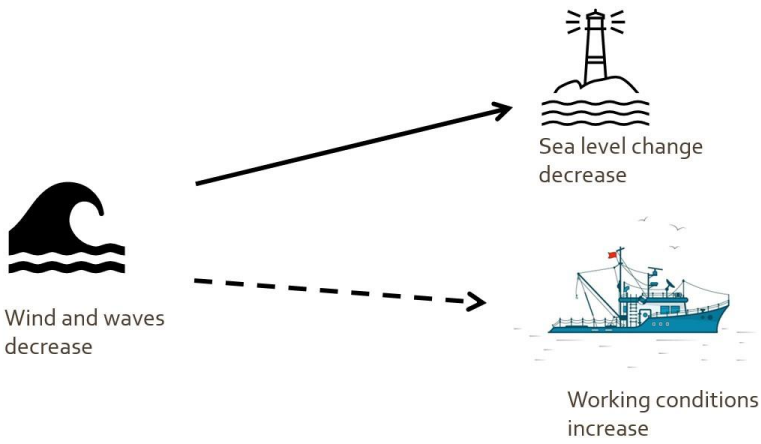


What's in the model?

- Model components (e.g. fishery, wind, whale management)
- Linkage or connection (how a model component impacts another)
  - Trying to understand mostly direct linkages.
  - Some components are impacted through other components.
- Currently there are 6 submodels
  - Ecological, Economic, Governance/Institutional, Climate, Indigenous Rights and reconciliation, Social-Cultural.







Capturing Information for the Model

What?

- Topics and reactions

How?

- Note table
- Flip Chart
- Model

What information is being captured?

- Determine whether there is consensus
- Help researchers reflect on and learn about how to do the process better.
- To ensure information captured is accurate

How today is going to work

- This is an evolving process, we will go back and forth a lot.
- We can start with a submodel where your input would be most valuable
- When we all agree to a change in the model, it will be done on the computer model. You will have access to this at the end of the day.
  - Change in the model needs consensus- no strong opposition
- We are trying to develop a model of the current state of the lobster fishery.
  - Information about the future and past will be noted for potential future use.

S2. Element table presented to harvesters and harvester groups during the Participatory Modelling workshop, May 24, 2023.

Label	Tags	Description
Partnerships	Economic	**Partnership** Lengthy discussion about partnerships during the internal DFO workshop: By stacking you end up with less effort, 1.5 from compliment-- effort is different from gear authorized, they may fish harder. More profitable fishing enterprise for 2 people involved because reduced vessel and other costs, end up with impact on employment because there are fewer crew required Policy: partnership can be formed in advance of the season-- can dissolve partnership at any time Used to be mostly in LFA 33 -- doesn't think there is much that happens in 34, license stacking happens in 38 Partnership may happen because: family, 2 members of family choose to fish together, skills development even though they may have 2 separate licenses, vessel availability, difficult to find substitute vessels that meet your requirements especially with restrictive vessel lengths, through license appeals hear it cuts down on costs, fewer crew, taking larger share.
Market access	Economic	Trade embargos can impact lobster price. https://www.cbc.ca/news/canada/nova-scotia/lobster-export-boom-nova-scotia-fisheries-loan-board-lending-1.5451651 https://www.cbc.ca/news/canada/nova-scotia/stephen-mcneil-canada-china-trade-guangdong-1.5138735 https://www.cbc.ca/news/canada/nova-scotia/clearwater-sees-sales-grow-in-china-1.5135950
Use of the Harbours & infrastructure	Institutional	Harbors and condition https://www.canada.ca/en/fisheries-oceans/news/2021/07/the-government-of-canada-invests-over-22-million-in-the-fishing-harbours-across-south-western-nova-scotia.html https://www.newswire.ca/news-releases/the-government-of-canada-invests-42-million-in-small-craft-harbours-infrastructure-in-the-province-of-nova-scotia-691104441.html https://www.canada.ca/en/fisheries-oceans/news/2021/07/the-government-of-canada-invests-more-than-8-million-in-the-fishing-harbours-of-southeast-new-brunswick.html Greenan, B., Cogswell, A., Greyson, P., Jean, D., Cloutier, M., Bird, E., Losier, R., Marceau, E., Fan, W. 2018. Small Craft Harbours Coastal Infrastructure Vulnerability Index Pilot Project. Can. Tech. Rep. Fish. Aquat. Sci. 3245: xiv + 73 p https://www.frontiersin.org/articles/10.3389/fmars.2019.00579/full https://dalspace.library.dal.ca/bitstream/handle/10222/80723/MonicaRagan2021.pdf?sequence=3&isAllowed=y +Small craft harbours in Nova Scotia, Canada: Examining livelihoods beyond the commercial fishery +by Monica Ragan Submitted in partial fulfilment of the requirements for the degree of Master of Environmental Studies at Dalhousie University Halifax, Nova Scotia. August 2021 Walker, T. R., Bernier, M., Blotnicky, B., Golden, P. G., Hoffman, E., Janes, J., ... & Vermeulen, S. (2015). Harbour divestiture in Canada: implications of changing governance. Marine Policy, 62, 1-8. https://doi.org/10.1016/j.marpol.2015.08.018

Shell disease	Ecological	Population impacts of shell disease are expected to increase with increasing seawater temperatures. Warmer spring temperatures leading to earlier spring molting (losing diseased shell), but increases in later summer infections. Groner, Maya L. et al. (2018), Data from: Rising temperatures, molting phenology and epizootic shell disease in the American lobster, Dryad, Dataset, https://www.journals.uchicago.edu/doi/10.1086/699478 Robert P. Glenn, Tracy L. Pugh, Epizootic Shell Disease in American Lobster (Homarus americanus) in Massachusetts Coastal Waters: Interactions of Temperature, Maturity, and Intermolt Duration, Journal of Crustacean Biology, Volume 26, Issue 4, 1 October 2006, Pages 639–645, https://doi.org/10.1651/S-2754.1
Buyers and processors	Economic	The economic benefits of processed lobster https://www.perennia.ca/wp-content/uploads/2021/03/Nova-Scotia-Ministers-Conference-presentation-version-corrected-sm-3.pdf https://www.cbc.ca/news/canada/nova-scotia/canadian-lobster-exports-topped-3-2-billion-last-year-1.6367872 https://waves-vagues.dfo-mpo.gc.ca/Library/40966392.pdf Nova Scotia MP questions Chinese 'control' over lobster industry

Timing of moulting	Ecological	Here, increase in time of moulting means earlier moulting in the season. Phenological mismatch and its impact on defense and growth Climate change can impact duration of 'seasons' (e.g., longer summers, shorter winters) which can influence the onset of molting, which can then change the optimal time for fishing seasons. Potential to create a mismatch between the current seasons and moulting. Competition with other regions (e.g., Maine). https://atlanticfisherman.com/warming-water-leading-to-lobster-molt-variability/ Groner, M.L., Shields, J.D., Landers Jr, D.F., Swenarton, J. and Hoenig, J.M., 2018. Rising temperatures, molting phenology, and epizootic shell disease in the American lobster. The American Naturalist, 192(5), pp.E163-E177. The 2012 marine heatwave in the Gulf of Maine revealed unexpected connections within the ecosystem and between the natural and human components of the system. The strongest economic impacts were to Maine's valuable lobster fishery. In 2012, early and intense landings led to a backlog in the supply chain and a drop in price. This experience prompted the lobster industry to implement changes throughout the supply chain to avoid the severe drop in price should another warm year with early landings occur. Absolute and percent change in projected habitat suitability of lobster will increase with projected ocean temperature changes from two future scenarios (Greenan et al. 2019). It is likely that future climate conditions will reduce prey availability, where studies have shown that adequate food abundance can buffer some of the effects of climate change. Future diet limitations increases female adult aggression (impact on mating success?), delays embryo development (later hatching) and decreased molting success. These factors will potentially affect population size. Multiple global change drivers will interact to alter lobster environments. Interactive effects of temperature, acidification and diet will heighten individual stressor impacts on lobster population abundance. Increased temperatures results in earlier lobster spawning and hatching of embryos. This will affect fishery harvest timing. Increased temperatures increase aggression in females prior and during egg bearing. Mating studies have not been conducted but increased aggression may affect mating success and therefore lobster population abundance. Future projected pH changes due to ocean acidification are expected to reduce clutch volume, hatching success and larval survival. Future decreased pH is linked to less larvae, but the larvae are larger (is there any benefits of being larger at hatch?) Stage IV larvae are more susceptible to ocean acidification than stages Where population structure is associated with environmental variation and adaptive variability there can be different expected responses of populations to climate change. Spatial management within a region (e.g., LFAs) may need to consider local-scale (LFA) response to climate change (also what to be expected). Blair J. W. Greenan, Nancy L. Shackell, Kiyomi Ferguson, Philip Greyson, Andrew Cogswell, David Brickman, Zeliang Wang, Adam Cook, Catherine E. Brennan, Vincent S. Saba. Climate Change Vulnerability of American Lobster Fishing Communities in Atlantic Canada. Frontiers in Marine Science, 2019; 6 DOI: 10.3389/fmars.2019.00579 Stanley, R.R.E., DiBacco, C., Lowen, B., Beiko, R.G., Jeffery, N.W., Van Wyngaarden, M., Bentzen, P.,

		Brickman, D., Benestan, L., Bernatchez, L., Johnson, C., Snelgrove, P.V.R., Wang, Z., Wringe, B.F., and Bradbury, I.R. 2018. A climate-associated multispecies cryptic cline in the northwest Atlantic. Science Advances 4(3). Harrington et al. 2019. Effects of temperature on larval American lobster: Is there a tradeoff between growth rate and developmental stability. Ecological indicators. 96. 404-41. Steneck & Wahle (2013) American Lobster Dynamics in a brave new ocean. Can. J. Fish. Aquat. Sci. 70: 1612–1624 (2013). https://cdnsciencepub.com/doi/10.1139/cjfas-2013-0094 Pershing A, Mills K, Dayton A, Franklin S, Kennedy B. Evidence for adaptation from the 2016 Marine heatwave in the Northwest Atlantic Oceans. Oceanography 31 (2) 152-161. https://www.jstor.org/stable/26542661?seq=1 Steneck et al (2011) Creation of a Gilded Trap by the High Economic Value of the Maine Lobster Fishery. Conservation Biology, Volume **, No. **, 1–9. DOI: 10.1111/j.1523-1739.2011.01717.x Wilson et al (2020) Potential Socioeconomic impacts from ocean acidification and climate change effects on Atlantic Canadian Fisheries. PLoS ONE 15(1): e0226544. https://doi. org/10.1371/journal.pone.0226544.
Other commercial species abundance		Makes the fishery's portfolio more diverse. Daniel R. Mombourquette 2019 A Science-industry study of the Distribution of Fishing Benefits to the Community of Grand Manan, Bay of Fundy. https://www.jstor.org/stable/j.ctt817fs

Bait Species	Ecological	Harnish, Luke and Willison, Martin J.H. (2009) Efficiency of bait usage in the NS lobster fishery: a first look. Journal of Cleaner Production. 17, p. 345-47 Lobster fishery has an impact on bait species, also bait costs are an impact on the lobster fishery. Steneck et al (2011) Creation of a Gilded Trap by the High Economic value of the Maine Lobster Fishery. Conservation Biology, Volume **, No. **, 1–9 2011 Society for Conservation Biology DOI: 10.1111/j.1523-1739.2011.01717.x DFO (2017) Results of an informal survey of Canadian Atlantic mackerel commercial, recreational and bait fishers. CSAS Research Document 2017/029 https://waves-vagues.dfo-mpo.gc.ca/Library/40606016.pdf Most lobster harvesters hold a bait license. Status of herring/mackerel → bait fishery (More context and citation is needed) https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/maritimes/2019/inshore-lobster-eng.html https://link.springer.com/article/10.1007/s13280-021-01617-8
Sea level change	Climate	considering impacts to shell disease, temperature, decadal fluctuations, storm frequency and severity,
Operational expenses		Includes fuel, cost of bait, hiring crews and deckhands
Number of lines and traps	Institutional	Trap limit varies between 275-400 across LFAs (Trap limit of 375 for LFA 38)https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/maritimes/2019/inshore-lobster-eng.html Single line Vs. Multiple lines of traps. This element CAN also include soak time and the overall number of trap hauls across the season.
Calanus copepod abundance & distribution	Ecological	Zooplankton abundance of the Maritimes region https://www.dfo-mpo.gc.ca/science/data-donnees/azmp-pmza/index-eng.html https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/347246.pdf Egg production rates of Calanus finmarchicus in the western North Atlantic: effect of gonad maturity, female size, chlorophyll concentration, and temperature https://cdnsciencepub.com/doi/pdf/10.1139/f99-278

IUU	Economic	Illegal, unreported and undocumented catch and sale of lobsters Scott D. J. Graham , John Hasseldine & David Paton (2009) Statistical fraud detection in a commercial lobster fishery, New Zealand Journal of Marine and Freshwater Research, 43:1, 457-463, DOI: 10.1080/00288330909510014 https://doi.org/10.1080/00288330909510014 https://www.cbc.ca/news/canada/nova-scotia/illegal-sales-of-first-nations-lobster-nets-55k-fine-1.6410787 Reports from fishery officers can be included in here. Shelly Denny thesis CHAPTER 7. Explanation for the perception of illegal fishery https://dalspace.library.dal.ca/bitstream/handle/10222/81499/ShelleyDenny2022.pdf?sequence=3 https://www.sciencedirect.com/science/article/pii/S0308597X2200080X
Right whales management	Institutional	New regulations to help protect right whales (ropeless fishing gear etc.) https://www.narwc.org/ Canada-US Right Whale meeting https://www.cbc.ca/news/canada/new-brunswick/right-whale-meeting-dfo-2019-1.5350058 Fisheries and Oceans Canada. 2014. Recovery Strategy for the North Atlantic Right Whale (Eubalaena glacialis) in Atlantic Canadian Waters [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 68 pp. https://www.sararegistry.gc.ca/virtual_sara/files/plans/rs_bnan_narw_am_0414_e.pdf https://www.sararegistry.gc.ca/virtual_sara/files/plans/rs_north_atl_right_whale_0609_e.pdf MMPA prohibits harassment, hunting, capturing, collecting, or killing of marine mammals; https://www.fisheries.noaa.gov/topic/marine-mammal-protection

Marine protected areas (MPAs)	Institutional	Marine Protected Areas across Canada https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/index-eng.html Canada National Marine Conservation Areas Act (S.C. 2002, c. 18) https://laws-lois.justice.gc.ca/eng/acts/c-7.3/index.html DFO tries to allay fishermen's fears that protected area would impact livelihood https://www.cbc.ca/news/canada/nova-scotia/no-mpa-here-signs-eastern-shore-1.4996534 Eastern Shore Islands Risk Assessment (Marine Planning and Conservation - unpublished) https://www.facetsjournal.com/doi/10.1139/facets-2020-0109 DFO 2022 Oceans Act Areas of Interest Retrieved online https://open.canada.ca/data/en/dataset/32bf34ea-d51f-46c9-9945-563989dfcc7b https://www.cbc.ca/news/canada/nova-scotia/feds-hit-reset-button-marine-protected-areas-ns-nb-1.6236329 https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/gully/index-eng.html https://www.dfo-mpo.gc.ca/oceans/oecm-amcepz/refuges/eastern-canyons-est-eng.html https://www.dfo-mpo.gc.ca/oceans/oecm-amcepz/refuges/eastern-canyons-est-eng.html https://www.facetsjournal.com/doi/10.1139/facets-2020-0109 DFO 2022 Oceans Act Areas of Interest Retrieved online https://open.canada.ca/data/en/dataset/32bf34ea-d51f-46c9-9945-563989dfcc7b https://www.cbc.ca/news/canada/nova-scotia/feds-hit-reset-button-marine-protected-areas-ns-nb-1.6236329 https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/gully/index-eng.html https://doi.org/10.1016/j.marpol.2011.10.022
Ocean water temperature	Climate	Bottom and sea surface temperature From Harr et al. 2018 (https://doi.org/10.1139/cjfas-2016-0434) "SST is an acceptable proxy for bottom temperature in our study given that (i) in the Canadian portion of their range, the vast majority of lobsters are captured in relatively shallow, well-mixed water (e.g., Ennis 1984a; Campbell and Stasko 1986; Comeau and Savoie 2002b) where bottom and surface temperature anomalies are highly correlated (Hebert et al. 2014; Galbraith et al. 2015; Richaud et al. 2016), and (ii) LeBris et al. (2017) showed that the relationships between SM and temperature from New England to the Bay of Fundy are comparable whether using bottom temperature or SST". Greenan, B. J. W., et al. "Changes in oceans surrounding Canada." Canada's Changing Climate Report, eds E. Bush and DS Lemmen (Ottawa, ON: Government of Canada) (2018): 343-423. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR-Chapter7-ChangesInOceansSurroundingCanada.pdf Greenan, Blair JW, et al. "Climate change vulnerability of American lobster fishing communities in Atlantic Canada." Frontiers in Marine Science (2019): 579. https://doi.org/10.3389/fmars.2019.00579

		https://www.pnas.org/doi/epdf/10.1073/pnas.1711122115
Community assets		Follow up with Bonnie about this element! e.g. skate park was brought up by Bonnie
Working conditions and safety at sea	Social/cultural	Fishing industry has the highest fatality rate among employment sectors in Canada https://www.theglobeandmail.com/news/investigations/fishing-industry-deadliest-sector-canada/article36725324/ In Nova Scotia, safety at sea training is a key focus of the Fish Harvester Registration and Certification Board. They provide other training, e.g., quality handling while New Brunswick does not have a professionalization regime. Provincial legislation and federal regulations and policies that authorize industry-led registration and certification boards https://www.nsfishharvesters.ca/wp-content/uploads/2021/01/press-release-dec-2020-1-8.pdf https://www.fisheriessafety.ca/ Use of illicit drugs https://www.cbc.ca/news/canada/nova-scotia/fishermen-drug-use-cocaine-1.5158772 https://www.saltwire.com/nova-scotia/business/already-the-most-dangerous-profession-fisheries-facing-an-increasing-drug-use-problem-364541/ It includes skills development. Number of incident reports (violence, workplace accidents, fatalities). Includes the concept of safety at sea and the technology being used. https://www.theglobeandmail.com/news/investigations/fishing-industry-deadliest-sector-canada/article36725324/ In Nova Scotia, safety at sea training is a key focus of the Fish Harvester Registration and Certification Board. They provide other training, e.g., quality handling while New Brunswick does not have a professionalization regime. Provincial legislation and federal regulations and policies that authorize industry-led registration and certification boards https://www.nsfishharvesters.ca/wp-content/uploads/2021/01/press-release-dec-2020-1-8.pdf Growing concerns in some communities of NS about the use of hard drugs: https://www.cbc.ca/news/canada/nova-scotia/fishermen-drug-use-cocaine-1.5158772

		Bridging fragmented knowledge between forecasting and fishing communities: Co-managed decisions on weather delays in Nova Scotia's lobster season openings Emily Reid-Musson *, Joel Finnis, Barb Neis Applied Geography 133 (2021) 102478
In-migration		People coming to the community temporarily or permanently E.g. Temporary foreign workers, retirees, families returning to settle and raise kids. https://www.jobbank.gc.ca/trend-analysis/job-market-reports/atlantic-region/sectoral-profile-fishing-processing?wbdisable=true
Local onshore benefits from lobster fishing	Economic	It includes groceries, community services, gas stations, boat maintenance, construction, housing, population. https://www.jobbank.gc.ca/trend-analysis/job-market-reports/atlantic-region/sectoral-profile-fishing-processing?wbdisable=true also includes links to harbours and infrastructure Carruthers et al. 2019, Greenan et al. 2018, 2019. Also includes buyers and processors.
Bycatch of species of concern	Institutional	It only includes bycatch of fishes not Right Whale. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/360446.pdf https://doi.org/10.1016/j.marpolbul.2021.112766

Intergenerational transfer of licenses	Economic	Ability of subsequent generations to access and benefit from a license. The ability to transfer licenses to family members. Trust agreements inhibit the ability to transfer licenses to family members. Trust agreements undermine PIFCAF (owner operator, Fleet separation) Includes **intergenerational transfer of licenses** and **corporate structure** (incorporation allows for easier intergenerational transfer). Includes **capital gain exemption**: Complex corporate structures and family trusts - capital gains exemption expanded to $1 million. A fishermanould not pay tax on first $1m if selling licence. Qualified farm or fishing property Court cases, where the court declared that farm etc. are property for a separated party to benefit (divorce settlement) If you have a taxable capital gain from the sale of qualified farm or fishing property (QFFP), you may be able to claim a capital gains deduction. QFFP is property owned by you, your spouse or common-law partner, or by a family-farm or family-fishing partnership in which you, your spouse or common-law partner, holds an interest. QFFP includes: a real property, such as land and buildings a share of the capital stock of a family farm or family fishing corporation you or your spouse or common law partner owns an interest in a family farm or family fishing partnership that you or your spouse or common law partner owns a property included in Class 14.1 used in the course of carrying on a farming or fishing business, such as milk and egg quotas Thiessen, Victor., and Davis, Anthony (1988) Recruitment to small boat fishing and public policy in the Atlantic Canadian fisheries. Rev. Canad. Soc. & Anth. 25(4), pp. 603-627 https://laws-lois.justice.gc.ca/PDF/F-14.pdf Section 2.5, (h) the preservation or promotion of the independence of licence holders in commercial inshore fisheries Regulations Amending the Atlantic Fisheries Regulations, 1985 and the Maritime Provinces Fishery Regulations Owner-operator policy and PIIFCAF, impact distribution of access and benefit, employment and livelihoods in fishing sector, contribution to community wellbeing, independence among harvesters, cultural identity and sustainable communities. Enforcement of regulations and license conditions is a key factor in stability. PIIFCAF has actually been phased out due to the new Inshore regulations. PIIFCAF Policy has been inscribed into legislation, Section 2.5 of Fisheries Act Fisheries Act (R.S.C., 1985, c. F-14) Section 2.5 Except as otherwise provided in this Act, when making a decision under this Act, the Minister may consider, among other things, (a) the application of a precautionary approach and an ecosystem approach; (b) the sustainability of fisheries; (c) scientific information; (d) Indigenous knowledge of the Indigenous peoples of Canada that has been provided to the Minister; (e) community knowledge; (f) cooperation with any government of a province, any Indigenous governing body and anybody — including a co-management body — established under a

		land claims agreement; (g) social, economic and cultural factors in the management of fisheries; (h) the preservation or promotion of the independence of licence holders in commercial inshore fisheries; and (i) the intersection of sex and gender with other identity factors.
Number of days fished		This is average number of days fished using logbook and survey data

Use of technology for conservation	Institutional	This includes using rope less gears, biodegradable panels. https://www.dfo-mpo.gc.ca/fisheries-peches/commercial-commerciale/atl-arc/narw-bnan/management-gestion-eng.html https://www.clf.org/blog/ropeless-fishing-gear/ https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/maritimes/2019/inshore-lobster-eng.html https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/infographics-infographies/narw-bnan-protecting-protege-eng.html https://static1.squarespace.com/static/5cb508c529f2cc1a09c7fbc0/t/5db99d7a2370a55966a72a8d/1572445565964/CAN+LOBSTER+INDUSTRY+PROTECTION+of+the+RIGHT+WHALE.pdf https://lobstercouncilcanada.ca/all-about-lobster/sustainability/ https://dalspace.library.dal.ca/bitstream/handle/10222/75165/Goodman_A_MMMGraduateProject.pdf?sequence=1&isAllowed=y
Trust/Controlling agreements	Economic	**Trust Agreements** (Includes preservation of inshore fleet) In a controlling agreement, a company or individual agrees to pay a retiring harvester to transfer their license. The retiring harvester will then transfer that license to an eligible harvester in a contractual agreement with the company. The new entrant, then, is bound to the obligations set out in the contract with the company. This arrangement has become more prevalent as the market price of licenses increased to as much as $500,000, and banks became hesitant to lend money for license purchases (Bodiguel, 2002; Weston, 2009). In Barnett & Eakin 2015; Barnett et al. 2017 pg 64 A form of corporate concentration. Control over the license holder. Employee fishing under trust agreement makes a percentage (less money) of the gains. Difficult to tell legally if someone is in a Trust Agreement. - Barnett, Allain J. (2018) Recommendations for full-spectrum sustainability in Canadian Lobster integrated management plans based on a socio-economic analysis of Barrington, Nova Scotia https://doi.org/10.5751/ES-09981-230136 Barnett, Allain J., Messenger, Robin A., and Wiber, Melanie G. (2017) Enacting and contesting neoliberalism in fisheries: The Tragedy of commodifying lobster access rights in Southwest Nova Scotia. Marine policy, 60-68. Barnett, Alain J., and Eakin, Hallie (2015) "We and Us, not I and me": Justice, social capital, and household vulnerability in a Nova Scotia fishery. Applied Geography, 59, pp. 107-116. Link Bodiguel, Clotilde (2002) Fishermen facing the commercial lobster fishery licensing policy in the Canadian Maritime Provinces: origins of illegal strategies, 1960–2000 .Marine Policy 26, pp. 271–281 Mombourquette, Daniel R. (2001) A Science-industry study of the distribution of fishing benefits to the community of Grand Manan, Bay of Fundy. A Thesis submitted to Saint Mary's University, Nova Scotia. In partial fulfilment of the requirements for the Degree of Master of science in applied science. March 28, 2019, Halifax, Nova Scotia. https://www.dfo-mpo.gc.ca/reports-rapports/regs/piifcaf-policy-politique-pifpcca-eng.htm Squires, K., and M. G. Wiber. 2018. Distribution of fishery benefits and community well-being: a

		review of increased access to the Eastern Nova Scotia snow crab fishery. Ecology and Society 23(2):25. https://doi.org/10.5751/ES-10137-230225
Distribution of access and benefits	Economic	It also encompasses **Distribution of landings** (Distribution of lobster landings across all fishers) + Fisheries Act + owner operator policy + gender + Equity and access (includes social capital) + limited entry licensing The extent to which the ability to fish and the ability to benefit from fishing is distributed within a community. (??) Mombourquette, Daniel R. (2019) A Science-industry study of the distribution of fishing benefits to the community of Grand Manan, Bay of Fundy. A Thesis submitted to Saint Mary's University, Nova Scotia. In partial fulfilment of the requirements for the Degree of Master of science in applied science. March 28, 2019, Halifax, Nova Scotia. Link Squires, K., and M. G. Wiber. 2018. Distribution of fishery benefits and community well-being: a review of increased access to the Eastern Nova Scotia snow crab fishery. Ecology and Society 23(2):25. https://doi.org/10.5751/ES-10137-230225

Lobster fecundity	Ecological	Negative impact of higher temperature on lobster fecundity: Heather N. Koopman, Andrew J. Westgate, and Zachary A. Siders. Declining fecundity and factors affecting embryo quality in the American lobster *(Homarus americanus)* from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences. 72(3): 352-363. https://doi.org/10.1139/cjfas-2014-0277 Estrella, Bruce T. and Steven X. Cadrin. "Fecundity of the American lobster *(Homarus americanus)* in Massachusetts coastal waters." (2013). Reproductive Status of the American Lobster in Southwest Nova Scotia and the Bay of Fundy (Lobster Fishing Areas 34-38): https://waves-vagues.dfo-mpo.gc.ca/Library/360426.pdf
Escape vent size	Institutional	Escape vents are required to allow escapement of undersize lobsters https://www.ilesdelamadeleine.com/wp-content/uploads/2020/04/Homard-22-IDLM-PPAC-2020-vE-2020-04-24.pdf
pH	Climate	Wilson TJB, Cooley SR, Tai TC, Cheung WWL, Tyedmers PH (2020) Potential socioeconomic impacts from ocean acidification and climate change effects on Atlantic Canadian fisheries. PloS ONE 15(1): e0226544. https://doi.org/10.1371/journal.pone.0226544 Stage IV larvae are more susceptible to ocean acidification than other stages (This needs to be validated/cited) Ocean Acidification Decreases Growth and Development in American Lobster (Homarus americanus) Larvae: https://journal.nafo.int/Volumes/Articles/ID/336/Ocean-Acidification-Decreases-Growth-and-Development-in-American-Lobster-emHomarus-americanusem-Larvae Future projected pH changes due to ocean acidification are expected to reduce clutch volume, hatching success and larval survival. Future decreased pH is linked to less larvae, but the larvae are larger (is there any benefits of being larger at hatch?)
Average age of community	Economic	We should consider having two separate elements for this: + average age of fishers This is the age structure and how difficult it is to recruit new staff. For the purpose of this model we consider adults only (18+). Atlantic provinces will have highest proportion of seniors over 85: census Mombourquette, Daniel R. (2001) A Science-industry study of the distribution of fishing benefits to the community of Grand Manan, Bay of Fundy. A Thesis submitted to Saint Mary's University, Nova Scotia. In partial fulfilment of the requirements for the Degree of Master of science in applied science. March 28, 2019, Halifax, Nova Scotia. Squires, K., and M. G. Wiber. 2018. Distribution of fishery benefits and community well-being: a review of increased access to the Eastern Nova Scotia snow crab fishery. Ecology and Society 23(2):25. https://doi.org/10.5751/ES-10137-230225 Maritimes GBA+ work by P&E

Commercial communal	Indigenous Rights and Reconciliation	Aboriginal Communal Fishing Licences Regulations (SOR/93-332) https://laws-lois.justice.gc.ca/eng/regulations/sor-93-332/index.html Maritimes Region Commercial Fisheries Licensing Policy https://www.dfo-mpo.gc.ca/reports-rapports/regs/licences-permis/maritimes/licensing-pol-permis-peche-eng.htm https://policyoptions.irpp.org/magazines/may-2021/finding-a-way-forward-on-the-mikmaq-and-maliseet-treaty-right-to-fish-for-a-moderate-livelihood/
Occupational pluralism	Economic	Income and type of employment outside of lobster fishing. Ability to hold other means of income outside of lobster fishing (carpentry, landscaping, etc...), including tourism (Ecotourism, whale watching, recreational fishing of lobsters). Licensing policies (eligibility requirements re: time spent fishing) has made it difficult to pursue other occupations that have historically contributed to harvester income and the viability of an enterprise; to get core, have to fish certain number of months (varies by province and by county) DFO licensing policy – Number of hours required to be a full time/Bona Fide harvester CCPFH-LABOUR_MARKET_INFORMATION_STUDY-ENG-WEB.pdf (fishharvesterspecheurs.ca) Barnett, Alain J., and Eakin, Hallie (2015) "We and Us, not I and me": Justice, social capital, and household vulnerability in a Nova Scotia fishery. Applied Geography, 59, pp. 107-116. Link In some households, spouses have taken jobs to supplement household incomes. Nothing to stop fishermen from finding other jobs (infomedia.gc.ca)
Wind and wave	Climate	This includes storm frequency and severity Greenan, B. J. W., et al. "Changes in oceans surrounding Canada." Canada's Changing Climate Report, eds E. Bush and DS Lemmen (Ottawa, ON: Government of Canada) (2018): 343-423. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR-Chapter7-ChangesInOceansSurroundingCanada.pdf Greenan, Blair JW, et al. "Climate change vulnerability of American lobster fishing communities in Atlantic Canada." Frontiers in Marine Science (2019): 579. https://doi.org/10.3389/fmars.2019.00579 Development Trends and Vulnerability to Severe Storms (A Case Study Analysis in Nova Scotia) : https://www.novascotia.ca/nse/climate-change/docs/DevTrendsVulnerability_SevereStorms_Historical_Wightman.pdf Correlation between intense cyclonic activity and sea surface temperature: Walmsley, J. (editor). (2009). The 2009 State of Nova Scotia's Coast Technical Report. CBCL Limited. Province of Nova Scotia. www.gov.ns.ca/coast.

Social license & compliance	Institutional	Experiential knowledge/information: Harvesters are having a hard time understanding how to comply based on conflicting regulations from Transport Canada & DFO for example Community-level permission (activity-based). In those LFAs where v-notching is mandatory, the operationalization of this tactic relies on collaborative governance with industry. There are ongoing challenges with enforcement of v-notching related to definition. Ability to set up suitable regulatory framework to enact what needs to be done Rochette R, Sainte-Marie B, Allain M, Baker J, Bernatchez L, Boudreau V, Comeau M, Côté J, Miron G, Ramsay L, Squires K, Tremblay JM. 2018. The Lobster Node of the CFRN: Co-constructed and collaborative research on productivity, stock structure and connectivity in the American lobster Homarus americanus. Canadian Journal of Fisheries and Aquatic Sciences 75: 813-824, https://doi.org/10.1139/cjfas-2016-0426 https://www.cbc.ca/news/canada/nova-scotia/no-mpa-here-signs-eastern-shore-1.4996534 https://www.cbc.ca/news/canada/nova-scotia/skeptical-fishermen-briefed-on-proposed-eastern-shore-marine-protected-area-1.4606757 https://reader.elsevier.com/reader/sd/pii/S0308597X20308630?token=DB143E06CB17A65F860BB399B434550CFAC45202775BE53554A935C8ABFC49C8D50D8C6BAFBC1B5A8137ECE925642D36&originRegion=us-east-1&originCreation=20220706150506 https://www.facetsjournal.com/doi/10.1139/facets-2020-0109 https://www.jstor.org/stable/3147040
Lobster larval abundance	Ecological	This could include post-larval settlement (see the links below) https://cdnsciencepub.com/doi/full/10.1139/cjfas-2013-0060 https://doi.org/10.5343/bms.2017.1150 Abundance changes of juvenile lobster over 20-year period; juvenile faunal abundance and associations established for NS and NB sites (Wahle, Hunt, Lawton) brought up by Shelly Armsworthy Cowan, Diane & Solow, Andrew & Beet, Andrew. (2001). Patterns in abundance and growth of juvenile lobster, Homarus americanus. Marine and Freshwater Research. 52. 1095-1102. https://doi.org/10.1071/MF01191

Aquaculture	Institutional	The impact of aquaculture on displacement of fishers from traditional grounds and also pressure on harbors and infrastructure mentioned during the meeting with GM. And also concerns about expansion of aquaculture in the area. Interaction between lobster and other industries (i.e. Aquaculture): An Aquaculture company pleaded guilty to 2 charges related to deaths of lobsters in Bay of Fundy https://www.cbc.ca/news/canada/new-brunswick/aquaculture-company-on-the-hook-for-500k-for-pesticide-use-1.1317105 Defining Lobster Fishermen Concern for Finfish Aquaculture on Lobsters and Lobster Fishing Communities in Nova Scotia: A Pilot Study https://novascotia.ca/fish/Defining_Lobster_Fisherman_Concerns_-_U_Sainte_Anne.pdf Wiber et al 2012 Impact of Aquaculture on Commercial Fisheries: Fishermen's Local Ecological Knowledge. Human Ecology 40(1). link Donna G. Curtis Maillet, Melanie G. Wiber & Allain Barnett (2017): Actions towards the joint production of knowledge: the risk of salmon aquaculture on American Lobster, Journal of Risk Research, DOI: link Loukes et al 2014 Interactions between finfish aquaculture and lobster catches in a sheltered bay. Marine Pollution Bulletin 88, 255–259 Grant et al 2016 Correspondence: Lack of interaction between finfish aquaculture and lobster catch in coastal Nova Scotia. Marine Pollution Bulletin 110, 613–615
Pollution & Marine debris	Institutional	Micro-plastics associated with fishing gear (not just specific to lobster) have been linked to stress and potentially survival of larval lobsters. Plastic ingested - rubber bands a major source Woods, M.N., Hong, T.J., Baughman, D., Andrews, G., Fields, D.M. and Matrai, P.A., 2020. Accumulation and effects of microplastic fibers in American lobster larvae (Homarus americanus). Marine Pollution Bulletin, 157, p.111280. Potocka et al. 2019. Plastic pollution affects American lobsters, Homarus americanus. https://doi.org/10.1016/j.marpolbul.2018.12.017 Barnett et al (2016) The role of public participation GIS (PPGIS) and fishermen's perceptions of risk in marine debris mitigation in the Bay of Fundy, Canada. Ocean & Coastal Management 133 (2016) 85-94 Goodman et al (2021) Retrieval of abandoned, lost, and discarded fishing gear in Southwest Nova Scotia, Canada: Preliminary environmental and economic impacts to the commercial lobster industry. Link
Boat size	Institutional	The fishery is undertaken almost entirely by vessels less than 13.7m (45') length overall (LOA) https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/maritimes/2019/inshore-lobster-eng.html https://waves-vagues.dfo-mpo.gc.ca/Library/186156.pdf

Moderate livelihood	Indigenous Rights and Reconciliation	R. v. Marshall [1999] 3 SCR 456 https://scc-csc.lexum.com/scc-csc/scc-csc/en/item/1739/index.do https://www.dfo-mpo.gc.ca/fisheries-peches/aboriginal-autochtones/moderate-livelihood-subsistance-convenable/2021-approach-approche-eng.html Loring, P.A.H., Hannah L. 2021. Evaluating cultural impacts of fisheries management. Department of Fisheries and Oceans. https://acadiafirstnation.ca/resources/735-kespukwitk-netukulink-livelihood-protocol-nov-2021-bravfna/file.html POTLOTEK FIRST NATION, NS. NETUKULIMK LIVELIHOOD FISHERIES. POLICY AND PROTOCOL. October 2020. https://mikmaqrights.com/wp-content/uploads/2020/12/Potlotek-NETUKULIMK-LIVELIHOOD-FISHERIES-PLAN_full-doc.pdf Sipekneka'tik Treaty Fishery 2021 https://www.ourcommons.ca/content/Committee/441/FOPO/WebDoc/WD11570511/CPC-Dissenting-ModerateLivelihood-e.pdf Extending the fishing season for moderate livelihood: https://www.dfo-mpo.gc.ca/fisheries-peches/aboriginal-autochtones/moderate-livelihood-subsistance-convenable/lobster-homard-eng.html https://www.cbc.ca/news/canada/nova-scotia/we-koqma-q-moderate-livelihood-fishery-gets-federal-approval-1.6462391 Rotman, L. I. (2000). My hovercraft is full of eels: smoking out the message in R. v. Marshall. Saskatchewan Law Review, 63(2), 617-644 McMillan, L. J., & Prosper, K. (2016). Remobilizing etukulimk: indigenous cultural and spiritual connections with resource stewardship and fisheries management in Atlantic Canada. Reviews in Fish Biology and Fisheries, 26(4), 629-647. https://086gc-my.sharepoint.com/:b:/g/personal/jill_campbell-miller_dfo-mpo_gc_ca/EZoTw9reXzxPky-Wjaq1XyEBMKQhYiJlLBnoKdIG-EWcIQ Guerrier, E. A. (2001). From" Bare Subsistence" to" Moderate Livelihood": Limitations on Mi'kmaq Rights to Resources in R. v. Marshall. Algonquian Papers-Archive, 32 https://086gc-my.sharepoint.com/:b:/g/personal/jill_campbell-miller_dfo-mpo_gc_ca/EZ1whEj6j61LlHZbQOv8n5cBnnf_QSaKN02Y-DcPW_-4Iw Naiomi Metallic & Contance MacIntosh, "Canada's Actions Around the Mi'Kmaq Fisheries Rest on Shaky Legal Ground" (9 November 2020) online: Policy Options https://policyoptions.irpp.org/magazines/november-2020/canadas-actions-around-the-mikmaq-fisheries-rest-on-shaky-legal-ground/ https://www.cbc.ca/news/canada/nova-scotia/first-nations-moderate-livelihood-elvers-proposal-1.6080471 https://www.cbc.ca/news/canada/nova-scotia/dfo-hands-percent-of-commercial-baby-eel-quota-to-mi-kmaw-1.6404503

		Wiber & Kennedy 2001. Impossible Dreams: Reforming Fisheries Management in the Canadian Maritimes after the Marshall Decision. *Law & Anthropology.* Wiber & Milley 2007. AFTER MARSHALL: IMPLEMENTATION OF ABORIGINAL FISHING RIGHTS IN ATLANTIC CANADA. https://commission-on-legal-pluralism.com/system/commission-on-legal-pluralism/volumes/55/wibermilley-art..pdf

Minimum legal size	Institutional	There are conservation measures in the management plan to promote productivity (which vary by LFA) such as input controls and biological controls. Minimum legal size (MLS) aims to allow half of females to reach maturity and spawn before being taken by the fishery. Gendron, L. and P. Gagnon. 2001. Impact of various fishery management measures on egg production per recruit in American lobster (Homarus americanus). Can. Tech. Rep. Fish. AquiatSci. 2369: vi + 3 1 p. https://publications.gc.ca/site/eng/422192/publication.html Protection of large and/or berried females contributes to productivity. DeAngelis, B. M., R. Cooper, M. Clancy, C. Cooper, T. Angell, S. Olszewski, W. T. Colburn, and J. Catena. 2010. Impacts of V-notching the American lobster. Journal of Shellfish Research 29: 489-496. Goetting, Kathryn and Whiffen, Cathy (2011) The effects of v-notching on reproductive potential in American lobsters (Homarus americanus) in Newfoundland. Research Report. Memorial University of Newfoundland, St. John's, Newfoundland and Labrador. http://www.curra.ca/documents/Goetting-Effects_of_V-Notching-web_version.pdf Jeffery, Nicholas & Heaslip, Susan & Stevens, Lydia & Stanley, Ryan. (2020). Canadian Science Advisory Secretariat (CSAS) Biophysical and Ecological Overview of the Eastern Shore Islands Area of Interest (AOI). https://waves-vagues.dfo-mpo.gc.ca/Library/40820671.pdf Eastern Shore Islands Risk Assessment (Marine Planning and Conservation - unpublished) Commercial fisheries licensing policy for Eastern Canada: https://www.dfo-mpo.gc.ca/reports-rapports/regs/licences-permis/index-eng.htm#ch4_0 Atlantic Fishery Regulations, 1985 (SOR/86-21): https://laws-lois.justice.gc.ca/eng/regulations/sor-86-21/page-2.html#h-891774 Timing of season relates to catchability of lobster at a given time = peak fishing times. Regional fishing timing vs major competitor (Maine) Tremblay, M. J. and Stephen J. Smith. “Lobster (Homarus americanus) catchability in different habitats in late spring and early fall.” Marine and Freshwater Research 52 (2001): 1321-1331. Landings data, StatCan trade data, US landings/trade data Tremblay and Smith 2001. Lobster Catchability in different habitats in late spring and early fall. Mar Freshwater Res. 52. 1321-31 McLeese and Wilder. 1958. Activity and catchability of lobster in relation to temperature. Robichaud and Campbell 1991.Annual and seasonal size frequency changes of trap caught lobsters in the Bay of Fundy. J. Northw. Atl. Fish. Sci. 11: 29-3. Opportunity to appeal DFO licensing decisions: https://waves-vagues.dfo-mpo.gc.ca/Library/40784897.pdf

		Davis, Anthony. (1984). Davis 1984 - "You're your own boss": An Economic Anthropology of Small Boat Fishing. DOI: 10.13140/RG.2.2.32188.46725 First
lobster stock abundance	Ecological	This should be biomass estimates, but could also refer to density. NOT CPUE. Assessment Of American Lobster *(Homarus americanus)* In LFAs 35–38: https://waves-vagues.dfo-mpo.gc.ca/Library/4097943x.pdf Boudreau, Stephanie & Anderson, Sean & Worm, Boris. (2014). Top-down and bottom-up forces interact at thermal range extremes on American lobster. Journal of Animal Ecology. 84. https://doi.org/10.1111/1365-2656.12322 ![jane12322-fig-0002-m](https://s3.amazonaws.com/cloud.kumu.io/accounts/333072/727620/213ba975-d932-4505-8151-326ba9296695.jpg)

Designations	Economic	Application for First Nations: https://laws-lois.justice.gc.ca/eng/regulations/sor-93-332/page-1.html Food, social and ceremonial fisheries (dfo-mpo.gc.ca) A First Nation retains the license and all members are designated to fish under it. The First Nation can also designate members of other Indigenous communities and non-Indigenous individuals to fish their license (communal commercial). The First Nation always retains the license and the ability to fish it (it's not given to anyone else and not a partnership). Designations can be assigned in rights-based fisheries, where FN would have ability to designate who they want to fish their license, food security comes at a cost to fish FSC, so they may have FN X to designate FN Y (or a non-indigenous captain) Under aboriginal community fishery licenses, license is designated to band as a whole, have flexibility to designate FSC and communal commercial licenses-- common to designate a non- indigenous captain https://www.dfo-mpo.gc.ca/reports-rapports/regs/licences-permis/maritimes/licensing-pol-permis-peche-eng.htm Non-indigenous Application: Where the holder of a license is affected by an illness which prevents him from operating a fishing vessel, upon request and upon provision of acceptable medical documentation to support his request, he may be permitted to designate a substitute operator for the term of the licence. Such designation may not exceed a total period of five years.
Use of technology for lobster fishing		Radar. Sounder. Plotter. Olex/Time Zero (or equivalent).
Season duration	Institutional	The commercial lobster fishery in Atlantic Canada is managed by lobster fishing area (LFA) which also implies fishing seasons. The fishery within Maritimes Region occurs within LFA 27 through LFA 38 (the inshore lobster fishery) and LFA 41 (the offshore lobster fishery). LFA 40 also falls within Maritimes Region. LFA 40 is a lobster conservation area and is closed to lobster fishing. Catch rates, regulations and season lengths vary among the LFAs. The 13 LFAs bordering Nova Scotia were delineated for reasons of geography, weather, local seasonal molt and market demand [4]. More broadly the Nova Scotia lobster fishery is often divided into two large sectors, namely Scotia Fundy (encompassing LFAs 27–35) and the Gulf of St. Lawrence (encompassing LFAs 25–26b). 345 Quigley, S. (2020) The purpose of Fishing Seasons in the Inshore Lobster Fisheries in Maritimes Region. Internal DFO document. Reid-Musson et al (2021) Bridging fragmented knowledge between forecasting and fishing communities: Co-managed decisions on weather delays in Nova Scotia's lobster season openings. Applied Geography,133(6):102478 Atlantic Fisheries Regulations and variation orders https://www.gazette.gc.ca/rp-pr/p2/2021/2021-05-26/html/sor-dors100-eng.html Should we put in our tech report here on historical season info?

Lobster market price	Economic	International and domestic market prices for lobster Includes use of holding cars. Fluctuations in lobster markets over time for pricing and demand Holding spaces for lobster to capitalize on market prices US exchange rate also a significant factor in determining lobster price Nova Scotia creates its own seafood quality certification program https://www.cbc.ca/news/canada/nova-scotia/nova-scotia-seafood-quality-certification-program-1.6075542 Timing of lobster on the market. Supply vs demand. https://www.jstor.org/stable/26542661\ https://www.pressherald.com/2012/08/11/market-forces-make-everyone-feel-the-pinch_2012-08-12/ Thériault, Gilles, John Hanlon, and Lewis Creed. Report of the maritime lobster panel. Prince Edward Island Department of Fisheries, Aquaculture and Rural Development, 2014. https://seagrant.umaine.edu/wp-content/uploads/sites/467/2019/03/2015-henry-johnson-social-resilience-maine-lobster-industry.pdf exports and international markets included here Financial value, viability & prosperity Carbon footprint of live lobster flights to EU and Asia could be a future vulnerability. The pandemic is an example of what could happen if those markets are no longer accessible. Borthwick (2019) Climate Impact of Swedish imports of American lobster from North America https://lobstercouncilcanada.ca/wp-content/uploads/2011/04/2FINAL-Lobster-Report.pdf Parker et. al. “Fuel use and greenhouse gas emissions of world fisheries.” Nature Climate Change. 2018. https://www.nature.com/articles/s41558-018-0117-x.pdf COVID-19 pandemic on lobster industry’s radar as 2020-21 season gears up | SaltWire Lobster fishers who decline work due to COVID-19 are eligible for federal benefits: Ottawa | Globalnews.ca Impact of foriegn exchange rate: Eco certification MSC certification.

		ENGOs responding to Traceability requirement ThisFish: Atlantic Lobster Marine Stewardship Council (MSC). (2019f) From Ocean to Plate: How DNA testing helps to ensure traceable, sustainable seafood. Retrieved online December 12, 2019: Parlee, Courtenay E. & Wiber, Melanie G. (2011) Power and Legal Pluralism in Lobster Traceability. Journal of Legal Pluralism and Unofficial law, 64, pp. 121-148. Foley, Paul (2012) The Political Economy of Marine Stewardship Council Certification:Processors and Access in Newfoundland and Labrador's Inshore Shrimp Industry. Journal of Agrarian Change 12(2/3), pp. 436-457. Foley, Paul (2013) National Government Responses to Marine Stewardship Council (MSC) Fisheries Certification: Insights from Atlantic Canada. New Political Economy, 18(2), pp. 284-307. If lobster fishery doesn't demonstrate that it's taking measures to address entanglements, MSC could be revoked or suspended. Maritime Canada inshore lobster trap fishery - MSC Fisheries Nova Scotia creates its own seafood quality certification program Increasing pressure by large companies to source certifies seafood (including lobster) https://www.seachoice.org/retailer/walmart-canada/ Walmart's Sustainability Efforts Take to the Seas with MSC-Certified Sustainable Private Brand Canned Tuna Government of Canada launches consultation on boat-to-plate traceability for fish and seafood products - Canada.ca Canadian Food Inspection Agency (CFIA). (2019) European Union (EU) – Export requirements for fish and seafood. Retrieved online December 12, 2019: Link National Ocean Council Committee (NOCC). (2018) U.S. Seafood Import Monitoring Program. Retrieved online December 12, 2019:Seafood Import Monitoring Program | NOAA Fisheries https://www.canada.ca/en/food-inspection-agency/news/2021/08/government-of-canada-launches-consultation-on-boat-to-plate-traceability-for-fish-and-seafood-products.html https://fisheries.msc.org/en/fisheries/maritime-canada-inshore-lobster-trap-fishery/@@view https://oceana.ca/wp-content/uploads/sites/24/Boat-to-plate-stakeholder-sign-on-letter-Dec-2021.pdf https://www.sciencedirect.com/science/article/pii/S0308597X1000062X

Regulatory burden		The cumulation and interaction of regulations from various departments and jurisdictions including but not limited to : Transport Canada CRA WorkSafe NB DFO RNAC CIRNEC
Food social and ceremonial (FSC)	Indigenous Rights and Reconciliation	Food, social and ceremonial fisheries (dfo-mpo.gc.ca) R. v. Sparrow - SCC Cases (lexum.com) R. v. Sparrow [1990] 1 SCR 1075 https://scc-csc.lexum.com/scc-csc/scc-csc/en/item/609/index.dohttps://scc-csc.lexum.com/scc-csc/scc-csc/en/item/609/index.do Aboriginal Fisheries Strategy: https://www.dfo-mpo.gc.ca/fisheries-peches/aboriginal-autochtones/afs-srapa-eng.html Sipekne'katik Band FSC Lobster Fishery Management Plan Statement of Intent of Food, Social and Ceremonial Sipekne'katik Band Lobster Fishery Management Plan https://sipeknekatik.ca/wp-content/uploads/2016/03/fsc_lobster_fisheries_management_plan_final-1.pdf Evaluating cultural impacts of fisheries management. Philip A. Loring, PhD Hannah L. Harrison, PhD UINR 2007-2008 Food, Social Ceremonial Fishery Management plan https://www.uinr.ca/wp-content/uploads/2009/11/lobster-food-fishery-WEB-1.pdf https://www.dfo-mpo.gc.ca/fisheries-peches/aboriginal-autochtones/fsc-asr-eng.html Information on other FSC fisheries Assessing Socio-Economic Parameters and Methodology for Food, Social and Ceremonial (FSC) Fisheries in a Species at Risk Act (SARA) Perspective Ed Koenig and Robert Adlam Fisheries and Oceans Canada Gulf Region 343 Université ave Moncton, NB https://publications.gc.ca/collections/collection_2013/mpo-dfo/Fs103-3-2012-4-eng.pdf ACADIA FIRST NATION 2021/22 NETUKULIMK FISH HARVEST PLAN https://acadiafirstnation.ca/706-2021-2022-fsc-netukulimk-fish-harvest-plan/file.html https://www.apcfnc.ca/wp-content/uploads/2020/06/Listiguj_Fisheries_Article.pdf
Cultural attachment	Social/cultural	Fishing as a way of life. Needs more thought. ~~Combining the concepts Fishing as a way of life, community culture, community development and stability~~ ~~Sustainable communities: contribution of fishing to wellbeing of communities , social capital, informed citizenry and cultural heritage~~ ~~https://onlinelibrary.wiley.com/doi/10.1111/faf.12296~~ ~~https://cdnsciencepub.com/doi/full/10.1139/cjfas-2017-0345~~ ~~https://www.dfo-mpo.gc.ca/sds-sdd/2020-2023/index-eng.html~~

Lobster size at maturity	Ecological	Size at maturity changes with temperature/LFA. MLS changed in some LFAs to reflect Size at maturity https://waves-vagues.dfo-mpo.gc.ca/Library/344465.pdf Haar et al (2017) Female American lobster (Homarus americanus) size-at-maturity declined in Canada during the 20th and early 21st centuries. Canadian Journal of Fisheries and Aquatic Sciences. https://doi.org/10.1139/cjfas-2016-0434 Estimate of 50% maturity in LFA 34 can be found in the report: https://waves-vagues.dfo-mpo.gc.ca/Library/348830.pdf Benestan, Laura & Gosselin, Thierry & Perrier, Charles & Sainte-Marie, Bernard & Rochette, Rémy & Bernatchez, Louis. (2015). RAD-genotyping reveals fine-scale genetic structuring and provides powerful population assignment in a widely distributed marine species; the American lobster (Homarus americanus). Molecular ecology. 24. 10.1111/mec.13245. Dorant, Y, Benestan, L, Rougemont, Q, et al. Comparing Pool-seq, Rapture, and GBS genotyping for inferring weak population structure: The American lobster (Homarus americanus) as a case study. Ecol Evol. 2019; 9: 6606– 6623. https://doi.org/10.1002/ece3.5240

Capital	Economic	Individual-level Land, boat, assets as well as money. Enterprise-level money. Barnett, Alain J., and Eakin, Hallie (2015) "We and Us, not I and me": Justice, social capital, and household vulnerability in a Nova Scotia fishery. Applied Geography, 59, pp. 107-116. link Household income Davis and Thiessen 1986. Marine Policy Income distribution in Atlantic fisheries Rutherford et al. 1967 Economic appraisal of lobster. Mike Campbell Maritimes Region Lobster Economic Update Prepared for the Maritimes Region Lobster Advisory Committee Sept 24, 2021 profitability and viability included here Includes Cost of license profitability and viability of license holders IFMP talks about profitability : https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/maritimes/2019/inshore-lobster-eng.html Fisheries Act also talks about owner operator policy that is connected to profitability Cost prohibitive for younger people to get into the fishery. Will it self-regulate? How to protect value of licenses and enable intergenerational transfer? Can change distribution of licences if sold to individuals in other communities. Link to PIICAF/owner-operator DFO licensing policy – Number of hours required to be a full time/Bona Fide harvester link Henry, Anna M, and Teresa R Johnson. "Understanding Social Resilience in the Maine Lobster Industry." Marine and coastal fisheries 7.1 (2015): 33–43. Web. https://afspubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1080/19425120.2014.984086
Food security	Social/cultural	Study on the Implementation of Mi'kmaq Treaty Fishing Rights to Support a Moderate Livelihood https://www.dfo-mpo.gc.ca/transparency-transparence/briefing-breffage/2021/livelihood-subsistance-eng.htm https://www.facetsjournal.com/doi/full/10.1139/facets-2022-0048?fbclid=IwAR1akuQWjMVYvGJr49tFnB_Io7kPJISkArYoHzFjflSz4PycHmh-FjQ7WTs& https://link.springer.com/article/10.1007/s12571-016-0594-6 Indigenous peoples' fisheries and food security: a case from northern Canada
season timing		Season as per LFA regulation. When during the season fishing starts and ends. This is a conservation measure but in theory it could become regulatory measure (part of regulatory toolbox). (to be clarified with harvesters)
out-migration		People who permanently or temporarily leave the community

Commercial lobster fishery	Economic	It encompasses CPUE Stock status updates: https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2022/2022_010-eng.pdf https://publications.gc.ca/collections/collection_2021/mpo-dfo/fs70-7/Fs70-7-2021-029-eng.pdf Anthony Davis and Victor Thiessen Making sense of the dollars Income distribution among Atlantic Canadians. THE LOBSTER FISHERY OF THE MARITIME PROVINCES: ECONOMIC EFFECTS OF REGULATIONS https://waves-vagues.dfo-mpo.gc.ca/Library/1489.pdf https://www.sciencedirect.com/science/article/pii/0308597X86900539 A right to fish for a living? The case for coastal fishing people's determination of access and participation. https://www.sciencedirect.com/science/article/pii/S0964569106000706#fig1 ASSESSMENT OF AMERICAN LOBSTER IN LOBSTER FISHING AREAS 35–38 https://waves-vagues.dfo-mpo.gc.ca/Library/4097943x.pdf Barnett, A. J. 2018. Recommendations for full-spectrum sustainability in Canadian lobster integrated management plans based on a socioeconomic analysis of Barrington, Nova Scotia. Ecology and Society 23(1):36. https://doi.org/10.5751/ES-09981-230136 "We and us, not I and me": Justice, social capital, and household vulnerability in a Nova Scotia fishery https://core.ac.uk/download/pdf/79587763.pdf https://waves-vagues.dfo-mpo.gc.ca/Library/40946204.pdf https://www.dfo-mpo.gc.ca/fisheries-peches/decisions/fm-2021-gp/atl-29-eng.html https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/maritimes/2019/inshore-lobster-eng.html Miller and Rodger 1996_Fisheries Researchsoak times and fishing strategy for American lobster https://www.sciencedirect.com/science/article/pii/0165783695004459 https://www.cbc.ca/news/canada/prince-edward-island/pei-lobster-fishing-101-everything-you-wanted-to-know-1.6023324

Working condition and Safety at sea		Fishing industry has the highest fatality rate among employment sectors in Canada https://www.theglobeandmail.com/news/investigations/fishing-industry-deadliest-sector-canada/article36725324/ In Nova Scotia, safety at sea training is a key focus of the Fish Harvester Registration and Certification Board. They provide other training, e.g., quality handling while New Brunswick does not have a professionalization regime. Provincial legislation and federal regulations and policies that authorize industry-led registration and certification boards https://www.nsfishharvesters.ca/wp-content/uploads/2021/01/press-release-dec-2020-1-8.pdf Use of illicit drugs https://www.cbc.ca/news/canada/nova-scotia/fishermen-drug-use-cocaine-1.5158772 https://www.saltwire.com/nova-scotia/business/already-the-most-dangerous-profession-fisheries-facing-an-increasing-drug-use-problem-364541/
Revenue	Economic	Income generated through the sale of lobster for a lobster fishing enterprise. Has the greatest impact on the profitability and viability of the fishing enterprise. Estimate of revenues by licences is available but not much at crew level. There is potential for getting data from CRA