Applying Socio-Ecological Thinking to Canadian Regional Assessment

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Abstract

Regional assessments inform the planning and management of a proposed developments impact to society and nature. They are the broadest tool in the impact assessment process and are designed to consider the impacts of human activity, as well as the accumulation of these impacts at a regional level. Under current federal impact assessment legislation, topics of regional assessment consideration must go beyond the possible environmental effects of a proposed development to include the potential impacts this development could have on regional social, cultural, and economic conditions. In practice however, considering all such factors in a representative manner has proved difficult. In this graduate project, I explore the possibility of applying methods not yet used in Canadian impact assessment with respect to scoping the potential impacts of offshore wind development. I apply these techniques to a single marine use potentially in conflict with offshore wind development– Nova Scotia's culturally and economically important lobster fishery. While novel to impact assessment the basis of this technique is deeply rooted in socio-ecological systems thinking, and is able to capture the coupled and interdependent nature of ecological, social, cultural, and economic factors in a manner applicable to Canadian offshore impact assessment.

Keywords: Socio-ecological systems; offshore wind; Canadian regional assessment; impact assessment

Abbreviations

EARP	Federal environmental assessment review process
EIA	Environmental impact assessment
SIA	Social impact assessment
CEA	Cumulative effects assessment
SEA	Strategic environmental assessments
R-SEA	Regional strategic environmental assessment
RA	Regional assessment
IAA	Impact Assessment Act
SES	Socio-ecological system
IM	Integrated management
EBM	Ecosystem-based management
MA	United Nations Millennium Ecosystem Assessment
CER	Canadian Energy Regulator
OSW	Offshore wind
mW	Megawatt
GW	Gigawatt
TW	Terawatt
TwH	Terawatt Hour
NEDIA	Network for Expertise and Dialog in Impact Assessment
BELT	Blue Economy Lobster Team
CBA	Community Benefits Agreement

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Chapter One: Canadian Impact Assessment

1.1 Impact Assessment: The Basics of The Process

An impact assessment is a management tool used to assess the potential positive and negative effects of any form of human development, be it a proposed project, plan, program, or policy (Government of Canada, 2019). In essence, it can be thought of as a legally required 'checks and balances' process to better understand if proposed human activity is likely to affect the environment or society in a significant manner. If there are significant risks, as is often the case with development, the process must also explore the potential to reduce such risks through appropriate impact mitigation measures (ibid).

Currently, there are many different forms of impact assessment that help discern the various ways in which development impacts both nature and society. Despite such practical variation, however, all Canadian impact assessment follows a similar procedural framework (Fig 1). To better understand the process, the steps or 'phases' of a project-specific impact assessment are described as follows. Project-specific assessments can be thought as the simplest form of impact assessment, as they are temporally and spatially focused on a single development. These assessments are conducted by a 'proponent', which can be a consultant hired to do the assessment on behalf of a development company or an independent review panel. Review panels are groups of independent subject matter experts appointed by the Impact Assessment Agency of Canada (the Agency) to conduct such assessment. Upon the commencement of the assessment process, a planning phase is triggered where the public are invited to provide information and contribute to planning the assessment (Phase 1, Fig. 1). This planning stage involves the 'scoping' of potentially relevant issues, referring to the process of identifying factors which are likely to be of most importance while eliminating those of little concern. Aided by public opinion, Indigenous consultation, and expert advice, the matters relevant to the potential social and environmental implications of the proposed development are identified.

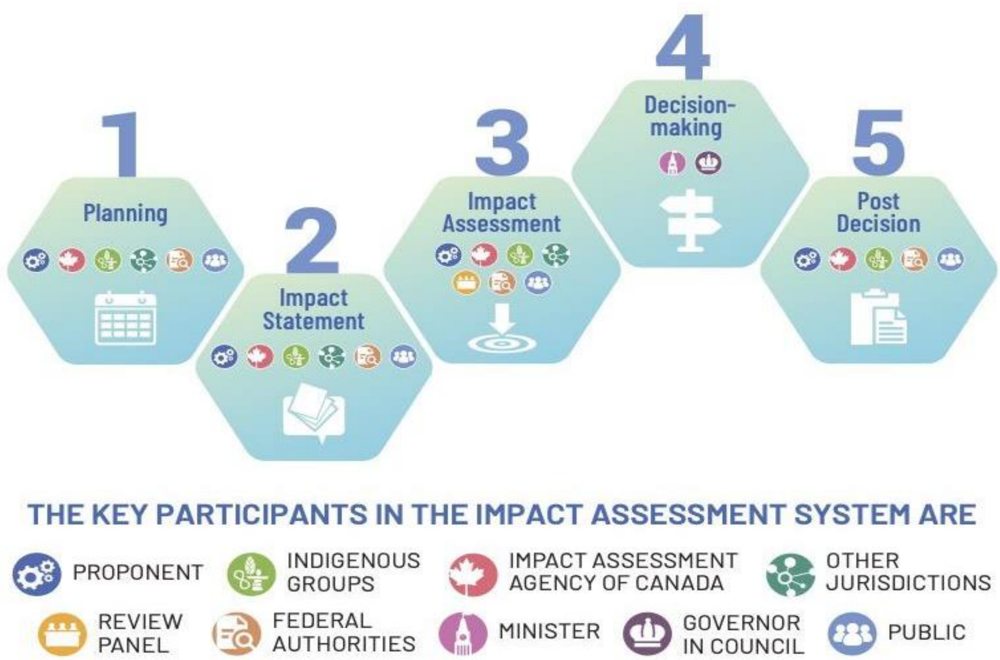

Fig. 1. Overview of the Canadian impact assessment process : Retrieved from https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/impact-assessment-process-overview.html (Impact Assessment Agency of Canada, 2021).

In the next phase, the proponent outlines the information needed to develop the impact statement, then conducts and compiles such information into a detailed technical document. Within this phase, the proponent outlines the research necessary to best understand the issues identified through scoping (conducted in Phase 1, 'Planning'), with respect to how the activity could impact the environment or society. The Agency must be satisfied that the proponent has provided the required information as defined by the scoping stage, and that such information has been provided within the allotted time. If deemed satisfactory, the project moves on to phase three of the impact assessment process. Within the

Box 1: Factors to be considered in an impact assessment, retrieved from Section 22 (1) of the Impact Assessment Act (2019).

- the purpose of, and need for, the project
- alternative means of carrying out the project
  - alternatives must be technically and economically feasible
- changes to the environment, and to health, social, and economic conditions
  - as well as the positive and negative consequences of these changes, and
  - the effects of malfunctions or accidents that may occur in connection with the project
- measures to mitigate adverse effects
  - must be technically and economically feasible
- the impact that the project may have on any Indigenous group
  - and adverse impacts on the rights of Indigenous peoples as recognized and affirmed by section 35 of the Constitution Act, 1982
- Indigenous knowledge, where provided
- considerations related to Indigenous cultures
- any assessment of project effects conducted by, or on behalf of, an Indigenous governing body and that is provided
- community knowledge, where provided
- the extent that the project contributes to sustainability
- the extent to which the effects of the project contribute to or hinder the Government of Canada's ability to meet its
  - environmental obligations, and
  - climate change commitments
- any change to the project that may be caused by the environment
- the requirements of the follow-up program
- any relevant strategic or regional assessments
- the cumulative effects of physical activities in a region
- studies or plans related to the region
- the different impacts of a project on diverse groups of people
  - such as those identified by gender and other identity factors like age, ethnicity, ability (this type of analysis is referred to as Gender-Based Analysis Plus
- any public comments received
- any other matter deemed relevant by the Agency

actual assessment, a variety of factors (summarized in Box 1) are considered to gauge the potential positive and negative implications that such a project would have on the social and ecological condition of the area to be developed (Impact Assessment Agency of Canada, 2021). The outcome of this process is a technical document termed an 'impact assessment report' which outlines the underlying reasoning, methodology, findings, and recommendations of the assessment.

Upon the completion of the assessment and all relevant public inquiry, Indigenous consultation, and subject-matter expertise, a decision must be made regarding whether the proposed project should be allowed. Central to the decision is public interest, where the impact assessment report and consultation outcomes inform the Minister or Governor in Council's decision. If it is deemed that such impacts are in the public's interest (see below), conditions are established for the proponent through a 'decision statement' which outlines the rationale of such decision and any necessary impact mitigation measures. Lastly, the final post-decision stage of the impact assessment process promotes proponent compliancy with the terms outlined in the decision statement, and follow-up and monitoring occur where deemed necessary (Government of Canada, 2019).

Upon completion of an impact assessment, a decision is made by Minister of Environment and Climate Change whether the proposed development is in the public's interest. Within this decision the proposed project's contribution to sustainability, the extent to which effects are significant, the associated mitigation measures, and the impact to Indigenous groups and their associated rights are considered. As such, the impact assessment process must not be thought of a means of management, but rather a tool to help make decisions regarding the proposed development at hand.

1.2 Impact Assessment as a Principal Tool of Environmental Management

Today, impact assessment is concerned with the comprehensive notion of 'sustainable' development, that is the continued wellbeing of the various social, cultural, economic, and environmental factors which proposed development may affect (Government of Canada 2019). While the practice is now multifaceted in nature, this has not always been the case. In the past, impact assessment was a means of environmental protection, used to prevent transboundary environmental harm (Read, 1963). Since its initial form as an environmental management measure 70 years ago, the practice has diversified to assess many different facets of society and our interactions with the natural world. To fully understand the methodological evolution of impact assessment to capture the broad range of issues to which it is applied to today, as well as the underlying reason behind the current array of approaches, we must consider the history of the process. In tracing the history of impact assessment in Canada, four stages of significant methodological advancement appear which have shaped its focus and purpose to the process which we recognize today (Hanna, 2005).

Impact assessment began as a means to identify a source of pollution, specifically point source pollution as to mitigate its effect on the local environment. Early examples include the famous 'Trail Smelter' dispute which involved international tribunal between Canada and the

United States (Read, 1963), or the siting of an industrial complex on the north shore of Lake Erie (Chanasyk, 1970). While not technically impact assessments, as the term was not used until the 1970's, these early environmental assessments have formed the origins from which the impact assessment process continues to evolve (Couch et al., 1983). Early environmental assessment studies were retrospective, meaning the impact of these industrial activities were only studied once they had happened. Furthermore, the 'impact' of consideration was limited to the environmental pollution, such as the sulfur oxide, nitrous oxide, and other contaminants as released from these point-source activities.

From its initial purpose as a reactionary measure to an individual environmental issue, there was a central shift within the practice to make it more proactive. During the late 1960's, after decades of industrial development following the second World War, the public's interest around environmental issues began to grow. In 1969, the United States catalyzed impact assessment practice within their National Environmental Policy Act, and in 1972, the United Nations' Conference on the Environment was held in Stockholm. Other factors behind this societal shift towards furthered environmental consciousness include the publishing of Rachel Carson's "Silent Spring" (1962) or the worrisome Torry Canyon oil spill (1976) and Minamato mercury poisoning events (1956). In lieu of such national, international, and societal conditions, and with large energy and transportation projects on the horizon, Canada quickly followed suit with their own domestic environmental policies. In 1973, the Government of Canada established the Federal Environmental Assessment Review Process (EARP) to proactively conduct environmental impact assessments (EIAs) (Government of Canada, 1987). These early efforts were non-legislative self-assessments, whereby federal departments developed and applied their own screening processes to identify proposed projects that had the potential to cause 'unacceptable' pollution. Those with significant effects were sent to Environment Canada for review by the Environmental Assessment Panel, which later became the Federal Environmental Assessment Review Office. EARP, which was the first nationally coordinated attempt to proactively help manage the environmental implications of a project, remained largely concerned with the physical and biological aspects of development proposals—specifically the effect on air, land, water, plants, and animals (ibid). These processes were to some capacity, however, concerned with the effect that development could have on 'people'. While these screening and review processes remained highly individual and technical in nature, they are the genesis of the impact assessment process we recognize today.

In its third developmental stage, as exemplified by the Berger Inquiry (Box 2), EIA looked to integrate environmental protection into broader planning initiatives. While the practice remained individual in context in that it focused on distinct projects or activities, there was an essence of pluralism in that impact assessment now looked to assess the various cultural, historical, and economic factors associated with the environment. These progressive aspects were not random, of course, and instead reflected the political will of the time. Considering that all assessment screening under EARP was done by various federal departments, discrepancy of goals and methods emerged within these processes. Furthermore, as EIAs evolved autonomously at the provincial and national levels in Canada, there was further opportunity for procedural inconsistency to arise. Not wanting the legal battles that had begun to plague EIAs in the United States, as Canadian courts do not hold the same quasi-legal powers as some do in other countries, efforts were made to better organize the process while making it more publicly transparent (ibid). These efforts included the integration of public opinion within the impact assessment process, and the publication of assessment consultations, proceedings, and reports.

Box 2: The Berger Inquiry

In 1976, during the hearings of the Mackenzie Valley Pipeline Inquiry, Supreme Court justice Thomas Berger was tasked by the federal government to assess the impacts of a gas pipeline down the Mackenzie River Valley and the subsequent development of the Valley as an oil and gas transportation corridor ((Berger, 1978). During this process, Berger met with senior government officials, leaders of industry, and scientific experts in southern Canada, but also with the northern public who would be directly affected by this development (Couch et al., 1983). In these informal meetings, he heard their concerns regarding the social, economic, technical, and environmental implications of the proposed development. Perhaps aware of the degree to which local knowledge could inform his report, or in recognition of the interconnectivity of people to place in rural communities, Justice Berger incorporated his reflections of this discourse in his 1978 report (Berger, 1978). Not only did this set a precedent for the notion of public involvement in government decision-making, this also spurred the impetus to the comprehensive nature of environmental assessment as it pertains to social elements of health and wellbeing. Berger recognized that the inquiry was not just about a gas pipeline, but rather the future of the North (ibid) In addition to assessing the possible biophysical implications of the project, issues of health, education, social services, employment, energy, transportation and economic growth were also considered in the assessment (Doelle et al., 2021). Although technically an environmental protection measure, the Mackenzie Valley Pipeline Inquiry showed that EIA must also be comprehensive in its procedural consideration of various social and economic factors. This notion remains fundamental to impact assessment, and has shaped the way we attempt to capture both social and ecological facets of human action through Canadian impact assessment to this day.

It was also at this time that impact assessment began to diversify in practice. Despite the recognition of the potential social implications of development within the EIA practice, a new discipline of impact assessment was developed to better capture the potential social implications. These social impact assessments (SIAs) can be thought of as an evolutionary offshoot of the original EIA process. Where the EIA assessed the environmental implication of development, SIA places focus on the potential social, cultural, and economic implications of these developments instead. Such implications could include the associated impact to health and wellbeing from air or water pollution, or the impacts to security of harvested food as disrupted by development. The introduction of SIA represented a modernization of impact assessment, diversifying the practice to frame and address different aspects of development while further recognizing the human component of environmental degradation (Klingler-Vidra, 2019).

In the current evolutionary phase of impact assessment, emphasis has been placed on orienting the practice to better capture the collective impact of development on various aspects of human and ecological sustainability. Of interest are both the physical forms of development (mines, oil facilities, bridges, etc.), and non-physical development (new policies, plans, or programs). One such attempt to capture the collective impact of development was through the introduction of cumulative effects assessment (CEA) to the EIA process. ‘Cumulative effects’ are the aggregate effects of many different impacts or activities over various spatial and temporal scales which influence the underlying social and environmental conditions of a greater area (Peterson et al., 1987). While the phrase suggests an additive increase of an effect, such as the progressive increase of carbon dioxide in the atmosphere, cumulative effects also include negative persistent change. Examples of this could be the progressive loss of soil nitrogen from farmlands, or the impact of multiple resource extraction sites on the health and wellbeing of Indigenous communities. CEA, rather than a separate procedural entity to the EIA process such as SIA, has been complementary to EIAs since the 1990’s in an attempt to better understand the total and accumulating effects of project-specific development. This need for EIA to consider the cumulative environmental effects of development was further reinforced by a number of revisions of the *Canadian Environmental Assessment Act* in 1995, which gave it further procedural recognition. What was also recognized at this time, however, was the importance of regional studies to support project-based impact assessment (Canadian Council of Ministers of the Environment, 2009).

Until this point, impact assessment remained an issue-specific process, meaning that these studies were focused on a single development— be it a project, plan, program, or policy. The total implications of multiple developments and activities, and the effect that they may have over a larger geographic area, remained largely unrecognized within impact assessment processes. A means to better understand the aggregate implications of development came with the introduction of strategic environmental assessments (SEAs). SEA marked a progression within the practice to assess multiple forms of development to better understand their collective effect within an entire region or sector. At the federal level, SEA was formally established in the 1990s by way of a Cabinet directive, making it one of the first in a new generation of impact assessment (Sadler et al., 2012). Like SIAs, SEAs can be thought of as a distinct discipline within the growing array of impact assessment practice. In both Canada and beyond, SEA has proved pivotal providing the foundation for which we currently identify and evaluate the possible regional implications of development in current impact assessment practice. This shift, although monumental in domestic impact assessment legislation and international practice, reflects the same underlying notion that some of the earliest of environmental assessment, such as the Berger Inquiry, had begun to address decades earlier.

In February of 2008, the Canadian Council of Ministers of the Environment Environmental Assessment Task Group commissioned the report "Strengthening the Foundation for Regional Strategic Environmental Assessment in Canada." This report established the concept and core principles of a new form of strategic assessment: the Regional Strategic Environmental Assessment (R-SEA). In order to support a more spatially relevant and strategically oriented framework for environmental assessment, R-SEA was posed to re-conceptualize the relationship between regional cumulative environmental effects assessment and SEA (Canadian Council of Ministers of the Environment, 2009). Rather than considering cumulative effects as an additional assessment component, R-SEA was designed to systematically assess the potential environmental effects, including cumulative effects, of various forms of development for a particular region (Buse et al., 2020). While similar to SEA, this new form of regional assessment offered a more integrated approach to assessing the cumulative impacts of development on both biophysical and human components, as well as their interactions over large spatial scales.

From the R-SEA process emerged the regional assessment (RA) that is used today. Like R-SEAs, RAs are a means to better capture cumulative effects of development on both humans and nature. In 2019, Canada replaced existing impact assessment legislation (the Canada Environmental Assessment Act, 2012) with the Impact Assessment Act (IAA), which came into force in August of that year. One of the goals of the IAA was to better capture these aforementioned goals of cumulative assessment as a means of ensuring sustainability. In particular, the RA was given greater prominence within the impact assessment suite to help address the possible implications of development over larger geographic and temporal scales.

In theory, RA allows the assessment practitioner to go beyond project-focused impact assessments to better understand the regional context in which proposed development may occur. Among the purposes of the new IAA, section 6(1)(m) encourages "the assessment of the cumulative effects of physical activities in a region and the assessment of federal policies, plans or programs and the consideration of those assessments in impact assessments" (Government of Canada, 2019). Among the factors to be considered in impact assessment, the Act stipulates that the impact assessment of a designated project must consider "any cumulative effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out" (ibid). As attention has been placed on the assessment of all cumulative impacts, not just those resulting from the proposed activity or other major forms of development, a key aspect of RA lies in situating such proposed development within a specific regional context. In doing so, a RA must identify and capture all of the various human activities within a study region, as well as consider how proposed development may add to such existing human impact to both humans and nature.

As current impact assessment processes are now meant to capture the various cumulative impacts of development on both society and the environment, a continuing evolution towards a multidisciplinary form of assessment has emerged. The evolution of impact assessment practice demonstrates a gradual attempt to better understand the often complex and cumulative effects that development may have on both natural and social aspects of the region in which it takes place. It is thought that, as a broad and holistic means of impact assessment, RA is an appropriate management tool in addressing issues of sustainability. The notion of 'sustainable' as it pertains to sustainable development is a complex and challenging affair. On one hand, current human demand is almost certainly beyond what our ecological and biophysical systems can sustain over time. On the other hand, simply cutting back is neither moral nor practical in considering the divergent state of social condition within our ever-growing global populations. Impact assessment, particularly RA in its current context, can thus be thought of as a dynamic interface between science, policy, and civil society towards managing the underlying purpose, alternatives, mitigations, and conditions in which development should be deemed acceptable.

1.3 Towards a Holistic Assessment

Since the time of the Berger Inquiry, societal values have changed to reflect the degree of globalization we recognize today. While the current global context is rich in technological and financial capabilities, there are deep concerns regarding unequitable and unstable socio-economic conditions, a changing climate, and the overexploitation of both terrestrial and aquatic natural resources. As a process rooted as a means to consider the social and ecological implication of development, impact assessment has evolved to reflect these concerns. What was once used for distinct local matters, impact assessment is now tasked with the complex and often uncertain world in which we currently live. As such, the practice has, and continues to place further effort towards better capturing the cumulative impact that human activity has on natural and social systems as a means to address issues of human sustainability.

Through the use of project-level EIAs, it could be assumed that any project which poses significant adverse risk to the environment or society would be stopped prior to inducing such damage. However, these assessments are limited to the spatial and temporal boundaries of the singular project in question and are only conducted on certain projects or activities. As such, EIA has been criticized for not adequately portraying the entirety of a projects effects, nor the potential for cumulative impacts with other activities in the surrounding region, nor the potential for 'collective impact' on interrelated social and ecological components of consideration (Bond et al., 2020; Ehrlich, 2022). Provided these issues, there has been great attention within the practice to try and go beyond the spatial, temporal, or sectoral limitations of project-level assessment to capture the cumulative impact of human activity which influence the underlying social and environmental conditions of a region.

CEA was the first such attempt to recognize the collective impact that multiple projects may have on a region. However, as CEA only pertained to the addition of projects that required an impact assessment in an additive stepwise manner, its efficacy in capturing the larger issues of sustainability has been deemed insufficient (Noble, 2015). This is largely due to procedural failings to capture activities not subject to impact assessment, as well as the degree to which socio-cultural implications of development are captured, and thus assessed within EIA practice. Growing awareness of novel, complex, and connected global risks, coupled with an increased attention to larger issues like climate change, ocean acidification, and loss of biodiversity, precipitated the need for new methods of impact assessment. SEAs, in particular, were introduced as a means to consider the total impacts of all activities within a region or a sector. However, they were slow to evolve in practice, meaning their value with respect to regional environmental planning and decision-making was never fully realized (Canadian Council of Ministers of the Environment, 2009). Furthermore, as cumulative effects assessment was still an auxiliary element, and not fundamentally 'baked into' the process, it proved insufficient in understanding and addressing cumulative environmental and social effects at broader regional scales (ibid).

Despite such shortcomings, the introduction of SEA served another, more deliberate purpose within the larger suite of impact assessment. The current generation of impact assessment has been structured to strategically nest multiple assessments towards various focal issues; where broad-scale effects are considered at a regional level, which in turn inform future project specific impacts through more focused assessment processes. These broader management tools such as SEA can be used to comprehensively frame regional issues, setting the stage for future project-specific assessments to achieve a greater degree of precision. Not only can a broader assessment scope elucidate potential issues to benefit of later project-specific assessments, but it can also lead to more consistent and comprehensive attempts to mitigate such impacts at a project level (Therivel et al., 2021). This nesting of impact assessment, from broad to specific study, is a widely regarded best practice to streamline project-level impact assessments while establishing thresholds and objectives across an area in question (Canadian Environmental Assessment Agency, 2017).

With the introduction of R-SEA, which has evolved to current day RA, the process is poised to better capture the notion of sustainability through the fundamental incorporation of cumulative effects assessment and a large regional scope. Critical ecosystem function and the pressures of human activity rarely coalesce within the boundaries of an oil derrick, for example. Instead, it is at a broader spatial scale where ecological function and human activities interact most significantly—where seemingly insignificant human impacts have additive or even compounding environmental and social effects (Graymore et al., 2008; Ramos, 2009). It is also at this regional scale where the balance of human and nature are most critical, and where management decisions and community choice can have the greatest effect (Clark et al., 2003; Forman, 1995). Provided this, the introduction of the RA marks a legislated step towards capturing the larger notion of sustainability, and a promising one, considering the attention placed on fundamentally incorporating cumulative effects assessment within the very fabric of the RA process.

1.4 Remnants of Tradition within Current Impact Assessment

Within impact assessment practices, there are major strengths which have made the process generally accepted as an effective tool in environmental management (Pope et al., 2013). Furthermore, as recent efforts have been placed on assessing the collective impact of human activity on broad spatial and temporal scales, the efficacy of the practice is further poised to strengthen. Despite such promise, challenges appear to persist with respect to how impact assessments conceptualize, thus assess, the concept of sustainability (Retief et al., 2007; Snyman-van der Walt et al., 2022).

Perhaps as a result of its historical roots, the majority of modern-day assessment study has been criticized for largely focusing on the biophysical impacts of development, and leaving the consideration of potential social implication as a resultant second thought (Glasson et al., 2019). Where these socio-economic or socio-cultural impacts are assessed, there is a tendency within the practice to focus on positive, measurable, and direct economic impacts of development (Bowd et al., 2015). Although this is practical as it facilitates traditional scientific methods of analysis, it leaves room for potentially significant socio-cultural implications to be forgotten, or not captured in full within these assessments. Like many types of science, especially those rooted in empirical study, the consideration of social parameters is challenging as they do not 'fit' within set analytical methods and frameworks. Since impact assessment evolved from the natural sciences as a means to assess the biophysical implications of development, fully capturing the various socio-cultural and cumulative social implications of development within the practice may continue to pose a challenge.

Persistent challenges to impact assessment include the spatial and temporal boundaries in which assessments take place. With respect to the RA process, the spatial confines of the study area are determined at the beginning of the process when Ministerial decision affirms that an RA will be conducted. As for the temporal scope, the assessments are legislated to consider all "physical activities that have been or will be carried out" within the study area (Government of Canada, 2019). Provided that the assessment study area appears to lack explicit spatial reason and may be ambiguous with respect to the temporal confines of study, there is potential for pertinent issues to fall outside of the scope of impact assessment processes (Bond et al., 2020; Lenzen et al., 2003).

The last persistent challenge is the tendency for impact assessment processes to be overly reductionist with respect to the social and ecological complexity in which development may affect. Like all science, impact assessment is tasked with isolating issues of consideration as a feasible means to facilitate further analysis. While a reductionist approach is necessary, impact assessment is critiqued to be over reductionist in that it often focuses on the main elements of study (be it biophysical, economic, or social) in isolation, without consideration of how these elements are related to one another (Bond et al., 2015; Morrison-Saunders et al., 2012). While elements may be distinct and integral in themselves, such as a social or economic system, they must also be recognized as constituents within the larger social, economic, and ecological system on which they ultimately depend (Ostrom, 2010). As modern impact assessment (especially RA) is tasked to capture the intrinsic nature of human and natural sustainability, doing so in a manner which respects the interrelation of social and ecological components is thought to be paramount (Ehrlich, 2022; Nooteboom, 2007; Snyman-van der Walt et al., 2022).

While the modern RA stands as a possible solution to the issue of spatial scoping, provided the regional breadth in which it can frame issues, delineating the temporal boundaries in which impacts may arise could remain a challenge. As RA is concerned with all aspects of sustainability— its social, economic, and ecological elements— these challenges may be especially difficult to overcome.

1.5 Persisting Challenges in Assessment Practice

Considering the apparent challenges of impact assessment, it is of interest to see if they remain within current Canadian impact assessment processes. Under the IAA of 2019, there has been a single RA conducted to date, on the subject of offshore oil and gas exploration off the coast of eastern Newfoundland. This assessment, which began in September of 2018, concerned a roughly 730,000 km^2 offshore study area (Fig 2, a). While an immense undertaking for such an area, it is first important to note the degree to which the province of Newfoundland (and IAAC) are well-versed in conducting such impact assessments for the oil and gas industry in the province.

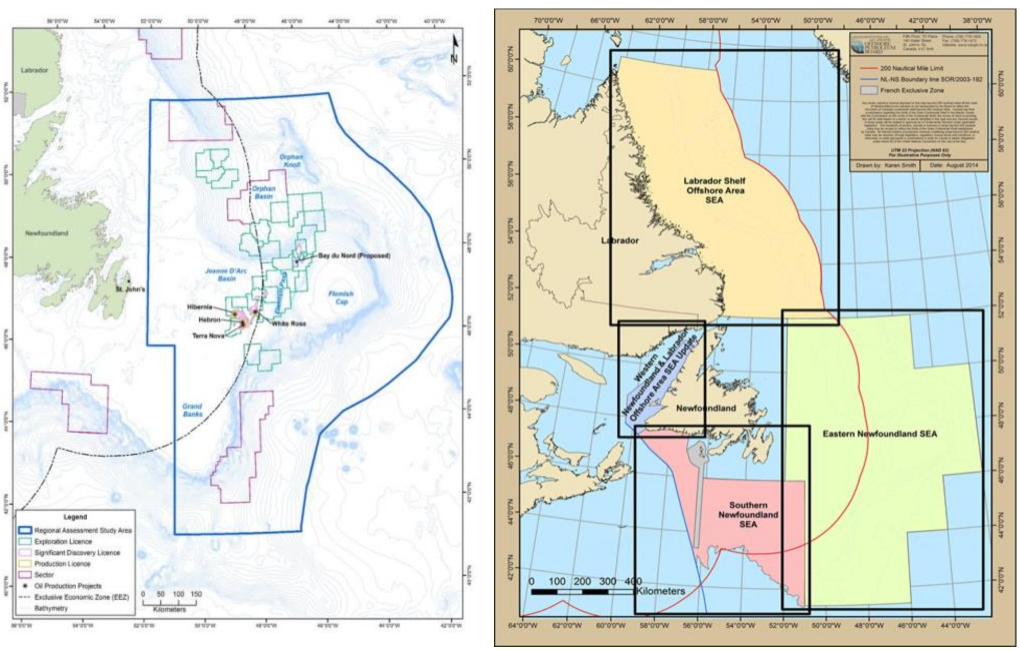

Fig 2. a) The study area of the 2018-2020 RA for offshore oil and gas exploration east of Newfoundland. Note that the province of Newfoundland lies outside of the study area, despite the RAs mandate to include the consideration of various social and cultural aspects within the study (Bangay et al., 2020); and b) The multiple Strategic Environmental Assessments (SEAs) off Newfoundland and Labrador (C-NLOPB Registry, n.d.). The overlapping study area with the most recent Regional Assessment (Fig 2, a) demonstrates how the region has undergone multiple broad, planning level impact assessments on the subject of offshore oil and gas.

The exploration and production of offshore oil and gas is not new to the province of Newfoundland. Reserves were first discovered in 1979, with first oil in 1997. Twenty years later, four fields produced an average of 240,000 barrels per day and a fifth field, the Hebron project, began producing oil in 2017. Exploration and licensing continued with the last round in 2018 achieving a record cumulative successful bid of just under $1.4 billion. With such a significant industry history, considering that all exploration and production has had to undergo a multitude of impact assessments provided the innate risk that offshore oil and gas poses to the environment, offshore oil and gas is also not new to the province nor the practice of impact assessment. There are many project specific EIAs on the matter, and a multiple of SEAs for various regions of the continental shelf (Fig 2, b). As SEAs predated RA as a broad form of impact assessment, the region has undergone a variety of planning-level impact assessments as the practice has evolved. Despite a well versed, well researched, and well documented experience within impact assessment records and surrounding academic literature, the RA report of 2020 indicates that the aforementioned challenges may continue to persist. In particular, there appears to be uncertainty regarding the spatial and temporal boundaries in which the assessment took place, the degree of focus in which various social and ecological components were recognized (especially pertaining to cumulative effects), as well as the manner in which the interconnected nature of social and ecological components was portrayed throughout the assessment.

Within the RA, the conceptual boundaries of study appear to be vague. Despite the RAs mandate to consider various social and cultural factors within the assessment, the area of study (Fig 2, a) lies entirely offshore. However, although the province of Newfoundland is technically outside of the study area, the baseline social, economic, and cultural conditions of the province are mentioned in Chapter 3.3 of the assessment report (Bangay et al., 2020). In particular, a high-level overview of the province's population, economy, GDP, and labour force is discussed (ibid). Later in the assessment report, however, where the potential effects of oil exploration are discussed in Chapter 4, there is no further discussion as to the impact this activity could have on these aforementioned socio-cultural factors. Instead, the only social consideration is of the various fisheries and other ocean uses that take place within the spatial confines of study area. Assessment boundaries appear to be far more than a procedural concern. As the spatial boundaries appear to limit the conceptual boundaries with respect to the potential issues that are addressed within the study, the entire effect that this activity could have on the social, ecological, and cultural conditions of Newfoundland are not recognized in full. As the RA has been posed as a tool to help assess the multifaceted nature of sustainability, failure to assess the social and economic implication of oil exploration may fail to grasp the true sustainability of this activity.

The RA, while mandated under the new Act to address various social, cultural, economic, and ecological factors within its study, appeared fundamentally eco-centric in scope. Despite the aforementioned appearance of various socio-cultural baseline conditions within the report, they were not considered in equal depth as the potential bio-physical implications, nor as potentially affected by the activities of exploratory drilling or future oil development within the region (ibid). While such discrepancy between society and ecology is not uncommon in impact assessment, it perhaps speaks to the persisting challenge of capturing the interrelated social, economic, and cultural aspects of a project along with its biophysical implications (Glasson et al., 2019). This is especially notable considering the underlying impetus of RA towards capturing the holistic social, economic, and ecological aspects of sustainability, which further reflects the issues of scoping and the underlying goals of sustainability that form the RA mandate.

In the Newfoundland RA, the cumulative effects of stated interest were those resulting from the total effect of multiple drilling programs in the region over time, as well as the effect of exploratory drilling in combination with other types of human activities and sources of environmental change (Bangay et al., 2020). While this sounds promising, and reflects the language of the new Act, the focus of such potential cumulative effects was almost exclusively placed on the environmental implication of the proposed exploration. This eco-centric focus may again reflect a persistent challenge of impact assessment practice, as the RA paid no attention to the potential cumulative effects of the activity on human health, culture, and society (ibid). The RA did not note any cumulative socio-cultural implications, and cumulative socio-economic consideration was limited to the potential issue of spatial exclusion between oil and gas activity and the fishery. As oil exploration, specifically the use of seismic airguns to locate potential subsea oil deposits is understood to greatly impact fish harvester wellbeing both on and off the water (Andrews et al., 2021), such consideration of the socio-cultural implications of this activity appears to have been lost within the impact assessment procedure.

Provided these issues of scoping, and the lack of consideration of cumulative social and ecological impacts of development, these persistent challenges appear to continually exist within Canadian impact assessment. While the impact assessment process has evolved to better capture and address the cumulative effect of human activity on both society and nature, the shortcomings of most recent RA suggest we are not yet there. As such, it is of practical interest to not only explore the possibility to address these persistent challenges, but to also assess the potential to implement solutions within current RA practice. As such, I look to a school of thought that is currently modernizing the way we not only approach sustainable resource management, but the larger issues of human-ecological sustainability that currently challenge human life on the planet.

Chapter Two: Systems Thinking

2.1 Socio-Ecological Systems

It is becoming apparent that not only are various aspects of human society and natural systems changing, but these changes also appear to be accelerating. While this is largely a product of globalization, advances in technology, an increasing population, and rising levels of wealth and consumption, they have dramatically affected the Earth's climate, biological diversity, and biophysical and ecological systems. It is thought that these changes may not only be consequential to the health and wellbeing of human life on the planet, but to the health of the planet itself. The environmental and social sustainability challenges we face in the 21st century are deeply intertwined and reflect the confluence and interaction of various social and ecological processes at various temporal and spatial scales.

This notion that the recognition that environmental and social sustainability challenges are inherently systemic and interrelated has driven a paradigm shift in how human interaction with natural systems has been studied (Ostrom, 2009; Schoon et al., 2015). At the heart of this school of thought is socio-ecological system (SES) thinking. SESs are not all social systems, nor all ecological systems, but rather the subset of these systems where human-nature interaction takes place. Provided the multiple ways in which humans and nature interact over space and time, SESs are inherently complex, and often difficult to capture within study (McGinnis et al., 2014). Furthermore, as social and ecological phenomena are often studied in distinct scientific disciplines, challenges lay within integrating these disciplinary studies into a coordinated whole (Gunderson et al., 2002). To interpret such complexity and coordinate multidisciplinary study, frameworks can be used to discern various aspects of SES composition and interaction.

Central to SES epistemology lies the work of Elinor Ostrom, who initially posed and further developed what is called the Socio-Ecological System framework (Fig 3; Ostrom, 2009). Analytical frameworks can be applied to help scholars and policymakers accumulate knowledge from a variety of disciplinary studies and assessments to coordinate information. In essence, they can leverage the analytical, diagnostic, and prescriptive capabilities of various forms of study into a comprehensive, 'usable' output. To help frame such complexity towards practical use, the SES framework partitions elements of a system into classes and subclasses. In doing so, however, a degree of complexity is preserved which recognizes that, although subsystems may be relatively separable and independent in many functions, they are ultimately inter-dependent to some degree in function and performance. This complexity is important to maintain because it holds valuable information about how the SES in question actually exists. The framework also recognizes that the system, as a whole, is greater than the sum of its parts. These aspects of system complexity, which form the basis of SES thinking, are further broken down within the framework into subsystem levels (Fig 3).

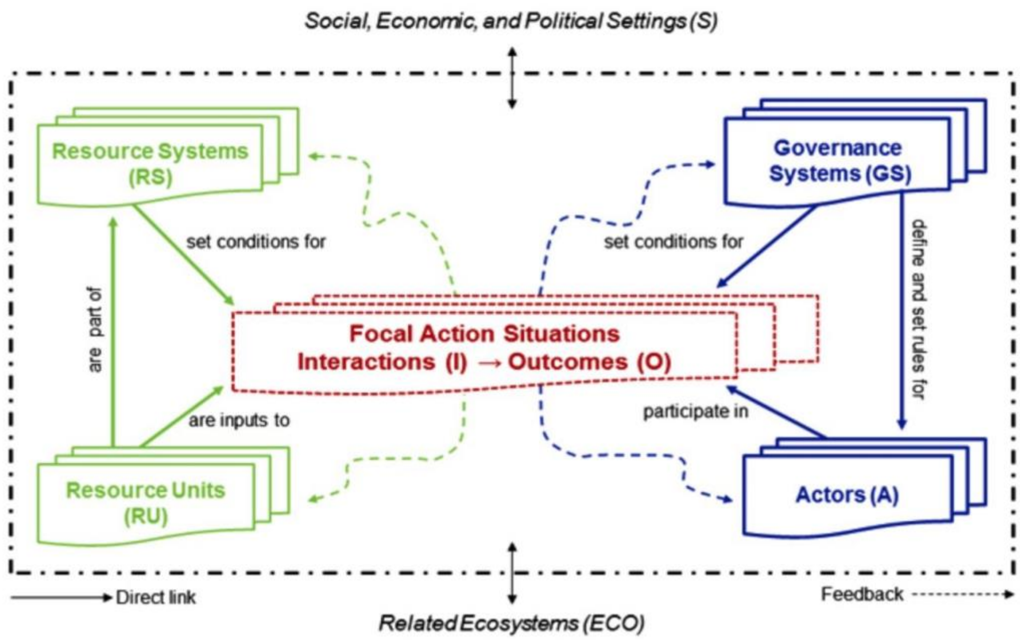

Fig 3. In Ostrom's SES framework, solid boxes denote first-tier categories: Resource Systems, Resource Units, Governance Systems, and Actors. These first-tier variables contain multiple variables at the second tier as well as lower tiers, described in Appendix 1. Action Situations are the various interactions between the main elements of the system. Dashed arrows denote feedback from action situations to each of the top-tier categories. The dotted-and-dashed line that surrounds the interior elements of the figure indicates that the focal SES can be considered as a logical whole, but that exogenous influences from related ecological, social, economic, and political systems at various scales can affect any component of the SES (McGinnis et al., 2014).

The SES framework is composed of four 'first-level core subsystems', which are resource systems, resource units, a governance system, and resource users. What connects these four subsystems are 'focal action situations', namely the various interactions of the subsystems, which are also influenced by the social, economic, political, and ecological setting in which these systems exist (Fig 3). As the SES framework was designed to identify basic working parts and critical relationships among the elements essential to system function, it provides a general list of concepts that can be used to analyze all types of SESs, termed 'second-tier' variables. While the list of potential second-tier variables is extensive (Appendix 1), in large to facilitate the applicability of this framework across various study stems, it provides insight into the possible factors to be considered when applying such SES thinking.

Not only has the SES framework provided a widely accepted language to describe social and ecological interaction, but it has also advanced the recognition of the underlying social, economic, political, and ecological dependencies as it pertains to environmental governance. Nature no longer simply sets the context in which social interactions take place, and likewise, human enterprise is not an external disturbance acting upon an ecosystem. Rather, natural and human systems are indistinct, feeding off each other through impetus and effect in an ever-reciprocating manner. Considering such underlying dependency between the economic, environmental, social, and governance systems of today's world, there has been increasing attention within natural resource and marine management to better consider these interdependencies as a means to more effectively integrate sustainability in application (Preiser et al., 2018).

2.2 Socio-Ecological Systems Thinking and Sustainable Management

The recognition and study of the coupled nature and complexity of social and ecological systems has begun to fundamentally change how we address larger issues of sustainability in environmental management. In marine management, especially the management of competing marine sectors and activities, SES thinking has been applied to help frame issues in attempts of integrating socio-ecological management measures over various spatial and temporal scales.

This concept of integrated management (IM), emerging as an alternative tool to sector based management, stands as a more holistic measure in addressing the complex and often interconnected challenges of the marine space. In practice, integrated management is the coordination of management between ocean regulators, sectors, and users so that human-ecosystem and human-human interactions can be anticipated and harmonized. While there is a long, relatively fragmented history of IM in the waters off Nova Scotia, the impetus of such measures is clear. IM, like all SES thinking, is an attempt to approach complex problems from an inter- or transdisciplinary systems-based perspective. Given the social and ecological complexity and uncertainty of the majority of challenges facing marine management, a wholistic, systems thinking approach is thought to be necessary to capture issues around social and ecological sustainability (Bennich et al., 2022; Schoon et al., 2015; Virapongse et al., 2016).

In natural resource management, specifically fisheries management, SES thinking has helped shape modern attempts at capturing the complexities of social-ecological interaction as it pertains to the human use of fishery resources. This modern approach, coined ecosystem-based management (EBM), is an attempt to better consider the various interrelationships among the fishery and ecological system while considering humans as an integral part of the ecosystem, not an externality. Practically, EBM is a means to go beyond a single-species approach, to consider the 'full-spectrum' sustainability of the activity (Paul et al., 2020). 'Full-spectrum' as a means to which governance, management, and science are explicitly considered when assessing the total collective impact that human activity may affect a fishery (Link et al., 2011; Paul et al., 2020). In essence, EBM is an attempt to better grasp the social-ecological interactions of fisheries to better orient decision-making within the various facets of ecological and social sustainability. While this multifaceted systems perspective to fisheries management remains relatively new in Canada, various successful implementations of the practice internationally give clues to both its feasibility and success (Pikitch et al., 2004). Canadian interest in further developing a holistic EBM framework, through both the socio-ecological framing of these issues and the associated study of the social-cultural aspects in which fisheries exist and operate, indicates a gradual adoption of SES thinking as well as its application to multi-sectoral fisheries management (Bundy et al., 2021; Parlee et al., 2023; Paul et al., 2020; Stephenson et al., 2018). Not only does this further legitimize SES capacity for more effective and holistic management of social-ecological interaction within the marine space, but it also speaks to its capacity to address complex, historically rooted issues within the marine management space.

Globally, the capacity of SES thinking to address the complex issues of human and natural sustainability at the greatest spatial and temporal scale has also been demonstrated. The United Nations Millennium Ecosystem Assessment (MA), perhaps the largest international effort concerned with the consequences of ecosystem change and human wellbeing, spearheaded a conceptual SES framework to assess the implication of human action on global sustainability (Millennium Assessment Board, 2005). Their framework, which captured the ecosystem services which directly and indirectly contribute to human wellbeing and quality of life, recognized a variety of dynamic interactions which exist between humans and nature at a global level. Of similar essence to IM and EBM, this approach not only conceptualized how cumulative human action fundamentally impacts the underlying function of natural systems, but it also recognizes the reciprocal implications that these interactions have on the global condition of human well-being. MA findings also suggest that concurrent with social and ecological interaction, a variety of exogenous social and ecological factors influence both the state of the environment and human condition independently (ibid).

As the findings of the MA share a striking resemblance to the SES framework, they illuminate the congruent evolution of various forms of modern management towards SES thinking as a means to address pertinent issues of sustainability. This shared recognition, that coupled social-and ecological systems thinking can help reveal the most pertinent issues that shape human and natural life on this planet, demonstrates not only the feasibility of this thinking in various applications of governance, but also how it is fundamental in framing and studying contemporary issues of sustainability.

2.3 Capturing Socio-ecological Systems through Representative Modelling

There are different ways to frame the interactions between social and ecological components within an SES, and each method of illustration does so to various strengths and weaknesses. With respect to Ostrom's SES framework, these interactions between various social and ecological factors take place within the focal action situations in the central red box of Fig 3. As there are various ways to portray the interaction of social and ecological factors system dynamics, considering how these systems are portrayed in practice must not be overlooked as it is central to the applicability of this science towards helping in decision-making. To illustrate such nuance, and further introduce the underlying mechanisms of SES thinking, I compare two such system approaches— a representative SES model and the renowned DAPSI(W)R(M) framework (Box 3)—to illustrate the similarities and differences in which these approaches capture the inter-system dynamics of an SES.

Box 3: DPSIR, and its Evolution to DAPSI(W)R(M)

DPSIR is a framework used to assess and manage the impact of environmental policy changes and associated problems. DPSIR is an acronym for the manner in which the framework interprets socio-ecological complexity, categorizing issue components as one of the following categories: *drivers* which put *pressures* on the *state* of the system, which in turn results in certain *impacts* that will lead to various *responses* to maintain or recover the system under consideration.

DPSIR manages complex additive systems through recognizing the interconnection of natural systems (ecosystems), designed systems (extractive industries, tourism, power generation) and social systems (fishing communities, for example). It is a method to structure issues which can be used to assess the causes, consequences and responses of a system to change.

The modification of DPSIR to DPSWR (Drivers-Pressures-State-Welfare-Responses) was to avoid potential confusion between the impacts on the environment (such as changes in State) to the impacts on human Welfare. Such a distinction was recently made by the UK National Ecosystem Assessment Follow-On project which applied a DPSWR model for the coastal and marine environment.

It was then suggested that DPSWR should become DAPSI(W)R (Drivers- Activities-Pressures-State changes-Impacts (on Welfare)-Responses). This recognises that the Pressures are the mechanisms of change, that it is human Activities that cause Pressures not the Drivers themselves, and that Impacts are on human Welfare.

The last evolution to DAPSI(W)R(M) came to match the wording of the marine governance it was being used within. Essentially, Measures are the economic and legal instruments, new technologies and stakeholder consultation needed to fulfil the obligations of such directives (Elliott et al., 2017).

To represent a socio-ecological system, the DAPSI(W)R(M) framework assumes a cyclical cascade of events, where human activities affect the biotic and abiotic processes of a natural system (Fig 4.a). As a result of anthropogenic impact, it is the changes within the environment which then cause an associated impact on society, garnering responsive action to address the initial causes of system change. Note that under this framework, the initial human activities do not cause an impact to society (or vice versa) but rather provide impetus for a downstream societal impact through an altered environment in a sort of 'chain reaction'. Here, it is assumed that interaction only occurs between adjacent levels of the system, and only in one direction in a cyclical manner. Although this method respects the coupled nature of human and environmental systems, it assumes a single causal pathway that overlooks the nuance of direct social impact from human activity.

Changes in the environment as a result of human activity can have a widespread effect on society, but it is not the only manner in which society is affected by human action. In many cases of development, there are other more direct impacts which could affect society regardless of environmental consequence. These social impacts can be thought of as inter-system dynamics within the social subsystem of the larger social-ecological system. Examples of this dynamic could be the potential spatial conflicts of multiple ocean users, or the employment and job security benefits of a new industry. Although the social ramifications of possible environmental change must be considered within a socio-ecological analysis, the potential for multiple pathways of direct social and ecological effects must not be ruled out when framing such a model.

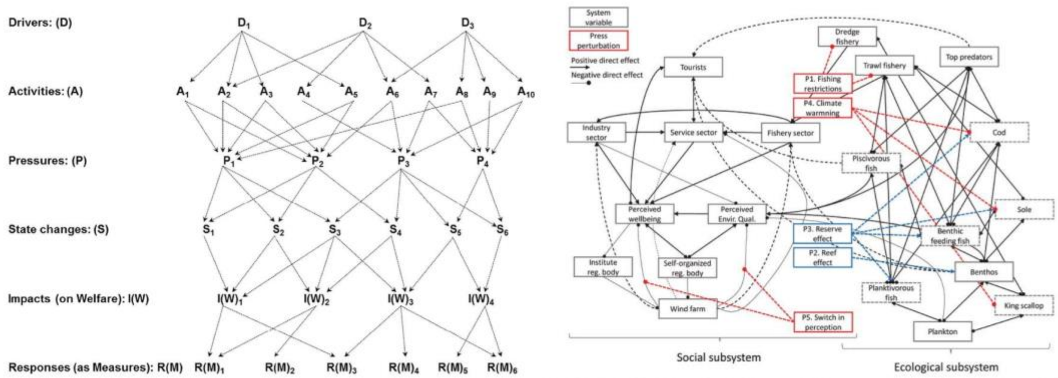

Fig 4. a) The linear nature of DAPSI(W)R(M) framework (Elliott et al., 2017); b) compared to the intercorrelated nature of the representative SES (Haraldsson et al., 2020).

Comparatively, the representative SES model structures the socio-ecological system quite differently. Rather than classifying human activities and their resulting impact on the environment by their position in a chain of events, the representative components of the model are correlated to other components which they affect and are affected by (Fig. 4.b). Not only does this respect the interconnectivity of all levels of the socio-ecological system, but it also illustrates a higher degree of causal relationship and intra-system feedback between representative aspects of the larger system. Although this makes the model complicated at a glance, it preserves some necessary complexity that is otherwise oversimplified by the linear nature of the DAPSI(W)R(M) cycle.

An important benefit of preserving such complexity, with respect to the utility of systems thinking in decision-making, is that the direct positive and negative effects of human activity can be associated with the system components with which they interact. Rather than allocating system components to labeled tiers, lobster fishing as a driver of ecosystem changes per se, the activity of fishing can be recognized as more of a dynamic component within the SES model.

This can be recognized by the correlation between both the components it affects (eg. lobster, the value chain of the fishery sector), and is affected by (public wellbeing, perceived environmental quality, ecosystem health). From a system thinking perspective, the nonlinearity of the SES model, as well as the bi-directional feedback loops within it enables the recognition of the intra-subsystem dynamics, that are dynamics within each social and ecological subsystem of the larger model. This approach also respects the larger system dependencies within the entire SES, which are the dynamics between such social and ecological subsystems. As such, provided a greater degree of system complexity is preserved, the representative SES is likely a more accurate representation of an SES in question.

2.4 The Existing Notion of Systems Thinking in Impact Assessment

The current application of SES to various facets of natural resource and marine management indicates the potential for this school of thought as a practical means to addressing the often-complex issues surrounding sustainable human action (Berkes, 2017). As current impact assessment has been tasked to answer questions of sustainability as it pertains to sustainable human development, systems thinking has been posed as a means to help address these questions (Bowd et al., 2015; Ehrlich, 2022; Perdicoúlis, 2016; Snyman-van der Walt et al., 2022). Despite this attention, however, there remains little application of SES thinking within Canadian impact assessment practice, and only a few examples globally within the academic literature (eg. Bowd et al., 2015; Ehrlich, 2022; Gallardo et al., 2022). Provided the seemingly immense potential for this school of thought to revolutionize the manner in which impact assessment in conducted in Canada, however, scholars and practitioners alike have begun to show keen interest in exploring its application (Davidson, 2019)(Government of Canada, 2022).

Interestingly, the fundamental basis of SES thinking is alluded to in the earliest impact assessment theory and practice. This is largely through the lens of causality, or the cause-and-effect relation of development and its associated effects (Snyman-van der Walt et al., 2022). Causality is central to impact assessment, as the process has always recognized that humans and environmental systems affect each other to some degree. Furthermore, the recognition of *indirect* and *cumulative* effects in impact assessment legislation suggest that this causality is more complex than linear interaction, and may be a result of multiple causal pathways happening simultaneously over time and space. These can be thought of as the same causal pathways that the previously discussed SES approaches look to illustrate. As modern impact assessment practice calls for the consideration of potential biophysical, social, and economic impacts (Box 3), as well as assessment of impact interactions, cumulative impacts, and indirect impacts, the complexity of factors to be assessed has become ever so intricate (Government of Canada, 2019; Perdicoúlis et al., 2009). Not only is this because there are more factors to consider thus more inter-system dynamics to capture within assessment, this complexity is a result of a greater number of intra-system dynamics—the interaction or cumulation of effects between the various social, economic, or ecological subsystems of a larger study area.

In its most basic form, causality is manifested in the sense that impacts are expected to arise from the proposed action with a variety of complex effects. Despite such fundamental recognition of interdependency and inter-causality between many different factors, as well as repeated acknowledgement that the impact assessment process could benefit from systems thinking approaches, such action has been slow to permeate into practice (Morrison-Saunders et al., 2012; Nooteboom, 2007). Within the aforementioned RA for offshore oil and gas exploration off Newfoundland, the applicability of systems thinking to RA is explicitly acknowledged:

"*There are… clear inter-relationships and inter-dependencies between the various, diverse components of these human- ecological systems, where changes in physical and biological characteristics and processes may in turn have implications for the social and economic conditions and health of people and communities, and vice versa. As a result of these interconnections, effects on one component may have implications for another, and thus for the overall sustainability of these human-ecological systems*" (page 168, Bangay et al., 2020)

Despite this recognition, however, a genuine systems-based approach has yet to be operationalized in Canadian impact assessment. Instead, a historically rooted and largely 'siloed' methodology continue to assess social and ecological factors in relative isolation, and to varying degrees (Gibson et al., 2010; Noble et al., 2019). As such, there appears to be a window of opportunity as well as an immense potential to integrate SES into Canadian RA to perhaps better capture the interconnected nature of social and ecological system components in a pertinent attempt of sustainability. This extension of SES thinking, considering its application to other aspects of human-ecological sustainability, could also be thought of as a natural progression of the ever-continuous evolution of impact assessment practice.

Chapter Three: Offshore Wind Development

3.1 Offshore Wind Energy, and the Potential of the Scotian Shelf

As global climatic concerns increase and the rate at which human development persists, calls for change echo around how we fundamentally perceive the sustainability of human action. Within this discussion, there is an opportunity to reduce emissions within the energy procurement systems that continually fuel our economic and social activities (Owusu et al., 2016). In large, these calls are for the greater use of renewable energy to help mitigate the cause of climate change and its associated impacts (Hasselmann et al., 2003; Watson, 2003). Naturally, there is widespread international support for this greater use of renewable energy to better guide the global community towards more sustainable energy production (United Nations, 2016). At a national level, the Canadian government has reflected such values within its own legislation. Goals of reaching net zero carbon emission by the year 2050 have been made into law, enshrined in the Canadian Net Zero Accountability Act of 2021 (Government of Canada, 2021). Currently however, as over 80% of all national greenhouse gas emissions are generated from domestic energy production and consumption processes, there appears to be room within the sector to reduce emissions (Canada Energy Regulator, 2021). Largely, this will be through the development and adoption of alternative renewable energy sources (ibid).

Box 4: Electrical Energy by the Numbers

Energy is expressed in a variety of different units, and can often be confusing. When discussing the amount of energy generated over a period of time, it is expressed in varying amounts of watts— kilowatt, megawatt, gigawatt, and terawatt— all successive multiples of 1,000.

Energy can also be expressed in units of power multiplied by a unit of time — e.g., kilowatt hour (kWh), which is the amount of electrical energy produced by a one-kilowatt source for one hour.

Furthermore, the various sources of electricity generation — hydro, nuclear, natural gas, coal, wind, solar, geothermal, etc. — are all intermittent to varying degrees, meaning they do not operate at their full power capacity at all times. This irregularity is captured by what is called a “capacity factor”—the ratio of actual energy generated in a typical year to the amount that would have been generated if the source operated at its full capacity. For example, offshore wind turbines typically have annual capacity factors ranging from 0.45 to 0.55, often higher in the winter. A 15 MW turbine with a capacity factor of, say, 0.45 would be expected to generate about 4,900 MWh of energy in a day. The exact same turbine operating at a higher capacity factor of 0.55 during a colder time of year would be expected to generate over 6,000 MWh of energy per day.

In 2023, the Canadian Energy Regulator (CER) published two scenarios outlining possible scenarios consistent with achieving net-zero carbon emissions by 2050. These scenarios are Canada-specific, and suggest that the Canadian energy generation will likely need to double before the half-century. In both CER scenarios, at least half of the net increase in annual electricity generation between 2021 and 2050 must be supplied by wind (Canada Energy Regulator, 2023). These figures suggest a 300-terawatt hour (TWh) increase in energy in less than 30 years from an industry that has grown domestically by roughly 1 TWh per year over the past 5 years. Considering this, development in the wind generation space appears to be both massive and imminent if national net-zero targets will be achieved. At the moment, the federal government is taking a large step, and are currently conducting an RA assessing the feasibility of generating offshore wind (OSW; Box 5) off the coast of Nova Scotia. This will be the second

RA under the new Act, on a subject (offshore wind) which Canada has no previous experience. With a history of offshore oil and gas success and robust offshore wind regime, however, this transition towards renewable offshore energy could appear natural.

Box 5: Generating Power from Offshore Wind

Offshore wind (OSW) energy generation is the generation of electricity using wind farms installed in bodies of water, usually at sea. While technically difficult to install, the higher and more consistent wind speeds of the offshore, coupled with the massive size of turbines that can be installed allow these farms to generate more electricity per installed capacity than their onshore counterparts.

Modern OSW installments are getting larger and larger. At greater heights above the sea, wind can flow more freely as it is undisturbed by the ‘friction’, thus turbulence, of wind closer to the water. Larger rotor diameters, that is the length of the turbine ‘blades’, allow wind turbines to sweep more area, capture more wind, and produce more electricity. Larger rotor sweep also facilitates the generation of energy at lower wind speeds, helping with the issues of intermittency that many renewable energy generating techniques face. Furthermore, considering the degree of wind energy generation needed to meet Canadian national green energy goals, the offshore area provides room to support such expansive growth.

Once turbine blades capture the wind's kinetic energy, they spin a gearbox/turbine assembly located in the turbine body, or ‘nacelle’ which converts this kinetic energy into electricity. This electricity travels down the shaft and into subsea cables, which go directly to an offshore substation though cables buried within the seabed. Substations receive the power produced by wind turbine generators, which is ‘stepped up’ to a higher voltage and sent onshore via high voltage cables. The high voltage cables are then connected to the onshore infrastructure where the energy is dispersed through the larger grid.

The harnessing of OSW to generate electricity is not a novel feat. Europe, where the technology originated, has used OSW turbines since the early 1990’s. The development and adoption of this technology has proved fruitful, with over 225 gigawatts (GW) of offshore wind capacity collectively generated in Europe (Costanzo et al., 2022). Global OSW capacity has also increased, and continues to do so exponentially. Currently, there are roughly 64 GW of installed

OSW capacity producing the energetic equivalent of roughly 1.2 million barrels of oil in 2022 (International Energy Agency, 2022). Growth in the offshore wind space has been rampant, and these trends are expected to continue. Forecasts suggest that by 2028, a further 182 GW of offshore wind will be installed around the globe (Fig. 5; Musial et al., 2023). Despite this global attention, the development of OSW has been slow to reach North America. The United States' first OSW farm, off the coast of Rhode Island, only began generating power for commercial sale in 2016. In Canada, the industry remains nascent aside from developer interest.

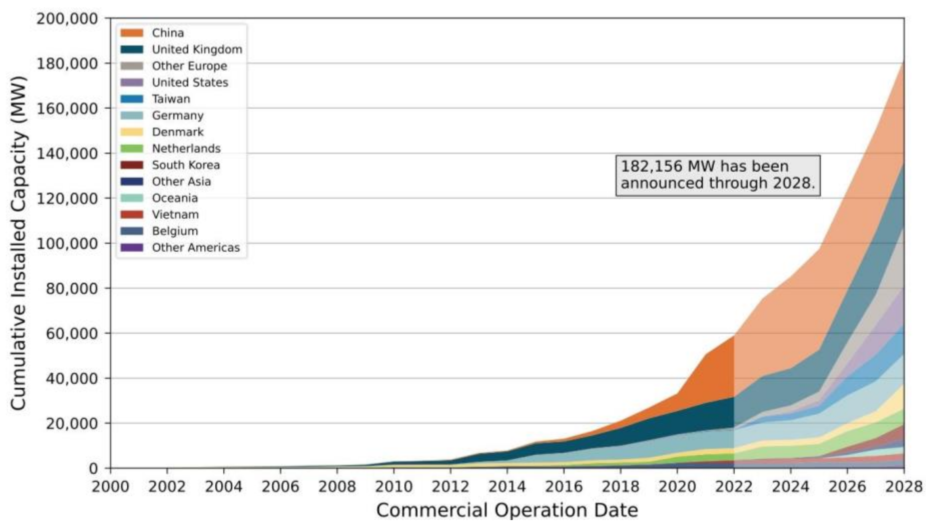

Fig 5. Estimated cumulative offshore wind capacity by country based on developer- announced commercial operation dates. The darker areas here represent existing deployed capacity, and the lighter areas represent projected developer announced deployments (Musial et al., 2023).

In Canada, the potential to harness this resource is immense. On the Scotian Shelf in particular, annual average wind speeds of over 36 kilometers per hour and a large and relatively shallow continental shelf make the region especially suitable for this technology (Aegir Insights, 2023). Modern advancement in the OSW industry has enabled the installation of wind farms in deeper water through the use of floating turbines. However, as this floating technology is still maturing, any wide scale development in Nova Scotia will likely use the traditional bottom fixed structures, in large part to keep the cost of energy down (Stehly et al., 2021). Nonetheless, with multiple offshore banks and an inshore region of applicable depth for fixed-bottom structures, it is estimated that, at a maximum, there is potential for over 900 GW of installed OSW capacity within our territorial waters (Aegir Insights, 2023). To put this in perspective, the potential capacity for generating electricity on the Scotian Shelf is second to none, globally. As wind speeds in this region have been modeled to further increase with expected global climatic changes, and as necessity to produce more clean energy continues to increase, the potential for generating power from offshore wind installments is large (Fernández-Alvarez et al., 2023).

3.2 Offshore Wind in the Context of Regional Assessment

There appears to be great potential to generate energy from OSW in Nova Scotia. Not only would this benefit legislated national green energy goals, it would provide an immense benefit to the Canadian energy sector and the many facets of human life that depend on electricity. Furthermore, as OSW has been adopted in many countries worldwide, the environmental and social implications appear to be manageable in a variety of different situations. As such, it is possible that OSW development, regardless of RA findings, will be deemed within the public's interest. While the seemingly imminent development of OSW could suggest that the RA is a relatively pointless endeavor, this is far from the case. Again, impact assessment is a management tool, used to illuminate the positive and negative socio-ecological implications of development. As such, it is ever pertinent that the RA elucidates these potential effects so they can be properly addressed before undue harm is caused. If the RA neglected to look at the social implication of OSW development, for example, those whose health, livelihood, or wellbeing as impacted by such activity would go unnoticed within the larger course of development. On the other hand, if the RA identifies who is likely to be affected, as well as the nature of these implications, measures can be put in place to address such impacts in a proactive manner. With this in mind, and with respect to RA practice, further importance must be placed on the identification of potential socio-ecological implications, both direct and cumulative, that OSW development may have on the social and natural climate of Nova Scotia.

Considering the potential scale of development, the development of OSW could have lasting effects on the Maritime region as a whole. Considering how this potential industry could affect both the environment and society is a rather complex subject. As such, there lies great importance in the adequate scoping of the potential issues to guide further study. The complexity of human uses, governance jurisdictions, and biophysical and ecological processes of the marine space are often highly location specific. With respect to the exact impacts that the RA is concerned with, these issues will be thus regional in context. As such, illustrating the many potential environmental, social, and economic implications through the lifecycle of a single OSW project, and how they change through the phases of OSW development, contributes to our more comprehensive understanding of the complex nature of the subject.

3.3 The Potential Impacts of Offshore Wind: Site Surveying and Construction

For clarity, the following potential ecological, socio-ecological, and social impacts of OSW development have been separated to first consider the site-surveying and construction phases of OSW installment, followed by the operational and decommissioning phases. The potential nature of impact, referring to the implication it may have on the social, socio-ecological, and ecological state of the region in question, are first considered in distinction of one another. This has been done to demonstrate the breadth to which OSW development may potentially affect the current natural and social climate of Nova Scotia. In Chapter Four, some of these potential impacts (specifically those that pertain to the Nova Scotia lobster industry) are considered in relation to each other through a systems-thinking approach. This is done in a manner which respects the interrelated nature of the various factors discussed below. The following potential impacts considered here do not reflect all of the environmental and social implications of OSW development, but rather illustrate the comprehensive and interconnected nature of the potential issues to be considered when assessing such impacts.

3.3.1 Environmental Implications of Site Surveying and Construction

Currently, the majority of modern turbines are mounted to concrete and steel piers that tower up to 500 feet in the air, and support blades up to lengths of 200-feet. To support such infrastructure, the underlying benthic and geologic structure of a potential site must be surveyed to determine its suitability for development. Here, the seafloor is initially mapped using multibeam or side-scan sonar, with the underlying geologic structure determined by shallow and deep penetrating seismic survey systems used in tandem (Mooney et al., 2020). Physical core or grab samples may also be taken to validate acoustic survey procedures. While the use of acoustic benthic surveying is widespread, especially in the offshore oil and gas industry, it is not without its environmental effects. Noise from such procedures can cause physical damage to auditory structures, delay development and growth in certain fish species, as well as elicit behavioral change in predator evasion, schooling behaviour, and mating (Weilgart, 2018). Large marine mammals can be affected by this activity through signal masking, changes in diving and feeding patterns, and disruption to habitat and migration (J. Gordon et al., 2003). Bivalves, such as blue mussels, settle faster and at smaller sizes in their juvenile planktonic stage in noisier environments (Wilkens et al., 2012). Zoo and phytoplankton, which form the very foundation of marine ecosystems, suffer high rates of mortality in the wake of seismic operations (McCauley et al., 2017). Although these are just a few examples of the known ecological effects of site surveying practices, they exemplify the trophic breadth in which ecosystems can be affected by site surveying processes. In a regional sense, the acoustic pollution created from such survey activity, as well as the increased presence of ships to do such surveying, further adds to the collective impact of human produced noise in the ocean.

Through the next phase of wind farm development—where steel and concrete substructures are fixed to the seabed prior to the attachment of turbine superstructures, and supporting electrical infrastructure is installed both on land and at sea —a new set of potential impacts arise. During construction at sea, which lasts for a duration of roughly four years for a single wind farm, the noise created and sediment disturbed from such activities are of most notable effect. The majority of installed OSW sites employ a monopile foundation; a cylindrical steel structure pile-driven into the seabed substrate to depths of 30 meters (Asgarpour, 2016).

During this process, noise and sediment are released into the water column with deleterious environmental effect. The acoustic signature created by the pile driving process is not dissimilar to that of seismic surveying, as contact of the vibrational/percussive hammer to the pile, as well as the contact of the pile to the seafloor, creates acoustic waves that radiate out from the source through both the water column and substrate in multiple directions (Andersson et al., 2016). The result is loud, high-energy, impulsive sounds with sharp rise times that elicit high degrees of sound pressure and particle motion (Mooney et al., 2020). Akin to the impacts of seismic surveying, pile driving can induce physical harm to auditory systems, changes in behaviour, and increased physiological stress while negatively affecting communication in a variety of organisms across a variety of spatial and temporal scales (Bailey et al., 2010)(Popper et al., 2009).

Sediment resuspension, also a product of construction activities, has a much different effect. Sediment can be disturbed by the pile driving process itself, from the laying of transmission lines on the seafloor, or during the placement of protective rocks around the turbine foundation. These activities resuspend fine particles which are released indiscriminately into the water column, decreasing water clarity while changing the overall sediment structure of the surrounding benthic ecosystem (Engell-Sørensen et al., 2002; Wilson et al., 2010). Not only can this cause a smothering of benthic life including filter-feeders that live on top of the sediment, egg capsules, and organisms that live within the sediment, it can cause changes to the sediment structure and the associated ecological communities that inhabit the area (Wilson et al., 2010).

3.3.2 Social-environmental Implications of Site Surveying and Construction

In addition to the ecological impacts of site surveying and construction activities there are also many social, economic, and cultural implications that could transcend the health and wellbeing of those impacted by these developments. The following effects identified here can be thought of as a social-ecological interaction, where any positive or negative impact to the environment has a reciprocal impact to society. During the events of seismic surveying and pile driving, for example, significant reductions in fish distribution, abundance, and catch rates have been observed over large areas for extended periods of time (Affatati et al., 2023). The social impact that this activity has on surrounding fisheries and fish harvesters, although a topic not new to impact assessment or the larger fishing community, is not yet thoroughly understood. What is understood, however, is that a reduction in or a complete loss of catch, especially for extended periods, places undue stress on harvesters with respect to income security, as well as through perceptions of individual social and cultural wellbeing (Gien, 2000; Yunan et al., 2000). Loss of income, even temporarily, can have associated negative effects on health, identity, and perceptions of security among many other social factors (ibid). Individual perception of one's social or cultural wellbeing, as affected by such social factors of health, identity, etc., is further understood to be directly related to an individual's objective wellbeing— that is one's physiological and psychological health as measured by indicators of blood pressure or of stress hormone concentrations (Hepburn et al., 2021; Rosengren et al., 1993). This declined state of wellbeing, while individual in nature, can further percolate through to the collective social state of a larger community (Atkinson et al., 2020). As such, the declined state of harvester wellbeing in lieu of site surveying procedures or pile driving activity, while a seemingly small and necessary product of development, can have collective or cumulative effect on the larger social climate of a region. With respect to impact assessment, which is mandated to assess the cumulative effect of development on the social, ecological, cultural, and economic conditions of a study area, considering these underlying interaction and causal pathways of effect are of vital importance to the study.

Aside from the economic and social impacts of reduced harvest, human wellbeing can also be affected by the perceived state of the environment (De Vries et al., 2003; Marselle et al., 2015). Decreased perception of environmental wellbeing, that may result of industrial activity in otherwise pristine places or the aforementioned observed decrease in natural resource harvest, can also negatively impact an individual's perception of wellbeing (Ronen et al., 2020). Importantly, this very same perception of socio-ecological relations can be reinforced in a constructive manner if the perceived state of the environment is positive. While this is not exclusive to the site surveying and construction phases of OSW development, capturing the reciprocal effect that an altered environment has on resource harvesters and society alike remains central. Provided this, the social impacts of development and the cumulative effect that it has on socio-cultural wellness must be considered in whole when scoping and assessing the possible socio-ecological impacts of OSW development.

3.3.3 Social Implications of Site Surveying and Construction

Beyond the social-environmental implications of OSW development, there are also direct social impacts from these activities as well. These are the effects that human activity can have on society, aside from reciprocal environmental change. During site surveying and construction, for example, a spatial conflict emerges between OSW and other contemporary marine uses, such as fishing, shipping, conservation, or other ocean activities not allowed within the area of construction (Möller Bernd, 2011). While the majority of this issue can be properly mitigated by the proper spatial planning of eligible OSW areas, the exclusionary effects of OSW on certain ocean uses may be continuous if regulations demand so. In some European countries for example, OSW sites are strict 'no take' zones for all fisheries (Schupp et al., 2021). In others, co-location measures have been implemented where some fisheries are allowed to continue harvesting the region upon the completion of construction activities (Stelzenmüller et al., 2021). In either case, however, a spatial conflict exists during the construction phase of OSW which may have further social implications, and thus must be considered at the earliest (and regional) stage of management.

Potential spatial conflict can have further social implications on other marine users, such as fishing, through negatively impacting the safety of such practices at sea. During OSW site surveying or construction activities, vessel activity or exclusionary zones may force harvesters to travel further to fishing grounds. Not only would this increase steaming times and fuel costs, which would have the greatest negative effect on smaller fisheries, increased steaming times also leaves harvesters more susceptible to foul weather and the associated dangers. As safety at sea is one of the most prevalent concerns of those who make a living on the water, especially in small boat fisheries (Parlee et al., 2023), it is of the utmost importance when considering the associated social ramification of proposed OSW development.

Further direct social implication of possible development can be seen in the workforce needed to complete such engineering and construction activities. Offshore wind energy projects are complex and require an extensive, varied, and well-trained workforce. In the US, it was estimated between 15,000 and 58,000 annual jobs will be created on 25% and 100% domestic content scenarios for their OSW industry, respectively (Stefek et al., 2022). Importantly, this estimate only includes the direct and indirect offshore wind jobs associated with development, manufacturing, installation, and operation of offshore wind energy sites, and does not include what are called ‘induced impact’ jobs. Induced impact jobs are the peripheral jobs created within a community to support such development activity, such as in the service and hospitality industry (ibid). A large source of induced impact jobs in Nova Scotia, for example, will be through the work needed to update the Nova Scotia electrical grid to support such OSW capacity. As the province of Nova Scotia is experiencing a shortage of skilled tradespeople, the workforce needed for OSW would place the province in a furthered demand for skilled trades. While the creation of jobs will likely be portrayed in a positive sense, and rightfully so, the associated impact that this may have on other skilled trade industries, such as the fishery and surrounding supportive industry, must also be recognized as a cumulative effect of such development.

3.4 The Potential Impacts of Offshore Wind: Site Operation and Decommissioning

3.4.1 Ecological Impacts of Operation and Decommission

During the next phases of OSW installment, that is the operation of the wind farm to generate electricity and its eventual decommissioning, a new set of potential impacts arise. After a wind farm is constructed, it operates for a lifespan of 25-40 years. Through the duration of this operational phase, continuous noise of roughly 100 dB is emmitted within an affected area of a few kilometres before it attenuates and is masked by ambient noise (Tougaard et al., 2020). The degree of noise pollution here is comparable to the sound source level of a large commercial ship, and while this is understood to elicit temporary behavioural changes in a variety of species, the effects are understood to be minimal (Mooney et al., 2020). Aside from acoustic pollution, the presence of OSW has further environmental effects. As turbine monopile stand vertically in the water column, they are understood to cause multiple physical changes to local hydrodynamic conditions. These impacts include changes to circulation, stratification, mixing, and sediment resuspension within the water column (Carpenter et al., 2016)(Lass et al., 2008).

The water column is not homogenous, but rather divided up into layers (strata) by temperature and salinity. Naturally stratified waters cause phytoplankton to become ‘trapped’ in the well-lit surface layer, with the thermocline acting as a barrier to mixing. Eventually, the nutrients in this stratified layer become exhausted, which naturally limit the size and duration of phytoplankton blooms. The introduction of OSW piles changes this natural process. Through the mixing of water downstream of the piles, thermoclines and salinity bands are disturbed. This allows for cold nutrient rich bottom water to mix with warm nutrient poor surface water, resulting in larger and longer plankton blooms. As all marine life (aside from chemotrophs) ultimately rely on primary production, this impact is understood to have further downstream implications on nutrient pathways, ecosystem functioning, and oceanic carbon sequestration (Dorrell et al., 2022).

It is important to note that although the environmental impacts of this activity are unnatural, they may not always be ‘harmful’. Examples of this effect can be seen after monopiles have been installed and scour protection is in place. Scour protection is the synthetic mats and large rocks placed at the bottom of turbines to limit the degree to which sediment is naturally excavated by the increased flow of water around the turbine substructure. Although there are various methods of protecting foundations from scour, and the amount of scour protection that is placed varies on a site to site basis, its ecological effect is understood to be relatively large (Hiscock et al., 2002). For each turbine foundation, there is roughly 600 square meters of new rocky surface area on the otherwise sandy banks (Wilson et al., 2010). This placed rock, although unnatural in location, acts as a novel habitat on which a variety of organisms colonize (Whitehouse et al., 2011). Interestingly, the ecological niche of this man-made environment is similar to that of a natural rocky outcrop, and early colonization by barnacles, tube worms and sea squirts leads to the arrival of species such as lobster, crab, and various reef fish. Although natural rocky outcrops generally have higher levels of biodiversity and species abundance than sandy seabed, they are a fundamentally different ecosystem than those that naturally occur in regions of OSW development (Linnane et al., 2000). This introduction of new biomass to the region changes the local trophic structure and food web dynamics. Provided the increase in biomass on and around the structures, the food web changes from one of nutrient space to nutrient rich (Raoux et al., 2017). This shifts the food web to one favouring detritivores, organisms such as lobsters and crabs that consume dead organic material. In this sense, although OSW farms are hotspots of biodiversity, the ecosystems they support are unnatural in essence and must be considered as such when assessing the potential ecological impact that OSW farms may have.

3.4.2 Socio-ecological implications

Considering the changes to the ecological conditions around OSW farms, there are associated implications and opportunities that can impact human wellbeing. While a topic that remains debated, these socio-ecological implications of OSW appear to be largely favorable (Glasson et al., 2022). Examples of these socio-ecological impacts are largely a result of the altered human uses of offshore space. Through natural colonization of the habitat created by

OSW foundations and associated scour protection, the modified ecosystems that are established in these areas may be beneficial to the socio-economic state of some of ocean users.

Settlement densities of juvenile lobsters are understood to be increased within cobble- and boulder-covered areas, compared to adjacent sandy areas of the seabed (Linnane et al., 2000). The artificial habitats created by OSW foundations and scour protection appear to induce the same ecological effect (Skerritt et al., 2012). Providing a variety of different sized holes, cracks, and crevices between the placed rocks, scour protection is thought to be ideal habitat for lobster through all stages of development, from larva to juvenile to adult (ibid). While the exact extent to which this could benefit harvesters remains unknown, and is likely highly location specific, it is expected that an increase in size and catch rates of lobsters will occur around OSW turbines (Roach et al., 2022). As such, the potential beneficial effect of OSW installations on commercially valuable species, and the benefit that this would bring to those who harvest it, must also be of consideration as a potential social-ecological effects of OSW development.

Further positive social effects of this changed environment may go beyond the harvesting of commercially valuable species. Due to their presence in the water column and the shadows they cast, OSW turbines act as fish aggregating devices. Aggregating devices elicit behavioral changes in schooling fish, which are attracted to the disturbance in the water column (Raoux et al., 2017). Furthermore, as the structures and scour protection support communities of various reef species, they alter local predator/prey dynamics within the windfarm. While unnatural, this provides opportunity for a variety of new tourism and recreational uses of the offshore space (Smythe et al., 2020). Such opportunities include spearfishing, diving, and shark fishing, which have benefited coastal economies in both Europe and the United States (Svendsen et al., 2022; ten Brink et al., 2018). Increased tourism may have further positive cumulative effect to local hospitality and service industries through the creation of induced impact jobs.

3.4.3 Social implication of Site Operation and Decommissioning

The direct social implementation of OSW operation is thought to be rather large. This is due to the production of renewable energy, and the effect that it has on the various facets of society which it benefits. However, the social perceptions of OSW energy may be ultimately dependent on how it is allocated. If a community affected by the various impacts of development does not receive adequate direct benefit of this renewable resource, perceptions and feelings surrounding the development could suffer. While this issue is further discussed in Chapter 4 with respect to the lobster industry, it must be noted as a potential social implication of OSW development.

Other such social implications can be illustrated by how OSW infrastructure affects perceptions of ‘nature’, and the natural sea stake that many value quite deeply. OSW farms alter the seascape through the introduction of relatively permanent large-scale fixed structures into a space where previous uses have been mostly transient. As such, OSW represents a shift toward a greater industrialization of the sea. Furthermore, it has been found that local residents in an affected area perceive these effects of industrialization, irrespective of the visibility of an OSW farm (Gee, 2010). This is due to the prevalent view of the sea as a largely nonindustrial space where human impact has so far remained relatively restricted. These feelings could also reflect the view that the sea should be kept free of man-made structures, or that interests such as nature conservation should have priority.

Further examples of direct social implications of OSW can be illustrated by resource harvesters that operate within a wind farm, if such co-location measures are allowed. As safety is a paramount concern of those who make a living at sea, the further risk that OSW infrastructure places on harvesters working within the wind farm must be recognized. Importantly, such dangers go beyond the collision risk between vessels and turbine structures. In the winter, snow and ice can accumulate on turbine blades and fall indiscriminately. For fisheries that use bottom contact fishing gear, cables, scour protection, and other foreign objects on the seabed can pose a risk of gear entanglement. Considering these risks, further indirect or cumulative effects may be recognized in the insurability of these operations, where harvesters may be forced to pay higher insurance premiums to continue fishing in these areas. Concerns over the potential for higher costs of insurance due to safety risks have been echoed by fishermen both in the United States (Hall et al., 2015) and abroad (Gusatu et al., 2020). As such, the direct and indirect social implications illustrate the nuance of the social effect that OSW development may pose.

3.5 The Management Challenge of Scoping a Novel Subject

The potential social and ecological impacts of OSW allude to the intertwined nature between social and ecological wellbeing, as well as the reciprocal causal pathways in which society may be affected by OSW development. Provided the degree of nuance of the potential social, socio-ecological, and ecological impacts of OSW, a significant challenge lies in characterizing these potential effects within the impact assessment process. Unlike the previous RA under the new Act (see section 1.5), where the majority of ecological, socio-economic, and (to a degree) socio-cultural impacts of proposed activity have already been captured within impact assessment, the possible effects of OSW remain largely unrecognized in the region.

Furthermore, considering the underlying challenges within impact assessment practice of spatial and temporal scoping, the assessment of social and coupled socio-ecological cumulative effects, as well as the recognition of interconnectivity and feedback between social, economic, and ecological systems, such complexity will likely be especially hard to conceptualize. These conceptual challenges, if not enough, have been scheduled on a tight timeline for the current RA. In light of these challenges, I look to the many SES techniques to better capture these key socio-ecological interactions. As the underlying goal of the current RA is towards understanding how offshore wind could affect the environment, society, human health, and the economy, the importance of identifying key potential socio-ecological impacts of this development is paramount. As such, I consider these potential effects in a manner which respects the underlying complexity at hand. While the underlying purpose of this project is towards elucidating the potential of conceptualizing the socio-ecological implications of OSW through a systems thinking lens, doing so for all potential impacts is beyond the capacity of this graduate project. As such, I look to explore the capability of using SES thinking to frame socio-ecological complexity through a study system, and focus on the potential implications that OSW may have on the Nova Scotia lobster industry. It is my hope that, through such focus, the potential of addressing issues of sustainability within impact assessment through a more integrated and holistic perspective will be made clear.

Chapter 4: Lobster Industry and Offshore Wind Study System

4.1 Approach and Methodology

To best situate my graduate project within the modern context of impact assessment and SES thinking, in an attempt of pertinence, I needed to first develop a perception of the issue at hand. This started in February of 2023, where I assumed my role within the Network for Expertise and Dialog in Impact Assessment (NEDIA) under the guidance of Dr. Ian Stewart and NEDIA postdoc Dr. Leah Fusco. Here, I assisted in research around how social-ecological dynamics are captured within project specific EIAs for the offshore oil and gas industry of Newfoundland by examining a Regional Assessment undertaken by the Agency for exploratory drilling in East Newfoundland (Bangay et al., 2020). My research included literature surveys on aspects of impact assessment in this sector (including impacts of seismic surveys), and review of other impact assessment literature (such as SEAs) in the Atlantic region to help capture how fish harvesters were engaged within the impact assessment process within this sector. Specifically, we used discourse analysis methods to look into how the voices of natural resource harvesters affected by actions of the oil and gas industry were framed and represented within the impact assessment process documentation. Not only did this provide insight into the procedural workings of impact assessment, and regional assessment in particular, it shed light on the manner in which impact assessment portrays the coupled socio-ecological impacts of development. This work also provided me the opportunity to observe how the academic study of such issues are conducted, which helped me frame my graduate research immensely.

In June, I attended the two-day NEDIA workshop hosted by the University of Ottawa. Here, I was exposed to a variety of academic initiatives from impact assessment researchers across Canada, which showcased both the breadth of impact assessment as well as the degree of academic study on the subject. A principal takeaway here was the various ways in which current impact assessment is tailored to capture the social implications of development, as well as how these social (including gender-based) analyses are framed within academic study. This juxtaposed the previous research I had been doing around the offshore oil and gas industry, and provided insight regarding how the social side of socio-ecological systems could be captured or better represented within the impact assessment practice. In application to my graduate work, this experience spurred me to contemplate how I could tailor my own research methodology to capture the notion of sustainability or sustainable development as it pertains to the social, economic, ecological factors to be considered in the current RA for OSW development.

Through developing an understanding of the variety of ways impact assessment is conducted in practice, as well as the variety of ways it is studied within academia, I began to further refine my own project. As the RA for OSW development is concerned with a variety of social, cultural, economic, and environmental factors, I thought it apt to capture such factors within my case study. Furthermore, in seeing how social-ecological coupled systems were represented in the RA for offshore oil and gas development, focusing on a fishery, or an aspect of a fishery, seemed appropriate. In meetings with various personnel at the Department of Fisheries and Oceans (DFO) Maritimes, the federal fisheries management organization concerned with Nova Scotia fisheries, something became clear: our understanding of the human dimension of natural resource harvesting remains relatively sparse. Considering this, I had to shape my study around the availability of social data as it pertains to the Nova Scotia fishery. The Blue Economy Lobster Team (BELT), composed of social and natural scientists within DFO, is an example of a changing focus within fisheries management. BELT has engaged both internally (Pourfaraj et al., 2022) and externally with Rightsholders and stakeholders in a pilot project to develop comprehensive advice on the sustainability of the lobster fishery in the context of a Blue Economy and the budding DFO EBM framework (Parlee et al., 2023). Within this preliminary work, they have elucidated a variety of socio-cultural aspects of the lobster fishery, providing me the opportunity to represent such socio-cultural elements in my own work. Their insight has remained central to my work in framing the lobster industry through a SES lens.

Choosing to focus on the lobster industry provided an opportunity to capture further milieu within my case study. In November of 2022, I spent two weeks as a deckhand on a lobster fishing boat exploring the 'conflicts of management' within the lobster industry to inform previous graduate work. While I had not yet conceived of this project at the time, the experience connected me to the hardship, importance, and cultural history of those who make a living from the lobster fishery. This experience undoubtedly shaped my perspective and approach in capturing the social systems within this work, and further drove my passion to try and help better capture the potential social implications of development as it appears within impact assessment.

Lastly, to further help situate my project and better familiarize myself with the process of conducting a RA in practice, I attended RA public outreach sessions. I attended two of these sessions—one in Sheet Harbour and one in Dartmouth—to observe how these sessions were conducted as well as hear some concerns of the general public. Attending these sessions also provided me the opportunity to familiarize myself with the RA committee, the individuals conducting the assessment on behalf of the Impact Assessment Agency of Canada, to grasp a better sense of how this study is currently being conducted. This allowed me to further develop my project with respect to helping incorporate systems thinking into the ongoing RA for OSW development.

4.2 Case Study Specifics

As noted, an RA is being undertaken to assess the potential implications of developing OSW off the province of Nova Scotia. The goal of the assessment is to provide information, knowledge and analysis regarding future offshore wind development activities in the Study Area and their potential effects. The purpose of the assessment is to inform and improve future planning, licencing and impact assessment processes for these activities in a way that helps protect the environment and health, social and economic conditions while also creating opportunities for sustainable economic development (Impact Assessmet Agency of Canada, 2023). While the assessment looks to consider the health, social and economic conditions of the study area, the region lies entirely offshore (Fig 6). As this phenomenon appeared to limit the consideration of direct and cumulative social effects in the most recent RA (see Chapter

1.5), there is great interest in capturing how various factors of social, cultural, and economic wellbeing extent to human activity that occur 'on the water' within the study area.

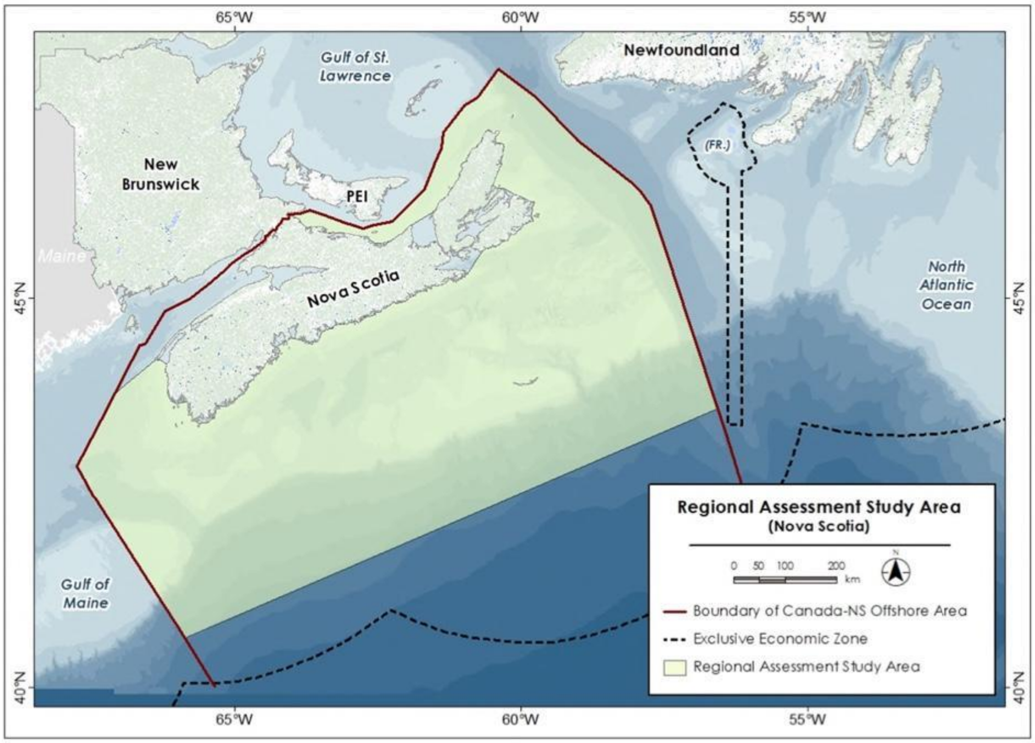

Fig 6. The current RA study area for OSW development in Nova Scotia. Note that the province of Nova Scotia lies outside of the study area, despite the RAs mandate to include the consideration of various social and cultural aspects within the study (Government of Canada, 2023).

The commercial lobster fishery is currently the most lucrative in North America with the landed value of Inshore lobster in the Region being $648 million dollars (Fisheries and Oceans Canada, 2022). The lobster fishery is economically significant to the Maritimes Region, and it has been an active commercial fishery for over 150 years. Within the last 30 years, total landings in many areas have doubled. This dramatic increase in landings has led to higher profitability as well as greater social and cultural reliance of fishing communities on the fishery (Greenan et al., 2019). However, as previous research out of Dalhousie's Marine Affairs

Programs indicates, there is potential for a relatively spatial conflict between fixed based OSW and areas of lobster harvesting (K. Gordon, 2022). Considering the potential for spatial conflict, as well as the available data on relevant economic and socio-cultural aspects on the fishery, this topic presented itself as pertinent and important case study.

4.3 Methods of Case Study

4.3.1 Literature Review

An initial literature review was undertaken to identify and assess the existing academic application of SES methodology to impact assessment. This study began in Scopus, where my preliminary searches rendered over 350 collective results (the exact search terms are included in Box 6). To further refine these preliminary searches, I systematically sorted through the identified documents, read abstracts of any paper potentially applicable, and skimmed documents of question to identify any application to SES to impact assessment. Out of the initial search, 17 papers demonstrated conceptual application of SES methodology to impact assessment. Once I had developed this shortlist, I used Scholar, Connected Papers, and Web of Science to find any related papers through citation and deductive reason. This body of identified literature was further visualized using Research Rabbit to determine both the relation of citations, as well as the chronological order in which the study had progressed.

Box 6: Scopus Search Terms

In Scopus, using "quotation marks" will search for a loose phrase, where the words appear together in a fixed order. By default, Scopus automatically includes common variants and most plural forms in the search. As such, *“socio ecological”* will also return *“socio-ecological”*. Additionally, {curly brackets} will return only for the exact words as given. This was done as *“socio ecological” AND impact AND assessment* returned 501 results, for example, whereas *{impact assessment}* returned a more focused 97 results.

"socio ecological" AND {impact assessment}
"social ecological" AND {impact assessment}
ses AND {impact assessment}

"socio ecological" AND eia
"social ecological" AND eia
ses AND eia

"socio ecological" AND {strategic environmental assessment}
"social ecological" AND {strategic environmental assessment}
ses AND {strategic environmental assessment}

"socio ecological" AND {regional assessment}
"social ecological" AND {regional assessment}
ses AND {regional assessment}

While I found examples of novel SES frameworks, quantitative SES assessments, and the various applications of ecosystem services to the world of impact assessment, the work of Haraldsson et. al (2020) stood out. As this graduate work is concurrent with the RA for OSW development, I wanted to frame my case study in a way that reflected the fundamental dimensions of systems thinking to best portray my interdisciplinary message, which includes capturing system structure, function, and the identification of leverage points or the 'importance' of system components to one another. The use of a representative SES not only identified the effects of OSW on both society and the local ecosystem, it captured system structure and illustrated system function. Furthermore, as representative systems can be further studied using qualitative mathematics to identify leverage points and overall system stability, this approach appeared to be an appropriate fit. Prior to the illustration of my study system, however, I first needed to identify system components on interest and their relation.

4.3.2 Identification of SES Components

The illustration of complex SES can be facilitated through the use of representative models as they allow the researcher to make precise assumptions regarding the general causal logic of the SES at hand, while also respecting the various pathways of interaction between components of the system (see Section 2.3). To identify representative components of both the social aspect of the Nova Scotia lobster industry, as well as the larger ecosystem in which it operates, I met with many subject matter experts. Of particular help were members of the internal BELT team at DFO who provided advice on what to focus on as it pertained to capturing the potential social impacts (which I have included as perceived harvester wellbeing, cultural identity, income security, and harvester safety of Table 1) of the lobster industry. As the Nova Scotian lobster population is stable, perhaps growing, they suggested that the greatest implications to this industry would be social, not ecological. They pointed me towards preliminary work they had published around the social aspects of the Nova Scotia lobster industry, and discussed some precursive findings of similar study they are currently conducting.

In comparison to the social subsystem, the ecological subsystem of my coupled socio-ecological system was generated in a different manner. As the underlying goal of the representative model is to capture system dynamics, I based my approach on trophic representation within the ecosystem. Here, I employed non-specific language (except the focal species Lobster) to facilitate both the comprehension and spatial applicability of this modeling approach. While this perhaps leaves the door open for species mischaracterization within the model, I believe it is easier to understand for those who may not have recognized the names of representative species, and provides a better understanding of the ecosystem dynamics which occur as a result of the introduction of a wind farm.

The shelf seas of the North Atlantic can be characterized by a food web dominated by intermediate trophic level species (Holt et al., 2014), opposed to a classical bottom-up or top-down control observed in other ecosystems (Cury et al., 2008). In large part, this is due to the dominance of small to medium size pelagic species (e.g., herring, mackerel, blue whiting, capelin), which feed on small benthic organisms and zooplankton. As ecological modeling scenarios have shown that the dominating impact of offshore wind farms are the reef effect due to the arrival of mussels and associated species on the hard substrate, the anticipated biomass increase of colonizing species after OSW construction is predicted to shift trophic dynamics towards a detritivore and omnivore-dominated food web (Niquil et al., 2020)(Raoux et al., 2018). This leads to a higher level of intrasystem nutrient recycling, in large due to the reef effect and the action of filter feeding organisms.

To reflect the initial dominance of small to medium size pelagic species, and the trophic shift towards a detritivore and omnivore-dominated food web, I have strategically included subsystem variables to aid in this illustration. To recognize the initial dominance of pelagic species in this ecosystem, two indicators of small pelagic fish species (planktivorous fish and grazer feeders) have been included who feed on the phyto-, zooplankton, protozoan, and small planktonic mollusks of the category ‘plankton’. To illustrate a shift towards a detritivore and omnivore-dominated food web with lots of nutrient recycling, I have included filter feeding organisms within the category ‘bivalves’, while recognizing the shift to a nutrient laden ecosystem through the introduction of ‘seaweeds’ and ‘detritus’.

While the representative components of the regional ecosystem and the Nova Scotia lobster industry are possible to describe through the use of representative components and, the fundamentals of each subsystem, and the resultant ecological trophic shift are perhaps better conveyed through the use of broader classification language rather than specific terms. As such, I step away from methods of Haraldsson et. al (2020) to generate the following representative socio-ecological components of my study system (Table 1).

Code	Variable Name	Definition
Social Subsystem		
PW	Perceived Harvester Wellbeing	The self-perceived wellbeing of the local harvesting community as based on spiritual, cultural and economic values
CI	Cultural Identity	The perceived state of one’s connection to culture
EQ	Perceived Environmental Quality	Perception of local quality of the environment
TR	Traditional Resource Use	Rightful and unimpeded access to traditional resource harvesting for food, social, and ceremonial purposes
IS	Income Security	The state of well-being from being able to afford expenses without stress
HS	Harvester Safety	The safety of lobster harvesters, both on the water and the wharf

FM	Fishery Management	Management body concerned with regulating the lobster fishery
FIS	Supportive Industry (Fishery)	Boat builders, trap makers, and the larger supply chain of the lobster fishery
SS	Service Sector	The local service sector, in terms of job opportunities and work activity.
ET	Eco-tourism	Various tourism opportunities, including harvesting for educational purpose
LH	Lobster Harvesting	The local lobster fishery, in terms of job opportunities and work activity.
Ecological Subsystem		
PK	Plankton	Phyto-, zooplankton, protozoans, and small planktonic mollusks
BV	Bivalves	Filter feeding mollusks
BNTH	Benthos	Hard and soft bottom species of the epibenthos and benthos
DT	Detritus	Organic matter deposited on the ocean floor
SW	Seaweeds	Seaweeds and algae
FF	Forage Fish	Fish whose diet consists of phytoplankton, zooplankton, and protozoa (eg. capelin)
PF	Planktivorous Fish	Fish whose diet consists of phytoplankton, zooplankton, and protozoa (eg. blue whiting)
PSF	Piscivorous Fish	Fish whose diet consists of other fish (eg. mackerel)
LB	Lobster	American Lobster (*Homarus americanus*)
TP	Top Predators	Larger predatory species (eg. sharks, seals)

Table 1. The representative socio-ecological components of the Nova Scotia lobster industry included in study system, described.

4.3.3 Representative Systems, Signed Diagraphs, and Qualitative Mathematics

Simple SESs are a means to portray a system in whole while preserving a representative degree of complexity between system variables. They are constructed from representative elements of the SES in question, and show the relation between such components. While cumbersome and unexpressive in tables, these SESs can be illustrated through what are called signed directed graphs (also called signed diagraphs), or more amusingly 'horrendograms', given their complexity. These signed diagraphs depict the positive, negative, or null [+/-/0] direct effect between variables in a system, and are used to show both how elements of a system are connected, as well as the effect in which they have on another. Within the graph, a direct positive effect between two variables, for example a prey population on its predator population, is depicted as a link ending with an arrow (→). A direct negative effect, that predators have on prey populations to continue the example, are represented by a link ending with a circle (—•). System elements without direct effects, essentially null interaction between system components, are not connected.

After elucidating representative components of the social and ecological aspects of the Nova Scotia lobster industry, I described their interaction. As the purpose of this approach is to capture how system interaction changes through the introduction of a wind farm, and the subsequent life span of the farm, the interaction of system elements was first described pre-wind farm. To show how these interactions change first through site surveying and construction, then through the operation and decommissioning of a wind farm, the phases of development were modeled respectively. Following best practices, the number of components between my social and ecological subsystems within my representative system were balanced (Berkes et al., 2000). Using this preliminary model, I elicited feedback from my supervisors initially, then from select RA committee members. In all, the 'tweaking' of interactions within my system, both of the initial null system and its temporal variation, was most demanding. While the resultant systems as seen in this report are a product of countless hours of background study, professional opinion, and academic milieu in which I have been surrounded, they are innately and unavoidably subjective as well as uncertain. We have only just begun to study the socio-cultural aspects of our fisheries, and as much of the interaction within socio-ecological systems is highly location specific, there remains a degree of uncertainty as it pertains to generalizing these interactions as I have done here. However, as this project is concerned with the capacity of applying such SES techniques to impact assessment practice as a means of scoping potential socio-ecological impacts, I refined the system to an appropriate degree of representation, not to one of certainty. In this light, once I had acquired an provisional degree of feedback and understanding of the components of my model (Table 1) and their relation to one another (Table 2) in a regional context, I encoded these systems in PowerPlay (Westfahl et al., 2002).

4.4 Results

4.4.1 Null Socio-Ecological System (Structure 1)

The initial state of the socio-ecological system was first described 'as is' prior to the introduction of OSW. The interaction between system components (Table 1) have been described (Table 2) prior to any effect of development.

Social Subsystem

From	**Effect**	**To**	**Description**
Perceived Harvester Wellbeing	—	Fishery Management	Positive harvester wellbeing is understood to relieve pressure on resource management bodies, largely through the reduction of conflict (Klain et al., 2014).
	+	Cultural Identity	Positive perceptions of wellbeing strengthen cultural identity.
Perceived Enviro. Quality	+	Perceived Harvester Wellbeing	Harvester wellbeing is understood to be impacted by their perceptions of environmental quality and climate vulnerability (Runnebaum et al., 2023).
	+	Cultural Identity	Positive perceived environmental quality strengthens cultural identity (Yang et al., 2022).
	—	Fishery Management	Strong positive perception of environmental quality reduces public pressure on resource management (Wang et al., 2018).
Cultural Identity	+	Perceived Harvester Wellbeing	Continuation of culture increases perceptions of wellbeing among resource users (Young et al., 2016).
Traditional Resource Use	+	Cultural Identity	Access to traditionally harvested resources allows for the continuation of culture.

	+	Income Security	Access to traditional resources is a source of income.
Income Security	+	Cultural Identity	Income security is understood to facilitate cultural practice (Young et al., 2016).
	+	Perceived Harvester Wellbeing	Adequate and secure income increases perception of wellbeing.
Harvester Safety	+	Traditional Resource Use	Safe harvest allows for the traditional use of resources (Parlee et al., 2023).
	+	Income Security	Safe harvest allows harvesters to make a living, unimpeded by undue risk
	—	Fishery Management	Safe harvest lowers the burden of management to ensure safe practices (Windle et al., 2008).
	+	Lobster Harvesting	Safe harvest facilitates further harvest.
	+	Perceived Harvester Wellbeing	Safe harvest increases perception of harvester wellbeing (Young et al., 2016).
Fishery Management	+	Perceived Harvester Wellbeing	Proper fishery management reduces potentially negative issues of wellbeing, such as conflict (Klain et al., 2014).
	+	Harvester Safety	The rules in place by management bodies increased the safety of harvesting practices (Power et al., 2010).
	+	Perceived Enviro. Quality	Fishery management is a measure to prevent resource overexploitation. This maintains ecological function, and strengthens perceptions of environmental quality.
	—	Lobster Harvesting	Management quotas limit the amount of lobster harvested through limiting fishing effort.

	+	Piscivorous Fish	Management quotas limit the harvest of piscivorous fish harvested.
Fishing Industry Sector	+	Income Security	Industry sector provides job opportunity, such as boat building, trap making, and transportation.
	+	Service Sector	Activities in local industry increase the demand for the local service sector (fish markets, restaurants, etc.)
	—	Perceived Enviro. Quality	The transportation of live lobster to over sea markets requires extensive petroleum-based transportation.
Service Sector	+	Income Security	Service sector provides job opportunity.
Eco-tourism	+	Service Sector	Tourism creates jobs thus income within the service sector.
	—	Perceived Enviro Quality	Excessive tourism has a negative effect on local environment (Buckley, 2011).
	+	Income Security	In Nova Scotia, the lobster is fished during the winter. Tourism during the summer can provide a secondary source of income to fishing.
Lobster Harvesting	+	Traditional Resource Use	The harvesting of lobster exercises traditional resource rights.
	+	Income Security	Harvesting generates income.
	+	Fishing Industry Sector	Continued harvesting necessitates the larger supportive industry.
	—	Top Predators	Traditional harvesting methods pose a risk of entanglement to larger top predators.
	—	Lobster	Harvesting has a top down effect on the lobster population.

Ecological Subsystem			
Plankton	+	Planktivorous Fish	Bottom up availability of food.
	+	Forage Fish	Bottom up availability of food.
	—	Seaweed	Plankton limit the degree of light which can penetrate the water column.
	—	Perceived Environmental Quality	High densities of phytoplankton increase water turbidity that can be seen as less clean or attractive, which decreases the perception of a good environmental quality.
Planktivorous Fish	—	Plankton	Top-down predation reduces plankton abundance.
	+	Detritus	Biomass decomposed to organic matter upon death.
	+	Piscivorous Fish	Top-down predation reduces piscivorous fish abundance.
Bivalves	+	Benthos	The accumulation of hard shells increases benthic habitat abundance and variability.
Benthos	+	Bivalves	Hard benthos provides habitat for bivalves.
	+	Seaweeds	Hard benthos provides habitat for seaweed.
	+	Lobster	Hard benthos provides habitat for lobster.
Detritus	+	Benthos	Deposition of detritus accumulates on benthos.
	+	Lobster	Bottom up availability of food increases lobster abundance.

Lobster	—	Detritus	Consumption reduces detritus.
	+	Top Predators	Top-down predation reduces lobster abundance.
	+	Lobster Harvesting	Top-down harvest reduces lobster abundance.
	+	Perceived Environmental Quality	Abundance of lobster positively influences perceived environmental quality.
Seaweeds	+	Detritus	Biomass decomposed to organic matter, and settles as detritus.
Piscivorous Fish	+	Detritus	Biomass decomposed to organic matter upon death.
	–	Planktivorous Fish	Top-down predation reduces planktivorous fish abundance.
	+	Top Predators	Bottom up availability of food.
	+	Environmental Quality	Abundance of larger piscivorous fish positively influences perceived environmental quality.
Forage Fish	+	Detritus	Biomass decomposed to organic matter upon death.
	—	Plankton	Top-down predation reduces plankton abundance.
	+	Top Predators	Bottom up availability of food.
Top Predators	+	Detritus	Biomass decomposed to organic matter upon death.
	—	Forage Fish	Top-down predation reduces forage fish abundance.
	—	Piscivorous Fish	Top-down predation reduces piscivorous fish abundance

—	Lobster	Top-down predation reduces lobster abundance
+	Eco-tourism	Abundance of large top predators provide opportunities for tourism

Table 2: Intrasystem relation of null ‘undisturbed’ socio-ecological system. Each row represents an interaction within the null system, in the direction of ‘From’ to ‘To’. ‘+/- Effect’ represents the reinforcing or balancing nature of the interaction, respectively.

While unexpressive in a table, these interactions can be illustrated by a digraph (Fig 7).

Within a diagraph, the underlying dependencies between associated factors can be visualized.

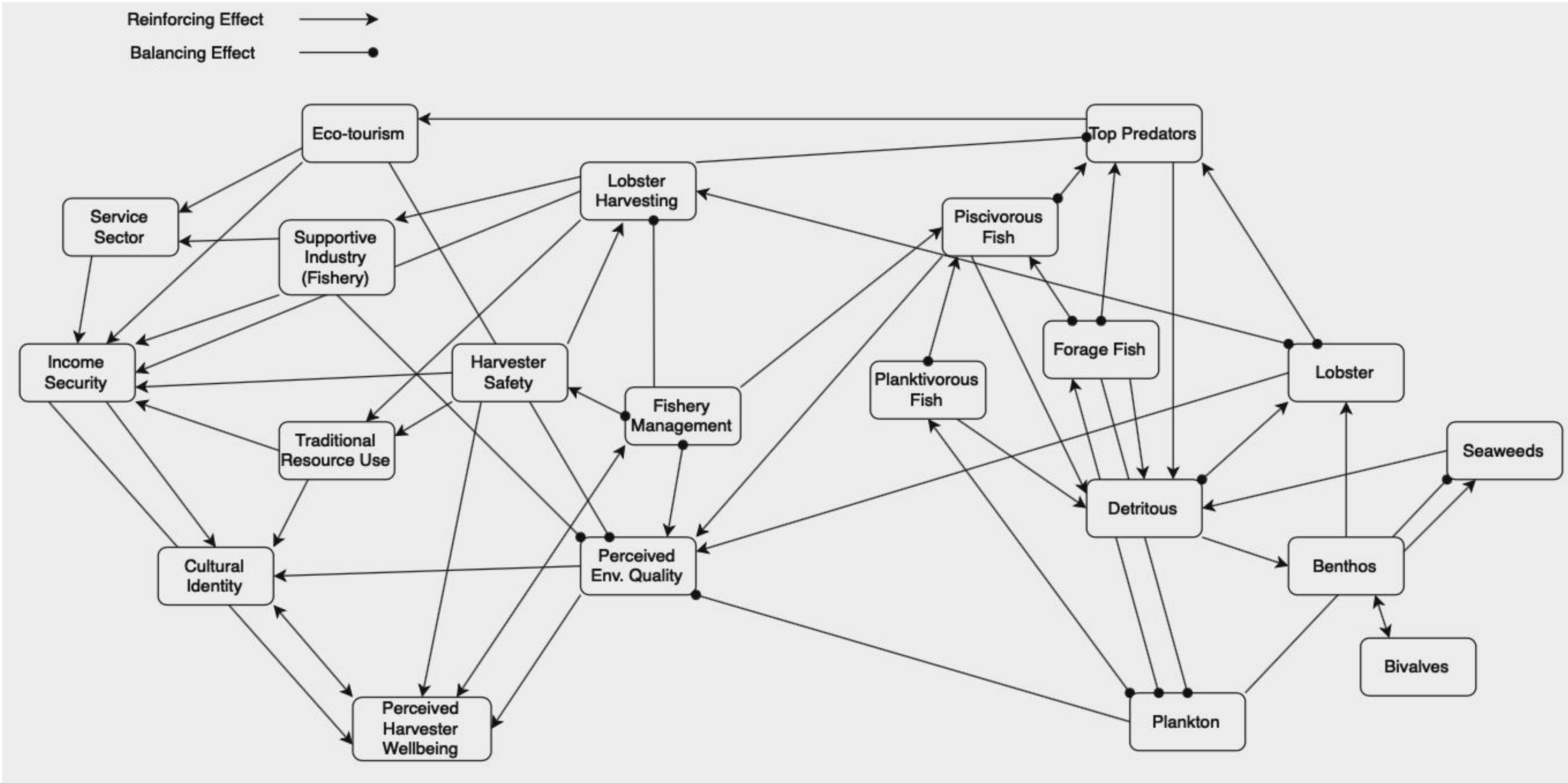

Fig 7. Signed diagraph of the representative SES prior to OSW development. The diagraph visualizes the system interaction outlines in Table 2. Reinforcing effects between system components are represented by an interaction terminating in an arrow, and balancing effects are represented by an interaction terminating in a dot.

4.4.2 Site Surveying and Construction (Structure 2)

The effects of site surveying and construction can be illuminated by changes within the representative SES. This is through the introduction of a new component 'OSW', which encompasses all activities associated with the site surveying and construction process. Table 3 summarizes new interactions between system components as altered from these activities.

Socio-Ecological Interaction as Directly Impacted by Site Surveying and Construction

Offshore Wind	—	Plankton	Noise from seismic surveying and pile driving can decrease plankton abundance through physiological damage.
	—	Piscivorous Fish	Noise from seismic surveying and pile driving can decrease piscivorous fish abundance through behavioral change and physiological damage.
	—	Planktivorous Fish	Noise from seismic surveying and pile driving can decrease piscivorous fish abundance through behavioral change and physiological damage.
	—	Piscivorous Fish	Noise from seismic surveying and pile driving can decrease piscivorous fish abundance through behavioral change and physiological damage.
	—	Forage Fish	Noise from seismic surveying and pile driving can decrease forage fish abundance through behavioral change and physiological damage
	—	Top Predators	Noise from seismic surveying and pile driving can decrease top predator abundance through behavioral change and physiological damage

—	Lobster Harvesting	Seismic surveying and construction activities can pose a spatial conflict with harvesting practices
—	Harvester Safety	Seismic surveying and construction activities can cause harvesters to travel further to fishing grounds
—	Fishing Industry Sector	Higher paying opportunities in the OSW industry can negatively impact the supportive fishing industry
—	Perceived Environmental Quality	Industrial activity in otherwise pristine places can decrease perceptions of environmental quality
—	Income Security	Further distance to fishing grounds can increase steaming times thus cost
+	Service Sector	The workforce needed to complete OSW activities can increases demand within the local service sector

Table 3. Novel direct interactions within the SES as a product of site surveying and construction activities.

The above table (Table 3) shows the direct impact that OSW site surveying and construction activities may have to the SES. For clarity, new reinforcing direct interactions within the system are denoted by a green arrow, and new balancing interactions are depicted by a red interaction terminating in a dot. The indirect implication of these impacts can be further visualized within the diagraph (Fig 8). Multiple effects on a variable, and the ‘downstream’ variables in which are then impacted, are the cumulative effects of the initial impact

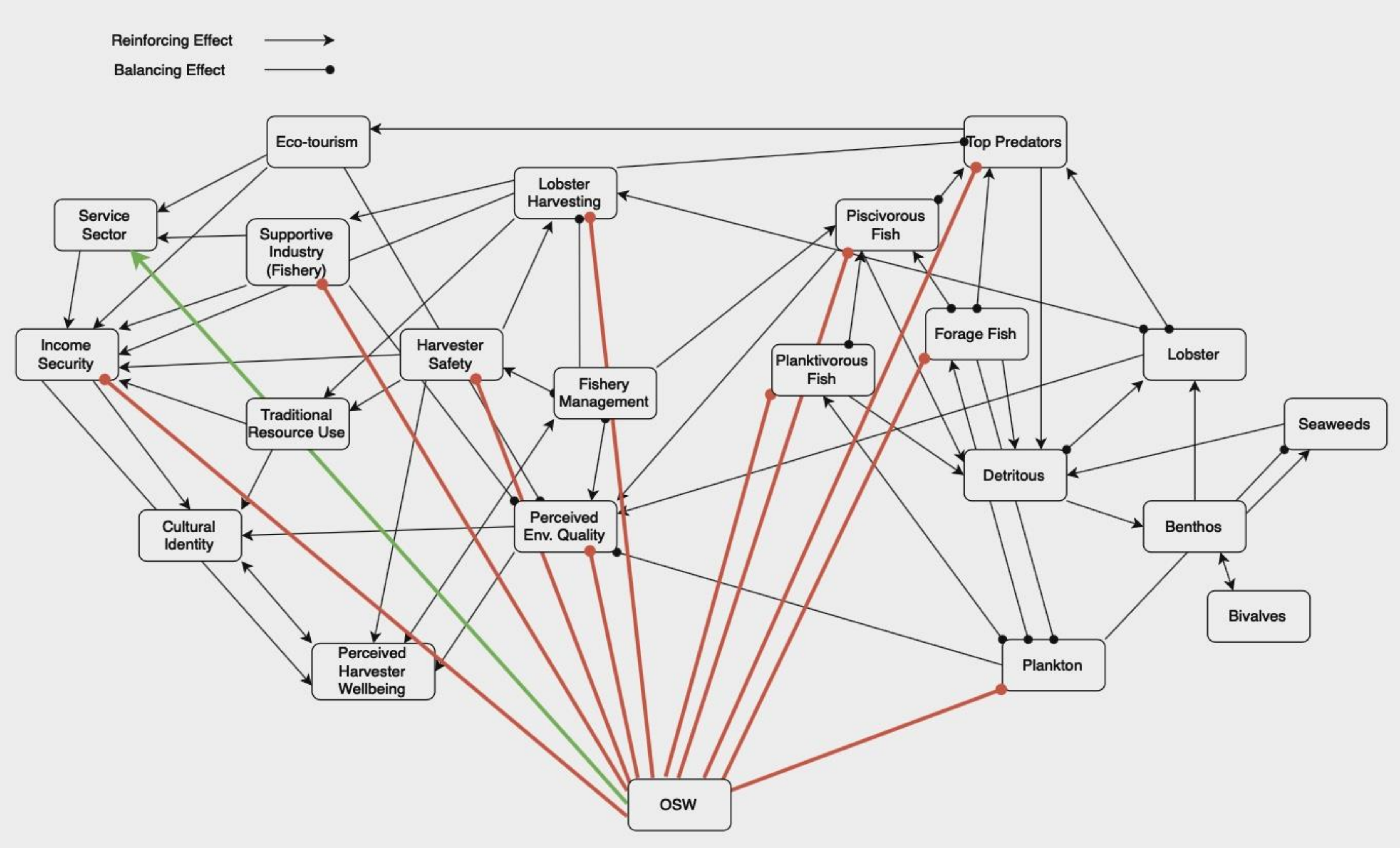

Fig 8. Signed diagraph of the representative SES as impacted my site surveying and construction activity. New reinforcing direct interactions within the system are denoted by a green interaction terminating in an arrow, and new balancing interactions are depicted by a red interaction terminating in a dot.

4.4.3 Operation and Decommissioning (Structure 3)

Socio-Ecological Interaction as Directly Impacted by Site Operation and Decommissioning			
Offshore Wind	+	Plankton	Downstream mixing of otherwise stratified water provides nutrients to plankton
	+	Bivalves	Hard substrate as introduced by the turbine substructure and scour protection provide habitat for bivalve species
	+	Benthos	Scour protection increases benthic surface area and habitat complexity
	+	Perceived Environmental Quality	Social perceptions around offshore winds impact on the environment gradually change with the production of renewable energy
	+	Planktivorous Fish	OSW aggregates schooling fish
	+	Forage Fish	OSW aggregates schooling fish
	+	Piscivorous Fish	OSW aggregates schooling fish
	—	Harvester Safety	The potential for vessel collision with OSW piles, falling snow and ice, and entangled gear pose a threat to harvester safety
Plankton	+	Bivalves	This correlation was included to better represent the trophic shift to a reef ecosystem upon the colonization of new hard OSW stratum

Table 4. Novel direct interactions within the SES as a product of site operation and decommissioning

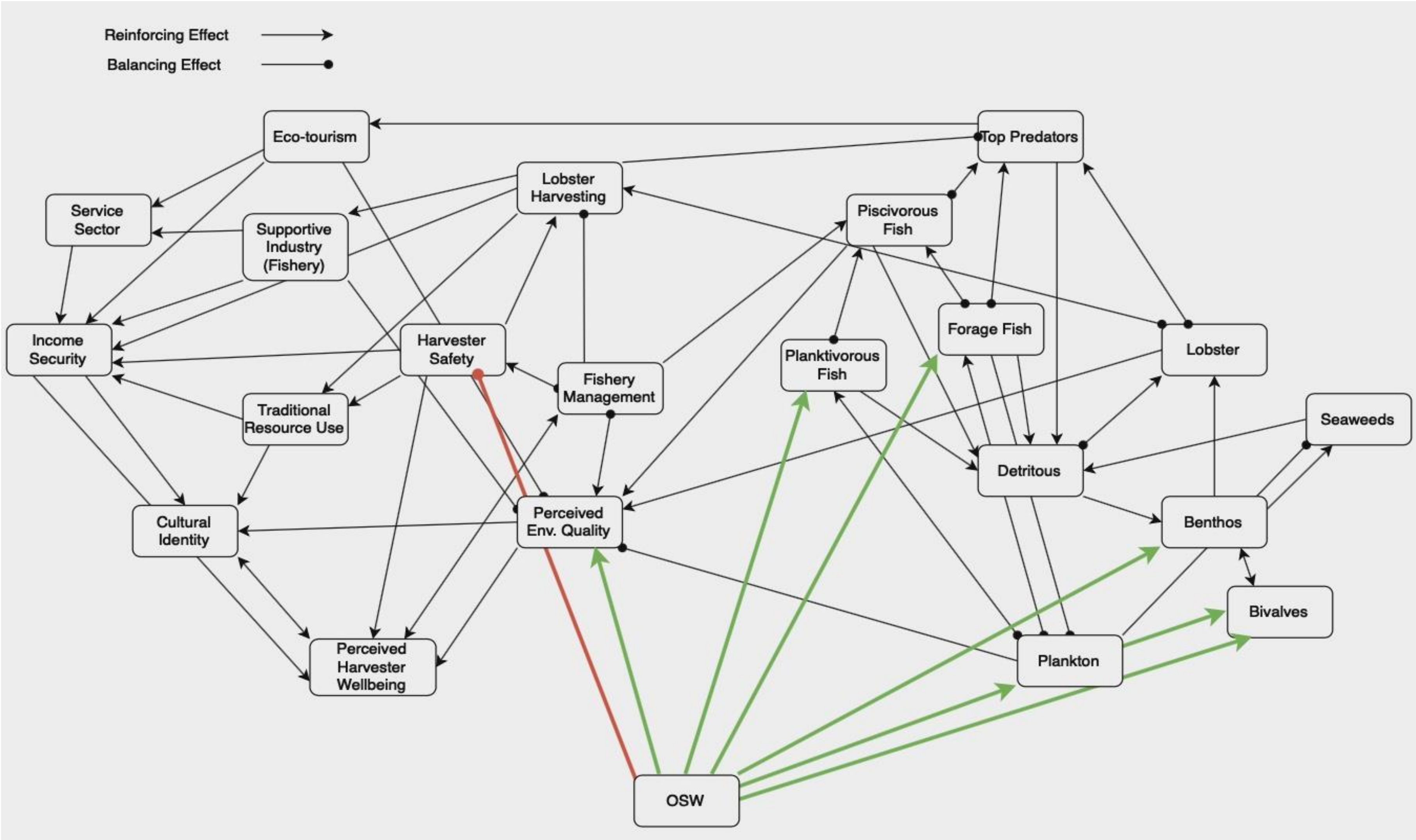

Fig 9. Signed diagraph of the representative SES as impacted my site operation and decommissioning activity. New reinforcing direct interactions within the system are denoted by a green interaction terminating in an arrow, and new balancing interactions are depicted by a red interaction terminating in a dot

4.5 Discussion

4.5.1 Efficacy of the Representative SES

The representative SES captured the potential positive and negative effects of OSW development on the various socio-ecological components of the lobster fishery. Importantly, considering the 'on the water' conceptual boundaries of the RA, this method proved effective in representing various social factors that may otherwise not be addressed as discussed in Chapter 1.5. These include indicators of culture, environmental perception, income security, tradition, and wellbeing, which are relevant to understanding the social implications of development (Golder Associates Ltd, 2019). Furthermore, this system was useful to determine the cumulative effect of direct impacts (Fig 10).

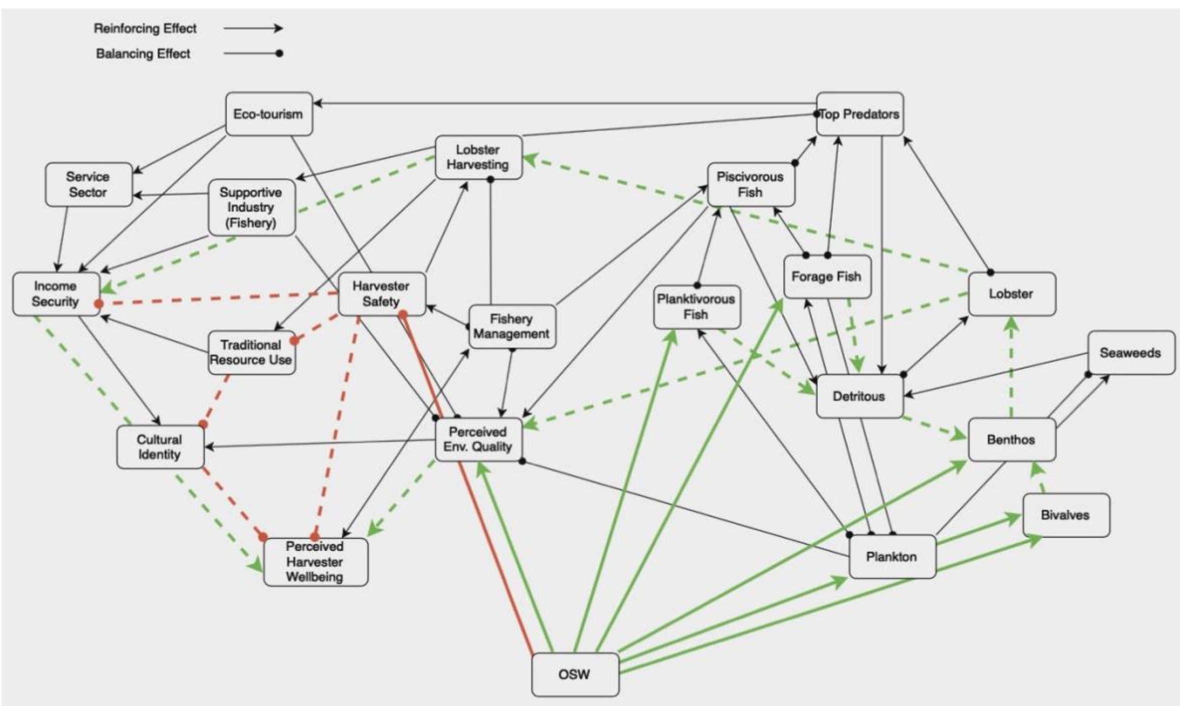

Fig 10. Cumulative socio-ecological effects of site operation and decommissioning are illustrated by dashed lines. Dashed green lines terminating with an arrow are positive cumulative effects, and dashed red lines terminating with a dot indicate negative cumulative effects. Note that cumulative effects can be recognized across social and ecological system

components. This figure does not illustrate all cumulative effects, but rather demonstrates how the system illuminates the underlying causal relation of cumulative impacts.

Again, cumulative effects are the aggregate effect of many different impacts or activities. While they can be visualized in any diagraph (Figs 7-9), a few are illustrated here (Fig 10) by dashed lines for the site operation and decommissioning phase. Not only was the system able to demonstrate cumulative social implications of development, which seems to trouble current RA practice, the SES allowed cumulative effects to be visualized across social, cultural, economic, and ecological factors. With respect to impact assessment, where social and ecological factors have often been studied in isolation, this technique provides a greater understanding of the potential coupled socio-ecological implications of development. In large, this is due to the system's ability to recognize the underlying causal relation of direct and cumulative impacts, through the cause-and-effect relation of system components.

The representative SES also able captured the changing impact of OSW activities through time. Through multiple iterations of the system for various phases of wind farm development and operation, the system not only captured the impact of human activity (such as site surveying and construction in Fig 8), but also the reciprocal impact of natural processes within the altered environment (Fig 9). This temporal variation of impact, while some anthropogenic and some a product of natural ecosystem rehabilitation, are all of interest as they are a direct product of human activity. As such, the SES was effective in recognizing the social and natural implications of OSW development through time, while also capturing the reciprocal effects that these impacts have on various social and ecological aspects of the SES.

While effective in recognizing the causal pathways of direct and cumulative impacts of development through time, the SES was not able to capture the magnitude of such impacts. While the degree of positive or negative implications of development is of great interest to impact assessment, this is not the goal of this approach. Instead, since the RA is still in the early stages of planning, it is relevant to assist in the scoping of potential issues. Again, scoping refers to the identification of factors which are likely to be of most importance while eliminating those of little concern. The direct implication that OSW has on harvester safety, for example, causes a variety of negative cumulative effects to other social aspects of the lobster fishery. With this understanding, further study can be allocated to identify the exact nature of harvester safety, as well as potential mitigation strategies to make these practices safer both on the water and on the wharf. As such, while limited to showing the causal relation of impact and not the magnitude of impact, the representative SES appears to be an effective tool in the scoping of potentially pertinent issues.

4.5.3 Application of Results

Perhaps most pertinent application of this methodology is towards both recognizing impacted communities to provide social benefit, as well as proactively managing the apparent negative social-ecological consequences of development as identified. To address the direct and cumulative socio-ecological effects, and to best mitigate those effects that cannot be proactively managed, there are a variety of ways in which these findings can help inform future OSW licensing procedures. Here, the negative socio-ecological implications can be incorporated into impact management strategies through community benefit agreements (CBAs), within the leasing process itself through specific non-price bid criteria, or through requirements within the 'rules' of OSW development as set by the offshore energy board. Furthermore, this methodology allows for the positive socio-ecological implications can be recognized, thus planned for and maxamized proactively.

A community benefit is an additional, positive provision for the area and people affected by a major development (Rudolph et al., 2018). Community benefits are negotiated agreements and have been utilized in renewable energy development as a means to mitigate conflicts over the impacts of these projects (Breukers et al., 2007; Zografos et al., 2009). In the offshore wind industry, community benefit requirements can vary based on the country. In countries like the United Kingdom or the United States, CBAs are not legally required (Aitken, 2010). However, in areas where the onshore and offshore wind industries are well established, it has become common practice. For example, in the U.K. the majority of wind farm developers offer benefits on a routine basis (Bristow et al., 2012). While often monetary agreements, CBAs can be more than compensation. Rather, money can be allocated towards specific issues at hand through a community fund. Such examples could include ecosystem restoration and habitat management to help mitigate negative perceptions of the environment, or the allocation of funds to improve harbours and wharfs to make them safer for harvesters and industry personnel. Furthermore, if a certain community is expected to be negatively impacted by such development with no means of mitigation, CBA can be used to allocate funding to improve various social infrastructure. This could include education, healthcare, public transit, and affordable housing to positively impact a negatively affected community.

Non-price bid criteria are the criteria that development companies have to meet upon applying to lease offshore area for development. These can focus on reducing the ecological impact of the windfarm, or by providing relevant resources to support potentially effected communities. Globally, the use of non-price bid criteria is relatively new. An example can be seen in Norway, however, which launched their first offshore wind auctions in 2023 with three socially applicable bid criteria. The first criteria concerns developing skills in the local supply chain, the second is based on using small and medium-sized companies to develop their experience in the offshore wind industry, and the third concerns the developer’s plan to enhance and support the local supply chain’s green transition (Aurand, 2023). While Norwegian criteria has been posed to further strengthen their OSW supply chain and larger industry, such non-price bid criteria can incorporate issue specific concerns. With respect to the study system, bid criteria could be put in place to help mitigate the impact of OSW development on the lobster industry through strategically reducing the environmental impact of harvesting and supply chain operations. This could include investments into electrifying the lobster fleet and transportation within the larger supportive industry to reduce noxious emissions to further Canadian energy targets. It could also include investments into the further development and outfitting of rope-less fishing gear to reduce entanglement risk and the environmental impact of the fishery. Through explicit visualization of the cause and effect relation between social and ecological components, the potential to reduce ‘negative’ effects within the system not only helps identify opportunities to better the entire socio-ecological condition of the system, but to proactively plan for them through direct measures.

Lastly, various regulatory measures can be put into place to reduce the identified negative implications while maximizing the identified effects of development. With respect to harvester safety, regulations for OSW developers can be put in place by the offshore energy board to increase safety on the water. These 'rules of development' could include the restoration of seabed to remove debris post-construction to pre construction state to reduce the risk of gear entanglement. They could also include mandatory turbine spacing to limit risks of collision and ice hazards for harvesters fishing in the area, or maximum turbine spacing to condense windfarms to reduce spatial conflict and preserve fishing grounds. The duality of turbine spacing perhaps highlights the benefit of this approach as it provides no answers, but instead is a tool to elucidate potential issues for further study, consultation, and consideration.

4.6 Conclusion

Through tracing the history of impact assessment, a continuous evolution towards a holistic means of assessment has become clear. However, as recent RA practice shows, there is a need for this evolution to continue to fully capture issues of social, cultural, economic and ecological sustainability. In the same manner that social conditions helped spur Canada to create their own EIA legislation, or how political will integrated environmental protection into broader planning initiatives in the 70's, the current conceptual application of SES principles to address issues of sustainability indicates an impetus for change. In this light, I applied one of the various tools of the SES toolbox to assess its suitability in helping scope the potential impacts of OSW development on the socially and economically relevant lobster industry of Nova Scotia.

The representative SES proved capable to not only able to capture the direct potential positive and negative effects of OSW development, but also the cumulative effect of these impacts on various social, cultural, economic, and ecological components of the lobster fishery. Furthermore, the underlying causal relation of direct and cumulative impact was recognized through the relation of system components, regardless of their social or ecological nature. This approach also enabled the recognition of key areas of direct and cumulative impact within the SES, and facilitated for the identification of mitigation measures which could be applied through various social compensation measures. Lastly, it facilitated this understanding, and how it changes with time while respecting the spatial boundaries of the RA study area.

Chapter 5: References and Appendix

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5.2 Appendix 1

First and second tier variables as included in Ostrom's SES framework:

Social, Economic, and Political Settings (S)

S1- Economic development. S2- Demographic trends. S3- Political stability.
S4- Other governance systems. S5- Markets. S6- Media organizations. S7- Technology.

Resource Systems (RS)

RS1- Sector (e.g., water, forests, pasture, fish)
RS2- Clarity of system boundaries
RS3- Size of resource system
RS4- Human-constructed facilities
RS5- Productivity of system
RS6- Equilibrium properties
RS7- Predictability of system dynamics
RS8- Storage characteristics
RS9- Location

Resource Units (RU)

RU1- Resource unit mobility
RU2- Growth or replacement rate
RU3- Interaction among resource units
RU4- Economic value
RU5- Number of units
RU6- Distinctive characteristics
RU7- Spatial and temporal distribution

Governance Systems (GS)

GS1- Government organizations
GS2- Nongovernment organizations
GS3- Network structure
GS4- Property-rights systems
GS5- Operational rules
GS6- Collective-choice rules
GS7- Constitutional rules
GS8- Monitoring and sanctioning rules

Actors (A)

A1- Number of relevant actors
A2- Socioeconomic attributes
A3- History or past experiences
A4- Location
A5- Leadership/entrepreneurship
A6- Norms (trust-reciprocity)/social capital
A7- Knowledge of SES/mental models
A8- Importance of resource (dependence)
A9- Technologies available

Action Situations: Interactions (I) → Outcomes (O)

Activities and Processes:
I1- Harvesting levels
I2- Information sharing
I3- Deliberation processes
I4- Conflicts
I5- Investment activities
I6- Lobbying activities
I7- Self-organizing activities
I8- Networking activities
I9- Monitoring activities
I10-Evaluative activities

Outcome Criteria:
O1- Social performance measures
(e.g., efficiency, equity, accountability, sustainability)
O2- Ecological performance measures
(e.g., overharvested, resilience, biodiversity, sustainability)
O3- Externalities to other SESs

Related Ecosystems (ECO)
ECO1- Climate patterns. ECO2- Pollution patterns. ECO3- Flows into and out of focal SES.