Navigating the Social Seas:

Using fuzzy cognitive mapping to understand community impacts at the intersection of offshore wind energy, fisheries, and climate change in the Gulf of Maine

by

Eliza Batchelder

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We acknowledge and respect the Lək̓ʷəŋən (Songhees and Xʷsepsəm/Esquimalt) Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ Peoples whose historical relationships with the land continue to this day.

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Abstract

Globally, as oceans warm and the rate of fishing continues to increase, the health of marine ecosystems has declined. From a community perspective, warming ocean temperatures have led to fish stocks shifting into regions that are harder to access or no longer viable for fishing, increased storm occurrence has destroyed important port infrastructure, and the adaptive capacity of fishing communities is sometimes limited. Around the globe, governments and energy developers have identified offshore wind energy generation as a viable and critical technology to aid in the transition away from fossil fuels to mitigate future climate change impacts. However, the nature of large-scale energy development projects means that the magnitude and directionality of benefits and impacts are not always well-understood at the community scale, and efforts to identify paths for coexistence among fisheries and offshore wind have been met with resistance from the fishing industry. This study aims to assess what stressors and opportunities are the most impactful to a fair future for commercial fisheries in the Gulf of Maine, where these various challenges converge. I use mental models and fuzzy cognitive mapping (FCM) to assess how commercial fishers and fisheries decision makers perceive the impacts from offshore wind development, climate change, and other regional stressors, and where there are areas of common prioritization. I followed the multi-step approach to cognitive mapping developed by Özesmi and Özesmi (2004) to collect and analyze mental model data. Both groups had complex understandings of what would contribute to or threaten a fair future for commercial fisheries in the Gulf of Maine. In addition to the development of new energy infrastructure in proximity to fishing grounds, respondents from both stakeholder groups indicated that fishing communities in the Gulf of Maine face a variety of changes, such as warming waters and shifting species distributions, rising costs of living, and changing gear regulations due to North Atlantic Right Whale conservation measures. These concepts frequently interact with one another in ways that reinforce or change the impact of one concept on the overall system. My results showed many similarities among stakeholder groups. Both commercial fishers and fisheries decision makers viewed access to healthy fish stocks as important for a fair future for fisheries and shared common values about the importance of preserving working waterfronts and job opportunities. Despite these commonalities, the two groups had different perceptions of what would be the primary drivers of negative or positive change. Fisheries decision makers viewed climate change, offshore wind, and stock health as equally impacting future access to fish stocks, whereas commercial fishers viewed offshore wind as the primary threat to accessing fish stocks. Although each group had unique views on the importance of climate change within the overall system, there was a common understanding that renewable energy would help address climate change and the impacts that it had on surrounding ecosystems and communities. However, fisheries decision makers were more likely than commercial fishers to view offshore wind as contributing positively to climate change, suggesting that decision makers' and fishers' underlying definitions of sustainability were not always aligned in scale. Fisheries decision makers took a higher-level approach to achieving "sustainability" through large-scale energy development and achieving federal, if not global, climate targets, whereas fishers took an individual and community-level approach to defining what sustainability means. Additionally, fishers' opposition to compensation packages as a means of addressing impacts from offshore wind development reinforces concerns about the distributional benefits of offshore wind projects. When considered together, my findings suggest that the regional vitality of coastal communities is being impacted by more than just offshore wind projects, and thus, proposals for financial support and equitable energy transitions should attempt to address underlying and system-wide challenges such as preserving working waterfronts, habitat restoration, affordable housing, or clean energy subsidies.

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Acknowledgements

On a hot August day, as we walked through a crowded parking lot of the Boothbay Lobster Wharf, a mentor said nonchalantly, “One day you’ll forget all of this, but you’ll have a master’s degree.” While the sentiment was a good one, I quickly realized that the moments of this research are ones I hope I never forget.

With all of the frustrating, exhausting, and doubtful moments this research has brought, there were also the quiet drives down spines of coastline I had never seen before, exploring calm coves and busy boatyards that are the finest exhibit of the working waterfront that is often touted as the backbone of the state of Maine. This research has brought me into living rooms of all sizes and decoration, talking with people whose hands show the generations of ocean knowledge that have been passed down, whose faces paint the picture of men and women raised by the sea, whose love for the ocean extends far beyond the paycheck they receive from it. With every interview, from the cab of pickup trucks to the wheelhouses of trawlers to the late afternoon beer at a crowded waterfront clam shack, another layer was added and then slowly peeled back. With the ticking of every hour spent driving back and forth on Route 1, I was challenged to keep trying to make sense of this world – of the challenges we face, the solutions we think are needed, and the unintentional consequences that are often a product of fear, concern, and deep care for what the future holds.

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Chapter 1: Introduction

Sea breeze and fish are synonymous with the coastal waters of the Northwest Atlantic. Since time immemorial, people of the Wabanaki Confederacy, Massachusett Confederacy, and Wampanoag Nation have harvested cod, lobster, and shellfish from what is now known as the Gulf of Maine to subsist during the summer months. When the first European colonists arrived on the coasts of so-called New England, they reported an abundance of fish back to their European nations. European settlements along the coast of New England were built around the booms and busts of whaling, cod, lobster, and the dozens of other marine species that can be found along the shores of the Gulf of Maine. The Atlantic Cod fishery quickly became a critical economic driver in the region, with nearly 50 boats fishing for cod out of Gloucester by 1624 (Jensen, 1967).

Today, the marine biodiversity of the Gulf of Maine continues to support commercial fisheries up and down the coast of New England. From lobster to groundfish to a growing shellfish aquaculture industry, commercial fisheries in the Gulf of Maine provide billions of dollars in revenue to Maine, New Hampshire and Massachusetts. Tens of thousands of jobs are directly and indirectly linked to fishing and marine resources throughout the region, from active fishers to processors and trap builders. The region is full of quintessential symbolism that attracts millions of visitors every year—clam shacks line coastal streets, colourful lobster buoys are dotted across every Maine harbour, and a wood-carved Atlantic codfish hangs in the House Chambers in the Massachusetts Legislature. However, many fishers express concerns about a barrage of changes that have been occurring in the last several years. The commercial fishing industry is facing changes in stock abundance and population health due to warming waters and the introduction of novel species (Cheng et al., 2025; Le Bris et al., 2018; McClenachan et al., 2020). The industry is experiencing increased regulations related to the protection of North Atlantic Right Whales (Briggs, 2022), rising housing costs and general inflation (Colburn & Jepson, 2012).

1. Fisheries in New England

In the United States, fisheries are managed at the federal, regional, and state levels. State waters extend to three nautical miles, and within this limit, states have regulatory authority over coastal activity and fisheries management. The U.S. Exclusive Economic Zone (EEZ) begins past the three nautical mile mark and extends out 200 nautical miles, as established by the Magnuson-Stevens Act (1976) and a Presidential Proclamation 5030 in 1983 under President Reagan. In the Gulf of Maine, the Maine Department of Marine Resources (DMR), New Hampshire Fish and Game, and Massachusetts Division of Marine Fisheries (DMF) manage each respective state's fisheries in state waters. The Atlantic States Marine Fisheries Commission (ASMFC) is responsible for managing a total of 27 interstate coastal fisheries, such as lobster, striped bass, and menhaden. The Commission and regional fisheries management councils jointly manage species that are found in both coastal and federal waters, such as Atlantic herring, black sea bass, and spiny dogfish.

In federal waters, the National Oceanic and Atmospheric Administration (NOAA) is divided into regional offices which regulate federal fisheries. The Greater Atlantic Regional Fisheries Office and Northeast Fisheries Science Center are arms of NOAA Fisheries, which monitor and regulate fisheries in the federal waters of the Gulf of Maine. Commercial fisheries in the United States are primarily legislated by the Magnuson-Stevens Act (MSA), which was first passed by Congress in 1976. The law created eight regional fisheries management councils and outlined 10 national standards that NOAA fisheries are mandated by. These standards are outlined in Table 1.

Table 1. The ten national standards as established by the Magnuson-Stevens Act (1976).

1. Optimum yield	"Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."
2. Scientific information	"Conservation and management measures shall be based upon the best scientific information available."

3. Management units	"To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination."
4. Allocations	"Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (a) fair and equitable to all such fishermen; (b) reasonably calculated to promote conservation; and (c) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privilege."
5. Efficiency	"Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose."
6. Variations and contingencies	"Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches."
7. Costs and benefits	"Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication."
8. Communities	"Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities by utilizing economic and social data that meet the requirement of paragraph (2) [i.e., National Standard 2], in order to (a) provide for the sustained participation of such communities, and (b) to the extent practicable, minimize adverse economic impacts on such communities."
9. Bycatch	"Conservation and management measures shall, to the extent practicable, (a) minimize bycatch and (b) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch."
10. Safety of life at sea	"Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea."

The New England Fishery Management Council (NEFMC) is the regional council tasked with managing federal commercial fisheries in the Gulf of Maine, as well as Georges Bank, and

Southern New England. NEFMC is composed of 18 voting members responsible for crafting Fisheries Management Plans (FMPs), which outline Annual Catch Limits (ACLs), how fish stocks will be managed, and how quotas will be allocated. Currently, NEFMC oversees nine active FMPs that regulate 29 different species.

2. Offshore wind in New England

The Outer Continental Shelf Lands Act (OCS Lands Act) was passed by Congress on August 7, 1953. The law designated the Department of the Interior (DOI) to manage mining and drilling rights in U.S. federal waters. The Bureau of Ocean Energy Management (BOEM) is an agency within the Department of the Interior that was established on May 10, 2010, by Secretarial Order 3299. The Outer Continental Shelf Renewable Energy Program was started in 2009 within BOEM. The mandate came from the Energy Policy Act of 2005, which gave BOEM authority over the leasing and regulation of renewable energy activity on the Outer Continental Shelf of the United States. Under BOEM, the leasing and permitting of offshore wind undergoes a multi-step process before a project can become operational. The four phases include planning and analysis, leasing, site assessments, and construction and operation. One of three lease types can be granted: either a commercial lease, a limited lease, or a research lease. These leases are often granted through a competitive lease auction. Once a developer has acquired a lease, they are responsible for developing a Site Assessment Plan (SAP), Construction and Operations Plan (COP) and General Activities Plan (GAP). Each of these plans must receive BOEM approval before construction can begin (Bureau of Ocean Energy Management, 2016). There are several mechanisms through which BOEM solicits public input and intergovernmental collaboration. BOEM has established 14 Intergovernmental Task Forces to bring together state and federal agencies, federally recognized tribes, and city or municipal governments. The agency also receives public comments at various steps of the leasing and permitting process.

In the United States, there has been a burgeoning interest in developing offshore wind along the eastern seaboard, the Gulf of Mexico, and off the Oregon coast. As of May 2024, there were 174 megawatts (MW) of operational offshore wind capacity in the U.S., and an additional 4 gigawatts (GW) of offshore wind capacity is under construction (McCoy et al., n.d.)—enough energy to power about 2 million homes. In 2021, the Biden Administration set a goal of installing 30 GW of offshore wind capacity by 2030, which built momentum in the commercial interest of both fixed-bottom and floating commercial-scale offshore wind. While the investment climate for new renewable projects in the United States is presently volatile under the second Trump Administration, and the status of incentives for wind development under the Inflation Reduction Act is unclear, one thing is very certain: there is growing demand for electrical power. This means that renewable electricity will also continue to be in demand as healthier for humans, communities, and the climate.

Offshore wind was first introduced in the United States in 2001 with the Cape Wind Project. Before the early 2000s, offshore wind only existed in Northern Europe, after the first project was installed in Denmark in 1991. Cape Wind was a proposed 468 MW project in Nantucket Sound northeast of Martha's Vineyard, Massachusetts. Although the project ultimately failed, and the developer relinquished the lease in 2018, the proposal had a lasting impact on regulatory frameworks and public perceptions of offshore wind energy in the region. About a decade after Cape Wind was initiated, Deepwater Wind began the permitting process for a 5-turbine array off Block Island, Rhode Island. Block Island Wind finished construction in 2016 and began generating about 30 megawatts of energy to power the island, making it the United States' first operational offshore wind farm.

The east coast of the United States is a particularly desirable area for offshore wind development given the region's consistent wind speeds and proximity to major urban centers (Musial, MacDonald, et al., 2023). Currently, in the Northeast region of the U.S., there are 15 separate development projects in the pipeline that are expected to generate over 14 GW of energy capacity (Musial, Spitsen, et al., 2023) (Table 2). Each of the projects is in a various phase of permitting and construction, but recent action from the Trump Administration has challenged further progress from being made. On January 20, 2025, President Trump issued a moratorium on the permitting of all offshore wind projects (The White House, 2025). The Trump Administration's first year has sown uncertainty in regards to the financing, siting, and permitting of future offshore wind projects in U.S. waters.

Table 2. List of the proposed offshore wind projects in the northeast of the United States.

Project name	Developer	Cable landing location	Project size	Status
Southfork Wind	Orsted	East Hampton, NY	130 MW	Operational
Revolution Wind	Orsted	North Kingstown, RI	704 MW	Under construction
Sunrise Wind	Orsted	Long Island, NY	924 MW	Under construction
Vineyard Wind 1	Avangrid and Vineyard Offshore	Barnstable, MA	800 MW	Under construction
Empire Wind 1	Equinor	Brooklyn, NY	810 MW	Under construction
New England Wind	Avangrid	Barnstable, MA	2,600 MW	Fully or mostly permitted
SouthCoast Wind	Ocean Winds	Somerset, MA; possibly Falmouth, MA	2,400 MW	Fully or mostly permitted
Starboard Wind	Orsted	TBD	1,200 MW	Without permits
Beacon Wind	BP	Queens, NY	2,400 MW	Without permits
Vineyard Wind 2	Vineyard Offshore	Likely New London, CT	1,200 MW	Without permits
Excelsior Wind	Vineyard Offshore	Long Island, NY	TBD	Without permits
TBD	Invenergy NE Offshore Wind	Gulf of Maine	TBD	Without permits
TBD	Invenergy NE Offshore Wind	Gulf of Maine	TBD	Without permits
TBD	Avangrid Renewables	Gulf of Maine	TBD	Without permits
TBD	Avangrid Renewables	Gulf of Maine	TBD	Without permits

In response to growing commercial interest in developing offshore wind in the Gulf of Maine, the State of Maine started the process of obtaining a research lease in 2020. Led by the Governor's Energy Office, with public and private partnerships, the State has been working to develop a research array to explore the viability of floating technology and its potential impacts in the region. In October 2021, the State applied for a 15.2 square mile federal lease located about 30 miles offshore from southern Maine. The Bureau of Ocean Energy Management (BOEM) approved the State's application for a research lease in August 2024.

The interest in commercial-scale offshore wind in the Gulf of Maine has continued to build since the Biden Administration's Executive Order declared a national target to deploy 30 GW of offshore wind by 2030. After years of task force meetings, siting decisions, and draft wind areas, BOEM completed a lease auction for four lease areas in the Gulf of Maine in October 2024. Avangrid Renewables and Invenergy New England both won two leases and have moved into the permitting stages of development.

3. Research questions and thesis structure

Management structures and stakeholder engagement processes currently in place that regulate offshore wind development and regional fisheries largely operate separately, where state and federal agencies act independently of one another to craft and implement regulatory measures. As highlighted, in the Gulf of Maine region, the federal regulatory process tasked with leasing and siting offshore wind arrays (BOEM, 2022) is separate from the state and federal processes that allocate lobstering permits, groundfish quota, and seasonal restrictions (Henry & Johnson, 2015). Given their spatial proximity to offshore wind lease areas, commercial fishing stakeholders are uniquely positioned to be impacted by the actions of both offshore wind and fisheries decision making processes. Furthermore, the Gulf of Maine is facing other changes, such as warming waters and shifting stock distributions, which affect coastal communities, including the commercial fishing industry. However, the cumulative impacts of these developments, decisions, and changes are not considered in conjunction with one another in social acceptance literature and are not fully accounted for in management decisions. This thesis aims to address this gap and identify the cumulative social impacts of offshore wind development, regional fisheries management decisions, environmental changes, and community changes. In the context of the various changes and challenges that coastal communities face, I aim to document the fishing industry's and fisheries decision makers' perceptions of what a "fair" future for commercial fishing looks like in the Gulf of Maine. I go about doing this by answering the following research questions:

1) How is a fair future for commercial fishing in Maine impacted by diverse factors, including offshore wind, fisheries management, environmental health, and community well-being?
2) How do these factors interact with one another?
3) How do fisheries decision makers and commercial fishers perceive the impacts of various stressors differently or similarly?

This thesis is organized into four chapters. This first chapter has contextualized the management of fisheries and offshore wind in the United States and the New England region more specifically. Chapter 2 summarizes key literature related to public acceptance of offshore wind, offshore wind and fisheries interactions, and Gulf of Maine fisheries.

Chapter 3 is structured as a standalone manuscript that sets out to answer the stated research questions. This chapter assesses how commercial fishers and fisheries decision makers perceive challenges and opportunities related to offshore wind, fisheries management, environmental health and community wellbeing. I use a mixed-methods research design, collecting mental models through semi-structured interviews and conducting a quantitative analysis of these mental models and a qualitative analysis of the interview transcripts.

In Chapter 4, I conclude the takeaways of this work, illustrate the applicability of this research and highlight future research opportunities that can stem from this project.

Chapter 2: Literature review

1. Offshore wind

Policymakers and scientists have been looking to offshore wind to generate high quantities of renewable energy near major urban centers. A careful balance of technological capability, a favourable regulatory landscape, and community acceptance is required for this development to occur. Technological advancements have resulted in more powerful turbine development and increasingly viable floating offshore wind technology. The regulatory framework has been developed under BOEM to enable the siting and permitting of offshore wind, although the Trump Administration has stated its intent to pause all permitting and new construction of offshore wind. Furthermore, economic uncertainty has posed significant challenges to supply chain requirements. In addition to these current challenges, in many of the proposed projects in the Northeast, public acceptance has been a barrier to the successful siting of new offshore wind projects. An abundance of research has examined the nature of public perceptions of offshore wind energy in regions around the world, and a growing body of work explores the social, ecological, and economic impacts offshore wind has on communities adjacent to the development sites.

The growth of an offshore wind industry introduces the opportunity for communities in proximity to offshore wind farms to benefit economically. However, as is the case with renewable energy developments anywhere, new energy developments pose certain economic and social risks that need to be accounted for and mitigated. As such, the processes and design of the developments are critical in ensuring that neighbouring communities are beneficiaries of the projects and do not incur disproportionate costs.

In regions where offshore wind has already been developed, there have been conflicts with other marine users, visual disruptions, and changes to cultural and socialized understandings of ‘place’ (Gill et al., 2020; Glasson et al., 2022; Haggett et al., 2020). Furthermore, in some cases, the processes used in the siting and development of offshore wind projects were perceived as unjust and inadequate, especially among low-income and BIPOC (Black, Indigenous, people of colour) communities (Smythe et al., 2025).

1.1 Social acceptance

Despite the interests of policymakers and energy developers, many proposed offshore wind projects in the Northeast have faced major delays or have not been developed. Construction timelines have been delayed due to production bottlenecks, regulatory challenges, and financing issues. Additionally, a lack of social acceptance and strong community opposition in certain regions have been limiting factors for the scaling and development of offshore wind in the region. This is consistent with the 'social gap,' which is a concept that describes the gap between high general support for renewable energy projects and low construction rates of projects that have gone through the offshore lease application process (Bell et al., 2005, 2013; Walter, 2014). Scholars have historically attributed the social gap in renewable energy project development to NIMBYism (Not In My Backyard). This concept has been liberally applied to categorize project opponents in attempts to generally describe individuals who voice opposition to projects that are proposed to be sited near their homes (Devine-Wright, 2009; Petrova, 2013). The use of NIMBYism to describe opposition is often associated with an assumption of ignorance and self-interest (Devine-Wright, 2009) and tends to simplify the concerns that individuals and communities have about development projects (Petrova, 2013).

Social science literature on energy developments has increasingly shifted away from describing opposition to renewable energy projects as NIMBYism and towards examining community opposition to renewable energy projects within more nuanced frameworks of environmental psychology (Petrova, 2013), energy justice (Jenkins et al., 2016; McCauley et al., 2013; Sovacool & Dworkin, 2015), and stakeholder engagement processes (Haggett et al., 2020; Stokes et al., 2023; Wüstenhagen et al., 2007). Literature on the social acceptance of renewable energy development has progressed to better account for the complexities that inform the perceptions of stakeholders. Research has shifted to consider how renewable energy projects can be more equitably and effectively sited and developed, rather than viewing community opposition as an inhibiting force needing to be controlled (Bidwell, 2015; Bidwell & Sovacool, 2023; Dwyer & Bidwell, 2019; Haggett et al., 2020; Petrova, 2013). This advancement in social acceptance literature includes frameworks of place identity (Devine-Wright, 2009), place attachment (Devine-Wright & Howes, 2010), place disruption (Devine-Wright, 2009; Jacquet et al., 2015), and place-technology fit (Devine-Wright & Howes, 2010; Devine-Wright & Peacock, 2024; Devine-Wright & Wiersma, 2020).

Notably, attributes leading to support for or opposition to offshore wind energy vary by local and regional context. For example, several studies have documented the importance of place-based landscape (or seascape) attributes in explaining attitudes toward wind energy (Bates & Firestone, 2015; Devine-Wright, 2005; Wolsink, 2007, 2010). Studies have demonstrated that the conceptualization of place, and further, of place-technology fit, is critical in assessing attitudes towards offshore wind energy (Devine-Wright & Howes, 2010; Devine-Wright & Peacock, 2024; Devine-Wright & Wiersma, 2020). For example, communities that find offshore wind developments consistent with their conceptualization of place meaning are more likely to support the development of these projects (Devine-Wright & Wiersma, 2020; Russell et al., 2020).

1.2 Social acceptance of offshore wind in the Gulf of Maine

In the Gulf of Maine region, the commercial lobster industry has been outspoken about their opposition to offshore wind projects that are being proposed, due to concerns about the loss of fishing grounds and navigation around turbines. The industry has presented a relatively uniform opposition to offshore wind in the region. Research on social acceptance in the region has been limited and often only focuses on single factors to explain the perspectives that stakeholders hold, such as siting concerns (Green et al., 2023), perceived fairness (Firestone et al., 2012), and turbine design (Green et al., 2023; Klain et al., 2017). Management efforts to increase the capacity for coexistence have not yet been successful in the region, as these attempts often fail to encapsulate the cumulative effects of the diverse sets of challenges that the industry faces, and lack an agreed-upon definition of what "coexistence" means (Sandzén et al., 2025). Efforts to achieve coexistence between offshore wind infrastructure and fishing activity do not account for how communities are impacted by multiple and overlapping issues, such as changing gear requirements, seasonal closures, changing species migration patterns, and rising costs. There is a need to better understand the cumulative effects that commercial fishers face and how management practices and proposed solutions can more meaningfully and accurately account for these impacts.

1.3 Energy justice

One of the levers through which scholars believe projects can be more equitably and effectively sited and developed is through frameworks of energy justice. Energy justice is an emerging concept in environmental studies that encourages a human-centric outlook on energy transitions and energy infrastructure development. A framework of energy justice views global energy systems in the context of their societal benefits and costs to ensure that positive and negative impacts are evenly distributed and that development decisions are made through representative and impartial processes. Energy justice is primarily defined and assessed through three elements of justice: distributional, procedural, and recognition (McCauley et al., 2013). Distributional justice refers to the allocation of negative and positive impacts, procedural justice refers to the structures of decision-making that engage stakeholders, and recognition justice refers to the representation and consideration of groups in engagement processes (Jenkins et al., 2016; McCauley et al., 2013). This framework enables scholars and policymakers to evaluate where injustices emerge in energy systems, which communities and sections of society are left out of decision-making structures, and what processes exist to amend these injustices (Jenkins et al., 2016).

While job creation, export revenue, local manufacturing, and port upgrades may benefit communities near offshore wind developments, research suggests that the public perception of energy exports from projects is less favourable than localized energy consumption (Bidwell et al., 2022). Distributional fairness, or the perceived fairness of the allocation of benefits and costs, is more likely to be achieved when the energy generated in a region is used within that same region or in proximity to where it is generated (Bidwell et al., 2022). Additionally, past projects and research suggest a difference between direct local and national benefits compared to supply chain benefits (Rudolph et al., 2018). Frequently, offshore renewable energy projects are cited as benefiting communities by creating new jobs and expanding or revitalizing economic opportunities for working waterfronts. These indirect, trickle-down benefits are not easily measured or guaranteed, yet are frequently the only form of community benefits that developers and regulators cite at the outset of project development (Rudolph et al., 2014).

One mechanism that is used to improve distributional benefits from energy development projects are Community Benefits Agreements (CBAs). CBAs are formalized agreements that aim to address community needs and distribute direct benefits from the developer to local communities (Gross et al., 2005). While CBAs can be used in any type of development project, CBAs have increasingly been a part of the dialogue around offshore wind development and other renewable energy infrastructure development as one mechanism to contribute to a more just energy transition. CBAs can act as a negotiation tool for communities to address the adverse impacts of offshore wind energy development and ensure that there are direct benefits felt when these developments take place (Gross et al., 2005).

CBAs can take many different forms, depending on the needs and goals of the community and the nature of the development project. However, at their core, CBAs are legally enforceable contracts negotiated by the developer and community groups that set forth development guidelines or specific benefits, in exchange for community support of the project (Gross et al., 2005). The benefits that CBAs can provide ideally meet the specific priorities of the communities that may be impacted by offshore wind development. Examples of such benefits include community programs, direct payments, living wage guarantees, workforce development and hiring programs, affordable housing, environmental concerns, infrastructure upgrades, etc. (Hoff & Segal, 2023). However, there are notable limitations to CBAs in terms of the efficacy and purview of these agreements on regional needs and distribution of benefits. Importantly, CBAs are typically a voluntary process that the developer pursues. Unless the regulating bodies that oversee the offshore wind leasing process stipulate CBAs in the lease application, these processes require project developers to negotiate agreements with community groups voluntarily. Given this critical limitation, there is a large range in ambition and ability to meet rights-based claims within CBAs, which is dependent on developer initiative.

The evolving research on energy justice and social acceptance of renewable energy projects has highlighted the importance of stakeholder participation and utilizing meaningful and equitable engagement processes (Haggett et al., 2020; Jenkins et al., 2016; McCauley et al., 2013). However, scholars have also raised critiques about the efficacy of engagement and assessment processes to equitably and accurately account for the impacts of such project developments (Arnold et al., 2022). While CBAs aim to address distributive justice of energy development projects, there are additional challenges in achieving recognition and procedural justice. One such critique is that the tools used in many decision-making processes fail to account for the socio-economic impacts on coastal communities and the cumulative effects that are a result of multiple development projects or stressors facing a region (Arnold et al., 2022; Glasson et al., 2022).

1.4 Offshore wind and fisheries interactions

Offshore wind farms present a myriad of ocean use conflicts, resulting in potential burdens on people who use the ocean and coasts. Notably, commercial fishing operations may be impacted, potentially restricting gear types, fishing behaviour, catch and effort (Gill et al., 2020; Van Hoey et al., 2021). Depending on the region, offshore wind development can result in fisheries exclusions due to spatial closures during construction and no-take zones around the wind turbines (Gill et al., 2020; Haggett et al., 2020). Additionally, offshore wind may result in regulations on acceptable gear and fishing practices in proximity to the array (European MSP Platform, 2015). These concerns and considerations about fishing around wind turbines have, in some instances, resulted in “de facto” exclusion of fisheries around offshore wind farms, even where legal frameworks do not exist specifically restricting access to traditional fishing grounds (Szostek et al., 2025; Van Hoey et al., 2021; Webster & Porter, 2020).

The impacts of offshore wind on marine ecosystems and fisheries are very species-specific and fishery-dependent. In March 2023, NOAA Fisheries published a Synthesis of the Science report that identified key considerations and gaps in the state of research on offshore wind interactions on fisheries, marine ecosystems, and fisheries management. This report marks a key step in understanding the impacts that offshore wind development will have on the Gulf of Maine marine environment and stakeholders who depend on it. There are a range of potential impacts that offshore wind can have on benthic habitat, oceanographic processes, demersal finfish, highly migratory species, shellfish, etc., and there are also many gaps in the state of knowledge as to how offshore wind will impact these various marine communities (Hogan et al., 2023).

Notably, offshore wind is expected to raise specific challenges for fisheries data collection and fisheries management. Successful fisheries management is dependent on fisheries-dependent data, fisheries-independent surveys, and the consideration of the best available science. As the Synthesis of the Science states, "Removal or significant modification to scope and geographic scale of these established efforts will critically challenge our ability to assess and manage stocks" (Hogan et al., 2023). These impacts have been evident in regions where offshore wind overlaps with stock assessment survey areas. For example, the Atlantic surfclam stock assessment survey has historically occurred in an area that is now occupied by offshore wind turbines. Model projections of spawning stock biomass (SBB) decreased by 3.5-17.3% when excluding wind energy areas from stock assessment surveys (Borsetti et al., 2023). The displacement of traditional stock assessment surveys increases uncertainty in stock abundance estimates and can impact the allocation of quota and regulation of fishing activity (Borsetti et al., 2023; Hogan et al., 2023).

Given the potential impacts on fisheries, fishing communities are sometimes outspoken about OWFs based on their perception of impacts. In addition to the potential for ecological and management impacts of offshore wind arrays, fishermen frequently cite concerns about how offshore wind farms will impact their access to fishing grounds. Perceptions often include physical conflict that includes concerns over navigational interference, safety concerns, and incompatible gear conflicts (Mackinson, 2006; Methratta et al., 2020; ten Brink & Dalton, 2018). Fishermen also express ecological concerns about offshore wind and its impacts on fish stocks (Mackinson, 2006; Szostek et al., 2025). Stakeholder attitudes are influenced by concerns about meaningful representation, process, and changes to place (Haggett et al., 2020; Smythe et al., 2025). Fishermen have also cited economic concerns about fuel expenditures, loss of revenue, insurance costs, and impacts on fishery support businesses (Chaji & Werner, 2023; Mackinson, 2006).

2. Fisheries in the Gulf of Maine

The fishing industry in New England looks different today than in past centuries, but fishing communities, working waterfronts, and related supply chains still make up a significant economic and social force throughout the region. The lobster fishery alone accounted for 68% of landings by ex-vessel value in 2023 (Maine DMR, 2024), and one estimate suggests that the industry contributes about $1 billion annually and about 4,000 jobs to Maine's economy when considering all related businesses and services (Donihue, Michael & Tselikis, Annie, 2018). Despite the modern economic impact of the industry, commercial fisheries in New England have paralleled global trends of resource depletion, increased fishing effort, and "boom-and-bust" cycles of extraction (Acheson & Gardner, 2014; Johnson et al., 2013; Steneck et al., 2011).

Historical fishing pressures and more recent changes in oceanographic conditions have resulted in marine community structure and composition shifts in the Gulf of Maine. Coastal cod and haddock populations were considered to be depleted by 1949 (Steneck et al., 2011). In the second half of the 20th century, the groundfish industry resorted to targeting offshore cod stocks before diversifying with other species such as monkfish, plaice, silver hake, northern shrimp, and urchin (Steneck et al., 2011). Many of these highly lucrative fisheries have since succumbed to similar trends of overfishing, climate impacts, or a mix of the two (Johnson, 2020). For example, the overfishing of Atlantic cod and other predatory finfish throughout the 20th century relieved several benthic invertebrate species, including the green sea urchin (*Strongylocentrotus droebachiensis*), from predation pressures, and populations exploded in the 1980s and 1990s (Johnson et al., 2013; Steneck et al., 2013). A commercial fishery for the green sea urchin began in 1987 and proliferated in favourable economic conditions. By 2001, green sea urchin biomass had declined by 90% across the coast of Maine, resulting in another "boom-and-bust" fishery in the Gulf of Maine (Steneck et al., 2013).

By the 1990s, as the groundfish industry in Maine languished, the lobster industry was flourishing. Depleted cod stocks and warming waters in the Gulf of Maine led to a boom in lobster landings (Acheson & Gardner, 2014). By the end of the 20th century, lobster became an increasingly important fishery, and the economic diversity of Maine's commercial fisheries was the lowest it had been since 1950 as more of the fleet moved towards fishing lobster (Steneck et al., 2011). These trends have continued into the present day. Whereas there has been a 78%

reduction in lobster abundance in the Southern Gulf of Maine compared to 1997 levels, the Gulf of Maine has experienced a 515% increase in abundance since 1985 (Le Bris et al., 2018). As the social and economic success of the fishing industry in Maine has become increasingly tied to lobster, scholars have documented the limited adaptive capacity of the industry to respond to climate-related impacts (Johnson, 2020; McClenachan et al., 2020; Steneck et al., 2011).

Significant ecological changes have already occurred in the Gulf of Maine as a result of climate change and human pressures, resulting in shifting stock distribution and abundance, altered prey interactions, and decreasing habitat availability. Although there has been an overall increase in species richness in the Gulf of Maine and Georges Bank between 2000 and 2019, this is in part attributed to the northward shift of warmer-water species into the Gulf of Maine (Caracappa et al., 2025). Within the region, there is a general trend of species shifting towards the northeast and into deeper waters. Continued climatic changes and fishing pressure are expected to result in sustained biodiversity decline. While species that previously inhabited the Gulf of Maine region move northward, other species, such as longfin squid, black sea bass, Atlantic mackerel, and silver hake, experienced range extensions and are increasingly found in the Gulf of Maine (Pershing et al., 2021). As new species move into the region and shifts at lower trophic levels persist, marine food web and fisheries interactions are expected to be impacted. Importantly, the outlook for biodiversity abundance and composition will largely depend on the success of current actions to curb climate impacts and conservation measures. Under varying warming scenarios, the Gulf of Maine will experience differing levels of biodiversity loss or change. Projections for lobster abundance suggest a 62% decrease by 2050 compared to 2014 levels in the Gulf of Maine under a high warming scenario, or a 40% decrease under a less drastic warming trend (Le Bris et al., 2018).

Management structures have attempted to address declining stock abundance in the Gulf of Maine, particularly in the case of the groundfish fishery and American lobster fisheries. After reaching their peak in the 1860s, groundfish catches have declined steadily (Acheson & Gardner, 2014). In 2010, the New England Fishery Management Council introduced and passed Amendment 16 to the Northeast Multispecies Fisheries Management Plan (FMP). Amendment 16 shifted the management of the groundfish fishery (which includes Atlantic cod) from input-based limits, such as days-at-sea (DAS), to output limits and sector management. This management change drastically altered the operation and organization of the industry into 15 active sectors that are allocated a defined annual catch entitlement (ACE) of each groundfish stock (Acheson & Gardner, 2014; Clay et al., 2014; Labaree, 2012). While this change in management structure has had immense impacts on the operation of the fishery (Huang et al., 2018; Labaree, 2012; Olson & Pinto da Silva, 2014), it has not led to much success in rebuilding Atlantic cod stocks. As of the 2021 stock assessment, both stocks of Atlantic cod were overfished and were subject to overfishing.

For the state lobster fishery in Maine, a dynamic history has led to a unique co-management structure, where regulations are co-developed between regional councils of lobster fishers and Maine's Department of Marine Resources. This co-management structure is often cited as a key contributor to the successes of the fishery (Acheson, 2003). Throughout the history of the commercial fishery, the management system has resulted in formal and informal societal structures that are evident along the coast of Maine today. For example, the regulation of entry into the fishery has meant that fishers frequently specialize in one fishery (i.e. are harvesting just one species), creating economic and cultural dependency on a single species (Stoll et al., 2016). This has had important repercussions for the evolution of the fishery, as license holders remain active in the fishery for longer rather than retiring, and younger generations have a harder time entering into the industry (Johnson & Mazur, 2018). Furthermore, the evolution of the co-management structure that regulates lobster fishing has influenced the political sway that the industry holds today (Acheson, 1997). The well-organized nature of the industry and its continued economic importance to the state have allowed the lobster fishing community to have an outsized political and social influence in the region that plays out in the debates and challenges that the industry currently faces (Acheson, 1997).

3. Cumulative Social Impacts

Capacity for integrating social impacts into siting, permitting, and management decisions is increasingly a focus of social science environmental research. Environmental assessment frameworks aim to determine direct impacts that result from a single project, and in the case of offshore wind projects, often focus on biophysical impacts (Glasson et al., 2022). Frameworks exist that are used in regulatory processes to account for social impacts; however, these are often peripheral to biophysical assessments (Esteves et al., 2012). While longstanding environmental statutes, such as the National Environmental Policy Act (NEPA), established the requirement of Environmental Assessments (EAs) or Environmental Impact Statements (EIAs), the incorporation of socio-economic impacts is a relatively newer component of some regulatory processes. For example, Social Impact Assessments (SIAs) are used in some jurisdictions as a part of the environmental assessment process, and social and economic indicators have been developed by the Northeast Fisheries Science Center (NEFSC) to determine the impacts of certain fisheries management measures (Clay et al., 2014). However, these mechanisms are frequently utilized to track social impacts that result from a single planned regulatory measure or project, rather than assessing social impacts that are inherently intertwined with the broader social, economic, and political systems within which the projects are being developed (Esteves et al., 2012; Lord, 2011).

There has also been an increasing focus in the field on shifting towards cumulative impact assessments, which view project impacts as interacting within a broader, nonlinear system, rather than trying to attribute direct causal relationships to single projects (Franks et al., 2010; Grace & Pope, 2021). However, even cumulative environmental assessments (CEA) are still limited in scope and only focus on biophysical and ecological effects (Durning & Broderick, 2019; Raoux et al., 2018). As such, most CEA frameworks fail to account for the human and social dimensions of project development (Arnold et al., 2022). Cumulative social impacts are considered the ways in which social impacts interact and aggregate to form the outcomes that individuals or communities experience (Loxton et al., 2013). There is limited research on the practicability of cumulative social impact assessments. A search for the phrase "cumulative social impacts" on Google Scholar provided 277 results, and the same search on JSTOR provided 19 results.

In order to address the gap in assessment frameworks that account for cumulative social impacts, Arnold et al. (2022) conducted a qualitative study in Manitoba and British Columbia in order to compare the capacity for management structures to incorporate the assessment of cumulative social effects within existing environmental assessment processes (Arnold et al., 2022). Through a series of semi-structured interviews with practitioners who are involved in the environmental assessment process, Arnold et al. (2022) established a three-dimensional conceptual framework to help identify cumulative social effects. This framework outlines the following dimensions of social impacts: impacts to social systems that directly result from project activities; social impacts that are caused by biophysical changes; and impacts to social systems caused by changes in human experience (Arnold et al., 2022). This framework enables regulators and developers to better understand the ways in which a range of actions or projects interact and compound to create social changes.

While Arnold et al.'s (2022) proposed framework is beneficial for considering how to systematically incorporate cumulative social impacts into existing environmental assessment processes, there are still challenges with the application of the framework. As with other assessment frameworks, accurate data collection and monitoring are major barriers to effectively applying this framework (Arnold et al., 2022; Esteves et al., 2012; Glasson et al., 2022; Grace & Pope, 2021). In order to assess cumulative social impacts, an accurate baseline of social conditions needs to be established, and obtaining sufficient data can often be challenging (Grace & Pope, 2021). Furthermore, it is difficult to define the scope of impacts that are included within a cumulative social effects assessment, including the time frame and regional scale of the assessment (Arnold et al., 2022).

Despite its shortcomings, cumulative social effects assessment frameworks offer compelling approaches to reimagining and restructuring the environmental assessment processes that are used for project development. Incorporating cumulative effects and looking at both social and ecological impacts as a part of a whole system, rather than in a linear causal relationship, can better inform decision makers of the complex dynamics within which projects or regulations are being proposed.

4. Fuzzy Cognitive Mapping

Mental models and Fuzzy Cognitive Mapping are helpful methodologies in social sciences and mixed-methods research and are tools that can be used to analyze complex socio-ecological systems. Mental models present an epistemological question, asking how knowledge is constructed both at the individual and group levels. Research that uses mental models uses a constructionist epistemology, positing that meaning is created from the interactions between the subject and the object (Moon & Blackman, 2014). Constructionist theory illustrates how individuals create knowledge through these models of understanding that catalogue, interpret and assign meaning to concepts and experiences. As Gray et al. (2013) describe, "The argument for representing knowledge with concept maps emerges from constructivist psychology, which postulates that individuals actively construct knowledge by creating mental systems which serve to catalogue, interpret and assign meaning to environmental stimuli and experiences" (Gray et al., 2013). Mental models are a representation of an individual or group's reasoning and ways of understanding, and they seek to better understand how knowledge is being constructed at both the individual and group level (Gray et al., 2013).

Fuzzy Cognitive Maps (FCM) are a tool to create physical representations of mental models and help describe the weighted and directional causal relationships that respondents ascribe to a variety of concepts (Gray et al., 2013; Özesmi & Özesmi, 2004). FCM can be used to help researchers better understand the perceptions of stakeholders and capture community understanding of complex systems. They are an increasingly popular tool within social sciences and have been utilized in research on environmental challenges, ecological modelling, and community decision making (Drew et al., 2021; Gray et al., 2015; McClenachan et al., 2020, 2022; Murphy et al., 2021). This methodology enables researchers to substantively incorporate and consider non-traditional expertise, such as fishers' ecological knowledge, into management decisions (Bell et al., 2013; Özesmi & Özesmi, 2004). Literature on Fuzzy Cognitive Mapping describes how individuals exist and interact with complex systems that leave infinite options for reaching the knowledge that is constructed. In other words, while there may be consensus on the end result of a process, utilizing these research approaches may better equip researchers or policymakers to identify the root causes of certain opinions or ways of knowing and identify leverage points at which stakeholders may have unique opportunities for impact.

Conclusion

Studying the future of commercial fisheries in the Gulf of Maine is inherently interdisciplinary and requires a familiarity with a number of theories, frameworks, and management contexts. As illustrated, these literatures are often not in dialogue with one another—a reality that is reflected in the regulatory and legal frameworks that guide the offshore wind and fishing industries. In the following chapter, I use Fuzzy Cognitive Mapping to bring together these frameworks to assess how multiple factors interact and influence the ways commercial fishers and fisheries decision makers conceptualize a fair future for commercial fisheries.

Chapter 3: Mapping a fair future for commercial fisheries in the Gulf of Maine

1. Introduction

Globally, climate change is impacting marine ecosystems and fisheries (Doney et al., 2012; Hoegh-Guldberg & Bruno, 2010). Changing ocean conditions can create a variety of societal challenges, posing risks to the communities and industries that rely on marine fisheries. Increasing ocean temperatures have resulted in fish stocks moving into regions that are harder to access or no longer viable for fishing (Poloczanska et al., 2013). Increased storm occurrence and sea level rise pose unique risks to seaports and have destroyed important port infrastructure (Becker et al., 2012). Among these environmental changes, the adaptive capacity of fishing communities is sometimes limited (Henry & Johnson, 2015; Maltby et al., 2023; McClenachan et al., 2020; Steneck et al., 2011). Consequently, climate change has impacted livelihoods, community identity, and resource availability in some coastal regions. At a time when the ocean environment is changing, some research aims to identify opportunities and pathways for sustainable and fair fishing access to continue into the future (Harper et al., 2023; Bennett et al., 2020; Cheung et al., 2019).

The effects of climate change on ecosystems and communities around the world have increased the urgency to reduce global dependencies on fossil fuels and carbon-emitting energy sources, with offshore wind energy generation identified as a viable and critical technology to aid in the energy transition away from fossil fuels toward renewable energy sources (Esteban et al., 2011; Kaldellis & Kapsali, 2013). In the last decade, offshore wind has been at the forefront of policy and development initiatives to reach global decarbonization targets, and interest in this renewable energy is growing worldwide (Backwell et al., 2024; Musial, Spitsen, et al., 2023). Despite benefits, offshore wind can have local impacts on fishing communities, including no-take zones and gear restrictions around the wind turbines (European MSP Platform, 2015; Gill et al., 2020; Haggett et al., 2020). While there are clear benefits and impacts, the nature of large-scale energy development projects means that the magnitude and directionality of benefits and impacts are not always well-understood at the community level. As a result, there is a growing focus on energy justice within offshore wind social science research, and the need for procedural, recognition, and distributive justice in the siting, permitting, and operational stages (Dwyer & Bidwell, 2019; Howley & Korein, 2024; Skjølsvold et al., 2024; Smythe et al., 2025). The concept of 'fairness' is also used in regards to energy justice. Several studies explain the importance of perceived procedural and distributive fairness (Bates et al. 2025; Elmallah & Rand, 2022), and link perceived fairness to public acceptance of offshore energy projects (Firestone et al., 2012; 2020).

Existing research has identified a range of stressors on coastal communities, including climate change (Flaherty et al., 2025; Le Bris et al., 2018), offshore energy development (Chaji & Werner, 2023; Perry & Heyman, 2020), shifting stock distribution (Cheng et al., 2025; McMahan et al., 2020), rising costs (Henry & Johnson, 2015), and coastal development (Colburn & Jepson, 2012; Portman et al., 2011). Yet, by considering these issues separately, this research fails to account for how multiple stressors can interact and ultimately compound the ways that new energy developments impact a region. There is an emerging field of research that considers social or economic impacts of management decisions or renewable energy development, but these assessment processes are relatively young and not yet streamlined into management processes. Furthermore, cumulative social impacts—or the ways in which social impacts interact and aggregate to form the outcomes that individuals or communities experience—are not commonly considered, and a clear assessment process or framework has not been identified (Arnold et al., 2023; Loxton et al., 2013).

These various challenges that might impact coastal communities have converged in the Gulf of Maine region, where sea-surface temperatures have increased at a rate three times greater than the global average (Gulf of Maine Research Institute, 2024). The primary fishery in the region is the American lobster (*Homarus americanus*) trap fishery, which has experienced a spatial shift as habitat suitability has deteriorated in the southern parts of the range, and landings have increased in the northeastern parts of the state of Maine and into Atlantic Canada (Flaherty et al., 2025; Kim et al., 2023). As other lucrative fisheries in the region, such as groundfish, shrimp, and herring, have become depleted, the value of fishing in the Gulf of Maine has become increasingly tied to lobster (McClenachan et al., 2020; Steneck et al., 2011). The region's fisheries have also been involved in years-long litigation over gear regulations to protect the highly endangered North Atlantic right whale (Briggs, 2022). Coastal development along the

Gulf of Maine has been increasing, resulting in higher housing costs and reduced access to working waterfront (Schauffler, 2013). Meanwhile, the environmental conditions of the Gulf of Maine are well-suited for commercial-scale offshore wind energy generation (Musial, MacDonald, et al., 2023), and since August 2024, BOEM has approved Maine's application for a research lease and completed an auction for four commercial leases. The emergence of new ocean uses has been met with efforts to find paths for coexistence, yet some of these attempts have resulted in stakeholder perceptions that coexistence with offshore wind is not possible (Sandzén et al., 2025). Public opposition to offshore wind, at times, is attributed to perceived unfairness or injustice (Bates et al., 2025; Firestone et al., 2020), yet existing research does not go so far as to categorize a desirable outcome for the commercial fishing industry in the Gulf of Maine. As ocean environments and coastal communities are undergoing various changes, it is therefore necessary to consider how different stakeholders conceptualize what fairness means in the context of commercial fisheries and offshore wind in the Gulf of Maine, and what combination of variables may create a perceived fair outcome for those who participate in the industry. In the context of fisheries, "fairness" has been used to explore the allocation of quota (Gray, 2024; Doering et al., 2016; Healey & Hennessey, 1998), ethical fisheries (Lam & Pauly, 2010; Gray, 1998), and fishing access in a changing climate (Harper et al., 2023; Bennett et al., 2020; Cheung et al., 2019). In this study, I use the phrase "fair future for commercial fishing" to explore the perceptions of commercial fishers and fisheries decision makers and how they conceptualize an optimal future for commercial fisheries in the region.

Thus, this research seeks to address these gaps and answer the following questions related to offshore wind development and social impacts in the Gulf of Maine: (1) How is a fair future for commercial fishing in Maine impacted by diverse factors, including offshore wind, fisheries management, environmental health, and community well-being? (2) How do these factors interact with one another? (3) How do fisheries decision makers and commercial fishers perceive the impacts of various stressors differently or similarly?

2. Methods

2.1 Interview approach

To assess stakeholders' perceptions of a fair future for fishing in the Gulf of Maine, the interactions of different variables, and the similarities and differences among stakeholder groups, I used a mixed-methods approach that centers on mental modelling and fuzzy cognitive mapping and is supplemented by semi-structured interviews. Mental modelling is a form of cognitive mapping that represents an individual or group's interpretation of sets of variables and is used to better understand how knowledge is being constructed at both the individual and group levels (Gray et al., 2013). Fuzzy Cognitive Mapping is an analytic tool used to quantify and synthesize individual mental models (Gray et al., 2013). Respondents are asked to describe the directionality of a relationship between two variables (i.e. positive, negative, neutral) and the weight of that interaction (i.e. very strong, strong, weak, very weak) (Gray et al., 2013). Mental models are helpful tools for mixed-methods research, management decisions, and community learning as they allow non-traditional expertise to be used to illustrate how individuals or groups think about complex problems (Gray et al., 2015). I followed the multi-step approach to cognitive mapping developed by Özesmi and Özesmi (2004) to collect and analyze mental model data (Özesmi & Özesmi, 2004). This framework has frequently been used in ecological modelling and environmental management research where public involvement is solicited to address complex environmental issues (Castro, 2022; Drew et al., 2021; Ilbahar et al., 2023; McClenachan et al., 2020, 2022).

Using this multi-step approach, I conducted semi-structured interviews to collect mental model data. In each interview, respondents were first asked open-ended questions to elicit their conceptualization of what a "fair future for commercial fishing" meant to them. Then, in order to draw the individuals' mental model, participants were asked to identify which of the 12 core concepts they viewed as benefiting or detracting from a fair future for fisheries. The concept of a "fair future for fisheries" was left intentionally vague in order to capture the components that respondents believed would contribute to or detract from the future they would like to see. Next, respondents were asked open-ended questions to identify potential interactions between the core concepts, aside from those that directly impacted a fair future for fisheries. For each interaction that was described, they were asked to specify the directionality (i.e. positive or negative) and the strength (i.e. weak, strong, very strong) of the relationship between the two variables. Respondents were also asked if there were any other variables that interacted with the concepts listed that were not already asked about, allowing for non-standardized concepts to be considered in the mental model.

The 12 core concepts were developed from a preliminary study conducted during the summer of 2023, in which dynamic visualizations (virtual reality) were used to assess stakeholder perceptions of a proposed offshore wind array off the coast of Maine (Bates et al., 2025). During the study's data collection, additional stressors and considerations regarding the development of offshore wind were prominent among respondents, which informed the concepts chosen for this study. The 12 core concepts were centered around four main themes of regional well-being that emerged: offshore wind, fisheries management, environmental health, and community well-being (Table 1), as well as the stand-alone and central concept of a "fair future for fisheries." After testing the interview protocol and mental model concepts, these concepts were then standardized for all interviews.

Table 1. The twelve core concepts that were standardized across all interviews. The concepts were organized within four categories (quadrants).

Area of concern	**Concept**	**Definition**
Offshore wind	Offshore wind infrastructure	Wind turbines, cables, construction needs, and other physical components that are required to generate offshore wind energy
	Renewable energy	Energy generated by renewable sources, such as wind or solar
	Payments or compensation	Financial resources provided to account for economic losses due to the direct impacts of offshore wind
Fisheries management	Access to decision-making	The processes used to engage stakeholders in management decisions, including but not limited to public meetings, public comments, accessibility

Area of concern	Concept	Definition
		of decision makers, etc.
	Access to fish stocks	Physical and regulatory measures that impact the ability to catch a given fish species, including permit allocation, spatial or seasonal closures, etc.
	Endangered species management	Measures taken to conserve endangered species such as North Atlantic right whales and Atlantic salmon
Environmental health	Climate change	Environmental shifts that are a consequence of human activity, including increased storm events, warming ocean temperature, and
	Stock health	Fish abundance and distribution
	Habitat health	Availability of biotic resources that support marine species
Community well-being	Job opportunities	Employment options in a given area
	Cost of living	Financial requirements to reside in a region, including housing and food prices, inflation, etc.
	Preservation of working waterfronts	Local, state, or regional initiatives to maintain or increase coastal access for fishing or other commercial activities

Each interview resulted in a physically drawn cognitive map, which was an individual representation of the respondent's conceptualization of these concepts and how the concepts related to one another. The majority of interviews (n=31) were held in person, and the remaining interviews (n=10) were conducted virtually over Zoom. Interviews lasted between 30 and 90 minutes.

2.2 Interviewee selection

In order to compare how commercial fishers and fisheries decision makers view key stressors in the Gulf of Maine region, I interviewed two groups of respondents: commercial fishers and fisheries decision makers. Commercial fishers were defined as individuals who received income from fishing and held permits for one or more commercial fisheries located within the Gulf of Maine. The geographic scope for this project was the Gulf of Maine region and included respondents who fished in both state (Maine) and federal waters. Fisheries decision makers were identified per Lane and Stephenson's (1998) conceptual framework of fisheries advice and management (Lane & Stephenson, 1998), which defines the process of fisheries decision-making as one that directly includes fisheries science, decision makers, and fisheries managers and that is indirectly influenced by industry and interest groups (Lane and Stephenson, 1998). Using this framework, the second study group was composed of individuals who work within the direct sphere of influence of fisheries advice and management in the Gulf of Maine region. The fisheries decision makers that I interviewed worked with Gulf of Maine fisheries at varying scales. Some respondents worked at the local or town scale, others at the state scale, and some at the regional and federal scale, including those who lived in and outside the state of Maine.

2.3 Data collection

In order to gain a sample of individuals who represented both stakeholder groups, targeted outreach began in June 2024 by contacting commercial fishers who had previously been involved with related studies and had expressed interest in participating in future research. Additional commercial fishers were identified through snowball sampling. Although snowball sampling is an effective outreach method to increase response rates and reduce fatigue and repetition among communities that are the focus of research, this method also introduces selection bias (Kirchherr & Charles, 2018). To minimize this bias and ensure that a range of fisheries and geographic fishing areas were represented, additional outreach was conducted to individuals who did not participate in previous research projects by soliciting participation at town docks and identifying individuals from public websites of fisheries organizations. In order to gain a sample of fisheries decision makers who spanned different scales (e.g. local, regional, federal), sectors (e.g. government, NGO, academia) and perspectives (e.g. science versus policy), I identified and contacted individuals using emails provided on public websites. Additionally, I utilized snowball sampling to identify other decision makers who would be relevant to interview.

2.4 Analysis

The interviews allowed respondents to quantify the directionality and strength of relationships between concepts to craft mental models, as well as provide more nuanced, qualitative responses. I analyzed these data in two ways. First, the mental models were transcribed into adjacency matrices showing the quantitative relationships among variables. Depending on how an individual described a relationship (i.e. very strong, strong, weak, very weak), these relationships were quantified on a scale from -3 to 3, where -3 represented a very strong negative relationship, and 3 represented a very strong positive relationship. These values were transcribed into the matrix, where I then calculated key metrics such as average centrality, indegree, and outdegree of variables among respondents. Indegree is a measure of how impacted that variable is by other concepts, whereas outdegree is a measure of how much a variable impacts other concepts, and centrality is a calculation of how linked variables are to the entire map (Gray et al., 2013). Individual models were averaged across all respondents within each stakeholder group, and these metrics were then compared between study groups (commercial fishers and fisheries decision makers) using a t-test.

Next, I conducted a qualitative analysis of the data to identify key themes across interviews. I transcribed quotes from each interview and organized the data into groups associated with each quadrant (offshore wind, management, environment, and community). I first conducted a deductive thematic analysis based on the results that emerged from the preliminary, quantitative analysis. To do this, I identified the metrics of interaction strength and centrality associated with the core concepts and identified quotes that supported these quantitative results. Next, I conducted an inductive thematic analysis to identify prominent themes that emerged outside of the quantitative results. I categorized quotes within each group based on the transmitting concept and the receiving concept. From here, I categorized each interaction as positive, negative, or uncertain (see Appendix 1). This allowed me to identify thematic findings that were not represented in quantitative data.

3. Results

3.1 Demographics

Between July 2024 and November 2024, I conducted 21 semi-structured interviews with commercial fishers and 20 interviews with individuals who work in the sphere of influence of fisheries management. This is a comparable or larger sample size to studies that similarly utilize a FCM approach among multiple stakeholder groups (Brown et al., 2021; d'Armengol et al., 2021; Drew et al., 2021; McClenachan et al., 2022).

Commercial fishers included in the study were involved with between one and six commercial fishing-related activities, including state and federal lobstering, aquaculture, fishing charters, and seafood retail operations. Of the 21 commercial fishers, 17 held state lobster licenses, eight held federal lobster licenses, six held groundfish permits, and four individuals held permits to fish each squid, herring, and scallops. Additional individuals were involved in the elver, urchin, and menhaden fisheries. In total, 13 forms of commercial fishing were mentioned among respondents, with many individuals participating in multiple fisheries or businesses. Respondents were involved in an average of 2.8 fisheries.

Representation of fisheries decision makers ranged from local town management to federal Congressional staff, and the respondents' work spanned a science-policy spectrum. 12 of the respondents worked for a government agency, and 8 individuals worked for non-governmental organizations. Of the 20 fisheries decision makers, 14 respondents worked in a policy capacity, and the remaining 6 worked in a science capacity. Among both government and nongovernmental employees, five worked at the federal level, three worked at a regional level (Northeast region), 10 worked at the state level, and two worked at a local (municipal) level.

3.2 Core concepts and a fair future for fishing

A fair future for fisheries was the organizing concept in the mental model, and therefore not surprisingly emerged as the most central concept within the system for both commercial fishers and fisheries decision makers (Table 3). Respondents defined a "fair future" in their own ways, including ideas of equitable access to resources, sustainable use of resources, and fisheries profitability. For example, one individual defined it as: *"a balance of the competing needs and uses of marine resources in a sustainable way."* Another respondent described it as *"equitable access to resources for those that are participating, those who want to participate, and those who have been excluded."* Others viewed a fair future as one in which they could still make a dependable living by working on the water, and where the health of the environment and profitability of fisheries were successfully balanced.

When describing what concepts would contribute to, or threaten a fair future for fisheries, three concepts were cited the most frequently among all respondents: access to decision making, access to fish stocks, and preservation of working waterfronts. 90% of respondents (n=37) viewed access to decision making as having an impact on a fair future for fisheries, 78% of respondents (n=32) mentioned that access to fish stocks would impact a fair future for fisheries, and 75% of respondents (n=31) viewed preservation of working waterfronts as benefiting a fair future for fisheries (Figure 1). These three concepts were consistently mentioned among all respondents as either contributing to or detracting from a fair future for fisheries.

When compared by stakeholder group, access to decision making, preservation of working waterfronts, and access to fish stocks were the three most cited concepts as impacting a fair future for fisheries for each group. However, among commercial fishers, offshore wind infrastructure (n=17) and endangered species management (n=15) were also among the most frequently cited concepts as impacting a fair future for fisheries, while among decision makers, stock health (n=13) and climate change (n=13) were among the most cited concepts (Figure 1).

Furthermore, not all respondents agreed on whether certain concepts would improve or detract from a fair future for fisheries. For those that mentioned the concept, there was agreement that concepts such as preservation of working waterfronts, stock health, job opportunities, habitat quality, and renewable energy would increase a fair future for fisheries (Figure 1). Similarly, among those that mentioned the concept in their mental model, there was agreement that the cost of living and offshore wind infrastructure would decrease a fair future for fisheries (Figure 1). However, respondents disagreed on the directionality of the impact of five concepts: access to decision making, access to fish stocks, payments and compensation, climate change, and endangered species management. Notably, 9 out of the 11 decision makers who mentioned payments or compensation viewed payments as increasing a fair future for fisheries, whereas 11 out of the 14 fishers that mentioned the concept viewed it as decreasing a fair future for fisheries (Figure 1).

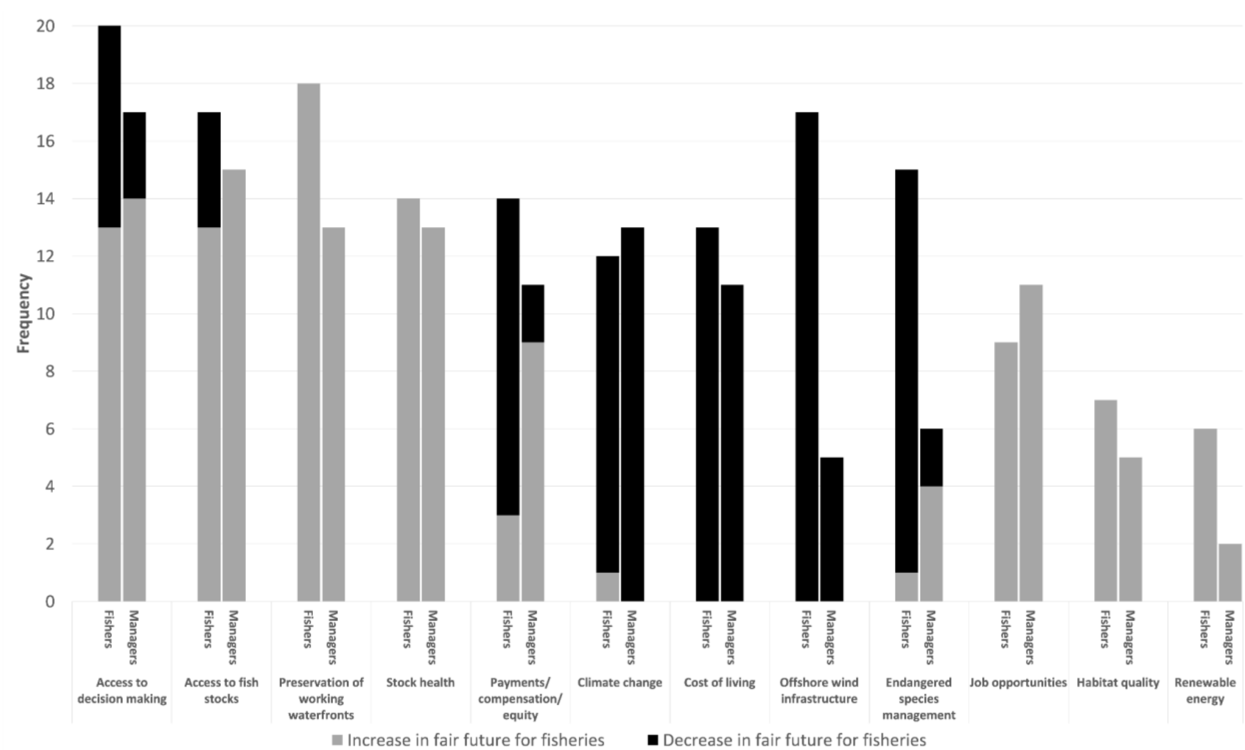

Figure 1. Frequency of core concepts mentioned by commercial fishers (n=21) and fisheries decision makers (n=20) as they relate to a fair future for fisheries. The figure is organized in order of the most frequently mentioned concepts among all respondents. Black indicates that the

respondent cited the concept as causing a decrease in a fair future for fisheries, and gray indicates that the respondent cited the concept as increasing a fair future for fisheries.

Frequencies measure the number of times a concept was mentioned in relation to a fair future for fisheries; in addition, interaction strength measures the magnitude of the connection drawn between different concepts and a fair future for fisheries. The results support those described above, but respondents also mentioned stock health as being one of the most impactful concepts to increasing a fair future for fisheries. Although access to decision making was cited with a high frequency among respondents, there were opposing views as to whether or not more access to decision making would benefit or detract from a fair future for fisheries. As such, there was a significant difference between the interaction strengths each group attributed to the concept, which are explored further below (Table 2).

Among all respondents, the preservation of working waterfronts was the most impactful concept to a fair future for fisheries, with an average interaction strength of 1.22 (Table 2). Respondents described the importance of working waterfronts in the region, and certain threats to maintaining access, such as climate change and high costs of living. One decision maker put it succinctly, saying *"[the] success of fishery is dependent on working waterfronts."* This sentiment was shared by some commercial fishers, such as this individual who said, *"Preservation of working waterfronts is one of the biggest issues for the fishery."*

Additionally, access to fish stocks was repeatedly cited as important for creating a fair future for commercial fisheries, with an average interaction strength of 1.07 (Table 2). For example, respondents described the importance of flexibility and adapting management to shifting stock distribution in order to access fish that were becoming more abundant in the region. As one individual said, *"New species are arriving and people don't have access to them."* Another individual said, *"Even if other species are here, the management/permit structure isn't."*

Among all respondents, stock health was also an impactful concept to a fair future for fisheries, with an average interaction strength of 0.93 (Table 2). Respondents shared the importance of healthy fish stocks to maintaining viable fishing access, stating, *"[You] can't* *maintain a future fishery if the fish don't exist."* Others shared the concern that maintaining or rebuilding stocks to healthy levels was critical to creating a fair future, saying, *"Future stock health is everything."*

Among all respondents, climate change was described as having the greatest negative impact on a fair future for fisheries, with an interaction strength of -1.12 (Table 2). As this respondent described, *"The only reason we're having this conversation about all of these stressors is because of climate change."* Others expressed similar concerns, *"[The] only thing that can kill us is the oceans warming up."*

Table 2. A comparison of the average interaction strength of 12 core concepts and their impact on a fair future for fisheries from respondents of the two stakeholder groups: commercial fishers (n=21), and participants associated with fisheries management (n=20). Asterisks indicate interaction values with significant differences ($p < 0.05$).

	ALL RESPONDENTS	**COMMERCIAL FISHERS**	**FISHERIES DECISION MAKERS**
Preservation of working waterfronts	1.22	1.43	1.00
Access to fish stocks	1.07	0.81	1.35
Stock health	0.93	1.10	0.75
Access to decision making	0.88	0.52*	1.25*
Job opportunities	0.61	0.62	0.60
Habitat quality	0.34	0.43	0.25
Renewable energy	0.22	0.33	0.10
Payments/ compensation/ equity	-0.05	-0.43*	0.35*
Endangered species management	-0.54	-1.14*	0.10*
Cost of living	-0.63	-0.67	-0.60
Offshore wind infrastructure	-1.02	-1.71*	-0.30*
Climate change	-1.12	-0.95	-1.30

When compared by stakeholder group, there were four concepts that had significantly different interaction strength values between groups ($p < 0.05$): access to decision making, payments and compensation, endangered species management, and offshore wind infrastructure. Differences in interaction strength values were, at times, attributed to varying perceptions of directionality among respondents of each group (Figure 1). For example, some commercial fishers believed payments/compensation would decrease a fair future, whereas decision makers believed payments would benefit a fair future for fisheries (Figure 1). The significant differences among these four core concepts were illustrated through qualitative data as well and are explored further below.

3.2.1 Access to decision making

95.24% (n=20) of commercial fishers mentioned that access to decision-making is interacting with a fair future for fisheries. However, of the 20 respondents who mentioned the concept, 65% (n=13) viewed it as contributing to a fairer future, while 35% (n=7) viewed it as detracting from a fair future for fisheries. Meanwhile, 85% (n=17) of fisheries decision makers viewed access to decision-making as having an impact on a fair future, and 82.35% (n=14) of those respondents believed it contributed to a fairer future, while 17.65% (n=3) viewed access to decision making as negatively impacting a fair future for fisheries (Figure 1). The resulting mean interaction strength between the two concepts was 0.52 among commercial fishers and 1.35 among fisheries decision makers ($p<0.05$; Table 2).

Commercial fishers voiced several reasons why they felt that access to decision-making negatively impacted a fair future for fisheries. One reason was that respondents did not feel as though access was the same as influence. While they believed that they had access, they did not think that their input or knowledge was solicited or taken seriously. For example, one respondent said: *"Fisher's knowledge extends far beyond the NOAA time series, but you don't ask us, never do."* Another respondent said, *"People aren't going to meetings anymore because they don't listen to us anyway."* Additionally, some respondents voiced that the stakeholder engagement process that was being used felt performative, rather than a genuine interest in working with other marine users. As this respondent put it, *“[There’s a] sentiment that engagement processes look like ‘thanks for your opinion, but [we don’t care].’”*

Some commercial fishers viewed access to decision-making more positively, especially management structures at the local level. For example, one respondent spoke highly of the Maine Department of Marine Resources (DMR), saying, *“DMR has a good commissioner, good relationship with managers."* Other respondents felt that the access that the public, and commercial fishers more specifically, had to decision-making processes was adequate, despite an abundance of people who feel negatively about management processes. As they said, *“We've had lots of access - don't need to have a PhD to do that, only 300 comments out of how many people that [complain] about it?”*

Among fisheries decision makers, there was a greater consensus that the stakeholder engagement processes that were used were benefiting the future of fishing. As one respondent voiced, *"Preserving a fair future for fisheries is a massive exercise in a balancing act – to deal with all of these factors, to consider, to take them in, to come up with the solution that is best for as many people as possible, I think is what our process gives us."* In specific reference to the process that BOEM has used in the siting of the lease areas, one respondent said, *“BOEM's process is based on stakeholder engagement, it doesn't work without it…BOEM is maximizing opportunities for meaningful engagement.”*

Despite more agreement that engagement processes and access to decision-making were contributing to a fairer future for fisheries, there was not total alignment among this stakeholder group. Some respondents voiced similar concerns to fishers who felt like decisions had already been made by the time these processes made it to public comment or hearings. One respondent voiced, *“[We] need more meaningful input; as is, things are often already hammered out. [We] need to invest more on the front end before the constrained public hearings.”* Other respondents cited the confusing nature of the engagement processes that can make it challenging to achieve meaningful and broad engagement. As this respondent said, *“Access and decision-making exist in complicated systems. It makes it very hard to have broad participation – there’s so much info and input, and it’s hard to filter that…Government structures are not as transparent and accessible as they once were and as much as they think they are.”*

3.2.2 Payments/compensation

Of the 14 commercial fishers who mentioned payments/compensation as impacting a fair future for fisheries, 78.57% (n=11) cited the concept as creating a less fair future for commercial fisheries. 21.43% (n=3) of commercial fishers viewed payments/compensations as benefiting a fair future for fisheries. Of the 11 fisheries decision makers who mentioned payments/compensation as having an impact on a fair future for fisheries, 81.82% (n=9) viewed the concept as contributing to a fairer future for fisheries, whereas 18.18% (n=2) viewed the idea as negatively impacting a fair future for fisheries (Figure 1). As a result, the mean interaction strength of payments/compensation among commercial fishers was -0.43 and 0.35 among fisheries decision makers ($p<0.05$; Table 2).

Of the fishers who viewed payments or compensation as negatively impacting a fair future for fisheries, many shared the sentiment that any sort of payment or compensation would not be adequate for the risks and losses that would be incurred due to offshore wind development. As one respondent voiced, *"That's not compensation, that's just a slap in the face."* Another fisher said, *"Most people don't want a check from Exxon – I just want to do what I have been doing for 5 generations."* Moreover, respondents felt that accepting any form of compensation as a result of lost fishing ground would represent being “bought out” of the industry. As one respondent put it, *"As soon as you've accepted compensation, you've accepted defeat."* In other words, not only did they feel that compensation would not be adequate to make up for the potential economic loss, but they also viewed payments or compensation as inherently detracting from a fair future for fisheries.

Conversely, decision makers were more likely to view compensation as a means to mitigate impacts, even while recognizing that it was not a perfect solution. As one fisheries decision-maker put it, *“No matter what we do, there is going to be displacement and there has to be compensation for this.”*

3.2.3 Endangered species management

The third concept that had significant differences in interaction strengths between stakeholder groups was endangered species management. 71.43% (n=15) of commercial fishers said that endangered species management impacted a fair future for fisheries. Of these respondents, 6.67% (n=1) viewed it as creating a fairer future for fisheries, while 93.33% (n=14) said it negatively impacted a fair future for fisheries. This was highlighted by one individual who stated, *"Endangered species management is the biggest threat that could immediately take away our fishery."*

Conversely, 30% (n=6) of fisheries decision makers mentioned endangered species management as interacting with a fair future, and 66.67% (n=4) of these respondents viewed it as benefiting a fair future for fisheries. In comparison, 33.33% (n=2) viewed it as negatively impacting a fair future for fisheries (Figure 1). The mixed perceptions held by decision makers were reflected in this quote: *"Endangered species management can be a positive and a negative, if it means we come up with new ways to fish, that's a good thing, but all of that costs more money."* Another individual shared similar ambivalence, saying *"[the Endangered Species Act] (ESA) mandates that we preserve the North Atlantic Right Whale - that is a good thing we should do, while understanding the impact that has on the industry."*

As a result of these differing stances on the impact of endangered species management, the mean interaction strength of endangered species management and a fair future for fisheries was -1.14 among commercial fishers, and 0.10 among fisheries decision makers ($p<0.05$; Table 2).

3.2.4 Impacts of offshore wind infrastructure

On average, both commercial fishers and fisheries decision makers viewed offshore wind as negatively impacting a fair future for fisheries, with commercial fishers perceiving a significantly stronger negative impact (Table 2). The mean interaction strength of offshore wind and a fair future for fisheries was -1.71 among commercial fishers, and -0.30 among fisheries decision makers ($p<0.05$). 80.95% (n=17) of commercial fishers mentioned offshore wind as a concept that would impact a fair future, and all 17 individuals cited the interaction as negative. As one fisher stated, *"Offshore wind will not work, we'll be paying for it in the future."*

In comparison, 25% (n=5) of fisheries decision makers cited offshore wind as affecting a fair future (Figure 1). All five of these individuals reported a negative interaction. Among decision makers who made the connection between offshore wind infrastructure and a fair future for fisheries, there was agreement that the interaction would be negative. One individual described it, saying, *"Offshore development is unfortunately somehow going to negatively impact fisheries."* Among this group, the magnitude of the impact of offshore wind was significantly lower, as described by one individual who stated, *"Everything's going to be impacted [by offshore wind], I don't know if that's necessarily this huge negative or positive, it's just another thing we have to consider."* No respondents mentioned offshore wind as creating a fairer future for fisheries.

3.3 Mental models

Beyond the impact that the core concepts had on a fair future for fisheries, fuzzy cognitive maps show that these concepts frequently interact with one another in ways that reinforce or change the impact of one concept on the overall system (Figure 2). For example, respondents viewed the cost of living as negatively impacting a fair future for fisheries, and this negative impact is exacerbated by climate change and offshore wind infrastructure, which was perceived as driving costs of living higher (Figure 2). Respondents also illustrated that maintaining a working waterfront was important in order to create a fair future for fisheries, but expressed that preserving working waterfronts is threatened by climate change and higher costs of living (Figure 2). These types of interactions are explored in more depth by considering metrics of centrality. Centrality considers both the interaction strength of the concept, such as the metrics described above, and the degree to which a concept is impacted by other variables.

Among all respondents combined, offshore wind infrastructure, access to fish stocks, and climate change had the highest centrality values, with average values of 12.51, 7.10, 6.71, and 5.49, respectively (Table 3; Figure 2). When analyzed by stakeholder group, there were both similarities and differences in concept centrality. Both stakeholder groups cited maintaining access to fish stocks as central to the overall mental model, with the mean centrality among fishers being 6.29 and 7.15 among decision makers (Table 3). Two of the four concepts that showed significant difference in interaction strengths above also had significantly different centrality values between stakeholder groups ($p < 0.05$): offshore wind infrastructure, and access to decision making. In addition, there was a significant difference in the centrality values of climate change between groups. Although offshore wind infrastructure and climate change were among the most central concepts when averaged across all respondents (Figure 2), these concepts were emphasized by stakeholder groups in significantly different ways.

Among commercial fishers, offshore wind infrastructure had the highest centrality (8.00), whereas offshore wind had a centrality value of 6.15 among fisheries decision makers (Table 3). This is reflective of how strongly commercial fishers perceived offshore wind infrastructure would impact a fair future for fisheries, while also highlighting the perceived impacts that offshore wind infrastructure had on concepts throughout the model. Fisheries decision makers viewed climate change as the most central concept (7.25), whereas climate change had a centrality value of 3.81 among commercial fishers (Table 3). Fisheries decision makers also viewed access to decision making as more central to the overall system than commercial fishers, with centrality values of 4.30 and 2.95, respectively (Table 3). These significant differences echo those described in Section 3.2, and also highlight the different connections that each group drew between offshore wind infrastructure, access to decision making, and climate change, and concepts within the broader cognitive map. These differences are explored further in Section 3.4.

Table 3. A comparison of the average centrality of 13 core concepts from respondents of the two stakeholder groups: commercial fishers (n=21), and participants associated with fisheries management (n=20). Asterisks indicate centrality values with significant differences ($p < 0.05$).

	ALL RESPONDENTS	**COMMERCIAL FISHERS**	**FISHERIES DECISION MAKERS**
Fair future for fisheries	12.51	13.81	11.15
Offshore wind infrastructure	7.10	8.00*	6.15*

Access to fish stocks	6.71	6.29	7.15
Climate change	5.49	3.81*	7.25*
Stock health	4.17	4.71	3.60
Access to decision making	3.61	2.95*	4.30*
Preservation of working waterfronts	3.12	3.33	2.90
Endangered species management	2.93	3.24	2.60
Cost of living	2.71	2.86	2.55
Job opportunities	2.51	2.52	2.50
Habitat quality	2.49	2.86	2.10
Renewable energy	1.78	1.43	2.15
Payments/ compensation/ equity	1.39	1.19	1.60

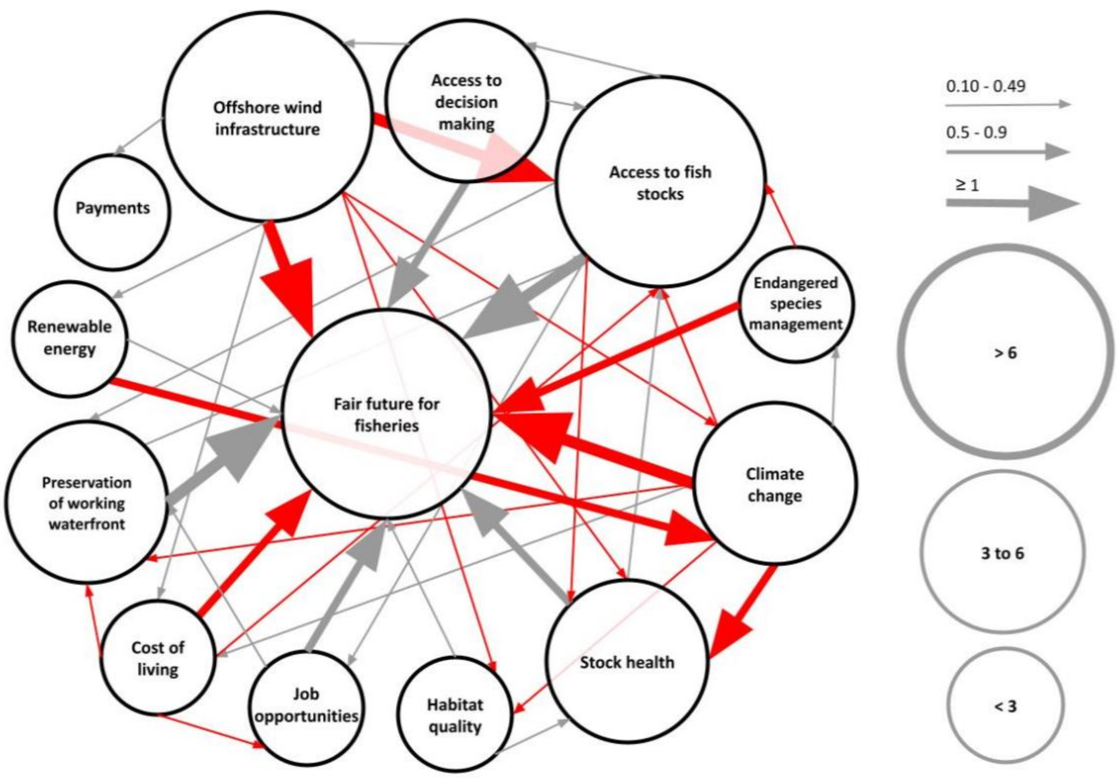

Figure 2. Average cognitive map of all respondents. The size of the circle represents the centrality of each concept, and the size of the arrow represents the interaction strength. Gray arrows indicate an increase, red arrows indicate a decrease.

3.4 Quadrant analysis

While all respondents conceptualized a fair future for fisheries as a product of many interactions between concepts, commercial fishers emphasized the offshore wind and community quadrants, while decision makers emphasized the management and environment quadrants (Figure 3). These variations are reflective of the significant differences shown above, where offshore wind infrastructure was the most central concept among commercial fishers, and climate change was the most central concept among fisheries decision makers (Table 3).

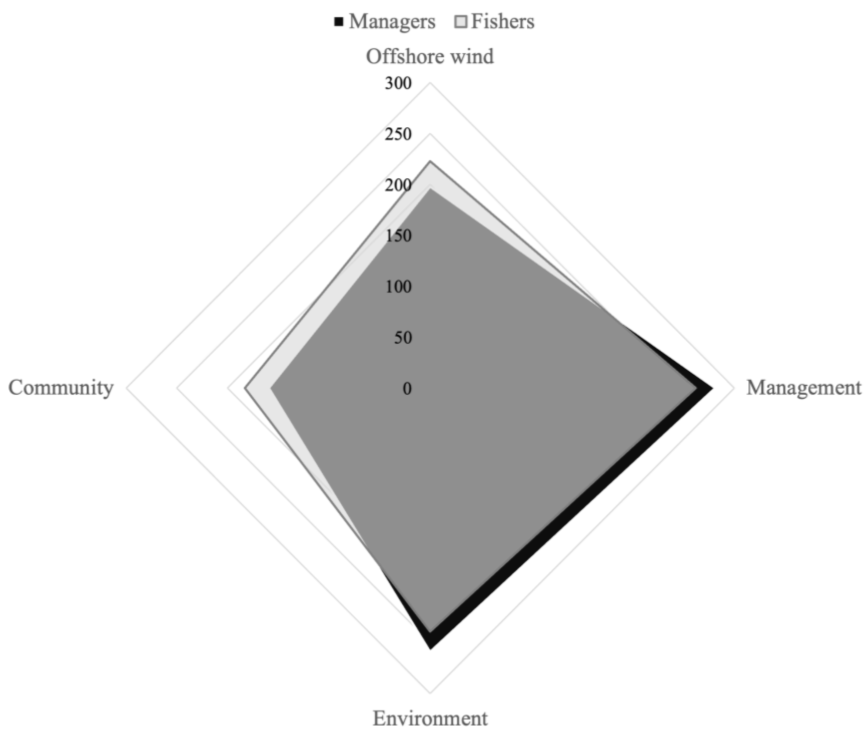

Figure 3. A comparison of the total quadrant centrality among all respondents, divided by stakeholder group. The light gray polygon represents commercial fishers, and the black polygon represents fisheries decision makers.

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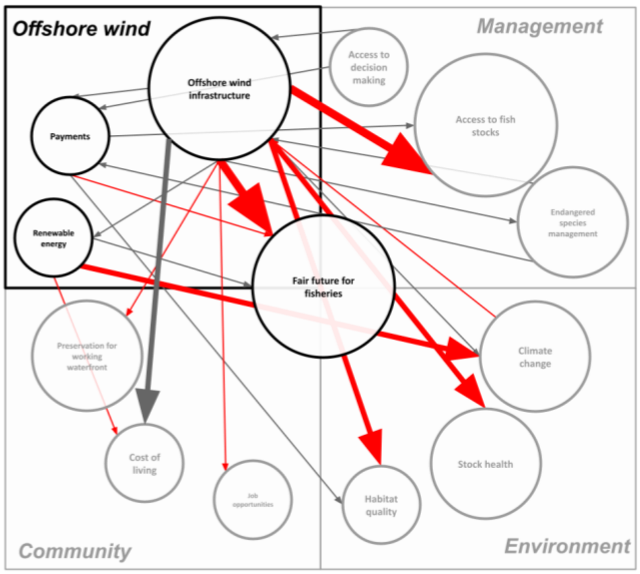

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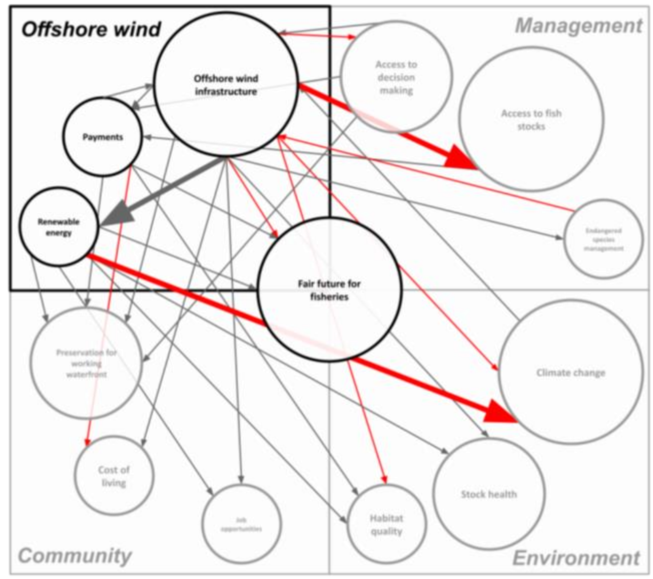

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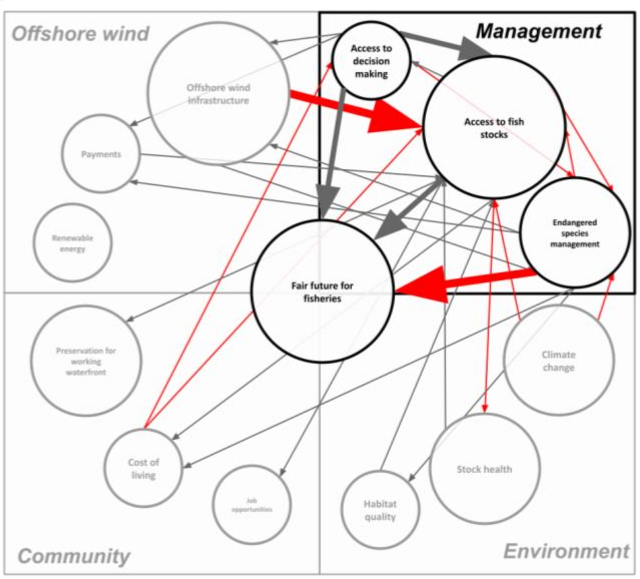

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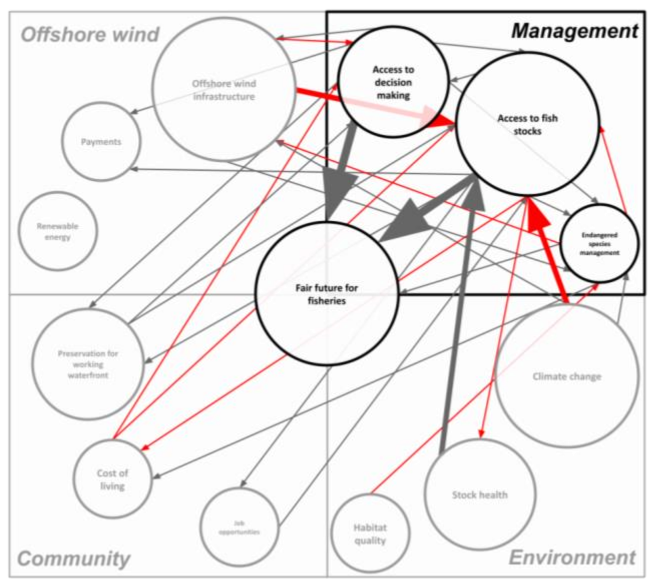

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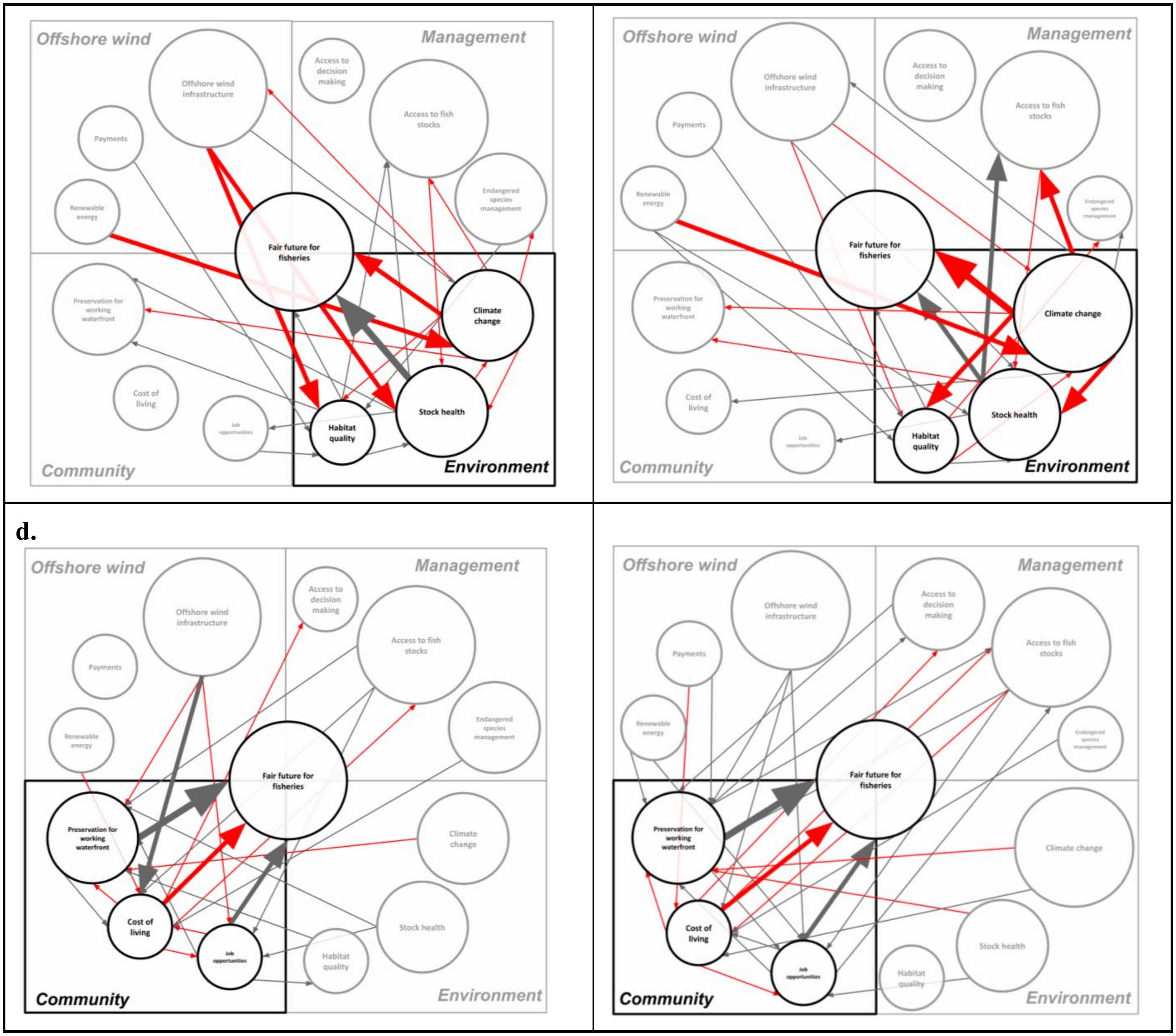

Figure 4. Average cognitive map of respondents, analyzed by stakeholder group. Cognitive maps are divided into quadrants, showing all interactions between that quadrant and other concepts. The size of the circle represents the centrality of each concept, and the size of the arrow represents the interaction strength. Gray arrows indicate an increase, red arrows indicate a decrease.

3.4.1 Offshore wind

Within the offshore wind quadrant, offshore wind infrastructure, renewable energy capacity, and payments all had impacts throughout the system, sometimes in contradictory ways when compared across stakeholder groups. On average, fishers viewed offshore wind infrastructure as a primary negative driver of the overall system. Commercial fishers reported an average interaction strength of -1.24, -0.86, and -0.76 between offshore wind and access to fish stocks, stock health, and habitat health, respectively (Figure 4a). Decision makers similarly illustrated that offshore wind infrastructure would have negative impacts on access to fish stocks and habitat health, with average interaction strengths of -0.85 and -0.15, respectively. Decision makers, on average, viewed offshore wind infrastructure as benefiting stock health, with an interaction strength of 0.05, due to an anticipated "reef effect," where the presence of added structure provides habitat for some fish species. Commercial fishers also viewed offshore wind infrastructure as decreasing job opportunities, with an average interaction strength of -0.14, whereas decision makers viewed offshore wind infrastructure as creating job opportunities, with an interaction strength of 0.30. Similarly, commercial fishers reported that offshore wind infrastructure would decrease the ability to preserve working waterfronts (-0.19), whereas decision makers perceived that offshore wind infrastructure could marginally increase working waterfronts (0.05). Additionally, both groups believed offshore wind would increase the cost of living, but commercial fishers perceived a stronger relationship (0.50) than fisheries decision makers (0.25).

Both groups viewed renewable energy as helping abate climate change, with average interaction strengths of -0.62 among commercial fishers and -0.80 among decision makers (Figure 4a). However, commercial fishers reported an average interaction strength of 0.14 between offshore wind infrastructure and renewable energy, whereas decision makers had an average interaction strength of 0.75 between offshore wind infrastructure and renewable energy. As a result, decision makers viewed offshore wind infrastructure as driving down climate change (-0.35 interaction strength), whereas commercial fishers perceived offshore wind infrastructure as worsening climate change (0.14 interaction strength). Some of these respondents perceived greater climate impacts of constructing offshore wind arrays compared to the renewable energy they would provide. When discussing renewable energy more generally, however, commercial fishers believed renewable energy would bring down the cost of living, with an average interaction strength of -0.10, and fisheries decision makers did not note a connection between the two variables. Fisheries decision makers perceived that renewable energy would improve habitat quality (0.10), stock health (0.05), and create job opportunities (0.05).

Commercial fishers did not view payments or compensation as having a strong impact on other concepts. They reported a relatively weak positive connection between payments and access to fish stocks, with an average interaction strength of 0.05 (Figure 4a). Additionally, they reported a positive interaction between payments and habitat quality (0.10), citing that compensation packages could take the form of habitat improvement grants or related improvement projects. Similarly, fisheries decision makers cited a small positive interaction between payments and habitat quality (0.05), and perceived that payments could lower the cost of living (-0.10) and increase the preservation of working waterfronts (0.11). Additionally, decision makers drew a weak connection (0.05) between payments and offshore wind infrastructure, noting that more compensation for fishers may result in more offshore wind infrastructure being built.

3.4.2 Management

In the management quadrant, access to decision-making was a key concept, as discussed above. Additional interactions that respondents highlighted included a positive relationship between access to decision making and access to fish stocks, with average interaction strengths of 0.35 among commercial fishers and 0.52 among decision makers (Figure 4b). Decision makers also perceived a positive interaction between access to decision making and better offshore wind infrastructure (0.30), as well as more endangered species management (0.20). Commercial fishers reported a weak connection between access to decision making and offshore wind infrastructure, with an average interaction strength of 0.05. Furthermore, commercial fishers cited that access to decision making would result in less endangered species management, with an interaction strength of -0.10.

Commercial fishers believed that endangered species management would decrease access to fish stocks, with an average interaction strength of -0.38 (Figure 4b). Similarly, decision makers reported an average interaction strength of -0.45 between these two concepts. Commercial fishers perceived that endangered species management could increase offshore wind infrastructure (0.10), citing concerns that displacement or closures due to North Atlantic right whale measures were related to efforts to develop offshore wind. Conversely, decision makers described that endangered species management would result in a decrease in offshore wind infrastructure (-0.15). Both groups described a connection between endangered species management and increased costs of living, with an interaction strength of 0.10 among decision makers and 0.05 among commercial fishers. This connection was usually described as a result of required gear changes that were more expensive than current gear. Commercial fishers also described a connection between endangered species management and improved habitat quality (0.05).

Both groups viewed access to fish stocks as resulting in increased access to decision making, with an average interaction strength of 0.14 among commercial fishers and 0.15 among fisheries decision makers (Figure 4b). Similarly, both groups viewed access to fish stocks as decreasing stock health, with an interaction strength of -0.05 among fisheries decision makers and -0.24 among commercial fishers. Commercial fishers perceived access to fish stocks as creating more job opportunities and increasing the preservation of working waterfronts (0.29 and 0.14, respectively), as did decision makers (0.25 and 0.21, respectively).

3.4.3 Environment

Among decision makers, climate change was the primary driver of negative impacts to the overall system, including stock health, habitat health, and access to fish stocks, with average interaction strengths of -0.90, -0.60, and -0.70, respectively (Figure 4c). Commercial fishers similarly viewed climate change as negatively impacting these same concepts but with average interaction strengths of -0.48, -0.05, and -0.05, respectively. Both groups also viewed climate change negatively impacting the preservation of working waterfronts, due to more frequent and intense storms, with an average interaction strength of -0.29 among commercial fishers and -0.21 among decision makers. Decision makers also viewed climate change as increasing endangered species management, with an average interaction strength of 0.35, whereas commercial fishers cited a weak negative interaction, with climate change resulting in a decrease in endangered species management (-0.05). Finally, decision makers perceived that climate change would result in an increase in offshore wind infrastructure (0.10), whereas commercial fishers perceived that climate change would result in a decrease in offshore wind infrastructure (-0.05).

Both groups described that improved stock health would lead to increased access in fish stocks, with interaction strengths of 0.29 among commercial fishers and 0.50 among decision makers (Figure 4c). Additionally, both groups described that improved stock health would result in more job opportunities, with interaction strengths of 0.19 among commercial fishers and 0.05 among decision makers.

Both commercial fishers and fisheries decision makers viewed a positive connection between habitat quality and stock health, with interaction strengths of 0.35 and 0.30, respectively (Figure 4c). Fisheries decision makers also perceived that improved habitat quality would decrease climate change (-0.05) and decrease endangered species management (-0.10). Commercial fishers cited that improved habitat quality could increase access to fish stocks (0.05).

3.4.4 Community

Both groups viewed community changes impacting a fair future for fishing, and shared similar views on the importance of preserving working waterfront and job opportunities, and that the cost of living was inhibiting a fair future for fishing (Figure 4d). Decision makers viewed preserving working waterfronts as allowing for improved access to fish stocks, with an average interaction strength of 0.30. Commercial fishers did not report any interaction between these two concepts.

Commercial fishers reported that increased job opportunities would increase the preservation of working waterfront (0.24) (Figure 4d). Fisheries decision makers made the same connection between job opportunities and the preservation of working waterfront, with an interaction strength of 0.16. Commercial fishers perceived that increased job opportunities would decrease the cost of living (-0.05), whereas decision makers perceived that increased job opportunities would increase the cost of living (0.05).

Both groups believed increased costs of living were decreasing job opportunities, with average interaction strengths of -0.24 among commercial fishers and -0.15 among decision makers (Figure 4d). Furthermore, both groups viewed costs of living as decreasing the preservation of working waterfronts, with interaction strengths of -0.43 among commercial fishers and -0.26 among decision makers. Both commercial fishers and decision makers described that the increased cost of living was having a negative impact on access to fish stocks and access to decision making. Both groups reported an average interaction strength of -0.10 between the cost of living and access to fish stocks, and an average interaction strength of -0.05 between the cost of living and access to decision making.

3.5 Thematic Analysis

Qualitative data from the semi-structured interviews supported the differences in centrality values that each stakeholder group expressed for core concepts. Specifically, the relative importance of offshore wind among commercial fishers compared to the relative importance of climate change among fisheries decision makers was illustrated throughout interviews (Appendix 1). However, further qualitative analysis highlighted three prominent themes that were not captured within the quantitative metrics and analyses. The three themes, highlighted below, include qualified support for renewable energy, the importance of climate-ready stock assessments, and siloed decision-making processes.

3.5.1 Qualified support for renewable energy

While, on average, both stakeholder groups viewed offshore wind as negatively impacting a fair future for fisheries, there was ample nuance among respondents from both groups about the prospect of increased renewable energy development and offshore wind specifically. Among many fisheries decision makers, there were common opinions that, although offshore wind could benefit decarbonization efforts, development needs to occur in a way that creates direct local benefits. For example, this individual said, *"Impacts of offshore wind need to be offset by direct benefits, not broad societal benefits."* Another individual voiced, *"Yes, we need renewable energy, but it needs to be done to minimize the impacts to other users and marine resources."* These sentiments were echoed among many commercial fishers, one of whom said, *"I'm not against renewable energy, just against big wind. It's just not good for me."* Another stated, *"I'm all for renewable energy, we need it, but it has to be done in the right way."*

Among both decision makers and fishers, there were also commonalities about how individuals prioritized different forms of renewable energy, and which types they felt would better serve the region's goals. One individual said, *"Maine's movement to decarbonize could be better served by solar projects."* Many fishers described their support for renewable energy, but their preference was for installing rooftop solar or developing onshore wind, citing that these options could be more cost-effective and less impactful to the marine environment. As this fisher put it, *"People on shore don't want to look at them, so instead we're impacted offshore. Put one in my backyard, I don't [care]."*

3.5.2 Importance of climate-ready stock assessments

Across all respondents, access to fish stocks was central to creating a fair future for commercial fisheries. While much of the focus of access to fish stocks was described in terms of physical access or permit structures (described in Section 3.2), another component of maintaining access to fish stocks was stock assessments and fisheries science. Many respondents highlighted the importance of ensuring that accurate stock assessments could be employed, especially given the challenges of climate change and the impacts of offshore wind arrays in conducting accurate and timely surveys. Although stock assessments (also noted as fisheries science or fisheries data) were not a part of the interview protocol as a core concept, five commercial fishers and 12 fisheries decision makers mentioned the concept in their mental model of a fair future for fisheries. For example, this respondent said, *"Climate change creates a lot of uncertainty in the science. Haddock, monkfish, scallop survey…climate change is making everything more difficult and creating uncertainty - it's easier to point fingers."* Another respondent echoed these sentiments, saying, *"What do we need for a fair future? Timely, real,* *accurate assessments done by trained professionals who know these waters better than anyone else."* Other respondents highlighted concerns about the potential impacts that offshore wind infrastructure would have on stock assessments. As one individual described, *"In some cases, surveys will be totally precluded from offshore wind infrastructure."* Another respondent illustrated the impact this may have: *"Offshore wind is going to impact stock assessments which increases uncertainty in data."* Taken together, accurate, climate-ready stock assessments were cited as an important element of maintaining access to fish stocks, and respondents illustrated how this concept may be impacted by both climate change and new offshore wind infrastructure.

3.5.3 Siloed decision-making processes

Among respondents who were part of the fisheries decision-making process, there was an emergent theme of siloed decision-making processes between fisheries management and offshore wind development. Although many respondents within this group spoke about access to decision-making in regard to fishers' access to decision makers, respondents within this group also brought up concerns about their own ability to contribute research and data during decision-making processes, as it concerned offshore wind development. Respondents reflected a degree of uncertainty about where there were leverage points to influence the decision-making process for offshore wind development, given their positions within the fisheries management space. For example, one respondent stated, *"I don't think anyone will come to us for input, we'll just have to submit through public comments to BOEM."* Another respondent who worked at the municipal level voiced, *"[We're] trying to figure out where our leverage is or if we have any."* Another respondent, speaking to the legal contexts of these processes, said, *"[Outer Continental Shelf Lands] Act gives BOEM the authority to manage offshore wind, but it comes at the cost of a lack of collaboration with NOAA."*

Another element of this theme was a concern among fisheries decision makers about the pace at which the offshore wind siting process was moving along. One respondent stated, *"We don't have enough baseline data, but we have to move forward because of national energy goals."* Another individual echoed these concerns, saying, *"I think we're going at such a fast rate, and the incentives to get these projects approved quickly have impeded the full evaluation* *of some of the data and resources. But we're trying to stave off world-level climate change, and we've got to act very quickly to change the trajectory that we're now on."*

3.6 Individual analysis

While there were trends across the two groups, when analyzed in the absence of a binary stakeholder group, there were further trends within respondents' quadrant centrality. For example, as discussed in Section 3.3, commercial fishers, on average, emphasized offshore wind infrastructure and community changes, while fisheries decision makers tended to focus more on management and environmental changes. However, on an individual basis, some respondents were more evenly dispersed across all quadrants. 71% of respondents (n=29) had one or more quadrants that comprised more than 35% of their mental model's overall centrality. Of the 29 individuals who disproportionately emphasized one or more quadrants, 17 were fisheries decision makers and 12 were commercial fishers. Conversely, 29% of respondents (n=12) had evenly distributed mental models, where each quadrant centrality was less than 35% of the mental model's overall centrality value. Of these 12 respondents, 9 were fishers, and 3 were fisheries decision makers (Appendix 2).

4. Discussion

4.1 General findings

The findings of this study exemplify that offshore wind is often considered by both commercial fishers and fisheries decision makers in conjunction with fisheries management and other ecological and community challenges. Overall, respondents had many similarities in how they valued which concepts were important to a fair future for fisheries (Table 1). For example, both commercial fishers and fisheries decision makers reflected that access to fish stocks and healthy fish stocks were important for a fair future for fisheries. Respondents also shared common values about the importance of preserving working waterfronts and job opportunities in order to contribute to a fair future for commercial fishing. Similarly, both groups agreed that increased costs of living would be detrimental to the future of fishing in the Gulf of Maine.

However, despite the commonalities that the two stakeholder groups shared, they also had different perceptions of what concepts acted as the primary drivers of negative or positive change. For example, although both groups prioritized maintaining access to fish stocks, commercial fishers viewed offshore wind as the primary threat to accessing fish stocks. In contrast, fisheries decision makers viewed climate change, offshore wind, and stock health as all equally impacting future access to fish stocks.

Just as there is increasingly a push for ecosystem-based management to better address how marine species are ecologically interconnected, a similar systems-thinking approach illuminates that the challenges that communities are facing are highly intertwined with one another. As such, the mechanisms used to address these challenges should aim to consider a similarly systems-wide perspective. However, the legal frameworks that drive the regulation of offshore wind and commercial fisheries create very little overlap for the two processes to inform one another. As respondents noted, the BOEM process, regulated through the Outer Continental Shelf Lands Act (OCSLA), does not require consultation with NOAA or the regional councils during the siting process. As the process currently exists, the public comment period is the only formalized opportunity for state and federal fisheries offices to influence the BOEM process. As a result, there is uncertainty in how the BOEM siting process will impact stock assessment surveys and how the two processes can inform one another. Social impact assessments are a relatively new consideration in management decisions. Furthermore, the lack of dialogue between these regulatory bodies means the cumulative social impacts of changes in fisheries management and offshore wind development are not considered together.

4.2 Views of climate change and renewable energy

As depicted in the different understandings of how offshore wind, renewable energy, and climate change are all connected, these findings suggest that decision makers' and fishers' underlying definitions of sustainability are not always aligned in scale. While both groups emphasized the need for renewable energy in order to address climate impacts, commercial fishers saw a weak connection between offshore wind and the generation of renewable energy. Where decision makers take a higher-level approach to achieving "sustainability" through large-scale energy development and achieving federal, if not global, climate targets, fishers take an individual and community-level approach to defining what sustainability means. This framing is consistent with the belief that the costs of climate solutions are necessarily incurred in order to address the overarching challenge of climate change. As Velasco-Herrejón et al. (2022) explain:

> "By contrast, wind energy developers, who are mainly based in Spain, France and Italy, follow an underlying philosophy rooted in the paradigm of modernization. This entails the transformation of traditional practices and customs of the local population towards a sustainability scheme that requires people to unreservedly accept clean energy production infrastructure as a necessary 'evil' in pursuit of a greater good" (Velasco-Herrejón et al., 2022)

Generally, commercial fishers were less comfortable making this sacrifice, whereas fisheries decision makers viewed this as a necessary trade-off.

On one level, fisheries decision makers perceived a greater impact of climate change on the overall system. This finding aligns with McClenachan et al. (2022) findings, which indicated that scientists perceived a stronger impact of warming waters on the lobster industry in Maine when compared with commercial fishers (McClenachan et al., 2022). On another level, even where respondents agreed on the impacts of climate change, fisheries decision makers viewed offshore wind as helping to combat the climate impacts that were a strong, negative driver of change to a fair future for fisheries. Conversely, commercial fishers perceived that the same renewable energy technology threatened a viable future for their fisheries and communities and believed that offshore wind development would have strong negative impacts on ecologically important habitat and species.

These differences in scale were mirrored in relation to ecological sustainability. Decision makers took on a higher-level view of sustainability, which framed overall climate health as the driver for negative impacts on stock and habitat health. In contrast, commercial fishers shared a similar importance of ecological health and sustainability but viewed offshore wind as the driver of negative impacts on stock and habitat health, without making as strong a connection between climate change and ecological health.

4.3 Need for renewable energy

Despite each group having varying views on the importance of climate change within the overall system, there was a common understanding that renewable energy would help address climate change and the impacts that it had on surrounding ecosystems and communities. Although it was not the most central concept within the average mental model, there was relative consistency in the belief that renewable energy would help address the impacts of climate change. However, the finding that fisheries decision makers were more likely to view offshore wind as contributing positively to climate change is an important difference when compared to fishing community members.

The nature of large-scale renewable energy projects, such as offshore wind, means that this energy is not necessarily being consumed within the communities that are most likely to be impacted by development (Bidwell et al., 2022). Therefore, the perspective that offshore wind is not going to contribute positively to climate change and the generation of renewable energy could be connected to the lack of ownership and direct benefit that is felt by coastal communities. This is consistent with Bidwell et al. (2022), who found that developments powering the communities they were directly in or next to were perceived as more equitable than those that exported power for it to be used elsewhere (Bidwell et al., 2022). Whereas smaller-scale renewable energy deployment can be driven at the community scale, it is more challenging to find clear pathways towards direct equity and ownership of large-scale developments. In contrast, however, the Maine Legislature passed a bill in July of 2023 that enables the procurement of 3,000 MW of offshore wind energy by 2040. These efforts indicate the intent to ensure that at least some of the energy generated by offshore wind in the Gulf of Maine is being consumed in Maine and that there are benefits directly felt within the state from development occurring in the region.

Regardless of the efforts made by state and regional entities to bring benefits from offshore wind development back to communities, the results from the study suggest that this renewable energy source is not viewed favorably by members of the commercial fishing industry. Despite a common belief that renewable energy is needed to address climate change impacts, fishers did not view offshore wind as a viable technology to achieve this goal. Another component of this difference could be the messaging that is used in the proposals for offshore wind development in the region. Scannell and Gifford (2013) found that individuals who engaged with climate change messaging that was locally relevant to where they resided, rather than more general global messaging, were more likely to engage with the information (Scannell & Gifford, 2013). The same 'local versus global' messaging could contribute to willingness to support climate change solutions, such as renewable energy development. Grounding the design of and communication about renewable energy development in terms of hyper-localized benefits could assist in community support for various forms of renewable energy.

4.4 Energy justice and the role of compensation

My findings also show that the majority of commercial fishing industry members did not view compensation as an adequate means of addressing impacts from offshore wind energy projects. This finding pushes back on previous research that suggests compensation plays a key role in obtaining distributional justice of energy development projects and accounting for environmental damages or impacts. While some existing energy justice literature has qualified compensation packages' ability to adequately address the impacts of energy developments (Leer Jørgensen et al., 2020), these findings push the narrative further by exploring how stakeholders perceive the impacts of offshore wind interacting with other regional stressors. Compensation packages are often crafted only to take into account the direct loss of fishing access from a specific development project. When considered together, however, these findings suggest that the regional vitality of coastal communities is being impacted by more than just offshore wind projects. Thus, proposals for financial support should attempt to address underlying challenges such as preserving working waterfronts, habitat restoration, affordable housing, or clean energy subsidies.

This framework of distributional benefits is similar to what is found in Community Benefits Agreements (CBAs). The benefits that CBAs can provide are wide-ranging and ideally meet the specific priorities of the communities that may be impacted by offshore wind development. Such benefits include community programs, direct payments, living wage guarantees, workforce development and hiring programs, affordable housing, environmental concerns, infrastructure upgrades, etc. (Hoff & Segal, 2023). However, community benefits agreements are often insufficient to act as a standalone mechanism for ensuring equitable outcomes from offshore wind development. Rather, they are one tool that can contribute to the responsible development of offshore wind and directly benefit proximal and impacted communities. Importantly, CBAs are typically a voluntary process that the developer pursues (Rudolph et al., 2014). Unless the regulating bodies that oversee the offshore wind leasing process stipulate CBAs in the lease application, these processes require project developers to voluntarily negotiate agreements with community groups.

Taken together, compensation packages are addressing one component of the overall equation that may impact fishing communities. While CBAs can have a more holistic impact, the details, delivery, and community support of the agreements are critical in determining the efficacy of the tool (Howley & Korein, 2024; Rudolph et al., 2014). O'Sullivan et al. (2020) explore the realities that many rural communities are not able to equitably engage in renewable energy technologies due to a lack of direct ownership (O'Sullivan et al., 2020). Exploring mechanisms for direct investment, equity, and other means of monetary benefit could play an important role in developing large-scale renewable energy projects that align with local communities' priorities.

While mechanisms to deliver financial benefits aim to create distributional justice within offshore wind development proposals, my findings highlight that the other tenets of energy justice are also of concern to fisheries stakeholders. In particular, both commercial fishers and fisheries decision makers shared sentiments that the processes used to site and permit offshore wind were not inclusive of necessary expertise and did not equitably consider the perspectives of fishers. These concerns over procedural justice and fairness have been demonstrated in other offshore wind development contexts in the New England region (Smythe et al., 2025; Bates et al., 2025; Bacchiocchi et al. 2022), and renewable energy development more broadly (Elmallah & Rand, 2022; Jami and Walsh, 2017). On average, both groups viewed access to decision making as benefiting a fair future for fisheries, however respondents perceived certain elements of access to decision as fairer than others. Efforts to achieve procedural justice in energy development projects should strive for effective collaboration with fisheries decision makers and industry members.

4.5 Fisheries management

As respondents from both stakeholder groups expressed, the aforementioned concepts were highly interwoven with one another. As such, it is necessary to consider the compounding impacts of various ecological changes on other systems that impact fish and fisheries in the Gulf of Maine. For example, the compounding impacts of climate change and offshore wind have significant impacts on survey and stock assessment capacity. As the abundance and spatial distribution of certain species in the Gulf of Maine change as a result of shifting climatic conditions, it is important to have the ability to accurately collect data on the health of these stocks. Climate change is already adding a high degree of uncertainty to the stock assessment process (Mazur et al., 2023), and offshore wind developments introduce another consideration in adapting stock assessment processes. Both offshore wind and climate change interact and impact the ability to collect sound data, determine accurate catch limits, and allocate quota.

Existing research suggests there are critical consequences of failing to account for climate change in groundfish stock assessment and management (Mazur et al., 2023) Although there is a growing discussion of the broader ecological implications of offshore wind arrays, there is not sufficient research on the specific impacts of the technology on the stock assessment process and how this added degree of uncertainty will be accounted for in ecosystem-based management (EBM) and quota allocation. In southern New England and the mid-Atlantic, offshore wind siting has impacted Atlantic surfclam stock assessment surveys, adding additional uncertainty to stock assessment models and quota allocation (Borsetti et al., 2023). One study suggests that 72% of stock assessment surveys in the United States and Europe are expected to interact with areas where offshore wind development is already constructed or is planned (Lipsky et al., 2024).

Among commercial fishers and fisheries decision makers alike, the importance of timely and accurate data was extensively highlighted. This included baseline data that were viewed as important in order to understand what the impacts of offshore wind would be, as well as fisheries data that are used for the allocation and management of fish stocks. Additionally, creating continuity between fisheries management and offshore wind regulation, more generally, is important. Assessing the cumulative social impacts of certain fisheries in the context of past management actions, changing species abundance, and future offshore wind development can help ensure that the burden of offshore wind development is not disproportionately shouldered by certain groups.

5. Conclusion

This study has shown that the regional vitality of coastal communities is being impacted by more than just offshore wind projects, and that a fair future for fisheries is challenged by a variety of factors that interact and compound in unique ways. Opportunities that were identified, such as the preservation of working waterfronts, are at times threatened by external forces, such as climate change, increasing storm occurrence, and higher costs of living. This is the context in which offshore wind is being proposed in the Gulf of Maine. The interconnected nature of the challenges and opportunities that exist in this region suggests that proposals for equitable energy transitions should attempt to address underlying causes for opposition and distrust.

Given the current political landscape and the Trump administration's hostility towards offshore wind development, the dialogue around offshore wind development and its impact on fishing communities is likely to change. Regardless of the evolving status of offshore wind development in the Gulf of Maine and changing regulatory environments, the findings of this study are still relevant. Notably, the agreement among respondents about the importance of access to fish stocks raises compelling questions about how stock assessments and scientific information, including social science data, can be incorporated into offshore wind siting and regulation.

Chapter 4: Conclusion

1. Academic contributions

As offshore wind has proliferated around the globe, so has the academic analysis of public perception, technological advancements, ecological interactions, and economic projections. In New England, much of the research that has occurred has attempted to catch up to the siting decisions that are being made. Social acceptance literature has pushed the narrative of NIMBYism and sought to explain the complexities of how individuals arrive at their perception of this renewable energy. I have demonstrated that the challenges that both commercial fishers and fisheries decision makers perceive in the Gulf of Maine frequently interact and compound to impact a fair future for commercial fishing in the region. This case study provides an example of how regional stressors and opportunities can be studied in dialogue with one another, rather than in isolation. Future renewable energy development, ecological changes, management decisions, and community shifts do not happen in a vacuum. The future of various industries and regional well-being is a product of a complex web of decisions, and therefore, utilizing a systems-thinking approach to research these topics is a useful contribution.

Furthermore, this research contributes a new and compelling methodology for studying offshore wind in the context of broader regional challenges. I have demonstrated the utility of Fuzzy Cognitive Mapping methodologies to model the complex challenge of fisheries management and offshore wind debates. Using this framework allows for the incorporation of stakeholder knowledge and can be structured in various ways to address different desired outcomes. There is a growing call for research that addresses the cumulative impacts (social and physical) of multiple offshore wind development projects. This research begins to fill a need to research the cumulative impacts of varying, but interconnected, regional changes.

2. Practical applications

The political landscape that this thesis is written within is changing by the day. On President Trump's first day in office, he released an Executive Order issuing a moratorium on the permitting of all offshore wind projects. Since then, he has halted all construction on the Empire Wind project off of the coast of New York (which notably is already fully permitted), only to reverse his decision and allow continued construction. On May 5th, 2025, 18 State Attorneys General filed a lawsuit against the Trump Administration seeking a preliminary injunction against the Trump Administration's offshore wind permitting freeze. This lawsuit is ongoing. Simultaneously, the policy landscape for fisheries management is shifting rapidly. Broad efforts to deregulate industry have implications for the management of commercial fisheries, and vast cuts to NOAA are expected to have critical impacts on the scientific capacity to inform decision making. On April 17, 2025, President Trump issued an Executive Order titled "Restoring American Seafood Competitiveness," which aims to deregulate the commercial fishing industry. This includes a review of existing marine national monuments to assess and recommend which protected areas should be opened to commercial fishing.

While these profound changes have occurred since the time I conducted the interviews for this research, I release this work into a world that is facing a new reality. In the past eight months, I have been painfully aware of the individuals I spoke to in the summer of 2024 who have since left their positions, the new regulatory contexts that relate to this work, and the fraught political climate that seems to be changing by the day. However, while the federal administration aims to undermine core environmental protections, there are efforts within the region, and elsewhere, to continue to prioritize equitable energy transitions, sustainable fisheries management, and meaningful science-based decision making. As such, the findings of this research continue to have practical application within this new context. Perhaps, this work can offer important considerations that enable us to reimagine how fishing stakeholders are involved in decision making processes, how offshore wind energy can contribute to a greener, and more just future, and how interagency collaboration can lead to more informed and holistic management.

There is a growing effort within New England fisheries management structures to incorporate social science data into decision making processes. The New England Fishery Management Council voted to establish a social science subcommittee of the Scientific and Statistical Committee (NEFMC SSCSSS) in December 2024. According to documents presented at the inaugural SSCSSS meeting on June 3, 2025, there is an acknowledgement that social science data are often readily available in the Northeast, yet these data are rarely incorporated into stock assessments. As one individual voiced, "We don't manage fish, we manage people." Both the findings of this study and the methodology that it uses can contribute to efforts to increase the presence of social sciences in the fisheries management process.

In addition to processes already underway, the findings of this study pose unique opportunities given the political crossroads that we are currently in. While the actions of the Trump Administration have threatened the present-day viability of the offshore wind industry in the U.S., this political whiplash provides an opportunity to take stock of the regulatory processes that have been used to site offshore wind. The findings of this study illustrate many similarities between commercial fishers and fisheries decision makers. Although there are key areas of disagreement, there is also common ground in the value respondents placed on monitoring and research needs, transparency and communication in engagement processes, and addressing community needs in both renewable energy transitions and fisheries management decisions. There is an opportunity to leverage these similarities to reimagine how renewable energy development can be developed to benefit local communities and aim to address existing regional challenges, rather than compound them.

3. Limitations

There are a number of limitations within this work that should be recognized. First, I set out in this research to compare the mental models of fisheries decision makers and commercial fishers. While this comparison has produced interesting and compelling analyses, the nature of this comparison has also required that I place respondents into quasi-artificial binaries of "commercial fisher" and "fisheries decision maker." In reality, the roles that these individuals serve within their respective communities exist on a spectrum. While I have attempted to address this limitation in the final analysis (see Section 3.5), there is ample opportunity to further explore how people come to their understandings of these concepts, such as using a multidimensional scaling analysis (Hout et al., 2013).

The second limitation is in the geographic scope of this research. The focus of this research was on the Gulf of Maine region; however, the spatial scale of the two stakeholder groups was not entirely aligned. Some of the fisheries decision makers that were included in the study represent the Northeast region more broadly, including Georges Bank and Southern New England. Their experiences in these regions may have contributed to the perspectives they shared. The offshore wind context in Southern New England, for example, is several years ahead of the Gulf of Maine. Furthermore, while many of the commercial fishers represented in the study fished in federal waters or from ports outside of the state of Maine, I did not interview any fishers who fished in the Gulf of Maine but lived outside of the state of Maine (i.e. New Hampshire or Massachusetts residents). Doing so could have produced different perspectives about how state-specific management structures, exacerbated costs of living, and other regional changes are unique from those who live in Maine.

Thirdly, fuzzy cognitive mapping is a promising methodology for studying interactions within complex systems. However, there are inherent limitations within this methodology. In this study, I opted to construct FCMs with a set of predetermined, standardized concepts. While this approach enabled a more streamlined data collection process and analysis of FCMs, the set of standardized concepts had the potential to bias respondents in the interview process (Gray et al., 2013). Although there were some freely associated concepts that occurred across respondents at high frequencies, additional concepts were not analyzed in as consistent a manner compared to standardized concepts. As with qualitative data of other kinds, mental models and FCM have an inherent degree of subjectivity. Mental models are often situation-specific and are evolving and incomplete representations of an external reality (d'Armengol et al., 2021; Jones et al., 2014). This methodology is effective in incorporating stakeholder knowledge of complex systems into management discussions, but has strengths and drawbacks, which should be assessed accordingly.

Finally, as discussed above, the political context of this research has shifted drastically since I began this project. While this research can only represent a snapshot in time of the perceptions and attitudes of individuals, the future of offshore wind development and fisheries management is changing so rapidly that these questions are deserving of continued monitoring and discussion that is outside the temporal scope of this study.

4. Future research opportunities

Considering social science research and the cumulative social impacts of offshore wind developments and fisheries management is a growing and important focus in management processes. However, the tools that exist to quantify and address the cumulative impacts of additive and interacting challenges are limited. While the use of mental models is an effective way of understanding how multiple changes and challenges interact to impact a socio-ecological system, this methodology does not go so far to quantify the cumulative social impacts in a way that could be leveraged in management decisions. The conceptual framework from Arnold et al. (2022), is a helpful tool, however future research should continue to refine these frameworks and assess the implementation of cumulative social impact assessments into management processes. Just as cumulative impact assessments are increasingly being proposed to study the broader ecological impacts of continued development or resource extraction, the use of similar frameworks to assess prolonged and cumulative socio-economic impacts should continue to be studied.

The framing of this research was around what respondents viewed as contributing to a fair future for commercial fisheries in the Gulf of Maine. The concepts that were discussed in each interview provided insight into how individuals conceptualize a "fair future" for fisheries and how individuals perceive these concepts interacting with one another. The analysis of these cognitive maps has illustrated key similarities and differences between the stakeholder groups, and between individuals, however each of these concepts could be studied in further detail to identify leverage points and thresholds. The nature of FCM requires respondents to attribute a value to any given interaction between concepts. Although the qualitative data collected during the interview process begins to unpack the nuances of the respondents' answer, further qualitative analysis would be beneficial to determine the specific elements of a concept that could be changed or leveraged. For example, "access to decision making" was a concept that had significantly different interaction strength and centrality values between stakeholder groups. While each believed access to decision making processes benefited the future of fishing, decision makers were significantly more likely to say that the current processes were positively impacting the overall system. Understanding more specifically what elements of contested concepts were deemed to be successful or unsuccessful could build on the results of this study.

Finally, Fuzzy Cognitive Mapping offers just one approach to studying this timely and ongoing discussion of contributing to fair, viable, and sustainable fisheries in the Gulf of Maine. There are alternative systems-thinking approaches that would lend themselves well to assessing how multiple challenges are impacting fisheries and how offshore wind contributes to, interacts with, or detracts from creating a fairer future. For example, one study uses a Life Cycle Sustainability Assessment (LCSA) approach to assess how offshore wind farms will impact fishery rights in Taiwan (Liu, 2025). The context of this study could also benefit from a more thorough assessment of fisheries and offshore wind through the frameworks of energy justice and social justice. There is a growing field of research that explores offshore wind development through the context of the triumvirate tenets of energy justice (recognition, procedural, distributive), but there have been more recent calls to consider similar frameworks in the impacts of climate change on fisheries (Harper et al., 2023). This presents an opportunity to utilize a justice framework to look at climate change impacts, commercial fisheries, and offshore wind in conjunction with one another.

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Appendix

Appendix 1.

Appendix 1. Qualitative data were derived from 41 interviews. The table is organized by quadrant, representing various types of interactions that respondents described as the mental models were being drawn. Red cells indicate a negative interaction, green cells indicate a positive interaction, and yellow cells indicate an uncertain interaction.

Driver (quadrant)	Type of impact	Commercial fishers	Fisheries decision makers
Offshore wind	Stock and habitat health	If you push turbines into soft bottom could make an artificial reef out of them	Lose access, but the tradeoff is a mini reserve that is created - spillover effect
		It could create a safe haven due to closed areas, good for stock health	OSW will affect stratification in addition to climate change
		"We're sacrificing the ocean in the name of green energy"	Structure tends to help marine species, and could possibly have benefits, but it could look bad
		OSW could change species migrations. Martha's Vineyard/Block Island fishermen not seeing crabs anymore	Offshore wind is actually pulling excess energy out of the system that is a product of climate change - this is a good thing
		Blasting for OSW impacting stocks	Not sure if OSW is going to have a positive impact on climate change - don't think it will hurt, but not sure if it will help this late in the game
		Lobster larvae are going to be impacted by cables and electromagnetic fields	OSW will help with climate change, but downplaying the environmental impacts of OSW with the Port Authority discussion and Sears Island
		It's not really an artificial reef…lobsters get zapped, shell disease, die-offs, etc.	
		Turbine that broke off in Martha's Vineyard, no recovery efforts	
		No one's talking about this cooling trend - pumping heated chlorinated	

		water seems ironic and impacts thermal patterns	
		EMF interference, cooling stations, impacts to haddock/lobster larvae	
	Access	Don't think fishermen should be bought out - everyone should have access to the ocean	The aggregation effect of turbines can help recreational fishers
		OSW will take over wharves	Defacto MPA, which may increase fishing opportunities
		Heard herring will bunch near windmills but we can't access them	Fishermen who fish for groundfish are already constrained by closed areas and management measures, so they can't just move somewhere else
		With offshore sites, you're blocking access to key groundfish	Some fisheries have done okay - some recreational fisheries have new opportunities, but some commercial fisheries are displaced
	Management of endangered species	Impacts to whales from surveys and turbines	"I don't think that building OSW will be the factor that drives right whales to extinction" - even if they contribute to noise, ship traffic, etc., continued burning of fossil fuels and climate change are bigger threats to right whales."
		OSW is right in the middle of whale migratory paths	
	Surveying	They haven't created any baseline data, so how do you measure the effects on fish stocks?	In some cases, the survey will be totally precluded from the OSW infrastructure
			"We don't have enough baseline data, but we have to move forward because of national energy goals."
			Climate change makes surveys more difficult - could be seeing a "decline," but really species are just moving, and it depends on the species; some surveys are meant to determine catchability

			OSW is going to impact stock assessments, which increases uncertainty in data
	Jobs	OSW could create jobs, but they are not going to be local jobs	OSW will create jobs - commercial vessels will be used as support services
		OSW is not going to create new jobs, going to divert other jobs, and they are not going to support lobstermen	Could be jobs created, but not necessarily jobs that contribute to a fair future
	Cost of living	Payments and/or renewable energy generated from it wouldn't impact the household budget	Jobs created by OSW may drive up living costs because of new movement and housing needs in the area
		OSW is increasing energy costs	
		OSW is creating higher insurance costs, more policies, and more stress	
		The cost of insurance will go up, cost of electricity will go up	
Management	Stock and habitat health	Catch shares are ruining stock health	
		There's too much access to fish stocks, trawlers destroyed the whole industry	
		Restricting gear types would help stock health	
		Endangered species management has benefited habitat (salmon recovery)	
	Costs	Right whale rules keep changing, so much money is spent changing ropes	
		The cost of going ropeless would outweigh any profit of the industry, $1500 per buoy	
		The cost of quota is prohibitive - staying on the dock	

		The cost of quota impacts people's ability to access fish stocks	
Ecological changes	Access		With climate change, species distribution is changing - management structure now makes it very hard to get access to these stocks Stocks are moving; how do we manage this? How can management be adapted and kept flexible? Species are moving in faster than regulations can change to have the ability to catch these species legally Can't maintain a future fishery if the fish don't exist
	Surveying	Haddock, monkfish, and scallop survey - climate change is making everything more difficult and creating uncertainty	We're not following the fish, we're surveying where we've historically fished
			Climate change is totally changing stock assessment processes
	Jobs	With better stock health, there could be more jobs (i.e. herring, canning, downstream impacts) "If herring were thick, there could be great community benefits."	
	Endangered species management		"Climate change pulled the rug out from under us in our right whale management."
	Cost of living		Climate change is increasing the cost of living - we have to go further to access stocks offshore, and higher fuel costs Cost of living and coastal development are increasing with climate change - ME is becoming more desirable from a climate standpoint
	Preservation of working waterfronts	Climate change is decreasing access to waterfront	Severe damage from 2024 storms - climate impacts are the most significant

			challenge to preserving working waterfront

Appendix 2. Radar charts showing the quadrant centrality of each respondent. Parts a-d) of the figure show individual respondents who had one or more quadrants that comprised over 35% of their mental model's overall centrality. Part e) shows individual radar charts that have even centrality across all quadrants (each quadrant centrality was less than 35% of the mental model's overall centrality value). The individual's index score is represented in parentheses.

a) Quadrant 1 (management) ≥ 35%

Fisher 4 (1)

Fisher 15 (1)

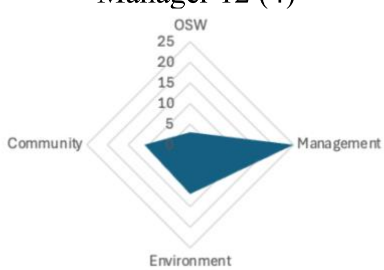
Fisher 18 (2)

Fisher 20 (2)

Fisher 21 (2)

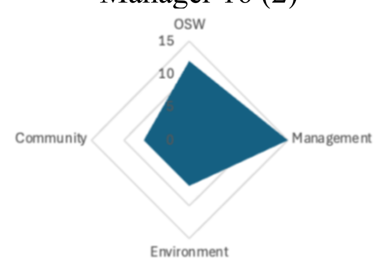
Manager 4 (1)

Manager 12 (4)



Manager 15 (2)

Manager 16 (2)



Manager 17 (2)

Manager 18 (4)

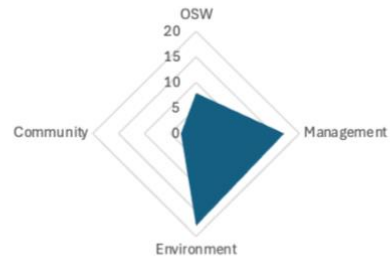
Manager 19 (4)

a) Quadrant 1 (management) ≥ 35%

b) Quadrant 2 (environment)

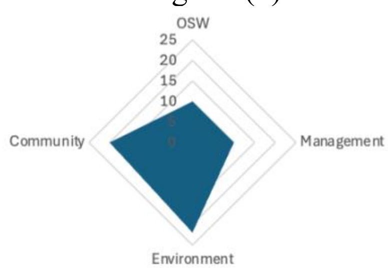
Manager 1 (1)

Manager 2 (4)

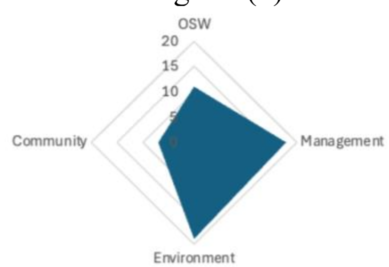


Manager 3 (1)

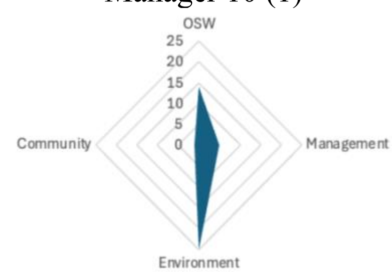
Manager 7 (1)



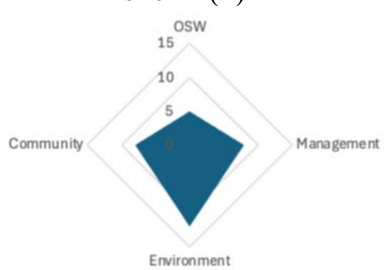
Manager 8 (1)



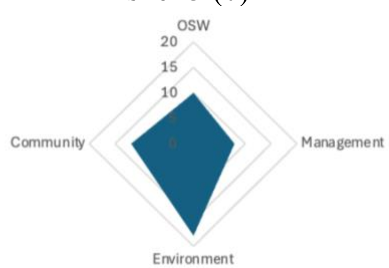
Manager 10 (1)



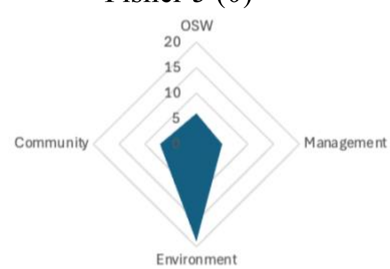
Fisher 2 (1)



Fisher 3 (0)



Fisher 5 (0)



Fisher 12 (1)

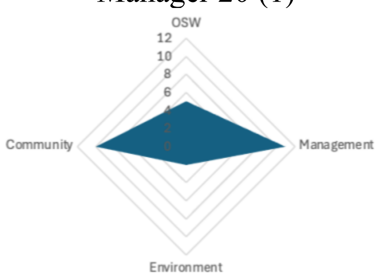
c) Quadrant 3 (community)

Fisher 8 (0)

Manager 5 (1)

Manager 14 (2)

Manager 20 (1)



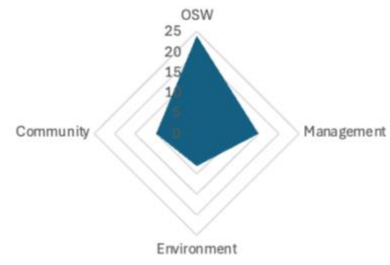
d) Quadrant 4 (offshore wind)

Manager 11 (4)

Fisher 10 (1)

Fisher 16 (3)

d) Quadrant 4 (offshore wind)



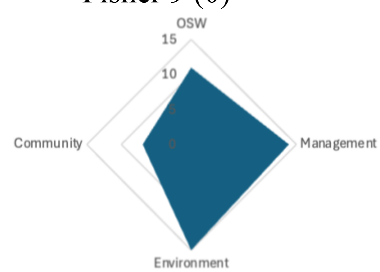
e) Even quadrant centrality

Fisher 1 (1)

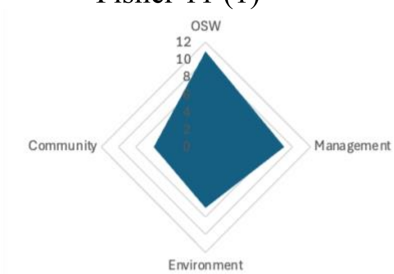
Fisher 6 (1)

Fisher 7 (2)

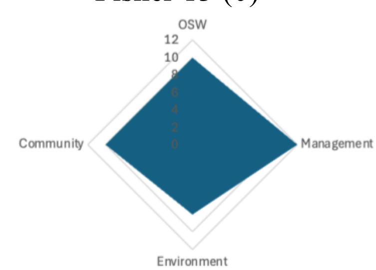
Fisher 9 (0)



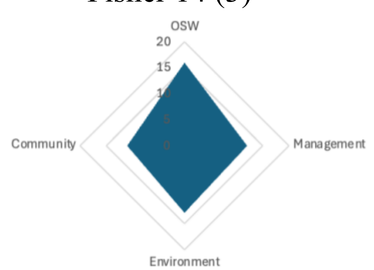
Fisher 11 (1)



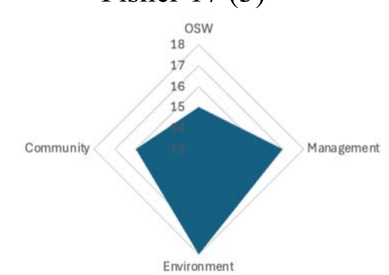
Fisher 13 (0)



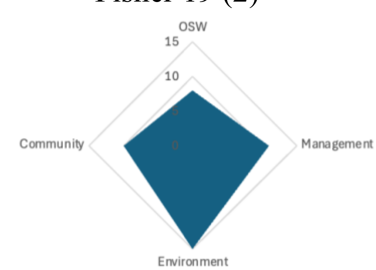
Fisher 14 (3)



Fisher 17 (3)



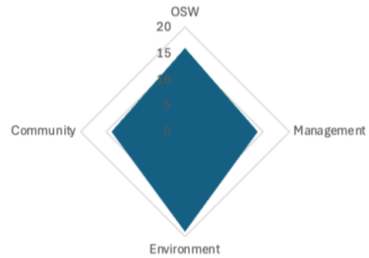
Fisher 19 (2)



e) Even quadrant centrality

Manager 6 (1)

Manager 9 (0)



Manager 13 (4)