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Analyzing Supply Chain and Water Quality Management in the Soft-shell Clam (Mya arenaria) Fishery under the Impact of Shellfish Closures in Downeast Maine

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ANALYZING SUPPLY CHAIN AND WATER QUALITY MANAGEMENT IN THE SOFT-SHELL CLAM (MYA ARENARIA) FISHERY UNDER THE IMPACT OF SHELLFISH CLOSURES IN DOWNEAST MAINE

By

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By Shuling Chen
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An Abstract of the Thesis Presented
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Water quality issues have affected Maine's soft-shell clam fishery which is of great significance to community livelihood, social employment and tourism. To ensure shellfish product safety for consumers, state government issues temporary closures on clam flats. As a result, access to this fishery resources has been decreased and has caused revenue losses to fishing communities. Despite the improvements in understanding the financial losses of shellfish closures, there is a lack of knowledge about stakeholder perceptions and actions under such impact.

This master's thesis looked closely at the clam dealers across the supply chain and water quality management in the soft-shell clam fishery. I used a mixed-method case study approach to explore key stakeholder responses to and perceptions about shellfish management. On the qualitative side, I conducted semi-structured interviews with certified shellfish dealers in the fall,

2017 (n=9). I gathered quantitative dealer reports to explore interactions of dealers (n=61) with fishers concerning five different species during 2008-2014 in Downeast Maine. I compared the characteristics of the supply chain in Downeast Maine and Midcoast Maine. To understand the water quality management on paper and in practice, I collected policy documents and past stakeholder interview data.

In Chapter 2, I evaluated the supply chain structure and geographical scale in the soft-shell clam fishery and clam dealers' daily trade performances. Results highlighted the differences of soft-shell clam supply chain geographical scales between Midcoast and Downeast Maine in terms of the upstream sources and downstream outlets of the clams. In terms of the trade interactions, I found high loyalty in harvesters when choosing how many dealers to sell their landings to.

In Chapter 3, I examined the water quality management through policy documents and stakeholder interviews. It demonstrated the top-down direction of policy implementation from federal to municipal level. Stakeholder interviews showed high diversity in terms of perceptions about pollution issues, water quality management, policy compliance and adaptation during closures. Results also revealed the lack of municipal participation in the management, leading to limited room for adaptation in different water quality conditions.

The results of this study underlined the importance to understand the supply chain in the fishery to inform shellfish management from market perspectives. The complexity of stakeholder perceptions advocates for more active participation of municipalities in the water quality management to enable adaptation during temporary closures.

DEDICATION

This work is dedicated to my mom and dad for giving me life and always convincing me that I am stronger than I think. It is also dedicated to the dreamers that inspire me with boundless possibilities.

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LIST OF ACRONYMS

DEI	Downeast Institute. 65
DEP	Department of Environmental Protection. 45
DMR	Department of Marine Resources. 1
FDA	Food and Drug Administration. 1
HABs	harmful algal blooms 56
HACCP	Hazard Analysis Critical Control Point. 36
ISSC	Interstate Shellfish Sanitation Conference 53
MCA	Maine Clammers Association 65
NGOs	non-governmental organizations....65
NOAA	National Oceanic and Atmospheric Administration 66
NSSP	National Shellfish Sanitation Program.....35
PSP	paralytic shellfish poisoning 56
SCM	supply chain management....21
ShAC	Shellfish Advisory Council....58
UNESCO	United Nations Educational, Scientific and Cultural Organization 1

CHAPTER 1

INTRODUCTION

1.1 Background

In the 21st century, water quality issues, have impacted social and political processes around the world. Untreated sewage discharge and non-point source pollutants due to anthropogenic activities have caused severe pollution and worsened water sanitation (UNESCO, 2015). Poor water quality affects marine ecosystems and services and threatens marine fisheries production (Islam & Tanaka, 2004). Among the affected marine fisheries species, mollusks, are substantially susceptible to the surrounding environment and are likely to be contaminated with bacteria and biotoxins. As filter feeders, mollusks such as soft-shell clam (*Mya arenaria*) might be affected by poor water quality and cause consumption concern due to pollutant accumulation (Brow et al., 1977; Metcalf et al., 1979; Rippey, 1994).

The soft-shell clam fishery in Maine has been susceptible to water quality problems (Congleton et.al, 2006; Evans et.al, 2016). To ensure the sanitation and quality of fisheries product, U.S. Food and Drug Administration (FDA) launched water quality standards for commercial harvesting (FDA, 2015). Following federal standards, the Maine Department of Marine Resources (DMR) classifies shellfish growing areas and issues temporary shellfish closures to promote shellfish security. Subsequently, decreases of access to the fishery have led to significant financial losses (Congleton et al., 2006; Evans et al., 2016; Hanna, 2000).

The soft-shell clam fishery has been the most valuable shellfish fisheries in Maine and has made contributions to community livelihood, employment and tourism. As a complex

social-ecological system, the soft-shell clam fishery is linked to a wide range of industries and is an important part of the resilience of coastal communities and livelihood (Hanna, 2000).

1.2 Research objectives

Past research has identified the economic losses due to poor water quality in the soft-shell clam fishery (Athearn, 2008; Evans et al., 2016). However, there is a lack of socio-political research about resource dynamics, especially related to adaptation and economic issues. To improve knowledge on responses to the impact of temporary shellfish closures in the soft-shell clam fishery, this study explores the characteristics of the clam seafood supply chain and water quality management.

1.3 Thesis organization

In Chapter 2, I examined the seafood supply chain structures and identify key stakeholders in the soft-shell clam fishery of Downeast Maine. The seafood supply chain is a series of entities that function as the upstream and downstream flows of the products from production sources to consumption ends (Mentzer et al., 2001). As shellfish closures are issued to guarantee seafood safety, clam supply is likely to go down due to poor water quality. According to the market adaptation theory (Trondsen, 2012), stakeholders on the supply chain take adaptation strategies in changing markets to optimize their benefits.

To understand the complex system of the soft-shell clam supply chain, I took a mixed-method case study approach (Creswell, 2009). Guided by past supply chain research, I analyzed the multiple aspects of the supply chain through qualitative interview data and

quantitative dealer reports. In comparison with the 1977 study, results demonstrated the general structure of the supply chain and also highlighted the complex relationship dynamics. As key players across the supply chain, clam dealers mirror the variations of characteristics and adaptation.

In Chapter 3, I explored how co-management in Downeast Maine soft-shell clam fishery deals with water quality. Co-management is a governance arrangement based on the shared rights and responsibilities among government and resource users (Berkes, 2009). Social-environmental changes require flexibility within management regimes to adapt (Armitage et.al, 2009). McClenachan, O' Connor and Reynolds (2015) described that co-management improves the adaptive capacity of Maine's soft-shell clam fishery under the threats of green crab (*Carcinus maenas*) predation. However, there is still a need to understand relationships between the co-management and water quality issues.

When exploring the links between water quality issues and soft-shell clam co-management, I collected and analyzed qualitative data from policy documents and interviews with state and municipal stakeholders. Water quality issues related to the soft-shell clam fishery have been addressed under the policy arrangements of co-management between state government and local municipalities. It suggested that after the water quality standards were set up by FDA, the state government would follow the federal guidelines and tend to have more power in the decision-making process in terms of water quality monitoring and closure issuance. Local municipalities, if under the co-management setting, are required to issue municipal shellfish ordinances and establish local committees to manage shellfish resources.

Findings also reflect emphasize the complexity of perceptions about the water quality issues and underlines the different perspectives of governance and resource use.

Multiple factors are found to shape the supply chain performances. These factors include price determination power, market competition and collaboration, which adds to the 1977 analysis. On the management side, however, supply chain stakeholders are managed separately. In the end, I call for more comprehensive supply chain management to take the complex dynamics of the supply chain into account. I also recommend more collaborations along the supply chain to improve the adaptation to water quality issues.

Discoveries of the water quality management provide valuable insights into the complex system of the soft-shell clam fishery from social and political perspectives. By demonstrating the present and potential limitations of the system adaptive capacity under the impact of water quality issues, this study calls for future research to pay attention to this dynamic system.

CHAPTER 2

ANALYSING SOFT-SHELL CLAM DEALERS ACROSS SUPPLY CHAINS IN DOWNEAST MAINE UNDER THE IMPACT OF SHELLFISH CLOSURES

2.1 Introduction

Water quality issues have affected marine ecosystems worldwide and have caused the significant impact on coastal fishing communities (Islam & Tanaka, 2004). In the face of water quality issues in polluted areas, fishery access has been limited to protect public health. Subsequent decreases in commercial landings can affect variations of supply in the seafood market. Past research found out that stakeholders in the market need to adjust their behavior to uncertain market supply (Grundvåg & Grønhaug, 2004). Therefore, stakeholders reliant on the supply chain need to adapt to the supply changes, which applies to Maine's soft-shell clam (*Mya arenaria*) fishery.

In the state of Maine, the soft-shell clam fishery has been among the top-three most valuable fisheries (ME DMR, 2018). In 2017, soft-shell clam was third after American lobster (*Homarus americanus*) and Atlantic herring (*Clupea harengus*) and took up 2.2% of the total commercial landing ex-vessel value of approximately $570 million (Fig 2.1). Among all the counties in Maine, Washington and Hancock in the Downeast region have historically been the most productive regions for clam landings. Washington County produced around two thirds of the State landings in the 1970s (Congleton et al., 2006).

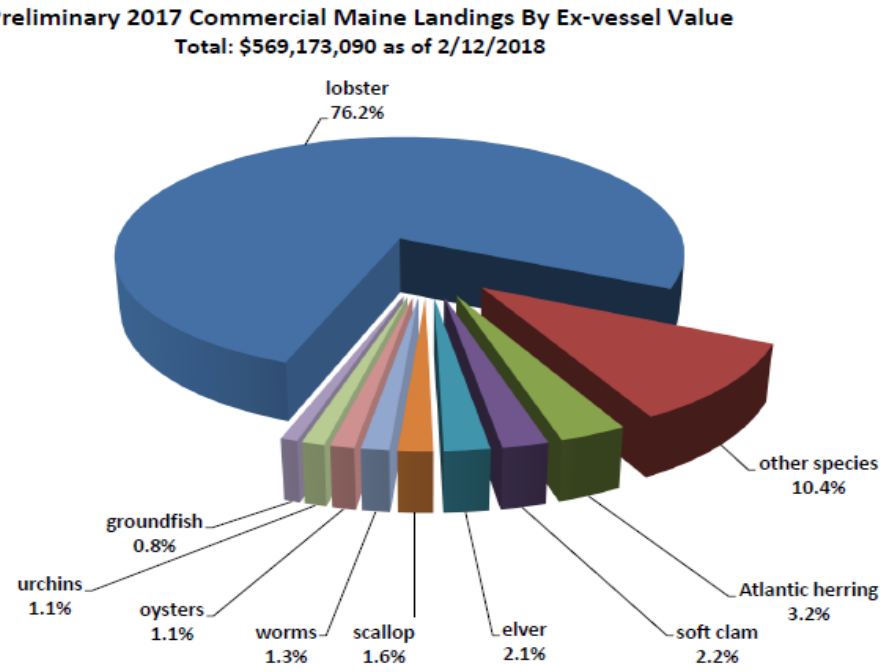

Figure 2.1 Preliminary Maine commercial landings by ex-vessel value in 2017 (DMR, 2018).

Because of its importance regionally and to the state, in this study, I focused on Downeast region.

Water quality issues in the soft-shell clam fishery are significant due to human impact (Athearn, 2008). Specifically, water quality issues in Maine can be attributed to coastal pollution and red tide (Evans et. al, 2016). Coastal pollution includes point source pollution and non-point source pollution. Point source pollution is usually caused by sewage treatment plants, whereas non-point source pollution is related to rainfall and coastal flooding which wash the pollutants into the water systems. Because of the wide distribution of non-point source pollutants, it is hard to identify the source of pollution in this case, which adds challenges for the government pollution abatement.

To ensure shellfish sanitation, ME DMR conducts bacteriological and chemical testing with shellfish growing waters and shellfish sample to measure bacterial and biotoxin

level. When concentration of pollutant, such as fecal coliform, exceeds certain level[1], temporary shellfish closures are issued. The sanitary survey required by FDA to categorize shellfish growing areas include procedures of testing several key components related to water quality: 1) evaluating potential pollution sources; 2) assessing weather factors; 3) reviewing hydrographic factors impacting distribution of pollutants in the areas and 4) testing water quality. It is apparent that procedures to ensure water quality are more complicated than water quality sampling. Based on the causes of worsening water quality, there are two major types of temporary closures in Maine: bacterial (pollution and flood) and biotoxin (red tide) closures. Specific bacterial closures include conditional area closures, emergency flood closures, aquaculture closures and pollution abatement closures.

Biotoxin closures, also called as red tide closures, are organized by species of shellfish from soft-shell clams to blue mussels (*Mytilus edulis*). Closures can last for different lengths of time, from days to months, related to the specific causes. Information about closures location and duration has been updated on daily basis on DMR websites and is accessible through phone calls. The frequency and magnitude of temporary closures likely has an impact on stakeholders in this system, yet there is little known about these impacts. Further, shellfish dealers and shellfish supply chains have not been closely examined, and especially the connections between water quality issues and supply.

Recent research has paid attention to the financial losses of shellfish closures which decreased the access to the fishery (Athearn, 2008; Evans et.al, 2016). Results suggested

[1] Different concentration limits apply to different dilution tests.

there were substantial losses of income due to temporary closures. As a complex social-ecological system, the soft-shell clam fishery plays an important part in the health and survivability of coastal communities (Hanna, 2000). Considering the significant contributions of supply chains to the dynamics of wild capture fishery (Future of Fish, 2005), it is important to learn about the soft-shell clam supply chain.

Globally, the wild capture seafood supply chains consist of similar stakeholder and operation elements, including fishers, processors and distributors. However, there are also variations due to different local physical and regulatory situations (Fleming et.al, 2014). Across the wild capture seafood supply chains worldwide, seafood dealers play significant roles by transferring wild catch from fishers to a wide network of distribution down the chain (Future of Fish, 2015).

A 1977 Maine soft-shell clam dealer analysis has explored the supply chain structure and dealer performances (Prysunka et.al, 1977). In 1977 analysis about clam dealers across the coast of Maine, it showed that dealers might also harvest clams themselves. In terms of downstream directions, most of clams were sold to wholesale outlets. When asked about price determination, more than half of the interviewed dealers felt that market competition from other dealers tended to decide on the prices of clams whether purchase or sale price. Impact of individual buyer or seller decisions was also recognized. Despite the "high point" of clam harvests in the 1970s, 45% of the interviewed dealers expressed their thoughts about future decreases in firm growth opportunities. However, 40 years have passed, and the soft-shell clam market might no longer be the same given the landing decreases. This study

intends to improve the knowledge about dealer behavior across the supply chain under the impact of shellfish closures.

To describe the current soft-shell clam supply chain, I took a mixed-method approach with nine semi-structured interviews of certified shellfish dealer stations in Midcoast and Downeast Maine (Creswell, 2009; Yin, 1994). During these interviews, I asked questions about dealers' roles in the supply chain, their business performances around the year and responses to shellfish closures. A supply chain literature review helped guide the subsequent analysis. Results demonstrated various supply chain structures, dealers' business diversity, geographical scale and adaptation strategies. To examine dealers' performances from quantitative perspectives, specifically interactions with clam harvesters, I analyzed DMR shellfish dealer reports within Downeast region from 2008-2014. In these reports, I discovered multiple aspects of dealer performances including years in operation, trade species diversity, interacting harvester amount and annual trade volume etc. To understand dealers' potential differences in behavior, I compared our results with the 1977 soft-shell clam dealer analysis.

Results showed that the general supply chain structure remained the same, despite differences in locations, as dealers might function differently across the supply chain. The case of soft-shell clam shows that the supply chain is a complex system more than the flow of commodities from production to consumption. It is an interrelated system involving multiple relationship dynamics that are shaped by complex factors such as loyalty and power. Among the supply chain relationships, "dealer loyalty" is highlighted in this research. The concept of dealer loyalty can be traced back to the 1990s in the automobile markets (Bloemer &

Lemmink, 1992). It refers to customers' repeat purchasing from the same dealers and has been associated with brand loyalty. Such an idea has been described more as customer loyalty in past research and marketing researchers explored cognitive, situational and attitudinal factors affecting purchasing decisions. It was suggested that dealer loyalty is a complicated phenomenon (Dick & Basu, 1994; Oliver, 1999). In cases related to fishery, dealer loyalty has not been studied yet. However, exploring dealer loyalty could provide insights about dealers' interactions across the supply chain, especially with fishers. Therefore, I modified this concept to apply it to this research. Instead of dealers deciding which clammers to buy from, typically, clammers are more mobile and can decide which dealer stations they want to go to. Dealers might be less mobile as they might have to be in their stations, but they could go out to clammers to buy clams. Dealer loyalty, in this case, refers to harvesters' repeating sales to the same dealers, which is the opposite direction of traditional dealer loyalty (Bloemer & Lemmink, 1992). Long-standing reputation, consistent information exchange and stable supply are suggested to enhance dealer loyalty. However, in certain situations, the buyer-seller relationships are maintained due to imbalanced power as clammers might have more market power.

Under the impact of supply changes due to temporary closures, dealer responses vary in relation to their business scale and sizes. Dealers might not need to respond to temporary closures if their business includes multiple categories of commodities or other fisheries species. Dealers facing clam supply decreases might resort to other clam sources if they buy clams from a wide geographic range. Dealers with high reliance on the soft-shell clam fishery might close the station during severe closure season.

In the following contents, I will explain the mixed-method case study approaches in more details with the study site background in 2.2. Section 2.3. will mainly focuses on the findings from supply chain literature review. Following literature review, I will describe major findings from my qualitative and quantitative data in 2.4. At the end, I will discuss the characteristics of the clam supply chain and the dealer performances in 2.5.

2.2 Methods

2.2.1 Study site

In this research, I focused on the Downeast Maine region which has witnessed decreasing economic reliance on the soft-shell clam fishery due to landing decreases. Therefore it provides a great example to explore the adaptation of the soft-shell clam supply chain (Safford & Hamilton, 2012). Downeast region, at the north-eastern corner of the State of Maine (Fig. 2.2), consists of Washington County and Hancock County with different demographics and thus offers great conditions for inner comparison. The coasts of Midcoast Maine region which range from Waldo County to northern parts of Cumberland County will be explored mainly to compare with Downeast Maine region.

Washington County, which borders Canada, has been among the most reliant regions on the soft-shell clam fishery. During 2011-2015, three towns (Jonesport, Beals and Milbridge) in Washington County were among the top ten towns in Maine in terms of ex-vessel values (ME DMR, 2018). On top of direct commercial values out of the landings, the

Figure 2.2 Downeast region of Maine (Counties included are highlighted in red).

soft-shell clam fishery contributed to local employment, municipal services and tourism industry etc., adding to the reliance of the communities on the fishery. In comparison with Washington County, Hancock County is growing faster in part due to tourism-related industry. Hancock County has benefited from being close to the popular Bar Harbor and Acadia National Park which have served loads of tourists especially in summer seasons. The population in Hancock County has risen by 64% between the 1970-2010 period, which is closely related to the area's beautiful scenery and New England characters attracting seasonal housing in the area (Safford & Hamilton, 2012).

Historically, fishery and related commercial industry has been the economic core of the Downeast region. In the past decades, pollution has been a severe issue in the Downeast Maine region, especially in terms of its impact on the soft-shell clam fishery. With the diversifying of economic sources, however, recent decades have seen a decrease of Downeast Maine's reliance on the fishing industry together with the increase of salmon and shellfish aquaculture (Safford & Hamilton, 2012).

2.2.2 Mixed-method case study approach

I took a mixed-method case study approach (Creswell, 2009; Yin, 1994) to conduct explanatory inquiries into the supply chain structures and dealer performances (Fig 2.3). I collected both qualitative and quantitative evidence concurrently.

In the qualitative section, given the significant intermediary roles of shellfish dealers, I conducted nine semi-structured interviews are conducted with nine shellfish dealer companies. To explore supply chains in the Downeast Maine region and make comparison with Midcoast Maine, I conducted interviews from Machiasport to Portland.

Initially, I reviewed information list about DMR certified shellfish dealers and conducted semi-structured interviews at dealers' wiliness (ME DMR, 2018). During interviews, I asked questions about upstream clam sources, downstream interacting stakeholders, business operations and responses to temporary shellfish closures. I recorded conversations after receiving permission (Appendix A). During this process, since information about specific upstream and downstream collaboration across the supply chain might be sensitive to some dealers, it creates certain challenges to gather information about all the supply chain participants.

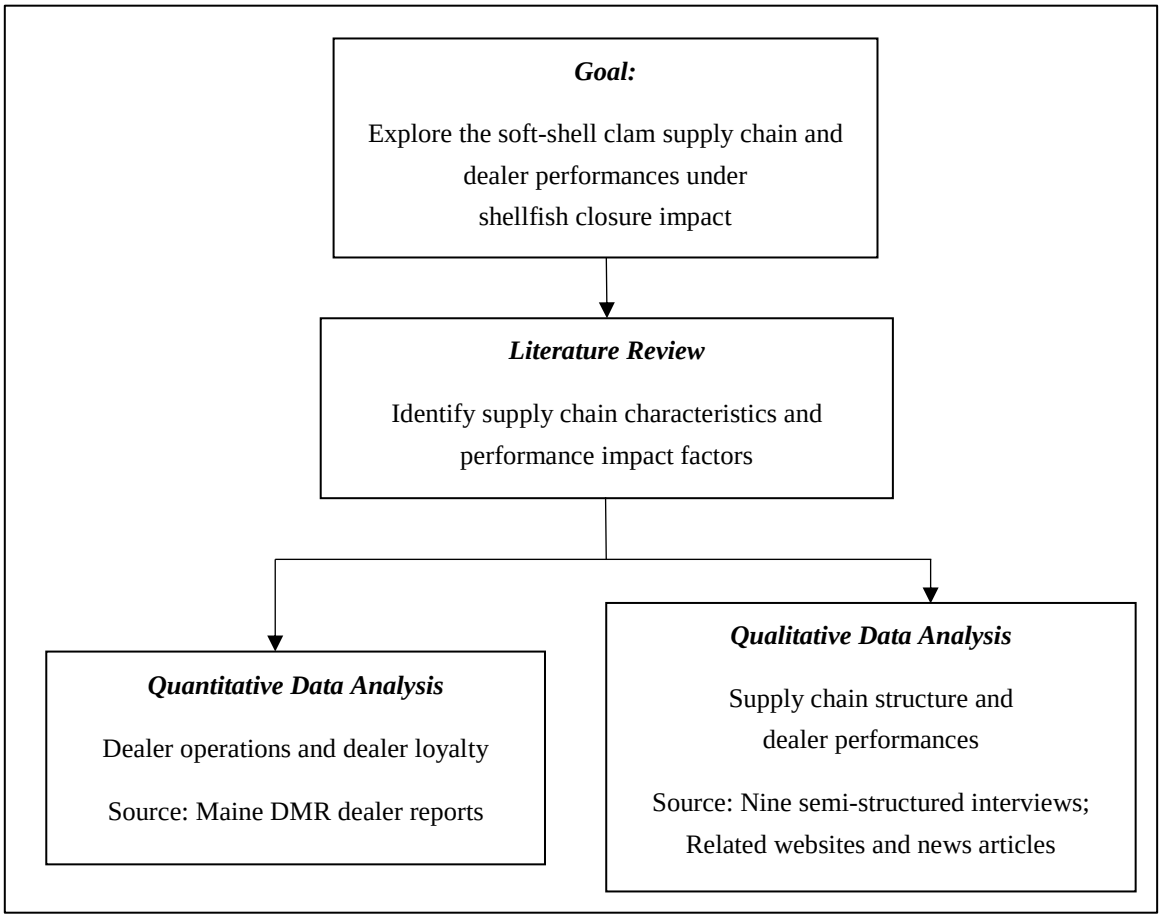

Figure 2.3 Mixed-method case study approach flowchart.

In the quantitative session, due to limited data availability, I compiled our data from daily DMR shellfish dealer reports documented about half of the Washington County from 2008-2014. The dataset covers information such as date, trade port locations, port id, harvester and dealer id, fishing methods, trade species, volume, and prices etc. These towns include Cutler, Dennysville, East Machias, Eastport, Edmunds, Lubec, Machias, Machiasport, Pembroke, Perry, Roque Bluffs, Trescott, Whiting and Other Washington areas. There are three other towns also involved in the dataset: Freeport, Scarborough and St. George. The trade port locations in the dataset refer to the transaction locations which might not be the same as locations of clam harvests (personal communications with Dr. Keith S. Evans).

I categorized dealers into three size groups according to the average annual volume of clams they purchased during the 2008-2014 period. I based my categorizing methods on the 1977 Maine soft-shell clam dealer analysis report. But instead of using values as indices, I chose to use trade volume, considering potential differences of inflation rates among the six years (Prysunka et.al, 1977). Referring to the 1977 study, small dealers were those whose average annual sales were under 1,000 pounds. Medium dealers had their average annual sales between 1,001 and 10,000 pounds. Dealers with average annual trade volume larger than 10,001 pounds were categorized as large dealers. It should be noted that the sales in the dataset only limit to the geographical scale within Downeast Maine listed above.

Since loyalty in this research was defined as the clam harvesters' repeat selling behavior to the same dealer, the concept of loyalty is assessed through calculating the total volume of shellfish exchanged and the frequency of interactions of each clam harvester with individual dealers during 2008-2014. To explore harvesters' loyalty, I similarly categorized the clam harvesters into three size groups based on their average annual trade volume within Downeast Maine. Small clam harvesters were those traded under 1,000 pounds annually. Medium clam harvesters had their annual trade between 1,001 and 10,000 pounds. And those who traded clams over 10,001 pounds will be categorized into large group. Data analysis includes years in operation, the species diversity of their business, the relationship between the number of harvesters each dealer interacted with and the volume of clams that went through them etc.

2.3 Literature Review

2.3.1 Seafood supply chain

Various definitions have been found in supply chain literature, despite the variations among supply chain, value chain and fish chain, all of them are focused on a common theme and will be used interchangeably given the nature of soft-shell clam fishery. Mentzer et.al (2001, p. 4) refer to supply chain as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer." Christopher (2016) describes supply chain as an organization network through upstream and downstream connections that produce products or services of certain values after different processes and activities and deliver them to the ultimate consumers. Van der Valk and De Vos (2016, p. 1) interpret supply chain as global governance systems that connect chains firms through various "sourcing and contracting arrangements". It suggested that in spite of the streamlined flow of products from production to consumption end, the definition of supply chain has taken the different processes and connections into considerations.

This literature review looks closest at the seafood supply chain structures and performances and related relationships and management within the supply chain under climate change to guide the data analysis. The seafood supply chain concept provides a significant network structure to learn about the soft-shell clam fishery. Along the supply chain, there are similar stakeholder and operation elements under the framework of "fisher-processor-distributor" (Fig 2.4), but there are also variabilities due to different local physical and regulatory situations (Fleming et al., 2014).

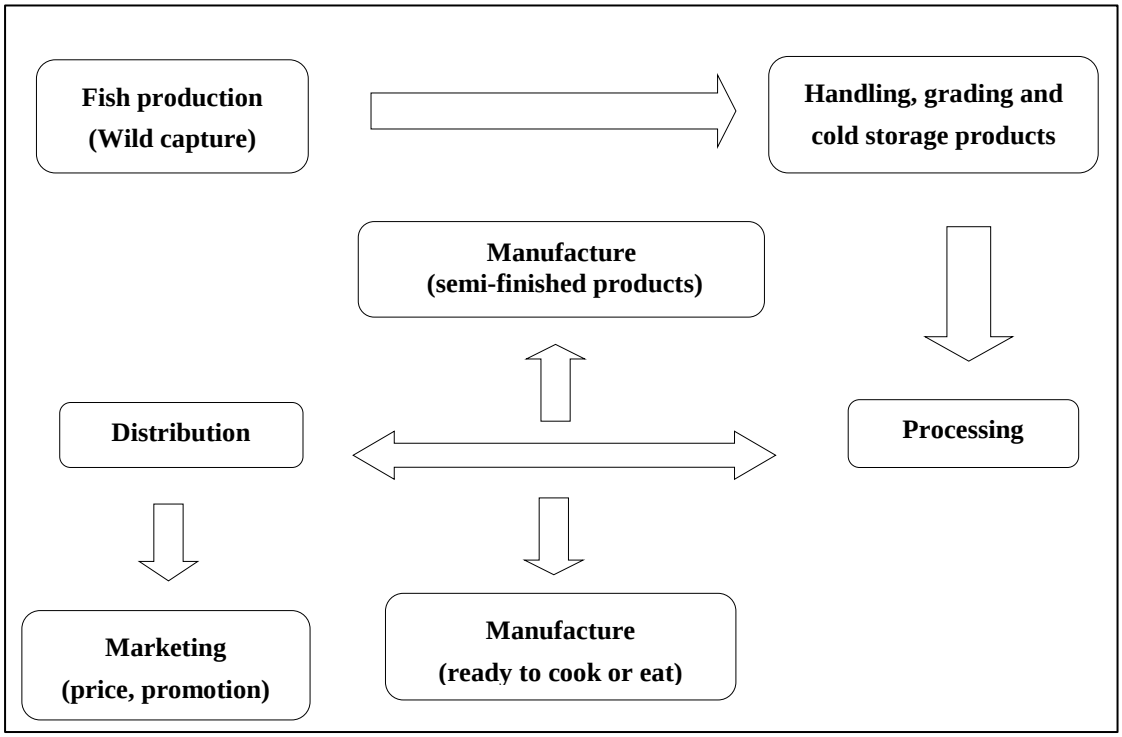

Figure 2.4 The general structure of the seafood supply chain worldwide adapted from De Silva (2011).

The types of seafood supply chains vary with different fisheries species. Depending on the scale and processing complexity of the seafood production, seafood supply chains might involve different number of stakeholders (De Silva, 2011). Comparing American lobster with soft-shell clam as an example, American lobsters are sold both in domestic and international markets, whereas soft-shell clams are mainly in the domestic markets (Stoll, Crona, Fabinyi & Farr, 2018).

In terms of the number of actors, as lobster production includes much more processing operations for products such as lobster chowder and lobster macaroni and cheese, while clam value chain is much simpler as most clams are sold fresh. As a result, the American lobster value chain of larger scale is much more complex than the soft-shell clam

value chain. With the increasing worldwide demand for seafood and the limited wild fish stock, aquaculture is playing an increasingly crucial rule in the global seafood value chain, which makes the value chain structure even more complicated (De Silva, 2011).

In wild capture fisheries, seafood supply chains start with fishers. There are different fishing practices to capture the fresh fish, form low-cost rakes to using gill-nets on fishing vessels. In artisanal fisheries, fishers might sell their harvest to customers directly (Future of Fish, 2015). Wild capture might also go through several mid-chain players such as processors, dealers and distributors etc. until it reaches the end buyer. Fishers might perform individually or collectively. Dealers are significant stakeholders on the seafood supply chain in terms of seafood storage and connecting seafood sources with retailers, restaurants, food services and companies (De Silva, 2011).

After fishers, there are mainly three types of seafood distributors: specialty seafood distributors, fill-time distributors and environmentally sustainable marketers. Specialty seafood distributors focus on seafood products and operate at regional level. Full-time distributors, such as Sysco and U.S. Food Service, sell a large variety of products and participate in national markets. Environmentally sustainable marketers initiate sustainable practices in their food productions and may label their products with sustainability certifications (Dubay et al., 2010).

The final products can usually reflect the complexity of mid-chain processes. For example, filets take more processing than whole fish to be sold in markets. Compared to fresh fish supply chain, refrigerated fish supply chain is more economically efficient duet to longer

shelf life (Sweenarain, 2012). Therefore, frozen supply chain might be more able to support large-scale fishery (Sweenarain, 2012). In addition to freezing operations, processing and value-added activities are also common in the global seafood supply chain (Fleming et al., 2014; Trondsen, 2012; Van der Valk & De Vos, 2016).

The highly perishable characteristics of fresh fish products have usually limited the geographic scale of their supply chain (Sweenarain, 2012). The most influential environmental factor that limits the shellfish value chain activities is the shelf life of the capture. The time constraint then requires the transportation distance be within certain ranges (Trondsen, 2012). As for some add-valued products, it might take several rounds of freezing and thawing and transporting among several different countries. During the process of product flow, fish products might be graded based on their appearances and quality etc. The more processing and transporting it takes, the more complicated a supply chain structure is and thus there will be more challenges for seafood traceability. Various factors influence the supply chain compositions. In most cases, however, the impact comes in a top-down manner (Future of Fish, 2005). These influential players could be end buyers, processors or certification programs. In some cases, one stakeholder might take on multiple roles across the supply chain.

The complexity of the seafood value chain structure has created the diverse relationship dynamics among the supply chain stakeholders. These relationships are usually long-lasting connections built on trust (Van der Valk & De Vos, 2016). Cooperation on the supply chain does not mean zero conflict in the relationship. Instead, cooperation describes the broad process of relationship and commitment building on the supply chain. Therefore,

conflicts do not necessarily mean the end of cooperation, especially in cases with high costs to terminate the relationship. This applies specifically to the seafood supply chain, as the transportation costs are rather high for distant regions (Zineldin & Jonsson, 2000).

In some artisanal fishing communities, these relationships might be both professional and personal. This applies particularly to fisher and buyer interactions. While some close bonds might help with the stability of the product flow, they might also limit fishers' access to the markets (Future of Fish, 2015). The relationships between suppliers and dealers are affected by factors more than customer satisfaction as changes are constantly creating challenges for both parties to "exploit each other and the relationship better" (Zineldin & Jonsson, 2000). Each action stakeholders take might either enhance the trust or increase the barriers in their collaboration. The complex set of factors that determine the trust level include adaptation, communications, loyalty and cooperation (Zineldin & Jonsson, 2000). As an important element, communication in this context mainly refers to the exchange of useful and timely information. Specifically, it is the "frequency and quality of the information exchange" that determine the trust and commitment level (Zineldin & Jonsson, 2000, p. 252).

I mainly focus on the dealer-fisher relationships. This type of relationships shares similar characteristics in many remote artisanal fishing communities where a few dealers buy landings from a large group of harvesters (Future of Fish, 2015). Fishers in places with more market access might have more power to decide whom to sell their catch, in this case, dealers might compete with different prices to get the products.

Consumer loyalty is defined as repetitive "purchasing frequency or relative volume of same-brand purchasing" (Oliver, 1999). The past customer satisfaction and loyalty research

has built on empirical studies and conceptual framework in which data were generated from questionnaires and surveys (Bloemer & Lemmink, 1992; Dick & Basu, 1994). In quantitative studies, customer behavior tended to be assessed based on factor analysis models (Biong, 1993). It suggested that past research on customer loyalty emphasized what factors determined the level of consumer loyalty. These factors include product quality, prices, customer satisfaction and relationships with the dealer etc. (Bloemer & Lemmink, 1992; Oliver, 1999).

The customer loyalty aspect of the supply chain relationship is closely related to the cost and benefit aspects of the trade. However, customer loyalty might take on positive, negative or no commitment in its essence, and this complexity means that long-term relationships do not necessarily mean that the collaboration is built on positive commitment but rather on the contextual bonds such as legal contracts (Zineldin & Jonsson, 2000).

Seafood supply chains in small-scale fisheries are significantly diverse and are related to local demographics (De Silva, 2011). In a top-down co-management scenario such as the soft-shell clam fishery, the existence of social network will be contributing substantially in terms of information dissemination. Based on the social network categorization of Kamiyama et al. (2018), seafood supply chain involves both “bonding network” which links similar groups of people among fishers for instance and “bridging network” which connects different groups of people such as between fishers and dealers.

Since the 1990s, the term seafood supply chain management (SCM) has become a popular research topic for several reasons (Cooper & Ellram, 1993). First, with the globalization of seafood production, corporations were forced to optimize their product flow

through the companies. Increasing competition and growing customer demands require closer coordination among suppliers and dealers. Secondly, as the seafood production is bound up with uncertainties related to natural resource availability, technology development and changing economy, supply chains are demanded to be more adaptive to the changing conditions. Despite the popularity of SCM, it has hardly been defined and instead supply chain has been interpreted more frequently (Mentzer et al., 2001).

Across the wild capture supply chain, there might be different degree of vertical integration. In cases where most major steps are under single corporation ownership, better management and fishing methods can be implemented. On the opposite end, if a supply chain involves multiple entities, it might be more challenging to manage the supply chain given individual incentives to minimize the costs (Future of Fish, 2015).

2.3.2 Supply chain adaptation

As social, environmental and economic changes happen simultaneously and are intertwined in affecting fishing communities, it is challenging to identify the exact impact factors. In the past decades, there has been economic diversification besides marine resource extraction such as aquaculture and tourism etc. In Downeast Maine, the coastal economy has been growing rapidly because of tourism-related development. The demographic change has caused the social and economic transition in Downeast Maine region (Stafford & Hamilton,

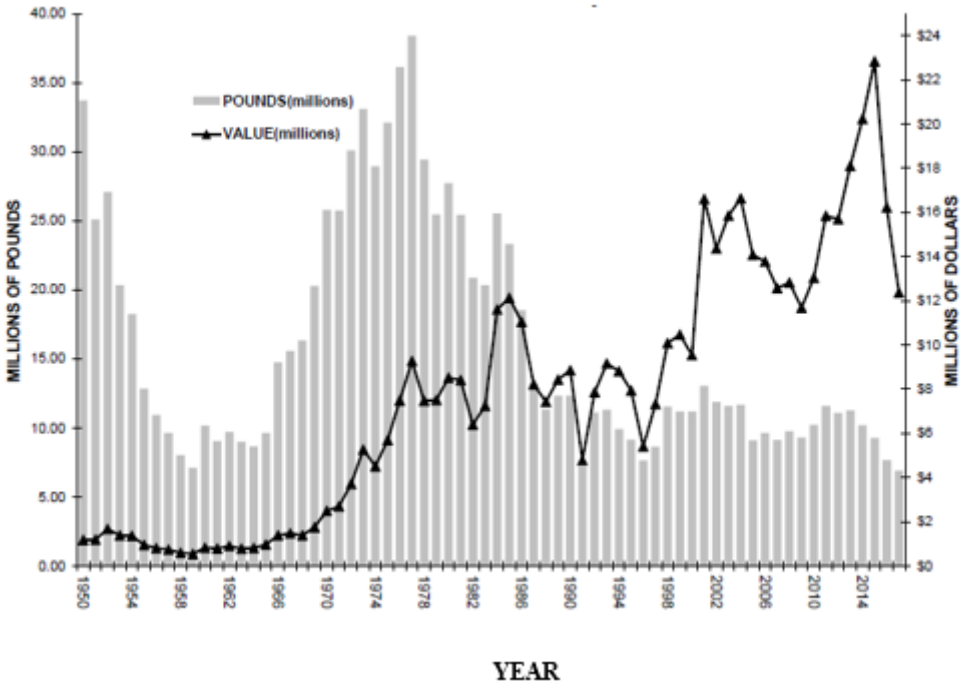

Figure 2.5 Soft-shell clam landing and ex-vessel value history (1950-2017).

2012). Adaptation evaluation is also limited by the availability of information and restricted by the fact that data about social and ecological systems are mismatched in scales (Armitage, 2005).

Past research concerning the soft-shell clam fishery in Maine has discussed several dimensions related to adaptation. Overharvesting and environment changes such as temperature rise and the invasive species green crab (*Carcinus maenas*) have been identified as factors that led to the decreasing trend of soft-shell clam landings between 1940-2000 (Congleton et al., 2006).

The seafood industry which is highly reliant on natural resource availability is susceptible to environmental changes. Anthropogenic climate changes such as pollution and ocean acidification are adding pressure to marine fisheries production around the world (Evans et al., 2016; Fleming et al., 2014). Under climate change, changing environments

require efficient adaptation of seafood supply chain stakeholders (Trondsen, 2012). Past adaptation research has focused on the harvest phase of the supply chain and has contributed suggestions in terms of controlling fishing pressure and improving the sustainability of the fishing practices. Little attention has been paid to post-harvest phases of the wild capture supply chain until recently (Fleming et al., 2014) The improvement of response mechanism is crucial for marine resource users to adapt to climate changes.

During adaptation processes, different stakeholders on the supply chain might take various forms of adaptation strategies, which is significant in affecting the relationships and trust between stakeholders. First and foremost, modifications in operations might happen in terms of products, trade volume and service procedures etc. Secondly, dealers might invest different resources in improving their interactions with others. And thirdly, new product or service development might be initiated to respond to the changes in the markets. As trust and commitment rely on consistency and honesty, opportunist behavior during adaptation will be harmful to the collaborative relationships on the supply chain (Zineldin & Jonsson, 2000). The quality and types of the relationship will determine whether stakeholders will switch their collaborating partners.

Throughout the climate change adaptation process, loyalty in dealer relationships have been constantly challenged. Depending on the complexity and scale of seafood supply chain, it might take different levels of capacity for the market to adapt. It was suggested that the structures of wild capture seafood value chain might constrain market adaptation in remote areas (Trondsen, 2012). Such adaptation processes might involve homogenization and standardization of seafood products.

2.4 Results

2.4.1 Supply chain structure

The supply chain structure of the soft-shell clam is relatively simple because of the time limit for shellfish storage and transportation due to clams' fragile characteristics and the limited processing operations involved (Webber & ME DMR, 2013; Prysunka et al., 1977). Most of the soft-shell clams are still harvested as wild capture today, due to the limited production out of aquaculture farms. A typical soft-shell clam supply chain includes commercial clam diggers, dealers, processors and end customers (Fig 2.6). The initial market transaction starts as clams are offloaded from clammers's trucks. Clams will be stored on site (under temperature), some dealers might choose to freeze certain amount of clams if supplies exceed demand. End customers include chain supermarkets, restaurants and retail customers. Some of the supply chains involve added processors and/or depuration plants, depending on the environment conditions and product forms of the clams.

Even though the processing of soft-shell clams involves shucking, grading and cleaning, some might involve depuration[2], freezing and added processing (clam juice and chowder as illustrated in Fig 2.7), the processing is relatively simple compared to other fish species. Depending on the processing, clams might be sold in several forms: fresh, shucked and canned clams, clam chowder and clam juice. The longer storage time of these processed products have the potential of helping dealers to make better profit in the shellfish fishery, even though there is no direct proof.

[2] Depuration refers to the process of transferring shellfish to a controlled aquatic environment to reduce potential pathogenic organisms in shellfish.

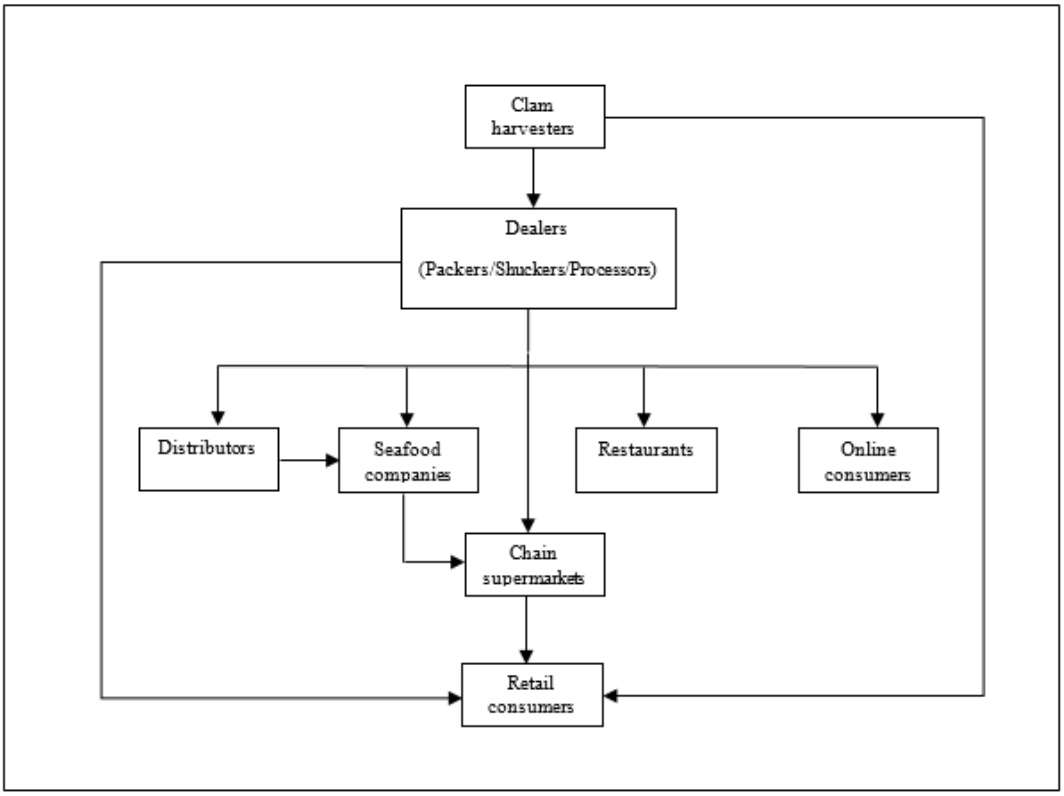

Figure 2.6 The soft-shell clam supply chain structure generated out of interviews.

2.4.2 Dealer performances

As significant stakeholders in the supply chain, clam dealers connect the source of seafood from harvesting to consumption end. Dealers' performances are likely to shape adaptation of different stakeholders across the supply chain. In this context, dealers refer to licensed entities that buy, sell or distribute soft-shell clams. Specific roles of dealers are shellstock shipper, shucker-packer, reshipper and depuration processor. Across the supply chain, dealers are at the core, in terms of transferring the products from the source end to the consumption end.

Figure 2.7 Processed clam chowder and clam juice at a local store.

Along the Maine coast, there are 121 Maine DMR certified shellfish dealers, and not all of them have soft-shell clam in their shellfish business. Some of the dealers have stations that clammers come and sell the clams directly, some will buy from other dealers that send buyers out to buy in clams from clam harvesters themselves. Dealers can play a significant role during trade interactions when clammers might go to dealers' stations and sell clams at the same time, depending on clam harvesters' personalities and willingness to share information.

During 2008-2014, among 109 active dealers in total who participated in the soft-shell clam fishery, 61 of them traded in Downeast Maine. Each dealer was different in terms of the species diversity in their business, business size, years in operation and their interactions with

the harvesters. Data showed that six dealers both traded inside and outside Downeast Maine region, which demonstrated their geographical distribution of business to a certain extent.

Dealers usually have multiple downstream directions of clams which include retail customers, distribution companies, restaurants and chain markets. These customers might be the end customers, but most of them are also dealers that do wholesale with restaurants and supermarkets. The geographical distributions of the clam sales vary for different dealers. Dealers might focus their sales within Maine but might also go to other states such as New York, and Minnesota. When dealers have online business, they may choose to ship clams across the states to places such as California.

Nine dealers interviewed have different history of selling clams and have different types of focus in their business. In terms of clams, only one dealer deal with processed clams exclusively, which takes up 1% of the business. Despite this, all the dealers have other food such as lobster, fish or beef for sale in their business. Such composition of commodities has shaped their different adaptation during soft-shell clam temporary closures, as their reliance on the soft-shell clam supply determines the impact of temporary closures on their business. For example, for one dealer whose business of soft-shell clams only took up 1%, temporary closures did not require adaptation actions to be initiated as decreases in clam supply can be compensated with supplies of other commodities.

Dealers have different clam sources which include diggers, dealers and sometimes a combination of both. In terms of geographic distributions, clammers locate from Cape Cod, Massachusetts to New Brunswick, Canada. Only one dealer buys clams exclusively from dealers in Maine now, and the two dealers will send out buyers to interact with clammers. For

dealers who buy clams from clammers might go to clammers or clammers might come to their station to trade. None of the interviewed dealers harvest clams themselves, and those primary dealers who buy clams directly from clammers also interact with different amount of clam harvesters themselves. The number ranges from two to twenty-five, related to the size of dealers' business. The number is also affected by the seasonality linked to tourism, when demands of clams rise substantially. One dealer described the soft-shell clam business in the following way:

> "You know, the soft-shell clam business is a tourist-based industry, and that's why it's so prevalent from May through September, because that's when the tourist season is. In other words, a soft-shell clam is not a staple food like macaroni."

During the interviews, it was noticed that five out of nine dealers have well-developed websites, and three dealers have Facebook pages which are almost empty. Among these five dealers with websites, three dealers sell their seafood online, which allows the business to be known by customers of larger geographic scale. Despite the lack of direct evidence, such marketing effort demonstrated their scale of business to a certain extent. However, the perishable nature of the shellfish limits the distance and time in which clams can travel. For example, fresh clams cannot travel as far as lobsters to areas like Asia. Processed and frozen clams, on the other hand, will be able to travel longer distance.

Among the 61 trading dealers in Downeast Maine, there were 26 clam dealers. Nine clam dealers traded clams under 10,000 pounds on average annually. Twelve dealers fell within the medium size group, and the large size group consisted of five individuals.

Table 2.1 Years in operation by size of dealer during 2008-2014.

Dealer size group[3]	2008	2009	2010	2011	2012	2013	2014
Small dealer	0	3	1	3	2	2	1
Medium dealer	6	5	7	6	6	4	4
Large dealer	3	2	2	2	4	5	5
Total # dealer	9	10	10	11	12	11	10

Each dealer had different participation pattern, with some out of the trade in the middle of the six years and some pausing for several years and re-entering the market etc. Not all the 26 clam dealers were participating in clam trade within the regions during the 7 years, however, the amount of participating dealers stayed rather stable (Table 2.1). According to a previous analysis (Prysunka, et al., 1977), due to the variety of dealers' roles on the supply chain, one dealer might have different sources of clams. These sources are mainly four types: harvesting themselves, direct buying from independent harvesters, buying from depuration plants and buying from other dealers, and sources might be combined for certain dealers the majority of dealers tend to buy clams from independent clammers. The size of the dealers which is directly determined by dealers' clam trade amount is also related to the source of the shellstock, however, there was no clear evidence that demonstrated such relationship (Table 2.1).

[3] Small dealers are those with annual trade volume smaller than 1,000 lbs; medium dealers are those with annual trade volume between 1,001-10,000 lbs; and large dealers are those with annual trade volume larger than 10,001 lbs.

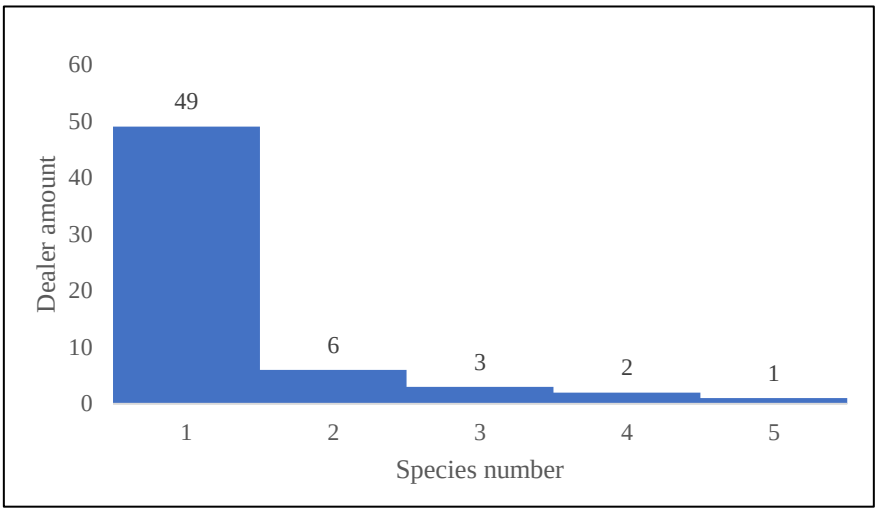

Figure 2.8 Dealer distribution in terms of species diversity in Washington County.

Most of the clam dealers only dealt with the soft-shell clam. Other species involved in certain business were American lobster, sea scallop (*Placopecten magellanicus*), blue mussel *(Mytilus edulis*) and green sea urchin (*Strongylocentrotus droebachiensis*). Demonstrated in Figure 2.8, only one dealer was involved in the business of the five species.

2.4.3 Supply chain relationship dynamics

The relationships between different stakeholders on the supply chain are more complicated than the streamlined structure of the supply chain. Cooperation among dealers was mentioned by several dealers, especially during summer time when the supply does not satisfy demands. At this time, dealers in different regions help each other with clam supply when there is shortage of supply. The amount dealers provide can be as much as 80 bushels which equal 4000 pounds (1 bushel=50 pounds). When the tourism cools down and Maine starts its winter season, soft-shell clam consumption can go down substantially, and the price will drop by a great extent.

2.4.4 Supply chain impact factors

Large demands and long-standing reputation strengthen the relationship as one dealer answered who they decide to sell their clams to: “Typically people with the most demand for it. They’ve got a couple of buyers that they will sell to because they’ve got a longstanding reputation with them. If they need them they get first priority and then after that they’re asking, depending on what the demand is.” As the relationship between dealers and harvesters does not tend to be based on contract, harvesters are free to choose the dealers they want to interact with. Consequently, markets might get flooded for certain dealers if they have a better price.

There are differences in distribution of clams after dealers, depending on where dealers sell the clams. Dealers tend to have three directions to sell clams: directly selling to customers, selling to hotels and restaurants and selling to other dealers.

Prices might decrease over time if dealers cannot finish selling all of them, during which dealers might refuse to buy any more clams. Fresh soft-shell clam retail prices vary from place to place, ranging from $1.99 to $6.99. Prices fluctuate substantially in different seasons of the year, depending substantially on the business of the tourism. Price setting power remains uncertain during interviews; however, different perceptions captured the characteristics of such a complicated process. As interviews were conducted around the same time, the price seasonality differences were not shown. When asked about the reason of the price differences, one dealer mentioned that the number of clams and the species diversity in the business affect the price for individual dealer.

Even though it remains uncertain how the price is set up in the market, however, the power imbalance exists in the general understandings about the market. A previous Maine soft-shell clam dealer analysis showed that dealers' different perceptions about the price setting body are related to the size of their business. For large-size (annual gross sales larger than $415,165[4]) and medium-size (annual gross sales between $41,516.5 and $415,165) dealers, market competition was understood as the major factor. Small-sized dealers (annual gross sales smaller than $415, 12.35) tend to think the price determination power to be in the hands of their sellers (Prysunka et. al, 1977).

The relationship between the business size and perceptions about price setting power was not clear due to sample size. The power of the market competition was mentioned by several dealers. Yet one dealer has expressed the opinion about large chain markets being able to set the price: "Usually their prices will be different because again they buy for a different amount than what other dealers will buy for, I guess. But when they're a large chain market, they can do that. They set their prices."

2.4.5 Dealer loyalty

The past definitions of customer loyalty do not necessarily apply to the case of the soft-shell clam fishery as clam harvesters tend to have more market power. The stakeholder group that clammers sell their clams to could determine the level of loyalty to a certain extent. In this research, consumer loyalty is defined as the clammers' repetitive selling frequency or relative volume of clam selling to the same dealers.

[4] 1977 dollar values were calculated into 2018 values using consumer price index.

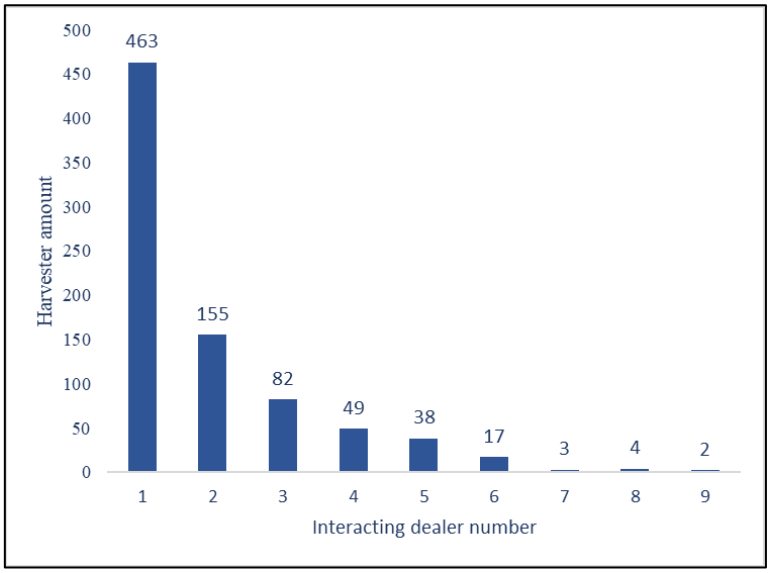

Figure 2.9 Summarized distribution of clam harvesters by number of interacting dealers.

There were 813 active clam harvesters during the six-year period, and each harvester interacted with different amount of dealers. According to Figure 2.9, more than half (56.9%) of the harvesters only interacted with one dealer, demonstrating high loyalty in the business. Approximately one in fifth of the harvesters had two different dealers in their business in six years. Very few dealers would have seven to nine dealers to trade clams with. As demonstrated in Table 2.2., small harvesters interacted with no more than 5 dealers. Medium-size harvesters interacted with a wide range of dealers. Larger harvesters, only interacted with three to six dealers.

2.4.6 Supply chain management

In order to "sell, ship, transport or process shellfish", clam dealers in Maine must apply for state licenses of wholesale seafood or shellfish transportation (Webber & ME DMR, 2013). Dealers of certain certificate type can only perform within the activity scale of the license. One certificate only applies to one dealer at one location.

Table 2.2 Summarized harvester number in terms of interacting dealer number by size of harvester.

Interacting dealer number /Harvester size group[5]	**Small harvester amount**	**Medium harvester amount**	**Large harvester amount**	**Total harvester amount**
1	365	98	0	463
2	80	75	0	155
3	22	57	3	82
4	9	39	1	49
5	4	28	6	38
6	0	13	4	17
7	0	3	0	3
8	0	4	0	4
9	0	2	0	2
Total harvester amount	480	319	14	813

To ensure the food security for shellfish consumers, Maine DMR inspects and certifies wholesale shellfish dealers in Maine under the standards of National Shellfish Sanitation Programs (NSSP).

The certification process looks into stock sources, storage conditions and processing operations etc. (NSSP, 2015). To guarantee the seafood security, operations along the seafood supply chain have to comply with the Hazard Analysis Critical Control Point (HACCP) policy and international safety standards (Sweenarain, 2012). HACCP, monitoring of Daily Sanitation practices and temperature control during transportation etc. are also required by

[5] Small harvesters are those with annual trade volume smaller than 1,000 lbs; medium harvesters are those with annual trade volume between 1,001-10,000 lbs; and large harvesters are those with annual trade volume larger than 10,001 lbs.

DMR in certifying dealers' practices (ME DMR, 2018). In addition to the dealer certification policy, regulations about shellfish growing area classification and temporary closures are also closely related to the dealers as they directly affect the supply of the clams.

2.4.7 Supply chain adaptation

As the soft-shell clam fishery is susceptible to environmental changes, anthropogenic climate changes are creating challenges for to the supply chain to maintain its performances. Temporary closures add to the uncertainties of supply and demand in the market and such uncertainties tended to increase economic risks on the dealer side in terms of product quality and prices (Wilson, 1980). The unstable nature of the clam supply has shaped the adaptation processes of the dealers and their perceptions on the fishery. Both pollution and red tide which caused temporary closures were in expressed in dealers' perceptions about the current impact factors of the soft-shell clam fishery.

The interviews showed different supply chain structure and positions of dealers on the supply chain. These factors shaped dealers' behavior pattern during temporary closures, even though there is no clear evidence. However, their business scale has determined the impact of temporary closures on them. In terms of adaptation strategies, there are various strategies clam harvesters and dealers took when facing temporary shellfish closures.

As for dealers, their responses depended on their scale of business, which was related to the diversity of species in their business and the range of upstream sources. Adaptation mostly happened in response to the changes in supply of clams which would be hard to predict, even though one interviewee stated that the company might plan out for temporary

closures to happen. Dealer of smaller scale and diversity in the business would be likely to shut down the station. In comparison, dealers with more upstream sources such as Canada would be able to operate normally during local temporary closures, and there are dealers who realize that "that's why a lot of companies now diversified their buying areas."

The demand of clams on dealers varies in different seasons, largely due to the seasonality of the tourism. The soft-shell clam fishery is a "tourist-based industry", and prices change dramatically in tourism season from May to September. However, annual clam harvests in Maine have gone down by almost two-thirds since the early 1980s (Congleton et.al, 2006). Among the reasons that cause low supply of clams, dealers ranked red tide, high price and digger shortage as the three most related reasons.

The location diversity of the clam sources shapes how dealers respond in the face of temporary closures. For example, if dealers buy their clams harvested from different locations, when one area gets closed, their supply can still be maintained to a certain level with the landings from open areas.

The scale and diversity of the customers influence the stability of demand level on dealers. Demand and supply might not be the same for dealers from time to time and therefore dealers take different strategies. When dealers have more clams they can sell, they might freeze and store clams; and when they need more clams than they bought from clammers, they might buy from other dealers.

During temporary closures which decrease the landings of the clams, dealers show different pattern of adaptation behavior, which depend on their size of their business. One

dealer who relies heavily on clams closes the shop during temporary closures. But as for other dealers with a more diverse business setting, more actions are taken: 1) diversifying the clam source locations: one dealer mentioned that “We just kind of expect it to happen. You try to plan for it as best you can. You know, you have to be able to. And that’s why a lot of companies now diversified their buying areas.” ; 2) diversifying the clam sources: dealers buy from other dealers with shellstock to satisfy the demand on them. As for dealers who do not rely much on soft-shell clams, they do not need to make as many adjustments as other fisheries and groceries are enough to support their business.

2.5 Discussion

In this section, I will discuss the soft-shell clam supply chain structure, dealer performances, relationship dynamics, impact factors, dealer loyalty, supply chain management and adaptation across the supply chain. To gain knowledge about the behavior pattern changes, I compared the results with the supply chain performances in 1977.

In comparison with 1977, the soft-shell clam market structure has not changed much. Clam dealers interviewed mainly supply fresh clams, and due to the limited shelf life of fresh clams, the length and geographical scale of the supply chain are rather constrained compared to other species like American lobsters. The general structure starts with clam harvesters and go through dealer and potential processing stage until the clams enter the distribution network and ultimately reach consumption end. However, results showed that there were different supply chain structures in different geographic locations and therefore dealers’ positions on the chain vary. In addition, with the recent development of the clam aquaculture projects, it

should be expected that clams coming from the aquaculture will make substantial contributions to the market in the future, like other shellfish species (FAO, 2016).

In 1977, there were 136 clam dealers holding Interstate Shellfish Shuckers Permits or Interstate Shellfish Certificates. In 2018, the number of Interstate Shellfish Shuckers Permits and Interstate Shellfish Shipper Certificate holders including clam dealers goes down to 108. Despite direct proof of less market participation, decline of dealer number has been substantially affected by the decreases of landings in the past 40 years. In 1970s, clam harvest was at its "high point", however, within the recent years, the number has reached unprecedented low level (Prysunka et.al, 1977).

These factors shaped dealers' behavior pattern during temporary closures, even though there is no clear evidence. However, their business scale has determined the impact of temporary closures on them.

Concerning relationship dynamics, the 1977 soft-shell clam dealer analysis has only focused on the purchase price determination aspect. It suggested that more than half (52%) of the dealers believed the power to be in other competing dealers' hands. In our interviews, there were also different views on the price determination power, and one dealer brought up the new point that the downstream large chain markets have power in setting the price. Nevertheless, it shows that without related regulations, the price setting is a complex process.

Besides demonstration of differences in stakeholder views about price setting power, this study reflects the collaboration aspects within the network and starts to show the complexity of relationship dynamics in the soft-shell clam supply chain. The collaboration

aspects, according to Van der Valk and De Vos (2016), help mutual sharing risks and rewards, are crucial for the supply chain to face changing needs down the demand chain.

In supply chain that relies on natural resources, supply and demand are not solely controlled by key stakeholders and thus the changing environment demands market adaptation along the supply chain (Trondsen, 2012). Not surprisingly, on the supply side, as soft-shell clam landings decrease (the access to the fishery has declined), the participation has dropped. On the demand side, however, the market is deeply affected by the tourism industry and demonstrates the seasonality pattern. In small-scale fisheries, the long-term relationships between dealers and fishers have been pointed out to limited fishers' access to the market (Future of Fish, 2015). However, in our case here, harvesters seem to have the power to decide their entry to the market. And in fact, when they are not satisfied their local dealers, they are willing to go further to trade with other dealers (personal communication with John Fendl).

During supply chain collaboration, several factors impact the relationships. In Downeast Maine's soft-shell clam supply chain, large demands and long-standing reputations were suggested to build up the collaboration among collaborating stakeholders through enhancement of trusts. Trust, as a key factor in fish chain collaboration especially in local fishing communities, was highlighted in previous fish chain research (Van der Valk and De Vos, 2016).

In the past 40-year history of the soft-shell clam fishery, despite dramatic decline of commercial landings, the ex-vessel values of the fishery are even higher than 1970s (Fig 2.5;

ME DMR, 2018). However, on the supply side, the fishery has apparently made less contributions to the seafood market. This can also affect Maine's contribution to the national shellfish industry, as states such as Massachusetts have relatively (personal communication with Dr. Keith S. Evans) stable soft-shell clam landings and pose threats to the prices of clams from Maine.

Results demonstrated high loyalty of clam harvesters as more than half of clam harvesters repetitively interacted with one dealer. It was mainly medium-size dealers that bought clams from more than five clammers. Bloemer and Lemmink (1992) suggested that dealer loyalty is an outcome mainly due to consumer satisfaction. This, however, might not be the case in the soft-shell clam fishery, as clam harvesters have a larger say in terms of the dealers they sell their products to.

Currently, there has not been any form of supply chain management, however, separate management on individual phases of the supply chain such as harvesters and dealers has been responsible for sustainable uses of the resources and shellfish sanitation. Supply chain management was found to be able to incorporate the relationship dynamics and therefore, instead of treating the supply chain as multiple firms, manage the supply chain as a dynamic system with product flow (Mentzer et.al, 2001). Given the dynamics within the fishery, it might be valuable for managers in the future to treat the supply chain as a complex interrelated system.

Supply and demand would not always be equal, and when there was more supply than they needed, some might freeze the clams. Freezing clams until winter as temporary closures might be issued and supply would go down was also an option for some dealers. Prices of frozen clams would decrease with time.

With environmental changes at different scales, marine fishery adaptation is a complex issue to explore. Despite the threats from other factors, this single-factor assessment enables us to learn about how temporary closures could affect this human-environment system, which can help inform policy makers and governance specifically dealing with water quality issues. Adapting to water quality changes require collective actions through the network of relationships. In addition to the market rationality, collaboration among stakeholders helped improve adaptive capacity more substantially. Adaptation strategies of more diversity might be needed for fishery-dependent municipalities to address water quality issues. Ultimately, more holistic understandings will help policy planning along the supply chain.

During the analyzing process, I realize there are limitations of this work that need further research exploration. The mismatches of temporal and spatial scales between qualitative and quantitative data and the animosity of documented dealers have created challenges to directly compare behavioral pattern and prove theories (Creswell, 2009). In addition, despite the direct changes of clam supplies in the market because of decreased access to the fishery, other factors such as predation issues and overfishing also affect the market through decreasing the population density. Therefore, further research about relative impact of various factors at larger geographical scale, whether economic, ecological or social, is needed.

CHAPTER 3

WATER QUALITY POLICY AND STAKEHOLDER PERCEPTIONS IN MAINE'S SOFT-SHELL CLAM CO-MANAGEMENT UNDER THE IMPACT OF SHELLFISH CLOSURES

3.1 Introduction

In recent decades, the concept of co-management has increasingly become a research focus in the field of natural resource management. Despite the wide range of co-management sectors, whether fisheries or forests, the management has a general setting that enables responsibility sharing between governments and resource users (Berkes, 2009). Co-management has the potential of including related stakeholders in the management process (Carlsson & Berkes, 2005). Through communication and partnership projects, the efficiency of policy creation and implementation is likely to be substantially enhanced. However, with environmental changes, natural resource co-management is facing tremendous challenges due to climate change and anthropogenic activities, especially in the wild fisheries sector (McClenachan et al., 2015; Sen & Nielsen, 1996).

Downeast Maine's soft-shell clam fishery provides an example about wild fishery co-management case under the impact of environmental changes. The management responsibilities are shared between Maine Department of Marine Resources (DMR) and local municipalities. The fishery has been under the threats of several environmental factors: ocean acidification (OA), predation by green crab (*Carcinus maenas*) and water-borne pollutants (Ekstrom et al., 2015; Evans et al., 2016; ME Sea Grant, 1998). As a result of cumulative

environmental and social impact, commercial landings of the fishery have gone down dramatically (Congleton et al., 2006). Among the environmental threats, poor water quality has caused significant financial losses to the clam fishing communities in Downeast Maine by decreasing their access to the fishery (Evans et al., 2016). Water quality issues also lead to shellfish recalling cases when harvested clams are tested unsafe to consume (McGuire, 2017). As a complex social-ecological system, the changing soft-shell clam fishery has wide implications (Hanna, 2000).

Past research concerning Maine's soft-shell clam co-management suggested that co-management, through sharing responsibilities and risks and incorporating local stakeholders, has improved the productivity and stability of the fishery (McClenachan et al., 2015). It was also found out that greater institutional flexibility has been created through co-management to adapt to environmental changes due to green crab predation. However, it is rarely understood how co-management deals with water quality issues. Given the significant impact of water quality on the soft-shell clam fishery, it is crucial to understand the performances and efficiency of water quality management in this co-managed fishery, which will be the major goal of this chapter.

To understand the current water quality co-management performances, I took a qualitative case study approach to incorporate both policy regulations and stakeholder perceptions concerning water quality issues. On the policy side, I collected water quality policy documents at federal, state and municipal levels. On the stakeholder perception side, I used the qualitative data out of 37 interviews conducted during 2014-2016. Interviewed stakeholders included state representatives, DMR biologists, municipal shellfish wardens and

clam harvesters etc. Referencing past co-management literature, I examined the multiple aspects of the soft-shell clam water quality management.

The top-down water quality policy setting reflects the significance of shellfish sanitation. Following federal guidelines, Maine DMR monitors water quality and issues two types of temporary shellfish closures: bacterial and biotoxin closures. In the process of water sampling, Maine Department of Environmental Protection (DEP) and certified municipal shellfish conservation warden might also be involved.

Results showed that despite the co-management setting in the soft-shell clam fishery, local stakeholders might not have much participation or power in water quality policy making and implementing. At municipal management level, the shellfish management mainly focuses on licensing and harvesting control, demonstrating limited power and participation in water quality management.

Interview data suggested that the federal level policy might not apply to specific water quality situations and local stakeholders expected closer water quality monitoring and more specified management policy. Multiple attitudes towards water quality management are expressed by clam harvesters and municipal committee members, emphasizing the complexity of the resource user population and lack of communications between state government and municipal stakeholders.

Through showing the complexity of the co-management system, this study provides valuable insights into the water quality management in the soft-shell clam fishery and points out the dynamics of the systems that need further research.

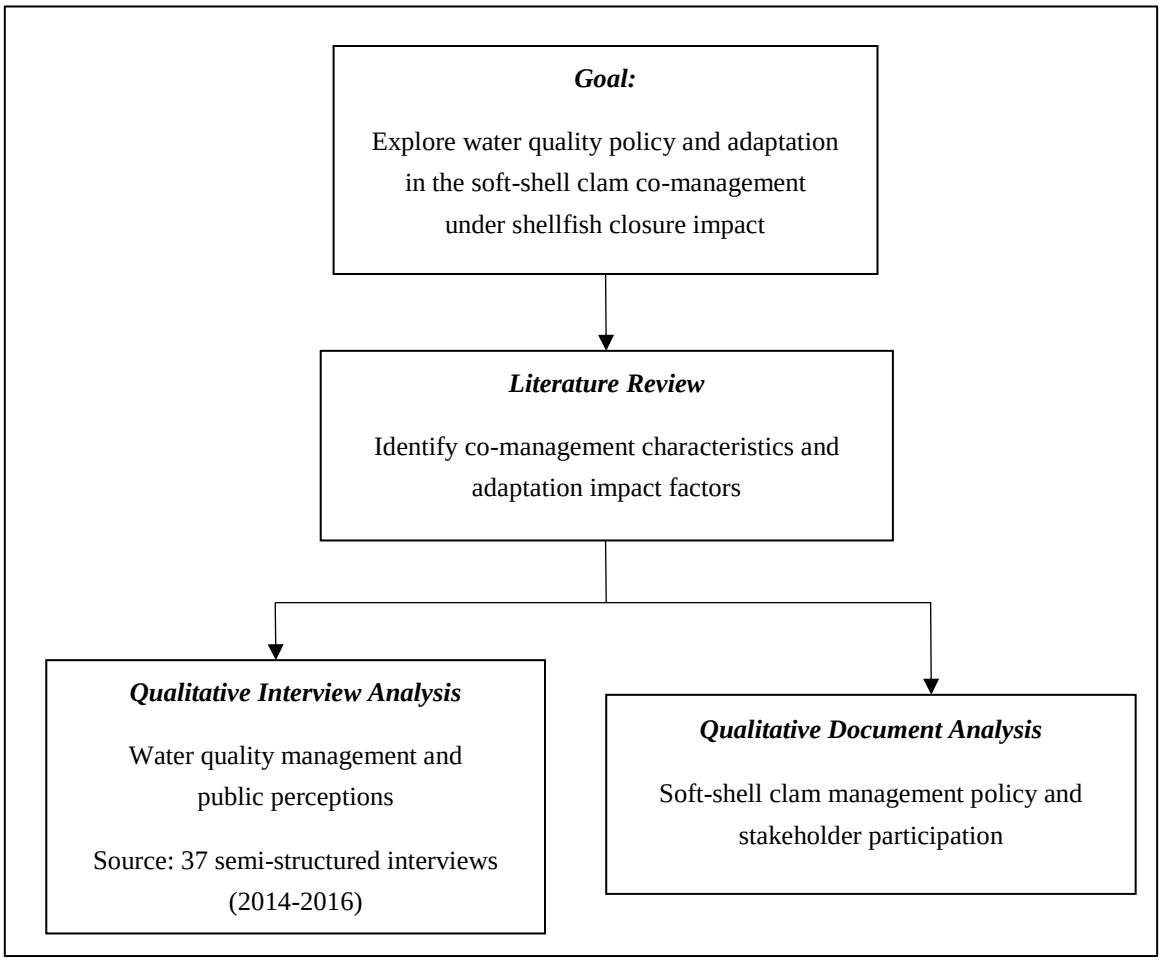

Figure 3.1 Qualitative case study approach flowchart.

Following introduction, I will describe the data collecting methods more specifically in 3.2 I will demonstrate major findings from co-management literature in 3.3. The result section (3.4.) will be presenting the water quality policy setting and stakeholder perceptions in the soft-shell clam fishery. In the discussion section (3.5.), I will summarize strengths and weaknesses of the water quality programs and the stakeholder perceptions about the management.

3.2 Methods

This study took a qualitative case study approach (Fig 3.1) to learn about the water quality co-management in Downeast Maine soft-shell clam fishery under the impact of temporary environmental closures. I started the case study approach with co-management

literature review to understand the theory and past research focuses and I built our analysis framework referring to Pomeroy et.al (2001). I incorporated 185 references from Dr. Bridie McGreavy's semi-structured interviews with 37 stakeholders involved in the soft-shell clam fishery. These stakeholders involved DMR biologists, state representatives, shellfish wardens, clam dealers and harvesters etc. Interviewees have different history of participating in the soft-shell clam fishery, which shows great representativeness of the fishery. Qualitative data mainly involve stakeholders' perceptions about the water quality issues and management in soft-shell clam fishery.

3.3 Literature review

3.3.1 Co-management

Due to the complexity of common-pool resources in the human-environment systems, governance of many resources such as wildlife, protected areas, forests and fisheries etc. has now involved more than one agency. In the past three decades, increasing research attention has been paid to various elements of co-management (Berkes, 2009; Jentoft,1989; McClenachan et al., 2015).

The co-management structures are different due to the regions, whether developed or developing countries, and the nature of the resources such as fisheries, wildlife, forest and grazing lands etc. (Berkes, 2009; McClenachan et al., 2015; Pomeroy et al., 2001). While co-management structures and compositions might vary, they share similar characteristics in nature (Berkes, 2009; Pomeroy et.al, 2001; Sen & Nielsen, 1996). Berkes (2009) describes co-management as "the sharing of power and responsibility between the government and local resource users". It was pointed out that co-management is different from the

community-based resource management (CBRM) in that governments are also involved in the management process (Sen & Nielsen, 1996). Depending on community participation and the directions from policy creation to implementation, there is a spectrum of co-management schemes, whether top-down or bottom-up (Kamiyama et al., 2018).

During the co-management process, it was suggested that compared to exploring the formal institutional arrangements, focusing on the organizations and distributions of the management tasks is more important (Carlsson & Berkes, 2005). One of the reasons is that emphasizing the structure of the co-management is more likely to neglect the functional side which is a constant "problem-solving process". Therefore, co-management should be taken as "an approach to governance" rather than "formalized power sharing arrangement".

Compared to single-agency top-down management setting, co-management regime has multiple advantages in terms of management flexibility. One of the suggested advantages of co-management is about knowledge and information sharing and opportunities for communities to learn together (Pomeroy et al., 2001). This process acknowledges the values of local ecological knowledge and improves the diversity of perspectives in the management. In fisheries management, fishers' knowledge (FK) includes empirical information about ecosystems, fishing methods, governance and relationships etc. (Medeiros et al., 2018). FK is mainly obtained from experiences in specific cultural and natural environments and may or may not be shared. When fishers choose to participate in the management process such as advisory council meetings and community planning etc., FK sharing can improve fisher representation in the policies.

Co-management helps build the base of motivations and interactions that can go beyond the fisheries management and apply to other similar fields. It has been suggested that social preparation which refers to the process of local value building towards resource management should be more of a priority than “technical and material interventions” (Pomeroy et al., 2001). Co-management is less about the rules but more about the process of interactions and collaboration as both the social and ecological systems are dynamic (Berkes, 2009).

Co-management also enables power redistribution by empowering marginalized coastal communities and inviting local stakeholders to co-manage natural resources. Enabling local resource users and communities to participate in resource management helps the governance to be more adaptive (McClenachan et al., 2015). However, challenges still exist for co-management in terms of reducing barriers due to management hierarchy system.

3.3.2 Co-management impact factors

According to Pomeroy et al, (2001), there are three levels of conditions that affect the success of co-management: supra-community level, community level and individual and household level. These three levels represent the management system from national-level administration to individual and household decision making. Among the 18 conditions under these three levels, aspects such as policy implementation, stakeholder participation, empowerment, adequate financial resources, community organizations and individual incentives are most relevant to this research.

Efficient policy implementation involves “vigorous, fair and sustained law enforcement” and is critical for successful fisheries co-management (Pomeroy et al., 2001). During the process of policy creation and implementation, financial resources are required to support specific operations and facilities. Funds need to be secure and timely in order to "sustain and maintain interventions". In certain circumstances, community stakeholders might need to invest their own capital in fisheries co-management.

Stakeholder participation focuses on local participation in the decision process and is required to ensure management efficiency and fairness (Pomeroy et al., 2001). Co-management participation empowers marginalized community members in the economic realm and effectively operationalized community and natural resource management. Stakeholder participation, during policy creation and implementation process, is closely associated with stakeholder attitudes and commitment. Local stakeholder perceptions about the management reflect various aspects of the co-management under multiple impact and are valued by researchers (McGreavy et al., 2018).

When local communities participate in the management process, empowering them to have more control over resources is crucial. Empowerment, capacity building and social preparation at the community level are about improving social awareness and attitudes, strengthening ability to manage natural resources and empowering local resource users through collective actions, which are among the most important conditions in this project. Therefore, instead of modifying the regulations, it is more powerful to improve the awareness and build capacity of involved stakeholders in face of changes and values and skills shape the adaptation mechanism (Pomeroy et al., 2001).

Individual incentives are about individual rational decision making in which costs and benefits of violating the rules are evaluated. Fishery resources are "common properties" and are likely to be overexploited if individual fisher wants to make most of the resources (Jentoft et al., 1998). Due to the low cost of participating in the soft-shell clam fishery and challenges of monitoring harvesting effort, it is difficult to control the fishing effort at individual level. Therefore, it is important to shape individual awareness towards sustainability. Individual awareness is related to resource user behavior patterns towards rule following. With sustainability awareness, individuals and communities also need skills and technologies to take actions under the co-management scheme. Therefore, education and training are needed to help build capacity to practice sustainably.

3.3.3 Adaptive co-management

With growing impact of climate change, co-management structures are required to take on adaptation, and researchers have started using the term “adaptive co-management” to refer to “a long-term management structure that permits stakeholders to share management responsibility within a specific system of natural resources, and to learn from their actions” (Hartanto, 2003, p.21).

Adaptive co-management research looks at the resilience of the management under environmental uncertainties and risks. During the co-management implementation, various factors might affect its adaptive capacity. Similar to the contribution of FK, the concept of “learning by doing” applies to the course of adaptive co-management (Armitage et al., 2008). In the past research, social learning which refers to “iterative reflection” during information sharing was emphasized (Armitage et al., 2008; Tompkins & Adger, 2004). Same as

environmental changes, learning is a dynamic process and has a more flexible response mechanism that can compensate for the limitations of current policy and management structure. Either support or objection influences the public behavior in the process of management implementation, and thus determines the adaptive capacity of the management system. Public participation and stakeholder communications have the potential of enhancing adaptive capacity through the process of building civic capacity in social learning.

During adaptation processes under the management scheme, collective actions are significantly affected by the conditions of social capital. Social capital involves a wide range of relations between actors and is a useful resource for adaptation (Pretty and Ward, 2001). Since social capital is mainly created through relationships, such a network of trust and reciprocity can shape institutions' performances in dealing with natural resource changes and uncertainties. The "unpriced environmental goods and services" which build basis for economic processes, human and non-human life can be categorized into "natural capital" (Adger, 2003).

Grothmann and Patt (2005) have addressed the impact of psychological factors on adaptation process through a socio-cognitive model. Despite the impact of objective resources and capacity, cognitive recognitions of the adaptation have been suggested as an influential factor, and sometimes even more effective in individual adaptation decisions (Grothmann & Patt, 2005). Adaptation decision making of individuals is a process of detecting changes, signal evaluation, decision-making and feedback. The feedback which refers to the outcomes after the adaptation is more complicated than a linear process of case

and effect. In certain situations, personal risk and adaptive capacity evaluation can be effective in affecting adaptation decision making.

As changes would affect stakeholders outside the governance structure, adaptation would involve participations and collaboration of non-governmental civil societies (De Souza Briggs, 2008; McGreavy et al., 2018). Civic capacity, as an aspect of the adaptation, relates to the public attitudes and actions towards the management. It was defined as the "capacity to devise, decide, and act collectively to improve our lives" (De Souza Briggs, 2008). In this research, civic capacity refers to the capacity of non-governmental institutions and individuals that participated in the soft-shell clam management to adapt to temporary environmental closures. According to Armitage et al. (2008), when local resource users participate in co-management, civic capacity contributes substantially to their self-organized learning processes.

3.4 Results

3.4.1 Maine's soft-shell clam fishery water quality policy structure

Federal Level

In 1984, the U.S. Food and Drug Administration (FDA) recognized the Interstate Shellfish Sanitation Conference (ISSC) as the major voluntary organization at national level for State shellfish regulatory managers that guide and counsel on shellfish sanitation and management. NSSP, as a cooperative program conducted by state and state governments, is acknowledged by FDA and ISSC to control shellfish sanitation and ultimately food security.

Table 3.1 Shellfish growing area classifications under NSSP standards.

Classification	Status	Shellfish Harvesting Activity
Approved	Open	Harvesting allowed
Conditionally Approved	Open	Harvesting allowed except during specified conditions (rainfall, STP bypass or seasonal)
	Closed	Harvesting NOT allowed
Restricted	Open	Depuration and/or Relay harvesting only
Conditionally Restricted	Open	Depuration and/or Relay harvesting allowed except during specified conditions (rainfall, STP[6] bypass or seasonal)
	Closed	Harvesting NOT allowed
Prohibited	Closed	No harvesting allowed or water use allowed for processing (administratively imposed precautionary closure)

NSSP has launched Guide for the Control of Molluscan Shellfish to improve and enhance shellfish sanitation for interstate shellfish commerce and unify State shellfish management. ISSC is mainly in charge of updating formal regulation guidelines and procedures to unify state program applications.

According to federal water quality standards, there are five categories of shellfish growing areas: Approved, Conditionally Approved, Restricted, Conditionally Restricted and Prohibited (Table 3.1). The decision on classifying shellfish growing areas depends on three key procedures: pollution source identification, marine water fecal coliform bacterial measuring under NSSP standards and pollutant distribution analysis. The sanitary surveys must be conducted on a 12-year cycle.

[6] STP stands for Sewage Treatment Plant.

Among the five categories, Approved areas' harvested shellfish could be put directly to marketing. Conditionally Approved areas are approved under predictable conditions and will be closed when the water quality does not meet the standards. Shellfish landings from Restricted areas which are regions with a limited amount of contamination must be "depurated" or "relayed" to be allowed in the markets. Depuration and relay mean to put shellfish in clean water areas to enable the species to become clean again through filtering (NSSP, 2015). An extra permit is required for Restricted area shellfish harvesting. Conditionally Restricted areas are regions that might be temporarily closed for harvesting if water and shellfish tissue sampling shows worse water quality. A Prohibited area might contain certain concentration of "fecal material, pathogenic microorganisms, poisonous or harmful substances" and fishing is banned within such an area. Growing areas without sanitary surveys will also go under Prohibited category (ME DMR, 2018). Areas getting closed surely decreases harvesters' access to the fishery, however, this is not the focus of this study.

State government role

Under federal standards DMR oversees local municipalities' performances and assists with management ordinance creation and implementation, if necessary. Within the DMR, there are usually three regional biologists that conduct clam population assessment and perform predator control and restoration projects. One of the most challenging things for a town to manage clam resources is to hire a municipal shellfish warden who is knowledgeable both in law and clam fishery. The costs of management include hiring a warden come from

license fees and fines and may exceed how much a municipality can afford. In this situation, municipalities might leave the fishery to be managed by DMR.

Bureau of Public Health Program of Maine DMR oversees shellfish sanitation and management programs. More specifically, the programs include marine biotoxin monitoring, shellfish dealer certification and inspection, shellfish growing area classification and temporary environmental closure issuance etc.

Temporary environmental closures are independent from the growing area classification. There are two major types of temporary shellfish closures: biotoxin and bacterial closures. Biotoxin closures, also called red tide closures, are caused by "harmful algal blooms" (HABs) which typically happen during warmer time of the year (ME DMR, 2018). The phytoplankton dinoflagellate species *Alexandrium ssp.* is the main cause of red tide in Maine and contains toxin that will lead to shellfish poisoning such as paralytic shellfish poisoning (PSP). Maine DMR Marine Biotoxin Monitoring Program collects shellfish samples along the coasts during March-October which get tested in Boothbay Harbor, and when the shellfish tissues' toxin level exceeds the standards, the growing area will be closed. The capacity of depurating biotoxin quickly after the phytoplankton bloom helps decrease the impact of red tide on soft-shell clams, compared to shellfish such as scallops. Bacterial closures are affected by environmental impact such as rainfall and anthropogenic activities and the existence of point source pollution caused by sewage treatment plants etc. Tests of seawater and shellfish shall follow NSSP procedures. Maine DMR issues four types of temporary environmental closures related to bacterial pollution statewide: conditional areal closures (including rainfall, tide, sewage treatment plant and river

discharge), emergency flood closures, aquaculture closures and pollution abatement closures. There are currently 98 segregated growing area bacterial closure regions from Piscataqua River to St. Croix River initiated by DMR.

Local municipal role

Local municipalities may choose to manage clam resources with shellfish management plans which need to be approved by DMR and are usually reviewed every three years (ME DMR, 2018). If a town has its own ordinance, then there must be at least periodic clam surveys and annual DMR report about clam flats. Municipal clam management cost tends to exceed the income from license sales and violation fines. It typically takes a town approximately $50,000 to manage clams annually, which might not be affordable for certain municipalities. If one local municipality does not manage the clam resources on its own, Maine Patrol Officers under DMR will enforce the 2-inch law and prohibit harvesting in closed/restricted areas (Ellis & Waterman, 1998).

Shellfish management committees are created during management process, and they should work closely with municipal officers to manage the fishery. A municipal shellfish management committee consists of different number of members (from five to seven) who serve in committee from one year to three years. Committee members are appointed by either the Town Council or selectmen. Within the local clam management system, volunteers play a significant part. There can also be volunteer committees which consist of clam harvesters, selectmen or just the citizens.

In 2001, 53 coastal municipalities had their own ordinances for the soft-shell clam management, which typically required a town license for harvesters besides state license. In 2014, 75 municipalities participated in the clam co-management and 34 municipalities chose not to have conservation projects (Maxwell, 2017). Now there are 58 local ordinances, 50 of which are run by individual towns. The rest eight ordinances are implemented higher than individual town level, either through cooperation (Damariscotta/Newcastle; Deer Isle/Stonington; Washington County UT; Yarmouth/North Yarmouth; Pembroke/Perry) or by building regional committee (St. George Regional; Frenchman's Bay Regional; Boothbay Regional) (ME DMR, 2018).

According to a previous research on the soft-shell clam management, most of the municipalities (n=42/75) that participate in the co-management programs hire at least one shellfish warden (Maxwell, 2017). Others not hiring wardens will partner with local police officers who take turns to conduct shellfish area patrolling. However, hiring shellfish wardens could take more than what municipal programs could afford, and in this case, NGOs have contributed to about half of all participating municipalities (45.9%). As for DMR's participation in municipal committee meetings, shellfish biologists attend meetings more often than water quality program employees.

Out of 131 DMR employees, 18 of them are conducting projects related to shellfish water quality, 5 of them participate in seafood supply chain related tasks and 4 oversee the biological aspects of the soft-shell clam management. Our observations at Shellfish Advisory Council (ShAC) meetings suggested that employees in the water quality programs were

willing to share technology updates specifically interactive maps to promote public awareness about water quality.

3.4.2 Water quality management impact factors

The interview references demonstrated the complexity of multiple stakeholders' perceptions related to water quality issues. These perceptions reflect the current situation of water quality policy implementation and individual respective values. The diverse values about the fishery showed different involvement in the fishery and access to information, knowledge and financial resources.

For the convenience of this research, impact factors are categorized into four types: governance, pollution, civic capacity and adaptation impact factors (Table 3.2). For those concerned about water quality, the difficulties about identifying upland sources were especially pointed out. Despite the recognized difficulties of identifying pollution sources, stakeholders were able to recognize several coastal pollution events. Motor boats were accused of discharging bleach and bilge. Summer house pollution was also identified especially concerning chemicals used on lawns. In this context, stakeholders emphasized the significance of awareness in terms of anthropogenic pollution.

While coastal development has benefited the infrastructure building, the tourism industry and usually an already wealthy population, it has raised the pressure on shellfish fishery. With coastal construction, water quality has been affected, access to the fishery has been decreased. In addition, freshwater input into Maine's coastal areas increases chances of inland development pollutants being found in marine environment. It was geographically

different as coastal communities were much more developed in Midcoast and Southern Maine, in comparison to Downeast Maine.

Table 3.2 Stakeholder perception qualitative analysis code summary.

Categories	Aspects	Quotes
Governance	**Policy implementation**	"Last year they did a lot better – like I say it was a new outfit that took over testing and they were getting us open in four or five days."
	Management participation	"I think the towns need to take a bigger role. Maybe more grants for these people to get their problems fixed as far as septic."
	Policy compliance	"So I have heard that, you know, if there's a flood closure on and we get heavy fog, people are digging."
	Inequity	"Why should someone be able to dig in a closed area just because they're on the board and if I did it I'd get a ticket?"
Pollution	**Sources**	"Find the point source. That's the bottom line."
	Impact	"So it was like two weeks without work."
Civic capacity	**Individual**	"And I have – as I said, I've actually learnt to be a volunteer for water quality."
	Institution	"I question whether those flats would have been reopened if it weren't for the 610 Project. So I think it's a good thing."
Adaptation impact factors	**Climate change**	"I grew up here. When I was a kid we didn't have any rain overflow. We didn't even know about paralytic poison, shellfish poison."
	Predation	"I think water quality is the biggest. And I think green crab producing (predation) is number two."
	Financial resources	"So I - everything I do is purely financially governed, so I used every tool I have in my book, from my education to my technical background, to my clam digging title."
	Coastal development	"There's more shoreline development. There's less access."
	Relationships	"But hey, if you see a friend in a spot and you know it's closed and they don't know – hey buddy, that's spot's closed."
	Perceptions	"I fully support it. I think it's a good thing. I think it is better to be safe than sorry and human health and public health needs to take precedence."

Coastal development has changed shoreline infrastructure substantially.

Perceptions about water quality were found to be closely related to specific municipalities, and interviewees were showing differences of water quality. There were municipal residents that said the water "could shine my light down in the water last night and

see six feet." At the same time, serious complaints about polluted water body were made. One stakeholder said that that water quality did not necessarily affect shellfish abundance.

The co-management structure has the potential of involving local stakeholders in decision-making processes. In practice, such impact existed in municipal committee constitute and it was suggested that diggers on board might be able to dig in closed areas while closure digging of non-board members might be reported. And as a result, the suggestion about including "non-clammers on the committee" was made.

The public understandings and perceptions about closure policy varied substantially, which subsequently affected their attitudes towards the policy implementation. Specifically, this involves whether stakeholders could tell the differences between bacterial and biotoxin closures and specific causes of the temporary closures. The process of the perception creation is complicated and involves human cognition aspects that go beyond this study (Grothmann & Patt, 2005). Nevertheless, awareness was recognized among factors that impacted adaptation and, in this respect, education projects initiated by towns with more grants to help with water quality improvements were recommended.

Shellfish management regulations especially concerning the illegal harvest fines seemed to help mitigate illegal harvesting, however, there were still suggestions that the fines should be the same for recreational and commercial diggers as one stated that" What's good for one should be good for all.".

As for support for closure policy, it was clear that stakeholders valued the public health, which could be demonstrated by the quote "I think it is better to be safe than sorry and

human health and public health needs to take precedence". The common ground of the shellfish security at the industry level was shared by multiple stakeholders.

During the process of policy implementation, local understandings and support might impact the efficiency of putting regulations in place. In this respect, it requires that government officials pay attention to communicating issues with local stakeholders. In Maine, DMR biologists are sent out to have conversations with coastal communities and it was proved that local clam harvesters valued these conversations.

Information sharing among clam harvesters has created dynamics that subsequently shaped individual behavior. In certain municipalities, as information about temporary closures might not be widely shared among clammers, illegal harvesting would happen and be reported to the warden. In municipalities with great information notification during shellfish meetings, however, meeting participation would be the factor that limited public awareness about the temporary closures. And because of this, municipal management would complain about clam diggers asking about temporary closures multiple times after the meetings.

Some local stakeholders criticized the poor performances of water testing and warden patrolling and the long time it took DMR to reopen a temporary closure or notify an opening. More specifically, one DMR official once said they just took samples and did not compile data, which caused concern about the water quality monitoring project to clammers. It was pointed out that testing was becoming better with "better technology and more people", and thus clamming communities would be expecting faster opening and less financial losses. For example, communities were getting rain gauges.

Complaints about lack of governmental support have also been made especially when one clam harvester compared their situations with the dairy farmers who were paid to stop milking. To improve governmental support, specific recommendations such as helping with getting more coolers were made since temperature is the key in keeping clams fresh before consumption.

Inefficiencies of the management have been attributed to the incompatibility of the federal policy with state situations. A quote such as “The FDA and the whole compact, they have put in place things that I don't feel apply to the state of Maine that apply for Florida.” demonstrated the perception. Also because of this, certain stakeholders might regard federal policy as the threats to efficient shellfish management policy.

Limited budgets and manpower have also been causing inefficient water quality management, which could be demonstrated by one response of the municipal manager to the reporting harvesters “I think your message is sound. However, with current budget constraints and time spent on enforcement it is unreasonable. In fact, we have determined that we cannot even help DMR with water quality any more here”. Doubts about the expenditure of the taxes have also been expressed by local stakeholders, especially in areas with limited infrastructure setting.

Previous research has shown that diversifying income sources helps fishers with their adaptation processes (Kasperski & Holland, 2013), which was certainly shown in the interviews. For clammers with alternative jobs such as working in post offices or with firewood, the closure impact would be lower as their income could be maintained to a certain

level. In cases where clammers could sense the upcoming temporary closures, they might dig double tides prior to the closures. It was recognized that certain individuals were “taking advantages of the loopholes” of policy and regulations. In restricted areas, policy requires that shellfish harvesting must go through depuration processes to be able to be sold. Now in the State of Maine, there is only one eligible company which was certified to operate the depurating procedures.

Changes have happened both in weather conditions and in harvesters’ behavior. In the past, “rain overflow” was much rarer and shellfish poison was unknown to fishing communities, and therefore clam digging covered much larger areas which included sewer line surroundings. Part of the reasons for this was mentioned to be the differences of consumption behavior, as in the past people were said to know how to cook the shellfish better.

When asked about the biggest threats to the soft-shell clam fishery, stakeholder also voiced concern about factors other than water quality. Factors are at different scale: predation, ocean warming and red tide etc. Predation by green crabs has been listed as the most influential factor as water quality by several stakeholders. Ocean warming was suggested to have the effect on *Vibrio* populations, specifically in southern New England. Stakeholders showed negative attitudes towards red tide, however, it showed that there was a lack of understandings about the mechanism behind red tide.

3.4.3 Civic capacity

The lack of adaptive capacity aspects in the current water quality system to deal with water quality issues instead gets compensated by the strong elements of civic capacity contributed by external agents. External agents refer to other government agencies, non-governmental organizations (NGOs), academic/research institutions and civil citizens etc. that help the co-management system to define, analyze and solve problems (Pomeroy et.al, 2001).

In Maine soft-shell clam fishery, civic capacity has been enhanced substantially by the civic participation such as clam enhancement and water quality projects and citizen volunteers. Collaboration between government institutions and researchers has improved the efficiency of project implementation. Collaborating project between institutions and individuals will be introduced as follows:

Citizen volunteers contributed by monitoring poaching activities and water quality. Certain responsible clam harvesters might report potential polluted areas to DMR to get the water quality tested, despite the risks of losing the access to such areas and getting blamed by fellow harvesters. Further civic capacity improvement suggestions were made such as education projects to increase clammer knowledge.

Besides the co-management body, governmental departments have worked with NGOs that help shape adaptation processes. Groups of different priorities and focuses such as ShAC, Downeast Institute (DEI) and Maine Clammers Association (MCA) etc. were created.

ShAC was established by Maine statute in 2007 to bring concerning issues in the shellfish industry to the commissioner. ShAC includes commercial soft-shell clam harvesters,

shellfish dealers, shellfish aquaculture lease holders, a depuration facility expert and a researcher etc as members. (ME DMR, 2008). ShAC, in particular, helps information exchange and policy making democracy by gathering clam harvesters, dealers, researchers, depuration companies and DMR officials for the quarterly meetings.

DMR has worked with DEI to explore netting technology to prevent soft-shell clam recruits from predators (DEI, 2015). Maine DEP has issued grants related to removing overboard discharges and replacing wastewater treatment plants (ME DEP, 2018).

Several grants have also been issued to support research and experiments of soft-shell clams. DEI, funded in 1987, has done educational and applied work related to soft-shell clams. In 2015, National Oceanic and Atmospheric Administration (NOAA) issued a grant of $288,000 to Manomet in Island Institute to support clam aquaculture work. NGOs such as DEI and Manomet have worked on clam aquaculture projects with researchers and clam harvesters (Island Institute, 2015).

MCA established by clam harvesters in 2008, deals with massive statewide closures. Its mission is to restore the ecological, economic and social sustainability of the shellfish resources in Maine.

The Maine Fishermen's Forum which is held every year aims to improve collaborations between fishers, scientists and government officials etc. During the forum, there is a shellfish day that focuses on specific issues such as water quality.

During interviews, other institutions such as DEP and Land Trust and projects like 610 projects were pointed out to help improve policy implementation especially pollution source identification.

610 Project which is a collaborating project between the DMR, the Hancock County Planning Commission, the Frenchman Bay Regional Shellfish Committee and the Frenchman Bay Partners were appreciated by local stakeholders. Frenchman Bay Partners is a consortium of stakeholders from research institutions, conservation groups, education organizations, tourism companies, marine industries, land trusts and municipalities. Such a consortium was established to collect and exchange information, facilitate conversations with bay users and stakeholders and initiate actions. In the past years, 610 Project has been working on the five-year goal of opening all 610 acres of restricted clam flats because of unknown bacterial pollution sources. Proposed activities included capacity building within shellfish committee to conduct watershed surveys and organizational development.

Knowledge generation and exchange have been substantially strengthened by the research and academic institutions. Multiple aspects of the sot-shell clam fishery have been studied in the recent decades.

3.5 Discussion

This research highlights that the policy setting of the soft-shell clam co-management system does not guarantee the equal sharing of management responsibilities and power, specifically during the process of water quality monitoring. Rather, it is the functions of the system that shape the capacity of the management to adapt to the changing environment,

which proves the research findings of Carlsson and Berkes (2005). In the soft-shell clam fishery, specifically, water quality standards are mainly implemented by state government following federal regulations. Municipal stakeholders, therefore, do not have enough participation or power to influence policy creation or implementation.

During the interviews, public perceptions towards water quality issues revealed high awareness of the pollution issues. However, it also showed that water quality was quite different in different locations, which means it might not be a serious issue for certain municipalities. Despite different concern surrounding water quality issues, the difficulties of identifying pollution sources and reopening the closed areas were commonly pointed out by both management and resource use sectors. Among the causes of pollution, human input such as lawn products and overboard discharges have been responsible for a substantial amount of non-point source pollution in the marine environment. It was also mentioned by state and municipal stakeholders that coastal development has a significant impact on water quality due to changes in shoreline structures.

In terms of water quality policy, both acknowledgements and concern have been expressed by stakeholders. Clammers who are most directly affected on the ground, showed their concern about water quality monitoring and emphasized the importance of closure notification. Municipal committee members, despite their support for closure policy, were concerned about the water quality policy implementation. At the same time, they identified the resource limitation for policy implementation and necessities for municipalities to take a bigger role in the water quality management to ensure public health. On the government side, several shellfish wardens have showed their concern about FDA uniform standards

might not apply to Maine. State representatives, on the other hand, have acknowledged public health program growth and contribution of local municipalities and encouraged municipalities to be more proactive during water quality management. It suggested that with better technology and more personnel, the management activities could be enhanced.

To improve the efficiency and adaptive capacity of the water quality co-management in the soft-shell clam fishery, multiple aspects of the co-management system require changes. These changes include better water quality monitoring and closure notification, improved local stakeholder incorporation, communications and education etc. It is also apparent that funds are not adequate to support state level policy implementation and for small-scale fishing communities in Downeast Maine, it is certainly challenging for local stakeholders to contribute their own financial resources, especially given the losses of revenue due to closures.

Despite the current focus of policy agenda to identify pollution sources in the water quality management, decreasing marine ecosystem exposure to pollution might be the ultimate approach to address water quality issues. Since water quality is mostly associated with local scale development and anthropogenic activities, decreasing exposures require more communications and collective actions among multiple government departments and civil societies. Such adaptation processes need discussions and actions of multiple levels, from regional to local, and meanwhile the adaptation actions shall be supported by the national governance systems through policy creation, education and implementation monitoring.

When closure policy gets implemented, not all harvesters followed the rules. As soft-shell clam fishery is relatively low-cost to participate in, clammers might take the risk to conduct illegal harvesting including poaching and closure digging. For affected clammer population, these related to drug uses and crime were among the most vulnerable group and were most likely to harvest illegally. Inequity issues were also highlighted as clam harvesters feel lack of support during closure adaptation comparing to other industry. While coastal development stimulates local economy and benefits the wealthier population, a lot of the subsequent pollution costs have been paid in the form of decreased fisheries landings, which put more pressure on the fishing communities. It is recommended that the pollution tax should be issued in that during tourist season, the already wealthy population tends to add pollutants into the water body while clam harvesters are losing income due to shellfish closures. Such perceptions have pointed out the potential conflicts among different resource users.

The impact of shellfish closures has demonstrated significant needs for multiple aspects of the society to change. Clam harvesters, with high reliance on the fishery, are among the most vulnerable population in front of water quality issues. With no alternative income sources, some clam harvesters might have to break the law and fish illegally during shellfish closures. Like other fisheries (Agnew et.al, 2009), the soft-shell clam fishery is threatened by illegal harvesting such as closure digging and poaching. It shows that greater information notification by the government through shellfish meetings will at least improve public awareness of the shellfish closures.

At the same time, it is crucial to enhance public understandings through education projects about the policy making. Better understandings will lead to better policy compliance and support. Some clam harvesters also voiced their hope about more support from the government to better adapt to water quality issues. Results also showed that the reputation of Maine soft-shell clam mattered tremendously to the industry, which provides a common ground for stakeholders. Given the considerable awareness of water quality issues at municipal and state levels, there are needs of improvements of collective actions. According to Jentoft (1989), the size of fishers' organizations determines the level of difficulties to manage the fisheries. Therefore, municipalities should be involved in water quality standard setting to incorporate local resources and network.

As Sindermann (1980) suggested, marine pollution management must be incorporating "best available scientific information" and considerations in economic, social and political aspects. Citizen volunteers have been improving water quality management efficiency through more water quality monitoring. Besides individual level support, institutional support from multiple NGOs is also shaping the adaptive capacity of the water quality management.

Policy has been set, but values, attitudes and subsequent behavior are ever-changing and may go beyond the scale of rules and regulations. Therefore, water quality management can be better implemented with collaboration of multiple parties involved in the fishery including clammers, dealers, resource managers and NGO partners etc. Because co-management is "a process in which relationships among the parties are constantly changing"

rather than “an end-point” (Pinkerton, 1992), future research shall incorporate the dynamics of the co-management system while analyzing the functions of the respective agencies.

The strong NGO participation has substantially improved the adaptive capacity of soft-shell clam fishing communities to deal with water quality issues and other threats in the fishery. Strong demonstration of civic capacity also provides inspirations for future modifications of the co-management structures to apply the “the sharing of power and responsibility between the government and local resource users” (Berkes, 2009, p. 1692).

Based on participant observation in meetings, we also discover the imbalanced power dynamics between state government and local stakeholders, which creates barriers to sharing local ecological knowledge. To be able to adapt to the water quality issues better, the governance system needs be more flexible. Co-management risks and costs might also be more manageable when there is a higher level of collaboration.

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APPENDIX A CLAM DEALER INTERVIEW PROTOCOL

Operations

Do you sell soft-shell clams all year-round?

Do you deal with seafood species other than clams?

Is there a time limit for you to keep the clams in storage?

Upstream sources

Who do you get your clams from? How many clammers/dealers do you interact with?

How do you decide how much clams you need?

Downstream distributions

Where do you sell your clams to? How was the demand?

How do you decide on the price of your clams?

Shellfish closures

How do you feel about shellfish closures, do you get deeply affected by them?

If yes, how do you usually deal with shortage of clams during these time periods?

BIOGRAPHY OF THE AUTHOR

Shuling Chen was born in Changsha, China on October 7th, 1994. She graduated from Yali High School in 2012 and then attended Ocean University of China in Qingdao, Shandong. In 2014, she exchanged in Semester by the Sea program at Darling Marine Center in Maine. She graduated as an outstanding graduate with a Bachelor of Science in Marine Biological Resources and the Environment in 2016. During her undergraduate years, she did her intern with China Blue Sustainability Institute in Hainan and World Wide Fund for Nature (WWF) in Beijing collecting and translating fisheries documents. She won several awards in national English public speaking contests and was the vice director of the campus radio station.

In August 2016, Shuling joined Marine Policy program in School of Marine Sciences at University of Maine. Her research interests include supply chain dynamics and co-management. She is funded by Maine Agricultural and Forest Experiment Station (MAFES), School of Marine Sciences (SMS) and Diana Davis Spencer Foundation. She is one of the scholars in Senator George J. Mitchell Center for Sustainability Solutions at UMaine. She was enrolled in 2017 Blue Pioneer Program in Monterey which intended to inspire changemakers in China's ocean and coastal social enterprise space. She has maintained her connections to Chinese fisheries industry and was recently selected as Natural Resources Defense Council's Chinese Fisheries Science Fellow based in Beijing, China. She is excited to work with China's fishery policy-makers and environmental governance experts from the U.S. to help promote the sustainability of Chinese fisheries. Shuling is a candidate for the Master of Science degree in Marine Policy from the University of Maine in August 2018.