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Participatory Modeling of Tidal Circulation on Maine Mudflats to Improve Water Quality Management of Shellfish Areas

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PARTICIPATORY MODELING OF TIDAL CIRCULATION ON MAINE MUDFLATS TO IMPROVE WATER QUALITY MANAGEMENT OF SHELLFISH AREAS

By

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An Abstract of the Thesis Presented
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Over the past decade, researchers have become increasingly aware of the vital role stakeholder knowledge plays in understanding complex social and environmental problems. Incorporating stakeholder knowledge into understanding complex problems allows for greater awareness and identification of community needs and can help build partnerships to support the development of applied research. In this thesis, I demonstrate the value of stakeholder knowledge and research partnerships by focusing on the soft-shell clamming industry in Maine and how a complex collaboration between clammers, municipal officials, representatives from state agencies, researchers, and other partners relied on and build adaptive capacity to address complex water quality issues within a watershed. One of the major threats facing the soft-shell clam industry is mudflat closures due to water quality concerns. Many of these large area closures are based on sparse monitoring and enforcement constraints that can cause clam flats to be closed due to presumed fecal coliform contamination when they do not need to be. This thesis is organized into two chapters. In the first chapter, I address this research need and opportunity using hydrographic and bacterial monitoring data coupled with knowledge from local clammers in an engaged research project to describe circulation dynamics that influence the fate and transport of fecal coliforms in

the Medomak River estuary, the most productive clam flat in the state of Maine from 2015-2017. The novel aspect of this engaged approach is the direct participation of clammers and other stakeholders in the design of research questions and methodology. I worked with the Medomak Taskforce to understand their information needs and tailored the research to meet those needs and this thesis is organized into two distinct studies. Bucket drifter experiments were used to calculate tidal excursion and provide dispersion metrics during varying environmental conditions (i.e., tide stage and river flow). These experiments found the dominate environmental factors effecting circulation in this estuary were changes in cross sectional area, tidal forces, and wind, and using a computer model that included drifter data, I was able to calculate residence time of fresh water in these areas. In the second chapter of this thesis, I focus more specifically on how collaborative projects can improve the overall management of the soft-shell clamming industry. I used semi-structured interview protocols, along with extended engagement methods provided for qualitative datasets, which were analyzed through NVivo Software®. Interview data was to understand the communication between state management and community management in regards to adaptive capacity. I found that the collaborative project, the Medomak Taskforce, influenced and supported multiple aspects of adaptive capacity. A major goal of this research was to use engaged research approaches to design the research so it would support decision making needs for water quality monitoring and for ongoing collaborative efforts in this watershed. It is hoped that the results will be used by state agencies to better characterize the temporal and spatial dynamics of pollution sources in an effort to make more informed decisions.

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LIST OF ACRONYMS

DEP - Department of Environmental Protection

DMR - Department of Marine Resources

MVLT - Medomak Valley Land Trust

DAg - Maine Department of Agriculture

FVCOM - Finite Volume Coastal Ocean Model

GPS - Global Positioning System

NOAA - National Oceanic and Atmospheric Administration

SEANET - Sustainable Ecological Aquaculture Network

NECOFS - The Northeast Coastal Ocean Forecast System

CFU – Colony-forming unit

p90 – 90^{th} percentile

TOV- Trinity of Voice

CHAPTER 1

INTRODUCTION

1.1 Background

Linking scientific findings with decision making and resource management is one of the great challenges in science. Over time, science has increasingly focused on providing technological advances and answers to many questions facing humanity (Gibbons et al. 1994, Lemos and Morehouse 2005, Liu et al. 2008, Tang and Dessai 2012, Wall et al. 2017). Research-based partnerships have been used as one strategy to develop science that is seen as useful for decision making (Liu et al. 2008, Hansson and Polk 2018). The first step in stakeholder engagement techniques is understanding the function of science in society. Namely, science is no longer a simple explorative endeavor, but scientific data and conclusions will be used to shape policy and practices in a variety of different areas (Gibbons et al. 1994). Here I briefly describe the value of a sustainability science approach to crafting useable knowledge, highlighting the major commitments in this orientation to research. I then introduce how these key commitments guided my research design process in the Medomak River estuary and with the Medomak Task Force.

Science that aims solve practical problems must balance three characteristics: saliency, credibility, and legitimacy (Cash et al. 2002, Liu et al. 2008, Hansson and Polk 2018). Saliency refers to the relevance to decision making and politics, credibility refers to scientific accuracy, and legitimacy refers to how well the scientific process is accepted by the general public. Incorporating stakeholders into the science during a majority of the stages of experimentation can enhance legitimacy and saliency, while maintaining scientific credibility (Cash et al. 2003). Having increased saliency can push a project towards political action, a critical component of protected areas, conservation, fisheries, and many other aspects of marine science (Cash et al. 2003, Wall et al. 2017). Engagement techniques have been used in a variety of marine science contexts, due to the multi-dimensionality of most projects, where environmental factors, human use, economics, and cultural values all come together (Carvalho and Fidélis 2013, Lemos and Morehouse 2005, Scott et al. 1999). The need and value of incorporating stakeholder knowledge in marine-based and coastal research process has become increasingly important, due to the concentration of human interactions and impacts on these environments and intensifying pressures due to climate change (Rangel-Buitrago and Anfuso 2015, Carvalho and Fidélis 2013).

Sustainability science, or science focused on the complex interactions between natural and socioeconomic systems, offers one approach for designing research that helps link knowledge with action. This approach to science advances a range of solutions to complex problems that occur at the nexus of the ecosystem, socioeconomics, and communities (Kates et al. 2001, Clark et al. 2016, Miller, 2015). While sustainability science offers diverse orientations to producing useable science, there are at least five commitments that appear to be especially important for designing research. First, designing the research questions so they align with the questions and problems that decision makers and stakeholders are asking helps set the research on a course so it will eventually be perceived as salient (Breir et al. 2007, Vogel et al. 2007, Cash et al., 2003). Second, it is essential to understand individual and group preferences for involvement in scientific processes to help ensure that they can participate in ways that work for them and do not create an undue burden on their time and resources (Lang et al. 2012). Third, research efforts, or any action towards developing research, must be iterative where collaborators regularly meet to discuss research progress and make adjustments as needed (McGreavy et al. 2015, Lang et al. 2012). Fourth, making an effort to co-produce knowledge and combine multiple forms of expertise can foster credible science and also helps people form relationships and create the social structure in which the knowledge gets used (Lang et al. 2012). Fifth and finally, researchers should be cognizant of the distribution of power, and make deliberate changes to promote equity within the process (McGreavy and Hart 2017). This can help mitigate the risks that the science may contribute to and reinforce unjust conditions (Wamsler et al. 2018, Lang et al. 2012).

Following this five-part commitment to research design, my thesis development process began with intensive efforts to understand what had already been done within the Medomak estuary (the study site) as well as interviews with stakeholders involved in that work. The overarching research questions identified and co-produced through this stakeholder process focused on the residence time of pollution and water quality. Co-production on this level required multiple meetings with stakeholders, as well as research into the Department of Marine Resources (DMR) and Waldoboro Town databases regarding the estuary. It also involved multiple interviews with key informants on the estuary. Meetings were held with the entire group of the Medomak taskforce every two months. The Medomak Taskforce is a community-led collaborative effort focused on water quality and other issues impacting the Medomak estuary. There were also multiple informal meetings of different group members and the research team on a more frequent basis. These meetings reflect the third and fourth sustainability science tenet described above, where collaborators meet to discuss the research progress and make adjustments as well as a continuous integration of stakeholder and scientific knowledge. Any findings from the work were shared immediately with the larger collaborative group, so that partners could remain involved and informed as the research moved from fieldwork to analysis. Finally, Glen Melvin, the vice-president of the Waldoboro Shellfish Committee was invited to be our co-author on a separate publication due to his commitment to the work as well as support offered for fieldwork and analysis. This invitation reflected not only his contribution to the project but was also in keeping with the fifth stakeholder engaged tenet of promoting equity.

1.1.2 Soft-Shell Clamming Industry

The soft-shell clam (*Mya arenaria*) industry has a very important role in the economy of many coastal communities in Maine and in the United States (Hanna 2000, Dow and Wallace 1961). Maine produces around 60% of the total U.S. soft-shell clam supply (Evans et al. 2016). This fishery originated in Maine as a bait industry around 1850 and grew to be the third largest seafood industry in the state by dollar value today (DMR Landings 2017, Dow and Wallace 1961). Originally, soft-shell clams were managed as an open-access resource, with individual township ordinances taking precedent and setting up authority for management. In 1894, the Maine Department of Sea and Shore Fisheries (DSSF) took over many of the responsibilities previously held by towns (Crouch et al. 2001). During the 1950s soft-shell clamming developed two specific spheres: a water quality sphere, and a shellfish co-management sphere. The water quality sphere was created with a newly established shellfish program developed by DSSF in accordance with the National Shellfish Sanitation Program (NSSP) (Figure 1). The NSSP was developed at the federal level from the U.S. Food and Drug Administration , and instituted varying nationwide laws that Maine (as a participating member of the program) had to adhere to (DSSF 1995, Wallace 1984). In the 1960s, the Maine State Legislature gave responsibility to towns to co-manage their clamming resource with the State through the DSSF, creating the co-management sphere (Crouch et al. 2001, Evans et al. 2015). Currently co-management provides a primary space in which representatives from theMaine Department of Marine Resources (DMR) work with individual towns and townships to manage clam flats (Evans et al. 2016). Co-management can support implementation of regulations and reduce the need for monitoring since the local stakeholders, in this case clammers and others who rely on the soft-shell clam resource for livelihoods have a vested interest in the health of the fishery (Hanna 2000).

Water Quality Management Sphere– Soft Shell Clamming Industry

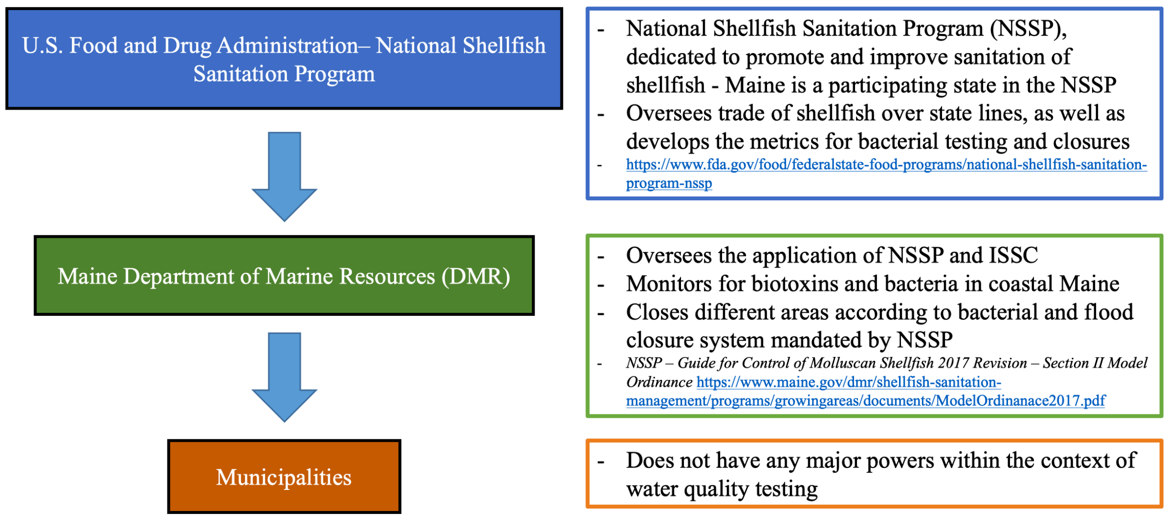


Figure 1. Water Quality Management Sphere. This figure details the overall responsibilities between different entities in the water quality management system for the soft-shell clamming industry. NSSP fda.gov, NSSP – Model Ordinance

There are many challenges to the soft-shell clam industry today. In general, there has been a marked decrease in shellfish populations and, consequently, in the amount of shellfish harvested over time. In 1977, Maine clammers harvested 40 million pounds, or around 18 thousand metric tons, while today clammers harvest an average of 10 million pounds per year, or 4500 metric tons (Congleton et al. 2006, Dow and Wallace 1961). The reasons for this major reduction in landings has been ascribed to a combination of biotic and abiotic factors including population increases of the invasive green crab (*Carcinus maenas* L.), climate change impacts such as warming temperatures and ocean acidification, and water quality (Beal 2018, Beal 2016, Tan et al. 2015, McClenachan et al. 2015, Whitlow 2010 Floyd and Williams 2004, Hanna 2000). The main water quality issue that negatively impacts harvest is bacterial pollution of fecal coliform bacteria and *E. coli*. This type of pollution is a major public health hazard (DMR- Closure Information 2017, McFeters et al. 1972, Parr 1939). The diverse nature of the source of this pollution (i.e., surface runoff, combined sewer overflows, and point source discharges) compounds the problem (Auer and Niehaus 1992, Berkes et al. 1998, Kanwit 2016, Evans et al. 2016).

1.2 Purpose of Research

The problem of bacteria pollution is relatively complex, and is a perfect example of a social-environmental problem (McGreavy and Hart 2017). Collaborators interested in the Medomak River estuary recognized the complexity of bacterial pollution, and the need to combine forces and form a partnership to understand the dynamics of the system and build capacity to address the problem and open closed clam flats. A resilience thinking approach is useful for describing this effort, as resilience "refers to the ability for linked human natural communities to anticipate, and respond to changes to adapt or transform as needed," (McGreavy and Hart 2017, pg. 3). This ability for such systems to respond to change depends on adaptive capacities, such as learning and the ability to use science to inform decision making.

This project is guided by a central tenet that engaging stakeholders in the scientific process will support the development of such adaptive capacities and lead to increased acceptance of and use of results and recommendations by clammers, state managers and other relevant stakeholders. This approach to research is important as the process used allows for the consideration of societal needs and builds partnerships within the community. As described above, sustainability science focuses on connections between nature and society and seeks to address complex problems that occur at this nexus (Kates et al. 2001). Though there are a range of methods used in sustainability science, many studies include qualitative and pragmatic approaches to understand and address multiple viewpoints through the five commitment design described above and identify solutions that align with community interests and needs (McGreavy and Hart 2017, Miller 2015). Participatory-modeling is defined within the context this thesis as the inclusion of stakeholder knowledge in oceanographic modeling (Basco-Carrera et al. 2017, Castelletti and Soncini-Sessa 2007). Using this technique, viewpoints from stakeholders are incorporated and can lead to the use of such science for multiple decision making needs in management and policy making.

The goal of this project is to incorporate stakeholder knowledge into the development of the interpretation of the results and to identify potential applications of the research to support the resilience of the soft shell clamming industry. My engaged approach consisted of a diverse set of activities through which I both built relationships with key partners and collected data to address my research questions. These activities included formal interviews, participant observations at numerous meetings in the town and with the Medomak Task Force, volunteering and becoming involved with applied shellfish projects on local clam flats, and related efforts., By taking this approach, I allowed for the science to be shaped through an in-depth understanding of community social, cultural, and economic needs (van Kerkhoff and Lebel 2006).

1.3 Thesis Organization

This thesis is divided into two studies that examine the hydrodynamics of the Medomak estuary and the collaborative characteristics of soft-shell clam projects in Maine, using the Medomak Taskforce as a case study. Chapter 2 uses data collected by drifter buckets in 2017 and 2018 to examine the basic circulation in the Medomak River estuary including flushing mechanisms, residence time, and environmental variables influencing circulation in the estuary. Chapter 3 uses data collected during interview and observations from 2017- 2019 to: 1) describe characteristics of the collaboration within the Medomak Taskforce as a partnership between municipalities, state agencies, and industry leaders works and; 2) understand how collaboration can fill gaps in the co-management structure to allow for localized preferences and improve adaptive capacity.

CHAPTER 2

USING AN ENGAGED APPROACH TO OCEANOGRAPHIC OBSERVING: MANAGEMENT IMPLICATIONS

2.1 Introduction

To contend with consequences to the clamming industry from polluted clams causing illness, the DMR instituted pollution-based mudflat closures in accordance with the NSSP. The DMR estimates the levels of fecal contamination by taking seawater samples from mudflats that are harvested multiple times a year. Fecal coliform bacteria is not a specific species, but represents a suite of bacteria derived from fecal pollution in the water. Any area that has a fecal coliform score of 31 CFU 100 mL^{-1} is prohibited, or closed to harvesting, and will not reopen until 90% of 30 tests, or a p90 is below a score of 31. These 30 tests are usually carried out over a period of 5 years. Areas are outlined on maps published by the DMR once per year, and lines are based partially on enforceability. There are three main types of these closures: prohibited, restricted, and conditionally approved. Prohibited areas are not allowed to be fished in any capacity while restricted areas are allowed to be harvested only with a special DMR permit. Typically, conditionally approved areas are closed for 14 days when rainfall meets or exceeds 2" (5cm) in a 24-hour period due to the potential for fecal pollution caused by runoff. However, in the Medomak River, conditionally approved areas are closed when rainfall meets or exceeds 1" within a 24-hour period, and are closed for 9 days (Kanwit 2016). The reason for this more conservative constraint on harvesting was multiple levels of effort on behalf of the DMR and Medomak Project, culminating in a clam meat study run by the DMR and Waldoboro shellfish committee. Across all Maine clam flat, these conditional closures can result in large economic losses, up to $2.0 million dollars over a harvesting season, in certain areas where flats are closed more frequently (Evans et al. 2016). Understanding the local hydrodynamics of these closed areas, as well as the origin of the bacterial pollution causing these closures, can allow for changes in the type and period of closure, leading to an increase in economic growth.

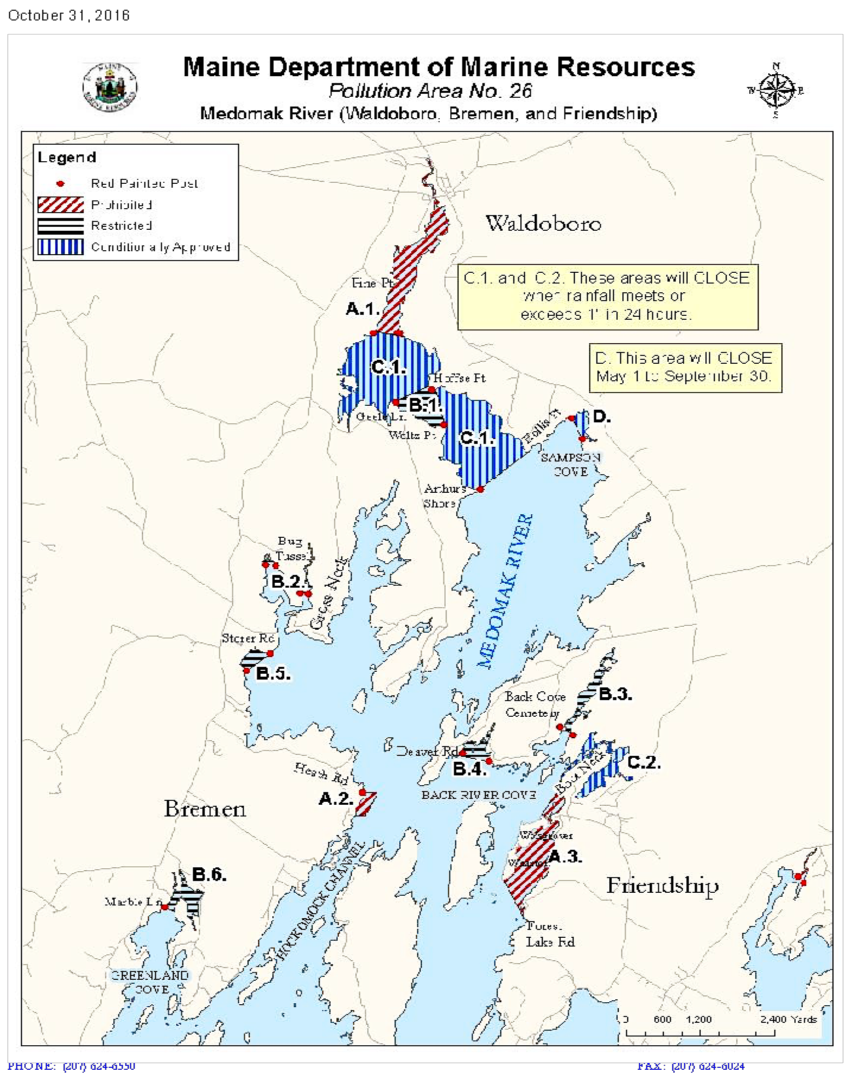


Figure 2. Closure map of the Medomak Estuary developed by DMR (2016). This map shows closure areas based on bacterial testing done by the DMR, where areas in blue stripes are conditionally closed, areas in red stripes are prohibited, and areas with black stripes are restricted.

Delineations of closures are often contested by stakeholders for a variety of reasons. Limited organizational and financial resources keep the DMR from sampling more frequently or at more locations. As stated previously, the lines are also drawn around the enforceability of the closure, rather than the physical characteristics of the system. Estuarine residence time coupled to the amount of time bacteria remain viable in the clam is the actual span of time bacteria would be in the system affecting clam flats. Using oceanographic techniques, maps of residence time can highlight areas that are more susceptible to bacterial pollution, and can also help water resource managers find areas that are in need of targeted sampling. By estimating residence times, the closure time could be shortened or lengthened in targeted areas around the estuary (Wen 2017). The dataset applies to the annual drawing of maps, showing areas that are flushed more frequently and could possibly be opened or given a more lenient closure type, while also informing storm based closures based on understanding of hydrodynamic characteristics that change with increase runoff (Wen 2017).

2.2 Background

Fecal coliform laden waters cause closures within and between watersheds as it travels from freshwater sources to estuaries. They are contained mostly to the surface layer of freshwater that extends into the estuary as bacteria rapidly decay in salt water (McFeters et al. 1972, Auer and Niehaus 1993). This layer is mixed downward towards the clam flats or left behind on outgoing tides, resulting in contaminated clams. These clams then filter out these bacteria laden waters after a period of time (Beal et al. 2018). To understand how long bacteria remain in the system contaminating clams, managers, scientists, and stakeholders need to understand how near surface waters circulate. Many studies have demonstrated that the primary parameters affecting the growth and persistence of bacteria in a hydrodynamic system, including temperature, salinity, and structural stability of the system (McFeters et al. 1972, Auer and Niehaus 1993 Canale, et al. 1993, Wilkinson et al. 1995). So, stakeholders need to understand how bacterial transport relates to environmental drivers that can cause variability, such as wind, freshwater flow fluctuations, and tides. I chose to use Lagrangian drifters because they are relatively inexpensive and effectively measure near surface transport, and can facilitate stakeholder engagement.

Lagrangian drifters are used in oceanography to study near-surface circulation of water masses. These drifters float passively with no propelling technology of any kind (Subbarya 2016). I released drifters into the Medomak River estuary which is a tidally dominated estuary with limited influences from waves and rivers. Generally tidal transport is modulated by other environmental factors including wind, precipitation, and other coastal processes (Yu 2016, Whilden 2014). In the Medomak, near-surface currents are primarily forced by the same factors, which have been studied extensively using passive Lagrangian floaters or drifters (Yu 2016, Whilden 2014, Spencer 2014). Lagrangian field theory allows for the computation of dispersion characteristics based on particle trajectories (Whilden 2014, Spencer 2014). Drifter trajectories would equate to these particles (Spencer 2014). Ultimately, drifter tracks capture the dominant circulation patterns of a body of water and have been applied to hydrodynamic models to understand tidal transport and dispersal of different particles. (Martin 1999, Yu 2016, Whilden 2014, Spencer 2014).

By studying trajectories based on tidal circulation, Lagrangian particle models can be developed and incorporated into larger scale hydrodynamic models. For example, hydrodynamic models such as the Finite Volume Coastal Ocean Model (FVCOM), are capable of tracking particles in estuaries (Chen et al. 2006, Li et al. 2011). FVCOM is an unstructured grid-based model that simulates the hydrodynamics of various coastal systems influenced by environmental factors (Chen et al. 2003).. By linking a Lagrangian particle model to a FVCOM it is possible to predict changes in the distribution of bacteria with temperature, salinity, and other environmental variables (Schakau et al. 2015, Chen et al. 2006).

The major purpose of the drifter survey was to quantify the residence time of different areas of the Medomak estuary, as well as get a better understanding of the rate of tidal flushing for bacterial-laden freshwater in this estuary. This will allow for a better understanding of how this system processes or divests polluted waters (Chapra 2011). The exploratory methods can also be used for the development of tidal circulation models that are more accurate to this estuary specifically.

The research objectives were to:

- develop new methodologies aimed at incorporating stakeholder knowledge into oceanographic modeling; and
- determine the general circulation characteristics of the Medomak Estuary, particularly what parameters influence the residence time of polluted waters impacting clam flats

2.3 Study Area

The Medomak river estuary (44° 4' 14.718" N, 44° 4' 14.718" N) is home to some of the most productive clam flats in the United States. The town of Waldoboro had the highest soft-shell clam landings in Maine between 2015 and 2017. The fishery employs 150 clammers out of 1500 across the state (DMR 2016). Therefore, the Medomak River estuary has been identified as a *place of interest* by the DMR, the Maine Department of Environmental Protection (DEP), and clammers located in nearby communities. This means that this area is of particular socioeconomic and ecological importance, and is part of the justification for the Medomak Taskforce, a group of stakeholders from multiple state and municipal organizations focused on solving water quality issues in the Medomak. The geomorphology of the Medomak is clearly an important control on circulation and it generally widens moving away from head of tide towards the river mouth and narrows before opening up to the larger Gulf of Maine. The estuary is centered around a deep channel (6-20m, Figure 3). A central channel spans the length of the estuary, and is anywhere from 2-3 times deeper than the surrounding clam flats (Figure 3).

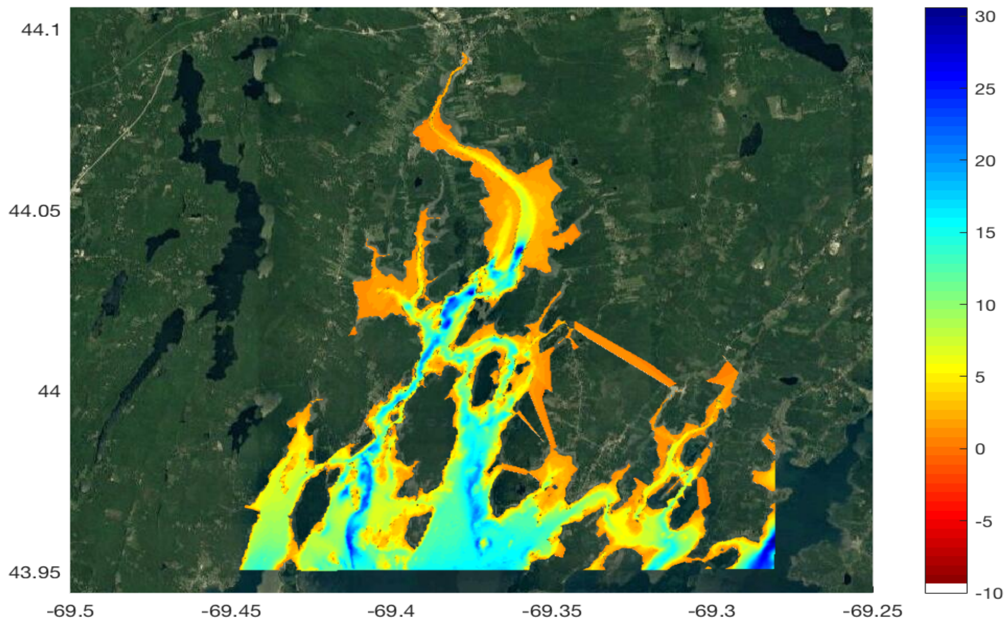


Figure 3. Medomak Estuary Bathymetry Map. The colorbar is in feet, where cool colors are deeper waters and warmer colors are shallower waters. The data was derived from multiple oceanographic cruises and Matlab interpolation.

The central channel is one of the keys to understanding the hydrodynamics in the Medomak estuary since the strongest currents and mixing occur here (Valle-Levinson 2010, Figure 3). As the tide comes in, or a flood tide, the channel fills, and then spills out onto the clam flats when the tide goes out, vice versa. This channel functions as straight tidal estuary. The funnel shape of the Medomak upper estuary tends to create two small gyres, or circular circulation patterns, in Sampson's Cove and near Long Cove that can trap water masses that spill out of the channel, and move them inshore towards the clam flats. The average flow for the Medomak River is 89.12cfs based on the watershed drainage size of 275 km^2 (Table 1). The river is 32 miles long, and remains in the Medomak estuary for another 8 miles.

Medomak Estuary – Waldoboro, ME	
Length of River	64 km
Watershed Drainage Size	275 km^2
Average Flow	89.12 cfs
Annual Precipitation	114.8 cm/year
Average Tide Range	3.5 m

Table 1. Characteristics of Medomak Estuary that applied to our research. Data came from public USGS river gauge datasets.

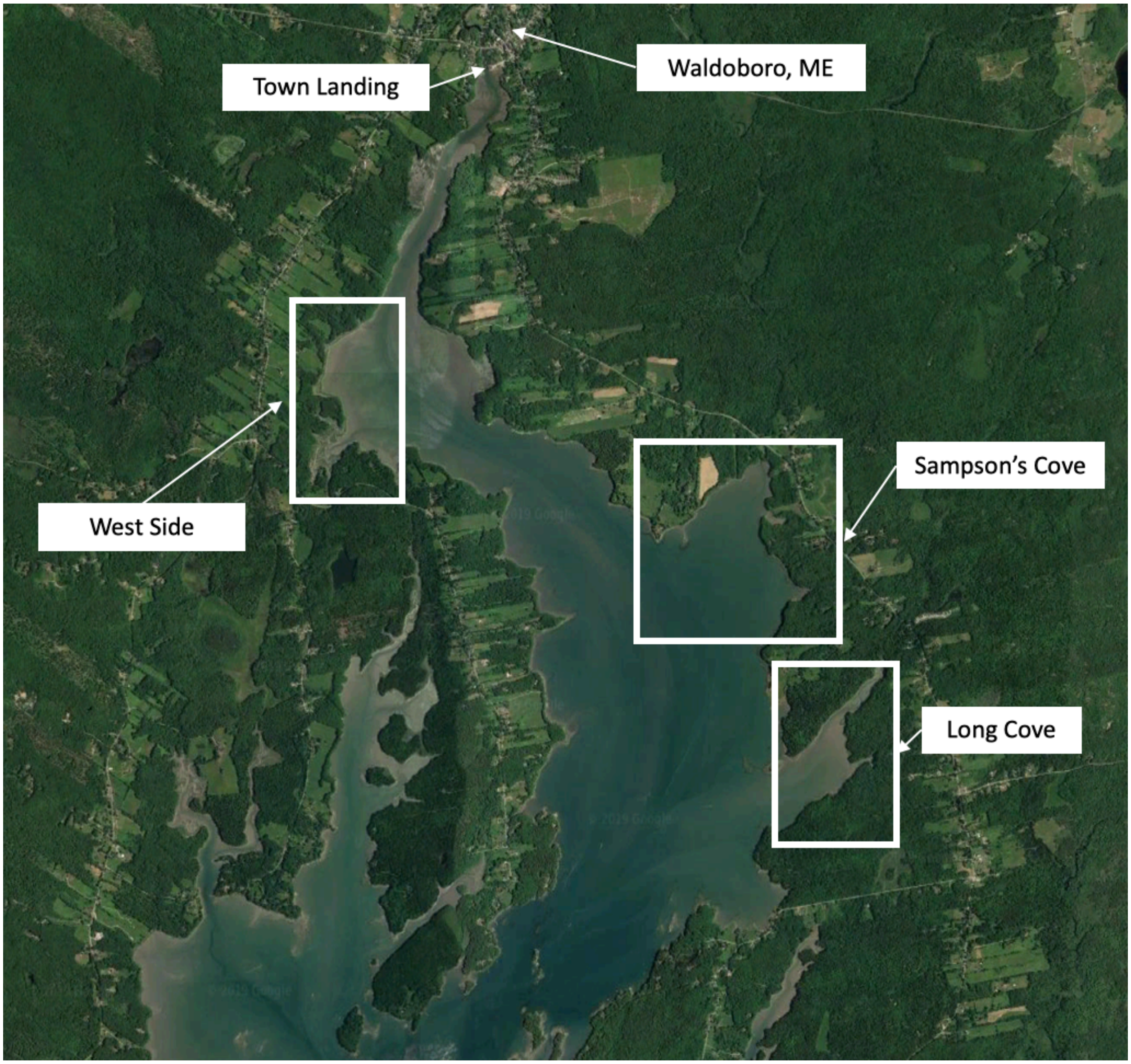


Figure 4. Points of Interest in Medomak Estuary. This map highlights points of interest in Medomak Estuary that will be referred to in this thesis.

2.4 Methodology

2.4.1 Engaged Case Study Approach

This study follows case study methodology, as outlined by Gillham (2010) and Creswell (2009). Case studies are specific, focused, in-depth investigations of particular problems or areas (Gillham 2010, Creswell 2009). This project is an exploration of a marine industry in a particular community (the soft-shell clamming industry in Waldoboro, ME), that focuses on specific research questions and uses a variety of sources to support conclusions (Gillham 2010). The data collection process has been developed to allow for emergent knowledge and is thus observational and follows models of other previous case studies on similar subjects, making it a descriptive case study, as opposed to an experimental design (Scholz and Tietje 2002, Tellis 1997). Single case studies are not generally replicable as they are built uniquely for a time, place, and set of circumstances (Zainal 2007, Tellis 1997, Yin 2013). The methodology used in this thesis is a single case, embedded case study framework, where researchers follow engagement methods and practices to incorporate societal needs and sustainability science commitments within the research (Gillham 2010, Creswell 2009, Yin 2013, Tellis 1997). An embedded framework uses both qualitative and quantitative methods, such as semi-structured interviews and Lagrangian drifters (Scholz and Tietje 2002). The unique parts of my case study were organized into subunits within the same case.

In addition to the case study methodology, this research also used an engaged research design. Crafting salient science requires paying attention to both the biophysical requirements for modeling and the needs and constraints for how the modeling results will eventually be used (Vogel et al. 2007, Cash et al. 2006). Cash et al. (2006) determined that science can fall into the trap of the loading dock, whereby science is delivered but is unusable, or no one is waiting to pick up the delivery (Beir et al. 2017, Vogel et al. 2007, Cash et al. 2006). Using the engaged approach (a sustainability science technique), scientists can circumvent this issue (Vogel et al. 2007). Stakeholder engagement represents a bottoms-up participatory approach to sustainability science (Reed et al. 2018, Ssebunya et al. 2017, Reed et al. 2009, Goodman 2007). Here, stakeholders participate in a collaborative space throughout the scientific study, developing methods, research questions, and analyzing and disseminating results (Reed et al. 2018, Goodman et al. 2007). This practice creates more salient, credible, and legitimate science, as described above (1.1 Background).

The extended engagement method has led to new emergent knowledge of clamming as a lifestyle and management of the overall industry, which will be described in Chapter 3 of this thesis. However, within the context of the oceanographic results, multiple meetings with managers from the DMR as well as stakeholders supported recommendations regarding adaptive co-management systems that allow for a more flexible localized legislation regarding clamming and pollution closures, which will be described in Chapter 3. These recommendations include techniques that incorporate stakeholder knowledge through multiple meetings, as well as incorporation of computer model output to understand threats (described previously in 1.1 Background) to the shellfish industry outside of bacterial pollution. This technique has built strong and productive connections between researchers, the community, and industry. As evidence, Julie Keizer, the Town Manager of the Town of Waldoboro, has now applied for multiple grants to place a river gauge in the Medomak under the recommendation that watershed dynamics are a clear knowledge gap identified by my work. Specifically rating curves that describe the response of the watershed to storms is the key to understanding the future of bacterial pollution in this system.

2.4.2. Semi-Structured Interviews

Interview protocols were developed in conjunction with CitiProgram training and the Institutional Review Board for the Protection of Human Subjects (IRB) at the University of Maine. Interview techniques are based on Creswell (2009) and Corbin and Strauss (2014). A set of interviews was conducted with six leaders in the clamming industry identified through attending Shellfish Advisory council meetings and who work on the Medomak, or have worked on the Medomak. The participants were chosen using "snowball" and key informant sampling. Snowball sampling is a "method of non-probability sampling where the respondents are themselves used to recruit further respondents from their social networks," and key informant sampling includes the identification of members of a community that could speak to larger processes and represent larger communities (Corbin and Strauss 2014, Dictionary of Social Research Methods 2016, p. 1). With 150 clammers being employed in the Waldoboro area, this round of interviews only captured a small percentage of the clamming community, follow up meetings, as well as informal conversations with other clammers outside the ones that were formally interviewed (50+) have corroborated that the areas chosen for release through this process are broadly considered important to the clamming community.

Each interview was recorded by digital recorder, at an area of the interviewee's choosing. All interviews were transcribed. Six clammers were interviewed. With these interviews, stakeholder knowledge of environmental factors influencing bacterial distribution were recorded and subsequently incorporated into the drifter study. Areas identified by stakeholders became study points in the drifter study design (Figure 4). This means that either drifters were released from those areas or around identified areas in order to better understand the overall circulation.

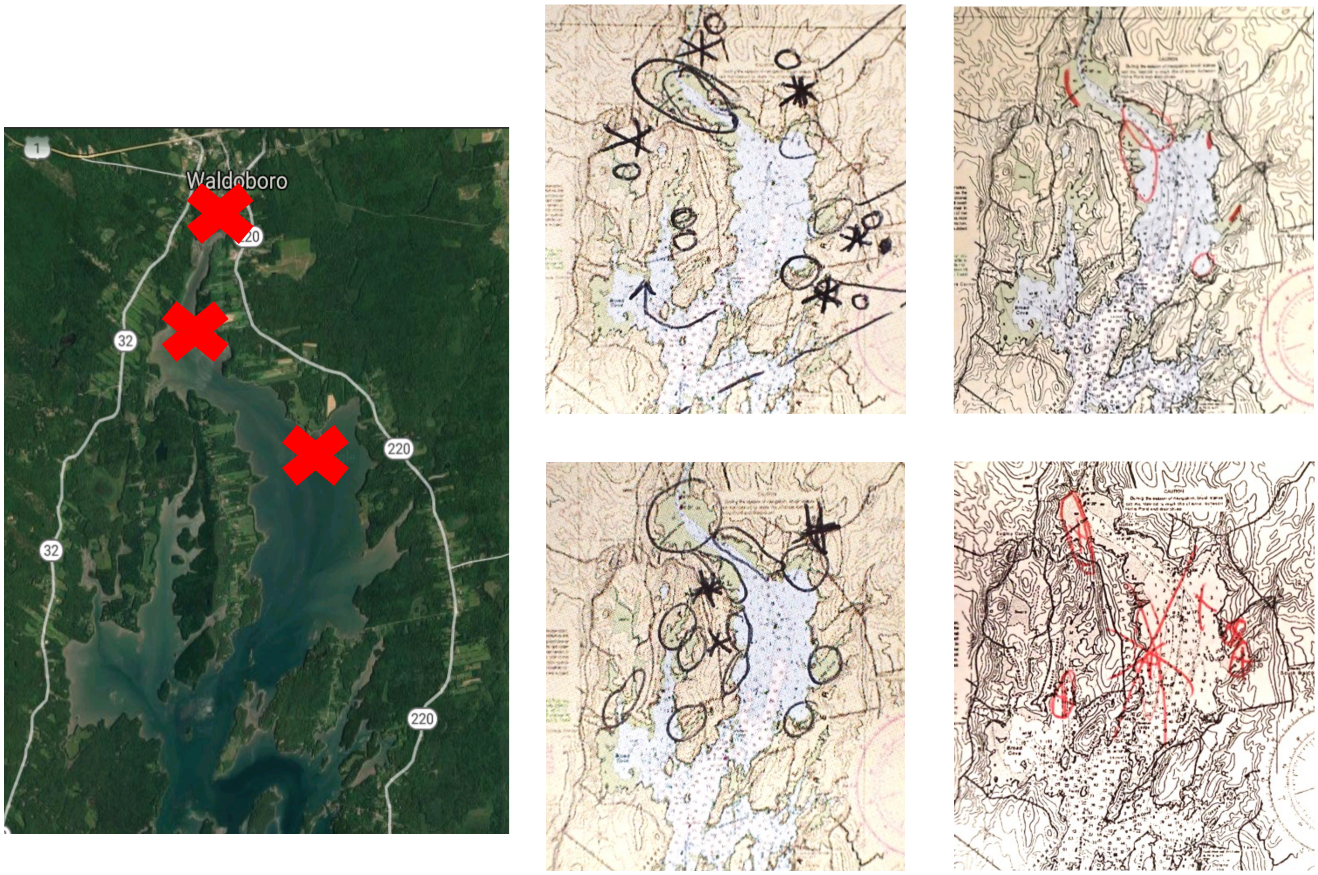


Figure 5. Connecting Clammers to Site Choice. Each clammer interviewed was asked to highlight areas on maps they wanted studied in a hydrographic sense. On the left, four maps are shown which were drawn on by interviewees, and easily connect to the map of study sites on the right.

2.4.3 Drifter Release

James Manning from NOAA Northeast Fisheries Science Center and I co-developed the drifter design. The design is based off the "super-bucket" design first designed by Daniel MacDonald at UMASS Dartmouth to examine the top 30 cm of the Merrimack River plume (MacDonald et al. 2007). This design and surface water focus was optimal for the study of bacterial transport as bacteria deteriorate rapidly in saltwater (McFeters et al. 1972, Auer and

Niehaus 1993). Pictures and schematics of drifters are attached in Appendix B. Briefly, the drifter consists of a plastic bucket, with a hole cut out of the bottom. This hole allows the bucket to sink after filling with water. Drifters were tested to determine necessary flotation in order to remain upright and within the surface water currents. Counterweights are attached to the bottom of the bucket, and a buoy float is attached to the upper handle. The design of the drifters allows for a majority of the weight to be subsurface, so that they move with surface currents (Spencer 2014).

Six individual drifters were used in this study. Drifters were released three at a time from one study point during each field day, with 12-24 hours between releases. Drifters were released at max ebb and max flood for 24-48 hours. Drifters were designed to incorporate a variety of oceanographic sondes, and the design was proven successful as drifters protected scientific equipment, while still being visible and retrievable. Each drifter was equipped with a StarOddi ® probe, as well as a HOBO thermal probe attached to the interior of the bucket. A satellite GPS tracker and a Garmin ® Hiking GPS XTrack were attached to each drifter. Satellite trackers were activated at the dock before deployment, while the Garmin GPS was turned on as the buckets were being placed in the water.

2.4.4 Drifter Analysis

Drifter tracks were mapped using Google Maps® for both satellite and GPS datasets, and analyzed for speed at each resighting. Displacement and the distance was also calculated for each drifter track using regression analysis in Matlab ® focusing on change in distance between GPS marker points, over time as referenced in calculations for velocity. The point assignment is decided by time stamps associated with each latitude and longitude from the Garmin GPS. Drifter tracks were plotted over each other to visualize full circulation of estuary.

Converting velocities ($m\ s^{-1}$) to flow rates ($m^3\ s^{-1}$) throughout the estuary is necessary to calculate residence time. In Eulerian and Lagrangian theory, when the particle is of finite size, flow velocity is equal to particle velocity, meaning that drifter velocities would equal to the overall surface water flow velocity. Hence, to calculate flow rates, 35 cross sections were created across the study area and drifter velocities were interpolated into these volume cross sections from the Midcoast Model Bathymetry dataset sourced from the Northeast Coastal Ocean Forecast System (NECOFS[1]) (Figure 5). Drifter tracks were incorporated into a Finite Volume Coastal Ocean Model (FVCOM) designed by Wei Liu a postdoc under Dr. Damian Brady. Details about this model are available in Appendix D.

2.5. Results and Discussion

There were two major goals of this study, incorporation and engagement of stakeholders, and determining tidal dispersion. From the interviews conducted, all clammers identified the "West Side" area of the Medomak as the area with the most productive clam flats (Figure 4). Areas that were identified of interest were mapped out for the field plan protocol as study points, or areas

[1] http://fvcom.smast.umassd.edu/necofs/

where stakeholders were focused on understanding circulation patterns (Figure 4, Figure 5). Two coves were mentioned including Sampson's and Long Neck cove, (Figure 4), both with large clam flats that have deteriorated over time based on landings. Bacterial closures were the primary concern of all clammers interviewed. Clammers also cited concerns about other environmental factors they believed were related to the deterioration of clam flats including the presence of eelgrass and green crabs.

The second of the goals of the study was to determine tidal dispersion by releasing three drifters at each deployment. After multiple deployments, it became clear that tidal velocity was a far strong driver of movement as the drifters stayed remarkably close to each other during every deployment. Our analysis therefore switched to understanding drivers of movement rather than tidal dispersion (Kakoulaki et al. 2010, Figure 6 and 7). There were 22 releases of drifters, over 15 separate days spread through four months. For more information on each individual drifter release, please see Appendix C. The average distance traveled by the drifters in 6 hours was 2.5 miles.

Two major results came from the drifter study. As predicted, at specific geologic constrictions, flow velocities increased dramatically (Figure 6). The first geologic constriction is west of Sampson's cove, downriver from the West Side. The second major constriction is downriver from Long Cove (Figure 3). As the drifters move seaward in the estuary, there are spikes in flow velocities to coincide with these constrictions (Figure 6). The geologic constrictions are important because if particles do not reach these constrictions, they are far more likely to remain in the upper estuary.

The second result is retention. During flood tides, the drifters speed up, moving in a variety of eddies generated by increased tidal flow spilling over the channel located in the center of the estuary. However, drifters do no speed up as the tide ebbs, or goes out, which may indicate that some of the freshwater deposited on the flats during flood tides does not completely flush out, but instead is retained in the upper estuary. This may also explain the breadth of mudflats in this area due to the flood dominant nature of flow that allows sediment to settle out, but this type of circulation may also indicate that bacteria can remain in the estuary past one tidal cycle.

2.5.1 Tidal-Centrifugal Forces

Tidal energy is one the most dominant forces in this estuary controlling residence time and other hydrodynamic characteristics (Wen et al. 2017 Yu et al. 2012, Fenster 1996, Hume 1988, Galloway 1975). In the Medomak River, this is shown through tight coupling of velocity increases and tidal flooding. Nearby, the Kennebec River estuary, which has similar morphological characteristics, has been proven to have an ebb dominated flow (Fenster 1996). However, in the Medomak, drifter speeds increase with flood flow, showing a flood dominated estuary. Shown in Figure 6 and 7, drifters released for longer lengths of time point towards this flood dominating pattern, where drifters move faster as the tide comes in, rather than as the tide goes out. There is a delay in peaks, where the tide will go out, and then drifters increase speed. This is most likely due to the location of the tidal gauge as compared to the drifters at that time or the distortion of tidal waves propagating up the estuary.

Eddies are generated through tidal currents rising from the central channel. These are circular rotating currents that are based on changes in bathymetry and wind patterns trapping water masses in small whirlpools. With the flood-dominated current structure demonstrated by drifters, most likely eddies are moving freshwater masses off of the channel onto clam flats shown by the drifters as small circular motions made at low speeds moving away from the channel (Figure 6 and 7).

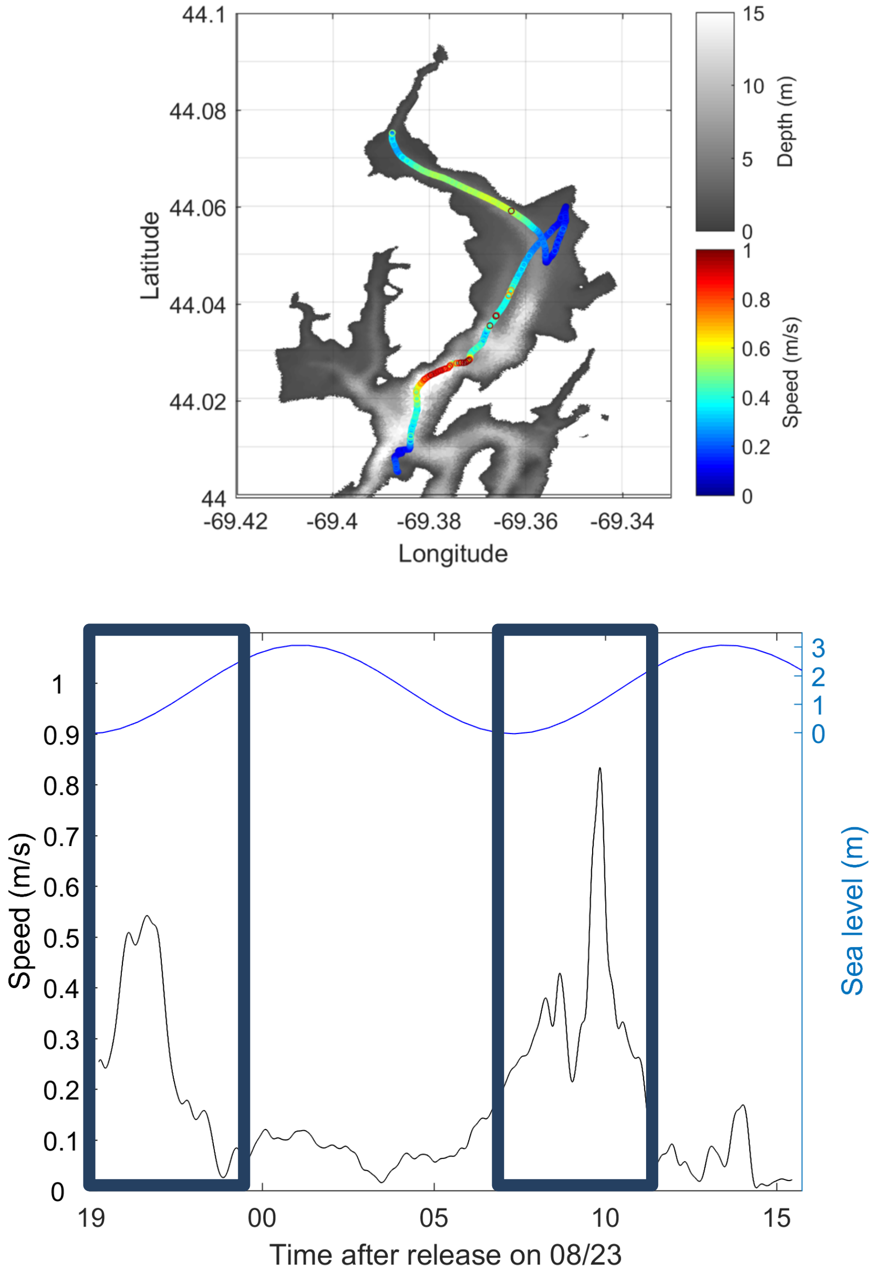
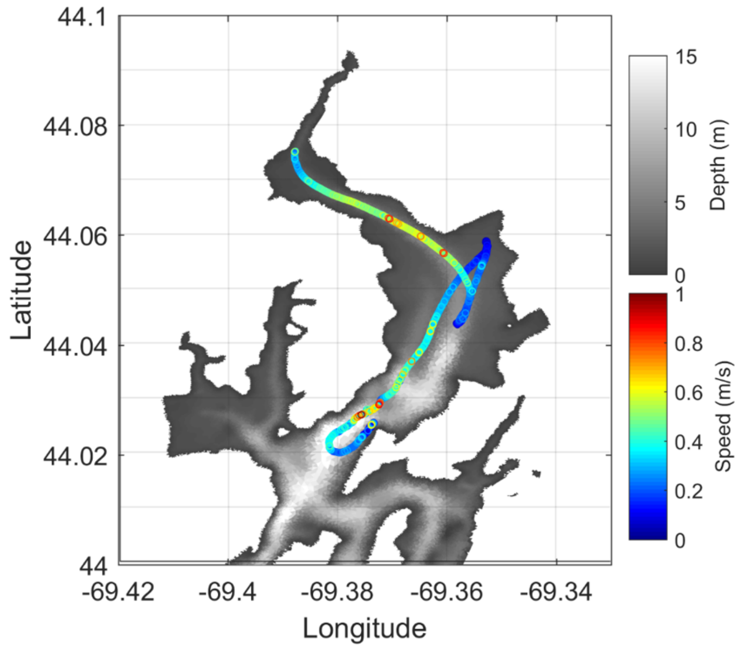


Figure 6. Centrifugal Forces A. On the top: the map of one of the drifters released on 8/23/17 shows the large loop near Sampson's Hill (Figure 4). Bottom: Speeds in m/s in the black line, with tidal stage in m in the blue line.



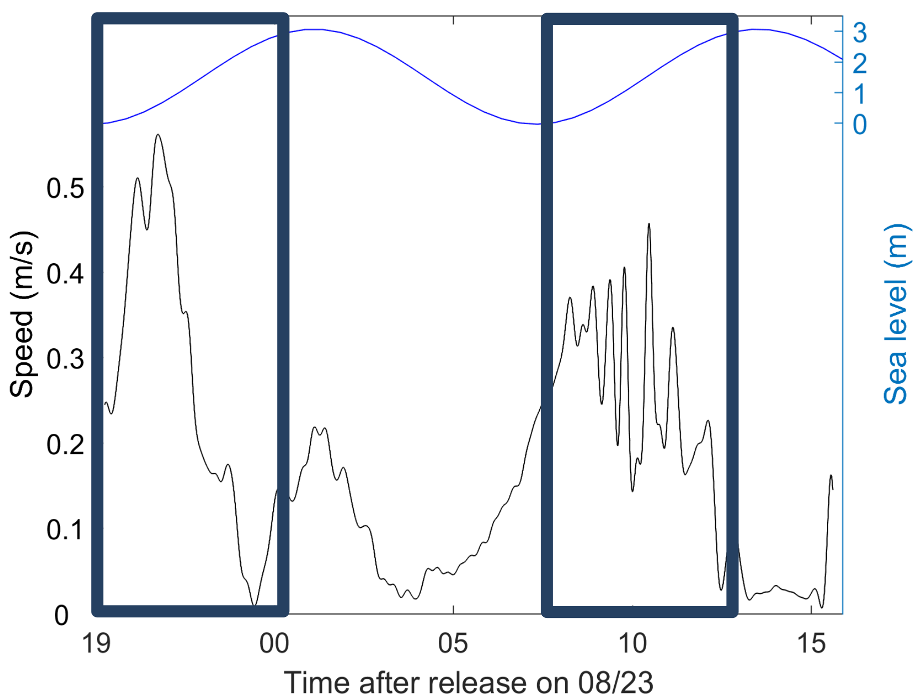


Figure 7. Centrifugal Forces B. On the top: the map of one of the drifters released on 8/23/17 shows the large loop near Sampson's Hill (Figure 4). Bottom: Speeds in m/s in the black line, with tidal stage in m in the blue line.

2.5.2 Bathymetry – Cross Sectional Area

Cross sectional area varies from the head of tide to the lower estuary. Near the head of tide, where the Waldoboro town landing is located, cross sectional areas are between 30 and 75 m^2. Although the estuary widens significantly south of Waldoboro, the volume does not change radically as the estuary is still very shallow as indicated by the reduction in the overall cross sectional area. There is a constriction, shown by the decrease of ~20m^2 in cross sectional area below the conditionally approved line (Figure 8), which affects drifter speed (Figure 9). This constriction increases flows by simply contracting a large volume of water into a small area. The constriction generates momentum that pushes water past the curve of the channel into nearby coves like the Sampson's Cove and Long Cove (Figure 4, Figure 7). The constriction is also important as it pushes polluted water masses onto the western shore, which in the past has shown higher scores than the eastern side (Figure 7). As the estuary widens, the estuary also gets deeper, and the channel widens as well, showing the sharp increase in cross sectional area at around 44.06 degrees North (Figure 9). Here, drifters slow, and are more easily impacted by vorticity currents, as well as wind driven changes in direction. As shown in Figure 8, the Medomak then again constricts, which can entrap waters from upper estuary. This has a direct effect on residence and flushing time which was estimated and will be discussed in later sections (Wen et al. 2017, Chapra 2011, Hume 1988).

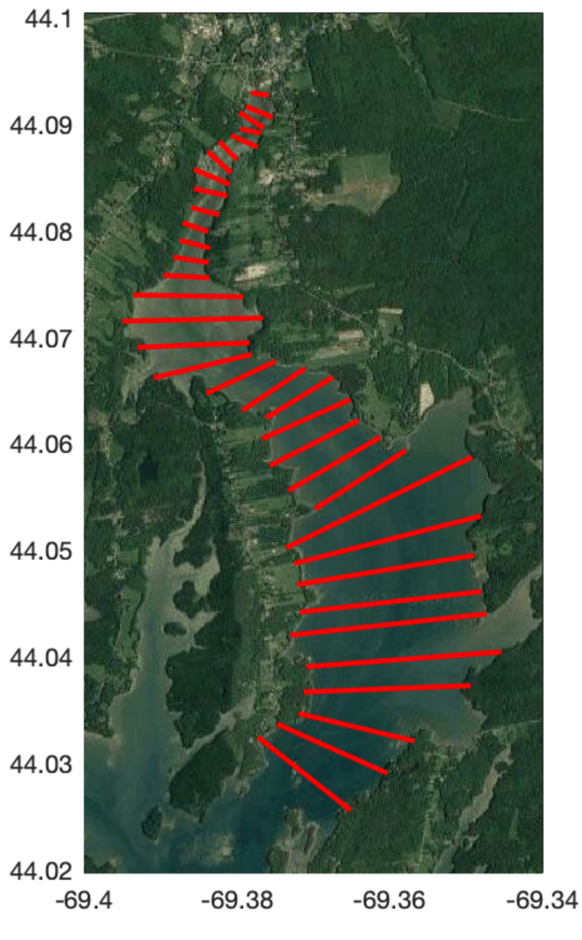


Figure 8. Cross Sectional Area Transects. This map shows the transects chosen to calculate cross sectional area as part of the drifter analysis. On the left, the area including bathymetry data from NECOFS is shown in m^2, the x axis is number of sections from the highest transect upriver.

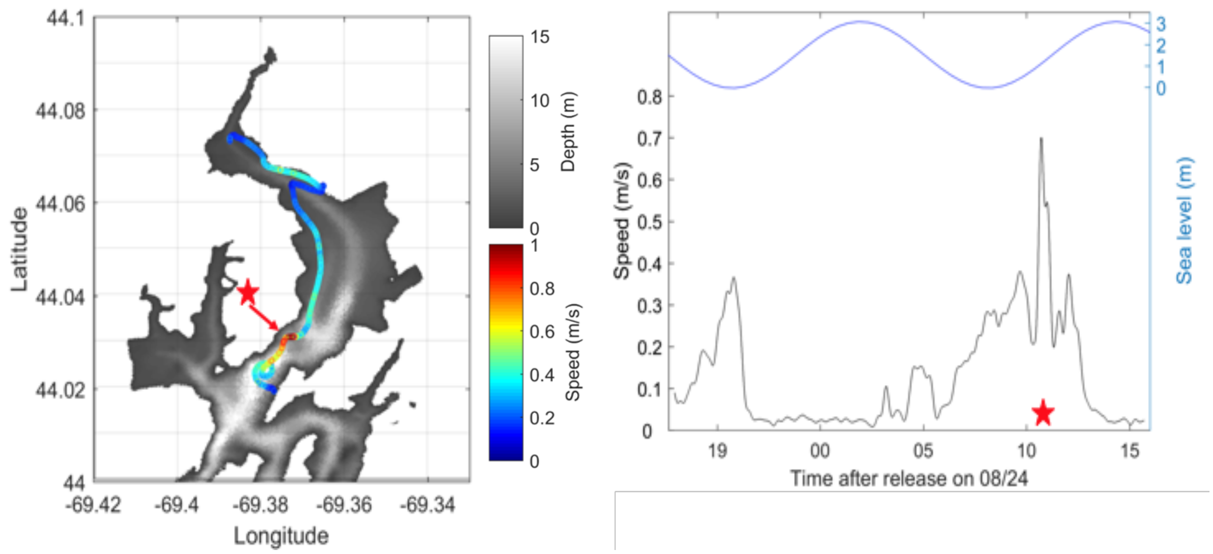
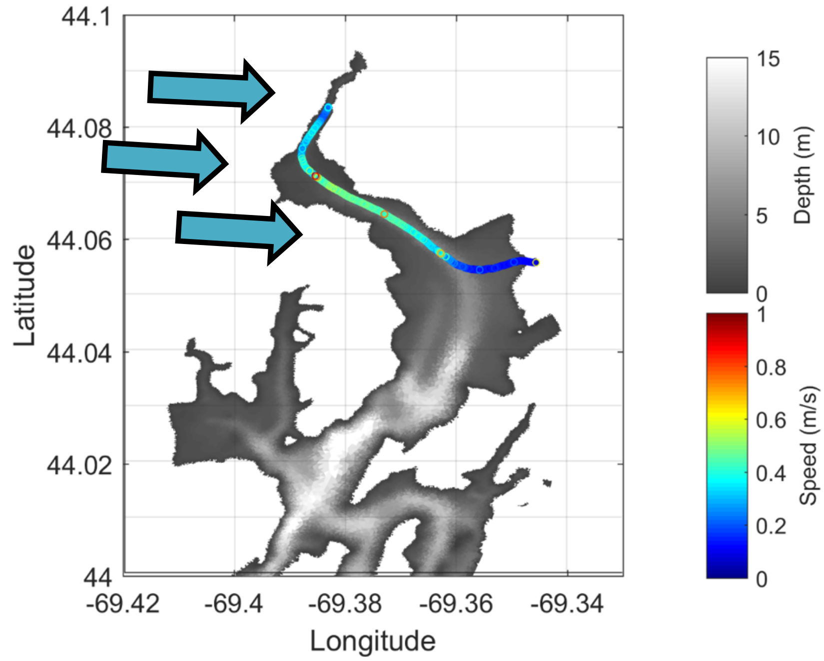


Figure 9. Cross Sectional Area Effects. On the left: Drifter track from 8/24/17 with a colorbar showing speed in m/s. On the right: Speed of drifter in a black line m/s, with sea level in a blue line in meters. The red stars are associated with a constriction in the river where velocities sharply increase regardless of tidal stage.

Most likely, the effects the cross-sectional area has on the estuary means that water downstream from below the constriction will be unable to re-enter the estuary. This is an extremely important concept, as now, past this constriction, more than likely pollution from downstream areas may have little effect on this upper section of the Medomak River (Chapra 2011, Figure 9). This has multiple management implications, with further studies, managers and clammers will be able to understand the water quality connection between Waldoboro and the Upper Medomak, and surrounding clamming communities.

2.5.3 Wind Effects

During slack tides or when the drifters were not near cross sectional constriction, drifter tracks showed a change in trajectory based on predominant wind direction in the estuary. Areas with low velocities, but distinct changes in direction, have been identified as being predominantly affected by wind (Figure 10). Based on the drifter track maps differing directions of winds will push water out of the channel in different directions. The wind either entraps the water in the upper estuary, before the major constrictions or pushing the water into the more open area, facilitating either entrapment in coves on the western side, or pushes the water along a path to escape this area of the estuary. When the predominant wind direction was perpendicular to the channel drifters were pulled away from the channel increasing retention (Figure 10). When wind pushes flow away from the channel, vorticity forces entrap pockets of water and move them towards the coastline (Southwick et al. 2017, Figure 10). These vorticity forces are generated by changes in bathymetry or salinity, whereas water is moved from deeper to shallow areas, or from freshwater layers to salty ones, friction and other turbulent forces impact the speed water masses are moving at, causing circulation patterns similar to eddies or whirlpools. These entrapped water masses can then be moved within these vorticity currents away from the channel and towards clam flats by the wind (Southwick et al. 2017, Xie et al. 2017).



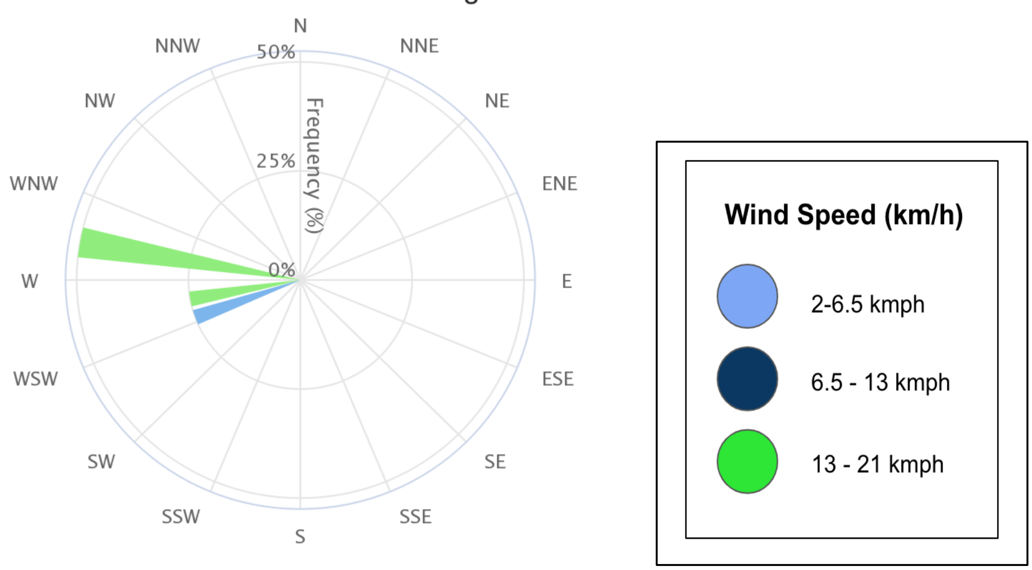


Figure 10. Wind Direction Influences. The top: Drifter track released on 8/17/17. Blue arrows show dominate wind orientation. Bottom: Wind sundial showing prevailing winds from the west.

This pushing mechanism defined by wind forces can relate to differing pollution issues found in these areas. Polluted waters from upstream, depending on the direction of wind forces, could be trapped in areas like the West Side, Sampson's Cove, or Long Cove, areas where drifters tracked water masses pushed away from the channel (Figure 4 and Figure 10). The entrapment of polluted water masses has direct implications for legislation concerning pollution closures for Waldoboro's clamming industry. One recommendation is that wind data be tracked during pollution sample times, as well as in future scientific endeavors in the area, to correlate wind data and pollution scores. This type of information could be used to relate wind data and closure times, particularly large scale seasonal changes.

2.5.4 Residence Time Calculations and Model Comparisons

Drifter tracks were compared with virtual particle releases from a FVCOM model of the region. This model was developed by Dr. Wei Liu. Briefly, the model domain consists of estuaries from the Kennebec River Estuary to the mouth of Penobscot Bay and includes the Medomak River estuary at a spatial resolution of approximately 10 meters in the area. The drifters were used to ground truth the current velocity, for more information please see Appendix D. One of the most relevant results to the original goal of the research was the residence time calculations, using salinity as a metric for how long freshwater remained in the prohibited and conditionally closed areas. As seen in Figure 11, the residence time in the prohibited section was closer to 2.5 days, while in the conditional area it was less than 0.5 days, showing a remarkable difference between two adjacent areas of the Medomak River Estuary. This residence time is reflected in our drifter releases, where drifters released at the bottom of the prohibited area remained for several hours without moving out, while drifters released from the conditional area left the conditional area in a number of hours (Figure 12). Dr. Wei Liu used his FVCOM model to residence time using isohaline analysis, or using salinity changes in the estuary to understand the salt flux. The calculated salt flux is attributed to the movement of freshwater in and out of the estuary.

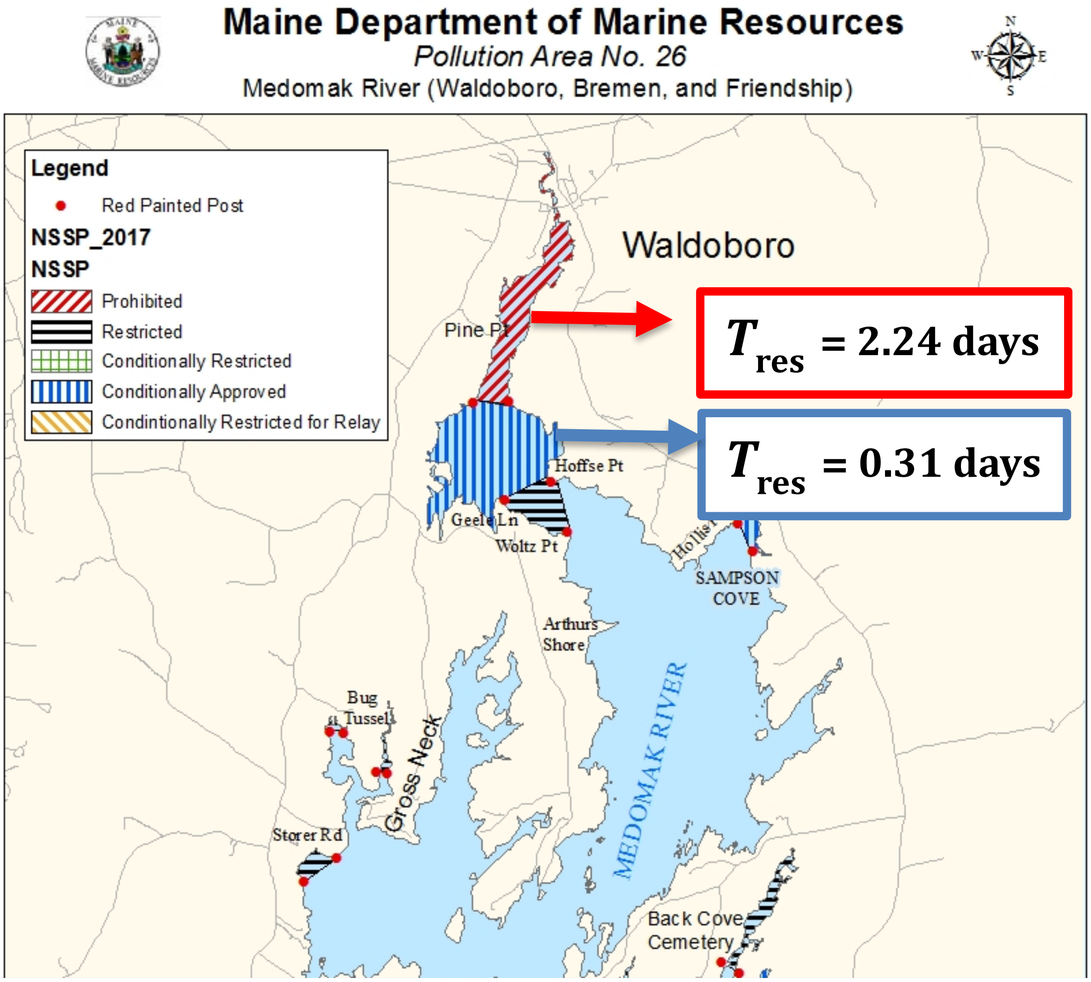


Figure 11. Residence Time Calculation. Overlaying a map of the Medomak, there are two white boxes referring to the residence time of the prohibited (red) and conditional (blue) closed areas.

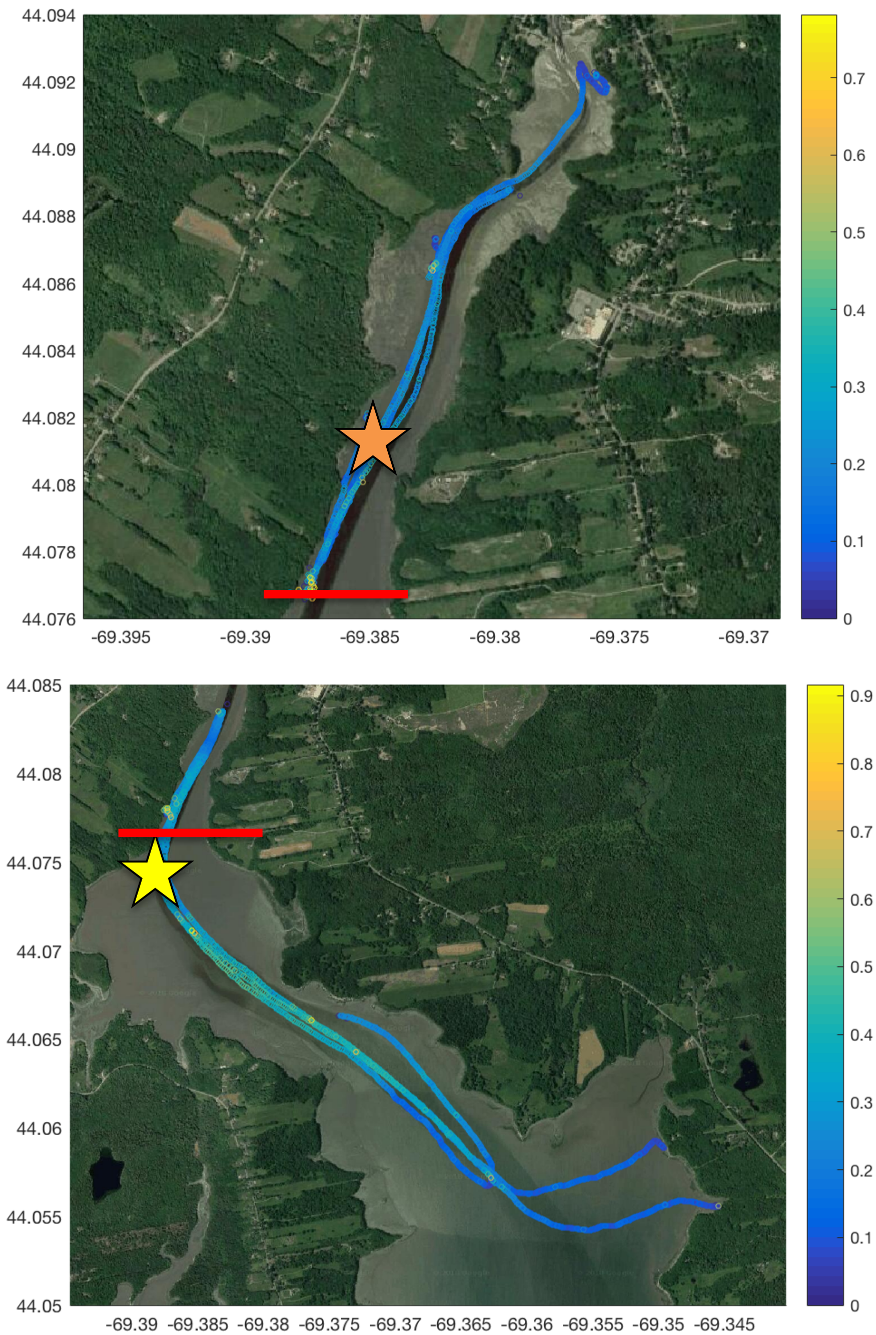


Figure 12. Residence Time – Drifter Tracks. Colobar shows speed in m/s. Top: Tracks on 8/22/17, released on a max ebb tide for 20 hours, orange star release point. Bottom: Drifters escaped conditional area in ~5 hours on 8/17/17, released two hours before high tide, yellow star release point. Conditional/Prohibited Line drawn on in red.

The residence time calculations have impacts far beyond highlighting the variability in residence time within the estuary. The conditional closure time of nine days was developed through work done by the Medomak Taskforce and a clam meat study run by the DMR. This was an experiment focused on how long soft-shell clam meat contained harmful bacteria based on the exposure time of nine days. This clam meat study could be replicated with exposure times much more accurate to the actual time clams would be exposed to polluted waters (*i.e.* 2.5 days or 1 day). From a management perspective, as areas with a shorter exposure to pollution levels could have a shorter closure time, allowing for clam flats to be open sooner.

2.6 Conclusions and Implications

Most interestingly, there appear to be connections between geomorphologically driven tidal transport and pollution closures. There are clear connections between hydrographic data and pollution closures. We found that tidal forcing, wind forcing, and cross sectional area of the estuary all had an impact on the flushing mechanisms within this estuary. This is shown through the general effects discussed above that each of these environmental factors had on the drifters. However, the magnitude of each of these factors shifts depending on where the drifters were within the estuary. Incorporating this data into a hydrographic model, we can make better estimates of residence time, and how it changes throughout the estuary. By incorporating this understanding into a hydrodynamic model, we can both make estimates of residence time and identify susceptibility. Residence time within the context of this paper is directly related to how long polluted water will remain in an area, impacting clam flats. With a better understanding of residence time, as well as the other hydrodynamic factors that relate to it (wind, tidal forcing, cross sectional area) management has the ability to adapt more flexible and targeted bacterial closures.

Our engaged approach created the foundation for new community-led projects and policy recommendations that actually inform decision making. This research supported the development of three specific recommendations. First, I recommend focusing on wind conditions during 1" closures. This would allow stakeholders to explore seasonal wind shifts and how they interact with residence time. Second, I recommend that mangers reexamine the sampling methodologies for bacteria laden waters, particularly focusing on taking samples at multiple depths, and the timing with the tides. This would allow for stakeholders to explore how lateral mixing may play a part in the movement of bacteria near the clams themselves. Finally, I would recommend recreating a clam meat study, where clams are exposed to polluted waters for a similar length of time as corresponding to higher resolution residence time calculations. This would allow for a deeper understanding of how exposure time and flushing time within the clam works.

The collaborative space that was built during this project also has allowed open discussions on how to tailor these recommendations to the needs of both the industry stakeholders and state agency representatives. These recommendations have already informed decision making at the state agency level, where members of the DMR have agreed to keep wind direction data as part of their sampling methodology. There have also been discussions on increasing the number of weather stations nearby to get more accurate wind speed data. There are also further talks scheduled to discuss new closure types based on hydrodynamic data. This type of meeting and continuous engagement is reflective of multiple aspects of sustainability science, particularly the commitment towards fostering structures where this knowledge is used through involvement.

Furthermore, the model predictions of current flows and particle releases are being used by clammers to inform their own community-led projects in the clamming industry which demonstrates saliency and credibility in the community. For example in, Waldoboro, ME Glen

Melvin along with other leaders of the Waldoboro Shellfish Committee are seeding flats based on recommendations of studying current structures generated by our validated model. Recommendations were made by generating plots of residual currents in areas where the Shellfish Committee had implicated they were productive in terms of landings, and that had been impacted by water quality closures. The Waldoboro Shellfish Committee determined the orientation and location of netted areas in Sampson's Cove based on the maps of the residual currents. As a result of our collaboration, the model results are trusted and credible, as participants were involved in the scientific process that generated the validation data. This type of engagement may be a model for industries and communities outside of the shellfish industry. If oceanographic and climate modeling efforts involve communities in multiple ways, these larger scale models may also become more trustworthy. Involving communities could include: inviting and collaborating with community contacts in groundtruthing studies; sharing findings for weather scenarios related to issues going on in the community; and making those models more accessible to a larger public base. A more trusted model can be more productive in a legislative context. Findings from this work have been shared between multiple state agencies, along with each of the Waldoboro Shellfish Committee, the Maine Shellfish Advisory Council, and the town management of Waldoboro, ME.

CHAPTER 3

UNDERSTANDING COLLABORATION AND PUBLIC PARTCIPATION IN SOFT-SHELL CLAMMING

3.1 Introduction

Co-management is the joint management of common-pool resources, usually shared between a state and community (Carlsson and Berkes 2005, Berkes et al. 1998). When co-management is developed effectively and equitably, adaptive capacity can be improved (Nursey-Nursey-Bray et al. 2018, Gupta et al. 2010). Adaptive capacity is defined as the ability to respond and adapt to change, and is integral to resilience (Nursey-Bray et al. 2018, Aguilera et al. 2015, Gupta et al. 2010, Smit and Wandel 2006, Gallopín 2006). Co-management provides a unique and potentially valuable space for growing adaptive capacities, such as learning, leadership, access to resources and more which I describe in greater detail in later sections. Co-management systems can foster collaboration and cooperation between communities and state level managers where the costs of responding to social-environmental issues such as water quality can be shared or distributed and where localized needs for support can be identified and met.

The benefits of co-management can be seen in Maine's soft-shell clamming industry. Within the soft-shell clamming industry, there are two spheres of management: a water quality management sphere and a shellfish co-management sphere (Hanna 2000, DSSF 1995, Wallace 1984, Dow and Wallace 1961). Water quality management, described briefly in Chapter 1, is guided by standards from the National Shellfish Sanitation Program (NSSP) at the federal level. This is a top-down system, where the state, through the DMR Department of Public Health, regulates clam flats according to their water quality based on federal regulations from the NSSP. Management decisions include the opening and closing of clam flats, as well as statewide closures due to threats like harmful algal blooms. In contrast, the co-management sphere is based on collaborative efforts to manage clam flats between the state through the DMR and municipalities that adopt a shellfish ordinance (McClenachan et al. 2015, Figure 13). Inside this sphere, municipalities and the DMR work together to sort out conservation strategies, shellfish licensing, and other specific size and harvesting restrictions (Figure 13). Within these two spheres, community collaboration and improving public participation can develop new communication pathways which can facilitate shared learning and shared experiences that can improve adaptive capacity (McGreavy et al. 2018).

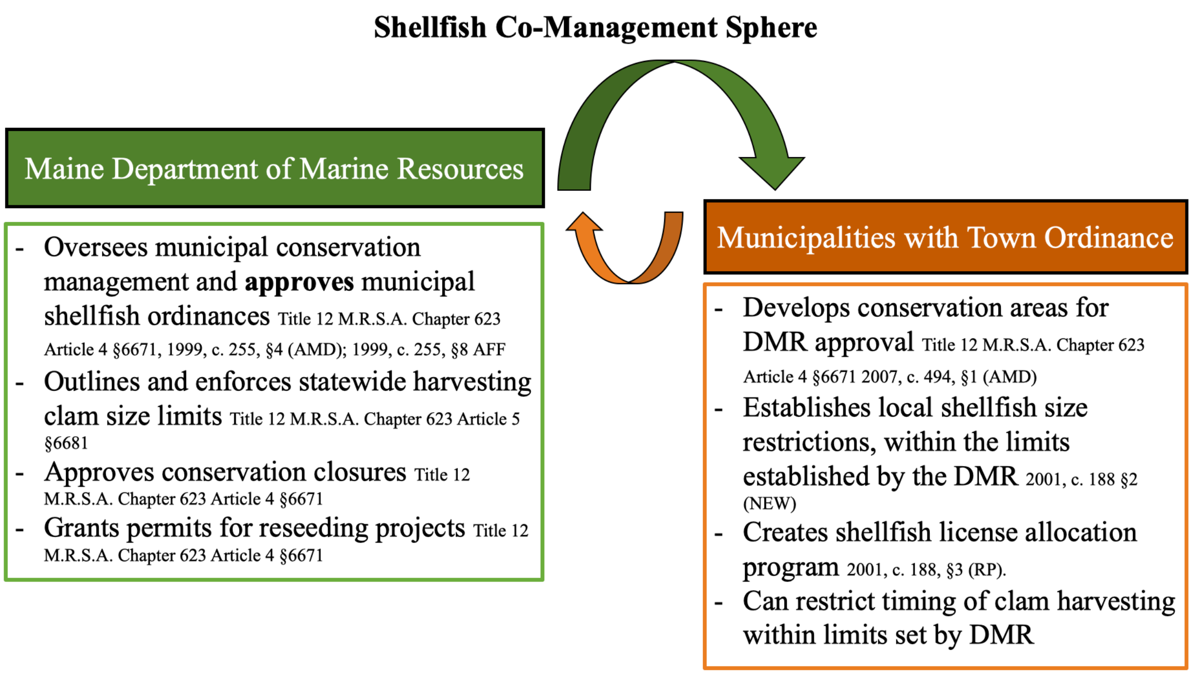


Figure 13. Shellfish Co-Management Sphere. On the left, the green box highlights the DMR responsibilities, on the right, the orange box highlights the municipalities' responsibilities.

In this chapter, I share results from a qualitative study that sought to examine a collaborative partnership, the Medomak Taskforce, that emerged in the space between water quality management and shellfish co-management. I begin by reviewing literature focused on adaptive capacity and co-management as well as public participation in environmental decision making. I then describe my methods for conducting observations and interviews of this collaboration as well as analysis. I then describe public participation pathways specific to the Maine soft-shell clamming industry. Next, I highlight the major themes I identified in this research, focusing on factors of adaptive capacity, such as learning, the value of diversity and resources, and the importance of trust and how collaborative projects like the Medomak Taskforce can influence those factors. I conclude with recommendations for supporting the development of adaptive capacities in water quality partnerships like the Medomak Taskforce.

3.1.1 Adaptive Capacity and Co-Management

Multiple examinations of adaptive capacity have been conducted, highlighting diverse orientations to this concept (Nursey-Bray et al. 2018, Melnychuk et al. 2014, Engle 2011, Gupta et al. 2010, Smit and Wandel 2006, Gallopín 2006). Across these, the Adaptive Capacity Wheel serves as a foundation for understanding how the impacts different management trends may affect the overall adaptive capacity of the soft-shell clamming industry (Gupta et al. 2010). I focused on a subset of the factors described including: leadership, resources, variety, and learning capacity (Nursey-Bray et al. 2018, Aquilera et al. 2015, Gupta et al. 2010). Leadership refers to motivating individuals who inspire action as well as diverse forms of leadership (McGreavy et al. 2018, McGreavy et al. 2016, Gupta et al. 2010). Resources refers to the ability to generate resources to perform an action (Nursey-Bray et al. 2018, Gupta et al. 2010). Variety is the concept that no single solution will present itself and fix all of the issues facing an institution. That is, problem solving should include a variety of expertise and knowledge in developing action plans (Gupta et al. 2010). Finally, learning capacity is the promotion of learning by an institution, and multiple types of learning being included in different aspects of study (Gupta et al. 2010, Nursey-Bray et al. 2018). These traits are summarized in Table 2. Each of these traits is reflected in aspects of the management and collaborative efforts in the soft-shell clamming industry.

Community collaboration between fisheries stakeholders and managers can improve adaptive capacity in research and management contexts. Clammers maintain a wealth of knowledge by engaging with the resource daily. The use and incorporation of stakeholder knowledge into legislation is vital to increase the efficacy of environmental policy (Reed et al. 2017, McGarry and Agarin 2014, Glucker et al. 2013, Parkins and Mitchell 2005, Coffey 2005). Stakeholder knowledge can be incorporated through public participation in management as well as through collaborative projects that facilitate the sharing of information between stakeholders and management. Knowing how clammers and other stakeholders participate in their industry and recognizing the power they wield to improve management is paramount to understanding how this fishery and others like it can economically and socially adapt to future changes that the resource may experience.

Adaptive Capacity - The ability to respond and adapt to change	
Variety	- No single solution will ever present itself and fix all issues facing an institution
Leadership	- Diverse forms of leadership that inspire action
Learning Capacity	- Promotion of learning by an institution - Multiple types of learning
Resources	- Having multiple resources (either money, manpower, etc.) - Ability to generate new resources

Table 2. Components of Adaptive Capacity. These definitions of adaptive capacity are drawn from the following sources: McGreavy et al. 2018, Nursey-Bray et al. 2018, Aquilera et al. 2015, Gupta et al. 2010.

3.1.2 Public Participation in Shellfish Decision Making

The commitment to effective and equitable public participation refers to the ability for an informed community to know what decisions are being made about collective life and ideally have the opportunity to shape those decisions in meaningful ways (Pezzullo and Cox 2018). Public participation in environmental decision making was developed from the democratic principles outlined in the National Environmental Policy Act (NEPA), which requires Environmental Impact Assessments (EIAs) for any major federal project (Glucker 2013, Petts 2003, Webler et al. 2001). This was later highlighted in multiple United Nations (UN) meetings, and is now generally accepted as the global standard, where EIAs allow for communities to make their voices heard regarding management decisions that will affect their environment (Glucker 2013, Brown 2012). This type of participation is fundamental in creating salient and applicable legislation regarding natural resources and environmental issues, by incorporating stakeholder knowledge and recognizing cultural and social needs in legislation (Reed et al. 2017, McGarry and Agarin 2014). Participation is not just a formal process, but one where interactions and discussions outside of public hearings shape policy, and "individuals engage each other about subjects of shared concern" (Pezzullo and Cox 2018, p. 294). Not all public participation practices are created equal. Compounding issues often lead to the unequal distribution of opportunity to publicly participate among citizens.

A democratic understanding of public participation centers around the three specific rights: the right to know, the right to comment, and the right of standing (Pezzullo and Cox 2018). The right to know refers to the access of information as well as transparency of the process. As a portion of NEPA, it requires the disclosure of information to the public regarding the environmental ramifications of different pieces of legislation, as well as relative transparency about where the information regarding environmental impacts came from (Brown 2012). Transparency is defined as "the openness of governmental actions to public scrutiny," (Pezzullo and Cox 2014, p. 287). This definition is fleshed out in both UN Conference on Environment and Development Rio Declaration Principle 10 and the Declaration of Bizkaia in 1999. Principle 10 states: "Environmental issues are best handled with participation of all concerned citizens, at the relevant level...states shall facilitate and encourage public awareness and participation by making information widely available (Rio Declaration 1992, p. 2)." Here, making the information widely available is intrinsic to responsible handling of environmental issues, and extended, management of fisheries (Glucker 2013, Brown 2012). The right to comment is the ability to participate and address the entities responsible for legislative decisions. This involves public hearings and public comments. Public hearings, are defined as "face to face meetings that solicit public input on a decision before an agency takes action that might significantly affect the environment," (Pezzullo and Cox 2018, p. 301). Finally, the right of standing refers to accountability, or the protection of the interest speaking to the legislative body. True public participation is defined as access to all three of these rights by stakeholders when participating with legislative spaces.

These democratic principles play out differently outside of theory. The reality of these principles has been discussed in many different works, primarily focusing on the implementation of the right to know, comment, and standing, rather than just the theories behind the rights themselves (Reed et al. 2018, McGarry and Agarin 2014, Parkins and Mitchell 2005, Senecah 2004, Webler 2001). Trinity of Voice (TOV) is a commonly-used environmental communication framework to assess public participation focusing on the realities of how the above democratic rights of know, standing, and comment are shaped and used outside of just EIAs (Klassen and Feldpausch-Parker 2011, Walker 2007, Senecah 2004). This framework presents three major tenets of participation: access, standing, and influence. Senecah (2004) expands the right of access from the previous democratic right of access to information to include other aspects around engaging with pertinent materials to legislation;

> At a minimum it seems that access should be characterized by: an attitude of collaboration, convenient times, convenient places, readily available information and education, diverse opportunities to access information and education, technical assistance to gain a basic grasp of the issues and choices, adequate and widely disseminated notice, early public involvement, and ongoing opportunities for involvement, (Senecah 2004, pp. 23-24).

The right of access adds legitimacy to the decision-making process by creating an informed community of stakeholders that can utilize pathways laid out by external legislation (Brisman 2013, Webler 2001, Arnstein 1969). The right of standing is defined as "the civic legitimacy, the respect, the esteem, and the consideration that all stakeholders' perspectives should be given," (Senecah 2004, p. 24). When broken down, standing is not only the ability for stakeholders to share their perspectives, but the notion these comments are considered and given respect (Carvalho et al. 2016, Senecah 2004). Meanwhile the concept of influence focuses on the consideration of stakeholder comments, whereby stakeholder input is considered and integrated in a manner that impacts the decision making process (McGarry and Agarin 2014, Senecah 2004). It also involves the idea that the management of this industry supports and helps facilitate public participation (McGarry and Agarin 2014). This tenet is notoriously difficult to evaluate in a legislative space as not all proceedings are transparent, particularly when considering closed door meetings of legislative bodies (Carvalho et al. 2016, Senecah 2004).

As this introduction and literature review begins to demonstrate, the soft-shell clam fishery faces numerous pressures that are contributing to the decline in landings and the loss of this important part of the community and economy in coastal regions. These challenges are compounded by a complex governance system that shapes and in many ways limits how members of the public can participate in relevant decision making about management and shellfish policy development. There is thus a need to explore and understand alternative ways in which stakeholders can become involved in addressing these complex challenges, and especially the emergence of informal collaborative projects to address water pollution and other shellfish management issues.

This study evaluated ways stakeholders engage with management through collaborative spaces. I focus on the Medomak Taskforce as a case study for collaborative efforts between communities, industry, and state managers. I draw from theories of public participation and collaboration to understand how fostering collaborative spaces shapes adaptive co-management for the soft-shell clamming industry and pose the following research questions: How do informal collaborative spaces create opportunities for stakeholders to participate in co-management? To what extent and in what ways did the Medomak Taskforce create public participation opportunities? How does this type of participation influence and strengthen adaptive co-management structures for the soft-shell clamming industry? Overall, I am exploring the ways in which the Medomak Taskforce operated as a collaborative project, and how it sits between the two spheres of clamming management influencing both public participation and adaptive capacity. In the following section, I describe my methodology to address these questions.

3.2 Methodology

As stated above, the main goals of this study are to understand how the Medomak Taskforce operated as a collaborative project that enabled different forms of public participation than the current quasi-co-management system allows. The methods below were generated in order to gather data from multiple spaces around this topic, as well as maintain scientific rigor through the analysis of multiple datasets.

3.2.1 Semi-Structured Interviews

I developed interview protocols in conjunction with the Institutional Review Board for the Protection of Human Subjects (IRB) at the University of Maine. Interview techniques were based on Creswell's (2009) and Corbin and Strauss's (2014) semi-structured methodology which allowed for flexibility between interviewees. Please see Appendix E for an example of the interview questions. Twelve interviews were conducted with multiple representatives from various regulatory agencies chosen through their affiliation with the Medomak Taskforce: DMR, Maine DEP, DAg, municipalities (Waldoboro Town Council), as well as the relevant non-governmental organization, Medomak Valley Land Trust (MVLT), (Figure 14). The interview questions were generally open-ended to allow for the broadest responses. They focus on the future of the shellfish industry, regarding opening up previously closed areas from pollution concerns, conservation techniques, aquaculture, and defense against anthropogenic and ecological threats to the industry. The questions also followed general themes from the previous interviews from the drifter survey (Chapter 2), focusing on specific issues to shellfishing (predators, pollution closures, market effects, etc.), participation in management, the use of science in management decisions, collaborative conservation efforts, and the overall experience of shellfish harvesting (Appendix E). Each interview was recorded by digital recorder at an area of the interviewee's choosing. All interviews were transcribed.

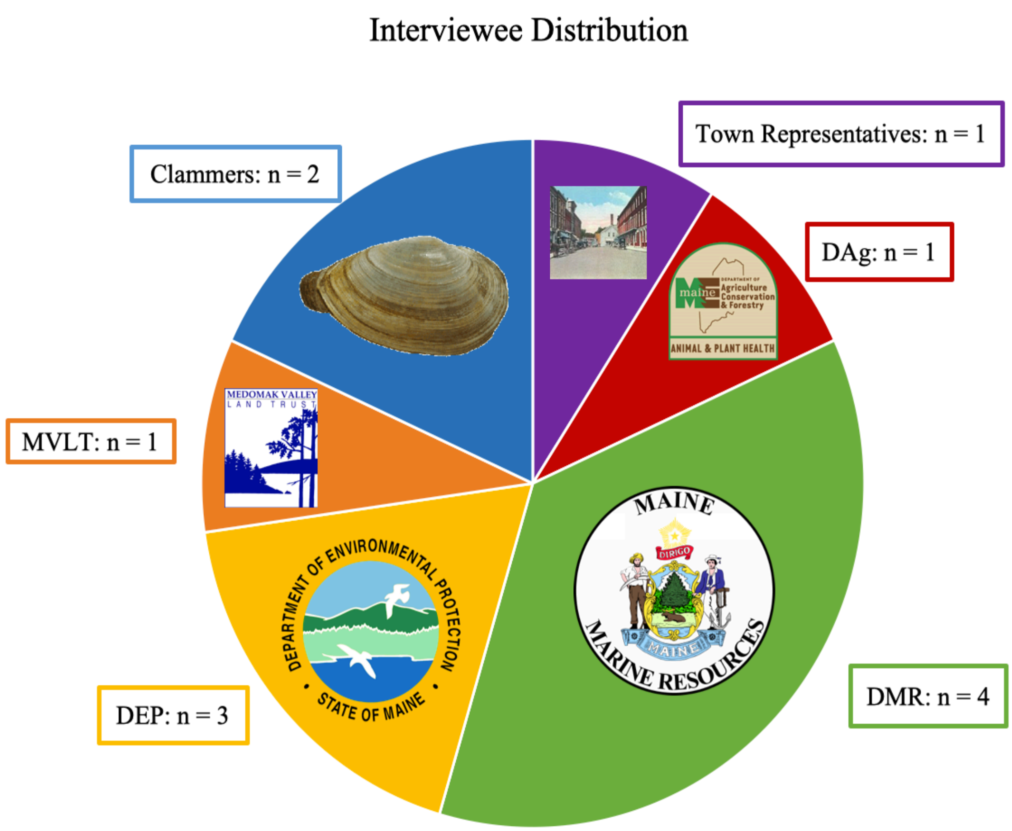


Figure 14. Interviewee Distribution. Pie chart describing multiple entities that were targeted during interview process (n= refers to number of interviewees conducted).

3.2.2 Trustworthiness and Triangulation

To promote rigor throughout the study, four aspects of trustworthiness of qualitative data based conclusions are addressed: credibility, transferability, confirmability, and dependability (Connelly 2016, Lincoln and Guba 1985). The major tools used to assure trustworthiness include peer-debriefing, member-checking, and triangulation of sources (Connelly 2016, Krefting 1991, Lincoln and Guba 1985). Peer debriefing sessions occur with my advisor Bridie McGreavy every two or three weeks to ensure decisions and conclusions are valid to other researchers. Member checking includes meetings with stakeholders and interviewees. In this study, reflective journals describing decision making analysis are used. Multiple discussions with advisors Damian Brady, Bridie McGreavy, and partner Glen Melvin were also used to address potential bias in the work (Connelly 2016). Triangulation is the use of multiple methods and data sources to ensure a more comprehensive understanding of the case (Carter et al. 2014). The various number of sources in this study include semi-structured interviews, newspaper articles, legislative documents, meeting minutes, as well as transcribed field notes. Each data source was cross-compared with the others to validate data (Carter et al. 2014).

3.2.3 Thematic Data Analysis

Thematic analysis methods were used, which allows for more generalized assessment and understanding of interviews, observations, and more casual conversations (Creswell 2009, Boyatzis 1998). In this study, thematic analysis was focused on understanding patterns between different data sources and stakeholders. It was used to identify what major problems are in the soft-shell clamming community from different points of view, either public, the clammers themselves, town management, and others. Coding (later described) focused on key words and concepts within the data (Boyatzis 1998). Interviews were uploaded and analyzed using NVivo Pro 11® software. Coding and identification of themes and recurring ideas were developed using the guidelines described by Bazeley and Jackson[2] (2013). Briefly, themes are identified through extensive coding and re-examination of interview transcripts, as well as connections to other types of data sources including meeting minutes, and newspaper articles.

Coding analysis keeps the relationships between different data sources viable, as well as creates labels for specific sources (Miles et al. 2014). In this case study, coding was done using Nvivo Starter ® and Nvivo Pro 11®. Each document and transcription was ordered by type into separate folders. Each folder was used in a query regarding frequency of words, and then compared to other folders. Specific segments pertaining to the research questions (either closures, soft-shell clamming, economy, and others) were clustered and displayed to draw conclusions (Miles et al. 2014). Collectively, a "grounded" approach was used in terms of coding and organization of data sources (Miles et al. 2014). This refers to an approach the incorporated guidelines for data collection and analysis that is grounded in real-life experiences, in my work, this refers to extensive engagement in the community and an understanding of overarching principles of adaptive capacity from coursework and literature reviews (Miles et al. 2014, Bazeley and Jackson 2013).

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[2] This is a standard text regarding NVivo Programming focused on qualitative data analysis that describes the thematic analysis method.

3.3 Results and Discussion: Existing Pathways and Emergent Opportunities for Participation in Shellfish Co-Management

In this section, I begin by briefly describing a set of participation pathways through which stakeholders may become involved in management and policy decision making in the soft-shell clam fishery. I do this to help highlight the need and opportunity for informal collaborative projects, such as the Medomak Taskforce, as these collaborative projects help create spaces in which people from diverse sectors in the fishery can advance projects to address pressing challenges related to water quality and the decline of clam populations. It is common in case study and qualitative research to combine results and discussion, where the identification and discussion of themes are integrated, as I have done here.

3.3.1 Pathways for Public Participation in Shellfish Decision Making

I reviewed public participation pathways present in the soft-shell clam industry co-management structure to help define gaps for stakeholder and clammer participation that could be filled using informal collaborative spaces such as that observed in the Medomak Taskforce. I constructed an analytic framework that focused on the three rights defined in Table 3, based on the literature review discussed above (Section 3.1.2) to assess factors that shaped participation in specific pathways. These pathways included the Maine Department of Marine Resources Website, the Maine Shellfish Advisory Council quarterly meetings, public hearings of the Maine Legislature’s Joint Standing Committee on Marine Resources, municipal shellfish committee meetings, and Shellfish Focus Day associated with the annual Maine Fishermen’s Forum. I briefly describe each of these major pathways and some of the TOV-related factors that shape the extent to which these pathways do or do not provide opportunity to participate in shellfish-related decision making. This discussion aims to provide important context for understanding how the emergence of the Medomak Taskforce was situated within and helped navigate and transform the existing constraints on public participation in this fishery.

Right	Definition
Access	- Information available in multiple areas (online, town office, DMR office) to remove barriers around information (McGreavy et al., 2018; Johnson 2019) - Convenience in location (central in Maine, or rotating locations across coastal Maine) to allow for travel by clammers - Convenience in time (not occurring solely during low tide) so clammers will not simply miss a day of work to engage
Comment	- Advertising for public comments - Accessibility in different forms (written documents – letters, speeches) - Civic legitimacy, or the rights of standing to provide comments
Influence	- Use of stakeholder comments in legislation, either direct wording, or citing multiple engaged activities with stakeholders - Legislation drafts in response to stakeholder concerns - Support given by management (either set aside time during agendas or specific comments made by management)

Table 3. Criteria for Evaluating Public Participation Pathways: I use these rights as criteria for evaluating the extent to which a specific pathway provides effective and equitable opportunity for public participation in management and policy decision making (Senecah, 2004).

For those with internet access, the Maine Department of Marine Resources (DMR) website is used to check water quality closure information, changes to management, as well as clam landings information. Incoming clammers also use this website to understand how to enter the industry, access licensing information, and get the contact information for Area Biologists and Water Quality Managers. With this contact information, stakeholders are able to contact different members of the DMR with questions or comments. Overall the DMR website meets criteria for access but only for stakeholders with internet access. The right of access in this case does not meet criteria for all stakeholders due to the variability within the audience. Dr. Tora Johnson presented at Shellfish Focus Day at Fisherman's Forum on the effectiveness of shellfish legal notices (Johnson 2019). In her talk, she focused on the fact that the audience is so variable, where stakeholders span multiple age groups, technological access, literacy, color blindness, and more. This concept must be consistently accounted for when considering true accessibility (Johnson 2019). With the DMR website, similar comments could be made where communication and visuals should be improved. Beyond the website, there is also the Maine Biotoxin and Shellfish Sanitation Hotline. This is provided by the DMR as a phone line people can call in order to get up to date closure information. Importantly, this increases the accessibility of DMR information for people who do not have access to the internet.

Stakeholders also engage management policy through the Maine Shellfish Advisory Council (ShAC). This body was founded in 2007, with the idea that multiple members of the shellfish industry would be represented on an advisory council to the Maine Legislative Government. This includes a public member, four licensed shellfishermen with three being focused on soft-shell clamming, two seafood dealers, two aquaculture lease holders, a municipal wastewater treatment representative, one member who has been issued a shellfish depuration license, and two shellfish wardens (Title 12: Part 9 Subpart 1, Chapter 603 §6038, Maine Legislature 2019). Each of the members of this committee are chosen at DMR discretion, with some input given by current members of the committee. ShAC discusses new legislative actions that would impact the shellfish industry, as well as major issues or projects going on within the shellfish industry. During the meeting, the public is given opportunities to provide feedback pending recognition by the committee, meaning they do not have free reign to discuss issues brought up, but instead have to be called upon by the chair, or other members of ShAC (DMR 2019). There is also a final public comment period but it is inconsistently included on the ShAC agenda. These comments are usually discussed during later deliberations, but not always. Each of these components infringes on the right to comment, as the public is not always given the chance to make their voices heard (Senecah 2004).

All ShAC meetings are open to the public, where stakeholders and community members can sit down, listen to new information, and weigh in on issues. This public forum fulfills most requirements for the right of access. Information is shared through presentations, as well as handouts, however location and timing have been cited as areas of concern by multiple stakeholders. Meeting attendance is variable as timing and changing meeting locations preclude clammers ability to participate, especially if driving to Augusta or Ellsworth would mean missing a tide. This is particularly important because while the committee is built to be geographically diverse, if members do not sit on shellfish committees or communicate effectively with others in the fishery, shellfishermen may not have access to information discussed at ShAC. However, ShAC meeting minutes are posted online so people who did not attend the meeting can review the minutes to understand issues discussed. For those without internet access, there are no other options to participate other than attending meetings. In the interviews, when I asked about impressions of relevant meetings in the industry, I regularly heard that there is a difference between municipal shellfish committee meetings and the state-level ShAC meetings, as demonstrated in the following quote:

> *Do you attend committee meetings often? Do you think they're useful?*
>
> Uh, shellfish committee meetings? Yes. Not all committee meetings. Not ShAC, or other ones. The town committee meetings are necessary to understand the level of communication if nothing else, you can communicate stuff that comes from the state directly to me and then I can go to the shellfish committee, which goes to the diggers. And the communication factor is the most important thing we do or one of the most important thing we do." *(Clam harvester*)

The above quote highlights the difference between ShAC meetings and municipal shellfish committee meetings. Here, the municipal shellfish committee member highlights attendance, but also showcases the pathway of communication that is creased by having municipal shellfish committee meetings. Information can be disseminated between clammers and state manager. This is an intrinsic benefit of having a co-management sphere where DMR and municipalities can interact on a regular basis (McGreavy et al. 2018). Municipal shellfish committee meetings are also held at a higher frequency than ShAC meetings, and are usually held at night, after tidal harvesting and general work hours, increasing the accessibility to clammers, but alienating other stakeholders (McGreavy et al. 2018). There is also generally space to allow for public comment at almost every meeting, whether originally scheduled, or allowed at the conclusion of planned discussions, which highlights the right to comment. They also foster diverse forms of leadership, through partnerships between committee members, as well as regular check ins with shellfish wardens. However, it should be noted that these committee meetings are extremely variable across the state, meaning the rights of access, comment and influence would also vary across different municipalities (McGreavy et al. 2018).

Stakeholders in the soft-shell clamming industry can also engage directly with the legislature by attending public hearings in front of the Committee of Marine Resources. This committee is composed of members on the Maine Legislative Body, senators and representatives, and is generally spread geographically across Maine. The Committee of Marine Resources decides on how different bills focused on marine resources will either proceed, be tabled, or die before being voted on by the greater State Legislature (Maine Legislature 2019). Generally, public hearing times are presented on the Maine Legislature Committee Information Website, however there are videos and transcriptions posted on the website, for stakeholders to access if unable to get to the meeting. Participants can also listen to live audio from the room. Stakeholders are able to email the committee as a group, as well as mail in letters (Maine Legislature 2019). At the public hearings, proponents and opponents are able to present comments over 3-4 hours to the committee directly. However, it is unclear how these comments are incorporated into later closed-door deliberations. For this pathway, the right of comment is met, where stakeholders can access the committee through both internet and non-internet based means. However the right of access and influence are both difficult to evaluate because of the lack of transparency in the process. Overall, the public hearings should include call-ins or other aspects for stakeholders that can't drive to the public hearing, or write in emails / letters. This would improve the accessibility of public hearings for stakeholders.

Finally, Shellfish Focus Day is a daylong seminar associated with the Maine Fishermen's Forum and held annually in late February or early March (http://mainefishermensforum.org/) and is intended to feature shellfish science, management, and policy developments. In a conference format, there are presentations from multiple source. For example, in 2018 presenters shared information related to the evolution of shellfish farms, the Pathways Program by the Schoodic Institute, clam recruitment studies, mussel drone surveys, harmful algal blooms, finding and fixing water quality issues, and green crabs. Over the last three years, efforts have been made to formalize the decision making about Shellfish Focus Day and to involve ShAC in setting the agenda, as this was previously led by the DMR with little public input. Prior to DMR's involvement, Shellfish Focus Day was organized by the Maine Clammers Association, and this history of decision making about this learning event is worthy of its own study that is beyond the bounds of this thesis. Currently, presentations are chosen based on a collective effort of members of ShAC and the DMR. This day provides a space for stakeholders to engage with managers, and ask questions directly about legislation and science happening in the industry.

> ...there are certain times where DMR staff are out in the public form, so like the Fisherman's forum, so like Clam Day, then, obviously you have a chance to see more people in a short amount of time… (*DMR Representative)*

Shellfish Focus Day provides stakeholders access to the DMR. With harvester presentations focused on applied science, this day also outlines how harvesters have influenced the direction of science in the industry. This is particularly important as it highlights the right of influence stakeholders have. This event also secures the right of access and comment, as stakeholders are able to ask questions about any work presented during the day.

Each of the pathways identified above were shaped by different factors that affected the extent which they provide effective and equitable opportunity to participate in management and policy decision making about the soft-shell clam fishery. In some meetings, there was a limited space to publically participate. For some, the timing of the meetings prevented clammers and other stakeholders from attending. It was also difficult to determine where and how stakeholder knowledge was included in management decisions. Comments made by stakeholders were not always reflected by decisions made. Despite stakeholders reserving the right of access, comment, and influence in management policy, all pathways to such rights are not equal across the population of stakeholders. Issues of internet access, literacy, and timing inhibit one's pathway to maintain those rights. These issues are highlighted below:

> Communication can be limited solely due to lack of computer savvy and internet. There are a lot of licensed harvesters and depending on what growing areas you are working in you know, we the scientists don't have time to call everybody. So email can be both friend and foe if you're trying to communicate with that because you're only going to get to the individuals who use emails as a communication tool and with this industry a lot of them don't even have smartphones (*DMR Representative)*

Here, the DMR showcases the need for multiple paths for different stakeholders to engage with legislation and management. Otherwise, stakeholders will not be able to participate in management, or share their knowledge to policymakers. Below, another harvester highlights the difference in sharing information between expectation and reality:

> *And where do you generally get your information?*
>
> Purely experience. There is no place to go, there is no library for us to go check this or that and people are different. I talked to a digger at ShAC …. and his problems are totally different than mine, so he listens to what I got I listen to what he's got, and we try and put something together, just to share information. (*Clam harvester*)

Harvesters highlight a major path of information sharing between stakeholders: word of mouth. This reiterates the earlier pathway between the DMR Area Biologists and Water Quality representatives, where stakeholders are able to engage and discuss issues with management processes through face to face meetings. These discussions represent their right to access, influence and comment in action. It may be useful to consider as institutions such as DMR and ShAC reassess how they share information with stakeholders and create opportunities for effective and equitable public participation. This dynamic is vital to maintaining adaptive, salient legislation, and key to creating a more holistic and democratic management plan for the industry. As a final note, one harvester mentioned the need to move beyond discussions into action which provides a pivot into the following analysis of the Medomak Taskforce as such a space of informal, collaborative action:

> Sharing of information I like discussion no matter how harsh it gets. Boosts your information. I sent a thing to [Name removed] I think last week, someone sent out something on the ShAC meeting and no one replied or I was the only one who replied, and I said get off your ass argue with me. I don't want you to agree with me, let's do something, otherwise I'll stay home. If there's no production here, I'll go. Let's share information, let's do something. I'm not bureaucratically oriented unless moved, instead let's go do something. (*Clam harvester*)

3.4 Characteristics of Collaboration in the Soft- Shell Clamming Industry

There are other pathways available to clammers to engage state level managers than through the pathways mentioned above, including collaborative projects that incorporate stakeholder knowledge and facilitate communication between state managers and other stakeholders. The Medomak Taskforce is a key example. This was a community project led by members of the Waldoboro Shellfish Committee and DEP personnel. It had members from the DMR, DEP, Maine Department of Agriculture (Dag), Medomak Valley Land Trust (MVLT) and others. As a case study, understanding how the collaborative space in the Medomak Taskforce developed within a co-management structure gives us key insights into the characteristics of collaboration in the soft-shell clamming industry. One of the most important factors that shaped collaboration was municipal leadership, where the leader of the collaborative project should come from a local level as opposed to top down leadership from the state. The local and shared leadership facilitated sharing of stakeholder knowledge, and supported other characteristics such as the ability to collectively identify goals and participate in advocacy. In this section, I begin with a general overview of findings which focus on the factors associated with adaptive capacity discussed above: *leadership, variety, resources,* and *learning capacity*.

3.4.1 General Overview

Multiple characteristics of collaboration were identified within the context of this study. It should be noted this does not mean every characteristic has been identified. Six topics surfaced during thematic analysis of 14 interviews, along with over 20 other sources: definitive goals, municipal leadership, advocacy, money, state requirements, and timing. Each of these is distinctly related to previously discussed components of adaptive capacity: *leadership*, *variety*, *resources*, and *learning capacity*. The most predominant characteristic of collaboration was municipal leadership, and will be discussed further in the following sections.

Briefly, definitive goals refers to the ability for the collaborative group to easily define their goals, and have a clear timeline. This is an important factor of *leadership* in an adaptive capacity context, where definitive goals can generate action particularly when jointly developed with a *variety* of different stakeholders. Having definitive goals allowed for stakeholder groups to coordinate responsibilities and resources to meet those goals, knowing there was a certain timeline that needed to be met. Advocates referred to multiple levels of advocacy within the Medomak Taskforce, including municipal management, land trusts and other non-profit organizations, as well as the state management representatives. The multitude of voices reiterated that having many different levels of advocates for a project allowed for more resources, highlighting how this collaboration fulfills *variety, learning capacity* and *resources*. Money (*resources)* refers to the capital available to the collaborative project, and at times is limiting and beneficial (depending on the amount available). While it was mentioned money was not always necessary depending on the collaborators (if other stakeholder groups can mitigate costs it is not limiting), it is necessary for distinct features of a project mainly scientific testing (depending on the goal of the project). In soft-shell clamming, state level requirements and timing also can impact the ability or formation of a collaborative group, where state level and national level requirements must be met in terms of management and experimentation, and timing can mandate who is available to participate in the collaborative space.

Collaboration in the soft-shell clamming community depends on localized leadership, and vested interest from all parties involved. This discussion is focused on community projects to improve the soft-shell clamming industry. As stated previously, the majority of information on collaborative projects is based on 14 interviews with people from multiple backgrounds who had all worked on the Medomak Taskforce, a large-scale community led project that has improved the water quality in Waldoboro, ME. During my research, it became obvious that specific ingredients were needed to create this type of collaborative space, a space that has continued outside of just the Medomak Taskforce.

3.4.2 Leadership and the Roles of Community

There were multiple stages where leadership was mentioned and highlighted as an important factor for other stakeholders to get involved in a community project. In sustainability science and fisheries management literature, community or local leadership is vital to successful co-management or community based fisheries management (Sutton and Rudd 2014, Wiber et al. 2009, Shackleton et al. 2002, Jentoft 2000). Here, these sentiments were reflected in multiple interviews. First, from a management perspective, working with communities who have their own leaders can improve collaborative efforts, as these leaders from the community highlight the issues facing the community, and are able to garner local support for salient solutions.

> We will absolutely prioritize areas where they're actively trying to do work. There's not much point in us knowing that we have a, say an emerging issue in an area, and we can do a set amount of proscribed investigative stuff for that. But beyond that, we really need to collaborate with the town to go beyond that. Our job isn't necessarily remediation of known issue. *(DMR Representative)*

Here, the DMR representative highlights another issue that can be mitigated by community leadership, namely jurisdiction. In the shellfish co-management sphere, towns have the ability to self-manage clam flats to a certain extent. There are still overarching requirements set down by the DMR the towns have to meet particularly with licensing or conservation practices. However, in a collaborative space, communities can use their extended jurisdiction to move outside of the state managed spaces to solve problems, as well as cross between multiple state agencies. In the Medomak Taskforce's case, this would include freshwater aspects which were managed by the DEP and estuary areas managed by the DMR. Pressure from communities can help facilitate cooperation and sharing between state agencies, where politics may have created non-collaborative spaces before. These sentiments are again stated by a representative from the DEP:

> So if there was another place that reached out to us and showed interest but needed someone to lead, it's not out of the question, but would we have the time to step up and lead would become the question. I think you really need a local advocate like [Name removed] who knows the area well enough and who has the right standing in the community, I think you really need that. (*DEP Representative)*

The quote above highlights that state agencies are more likely to collaborate with communities who put themselves in a leadership position. This mitigates costs on state agencies, while supplying communities with support as they work towards their own goals. This quote also highlights one of the major values of having community leadership, localized knowledge. Localized knowledge improves the saliency of management decisions, as well as improves the ability of management to understand local, contextualized, issues that may be different across larger statewide management areas. These community leaders also have social capital – "the collective processes needed to effect positive change," (Wiber et al. 2009, p.173). When community leaders are more involved in management decision (or the science that those decisions are based on) it improves the legitimacy of the decision to the exterior community, in this case, soft-shell clammers (Sutton and Rudd 2014, Wiber et al. 2009, Carlsson and Berkes 2005). To be clear, this does not mean that involving community leaders will garner universal support for legislation, but it does improve the chances for support from the clammer community. This co-production of knowledge can generate shared understanding of issues facing the industry, where clammers are able to share perspectives with management, and vice versa (Armitage et al. 2011).

3.4.3 Power

An overarching component of leadership is power. On multiple levels of this collaborative space, different members are supported differently according to power (Ryan 2017, Burgh and Yorshansky 2011). As the core organizations involved vary wildly from municipal management, clammers, and state agencies, members will have different levels of power according to their organization they represent (Ryan 2017). While the members of state agencies do have a vested interest in the projects, clammers often participated in collaborative work to save their livelihoods. Here is a sequence of quotes from clammers, highlighting their purpose of getting involved in the Medomak Taskforce, and municipal management:

> …..There's just so many reasons not to dig, we got closures. We never had closures, we could dig every day. We didn't care, we could dig every day in Waldoboro every day. Now we get a closure and you're two weeks without your paycheck. How many people can go two weeks without their paycheck and then come back. And what if it rains again then you've got two more weeks. How many people can take that kind of beating? Until you've got to get out of here. So it's become a part time subsidy where it used to be a full time job. I've seen the river the worse, I've ever seen, and I saw 10 guys who just left. (*Clam Harvester)*

Here, one major clammer leader discusses how his purpose was financial, and that a major purpose was not only a loss of access, but possibly also seeing a decline in the strength of the community around the industry. Bacterial closures, as described above, have devastating impacts on clamming livelihoods. Below, another clamming leader discusses their purpose behind getting involved in the local shellfish committee:

> I didn’t like the direction it was going. When I first got on it was more focused towards the part time guys, and I didn’t like that, we’ve converted the shellfish program to favor the full-time harvester, the commercial fisherman. It’s fine you have a fulltime job, a 40 hour a week job somewhere else, but don’t hamper us by us trying to make a living, because you want to save it while you’re at your 40 hour a week job. I mean we’ve changed this program and the same thing is happening in the St. George River, they’re preventing people to go make a living because there are so many guys who have other jobs outside of clamming that want it saved, so that when they decide to go clamming there’s clams there. They’re not taking care of the actual commercial fisherman. (*Clam Harvester)*

This quote not only focuses in on a desire to make a living but also the discrepancy of power. Clammers who are full time having less power than clammers who are on a part-time basis. This has many different socio-economic connotations, particularly on the perspective of full time vs. part time clammers. But, for the context of this thesis, there needs to be a focus on how when the management was not reflective of the population of clammers it was managing, there was a stress and struggle felt throughout the community, so much so, that it changed who became involved in management itself. As stated above, having community leaders, clamming leaders, involved in the management of a resource can have far reaching benefits in a co-managed system. By granting clammers more power, particularly in spaces where they can lend their expertise and localized knowledge, can improve the buy in of other clammers.

Based on my interviews, determining the goal of collaborative projects is an important part that can determine the success and buy in from multiple parties within that project. This was evident during my interview process. In my case, the Medomak Taskforce had an easily defined goal: cleaning up pollution. One state agency representative discussed their ability to collaborate, "We were focused on fairly small easily defined projects." Power discrepancies can also show themselves as different members take on more or less power during these deliberations. Different representatives of state agencies delegated major decision making towards the local leadership. So, the community leader set the goals of the Medomak Taskforce, rather than state management. This is an important distinction, as in other management spaces, the state and the NSSP have ultimate oversight, which can deteriorate the ability for the resource to be actually co-managed. Here, the local leader describes the purposes behind the Medomak Taskforce:

> Our is financial, theirs [land trust] is genuine caring about the environment. Those two would collaborate easily, the easiest they go. From what I understand dealing with multiple state agencies is tough because they don't get along. There is a lot of politics and that is tough from an outsiders point of view because I don't know this department hates the other departments. I don't know all the politics behind it. And the state's done a pretty good job to hide it from me, there's no one that's ever said I hate this person and that person. So, it's a great thing. I do understand there are industry things and I was impressed that all 3 of them came, I expected maybe 1 of them to bow out or quit, and it was much better than I expected. But the first one would be your local land trust, and then the state agencies from there. (*Clam Harvester)*

Here the clamming leader illustrated how all of these different representatives came together to work on this one project. Again, the clammers perspective is highlighted as a financial interest, whereas a land trust might be more environmental. The "3 of them came" is referring to the DMR, DEP, and the DAg. Their motivation isn't discussed, but it is separate. Different backgrounds led to different motivations, but the end result was the same. Was this due to the people in the room? Or the level of importance the Taskforce was given by other agency leaders? It's not quite possible to tell within the scope of this project. However, it is important to note this draws back again to the concept of *variety* and *learning capacity* in adaptive capacity, where this type of leadership that promotes inclusivity and protects multiple voices in a room can influence the adaptive capacity of an industry (Gupta et al. 2010).

It is easy to identify ways in which the Medomak Taskforce acted within both spheres of management, creating new pathways for participation and improving adaptive capacity. The Medomak Taskforce was able to generate new resources, foster diverse forms of leadership, share information, as well as create space for multiple types of expertise to focus on a common goal, solving water quality problems. Their success is obvious, where over 300 acres of clam flats were recently reclassified as open rather than conditionally approved.

3.5. Conclusion: Insights and Recommendations for Supporting Collaboration and Public Participation in Maine's Clam Fishery

In a research context, collaboration can improve the ability of scientists to come up with salient and relevant solutions to problems presented by stakeholders. This promotes science-based management, where stakeholders generally have an implicit buy in to collaborative science, which means it is more likely to be used in a management context. Research collaboration can also improve relations between scientists and other stakeholders. Scientists and stakeholders can act as boundary spanners, or participants who move across boundaries. Boundaries in the sustainability science framework are defined as, "challenges associated barriers or gaps...in knowledge-action systems," (Flynn et al. 2015, Cash et al. 2002). Stakeholder groups play the larger role in crossing boundaries, as including clammers in the process of producing knowledge gives a sense of transparency to the project, and allows for an easement of the boundary between scientists and stakeholders without compromising scientific credibility (Cash et al. 2002). By improving or creating these relationships and overcoming boundaries, stakeholder groups improve their adaptive capacity, by improving their *learning capacity*, where different aspects of issues facing the industry can be studied from multiple viewpoints.

Adaptive capacity depends fully on the ability to respond to changes. *Leadership* or municipal leadership, in collaborative spaces can be the driving force to action when responding to changes. Stakeholders, particularly clammers, in the soft-shell clam industry can also provide on the ground knowledge for changes happening to the environment, reflected in their experiences on the mudflats. In collaborative spaces, clammers can share these experiences with managers directly, and work on compromises that meet everyone's needs, whether they are nationally led standards or community based issues. This draws back to the idea of *variety* and *resources* where clammers can help provide new information on new solutions, and managers can help provide new *resources* to community led action. Collaboration also overcomes boundaries when discussing public participation in co-management. These collaborative spaces should be created around existing spaces for learning and coordinated decision making, such as Shellfish Focus Day, and the Maine Shellfish Advisory Council. These spaces could include smaller meetings with specific leaders, both municipal and state, to allow for more voices in a room, and improve the credibility of each of the boundary objects. This enhances communication, public participation, and decreases the stratified power dynamics that can damper collaboration. The flexibility of co-managed structures, where there is a balance between municipal and state allows for faster adaptation to new changes and issues. This is particularly important in the context of climate change, where there are still many unknowns about localized issues and timelines.

CHAPTER 4

CONCLUSIONS

The implications of this work are twofold, mainly focusing on the development of tidal modeling for specific estuaries and groundtruthing techniques for satellite data as well as developing better communication pathways between scientists, stakeholders, and lawmakers. Focusing on oceanographic data, the development of estuarine drifters that are inexpensive, easy to deploy, easy to retrieve, and can hold major oceanographic instruments while being versatile enough to be used in very shallow waters will have far-reaching effects in coastal oceanography. These drifters can be applied to salt-marshes, tidal mudflats, and other coastal systems that are becoming more important in terms of ecological, geochemical, and anthropogenic studies. This will also allow for a more extensive network of datasets that allows for the improvement of tidal circulation models.

These drifters also function as a boundary object, where multiple towns across the state are working with the research group to deploy these drifters in other areas, building new collaborative spaces between scientists and clammers (Akkerman and Bakker 2011). Clamming communities are engaging in our work in new and meaningful ways that can have huge implications for how other scientific work could be communicated in the future. For example, shellfish committees in Georgetown, and Brooklin, ME have contacted the research team and begun coordinating efforts either with other non-profits or schools in the area to build community engaged projects around drifter deployments. The extensive communication about this project, namely newspaper articles and open discussions, expressly demonstrates that the engaged approach used during this study incorporated the needs of communities in both the research question and the methodologies, as clamming communities are now able to take this study further by creating new datasets and understanding of the hydrodynamics in coastal Maine.

In a more political sense, understanding the pathways from science to policy is more important than ever as the laws of today will reflect on the environment tomorrow. By creating a more cooperative path between scientists and lawmakers, the results from scientific findings will be more effective in terms of real-world applications. These cooperative paths expand the ability for scientists to engage with communities in collaborative spaces. Reaffirming scientists' role in this space, following municipal leadership but maintaining scientific integrity, improves the adaptive capacity of the overall soft shell clamming industry. In the context of Waldoboro, ME, a final report will be prepared and given to managers and other stakeholder groups regarding information that was gathered during the extended engagement within this community, as well as how the techniques developed within this study can be used in other coastal areas. Already, documents detailing the methodology of deploying drifters has been shared with 14 different soft shell clamming communities, with increased interest from other groups including non-profit organizations.

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APPENDIX A: Engagement Efforts in Drifter Study

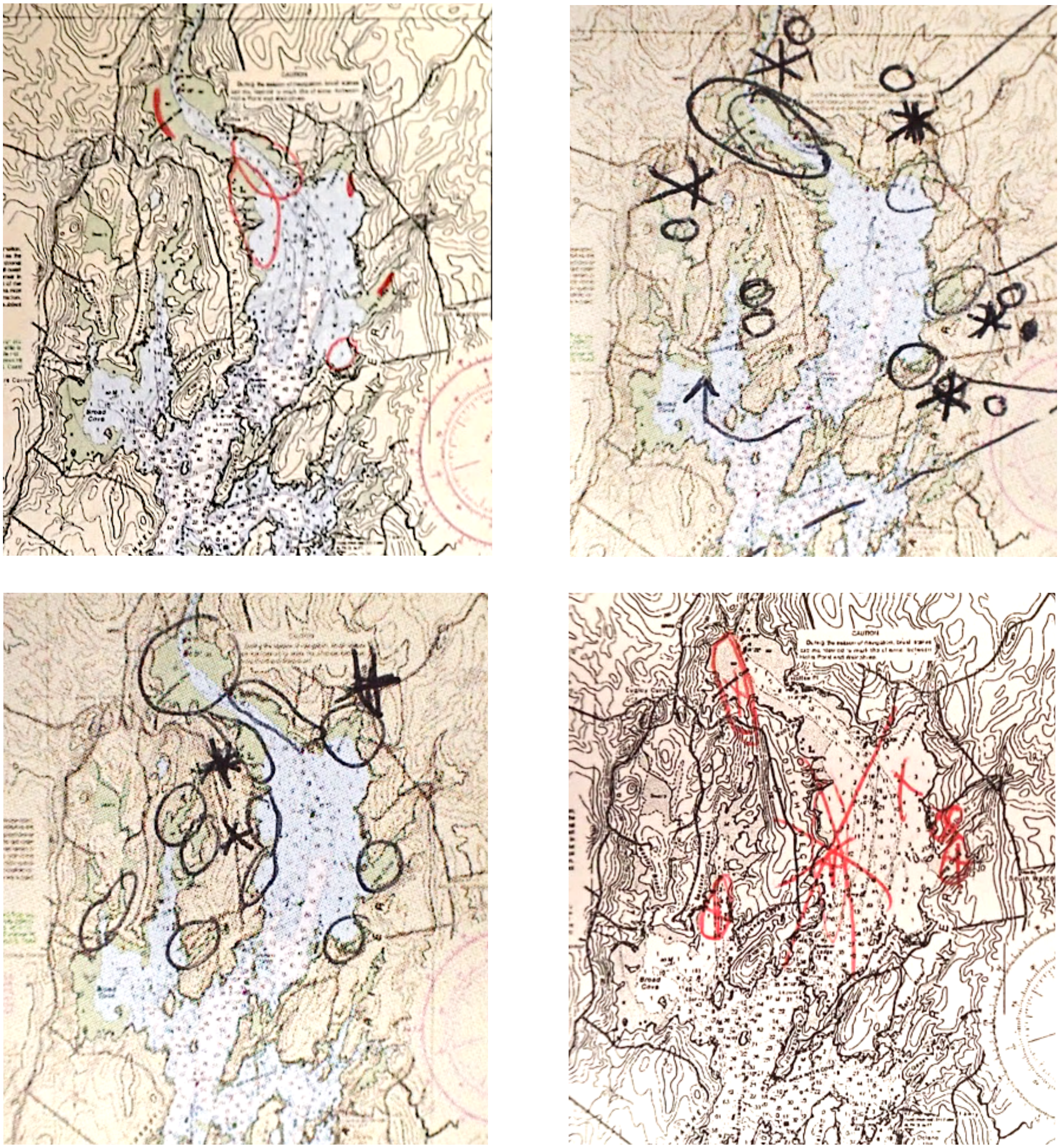


Figure 15. Engagement Maps. Maps drawn on by clammers to identify areas where drifters should be deployed.

APPENDIX B: Details on “Bucket Drifter” Design

Figure 16. Drifter Pictures. These are photos taken by the author during field release in July 2017.

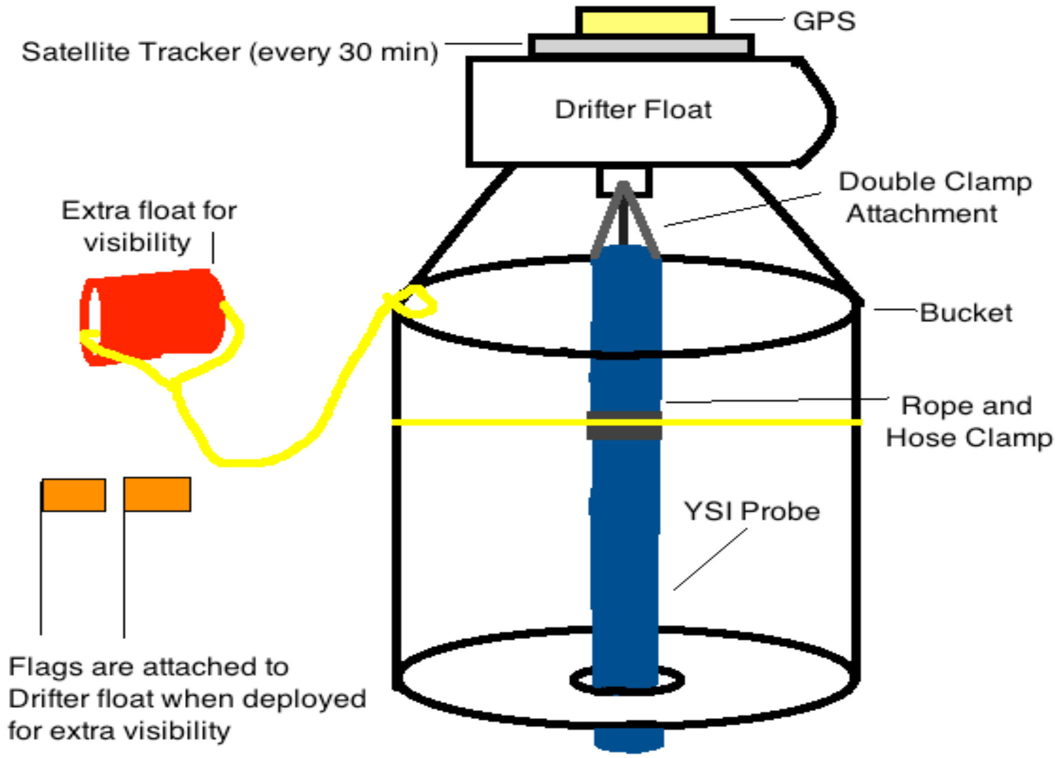


Figure 17. Drifter Schematic. This sketch shows all pieces involved, as well as how YSI probe/CDOM probe could be attached into drifter.

This bucket drifter was designed by myself and Jim Manning at NOAA. It meets recommendations by other oceanographic studies, including weights to create neutral buoyancy. As shown in Figure 1, buckets are completely submerged, and were tested to move with the first 1-2 feet (0.5 meter) of water.

List of Parts

- 5-gal bucket from the Falmouth MA plastic recycling collector station
- 7" acorn buoy labeled "drift study" bought at Ketchum trap in New Bedford
- 22cm stainless hose clamp to secure the transmitter & ballast on acorn buoy
- 5-6" stainless hose clamp to go around instruments and have something to lash to
- ½" shackle to attach instrument with
- Smartone transmitter programmed to 30 minute samples and sealed with silicon
- Garmin Etrex 10 GPS
- ½ window weight to ballast the transmitter mount
- 2-3 lb dive weight to ballast the bucket
- 3' length of 3/8" cord to secure the instruments
- small white toggle buoy to be tethered horizontally to increase visibility
- 2 used bright-colored spray cans to highlight floats
- Small red flags for added visibility
- 3' length of ⅜" cord to tether the toggle buoy
- Internal recording of salinity and temperature using StarOddi DST-CT

APPENDIX C: Drifter track summary data

Date	n =	Release Tidal Stage	Sheepscot Flow (cfs)	Precipitation (inches)	Flow Conditions	Distance (km)	Time (Hours)	AVG Velocity (mph)	Tidal Ex. (km)
07/20/2017	6	Max Ebb	23	0	low	3.701482			
07/26/2017	6	High Tide	18	0	low	1.287472	1.5	0.3	
08/15/2017	6	Max Ebb	7	0	low	3.540548	4.3	0.2	
08/16/2017	6	Max Ebb	7	0	low	1.126538	7.9	0.6	
08/17/2017	5	Max Flood	7	0	low	5.149888	8.1	0.4	
08/22/2017	5	Max Ebb	10	0	low	2.574944	17.2	0.3	0.6
08/23/2017	3	Max Ebb	10	0.04	low	15.449664	20.5	0.5	3.6
08/24/2017	3	High Tide	8	0	low	13.357522	23.5	0.4	1.8
09/14/2017	6	Max Flood	7	0	low	16.737136	31.5	0.3	1.7
09/20/2017	3	Max Ebb	7	0.02	average	5.310822	25	0.1	0.9
09/21/2017	3	Max Ebb	7	0	low	2.574944	5	0.3	1.6
10/05/2017	3	Max Ebb	5	0	low	9.977908	20.9	0.3	0.9
10/06/2017	3	Max Flood	5	0	low	9.977908	21	0.3	0.5
10/26/2017	3	Max Ebb	100	0.1	high		26		1.1
10/27/2017	2	Max Flood	250	0.01	high		21.5		1.1

Table 4. Drifter Track Summary Data. Information on each drifter track and release. N refers to the number of drifter released at that time. Flow Conditions are based on USGS datasets. Tidal excursion, or the distance travelled over a full tidal cycle, (column 10) was calculated in Matlab programming software.

APPENDIX D: FVCOM Model – applications of drifter tracks

by Wei Liu

Many studies have used drifter tracks to improve numerical model simulation skills (Proehl et al., 2005; Aretxabaleta et al., 2005; Xu et al., 2006; Chen et al., 2012). A realistic three-dimensional hydrodynamic model for the mid-coast of Maine was used to simulate drifter tracks in Medomak River. This model was based on unstructured-grid Finite Volume Coastal Ocean Model (FVCOM), which has the advantage of accurately following the complicated coastlines by using unstructured triangle elements (Chen et al., 2003; Chen et al., 2004b; Huang et al., 2008). The model domain covers a wide shelf area in mid-coast Maine and major estuaries including Madomak River. The unstructured grid allows a large model domain in the estuaries with high spatial resolution of about 10 m in Medomak River. The bathymetry of the Medomak River was obtained from a SEANET survey. The model is forced with offshore tides and river discharge from 6 major estuaries including Medomak River. The discharge of the Medomak River is estimated from StreamStats of USGS based on the size of watershed. The model results have been validated against data from the Maine EPSCoR SEANET Buoy Network and other observational datasets in Damariscotta River.

To conduct Lagrangian particle-tracking experiments in the model, neutrally buoyant particles were released at the surface of a modeled velocity field in the Medomak River. Their moving trajectories were compared with drifter tracks. By this comparison in initial experiments, it was found that the modeled particles moved much slower than the drifter, which indicates the velocity is underestimated in the model. Thus the model was adjusted to enhance or increase the flow velocities. In the final experiment, modeled particle tracks show a good consistency with the drifter's (Figure 17). The difference of tracks in the narrow head of the river is due to the discrepancy of release location between the on-site and model experiments. The modeled particles were released in a relatively wide channel, where model resolution is favorable. The drifter (black line) moved to the eastern shallow shore at the end due to wind while the modeled particle (red line) did not since there is no wind forcing in the model.

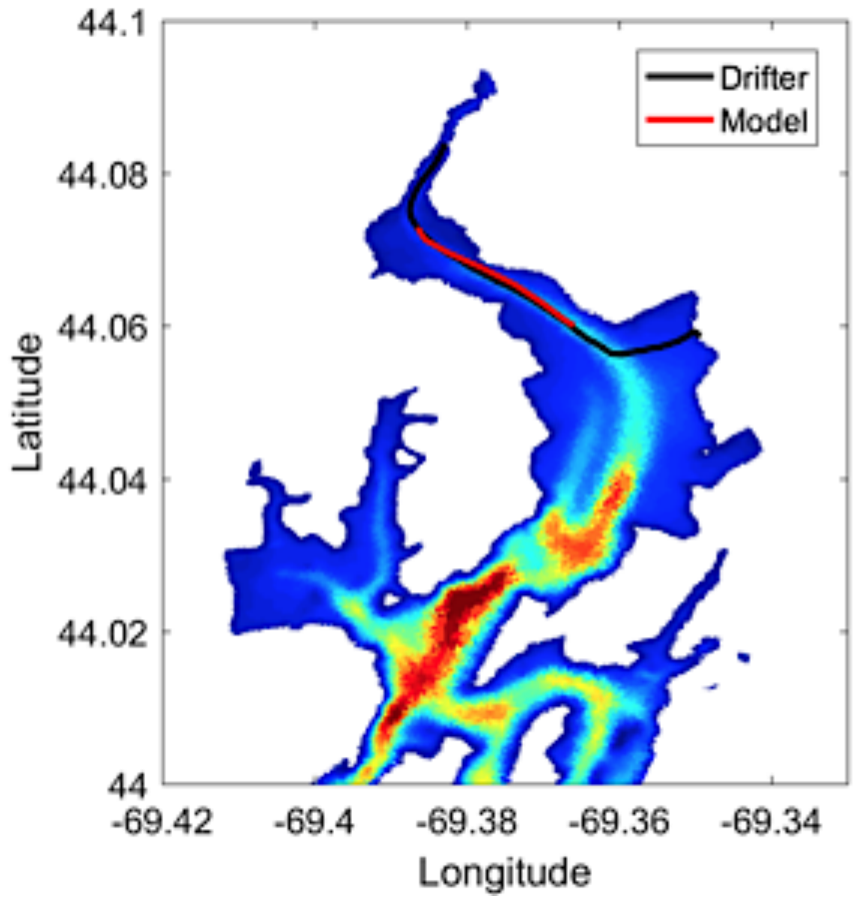
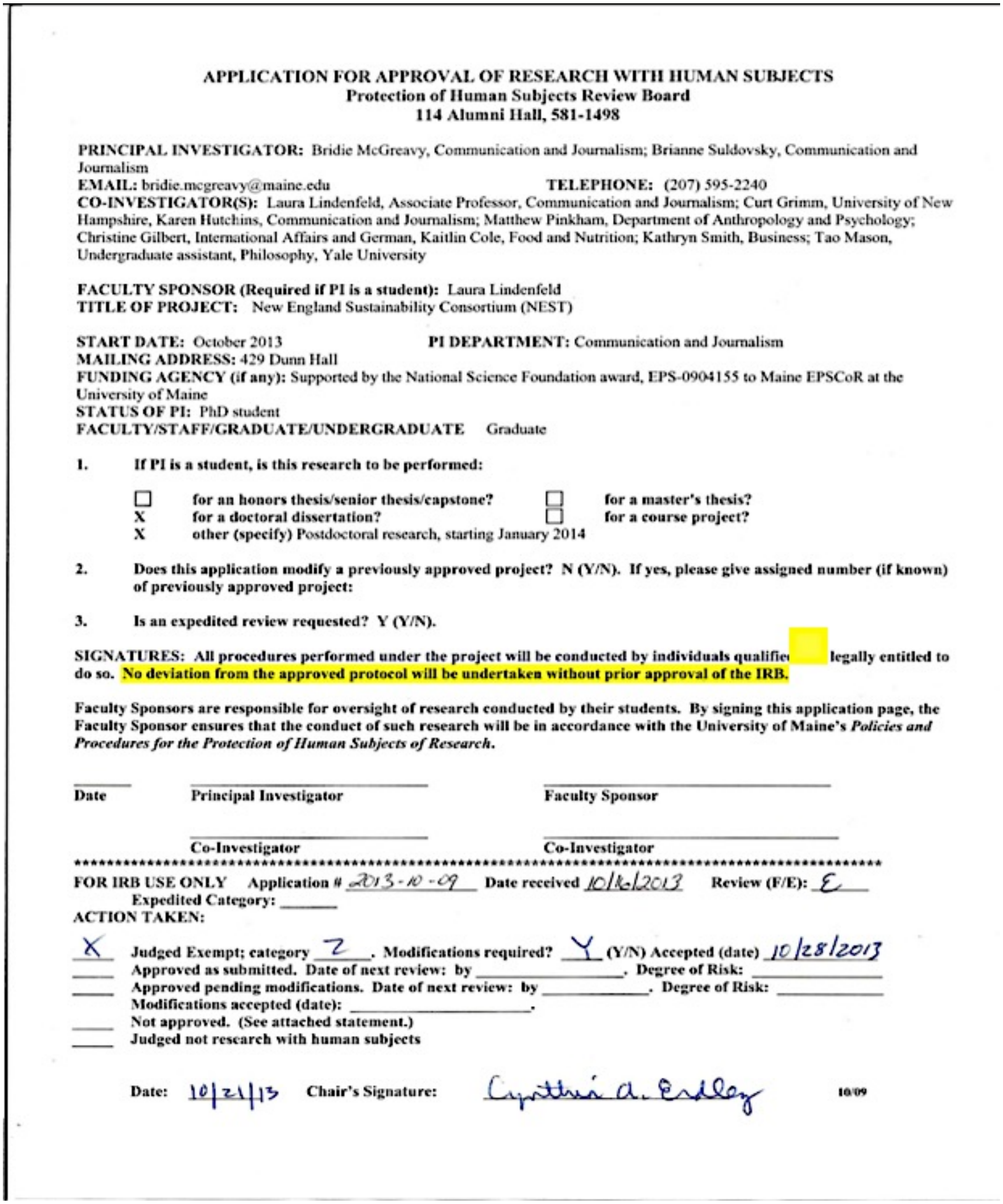


Figure 18. Model/Drifter Comparison. The black line showing a drifter track, and a red line showing the particle trajectory within the model. This figure shows the differences between model and drifter track over bathymetry map.

APPENDIX E: IRB Approval Cover Letter and Interview Questions



APPLICATION FOR APPROVAL OF RESEARCH WITH HUMAN SUBJECTS
Protection of Human Subjects Review Board
114 Alumni Hall, 581-1498

PRINCIPAL INVESTIGATOR: Bridie McGreavy, Communication and Journalism; Brianne Suldovsky, Communication and Journalism
EMAIL: bridie.mcgreavy@maine.edu **TELEPHONE:** (207) 595-2240
CO-INVESTIGATOR(S): Laura Lindenfeld, Associate Professor, Communication and Journalism; Curt Grimm, University of New Hampshire, Karen Hutchins, Communication and Journalism; Matthew Pinkham, Department of Anthropology and Psychology; Christine Gilbert, International Affairs and German, Kaitlin Cole, Food and Nutrition; Kathryn Smith, Business; Tao Mason, Undergraduate assistant, Philosophy, Yale University

FACULTY SPONSOR (Required if PI is a student): Laura Lindenfeld
TITLE OF PROJECT: New England Sustainability Consortium (NEST)

START DATE: October 2013 **PI DEPARTMENT:** Communication and Journalism
MAILING ADDRESS: 429 Dunn Hall
FUNDING AGENCY (if any): Supported by the National Science Foundation award, EPS-0904155 to Maine EPSCoR at the University of Maine
STATUS OF PI: PhD student
FACULTY/STAFF/GRADUATE/UNDERGRADUATE Graduate

1. If PI is a student, is this research to be performed:

☐ **for an honors thesis/senior thesis/capstone?** ☐ **for a master's thesis?**
X **for a doctoral dissertation?** ☐ **for a course project?**
X **other (specify)** Postdoctoral research, starting January 2014

2. Does this application modify a previously approved project? N **(Y/N). If yes, please give assigned number (if known) of previously approved project:**

3. Is an expedited review requested? Y **(Y/N).**

SIGNATURES: All procedures performed under the project will be conducted by individuals qualifie[illegible] legally entitled to do so. No deviation from the approved protocol will be undertaken without prior approval of the IRB.

Faculty Sponsors are responsible for oversight of research conducted by their students. By signing this application page, the Faculty Sponsor ensures that the conduct of such research will be in accordance with the University of Maine's *Policies and Procedures for the Protection of Human Subjects of Research*.

Date **Principal Investigator** **Faculty Sponsor**

Co-Investigator **Co-Investigator**

****

FOR IRB USE ONLY Application # 2013-10-09 **Date received** 10/16/2013 **Review (F/E):** E
Expedited Category: ______
ACTION TAKEN:

X **Judged Exempt; category** 2. **Modifications required?** Y **(Y/N) Accepted (date)** 10/28/2013
____ **Approved as submitted. Date of next review: by** ________. **Degree of Risk:** ________
____ **Approved pending modifications. Date of next review: by** ________. **Degree of Risk:** ________
Modifications accepted (date): ________.
____ **Not approved. (See attached statement.)**
____ **Judged not research with human subjects**

Date: 10/21/13 **Chair's Signature:** Cynthia A. Erdley **10/09**

Figure 19. IRB Approval letter.

Interview Questions – Round 1 – Chapter 2

- How long have you been clamming?
- How did you get into it?
- Do you clam in the Medomak? Only in the Medomak? If not, where do you go?
- How would you describe clamming in the Medomak?

  Probe: How easy or difficult is it? Can you make a living clamming here, why or why not?

- What do you see as the major challenges facing clamming in the Medomak today?
- What is your sense of water quality issues here?
- What do you see as the major challenges facing clamming in the Medomak?
- Have you noticed anything significant during closures? --- Meaning: strange currents, or plants or animals?
- Are you familiar with the Medomak Project? What is your sense of this project? What do you see as the goals?

  Probe: Is it working? Why or why not?

- What is your sense of the science that is being used in the Medomak Project? What if anything are scientists doing in the river?
- Are you familiar with DMR's water quality monitoring program?

  Probe: Do you see the water quality data being used to inform municipal or state policy?

- Will you draw on the map where your clam flats are currently?
- Will you draw on the map where you think the major source of bacteria pollution is / how many times (approx.) did your flat close last year?

- Is there a difference in point sources based on where their clam flat is / how many times it has closed?
- Will you write down your contact information on the back of the map if you would be available for more questions?
- Is there anyone else you would recommend I talk to about this?

Interview Questions – Example for Second Round in Chapter 3

Thank you for taking the time to meet with me today. I appreciate your willingness to contribute your thoughts to this research. This interview is part of a larger project being conducted to better understand collaborative projects within the soft-shell clamming community. It will be used in my larger thesis work, which I can explain in more detail if interested.

<u>Background Questions</u>

- Are you a clam digger, and if so, how long have you been a clam digger? How did you become a clam digger?
- Do you clam year round? If not, what do you do when you are not clamming?
- Is clamming your only source of income? If not, what other sources of income do you have?
- What is most important to you about clam digging?
- Do you like digging clams? If so, why? If not, why not?
- I am interested to learn more about clam harvesting as a livelihood and culture.
- Where do you generally dig? Why do you dig there? What is the mud like? What are the tides like there? Have you had any experiences there that stand out, and if so, what happened?
- Do you use a clam hoe when you dig? What other things do you bring out with you? What do other harvesters use?
- How do you find clams?
- How do you know what you know about clams?
- How does it feel to dig clams?
- What do you think about when you dig?

- Are there different types of mud? If so, what are the types and how are they different? What types of mud do you like best for digging and why?
- How do the tides affect you? Are the tides different in different places, and if so, how are they different?
- If you had to stop clamming, would you miss it? If not, why not? If so, why?
- Of all the time you have spent on the mudflats, what was your most memorable experience? Tell me about that experience, reconstruct it for me. Why was it so memorable? Any other experiences that stand out for you?

Now I am going to ask a few questions about your thoughts about changes.

- Have you noticed changes in the mudflats? If so, what changes have you noticed?

  Probe: Have there been changes in where clams grow? In the numbers of clams? Quality of the mud? In the ocean or the water? Different species coming in?

- How do you feel about these changes? How do you make sense of them? Are you concerned about these changes, and if so, what are your concerns?
- What do you think has caused these changes?
- Are there places where you used to clam but don't now? If so, why has this changed?
- What do you see as the future of clam harvesting? Probe: When you think about clam harvesting 20, 50, 100 years down the road, what do you see?

I am going to ask about your experience now with specific types of issues related to shellfishing.

- Do you face any specific issues or threats that affect your own ability to continue clam digging? If so, what are these issues? Do you have any health issues related to clam digging? If so, what are these and how do they affect you? Do you have access to health care for these issues?

- What do you see as the most major threat you face in your work as a clam harvester? What do you see as the most major threat to shellfishing as an industry?
- What other issues are you concerned about? Why are you concerned about these issues and what do you think could be done about them?
- Where do you get your information about these issues?

Now I am going to ask about a few specific issues that you didn't mention:

- What are your thoughts about water quality? Is it a problem here? If so, what do you think can be done about it?
- What do you think about the water quality closures—like the long-term State closures and the shorter term rainfall closures. Do these affect you at all? If so, how? Where do you get your information about closures?
- What about ocean acidification? Have you heard about this? Do you think it is happening? Why? Is it a problem? If so, what do you think can be done about it?
- Have you heard of climate change? Do you think that is happening? Why or why not?
- This is a different type of issue, but do you know harvesters who struggle with drug addiction and/or alcoholism? How does this affect them? How widespread do you think this problem is?

Now I'll ask a few questions about your experience with shellfish management in this town or region.

- Do you participate in the municipal shellfish management, in the committee work, in your town?
- How do you participate? (If he/she participates) Why did you become involved in the shellfish committee and ordinance work? What motivates you to be involved?
- Do you attend shellfish committee meetings? In what towns?

- What are your impressions of committee meetings? Do you think these meetings are effective? Why or why not? Could these meetings be improved, and if so, how?
- What do you notice about how the different towns manage their shellfish resource in the Bay? Probe: What do you think works? What doesn't work?
- Do you like attending the shellfish committee meetings? If so, what do you like about them? If not, what don't you like about them? If you don't like these meetings, why do you go?
- How would you describe the relationship between the DMR and the towns' shellfish committees? What role does the DMR play? How does that work?
- Does DMR provide science to the committee? If so, do you trust the DMR's science?
- What about the relationship between the harvesters and the warden (if there is one)?
- On a scale of 1 to 10, where 1 is the best it could be and 10 is the worst it could be, well do you think the municipal shellfish management is working? Explain.

Uses of science in management

- Do scientists ever give presentations or provide information to the committee? If so, which scientists share this information?
- Do you trust the information (or science) that is available? Prompt: For example, water quality monitoring? Why do you trust it? What is it about the information that makes you trust it or not?
- Does the committee ever use science or talk about science in their management? For example, do they use science to make decisions about conservation closures? If so, how do they use science?

So I wanted to ask about collaborative efforts clammers are involved in. I have been involved with the Medomak Taskforce, for a little over a year now.

- Why did you initially get involved? Was it a specific person? Reason?
- If there were other projects, “taskforces” similar to the Medomak Taskforce, would you collaborate with them as well?
- What are the deciding factors for you to collaborate? Probe: Is it simply accessibility to results? Purpose of the project?
- Are there groups more/less likely to collaborate with? Why or why not?

Wrap up:

- Can you recommend anyone else we should talk with about the things we talked about? What is the best way for us to contact them?
- Are there any other questions we should be asking?
- Is there anything you would like to offer this conversation that we didn’t think to ask about?

APPENDIX F: Newspaper Articles Pertaining to Research

Online Articles:

https://knox.villagesoup.com/p/drifters-to-aid-study-of-river-currents/1682720

http://knox.villagesoup.com/p/medomak-river-cleanest-it-has-been-in-25-years/1654592

http://www.waldoboromaine.org/index.php/departments/shellfish/535-

driftershttp://www.waldoboromaine.org/index.php/departments/shellfish/535-drifters

Hardcopy Articles:

Page Four THE LINCOLN COUNTY NEWS, DAMARISCOTTA, MAINE August 31, 2017

Medomak Project studies river with 'drifters'

"Drifters" float on the Medomak River in Waldoboro. Waldoboro Shellfish Committee Co-chair Glen Melvin hopes data from the drifters will lead to the state opening more of the river to shellfish harvesting. (Photo courtesy Glen Melvin)

By Alexander Violo

The Medomak Project is making use of floating data-collection devices called "drifters" to gather data on the Medomak River this summer.

Gabrielle Hillyer, a graduate student of oceanography at the University of Maine, and Glen Melvin, co-chair of the Waldoboro Shellfish Committee, have been deploying the devices to map tidal currents in the river.

Melvin described a drifter as a lobster buoy attached to a pail with Ty-Wrap and rocks, allowing the device to move with the current while mitigating the wind's impact on its course.

According to Hillyer, the drifters measure tidal current (how fast the water moves with the tide), temperature, salinity, light intensity (the clarity of the water), and colored dissolved organic matter (living things in the water).

"The main goal is to quantify how long any water in the Medomak stays there," Hillyer said.

Hillyer said the drifters are deployed to several spots on the river, with the majority of the research devices in the portion of the river where the mud flats have a "conditional" status.

The state classifies the Medomak as a conditional river, which means the river's mud flats are subject to closure after an inch of rain falls in a 24-hour span.

Hillyer said the drifters were first put into the river in July and plans are to continue research until the river freezes over.

She said the drifters may be redeployed next summer, but she wasn't yet sure if that would be the case.

Melvin said the sensors and technology on board the drifters collect data on the river while the current moves the devices.

Melvin encouraged those who come across the drifters in the river to leave them alone and allow them to travel with the current. He has posted signs at the town landing relaying this information.

Melvin said the drifters help to map tidal currents and measure the impact of rainfall on the river.

"They tell us how the river reacts when it rains," Melvin said.

Melvin said the drifters are deployed in a variety of different conditions, tides, and at different times of day to accurately map the currents in an effort to determine how bacteria travels in the river.

Melvin said the drifters are the next step of the Medomak Project, a joint effort between the town, local nonprofits, the Maine Department of Environmental Protection, and the Maine Department of Marine Resources to ensure the health of the river.

Melvin said he hopes information gained from the drifters will open more of the Medomak's mud flats to shellfish harvesting.

"It's an effort to open up more of the river or up the conditional trigger," Melvin said.

Melvin said if the river's threshold for closure went from 1 to 1.25 inches of rain within a 24-hour span, the economic impact could be substantial.

"Drifters" were first deployed in the Medomak River in July and will continue collecting data until the waterway freezes over. (Photo courtesy Glen Melvin)

MVLT's Summer Sizzle a success

State ends conditional closure of 300 acres of Medomak flats

By Alexander Violo

The Maine Department of Marine Resources has ended a conditional closure of about 300 acres of Medomak River clam flats, according to Waldoboro Shellfish Committee Co-chair Glen Melvin.

During a conditional closure, flats are closed to shellfish harvesting after an inch of rain in a 24-hour time span.

Melvin praised the work of the Medomak Project and the town's residents to keep the river clean and open the area to local commercial harvesters.

He said the DMR's decision means more of the Medomak River is open now than at any time since the early 1990s. "This is the least amount of closed area we have had," he said.

Melvin said the improved water quality in the river benefits not only shellfish harvesters, but also elver harvesters and recreational users of the river, including swimmers and other visitors to the waterfront.

He said that prior to the DMR's announcement regarding the end of the conditional closure, roughly 658 acres of the river were under conditional status.

He said the DMR is proceeding cautiously to ensure the newly open flats remain out of conditional closure before opening other portions of the waterway.

DMR regulations include standards for assessing water quality and shellfish meat to determine whether shellfish are or may become contaminated or polluted, requiring flat closures to protect public health and safety.

The DMR commissioner can repeal closures when sanitary surveys reveal that the pollution or contamination conditions in a flat no longer exist and that shellfish may be harvested from that area without a threat to public health.

Grants

Melvin said the Medomak River stands to benefit after the announcement of two grant awards.

The Medomak Project has received a $5,000 grant from the National Oceanic and Atmospheric Administration's Sea Grant program to fund DNA testing for the river in 2017, covering the costs of sampling in addition to transporting the samples to a University of New Hampshire laboratory in Durham, N.H.

According to Melvin, a separate grant, covering research and reinvestment, was awarded to a graduate student at the University of Maine Orono to study the Medomak River.

Gabrielle Hillyer, a candidate for a Master of Science degree in oceanography, is writing her thesis on the Medomak estuary.

"I'm developing a tidal model looking into how the tide enters and leaves the estuary in hopes of finding a resolution to pollution," Hillyer said.

Hillyer said her work will focus on the river's upper estuary, where she will study surface currents using floating data-collecting devices called drifters.

"The measurements taken by the drifters will help to give an idea of how water enters into the estuary and how it flows out," Hillyer said.

Hillyer said she will work with the drifters for the next four months and in total will work in the Medomak River estuary for the next 2.5 years.

Originally from Las Vegas, Hillyer completed her undergraduate studies at Boston University, where she worked with shellfish harvesters on Cape Cod and in Rhode Island.

APPENDIX G: LETTER FROM WALDOBORO TOWN MANAGER

Office of the Town Manager
Town of Waldoboro, Maine
http://www.waldoboromaine.org
Julie Keizer, Town Manager

P.O. Box J
Waldoboro, ME 04572-0911
Phone: (207) 832-5369
Fax: (207) 832-6061

September 4, 2019

Bridie McGreavy, Ph.D.
Assistant Professor of Environmental Communication
Department of Communication and Journalism
438 Dunn Hall
University of Maine
Orono, ME 04469

Re: Gabrielle Hillyer

Dear Dr. McGreavy:

Gabrielle Hillyer has been working with the Town of Waldoboro's Shellfish Committee since the summer of 2017 and we are genuinely grateful for all of her dedication and hard work to improve the health of the Medomak River. The data that the drifters aka "her children" provided has proven to be a valuable resource. Just yesterday the Shellfish Committee and 6 of our local harvesters together with Gabby were moving seed to an area that was chosen based on her research. The utilization of science in conjunction with the first-hand knowledge of our harvesters will be invaluable to sustain our clamming industry. Clamming is the number one employer in the Town of Waldoboro and is essential to our economic prosperity and growth.

Gabby's interest in the Medomak branched out as she became more involved with our harvesters and our community. She was instrumental in establishing the Town's own water testing program, even helping conduct sampling and teaching me how to process the actual testing. (I should have paid more attention in my science classes).

In my career I have been blessed to work with many graduate students, Gabby is highly intelligent, and I have been impressed with her analytical abilities and her attention to detail but what has distinguished her from all the others is her ability to communicate, that in my opinion makes her unique. Gabby took an interest in a fishery that is known for it's cast of unique characters, hard working men and women who are a self-reliant with diverse backgrounds and beliefs. Gabby came to our community and met with the harvesters, not to tell them what they need to do, but to ask them what they have experienced, she wanted them to share their knowledge with her and she wanted to help. Her approach and her ability to communicate with such a diverse group on any level is her greatest gift. The science is impressive, and her knowledge is expansive but the ability to present her findings and have them be accepted and validated by our clamming community speaks to her character and her commitment to our river and those who make their living on it. Gabby understands and appreciates the fishery, she has in just under three years become an integral and accepted piece of the fabric of the Waldoboro clamming community.

Sincerely,

Julie L. Keizer

Julie L. Keizer
Town Manager

BIOGRAPHY OF THE AUTHOR

Gabrielle Hillyer was born in Las Vegas, NV in 1994. She was raised in Las Vegas and graduated from Bishop Gorman High School in 2012. She attended Boston University and graduated in Fall 2015 with a Bachelor's degree in Marine Science, minoring in Earth Science and Biology. She won the Lara Vincent Prize for Outstanding Undergraduate Research from Boston University. She moved to Maine and attended the University of Maine Marine Science Program in the fall of 2016. After receiving her degree, Gabrielle will be attending University of Maine Ecology and Environmental Sciences doctoral program, as a part of the National Research Traineeship under Dr. Bridie McGreavy. Gabrielle is a candidate for the Dual Master of Science degree in Oceanography and Marine Policy in December 2019.