Integrating Local Ecology and Human Dimensions To Understand a Tidally Dynamic Ecosystem in Downeast Maine

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INTEGRATING LOCAL ECOLOGY AND HUMAN DIMENSIONS TO UNDERSTAND
A TIDALLY DYNAMIC ECOSYSTEM IN DOWNEAST MAINE

By

Gabriella Marafino

B.S. George Mason University, 2015

A THESIS
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science
(in Ecology and Environmental Sciences)

The Graduate School
The University of Maine
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Coastal community resilience requires connecting people with useful information that reflects their needs and interests and empowers them to make informed marine resource decisions. In this thesis, I explore how to effectively integrate disparate data from different disciplines and sources to make information more useful and usable at federal, state, tribal, and local levels in order to support more holistic and integrated management. To accomplish this, I draw on different types of knowledge and approaches, including Western science, local ecological knowledge, traditional ecological knowledge, and citizen science, to incorporate the social perspective and community values for holistic marine resource management. The central focus among all three thesis chapters is understanding knowledge gaps related to information use, accessibility, and sharing by taking an engaged research approach to co-produce potential solutions.

Chapter 1 focuses on understanding information usability and accessibility from the perspectives of federal and state regulators, industry developers, and tribal representatives. I investigated these ideas in the context of proposed tidal power development in Downeast Maine, and applied concepts of knowledge co-production to engage these groups of decision-makers. I
organized a series of workshops to explore strategies to improve information production and sharing. Through this process, I identified essential steps for researchers who want to make their science more useful to decision-makers, which include incorporating diverse stakeholder perspectives and co-producing holistic data integration strategies based on stakeholder needs and interests.

Chapter 2 focuses on engaging indigenous communities in meaningful partnerships to address questions about information use and accessibility at a local level. I partnered with the Passamaquoddy Tribe Sipayik Environmental Department to co-organize collaborative community meetings to discuss traditional ecological knowledge, stories, memories, and values associated with the local ecosystem. I built on well-established best practices in working as non-indigenous researchers with indigenous researchers and communities, but I also acknowledge our lessons learned during this process. I propose a set of key components from our lessons learned to share capacity with indigenous researchers and communities through GIS training, engaging local youth and elders, and addressing intellectual property concerns with dignity and respect. These key components can be applied to partnerships in other contexts to encourage more meaningful collaborations that prioritize community needs and interests, while also empowering the next generation of community decision-makers.

In Chapter 3, I focus on filling a knowledge gap identified by regulators: fish species in the Western Passage, a proposed tidal power project site in Downeast Maine. Traditional fisheries survey methods do not work well in this area and regulators were interested to know whether there were alternative ways to fish in the Passage. Coastal communities have extensive local and traditional ecological knowledge associated with how and where to fish. We built on this knowledge by using recreational fishing methods (hook-and-line gear). We also trialed two
pilot citizen science projects to engage local fishers in data collection. These collaborative approaches to data collection allowed us to collect important information on fish species presence. This chapter concludes with proposed strategies to improve this protocol for future work.
DEDICATION

I would like to dedicate this thesis to the Sipayik and Eastport community members who shared their knowledge, stories, and memories with me.
ACKNOWLEDGEMENTS

I would like to start by thanking the generous funding sources that allowed me to pursue both my thesis research and academic studies at the University of Maine (UMaine): the UMaine School of Marine Sciences, the UMaine George J. Mitchell Center for Sustainability Solutions, and The Nature Conservancy.

There are many people who have provided immense support and guidance to me during my time at UMaine. I would like to thank my advisor, Dr. Gayle Zydlewski, for mentorship and always taking the time to talk when I needed to chat. I would also like to thank my committee members, Dr. Jessica Jansujwicz and Dr. Tora Johnson, for helping shape my path as an interdisciplinary researcher (and greatly improving my map-making knowledge!). All three of you have taught me the value of patience and teamwork both in academic contexts and beyond. I would also like to thank all of the members of the Western Passage Student Research Collaborative (WPSRC), particularly Emma Dullaert, Jillian Dow, Louise McGarry, and Dr. Kristina Cammen, as well as members of the Zydlewski lab for continued guidance and support throughout my research. I would like to thank Maine Sea Grant Extension Associate Chris Bartlett; without you, a lot of my thesis research would not have been possible. I would also like to thank Chris Johnson at the Sipayik Environmental Department for sharing knowledge and expertise, as well as your commitment to partnerships and collaboration in support of environmental stewardship. All of these people (and many others!) have made my time at UMaine a truly rewarding experience.
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CHAPTER 1
APPLYING KNOWLEDGE CO-PRODUCTION TO IMPROVE INFORMATION USABILITY, ACCESSIBILITY, AND UPTAKE:
A CASE STUDY IN DOWNEAST MAINE

1.1 Abstract

Scientific information (data) are often not presented in a form that fits the specific needs and capacities of natural resource decision-makers, from federal and state agencies to municipal, tribal and other local entities. This mismatch and communication gap results in the “loading dock” problem, where information remains unused or the uptake is slow. In addition, it is challenging to integrate data collected from different disciplinary perspectives, using different approaches, and management techniques, and the lack of interdisciplinary data further widens the research-implementation gap. In response to this general lack of usable information, we collaborated with regulatory, industry, and tribal stakeholders to co-produce knowledge in support of decision-making for sustainable tidal power development in Downeast Maine. Federal and state regulators, a tidal power industry developer, and a tribal environmental department were engaged in a series of four facilitated workshops to discuss existing information, identify knowledge gaps, and co-produce data integration strategies. Using facilitation techniques to foster small group dialogue and hands-on interaction with different data types (raw, synthesized, and web-based repositories), we identified patterns in how these stakeholders accessed, used, and perceived data. Participants shared that interdisciplinary data (e.g. natural and social science data) and non-science data (e.g. local ecological knowledge) were particularly useful for informing decisions at the beginning of a project to identify data gaps and guide future scientific data collection. Workshop outcomes suggest pathways for better decision-support, including
integration of available spatial ecosystem data into an interactive map to serve as a knowledge base and creation of a central data repository for existing non-spatial information, and resulted in the development of these products. We propose a two-part step as part of a modified information production and sharing process to help connect the research-implementation gap and make information more useful and usable by decision-makers. While this study was motivated by the need to make timely, well-informed decisions related to tidal power development in Maine, our co-production process is applicable and transferable to other coastal development contexts.

1.2 Introduction

Science and society are often not closely linked (Phillipson et al. 2012; Chevalier and Buckles 2013; Djenontin and Meadow 2018), resulting in a research-implementation gap between research scientists and decision-makers (Phillipson et al. 2012). The research-implementation gap describes a disconnect in the traditional scientific research process, which typically involves research scientists continuously generating new information, yet often without input from people who use this information to make management and policy decisions (McNie 2007; Grygoruk & Rannow 2017; Djenontin and Meadow 2018; Fisher et al. 2020). Furthermore, this information is frequently either not shared outside of academic research settings (Grygoruk & Rannow 2017) or not shared in a way that is useful and accessible (Cash et al. 2006; McNie 2007). This lack of communication between researchers and decision-makers results in the production of information that is not useful or usable to decision-makers, termed the “loading dock” problem (Cash et al. 2006). This can also manifest in slowed uptake of information when decision-makers find it difficult to locate information that is relevant, accessible, and in a format they can readily use (McNie 2007; Silka 2013; Fisher et al. 2020).
Clark et al. (2016) and Dilling and Lemos (2011) describe this general lack of usable information as a barrier to informed natural resource decision-making.

The research-implementation gap is further exacerbated by a lack of sufficient interdisciplinary data integration, which is also essential to inform holistic and sustainable natural resource decision-making (Hiscock et al. 2003). Interdisciplinary approaches are increasingly required for effective environmental decision-making (Charles 2012; Lanier et al. 2018; McKinley et al. 2020), yet decision-makers often rely on a single type of knowledge: empirical data generated by Western science. Social and cultural information is often not included (St. Martin & Hall-Arbor 2008; McKinley et al. 2020) due to the challenges of integrating research data from different disciplines (St. Martin & Hall-Arbor 2008; Moore et al. 2017). Integrating different types of knowledge is challenging because information is often collected from different sources and at multiple scales (Cash et al., 2006), and language barriers and technical, disciplinary jargon between research disciplines can make collaborative and interdisciplinary work difficult (Cash et al. 2006; Silka 2013; Jansujwicz and Johnson 2015b; Alexander et al. 2019).

Participatory approaches to knowledge production and use offer new pathways for data collection and information exchange that better meet the needs and capacities of natural resource decision-makers. Knowledge co-production is a participatory action research (PAR) method used to connect the research-implementation gap by involving decision-makers in the research process to tackle questions, improve practice, and enhance information usability at the intersection of science and society (Merriam 2009; Chevalier and Buckles 2013; Djenontin and Meadow 2018). Knowledge co-production recognizes science as a “social practice” that requires an examination of stakeholder interests and a user-based approach (Alexander et al. 2019). This research method
requires collaboration between researchers, decision-makers, and other stakeholders to create outcomes together (Cash et al. 2006; Chevalier and Buckles 2013; Wall et al. 2017; Djenontin and Meadow 2018) that include the values, interests, and voices of all participating groups (Cash et al. 2006; Senecah 2011). This approach also provides space for participants to design research questions and objectives to help combat science occurring in “silos” or in isolation from other disciplines (Silka 2013). Essential to PAR is the need to remain flexible and responsive as the process changes or participants’ interests emerge and evolve (Merriam 2009), which paves the way for research that is reflexive to stakeholder needs to produce better outcomes by supporting iterative knowledge co-production learning loops (Cash et al. 2003; Cash et al. 2006; Johnson 2015). Encouraging input and participation from diverse stakeholders allows the group to develop a shared understanding, creating usable and useful information that is salient, credible, and legitimate (Cash et al. 2003; Cash et al. 2006; Cvitanovic et al. 2015; Roeckmann et al. 2015; Wall et al. 2017). The focus of participatory approaches is as much about the process of creating useful information as it is about the product created to sharing information (McNie 2007).

We applied participatory methods to co-produce knowledge associated with a proposed marine renewable energy project (MRE) in Downeast Maine. This is an exemplary case for this work because decisions related to this development have to be made in the midst of high uncertainty (due to missing information on cumulative impacts) and increasing complexity (due to multiple marine uses that span commercial, recreational, and cultural significance) (Lester et al., 2010; Fox et al. 2017; Cammen et al. in review). While we focus on a specific case study, our research process and findings are applicable and transferable to decisions in other complex,
multi-use coastal ecosystems where managers are faced with making informed decisions in high uncertainty and complexity.

Marine resources are culturally and economically important to Maine’s coastal communities (Johnson and Zydlewski 2012; Coombs 2020), and there are often many stakeholder groups associated with MRE projects due to development sites located in close proximity to coastal communities (Johnson et al. 2015). Previous studies in Downeast Maine identified important stakeholder groups associated with tidal power projects (Johnson et al. 2015; Jansujwicz and Johnson 2015a) and examined the transdisciplinary information production and sharing process to create actionable knowledge (Jansujwicz and Johnson 2015b). Downeast Maine has historically been an area of interest for a variety of coastal development projects, including proposed liquified natural gas, aquaculture, and, more recently, MRE. MRE offers an alternative to traditional fossil fuels in a changing environment (Staines et al. 2019). Sources of ocean energy are being explored for development globally, including offshore wind, wave, and tidal energy (Copping et al. 2015; Zydlewski et al. 2015), and the Gulf of Maine has been identified as one of the prime locations in the United States to develop tidal power (Kilcher et al. 2016).

Tidal power development was first attempted in Maine in the 1930s with the proposed Passamaquoddy Tidal Power Project that was ultimately never completed (Smith 1948; Trites 1961; Lowrie 1968). More recently, tidal power has been revisited through proposed development in Western Passage (Figure 1) by the Maine-based Ocean Renewable Power Company (ORPC). This project builds upon their prior short-term pilot project in nearby Cobscook Bay. Western Passage (Figure 1) is an international, tidally dynamic area in the Quoddy region that borders the state of Maine and southwestern New Brunswick, Canada. As
part of the larger Bay of Fundy, this region is characterized by extreme tidal ranges and an ecosystem with diverse social and ecological components. Many migratory and non-migratory species utilize this productive region, including fish (e.g. Atlantic mackerel, *Scomber scombrus*; Atlantic herring, *Clupea harengus*; Atlantic salmon, *Salmo salar*), marine mammals (e.g. harbor porpoise, *Phocoena phocoena*; minke whales, *Balaenoptera acutorostrata*; gray and harbor seals, *Halichoerus grypus* and *Phoca vitulina*) and birds (e.g. red-necked phalaropes, *Phalaropus lobatus*; Bonaparte’s gulls, *Larus philadelphia*; common and Arctic terns, *Sterna hirundo* and *Sterna paradiseaea*) (Mercier and Gaskin 1985; Lotzke and Milewski 2002).

Neighboring the Western Passage are multiple coastal communities, including the City of Eastport and the Passamaquoddy Tribal community at Pleasant Point (hereafter referred to as Sipayik, the term used by the community) (Figure 1). Before European colonization, traditional Passamaquoddy land spanned the region between the Penobscot River watershed in Maine to the St. John River watershed in New Brunswick (Bassett 2015). Sipayik is on the site of a traditional seasonal fishing village with access to both Cobscook and Passamaquoddy Bays (Bassett 2015). A variety of marine mammals and fish in this region, including river herring (*Alosa pseudoharengus*; *Alosa aestivalis*), Atlantic salmon, American shad (*Alosa sapidissima*), and harbor porpoise, are important cultural and subsistence resources for the Passamaquoddy peoples (Bassett 2015). The City of Eastport is located on Moose Island and is connected to the mainland via a remnant tidal dam, which is now a causeway that runs through the reservation and physically connects the two communities (Hall-Arbor et al. 2001; Bassett 2015). Historically, Eastport’s economy was driven by shipping, boat-building, lumber, and fishing activities, including numerous herring weirs that supplied fish for sardine canneries, the last of which
closed in 1983 (Hall-Arbor et al. 2001). Today, salmon aquaculture and harvesting scallops, sea urchins, and lobster sustain the seafood industry in this region (Hall-Arbor et al. 2001).

Here, we outline our PAR application to co-produce potential solutions to improve information production and use associated with proposed tidal power development in Downeast Maine. We present a modified information production and sharing process that includes a knowledge co-production step for research scientists who want to make the data they produce more useful and usable by decision-makers. We end with an examination of stakeholder perspectives related to information utility and accessibility, as well as review the beneficial outcomes and challenges related to co-producing knowledge.

1.3 Methods

1.3.1. Participant Recruitment

Participants selected for this study include stakeholders in Downeast Maine with different roles and capacities in the context of proposed tidal power development. We defined key stakeholders as the individuals and groups that either affect or are affected by tidal power development. The involvement of these groups is important because they could be affected by or have the power to influence decision-making processes (Reed et al. 2009; Johnson et al. 2013). Four key stakeholder groups (federal government, state government, tribal, and industry) were purposefully selected for inclusion in this study. Representatives from these four sectors agreed to participate in this research over the course of one year: a federal regulator (National Oceanic and Atmospheric Administration, NOAA), a state regulator (Maine Department of Environmental Protection, DEP), a tribal representative (Passamaquoddy Tribe- Sipayik Environmental Department), and an industry representative (Ocean Renewable Power Company,
ORPC). There were multiple representatives from NOAA and ORPC who participated in this study, and one representative each from Maine DEP and the Sipayik Environmental Department.

These key stakeholder groups were connected through the Federal Energy Regulatory Commission (FERC) licensing process. FERC is the lead permitting authority for tidal power projects, but federal and state agencies have the opportunity to comment on proposed projects pursuant to an array of statutes, including the Endangered Species Act, Clean Water Act, Marine Mammal Protection Act, Magnuson Stevens Fisheries Conservation and Management Act, and others (Jansujwicz and Johnson 2015). Within this regulatory context, NOAA and DEP provide input to FERC related to ORPC’s licensing and permitting applications. The Passamaquoddy Tribe is a sovereign entity that can intervene in the FERC decision-making process and would also be affected by the resulting decisions. Under the FERC pilot project license, ORPC was required to develop an adaptive management plan (FERC 2012), in which regulators address project uncertainty and knowledge gaps by working directly with stakeholders in a continual, iterative learning process (Jansujwicz and Johnson 2013; Jenkins et al. 2018). Prior to this study, the federal, state, and industry participants were already interacting with each other and our research team through the formal FERC adaptive management process. However, the tribal participant was not involved in ORPC’s adaptive management process or engaged with our research team or with other study participants in work related to the proposed tidal power project.
Figure 1. Map of the Western Passage study site that includes the City of Eastport and the Passamaquoddy Tribal community of Pleasant Point (Sipayik), as well as the surrounding major water bodies (Western Passage, Cobscook Bay, and Passamaquoddy Bay).
1.3.2. Data Collection

To better understand stakeholder perceptions of information use and access, and to identify information needs, data gaps, and other challenges to information uptake by decision-makers, we designed and implemented a series of three workshops. These workshops provided space for the knowledge co-production process because it allowed for small group discussion on information utility, while allowing our research team to be flexible and responsive to emerging needs and concerns of participants. Three stakeholder workshops (Table 1; Figure 2) were held over the course of one year (September 2018-2019) at the University of Maine in Orono, which was a central location for all participating groups. Workshops were held both in-person and via videoconferencing in response to the scheduling needs of participants. While this research was motivated by decision-making needs in the context of the proposed tidal power project, workshops addressed general decision priorities and information needs of the key stakeholder groups participating. We used the letters of support written by workshop participants for the project funding proposal as an additional data source for examples of anticipated uses of co-produced project outcomes. We also used monthly email correspondence between workshops to track participation and engagement and to solicit additional stakeholder feedback.
### Table 1. Overview of the participation, structure, and data collected at the three workshops to understand stakeholder decision-making needs. The number of participants reflects a count of individuals who attended the workshops (this number does not include our research team). Each of the four stakeholder groups and our research team were represented at all three workshops.

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<th>Data Collected</th>
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<td>8</td>
<td>In-person &amp; Zoom</td>
<td>Audio recordings, handwritten notes</td>
</tr>
<tr>
<td>Workshop 2</td>
<td>March 2019</td>
<td>5</td>
<td>In-person</td>
<td>Audio recordings, handwritten flip-chart notes</td>
</tr>
<tr>
<td>Workshop 3</td>
<td>September 2019</td>
<td>7</td>
<td>Zoom</td>
<td>Audio recordings, handwritten notes</td>
</tr>
</tbody>
</table>
Figure 2. Overview of workshop objectives and process to understand stakeholder perspectives on information usability and identify decision-making needs. Federal and state regulators, industry representatives, and a tribal environmental department representative attended the workshops, which were held in-person and via Zoom videoconferencing at the University of Maine in Orono.

1.3.2.1. Workshop 1: Identifying Decision Priorities and Data Gaps

Workshop 1 was held in September 2018 at the University of Maine in Orono (UMaine). The objectives of this workshop were threefold: (1) to understand what decisions participants were making in their role at their respective organization, (2) to identify existing knowledge gaps, and (3) to document the types of information participants use most often in their decision-making. Five participants attended the workshop in person, and three attended remotely via video conferencing. The workshop consisted of large and small group discussion facilitated by our research team.
Prior to the workshop, we created an inventory list of existing Western Passage data sources (Table A.1). The data included in the inventory list was collected and produced by different entities and presented in different forms. For example, site assessment data has been collected by ORPC, our UMaine research team contributed data on fish interactions with tidal energy devices, and local community members and citizen scientists have contributed information on fish, birds, and marine mammals. These data are presented in different formats and stages of analysis, from raw data on hard-copy datasheets to technical reports and peer-reviewed academic articles. After a brief introductory presentation to provide more detailed information on the data included in the inventory list (e.g. source format, and content), each participant was provided with a printed copy. This was followed by a large group discussion facilitated by our research team to solicit stakeholder perceptions on missing data sources and knowledge gaps.

We documented stakeholder priority decisions and information needs using a paired information-decision activity. This activity consisted of small group dialogue focused on: 1) the types of decisions participants routinely make in their respective roles and 2) the types of information they seek to make these decisions. Using this activity, our research team facilitators first asked each participant to write a typical decision they make in their role at their respective organization on one side of an index card, and the information they use to make that decision on the other side. Participants were then split into three breakout groups to discuss the decision types and information sources they listed on their index card. A research team member facilitated the small groups and took detailed notes. After 30 minutes, each breakout group reported back during a large group discussion; each were prompted to specifically discuss the type of decisions they were making, the information source (e.g., peer-reviewed article or research report), and the
format of information used (e.g., raw versus synthesized). General large group discussions and breakout sessions were audio-recorded with participant permission. Anonymous feedback forms were also collected (Figure A.1). Information collected on data types from Workshop 1 informed the design and structure of Workshop 2.

1.3.2.2. Workshop 2: Investigating Information Needs and Data Integration Strategies

Workshop 2 was held in March 2019, and all participants attended in-person at UMaine. The objective of this workshop was to document stakeholder perspectives of the different data types identified in Workshop 1. We used a modified group facilitation technique, World Café, to foster dialogue around a hypothetical decision-scenario and develop a shared understanding of the usability of different data types. The World Café is grounded in the idea that small group conversations form the basis of our everyday lives, and collective wisdom is achieved through cross-pollination of ideas as people converse across small groups to share and link ideas (Brown 2005).

The World Café process for this workshop was renamed Data Café to reflect the discussion topic. To structure discussion, the following decision-scenario was selected: “There is a proposed coastal development project in the Eastport area, and you are tasked with making a decision on appropriate siting.” While this study was motivated by the need to make timely, well-informed decisions in the context of tidal power development, our decision-scenario was intentionally kept broad in order to investigate stakeholder perspectives on information utility and decision-making needs. The room was arranged with separate tables, each with a representative data type using examples from existing data sources (Table 2). For the purposes of our research, scientific information was defined as data produced by Western science researchers, particularly through academic and federal/state research institutions. Citizen science
was defined as scientific data collected by individuals in the community, and we define the term local knowledge to encompass cultural science and historical or current observations.

<table>
<thead>
<tr>
<th>Table</th>
<th>Data Type</th>
<th>Primary Example</th>
<th>Secondary Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raw Data</td>
<td>Nautical charts with handwritten local ecological knowledge (LEK) (Figure A.2)</td>
<td>Citizen science fishing datasheet (Figure A.3)</td>
</tr>
<tr>
<td>2</td>
<td>Synthesized Data</td>
<td>Peer-reviewed articles (e.g. Viehman et al. 2014; Johnson et al. 2013)</td>
<td>Pacific Northwest National Laboratory (PNNL) State of the Science research report on marine renewable energy (MRE)</td>
</tr>
</tbody>
</table>

**Table 2.** Examples of data types from the *Data Café* activity at Workshop 2. Raw data examples included nautical charts with handwritten local ecological knowledge from a 2017 community meeting in Eastport and citizen science fishing datasheets from 2018. Synthesized data examples included peer-reviewed articles by Viehman et al. (2014) and Johnson et al. (2013) and a State of the Science research report compiled by the Pacific Northwest National Laboratory (see Copping et al. 2016 in Bibliography). Examples of web-based data portals included the Northeast Ocean Data Portal website and the marine renewable energy-specific Tethys Knowledge Base website (see links in table).

Workshop participants were split into two groups that were purposefully selected to integrate different stakeholder groups, particularly those that do not often interact. The first group included a state regulator and an industry representative, and the second group included an industry representative, a federal regulator, and a tribal representative. Each group proceeded together to one of the three tables. Each table had a “table host” (member of our research team)
who took notes on flip-charts and provided discussion prompts (Figure A.4). Participants were
given a few minutes to review the data category examples displayed on the table in front of them.
These data categories included raw data (e.g. citizen science fishing datasheets), synthesized data
e.g. 2016 State of the Science report on MRE), and web-based data portals (e.g. Northeast
Ocean Data Portal) (Table 2). They were then asked to comment on whether they could use the
specific data examples at their table to address the hypothetical decision scenario. After twenty
minutes of discussion, groups stayed together but rotated to the next table. Table hosts remained
at their assigned data category table. After three rounds of small group conversation, the flip-
charts were hung up and participants circulated to review the notes from each table. A “harvest
session” (i.e. large group reflection) (Brown 2005) was then used to come together and review
themes that emerged. Data integration strategies were co-identified during the harvest session at
the end of this workshop. Large and small group discussions were audio-recorded with
participant permission, and detailed notes were recorded on flip charts during the small group

1.3.2.3. Workshop 3: Sharing the Data Integration Products and Responding to Feedback

Workshop 2 identified, from the perspective of participating stakeholders, data
integration strategies and data sharing platforms that would fit their needs and capacities (details
in Results). Workshop 3 was organized to share an overview and interactive demonstration of the
knowledge base platforms that were developed in response to stakeholder’s stated needs and to
solicit feedback to improve the usefulness and accessibility of the knowledge base platforms.

Workshop 3 was held in September 2019 via Zoom video conferencing to allow all four
participating groups to attend and solve scheduling challenges and travel issues associated with
an in-person meeting. In advance of the workshop, participants were sent links to the two
knowledge base platforms created in direct response to stakeholder feedback from the previous workshops: 1) an interactive knowledge base (public ArcGIS Online interactive map) and 2) a central data repository (Google Drive folder). Stakeholders were encouraged to view these materials ahead of the workshop. Datasets included in these platforms reflected the data reviewed by participants at the Data Café in Workshop 2, including Western science (published peer-reviewed articles and reports), local ecological knowledge (LEK) (from a 2017 community meeting in Eastport), and citizen science data sources (e.g. eBird data and local fishing data). This workshop was structured to demonstrate and discuss the two knowledge base platforms as strategies to share integrated datasets. A separate discussion was held after each knowledge base demonstration, and questions posed to participants by our research team included: Does the scale of this platform fit your decision-making needs? Is there anything that seems challenging or hard to manipulate? What can be improved to make navigation easier? Due to the virtual format of this workshop, particular attention was paid to ensuring there was time for each participant to comment or ask questions, and participants who were not providing any input were promoted by our research team. Data collected from this workshop consisted of audio-recordings, handwritten notes, and feedback forms that were distributed via email to participants after the workshop.

1.3.3. Data Analysis

Data collected from the workshops consisted of audio-recordings and handwritten notes that were transcribed verbatim. We coded the transcribed data using NVivo (Version 12 Plus) qualitative analysis software. Using a deductive approach, we coded these data using a set of pre-identified categories (Table 3) (Merriam 2009; Schreier 2012; Elo et al., 2014). We identified these categories based on workshop observations and from literature on information usability and accessibility (e.g., Cash et al., 2003; Cash et al. 2006; Dilling and Lemos 2011; Cvitanovic et al.
We also used the project letters of support from stakeholder groups and email correspondence between workshops as a source of data, but these were not coded.

<table>
<thead>
<tr>
<th>Coding Category</th>
<th>Description</th>
<th>Examples from Data</th>
</tr>
</thead>
</table>
| Decisions       | Identification of priority decisions that need to be made | “siting”  
|                 |             | “permitting and licensing” |
| Format          | Key words or phrases that describe the form or layout of a data source | “raw data”  
|                 |             | “synthesized data in reports” |
| Scale           | Key words or phrases that describe the geographic focus | “regional”  
|                 |             | “high-level” |
| Source          | Key words or phrases that describe where data originated or who it was collected by | “citizen science”  
|                 |             | “academic science” |
| Content         | Key words or phrases that describe what kind of information the data source contains | “socio-economics data”  
|                 |             | “protected species data” |
| Accessibility   | Key words or phrases that describe how easily data sources are able to be located and obtained. | “challenging to get access to peer-reviewed articles” |

**Table 3.** Coding schema detailing the five pre-identified categories to analyze workshop data.
1.4. Results

We categorized and grouped results based on the deductive coding schema and data analysis outlined in Table 3.

1.4.1. Priority Decisions

Participants worked through the paired information-decision activity to match concrete examples of decisions they make at their given agency or organization with the type of information they use most often to make those decisions. Sharing results from these activities helped participants and our research team to think about the decision-making needs of diverse stakeholders, using real-world examples from their jobs. We found that decisions fell into three categories (Table 4): (1) siting, permitting, and licensing, (2) impacts on protected species, and (3) local capacity and stakeholder outreach. The federal and state regulators and the industry representative stated that decisions related to siting, permitting, and licensing of proposed projects were primary decisions they often faced in their roles. The federal and state regulators and tribal representative noted that determining impacts on species was particularly important. However, the federal and state regulators emphasized decisions focused on protected or endangered species, such as Atlantic salmon and right whales, whereas the tribal representative focused more on species of cultural significance to the Passamaquoddy Tribe, such as sea-run fish (i.e., alewives) and harbor porpoise. The industry representatives were the only participants to mention making decisions related to how to best share relevant information with community stakeholders, including fishermen. One industry representative noted that they also need to make decisions related to local capacity, which they referred to as the workforce, equipment, and infrastructure available at the site to allow for this development. As an example of local capacity concerns, one of the industry representatives elaborated:
“And what’s the human capacity at the site, so what’s their energy demand? What infrastructure do they have in place? If we can permit it, can we actually get it there? Can we install it?”

The federal participant summed up the scale and complexity of the multitude of required decisions as a “giant question” that involves assessing “everything that affects everything.” The challenge of tackling high-level, big picture questions prompted a discussion on determining cumulative impacts. This topic was mentioned in particular by the federal and state regulators who ultimately need to determine the cumulative impacts of a proposed tidal power project, with particular attention to changes in scale when moving from pilot projects to commercialization.

One of the federal regulators noted that:

“The information we need is going to be based off deployment, but now we need to do a risk assessment of how comfortable are we with putting out a deployment, a multi-array deployment, without any information on their cumulative impacts. That’s the unknown right now, that’s the missing piece. I think [NOAA] and [Maine DEP] and others in the licensing process to permit a single unit, or maybe two units. I don’t know what the plan is offhand, but if they are proposing ten, twelve, or fifteen, whatever units, we don’t have that kind of information. That’s the decision point that we’re going to be getting to. What are the cumulative impacts and how do we assess that?”
<table>
<thead>
<tr>
<th>Decision Category</th>
<th>Stakeholder Group</th>
<th>Exemplary Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Siting, permitting, and licensing</td>
<td>Federal regulator</td>
<td>“How do we determine the appropriate siting for a project?”</td>
</tr>
<tr>
<td></td>
<td>State regulator</td>
<td>“Do the benefits of the proposed project outweigh the risks?”</td>
</tr>
<tr>
<td></td>
<td>Industry representative</td>
<td>“How do we approach permitting and licensing efforts with the information at hand?”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Impacts on protected species</td>
<td>Federal regulator</td>
<td>“Will the proposed project jeopardize the continued existence of listed fish species... or result in an adverse modification of critical habitat? Does the project jeopardize an endangered or threatened species... with appreciable effect on species abundance, distribution, or reproduction?”</td>
</tr>
<tr>
<td></td>
<td>State regulator</td>
<td>“Are there direct or indirect effects to protected resources under NOAA jurisdiction (marine mammals, salmon, sturgeon)?”</td>
</tr>
<tr>
<td></td>
<td>Tribal representative</td>
<td>“Will [the project] disrupt fish migrations?”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Local capacity and stakeholder engagement</td>
<td>Industry representative</td>
<td>“Is there human capacity at a potential site?”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“How and what information is shared with stakeholders?”</td>
</tr>
</tbody>
</table>

Table 4. Categorized priority decisions and examples from the paired decision-information activity at Workshop 1.
1.4.2. Information Format

Findings from the paired information-decision activity provided preliminary insight on what information format and scales are most useful to the participants making decisions. All participants agreed that raw data (i.e. data that has not been analyzed or synthesized in any way) is not useful, whereas processed information in the form of technical reports, figures, and publications is useful. One participant said that a “memo” or “executive summary” that summarizes relevant information is particularly helpful. This was the most surprising finding for our research team since researchers most often use raw data. This highlighted the importance of engaging with information users in this process; without asking these questions, we would have provided these stakeholders with access to raw data sources that ultimately would have had limited usefulness. Using specific examples of data sources and formats during the Data Café allowed a more comprehensive investigation to better understand stakeholder information needs and barriers. In the Data Café decision scenario, all participants agreed that the examples of synthesized information and web-based data portals were more useful than raw data in making a decision.

1.4.3. Information Scale (Temporal and Spatial)

Participants at Workshop 2 noted that data collected at different scales are useful in different decision-making phases. For example, hard-copy nautical charts can help in the early phases of a project, particularly, as participants noted, to review the area from a “regional” or “high-level perspective.” Web-based data portals were viewed similarly. Participants noted that these information sources were most useful when making a decision for a project that has a coarser (i.e. broader and zoomed out) geographic scale. The federal regulator representative gave
the example of decision-making related to large-scale wind projects. This representative explained that these large-scale project proposals require viewing the Northeast shelf from a coarser geographic scale to achieve a high-level perspective for decision-making. As a project progresses, however, finer-scale (i.e. zoomed in) site-specific information becomes more relevant and urgent. For example, one of the industry representatives and the tribal representative agreed that a community-level scale is more important for the smaller, site-specific project decisions that they deal with, such as evaluating the tidal energy potential of a site (industry example) or assessing local streams for dam improvements to aid in fish migration (tribal example). The tribal representative noted that while knowing where projects are physically located is valuable information, the web-based data portal with a broader scale was missing community detail, such as “where people are fishing.” An industry representative emphasized use of these big-picture views in the planning process:

“...For ORPC, we look at it for ship traffic. We look for other existing uses, so aquaculture, cultural resources are on there, shipwrecks. Again, that’s somewhat site specific. But, you know, there is information on marine mammals... We’d look at all those aspects, and then use that in the planning process... Originally, you know, to help guide identifying a site that’s appropriate to minimize impacts...And then also, as you move into kind of like the permitting and licensing of the site, it helps inform that process as well.”

Regulators noted that, depending on the decision, the information source does not necessarily need to be site-specific. During Workshop 1, participants noted that it would be useful to expand the Western Passage data inventory list to also include datasets on the Cobscook and Passamaquoddy Bay ecosystems to inform a broader understanding of the region.
When asked what spatial and temporal scale was most useful, one NOAA participant summarized that:

“Well it depends on, you’ve got to, you know, you do the kind of retrospective look at things, because you want to do the baseline kind of look. Then you’ve got to move forward, like: okay, so now you’ve got what’s there and as a result of what was done this is what’s there, and then what’s going to happen as a result of the new activity going in. So there’s different times you’re kind of trying to look at. Really, the most up to date would be valuable to project forward in looking at what the impacts of the project would be on the area.”

Other participants also noted a similar need for up-to-date information. One federal participant expressed that it was most important to have recent data, rather than outdated information, even data a year or two old. Participants attending Workshop 3 highlighted that the challenge to using web-based data portals is finding when certain datasets were last updated. This was reflected by other participants as information that would boost credibility, with one industry representative noting that “It’s only as good as the data and how relevant the data is.” Easy access to metadata to determine when maps or other data portals were last updated was noted to be important.

1.4.4. Information Sources and Content

With regards to the source of information, all participants said that they regularly use scientific information. While the rigor of scientific data collection was noted to be valuable and credible, several participants elaborated that using citizen science and local knowledge in conjunction with research data helps target further scientific data collection. An industry
representative also noted that LEK is valuable in helping to identify potential resources (i.e.: areas of good flow for tidal power) and to also help avoid developing in areas with potential conflict of use (i.e.: fishing spots or vessel traffic). An industry representative noted that:

“...we discussed using citizen science or anecdotal data of those who use the water resource as ways to prioritize data collection as well. We know, historically, fish have acted this way during this time of year, but we don’t have any data. We use that to dial into, being mindful of that entire framework of what regulators are looking for, for decision making purposes. Then, how do we layer in things like climate change, the way that species are moving through the water, and how they’re adapting to that also factors in.”

Participants all noted that LEK is an important source of historical, place-based information, but that it is challenging to compare the utility of scientific data with local forms of knowledge because of the lack of a “consistent” or “standardized approach” in collecting this information. Citizen science was similarly viewed as most useful when a standardized approach was applied to achieve longer-term data collection. One state regulator noted that:

“... the source of the information is important. I don’t discount local knowledge, but I give more weight to somebody who’s actually been out there and did a scientific study.”

Another key finding was the differences in the content of information that federal and state regulators use to make certain decisions about endangered species. Federal participants noted that they do not consider socioeconomic data for Endangered Species Act consultations:

“Given the authority such as the Magnusson-Stevens Conservation Act or the Endangered Species Act, the determination is quite different. For instance, under the
**Endangered Species Act, we’re prohibited from taking any economic considerations. So it’s just the effects on the species and the populations themselves. I’m glad you brought that up because I wanted to clarify that my process is significantly different than [Maine DEP].”**

The DEP representative contrasted their role with that at the federal level, noting that they do take socioeconomic and fishing community impacts into account when making state-level decisions. This participant noted that they receive socioeconomic information from the Maine Department of Marine Resources (DMR) in memo form. They explained:

“Right, and that would go into my decision as well. Impact on fishermen, both commercial and recreational, as opposed to the impact of the project or the benefit of the project to those guys.”

### 1.4.5. Information Accessibility

Issues of access were brought up at Workshop 2 in the context of discussion about both the synthesized and web-based data portal examples. The industry and tribal representatives noted that it can be challenging to get access to peer-reviewed articles and similar publications or reports. The tribal representative also noted that not many people in their community have a computer, but that most have a mobile phone. We took this input on information access and technology barriers into account to identify and develop a knowledge base platform that is accessible via both a computer and mobile phone. In addition, participants said that simply finding a database with relevant information can be difficult, and that sorting through the data to find useful information is a further challenge that can be a barrier to information uptake.
1.4.6. Co-Produced Data Integration Strategies

Drawing on participant perspectives on the usability of different types of information formats, sources, and content from Workshops 1 and 2, our research team and participants co-identified data integration strategies. Participants identified two strategies at Workshop 2: 1) an interactive knowledge base and 2) a central data repository. Participants said that it would be helpful to see the spatial data for the Western Passage region represented on an interactive map to create a knowledge base for spatial information (Figure 3). ArcGIS Online was selected as the platform for the spatial knowledge base because it is accessible from any computer and can be enabled for use on mobile phones, which was identified as an accessible form of technology for the Passamaquoddy community. In addition, participants noted that it would be helpful to compile non-spatial information in a central data repository, with particular attention to including peer-review publications and reports that are difficult for some groups to access. Google Drive was selected as the platform for the central data repository because participants were already familiar with using this platform, and it can be easily accessed from any computer or phone using a link.

Feedback was solicited at Workshop 3 to make the knowledge base and central data repository more useful after preliminary data integration efforts. Our research team and participants agreed that this is an iterative process that will involve multiple reviews and edits to ensure these knowledge bases remain relevant and up-to-date for future decision-making needs. Feedback from participants on the interactive map knowledge base focused on simplifying access to and use of the information. This included adding pre-queried data layers that focus on temporal and species-specific trends to eliminate the extra step of learning how to query. Participants also noted that the central data repository could be improved by creating specific
folders for information on surrounding regions (i.e.: Passamaquoddy Bay) and to include a separate folder for marine hydrokinetic technology reports and publications. In addition, participants said that the metadata file would be more helpful if links were added to connect the user directly to the information resource by clicking on the name, again eliminating the need to search amongst folders.

Overall, participants said that the amount of information and how it was organized into the spatial knowledge base and central data repository was very useful and responsive to stakeholder needs. One participant said: “thanks for compiling; really helpful. Absolutely helpful and responsive to the last stakeholder meeting.” Another participant commented that this participatory process of co-creating a knowledge base is a model that could be applicable in other areas with proposed coastal development projects, noting that: “I think this is a good model. With wind stuff and other things in New England, this could assist with their efforts, data crunching, etc. Very helpful.”

Letters of support written by workshop participants also described anticipated uses of co-produced project outcomes and offered concrete examples of what decisions these products could plug in to. Maine DEP representatives noted that integrated datasets and knowledge sharing would benefit the Department’s evaluation of all projects that generate power using water to “balance any environmental impacts a project may have with the social, economic, and environmental benefits”, as required by the Maine Waterway Development and Conservation Act. NOAA representatives said that project outcomes could be applied to their agency’s role in “planning, organizing, and implementing programs for fishery management and protected marine species conservation.” ORPC representatives wrote that integrated datasets would help to provide a more holistic understanding of the ecosystem and directly support the Adaptive
Management Team (AMT), “an inter-agency and inter-disciplinary decision-making process regarding interactions between our power systems and the marine environment.” The Sipayik Environmental Department said that they are “committed to protecting and restoring the environment for current and future generations” and that project outcomes that include traditional knowledge and values “would be highly beneficial to developing community resilience at the onset of changing conditions.”
Figure 3. Inventory list of Western Passage datasets from Workshop 1 (top panel), and one of the resulting data integration strategies from Workshop 3, the interactive map knowledge base for spatial information (bottom panel). Both panels include the same datasets (sources of LEK, UMaine fishing survey data, eBird citizen science data), but datasets in the bottom panel have been integrated and visualized in a way that reflects the needs and interests of workshop participants.
1.4.7. Steps to Improve Information Production and Sharing

The traditional scientific research process involves the production of scientific data that could be used for management and policy decision-making (Figure 4, panel a). We acknowledge that not all researchers are engaged in applied research or want their data to be used for decision-making. However, we identified a two-part intermediate step for researchers who want to make the scientific data they collect more useful and usable for decision-makers (Figure 4, panel b). This intermediate step focuses on researchers applying knowledge co-production to engage decision-makers throughout the information production and sharing process. This involves researchers: (1) understanding stakeholder perspective on information utility and accessibility and (2) integrating information from other disciplines (e.g. social science), from alternative approaches to data collection (e.g. citizen science), and different forms of knowledge (e.g. LEK). The arrow that leads from “management and policy decisions” back to “scientific data” (Figure 4) represents that this is an iterative process that should be informed by the people who use the information that we are creating as research scientists.
Figure 4. Flowchart that illustrates the traditional scientific research process (panel a) where scientific data is produced and shared with decision-makers. Panel b illustrates our modified process that includes a knowledge co-production step for researchers who want to make their scientific data more useful and useable for decision-makers.

1.5. Discussion

Natural resource decision-makers are frequently confronted with the need to make decisions quickly, under high uncertainty, and often in complex political and public arenas (Lester et al., 2010; Cvitanovic et al. 2014; Fox et al. 2017; Fisher et al. 2020; Cammen et al. in review). Useful and accessible products (like the knowledge base and central data repository co-produced here) represent the type of co-produced solutions that Cash et al. (2006) call for to counter the loading dock approach. The co-produced body of knowledge resulting from our research can be applied to specific decisions made by participants at their given agency or
organization. However, as in McNie (2007), we emphasize that co-producing useful and usable information is as much about the process (i.e. our modified process to connect the research-implementation gap) as it is about the product (the co-produced data integration platforms). Our modified information production and sharing flowchart (Figure 4) is the type of process for crafting usable knowledge that Clark et al. (2016) calls for in helping researchers improve how they produce and share useful information.

Previous studies have outlined frameworks that include steps to enhance research impact on decision-making (Fisher et al. 2020) and to improve knowledge exchange between researchers and decision-makers (Cvitanovic et al. 2016). Our modified process is different from those identified by previous studies because we focus on a co-production step that involves a two-pronged approach to connecting the research-implementation gap. We recognize that the first piece involves addressing the “loading dock” communication gap (Cash et al. 2006) between researchers and decision-makers by applying knowledge co-production to actively collaborate and understand diverse stakeholder perspectives on information utility. This is similar to the stakeholder-driven approach to crafting useful knowledge described by Clark et al. (2016), and this is the exact type of information production that Cash et al. (2006) calls for to counter the loading dock approach. The second piece of our modified research-implementation process includes integrating information from different disciplines, from different data collection approaches, and from different forms of knowledge. This directly addresses previous studies that have identified the need for interdisciplinary approaches and data integration to support holistic natural resource decision-making (Hiscock et al. 2003; Charles 2012; Lanier et al. 2018; McKinley et al. 2020).
Our study offered an opportunity to examine beneficial co-production process outcomes and remaining challenges of using participatory methods to close the research-implementation gap. Benefits of this work included the development of products that were directly driven by stakeholder information and decision-making needs, creating space for dialogue and building capacity, and forming new partnerships. We also identify additional opportunities for future improvement, which include clarifying roles and expectations and improving how we include stakeholder input in the design of research questions.

1.5.1. Beneficial Process Outcomes

While the emphasis of the traditional scientific research process is on producing new information (McNie 2007; Grygoruk & Rannow 2017; Djenontin and Meadow 2018; Fisher et al. 2020), our study focused on improving the production and sharing process by working directly with the stakeholder groups who use the information we are creating. In doing so, we learned that researchers and decision-makers have different perspectives on information utility, in particular the usability of different data formats (raw versus synthesized data) and sources (scientific versus LEK) and ways of accessing these data, which is reflected in other studies by Cvitanovic et al. (2014) and Djentonin and Meadow (2018).

Soliciting and responding to user input allowed us (as researchers) to be more responsive to stakeholder needs and create more useful products. Similarly, Wall et al. (2017) found that project outputs are greatly improved by asking questions about what types and forms of information are most useful and taking these perspectives into account to design “use-inspired” science products. Without soliciting user input through the co-production process, our knowledge base and central data repository may have reflected researcher perspectives and thus
would have had limited utility for stakeholders, which is reflected by findings by Cvitanovic et al. (2016) and Djenontin and Meadow (2018). Detailed observations, notes, and feedback from the three data workshops allowed us to directly respond to the specific information needs of diverse participant groups: for example, the need for access to published, peer-reviewed articles to overcome barriers to access. This barrier to accessing scientific research is well-documented in the literature (Cvitanovic et al. 2014; Djenontin and Meadow 2018; Alexander et al. 2019; Fisher et al. 2020).

Previous studies have also found that stakeholders have distinct information needs (Grygoruk & Rannow 2017; Djenontin and Meadow 2018), and we found that these were influenced by their respective roles, responsibilities, and decision-making priorities. However, we also identified similar general patterns in what information sources and formats are viewed as most useful and accessible. Access to raw data was only viewed as usable by our research team and the participant from the Sipayik Environmental Department. All participants found that processed information was the most useful for making decisions in their roles at their given agencies, including peer-reviewed articles, reports, and interactive maps that summarize the most important and relevant information. These findings are similar to a study by Cvitanovic et al. (2014) where managers were found to frequently use reports and other synthesized government documents to make decisions, rather than reaching for primary scientific literature.

All participants also expressed that there is value in collecting and recording different forms of knowledge, including LEK and TEK, as well as using alternative methods to collect scientific data, including citizen science. This represents a shift from a previously documented disregard for non-traditional sources of knowledge (Ames 2003; Teixeira et al. 2013). Viewing these results through Cash’s lens of information credibility, legitimacy, and saliency (Cash et al.
we found that participants expressed different perspectives on the credibility of different types of knowledge. One participant described that they viewed scientific studies as more credible than other forms of knowledge, but that other forms of knowledge are still legitimate and salient. Perspectives on when this information is most useful differed depending on the participants’ roles and decision-making needs. For instance, regulators and industry representatives noted that LEK, TEK, and citizen science methods for data collection are most useful at the beginning of new projects to help identify potential use conflicts and resources, and to guide further scientific data collection. The tribal environmental department values documenting TEK as a way to bring awareness and documentation of cultural uses to regulatory decision-makers, as well as a way to include the tribe in research and other projects at the local level.

The data workshops offered a safe space for participants to reflect on their own decision-making needs, as well as those of other participants. Chambers (2006) described that facilitation activities for participatory research need to be selected with the goals of creating a safe space, fostering dialogue, facilitating transparency in the research process, and building trust between all groups. Leahy and Anderson (2008) and Smith et al. (2013) describe the impact that trust (or conversely, the lack of trust) has on natural resource decision-making. The elements of dignity and voice underpin the relationship-building and engagement that is the foundation of effective participatory processes that close learning loops rather than disrupt them (Hicks 2011; Senecah 2011). Building trust and engaging these stakeholder groups with dignity were key objectives for our research team in selecting the facilitation activities and structuring the workshops, particularly the Data Café activity in Workshop 2. We found that the concept of cross-pollination of ideas was an essential component to encourage dialogue between participants and our research team, which Brown (2005) highlighted to building capacity through the co-
production process. The data workshops also provided space for dialogue between stakeholders who do not interact in other ways (i.e.: as part of the formal administrative process in the FERC Adaptive Management process), namely the tribal environmental department.

Another important outcome of applying knowledge co-production to this work was forming a new working partnership with the Sipayik Environmental Department. Although trust and relationship-building are sometimes viewed as pre-cursors to the knowledge co-production process (Djenontin and Meadow 2018), our research team had not worked with the Department prior to these workshops, and this engagement strategy was key to fostering dialogue and inclusion. The representative who participated in the data workshops recognized the shared research interest in increasing information accessibility for other stakeholder groups, including local communities. This led to an invitation to organize two community meetings to engage Sipayik community members in dialogue about their knowledge and values of the local ecosystem (Chapter 2).

Participatory research methods have been shown to effectively include new groups in productive dialogue and collaborations, develop long-term relationships with new stakeholder groups, and incorporate local information into decision-making processes (Ames 2003; St. Martin & Hall-Arbor 2008; Moore et al. 2017; Djenontin and Meadow 2018; Alexander et al. 2019). An important success of the data workshops was that all four participating groups (federal, state, industry, and tribal representatives) attended the three workshops over the course of the year-long study, which reflected the capacity of the knowledge co-production process to engage stakeholder groups in dialogue and collaboration over a long time period. This consistent attendance at workshops was backed up by active participation by all groups in each data workshop, as well as in email correspondence between workshops. Actively engaging all groups
in these workshops allowed for a more thorough understanding of diverse stakeholder information needs.

1.5.2. Challenges and Opportunities for Future Work

Including user input in designing scientific research (Cvitanovic et al. 2016; Fisher et al. 2020) remains an opportunity for future improvement. Previous interdisciplinary Western Passage research focused on engaging stakeholders in designing research questions and data collection activities (Cammen et al. in review); however, lessons learned about federal, state, and local decision-making needs and information usability will help better inform the type of research output that interdisciplinary researchers generate in the future. For example, the need for specific information formats (i.e. reports, synthesized summaries) in the knowledge sharing process. In addition, participants in this study also noted the importance of access to up-to-date information from the past year or two. The “time-lag” in publishing scientific results (Cvitanovic et al. 2014) means scientific research results are often not accessible to decision-makers for a long time after completion. On the other hand, publishing too early could mean that results are shared prematurely or are shared in a way that does not respect confidentiality concerns. Cvitanovic et al. (2014) suggests that alternative modes of sharing knowledge before publication should be built into the scientific research process, and could offer ways to share relevant, up-to-date information with decision-makers while allowing time for the peer-review process.

Previous studies in Downeast Maine have identified a range of communication strategies to share news and results from scientific projects outside of academic settings and encourage stakeholder input and participation (Johnson and Zydlewski 2012; Jansujwicz and Johnson 2015b). These included formal (meetings and reports) and informal knowledge sharing methods
(newspaper articles and social media), and these findings have been reflected in other studies (Cvitanovic et al. 2014). Meetings have been organized with managers, industry representatives, and community members, and research reports have been prepared for industry members. However, a remaining challenge and opportunity for future work is the need to explore other methods for sharing scientific knowledge prior to publication that more effectively engages knowledge users and encourage participation and input more efficiently in the scientific research process.

Applying participatory methods are intended to include the voice and values of all participating groups (Cash et al. 2006; Senecah 2011), and previous studies have highlighted the need for making information available to all potential data users (Fisher et al. 2020). Although this is an ideal situation, it is essential for researchers to acknowledge the sensitive nature of documenting and sharing human dimensions data, such as LEK and traditional ecological knowledge (TEK). This can be met with distrust and uncertainty, specifically over disclosing locations (e.g. historical fishing spots) and how this information might be used (Ames 2003; Klain and Chan, 2012). As a result, integrating interdisciplinary datasets and making all information available to all stakeholder groups might not be appropriate, which we found to be the case with information that is the intellectual property of the Passamaquoddy Tribe (e.g. TEK; see Chapter 2). Acknowledging how this might counter a research agenda can be a challenging aspect for researchers, however well-intentioned they are. It is essential for researchers to remain responsive to these concerns as they arise and respect the need for confidentiality of certain information that is not appropriate to be shared with a broader audience.

Three out of four participant groups were already previously interacting with each other through a separate series of meetings as part of the FERC formal adaptive management process.
related to ORPC’s proposed tidal power development. Since these groups were already interacting, there was some confusion about the difference between those meetings and the data workshops. It was important for our research team to acknowledge “meeting fatigue” and to ensure that the specific project objectives were highlighted and reiterated at the beginning of each workshop. In addition, facilitation activities were chosen to foster deeper discussion into information utility, which helped to differentiate the research objectives from the adaptive management process goals. The process of listening to feedback and reiterating group objectives helped to keep participants on topic, while also providing a safe space for voicing concerns. In doing so, we were able to address group concerns as they arose, such as confusion about project overlap with the adaptive management process, and better support learning loops, two-way communication, and iterative processes for knowledge co-production (Cash et al. 2003; Cash et al. 2006; Cvitanovic et al. 2013; Johnson 2015; Djenontin and Meadow 2018).

1.6. Conclusion

The “loading dock” problem and the lack of interdisciplinary data integration are two persistent barriers for natural resource decision-makers seeking salient, credible, and legitimate information to make management and policy decisions (Cash et al. 2003; Cash et al. 2006; McNie 2007; Charles 2012; Hiscock et al. 2003; Cvitanovic et al. 2015; Roeckmann et al. 2015; Wall et al. 2017; Fisher et al. 2020; McKinley et al. 2020). However, knowledge co-production has been shown to be successful in improving the knowledge sharing processes in other marine resource systems (Cvitanovic et al. 2014). Working with stakeholders in this way allowed us to co-identify solutions in direct collaboration with the decision-makers who use the information we produce, while supporting iterative learning loops in participatory processes (Cash et al.).
Our study reiterates that research aimed at understanding ecosystems holistically requires an interdisciplinary approach to counter science occurring in isolation from other disciplines (Silka 2013) and view information and decision-making needs through a stakeholder-focused lens (Christie 2011; Cvitanovic et al. 2016; Alexander et al. 2019; Fisher et al. 2020). Our modified information production and sharing process adds to a growing body of knowledge aimed at bridging the research-implementation gap. By crafting information that is usable, accessible, and shared in a format that can be readily used, we can proactively support sustainable natural resource decision-making in Maine and different coastal development contexts (Clark et al. 2016; Dilling and Lemos 2011; Cvitanovic et al. 2014). Although our study was motivated by the proposed tidal power project in Maine, our co-produced products and process are applicable and transferable to decisions in other complex, multi-use coastal ecosystems where managers are faced with making decisions in high uncertainty and complexity.
CHAPTER 2

USING PARTICIPATORY MAPPING AND GIS TO SHARE CAPACITY WITH AN INDIGENOUS COMMUNITY IN MAINE

2.1 Abstract

The capacity for coastal communities to respond to change and manage risk depends on ready access to useful information to inform decisions and enhance their resilience. In indigenous communities, traditional ecological knowledge (TEK) is a valuable source of generational, place-based knowledge, but it can be difficult to present this information in a way that is useful for community decision-makers. This challenge was a communication gap that motivated our research and was identified initially by a researcher at the Passamaquoddy Tribe Sipayik Environmental Department in Maine. To foster meaningful collaboration between non-indigenous and indigenous researchers, we focused on capacity sharing and acknowledging our lessons learned as non-indigenous researchers to reflect on how we self-assessed to be more responsive to the needs and interests of the Sipayik researchers and community. We collaborated with the Sipayik Environmental Department to organize two community meetings at the Pleasant Point reservation to discuss TEK, stories, memories, and values about the local marine environment through participatory mapping. An information sharing agreement was discussed with meeting participants, and shared TEK was digitized and added to a private, password-protected ArcGIS Online interactive map for internal, tribal use only. This was where we learned a lot of important lessons as non-indigenous researchers, and, as a result, we re-directed the work occurred to focus squarely on the needs of the Sipayik Environmental Department and Sipayik community. This involved sharing GIS and data management expertise to empower environmental department staff to maintain the interactive map long-term, while engaging a local
student and elder to create story maps to share information with the Sipayik community. We expanded on best practices in working as non-indigenous researchers with indigenous communities and found that there are multiple ways to foster more effective and meaningful partnerships that foster dignity and respect through the mutual coexistence, rather than integration, of different forms of knowledge. Essential to this was discussing intellectual property and information sharing concerns to help foster trust and build new relationships. Key components to effective capacity sharing can be applied to partnerships with other indigenous researchers to empower communities to have greater ownership over the research process while making different forms of knowledge useful and accessible for community decision-making.

2.2 Introduction

Research engaging indigenous communities has historically involved one-sided information sharing that perpetuates colonial-era inequities and power imbalances (indigenous to non-indigenous) (Mataira 2019; Chapman and Schott 2020; Davies et al. 2020; Reid et al. 2020; Wilson et al. 2020). Traditional Ecological Knowledge (TEK) is a term used to describe the intellectual property of indigenous communities (Harding et al. 2012; Davies et al. 2020) that includes “knowledge, practices, and beliefs developed across generations by traditional cultures, being associated with both individual and groups” (Teixeira et al. 2013) specifically related to interactions between people and the environment (Kimmerer 2002; Peacock et al. 2020). Non-indigenous researchers and managers are increasingly acknowledging the value of TEK as a different way of understanding the natural world that can enrich scientific knowledge and help inform a more holistic understanding of the marine environment (Kimmerer 2002; Teixeira et al. 2013; Verma et al. 2016; Whyte et al. 2016; Davies et al. 2020). These different worldviews and nature ethics long pre-date many well-known Western science conservationists like Aldo
Historically, Western scientists have undervalued different forms of knowledge (Davies et al. 2020), yet Western science often confirms what indigenous researchers and other community members already know through TEK formed through observations, memories, and stories that have been passed down for centuries (Kimmerer 2002; Drew 2005; Verma et al. 2016). As recognition of the value of TEK as an important information source increases, a growing number of researchers seek ways to document and integrate this knowledge with Western science (Drew 2005; Verma et al. 2016; Chapman and Schott 2020; Davies et al. 2020). There are significant questions about whether TEK should be integrated or incorporated with Western science at all because of similarities to colonial-era assimilation and concerns about altering cultural knowledge and beliefs (Kimmerer 2013; Lowan-Trudeau 2012; Mataira 2019; Chapman and Schott 2020; Davies et al. 2020; Reid et al. 2020; Wilson et al. 2020). The approach frequently taken by non-indigenous researchers often involves an indigenous community sharing knowledge to benefit Western science, but not vice versa (Drew 2005; Mataira 2019), which contributes to greater distrust of outsiders, intellectual property concerns, and ineffective process and outcomes (Drew 2005; Harding et al. 2012; Chapman and Schott 2020; Davies et al. 2020; Peacock et al. 2020). Thus, however well-intentioned, this colonial-era approach is not meaningful engagement if it is carried out on the researcher’s terms rather than the community’s, as this only results in benefits for non-indigenous researchers (Drew 2005; Wilson et al. 2020).

Knowledge co-production and participatory mapping have emerged as ways to encourage collaboration and meaningful engagement that include the values and interests of all participating groups while remaining sensitive to cultural differences (Cash et al. 2006; Alexander et al. 2019; Chambers 2006; Davies et al. 2020; Chapter 1). Previous studies have identified best practices in
successfully building partnerships between non-indigenous researchers, indigenous researchers, and communities that focus on community needs and interests (Drew 2005; Mataira 2019; Chapman and Schott 2020; Wilson et al. 2020). These best practices highlight relationship-building to develop trust, empowering communities to have ownership over research objectives, building capacity, and de-colonizing research approaches to ensure more effective partnerships for all parties involved. Wilson et al. (2020) outlined a framework to guide non-indigenous researchers in actively practicing methods that de-colonize research, which include self-education about colonialism and reflexively and critically self-assessing research approaches. In addition, this framework also highlighted a central focus on community needs and interests and strengthening youth capacity (Wilson et al. 2020). Chapman and Schott (2020) proposed a framework that emphasizes knowledge unification, training, and capacity building as strategies to ensure that different forms of knowledge can be integrated without having one dominate and making sure the TEK knowledge stays intact. Mataira (2019) described guidelines for researchers that include active listening and recognizing assumptions to allow for sharing without judgement, embracing the mindset that there are different and valid worldviews, and to self-assess and be reflexive to critical feedback to fully commit to the process. Drew (2005) discussed training, education, and cultural empowerment as ways to ensure that indigenous researchers and communities have greater ownership over and leadership in the research process.

Hicks (2011) highlighted the significance of acknowledging dignity in conflict resolution and relationship-building, which has applications and relevance in all community partnerships. The “dignity model” moves beyond respect, which is earned, and encompasses the inherent values, worth, and vulnerabilities that form dignity (Hicks 2011). The elements of dignity (acceptance of identity, recognition, acknowledgement, inclusion, safety, fairness, independence,
understanding, benefit of the doubt, and accountability) (Hicks 2011) form the foundation of best practices for meaningful engagement that empowers communities and helps build trust (Johnson 2015). Senecah (2011) describes building trust in participatory processes as dependent on the “Trinity of Voice” (TOV) theory, which includes access, standing, and influence. Keeping the TOV components at the forefront of engagement processes are key to successfully applying participatory approaches to tackle environmental issues at the nexus of science and society (Senecah 2011). Understanding and acknowledging multiple ways of knowing are essential to engaging with indigenous communities. Reid et al. (2020) describe a framework for “Two-Eyed Seeing” (Etuaptmumk in Mi’kmaw), which involves seeing and understanding indigenous forms of knowledge with one eye, and using the other eye to see and understand other ways of knowing (e.g. Western science). This framework is grounded in the idea that a person can embrace multiple ways of knowing and forms of knowledge in coexistence, without integrating or assimilating these ways of knowing, and use these multiple perspectives to take action as stewards of the environment. Reid et al. (2020) emphasize the use of the term “pairing” or “adopting a Two-Eyed Seeing approach” to counter colonial-era terms like “integrating.”

Participatory mapping is a Participatory Action Research (PAR) method (Chevalier and Buckles 2013) that offers a way to include different types of knowledge and epistemologies by pairing Western science with other valuable information sources, such as TEK (Davies et al. 2020). Local communities have been making maps for centuries, but facilitated participatory mapping is novel (Chambers 2006). Participatory mapping allows people to interact and share knowledge about their local environment in a way that can also be digitized, visualized, and shared using geographic information systems (GIS) (Teixeira et al. 2013; Davies et al. 2020). Nautical charts and other maps act as boundary objects (Silka 2013) that foster dialogue and
create space for people to share place-based and stories, memories, and values that keeps the mapping focused on including the “people-based” perspective (Adelfio et al. 2019). Digitizing this information using GIS serves the dual purpose of serving as a knowledge co-production platform to pair disparate data sources as well as a way to share information visually (Adelfio et al. 2019).

There are also challenges associated with participatory mapping and resulting best practices developed in previous studies. It is essential that participatory processes create a space for productive dialogue, and the format of facilitated mapping or other participatory methods impact the process, outcomes, and power dynamics within a group (Chamber 2006). To create a safe space for discourse, participatory mapping should include a discussion on map ownership, access, editing permission, and user groups to ensure that participants are empowered, rather than disempowered, by participatory mapping research (Chambers 2006). This discussion is especially pertinent with the intellectual property and ownership concerns related to TEK and working with indigenous communities (Kimmerer 2002; Drew 2005; Harding et al. 2012; Davies et al. 2020). Davies et al. (2020) emphasized the need for developing an agreement with the community about how TEK information would be used and stored to ensure the knowledge system remains intact and secure. As concerns and questions arise, it is also important to acknowledge and respect the legitimacy of emerging questions or concerns (Ames 2003) by responding and being flexible to evolving needs and interests. This is an essential piece of the participatory mapping process where the elements of dignity and TOV are vital components of being able to close the knowledge co-production loop (Hicks 2011; Senecah 2011; Johnson 2015).
Here, we build on these best practices to foster three-way capacity sharing between non-indigenous researchers, indigenous researchers, and an indigenous community in Downeast Maine. We emphasize the use of the term “capacity sharing” rather than “capacity building” from previous best practice studies because we acknowledge that there is knowledge and expertise to be shared amongst all groups involved (Mataira 2019). The Passamaquoddy (Peskotomuhkati) Tribe at Pleasant Point (hereafter referred to as Sipayik, the term used by the community) is located in Downeast Maine in Washington County (Figure 1). Traditional Passamaquoddy land spans the region between the Penobscot River watershed in Maine to the St. John River watershed in New Brunswick (Bassett 2015). The sovereign Passamaquoddy Tribe today is located in three self-governing communities: Pleasant Point (Sipayik) and Indian Township in Maine and in St. Andrews, New Brunswick, Canada (Bassett 2015). The land that the current Sipayik community is located on is the site of a traditional Passamaquoddy seasonal fishing village with access to both Cobscook and Passamaquoddy Bays (Bassett 2015). A variety of marine mammals and fish in this region, including river herring, Atlantic salmon, American shad, and Harbor porpoise, are important cultural and subsistence resources for the Passamaquoddy people (Bassett 2015). The Western Passage ecosystem (Chapter 1) and the surrounding bays (e.g. Passamaquoddy Bay) and rivers (St. Croix River) are culturally significant for the Passamaquoddy people at Sipayik.

A Passamaquoddy Tribe Sipayik Environmental Department researcher (hereafter referred to as “Sipayik researcher”) participated in a separate series of workshops on information utility and decision-making needs at various federal, state, tribal, and local levels (Chapter 1). During these workshops, the Sipayik researcher identified a distinct community-specific communication gap in understanding how to effectively share information with indigenous
communities. As a result, our research team was invited to organize two community meetings at Sipayik in collaboration with their department to investigate how TEK and Western science can be paired and shared more effectively within the community. Here, we discuss the process that we followed to collaboratively organize these meetings at Sipayik, reflect on the lessons we learned along the way as non-indigenous researchers working in collaboration with indigenous researchers, and how we re-focused to better share capacity on the needs and interests of Sipayik researchers and community members.

2.3 Methods

2.3.1 Community Meetings

We co-organized Meeting 1 at Sipayik in June 2019. The objectives of this meeting were threefold: (1) to develop a working relationship with the Sipayik community, (2) to discuss information on the local Western Passage ecosystem gathered by Western scientists (Chapter 1), and (3) better understand how the Sipayik community perceives, values, and uses the marine environment. The day, time, and location of the meeting was based on insights from Sipayik researchers. The Bingo Hall was selected as a familiar, central location to make it as easy as possible for participants to attend. Meeting participants were recruited by the Sipayik researchers, and a flyer (Figure B.1) was distributed on social media to generate interest in the meeting.

These community meetings were not audio-recorded due to the sensitive nature of recording TEK and in an effort to build trust, maintain confidentiality, and remain transparent and open during the research process. The three-hour meeting was structured to include introductions, an overview of our research team’s work in the area, an information sharing
discussion, participatory mapping activity, and a wrap-up. We acknowledged that this evening meeting overlapped with dinner, and so we also purchased a catered meal through a local Sipayik business. A Maine Sea Grant Extension Associate was the primary facilitator at this meeting as he was a familiar person to both our research team and Sipayik community members. A Sipayik researchers and a member of our University research team served as co-facilitators, as needed. After introductions and clarifying roles, participants were split into four small groups, and nautical charts were utilized to foster place-based dialogue and share stories and memories about the local ecosystem. Each small group had two research team members with discussion prompt cards (Figure B.2) to help guide the discussion with a list of questions. These questions included: What makes Western Passage and Passamaquoddy Bay valuable to you and your community? Have you seen changes recently in where you would go to find fish/ birds/ marine mammals? TEK took the form of oral stories and memories that were shared and then recorded on the charts by members of our research team, including memories about changes in different species (e.g. where someone used to go to find a specific fish species) or stories passed down from family members about events that happened in the past that connected people and the marine environment. These TEK, stories, memories, and values shared at the meeting were later digitized using ArcGIS. Feedback forms (Figure B.3) were also collected as a way to solicit anonymous, written feedback on the meeting. The information sharing and confidentiality agreement was discussed again at the end of the meeting to specifically re-visit who can use, view, and access the TEK information shared at the meeting (in the form of nautical charts and notes).

Our research team was invited back to Sipayik again to share how the TEK information shared at Meeting 1 was digitized and added to an ArcGIS Online interactive map. Meeting 2
was again organized in collaboration with the Sipayik Environmental Department and held at the Sipayik Bingo Hall in September 2019. A separate flyer was circulated by the Sipayik Environmental Department to recruit participants (Figure B.4). The objective of this meeting was not only to share the interactive map, but to solicit feedback from participants and make the map more useful for both the Department and the community’s needs and interests.

This map included the digitized TEK data points from the first community meeting, as well as other western and citizen science data shared by our research team. Based on participant input from the first meeting and a separate series of workshops (Chapter 1), the ArcGIS Online map was enabled for both computer and mobile phone use. Prior to this meeting, a private account was set up for use by Sipayik researchers and community members, allowing the TEK data points to be kept secure and confidential on a password-protected map. Materials produced for this meeting included an instruction sheet for participants on how to access the map on both a computer and mobile device, based on research findings from Chapter 1, as well as printouts of map layouts to serve as a hard copy format example.

The structure of this meeting included introductions, a demonstration of the ArcGIS Online map, small group discussion, and a review of the Information Sharing and Confidentiality Agreement and next steps moving forward. The three participants were split up into smaller groups after the map demonstration. Each small group was provided with a laptop to view the ArcGIS Online map, as well as multiple printouts of the maps. Two research team members guided discussion in each group and prompted participants with targeted questions (Figure B.5) after they had a few minutes to view the digital and printout maps individually. Prompt questions included: Was this what you were expecting? Would you or others in your community use this map? Is there one format that is more useful than the other (interactive digital map vs. printout
and computer vs. phone)? Participants were encouraged to try out the password-protected mapping application on their mobile phones, and we prompted with questions such as: “Is there anything missing that you would like to add to the map?” to solicit feedback on map improvements to make it more useful. These break-out sessions were followed by a large group discussion on the information sharing and confidentiality agreement, as well as next steps moving forward. Data collected from this workshop consisted of handwritten notes that were transcribed and feedback forms.

2.3.2. Refocusing Research Due to the COVID-19 Pandemic

The COVID-19 pandemic required us to re-focus our work in a way that ensured a safe environment for everyone. This meant re-visiting goals and brainstorming with the Sipayik researchers on what type of work could be accomplished on a virtual platform. Our co-created strategies to re-focus our work were twofold and based on ideas identified by Sipayik researchers: (1) organize GIS trainings with a Sipayik researcher to optimize the map for their use and (2) engage and compensate a WaYS student and Cultural Knowledge Keeper (CKK) to create a series of story maps for and with their department. Story maps is a cloud-based GIS platform that allows a user to combine text, images, videos, maps, and other graphics to tell a compelling and dynamic story. Story maps have applications for sharing information and raising awareness in many different disciplines. The GIS training and working with local youth (outlined below) were both conducted remotely via Zoom videoconferencing.
2.3.3 GIS Training

A Sipayik researcher noted that it would be helpful to learn how to add to and manage the ArcGIS Online interactive map. Although their department does have a GIS trained staff member, there was another researcher who was more heavily involved in this work and expressed an interest in maintaining the interactive map long-term. We co-identified topics of focus that included adding, managing, and visualizing datasets on the ArcGIS Online platform, as well as how to share maps using different platforms (i.e. interactive maps on a computer versus mapping applications on mobile devices).

2.3.4 Engaging Local Youth

A Sipayik researcher identified the story maps platform as a useful way to share information within the community, as well as use for department research and writing grants. A local student at Sipayik was engaged and compensated through the Wabanaki Youth in Science (WaYS) program to create a collection of story maps for and with the department. The WaYS program represents a partnership between the University of Maine and tribal communities in the State of Maine (Carr et al. 2017). This program specifically aims to provide funding for Wabanki students in middle school, high school, and college to engage in science projects and training in a way that prepares them for science careers while connecting to their culture and traditions (Carr et al. 2017). The Sipayik Environmental Department was interested in engaging a WaYS student at Sipayik to connect a local student with their culture and traditions while getting youth in the community interested in the work that their department is pursuing. In addition to a WaYS student, a Cultural Knowledge Keeper (CKK) was engaged and compensated to mentor the WaYS student and provide important input and guidance on the project. In addition to the WaYS
student and CKK, a Sipayik researcher and University graduate student are also part of the team to provide story maps training and support to the WaYS student. This work is currently ongoing.

The Sipayik researcher identified a series of priority narratives that reflect their research and goals, as well as overlap with community values and interests. These include restoring sea-run fish, improving municipal water quality, history related to the causeway that runs through the reservation and efforts toward removing the causeway, and shellfish management and conservation. The WaYS student has access to both Western science and cultural TEK datasets. Virtual biweekly team meetings are held to discuss and reflect on progress, as well as to create a space for a productive student learning experience that supports their professional training and development.

2.4 Results

Here, we focus on the lessons learned in meaningfully sharing capacity with the Sipayik Environmental Department and engaging the Sipayik community in a way that fits their needs and interests, while also highlighting what we would have done differently as non-indigenous researchers with the lessons we learned as a result of this partnership. We propose a set of key components that highlight our lessons learned and translate them into practices that can be transferred to working with other communities (Figure 5). In accordance with our current information sharing and confidentiality agreement with the Sipayik community, we do not share results detailing the specific TEK, stories, memories, or values that were shared with us.
Figure 5. Key components for developing meaningful partnerships and collaborations with indigenous researchers and communities that focuses on sharing capacity and prioritizing community needs and interests.

2.4.1 Community Meetings

Sipayik researchers put in significant effort to recruit participants for the first community meeting in June 2019, including circulating a flyer created by our research team in the community and on social media, as well as interacting with community members on an individual basis to encourage attendance. This resulted in a turnout of 12 participants for the first meeting. We had to take a step back during introductions at the first meeting to address emerging
concerns and questions about our role as University researchers relative to the industry developer that is proposing tidal power development in the Western Passage. A Sipayik researcher intervened in the discussion at one point to explain why they invited us to Sipayik and talked about the potential value of having this information written down so that it can be brought to groups who make decisions at the federal level (i.e.: NOAA), as well as simply ensuring that the Sipayik community is aware and included in research conducted in the area. Although this took a significant amount of time to clarify and ensure all questions were addressed, it was important for us to respond to those emerging concerns to help develop trust and build relationships.

The information collected during the participatory mapping activity at the first community meeting consisted of TEK stories and memories written on nautical charts and notes. This information was digitized by indexing each story or memory as a data point with a unique identification code, and then added to an attribute table to visualize the data in ArcGIS. The attribute table includes quotes and summaries of the stories that were shared at the meeting. Each story has a unique identifying code and was categorized for specific categories such as species presence (e.g. observation of a fish species, such as alewife), changes in species in the area (e.g. disappearance of a seabird species from a nearby island), and events (e.g. a storm that resulted in a flooding event). This process resulted in approximately 200 TEK data points that were added to a private, password-protected ArcGIS Online map. An example of this process is depicted in Figure 6, but does not show any specific charts or examples from the meetings at Sipayik.
**Figure 6.** An example of the participatory mapping process using a nautical chart from a 2017 community meeting in the City of Eastport. The left hand panel shows a nautical chart with handwritten local ecological knowledge written on it. The right hand panel shows the resulting digitized version visualized using ArcGIS. Clicking on a point will bring up a small pop-up window (on the far right hand side outlined in blue) which contains the story or memory associated with that point.

Participants shared TEK stories and memories about different fish, birds, and marine mammals in the region, as well as changes they have observed. For example, a few participants shared stories about harvesting marine resources, and how they had observed changed in the location and abundance of these resources over time. The stories and memories shared were not just ecologically significant, but also held personal, emotional, and cultural values as well.
Another participant talked about activities they had undertaken with relatives or stories that had been shared by family members. These stories and memories highlighted the personal, emotional, and cultural connections between these community members and the local environment. In reflecting on the participatory mapping activity, several participants also noted that it was helpful to hear one another’s stories and memories about their traditional territory. At least one participant said, “I’ve never heard that story before” in response to a story shared by another participant. Many of the participants were older and some raised concerns about their memories and stories being lost. We also observed that participants were able to add details or another perspective to a story or memory mentioned by another person, which added a unique dimension to the value of participatory mapping in a small group setting rather than individual interviews.

The information sharing and confidentiality agreement was initiated as a large group discussion to pose questions about how participants wanted the TEK information shared at that meeting to be used (or not used), where it would be stored, and who would have access to it. Participants decided that the TEK stories and memories shared during the participatory mapping activity should remain confidential and secure until members had had a chance to review the digitized information at a follow-up meeting. An important outcome of Meeting 1 was an invitation to return and share the digitized maps with community members.

Meeting 2 was held in September 2019 and three Sipayik researchers attended. Although participation decreased significantly compared to the first meeting, this offered a valuable opportunity to share the generated map with their department and have in-depth conversations about how to make it more useful both for them and the community as a whole. Each of the three Sipayik researchers had access to a laptop and a phone to try out the ArcGIS Online map, as well
as a series of printed maps. Initial impressions of the interactive map included surprise at how much information was displayed on the map for both the number of TEK data points visualized in GIS, but also the amount of other data (i.e.: UMaine research and citizen science) that had been added. One participant even noted that it was a little “overwhelming” to see all the information at once, but quickly saw how layers could be turned on and off to break the data down. Observations like these highlight the advantages of an interactive map, in that it can be manipulated and tailored to fit the needs of the user, including, but not limited to, zooming, panning, selecting, and filtering data. This directly relates to our emphasis on capacity sharing because once participants know how to use the map, they are able to modify it and transform these stories into something more useful for their needs and interests.

Participants commented that the three map formats (TEK maps on the computer, mobile phone, and hard-copy printouts) would likely be more helpful or accessible to different people within the community. The printout maps were created directly from the ArcGIS Online map, so they contained the same type of information. However, participants noted that while the printed copies are useful to demonstrate examples of specific historical stories or changes in species, the meaning and detail is lost since it is not interactive. Working with the interactive map online using either a computer or mobile phone was noted to likely require some training to become familiar with a new platform, but one participant commented that this would be “worthwhile.” In addition, the attribute table codes were noted to be sometimes difficult to interpret, and consistent terminology usage, especially in coding for the species breakdowns, would make this more helpful. Other edits to the attribute table suggested by participants included making a simple metadata file where map users can find these categories and other instructions for querying more easily.
The Sipayik researchers said that the ArcGIS Online interactive map would likely be most useful to planners, scientists, and researchers in the community, including staff within their department, many of whom are already comfortable using GIS. One participant noted that this knowledge base would be helpful for making decisions related to prioritizing research projects. This participant also said that the knowledge base would be particularly helpful for writing grant applications because there are new data presented on the map, such as the eBird citizen science dataset, that they did not know about before. Another participant commented that it would be most interesting to look at TEK stories on the map that referred to specific animal groups or species, such as jellyfish and Minke whales. Participants made note of additional datasets that should be added to this TEK map that would be relevant for use by Sipayik community members, including ethnological information, wetland delineation, and projected sea level rise data. The Sipayik Environmental Department was given ownership and full editing access to the ArcGIS Online map.

The information sharing agreement was also revisited at Meeting 2. There were limited decisions that could be made due to the low attendance at this meeting. The Sipayik researchers who attended said they could review each of the TEK data points to screen for sensitive or personal information that community members may want to keep private, but that they were not sure they were entirely comfortable doing so. It was noted that there likely are some data points that are more sensitive than others, such as the location of sacred and cultural sites with artifacts, while other stories might just contain public information. Currently, none of these data points have been approved for public sharing, therefore the ArcGIS Online interactive map with TEK data points has remained private and password-protected for internal tribal use only.
2.4.2 GIS Training

We held three GIS trainings on Zoom over 4.5 hours. These trainings were attended by one Sipayik researcher. These trainings were focused on a general overview of the ArcGIS Online platform, how to add and visualize datasets effectively, data management best practices, and how to find open source data that is useful for their department. To encourage effective learning loops and knowledge co-production, we created a set of written summary notes after each meeting, and the Sipayik researcher provided feedback and posed follow-up questions to make these training sessions more useful for him. Overall, the Sipayik researcher expressed that the GIS training has been very helpful, and that being able to add to the maps will benefit the Department and the tribe as a whole. We will continue to add new data collected by their department and the University, as well as additional open source data. We also added other datasets collected by our research team to the ArcGIS Online map, including telemetry and species-specific layers (e.g. stories about alewives), based on previous input from department staff on other information that would be useful to include. Additional trainings on how to share maps and privacy settings are planned for a later date.

2.4.3 Engaging Local Youth

The WaYS student is focused on integrating information and producing the first story map on the “improving municipal water quality” narrative, which is currently a significant and urgent issue in the Sipayik community. The student has worked through training materials for dynamic storytelling and science communication that the team put together, including a flow chart to guide the process (Figure 7). In addition to using the existing Western science, TEK, and other cultural datasets, the student plans to include quotes and perspectives from close family
members through informal interviews and a Facebook survey, and will hopefully expand these interviews once in-person activities are resumed. The Sipayik researcher engaged in this project has identified several concrete opportunities for their department to use these story maps in outreach events, including at a career fair and plans to ask the WaYS student to present these at the next Tribal Leaders Environmental Summit.

![Image: Brainstorming and drafting process to create an effective story map as part of the WaYS student training.]

**Figure 7.** Brainstorming and drafting process to create an effective story map as part of the WaYS student training.

### 2.5 Discussion

We found that knowledge co-production and participatory mapping were successful approaches to build relationships and foster dialogue around TEK and cultural values in a way that was respectful and dignified (Hicks 2011; Davies et al. 2020). We expanded on best practices outlined by previous work (Drew 2005; Chapman and Schott 2020; Wilson et al. 2020) that emphasize the importance of education and training as ways to de-colonize research and give indigenous communities greater ownership over the research process involving TEK. The best practices that we expanded on include: (1) training and youth education (Chapman and Schott 2020; Wilson et al. 2020), (2) intellectual property discussions (Drew 2005; Harding et al. 2012; Davies et al. 2020), and (3) reflexive self-assessment to better support dignity and de-colonization in the research process (Hicks 2011; Mataira 2019; Wilson et al. 2020).
Our research team came into this partnership acknowledging that the Sipayik Environmental Department would lead and guide us through this work, and, throughout this process, we practiced active listening to diverse perspectives and engaged in two-way information sharing. Despite expanding on these best practices, our non-indigenous research team learned some important lessons along the way. After the two community meetings in 2019, our discussions with Sipayik researchers focused on the TEK map, sharing this more broadly with the Sipayik community, and collecting new information. We encountered a challenge in that no one was sure how to proceed and what to do with the map due to the information sharing agreement that stated all information collected would remain private and confidential for internal, tribal use only. In trying to figure this out, we misinterpreted that our goal of sharing information more broadly was also a goal shared by their department. This resulted in our team taking an approach that was not meaningful or useful for their department; instead, we realized that we needed to re-visit our focus of ensuring that information that we co-collected is useful and accessible to both Sipayik researchers and the Sipayik community. During this process, the COVID-19 pandemic in 2020 presented us with additional and unprecedented challenges, but also required us to re-focus on their department and community’s needs and interests in a more meaningful way. Rather than focusing solely on the TEK information, the first step to more meaningful partnership was asking how to make the information we collected more useful to them. The answer was GIS training and engaging a WaYS student and CKK in this project, both of which support the dignity framework elements of independence and acknowledgement, foster more meaningful dialogue, and support indigenous self-determination (Drew 2005; Hicks 2011; Chapman and Schott 2020; Wilson et al. 2020).
We are now more effectively sharing capacity between three groups: non-indigenous University researchers, the indigenous researchers at the Sipayik Environmental Department, and Sipayik community members (Figure 5). A critical piece of resolving power imbalances in the knowledge co-production process is that information needs to be shared in multiple directions (Chapman and Schott 2020), and we now are actively practicing this. Not only are we sharing GIS knowledge and training, but we are learning more effectively about how Sipayik researchers and the Sipayik community uses information to address urgent concerns and issues. For example, the WaYS student is addressing an urgent community issue on improving municipal drinking water co-identified by a Sipayik researcher, the student, and the CKK. The Sipayik researcher and CKK are providing important guidance to the student in terms of historical, political, and cultural context and information sources that the student is pulling from to create a story map. Information sharing between the CKK (an elder) and the WaYS student is an important component of this project (also as described by Chapman and Schott 2020), as is youth engagement in educational and professional training with the Sipayik researcher. The University team is sharing GIS and story maps support, while learning about cultural knowledge that enriches Western science and how to share information in a way that is useful to the community using the story maps platform. In this way, cultural knowledge and Western science are being paired on the community’s terms while keeping the TEK intact and confidential, which was outlined as a best practice for non-indigenous researchers engaging in partnerships with indigenous communities (Chapman and Schott 2020). Together, we are working towards embodying the “Two-Eyed Seeing” framework described by Reid et al. (2020) in which these different forms of knowledge can coexist and benefit everyone, while making sure the indigenous knowledge is not assimilated or reduced by integrating with Western science.
As non-indigenous researchers engaging in research with indigenous communities, the information sharing and confidentiality agreement developed during Meeting 1 was essential to ensuring TEK was only used, stored, and shared based on the wishes of the people who shared this information. This was an important piece of trust- and relationship-building that was separate from the University IRB ethics requirements in working with human subjects in research (Harding et al. 2012). Feedback from Sipayik researchers on this process included a suggestion that this component be in a written format in any future discussions. We found that self-assessing and responding to critical feedback in a positive manner that was respectful and supported elements of dignity resulted in a better outcome (Hicks 2011; Mataira 2019; Wilson et al. 2020), and from then on we produced written summaries that ensured everyone was on the same page and supported effective learning loops for knowledge co-production (Johnson 2015).

The current information sharing and confidentiality agreement outlines that the TEK discussed and documented in 2019 will remain private and confidential for internal tribal use only. While the idea of sharing cultural knowledge with a broader public audience is often proposed by non-indigenous researchers, it is not appropriate if that is not supported by the community (Chapman and Schott 2020). Even in non-indigenous communities, disclosing specific locations as a result of participatory mapping or other similar activities is often controversial and leads to distrust over how this information might be used against them (Ames 2003; Klain and Chan, 2012). Researchers are guests in the community they are working, and responding to and respecting these interests is a critical step in de-colonizing research and empowering community members to have ownership over their cultural knowledge (Mataira 2019). The elements of dignity (Hicks 2011) and the access, standing, and influence components
of the TOV theory (Seneca 2011) are fundamental in ensuring that all participating groups are building and maintaining trust through this participatory process.

Building on the best practice of discussing intellectual property allowed us to respectfully acknowledge that the tribe has ownership over the TEK (Harding et al. 2012; Davies et al. 2020), while also discussing ways to engage Sipayik researchers as equal partners in future research. A Sipayik researcher was engaged in a series of workshops as part of a separate study (see Chapter 1), and we continued to partner with their department to involve them in this study from the beginning. However, the information sharing and confidentiality agreement spurred further discussion on how to include the Passamaquoddy Tribe more effectively as a partner in research as part of the formal Institutional Review Board (IRB) in working with human subjects. One such example of this is the Penobscot Nation in Maine, which has an existing Memorandum of Understanding (MOU) with the University of Maine in which proposed research projects involving Penobscot territory or community requires a first review by the Penobscot IRB review board (Penobscot-University of Maine MOU 2018). Harding et al. (2012) identified IRBs affiliated with tribes as a way to “ensure against potentially adverse impacts to tribal individuals or governments that may be overlooked by academic IRBs.” Wilson et al. (2020) also suggests that including indigenous researchers and communities in the academic ethics review process is an essential piece of supporting self-determination and greater ownership over research that involves their communities or land. We hope to pursue this discussion in the future if this formalized review procedure continues to reflect the needs and interests of the Sipayik community.
2.6 Conclusion

During the course of this work, we followed some well-established best practices for engaging tribal communities, particularly as non-indigenous researchers (Drew 2005; Mataira 2019; Chapman and Schott 2020), while also adding and expanding on a few that were particularly relevant to our capacity sharing process. Along the way, we learned a lot as non-indigenous researchers, but we self-assessed and remained reflexive to emerging concerns. This allowed us to engage with Sipayik researchers and community members in a way that was more meaningful by focusing on their needs, interests, and concerns. We found that there are ways to include both indigenous knowledge and Western science in mutually beneficial co-existence, similar to the “Two-Eyed Seeing” framework (Reid et al. 2020). In looking towards integrating different types of information to inform natural resource decision-making (Verma et al. 2016), there remains significant questions and debate as to whether TEK should be integrated with Western science for a public audience, and if so, how to do this in a way that ensures that this does not violate cultural beliefs or alter cultural knowledge (Kimmerer 2013; Lowan-Trudeau 2012; Mataira 2019; Chapman and Schott 2020; Davies et al. 2020; Reid et al. 2020; Wilson et al. 2020). Most importantly, we left this question of whether and how to integrate or pair these forms of knowledge up to the Sipayik researcher, CKK, and WaYS student who are engaged in this work, rather than a decision made by our non-indigenous research team.

There is still more work to be done and this project is ongoing, but work conducted up until the writing of this thesis has highlighted the need for open, dignified, and respectful dialogue to build trust and relationships, as well as clearly recognizing, acknowledging, and accepting that all participating groups have important knowledge and expertise to contribute (Hicks 2011; Whyte et al. 2016; Mataira 2019). Despite these ongoing discussions, our key
components to meaningful engagement (Figure 5) have applications in working with other indigenous communities in Maine and beyond. Engaging a WaYS student and CKK led to important discussions about community issues that had not previously been brought up, specifically water quality concerns. The capacity of a community to respond to water quality risks depends on access to information, particularly on water rights and alternative sources of water (Lausier and Jain 2019). By working with the Sipayik researchers to make TEK and Western science datasets accessible and providing technical GIS and story maps training, the student can now pair these different forms of knowledge and make them more useful, relevant, and impactful for the Sipayik community. In addition, there is now a Sipayik researcher dedicated to maintaining the TEK map and story maps long-term. These key components for capacity sharing can be applied to partnerships with other indigenous researchers to empower communities to have greater ownership over the research process while making different forms of knowledge useful and accessible for community decision-making (Drew 2005; Mataira 2019; Davies et al. 2020).
CHAPTER 3

ALTERNATIVE FISHING STRATEGIES IN A TIDALLY DYNAMIC ECOSYSTEM IN DOWNEAST MAINE

3.1 Abstract

The Western Passage, located in Downeast Maine, is a tidally dynamic system that has been identified as a prime site for a type of marine renewable energy (MRE) development called tidal power. However, this is a challenging system to collect biophysical information in, and incomplete data on the fish species present in the Passage was identified as a knowledge gap by regulators. Coastal communities in Maine have a deep recreational and commercial fishing culture, and the Passage is a culturally significant area for the Passamaquoddy Tribe. Building on local knowledge about fish species, we took a collaborative approach and included multiple methods of fish data collection by engaging local recreational fishers in two citizen science data collection efforts and testing the use of a hook-and-line survey to fill the gap. Citizen science fishing datasheets were handed out to two charter captains in 2018. We conducted a pilot fishing survey from July through August 2019. Four sites were fished by boat in the Western Passage, and a fifth land-based site was fished at the Eastport Breakwater. A second citizen science project was initiated at the Eastport Breakwater in 2019 to engage local fishers in dialogue about the local marine ecosystem while collecting fish data. We caught six species, listed here in order of most frequently caught: Atlantic mackerel (*Scomber scombrus*), longhorn sculpin (*Myoxocephalus octodecemspinosis*), Atlantic herring (*Clupea harengus*), shorthorn sculpin (*Myoxocephalus scorpius*), Atlantic cod (*Gadus morhua*), and Atlantic pollock (*Pollachius virens*). Based on the Shannon-Weaver Diversity Index, we found that the Eastport Breakwater
site might be representative of the species richness in the Passage since all six species were captured at the Breakwater; however, this site also had the lowest species evenness and overall diversity. Continued monitoring would be needed to increase the sample size and effort to determine whether these diversity patterns between sites persist. Although the small sample size limited the statistical analyses that we could conduct with this dataset, we did collect important information on fish species present in the Western Passage using alternative, collaborative approaches that built on local expertise to fill a regulatory knowledge gap.

3.2 Introduction

The Quoddy region is an international, tidally dynamic area bordering the State of Maine and encompassing southwestern New Brunswick, Canada. Western Passage (Figure 1) is located in the inner Quoddy region that encompasses Passamaquoddy Bay and the West Isles archipelago (Lotzke & Milewski, 2002). This region is important to both migratory and non-migratory species, including fish (e.g. Atlantic mackerel, Scomber scombrus; Atlantic herring, Clupea harengus; Atlantic salmon, Salmo salar), marine mammals (e.g. harbor porpoise, Phocoena phocoena; minke whales, Balaenoptera acutorostrata; gray and harbor seals, Halichoerus grypus and Phoca vitulina) and birds (e.g. red-necked phalaropes, Phalaropus lobatus; Bonaparte’s gulls, Larus philadelphia; common and Arctic terns, Sterna hirundo and Sterna paradiseaea) (Mercier and Gaskin 1985; Lotzke and Milewski 2002). Aggregations of plankton and fish are concentrated in “hotspots of biological activity” (Lotze & Milewski, 2002), which result from unique oceanographic characteristics that drive upwelling (Lotze & Milewski, 2002; Thorne & Read, 2013).
Western Passage is one of a series of passages that connects Passamaquoddy Bay to the Bay of Fundy (Chevrier & Trites, 1960). The bathymetry and narrower width of these passages contribute to high current velocities. Non-tidal surface circulation is further complicated by additional seasonal differences in wind patterns and compounded when factoring in the dynamic tidal ranges (Trites, 1962). Abrupt and irregular bathymetry in these passages forces water up to the surface (Genin, 2004), transporting plankton and nutrient-rich water with it (Lotze & Milewski, 2002; Genin, 2004) and thus affecting the distribution of these organisms in the water column (Brown and Gaskin 1989). This, combined with the counterclockwise circulation pattern, traps and concentrates ichthyoplankton, phytoplankton, and zooplankton that attract fish, marine mammals, and birds (Lotze & Milewski, 2002; Genin, 2004). Upwelling sites in the Quoddy region accumulate and concentrate zooplankton at the surface (Lotze & Milewski, 2002), which supports a highly productive ecosystem.

The Gulf of Maine has been identified as a prime location to develop a type of marine renewable energy (MRE), particularly from the tides called tidal power (hydrokinetic, also referred to as MHK). The Western Passage in particular is one of the best sites in U.S. waters for this energy development due to the deep bathymetry and fast tidal currents (Yang et al. 2020). The regulatory requirements of the proposed MRE development (Jansujwicz and Johnson 2013) exposed knowledge gaps that were identified by regulators and highlighted the need to better understand what fish are present in this tidally dynamic system. This information is also needed to inform the potential effects on the local community because coastal communities in Maine have a deep culture of recreational and commercial fishing (Johnson and Zydlewski 2012; Coombs 2020). Acknowledging the breadth of this local knowledge, regulators were interested to
find out whether there were alternative methods to gathering fish species presence in the Passage.

The unique bathymetric and tidal features of the Western Passage contribute to challenging turbulence that makes it a difficult system in which to conduct biophysical surveys. There is a wide range of fisheries survey methods and gear types, including trawl, traps, hook-and-line, and hydroacoustics, and each has advantages and disadvantages depending on the system and target species (Kuriyama et al. 2019). However, all gear is selective to a certain extent (Lennox et al. 2017). More advanced fisheries methods, such as the hydroacoustics and DIDSON used in previous Cobscook Bay studies (Viehman and Zydlewski, 2015; Viehman et al., 2015) are challenging methods to collect data in the Western Passage (Cammen et al. in review), although they have been used at this site in previous studies (Staines et al. 2020). Other methods using nets, such as midwater trawling, have been shown to not work well in such high tidal current and flow conditions (Viehman et al. 2019). Furthermore, species well-documented in the Western Passage area (such as mackerel and Atlantic herring) frequently evade trawl capture (Glass and Wardle 1989; Misund 1993; Vieser et al. 2014), and this fishing method is typically either lethal or causes significant injuries when successful in capturing fish.

Previous studies have documented the fish community structure in neighboring Passamaquoddy Bay (McDonald et al. 2004; Cooper and Blanchard 2016), Head Harbor Passage (McDonald et al. 2004) and Cobscook Bay (Vieser 2014; Vieser et al. 2018), yet the fish community structure in the Western Passage is not well documented due to the aforementioned sampling challenges. A survey of recreational fishers at the Eastport Breakwater, located just adjacent to the Western Passage, from May-September 2007 (Athearn and Bartlett 2008) found that fishing captures at the Breakwater are primarily Atlantic mackerel that run from late July
through September. In addition to capturing mackerel, fishers also frequent the Breakwater to catch other species, including pollock, herring, flounder, and shark. Athearn and Bartlett (2008) noted that fishing activity was described as declining due to mackerel runs being less abundant and starting later in the season. However, it is unclear whether the catch at the Eastport Breakwater or other land-based sites are representative of the fish community in the Passage.

Today, sustainable tourism, such as saltwater and freshwater recreational fishing, remains popular in this region and provides a significant source of income and economic impact for the greater Washington County region (Athearn and Bartlett 2008). Communities adjacent to the Western Passage on the U.S. side include the City of Eastport and the Passamaquoddy Tribal community at Pleasant Point (hereafter referred to as Sipayik, the term used by the community). These communities, like many along coastal Maine, are deeply connected to marine resources both culturally and economically (Johnson and Zydlewski 2012; Coombs 2020). Marine resources, especially fish, marine mammals, and invertebrates, have long been important cultural and subsistence resources for the Passamaquoddy Tribe both pre- and post-European colonization (Bassett 2015). Historically, Eastport’s economy was driven by shipping, boat-building, lumber, and fishing activities, including numerous herring weirs that supplied fish for sardine canneries (Hall-Arbor et al. 2001). Many locals and visitors pursue saltwater land-based fishing from the Eastport Breakwater, and charter fishing boats and whale-watching tours out of Eastport offer opportunities for increasingly more people to gain access to the water and interact with the marine environment.

In a system where other approaches have proved less effective, hook-and-line gear could fill a “methodological niche” as demonstrated by other studies (Kuriyama et al. 2019). The term “hook-and-line” encompasses a range of methods from smaller scale rod and reel to larger scale
longlines and drumlines (Lennox et al. 2017). Utilizing recreational hook and line (rod and reel) fishing gear offers a less-lethal alternative to trawling that has been successfully used by many local recreational fishers in the Western Passage area to target pelagic and groundfish species (Athearn and Bartlett 2008). The Gulf of Maine Sentinel Survey is an example of the effective use of both collaborative science and hook-and-line gear to collect data on fish (Henry et al. 2020).

Citizen science, also called community science (Conrad & Hilchey 2011), is well-established as an effective method for engaging non-scientists in scientific research. These programs can be efficient ways to collect data in challenging systems (Gibson et al. 2019) and in a short period of time (Foster-Smith & Evans 2003). Citizen scientists are often driven to participate in research because of their existing interest and connection to a specific area, species, or recreation (i.e. fishing and hunting) (Gibson et al. 2019). For this reason, citizen scientists often provide important knowledge and expertise that is acquired from frequent time spent in the environment of focus, broadening and benefiting the overall research program (Foster-Smith & Evans 2003; Conrad & Hilchey 2011). These programs also serve a greater purpose than solely collecting data; rather, they also engage and include non-scientists in the research process (Foster-Smith & Evans 2003). Many fisheries-specific citizen science projects involve collecting recreational and fisheries-dependent data through the use of mobile applications (Gibson et al. 2019). Previous studies on the utility of data collected by citizen scientists have shown that citizen scientists can collect, identify, and record without much error and at a similar level of accuracy as researchers (Foster-Smith & Evans 2003; Conrad & Hilchey 2011; Gibson et al. 2019). However, concerns remain about how to evaluate the reliability and validity of citizen
science data versus traditional scientific data collection due to the differences in standardization and effort (Foster-Smith & Evans 2003; Conrad & Hilchey 2011; Gibson et al. 2019).

The Western Passage is a challenging system in which to conduct biophysical surveys, but the surrounding communities provide a rich historical and current traditional, recreational, and commercial fishing knowledge. This study builds on previous collaborative work conducted by Vieser (2014) on characterizing finfish diversity in nearby Cobscook Bay. Here, we outline how we collected fish species presence data in this challenging system to determine the utility and effectiveness of a new approach and evaluate whether this protocol can be used to fill a regulatory knowledge gap. As such, we used recreational fishing gear (hook and line) and started two pilot citizen science projects to investigate: (1) what kind of data can be collected using hook and line gear in Western Passage (i.e. can we collect quantitative data for statistical analyses or will the data be useful for documenting species presence qualitatively?), (2) whether catch at the Eastport Breakwater was representative of the fish caught in the Passage, and (3) whether we can collect robust and valid data using citizen science methods.

3.3 Methods

3.3.1 Pilot Hook-and-Line Survey and Sites

Four boat-based sites and one land-based site were fished from July 9 through August 7, 2019 (Figure 8). Sites were selected to survey a wide range of the Western Passage ecosystem, including three nearshore sites (Johnson’s Cove, Murphy’s Point, and Harris Cove) and one mid-Passage site. We selected the Eastport Breakwater as the land-based site because it is an easily accessible site near the Passage. We used recreational hook-and-line gear in Sabiki rig configuration to jig for pelagic species (Figure 9). The hook size most frequently used was #4
with artificial lures of various colors. At each site, we recorded fish species, total length, fork length, and weight.

We were constrained to fishing the boat-based sites in the Western Passage as close as possible to slack tides to reduce time spent on the water during high flow conditions. This still allowed for data collection on flooding and ebbing tides closest to the slack tide over a three-hour window. This meant boat-based sites were fished 1.5 hours before and after slack tide to maximize time spent fishing during safe conditions. The boat used in our survey was an 18 ft Lund with center console, powered by a 30hp Honda outboard.

These sites were surveyed 2-3 times weekly for 40-50 minutes, a survey period that was selected to ensure that all four sites were fished the narrow three-hour window. At each boat survey site, one to two anglers fished for five minutes or until the first bite. Once captured, fish were removed from the hook and placed in a live well for later measuring. A maximum total of fifty individuals per species were measured per site, and once that number was reached the remainder were counted. An anchor could not be set at each site due to the high flow conditions and the risk of tangling fishing and anchor lines. Therefore, in addition to recording fish species and measurements, GPS location was recorded every time anglers set and then recorded again once catch was recorded and the boat was repositioned.

The Eastport Breakwater site was fished once per week for three hours. To ensure tidal cycle consistency, this site was also only fished 1.5 hours before and after slack tide to allow a comparison with the boat-based sites. One research team member fished while a second recorded data and interacted with local fishers at the Breakwater (methods listed in section 3.3.2.1). The
same fishing protocol was followed as at the boat-based sites with fish caught, i.e., 50 were measured, the remainder counted.

3.3.2 Citizen Science

3.3.2.1 Hook-and-Line at the Breakwater

The Eastport Breakwater site was selected not only for its close proximity to the Passage, but also because it is a popular public fishing location for both local and visiting fishers. This offered the opportunity for our research team to interact with local fishers and engage them in data collection by contributing fish to the study. Fish caught and contributed by local fishers at the Breakwater were measured together with our research team, and we recorded species, length, and weight using the same protocol listed in the previous section (section 3.3.1). We also asked recreational fishers questions about whether they had observed any unusual species (e.g. sharks) or what date they had caught their first mackerel (i.e. phenology observations). These data were recorded on separate datasheets. The data collected at the Breakwater will be referred to as the “Breakwater citizen science data.”

3.3.2.2 Citizen Science Fishing Datasheets

A second citizen science pilot project was initiated in July 2018 to further engage community members and gather data on the local ecosystem. To distinguish this second citizen science project from the Breakwater citizen science data, we will refer to these data as “citizen science fishing datasheets.” Fishing datasheets (Figure C.1) were handed out in 2018 and 2019 to two local captains of charter fishing boats to record fish species caught, size, and catch amount. The effort we put in to distributing these fishing datasheets to charter captains in 2018 and 2019 for this pilot project was low in both 2018 and 2019. Sites fished by these captains are primarily
within the Western Passage, including the same Johnson’s Cove site fished by our research team in 2019. The other Western Passage sites that these captains frequent are closer to Deer Island on the Canadian side of the Passage, as well as the shores of Campobello Island. Fishers on these charter boats use recreational hook-and-line gear.

3.3.3 Data Analysis

Summary statistics were used to examine the utility of the hook-and-line approach. In addition, the Shannon-Weaver Diversity Index was calculated for each site to compare species richness, evenness, and overall diversity between the sites in the Western Passage versus at the Eastport Breakwater. Additionally, ArcGIS was used to visualize the calculated ratios of mackerel to non-mackerel species at each of the five sites.
Figure 8. The 2019 Pilot hook-and-line fishing survey sites, including four boat-based (1- Harris Cove, 2- Johnson’s Cove, 3- Mid-Passage, 4- Murphy’s Point) and one land-based site (5- Eastport Breakwater).
Figure 9. Recreational hook-and-line fishing gear used in the 2019 pilot fishing survey. Western Passage Student Research Collaborative (WPSRC) undergraduate student Emma Dullaert (left) and Maine Sea Grant Extension Associate Chris Bartlett (right) with three Atlantic cod (*Gadus morhua*). IACUC protocol number A2018-08-04.
3.4 Results

In total, 573 individual fish were caught and measured during a one-month fishing period between July 9-August 7, 2019. Six species were recorded in this pilot study, listed in order of most frequently caught to least: Atlantic mackerel (*Scomber scombrus*), longhorn sculpin (*Myoxocephalus octodecemspiniosus*), Atlantic herring (*Clupea harengus*), shorthorn sculpin (*Myoxocephalus scorpius*), Atlantic cod (*Gadus morhua*), and Atlantic pollock (*Pollachius virens*) (Table 5; Figure 10). Atlantic mackerel were by far the most frequent species caught, particularly by mid-to-late July, and comprised 77.3% of the overall total fish caught in 2019. The greatest number of mackerel caught was on the last survey day on August 7, where 82 total mackerel were recorded over a single three-hour fishing period. Non-mackerel species each comprised <7% of the total overall catch. Due to the small size of the two pollock captured (total lengths of 100mm and 156 mm), they were likely what local fishers refer to as “harbor” pollock, which is the juvenile stage of Atlantic pollock that prefers inshore habitat (Bigelow and Schroeder 2002).
<table>
<thead>
<tr>
<th>Species</th>
<th>Total</th>
<th>% Total</th>
<th>Min TL (mm)</th>
<th>Max TL (mm)</th>
<th>Mean TL (mm)</th>
<th>Min Weight (kg)</th>
<th>Max Weight (kg)</th>
<th>Mean Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic Mackerel (Scomber scombrus)</td>
<td>443</td>
<td>77.3</td>
<td>135</td>
<td>344</td>
<td>267.5</td>
<td>0.055</td>
<td>0.365</td>
<td>0.167</td>
</tr>
<tr>
<td>Longhorn sculpin (Myoxocephalus octodecemspinosus)</td>
<td>40</td>
<td>7.0</td>
<td>146</td>
<td>365</td>
<td>254.5</td>
<td>0.030</td>
<td>0.445</td>
<td>0.206</td>
</tr>
<tr>
<td>Atlantic herring (Clupea harengus)</td>
<td>37</td>
<td>6.5</td>
<td>126</td>
<td>249</td>
<td>184.1</td>
<td>0.025</td>
<td>0.175</td>
<td>0.045</td>
</tr>
<tr>
<td>Shorthorn sculpin (Myoxocephalus scorpius)</td>
<td>34</td>
<td>5.9</td>
<td>137</td>
<td>389</td>
<td>235.7</td>
<td>0.025</td>
<td>1.065</td>
<td>0.273</td>
</tr>
<tr>
<td>Atlantic cod (Gadus morhua)</td>
<td>17</td>
<td>3.0</td>
<td>175</td>
<td>355</td>
<td>280.0</td>
<td>0.160</td>
<td>0.495</td>
<td>0.278</td>
</tr>
<tr>
<td>Atlantic pollock (Pollachius virens)</td>
<td>2</td>
<td>0.3</td>
<td>100</td>
<td>156</td>
<td>128.0</td>
<td>0.180</td>
<td>0.180</td>
<td>0.180</td>
</tr>
</tbody>
</table>

Table 5. The capture results summary from the pilot hook-and-line fishing survey July-August 2019 in the Western Passage and at the Eastport Breakwater.
Figure 10. Photos of the five most frequently captured species in the 2019 pilot hook-and-line survey: Atlantic mackerel (panel a), Longhorn sculpin (panel b), Atlantic herring (panel c), Shorthorn sculpin (panel d), and Atlantic cod (panel e). IACUC protocol number A2018-08-04.

The greatest number of individual fish captured was at the Harris Cove site (n=234), and the lowest number of fish captured was at the Mid-Passage site (n=21) (Table 6). We found that Harris Cove was also the shallowest and least exposed site, whereas the mid-Passage site was the most challenging to fish at due to the fast currents that caused the boat to drift quickly. The Eastport Breakwater had the highest species richness, with all six species recorded (Table 6). However, the species evenness was low because out of the 65 total fish captured at the Breakwater, 60 were mackerel, and there were single individuals recorded for each of the other five species (Figure 11). In addition to the Mid-Passage site having the lowest number of individual fish captured, this site also had the lowest species richness with only three of the
species recorded. Species richness was highest in mid-July at three sites: Harris Cove, Johnson’s Cove, and Murphey’s Point (Figure 12). The results of the Shannon-Weaver Diversity Index calculations indicate that there was the greatest diversity at the Harris Cove site (H=0.96) and the lowest diversity at the Eastport Breakwater (H=0.39) (Table 6). However, an index of 0.96 is relatively low diversity overall even though this was the highest value for this pilot survey.

Mackerel was overwhelmingly the primary catch at each site, with varying numbers of other non-mackerel species. Mackerel was the primary catch by mid-July. We calculated the mackerel to non-mackerel species ratio for each site to determine whether the Eastport Breakwater catch was representative of the boat-based sites in the Passage (Figure 13). Survey sites in the Passage had higher species evenness because of the higher percentages of non-mackerel species. The Eastport Breakwater was the only site in this study to have records of all five non-mackerel species, yet these observations reflected low species evenness because there was only one individual fish recorded for each species.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Total Species Captured</th>
<th>Total Fish Captured</th>
<th>Shannon-Weaver Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harris Cove</td>
<td>5</td>
<td>234</td>
<td>0.96</td>
</tr>
<tr>
<td>Johnson’s Cove</td>
<td>4</td>
<td>103</td>
<td>0.87</td>
</tr>
<tr>
<td>Mid-Passage</td>
<td>3</td>
<td>21</td>
<td>0.77</td>
</tr>
<tr>
<td>Murphy's Point</td>
<td>5</td>
<td>150</td>
<td>0.62</td>
</tr>
<tr>
<td>Eastport Breakwater</td>
<td>6</td>
<td>65</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Table 6. Shannon-Weaver Diversity Index calculated for each site sampled in the 2019 pilot hook-and-line fishing survey.
Figure 11. Species capture frequency by site for the 2019 pilot hook-and line survey.

Figure 12. Species richness per site on each survey date during the 2019 pilot hook-and-line survey.
Figure 13. Map visualization of the ratio of mackerel to non-mackerel species caught at each site during the 2019 pilot hook-and-line survey (1- Harris Cove, 2- Johnson’s Cove, 3- Mid-Passage, 4- Murphy’s Point, 5- Eastport Breakwater).
There were not enough data collected to compare either of the citizen science projects (Breakwater citizen science data or the citizen science fishing datasheets) with what our research team caught. Datasheets were only returned from one captain in 2018 and none in 2019. Data included species, location, and time of day, but the datasheets were primarily filled out for groups of fish caught (e.g. 1.5 gallon bucket) and listed a total length range (e.g. 13 to 14 inches) rather than recording measurements per individual fish caught. In addition to also catching Atlantic mackerel and Atlantic herring at the Deer Island and Campobello Island sites, there were also five records of sea robin caught off Deer Island. The charter captains recorded the same species at the Johnson’s Cove site as our research team, but also two Atlantic Cod, which added species presence records for that site.

Of the 573 total fish recorded in our pilot hook-and-line survey, 34 of these fish were contributed by local fishers at the Eastport Breakwater and were included in the Breakwater citizen science dataset. These included 32 Atlantic mackerel, one Atlantic herring, and one Atlantic cod. During informal discussions with local recreational fishers at the Breakwater, our research team recorded other species observations on separate datasheets. These observations consisted of documenting the presence of different fish, birds, and marine mammals at the Breakwater and surrounding areas, including the timing of when they observed certain species (e.g. mackerel) appear for the first time in 2019 compared to previous years (i.e. phenology observations).
3.5 Discussion

The data collected during this pilot fishing survey generated information on fish species present in a turbulent system over a one-month period on the slack tide. The total number of fish caught and the species represented during this study indicate that using hook and line gear in this high flow system is an effective alternative fishing method that can fill in a “methodological niche” (Kuriyama et al. 2019) where other approaches have not been effective in Western Passage (Cammen et al. in review). While these data have limited usefulness for more advanced quantitative analyses or analyses to answer questions about fish presence in relation to different tidal cycles, they do provide important insights on the presence of pelagic and groundfish species in Western Passage.

We found that the catch at the Eastport Breakwater was primarily mackerel, which is consistent with results found by Athearn and Bartlett (2008). This site had a high species richness but the lowest overall Shannon-Weaver Diversity Index. The Eastport Breakwater could be representative of the species richness found in Western Passage; however, the difference in the number of individual fish caught and overall diversity index was lower than the Passage sites and this should be kept in mind should the Breakwater be used as a representative sample for the Passage. Also, the small sample size of this pilot survey makes it difficult to make a definitive statement on whether the data collected at the Eastport Breakwater site is representative of the data collected in the Western Passage. While there is limited quantitative usefulness of these data beyond the descriptive statistics, important information on fish species presence and preliminary diversity indices are a good first level assessment that may be used by stakeholders in this region (Chapter 1). Continued monitoring at each of these sites could help determine whether the trends found in this study over one month are reflected as sample size and effort increases.
Gear selectivity likely played a role in the species and the frequency at which fish were caught (Lennox et al. 2017; Kuriyama et al. 2019). Data were collected using a Sabiki rig with four #4 hooks artificial lures of various colors without bait, all of which are factors that can affect the species and size of fish that are caught (Lennox et al. 2017; Kuriyama et al. 2019). Although mackerel can effectively evade capture (McDonald et al. 1984), the high numbers of mackerel caught compared to other species suggests gear saturation where there are more fish in the water than available hooks (Kuriyama et al. 2019). In particular, by mid-to-late July, mackerel were biting even before the gear hit bottom. This type of competitive behavior combined with fast swimming speeds could contribute to the much higher abundance of mackerel caught compared to the other species (Kuriyama et al. 2019). However, this same fast swimming speed has contributed to other studies in the region not capturing mackerel in trawl surveys (Cobscook Bay: Vieser et al. 2004). Therefore, gear selectivity likely impacted the diversity indices because it is likely to affect the species richness. However, species richness is inherently challenging to assess since it is affected by the sample size (Gotelli and Colwell 2011), which was small in this survey. This could be avoided in the future by modifying the protocol to include different sized hooks with bait to target additional species.

A major goal of the pilot citizen science fishing datasheets in 2018 and fishing at the Breakwater in 2019 was to engage local fishers in dialogue about the local ecosystem in addition to collecting physical data on fish (Foster-Smith & Evans 2003). We found that the data collected and fish contributed by local fishers provided information on fish species present in different sites in this challenging, high flow system. This information is valuable because it provides data on fish species present while building relationships with local fishers. This citizen science protocol could be modified in future studies to collect data that is more useful for
quantitative analyses. For instance, one of the primary reasons that these data had limited statistical usefulness was that the datasheets were more conducive for the way a scientist records data (measuring every individual fish) versus the way a local fisher would record (by the bucket). Since these datasheets were utilized differently than anticipated, they could be modified or a training program could be implemented on recording data like scientists if there were more participating citizen scientists (Foster-Smith & Evans 2003). Participation in a citizen science project can be challenging to increase in a city like Eastport because there is a small year-round population, but a large influx of visiting recreational fishers in the summer months. Increasing citizen science participation will require our research team to put in greater in-person effort at the Eastport Breakwater during the summer months to distribute the citizen science fishing datasheets.

3.6 Conclusion

In summary, our pilot hook-and line survey and two citizen science projects serve as starting points to fill a significant knowledge gap about fish species presence in a challenging system that is a prime location for a variety of proposed development projects. This study is part of a larger effort to understand the Western Passage on an ecosystem level using interdisciplinary methods (Cammen et al. in review). In challenging, tidally dynamic systems, there is often not just one survey method (i.e. mid-water trawling) or research approach (i.e. collaborative work with local fishers) that will be effective solely on its own (Vieser et al. 2004; Cammen et al. in review). Incorporating alternative fishing strategies and smaller-scale citizen science efforts allowed us to maximize the potential for collecting information on fish species in the Passage in response to a knowledge gap identified by regulators.
In turn, the data collected during our study was added to a data inventory list on existing Western Passage datasets that was the focus of a separate study (Chapter 1). We found that regulatory, industry, and tribal decision-makers viewed citizen science data as salient and legitimate sources of information, but the data collected by researchers in this study were viewed as more credible (Chapter 1). Further expansion to collect more fish data could involve significantly increasing efforts to engage more citizen science fishers and incorporate a training program to address the issues of credibility. Future work will require our hook-and-line protocol to be expanded to address the additional issue of gear selectivity by incorporating different hook sizes and bait. Although the data collected by our research team was viewed as credible by decision-makers, synthesized versions of these data were described to be more useful than the raw data format (Chapter 1). Thus, collecting data to fill a knowledge gap identified by regulators is a starting point; however, crafting useful and usable knowledge to inform sustainable natural resource decision-making relies on communication between researchers and stakeholder groups to understand diverse information needs and perspectives (Cash et al. 2006; Clark et al. 2016).
CHAPTER 4

EPILOGUE

The findings and lessons learned outlined in my thesis contribute to a large body of knowledge on connecting the research-implementation gap through participatory processes. Scientific research is frequently not having the impact that it could and should have, and this motivated my focus on understanding diverse decision-making needs in different contexts and at various scales to better connect the research-implementation gap. I applied three different approaches under the rubric of participatory action research (PAR) to my thesis research: knowledge co-production, participatory mapping, and collaborative approaches to data collection. Through the knowledge co-production process applied in Chapter 1, I was able to produce both useful data integration products that better addressed decision-making needs, as well as propose a modified process for researchers who want to be more thoughtful in their approach to producing and sharing scientific information. Participatory mapping methods in Chapter 2 allowed me to start a conversation and build relationships with Sipayik researchers and community members, but focusing on their needs and interests allowed me to better share capacity and engage all groups in a meaningful partnership that involves two-way information exchange. Using the same fishing methods that recreational fishers use in Chapter 3, I was able to start to fill a knowledge gap identified by regulators and determine that recreational hook-and-line gear is a feasible fishing approach to fill that gap in the Western Passage.

The elements of dignity underpin and form the basis of meaningful engagement with communities (Hicks 2011; Johnson 2015). Meaningful engagement includes interactive, two-way information exchange to help to develop trust between researchers and communities, as well
as practicing active listening to understand how communities want to be involved in the information sharing process and what information they want. We found that acknowledging elements of dignity, trust, and power were essential to effectively applying participatory processes with a variety of stakeholder groups (e.g. the diverse regulatory, industry, and tribal decision-makers engaged in the data workshops and community meetings outlined in Chapters 1 and 2). These were also an essential part of our collaborative research approach in Chapter 3, where we aimed to understand a dynamic ecosystem while acknowledging and including the expertise and knowledge of citizen scientists and other community members. Increasing community capacity to participate in decision-making processes is dependent on stakeholders having a voice in the process (i.e. access, standing, and influence described by Senecah 2011). The process of developing and maintaining trust has been shown to be an integral piece of the relationships that impact natural resource decision-making, and shared values between groups can form the foundation of trust (Leahy and Anderson 2008; Smith et al. 2013). For example, a mutual interest and shared value in understanding what information indigenous communities need motivated the collaboration between our research team and the Sipayik Environmental Department in Chapter 2.

Crafting usable knowledge to support sustainable natural resource decision-making requires researchers to be more thoughtful in their approach to creating new information and sharing it with stakeholder groups (Dilling and Lemos 2011; Clark et al. 2016). This means that researchers who want their data to be used for policy and management decisions cannot work in isolation from decision-makers, since information is only perceived to be useful and usable if it is produced in a way that is perceived to be credible, salient, and legitimate by stakeholders (Cash et al., 2003; Cash et al., 2006). Expanding our worldview beyond Western science to
understand and acknowledge other forms of knowledge and ways of knowing is an integral part of environmental stewardship and natural resource decision-making (as in the “Two-Eyed Seeing” framework in Reid et al. 2020). My thesis work to support coastal resilience by tailoring information production and sharing is ongoing, particularly the work outlined in Chapters 1 and 2. The iterative nature of participatory processes requires us to continue to take a reflexive approach to responding to changing needs and emerging interests, which has been shown to be an essential component of supporting learning loops throughout this work (as in Cash et al. 2003; Cash et al., 2006; Johnson 2015). The lessons learned here offer pathways to the better inclusion of the social perspective and community values that need to be paired with Western science to make informed and holistic marine resource decisions. In addition to incorporating the social perspective, the various challenges we encountered associated with pairing different forms of knowledge highlighted the importance of having discussions about intellectual property to counter power imbalances and help develop trust (e.g. Whose knowledge is being used? What is it being used for? Who is able to access this information?). Although this research was originally motivated by the proposed tidal power development in Downeast Maine, the findings and lessons learned here are applicable and transferable to other complex, multi-use coastal ecosystems where federal, state, tribal, and municipal decision-makers are faced with making informed decisions in high uncertainty and complexity.
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Memorandum of Understanding Between the Penobscot Nation and the University of Maine System, University of Maine (Orono), 2018.


## APPENDICES

### APPENDIX A

Table A.1. Western Passage Data Inventory List from Workshop 1

<table>
<thead>
<tr>
<th>Category</th>
<th>Dataset Name</th>
<th>Source</th>
<th>Contact</th>
<th>Dates of Collection</th>
<th>Location</th>
<th>Format</th>
<th>Other Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical and Environmental Data</td>
<td>LOBO Buoy (Land/Ocean Biogeochemical Observatory)</td>
<td>UMaine LOBO/EPSCoR SEANET Buoy Network</td>
<td>Damian Brady</td>
<td>Jan 2016 - ongoing</td>
<td>Western Passage, Eastport Shpping Channel</td>
<td>Raw &amp; Synthesized Data</td>
<td>Online access (maine.loboviz.com); up-to-date data available; good tool to query data &amp; graph results. Records a variety of environmental and physical conditions.</td>
</tr>
<tr>
<td>Physical and Environmental Data</td>
<td>NOAA Tide Predictions-Tides &amp; Currents</td>
<td>NOAA</td>
<td>NOAA</td>
<td>ongoing</td>
<td>Eastport, ME Station ID: 8410140</td>
<td>Raw Data</td>
<td>Online access (<a href="https://tidesandcurrents.noaa.gov/stationhome.html?id=8410140">https://tidesandcurrents.noaa.gov/stationhome.html?id=8410140</a>)</td>
</tr>
<tr>
<td>Physical and Environmental Data</td>
<td>Environmental Acoustics</td>
<td>ORPC/Scientific Solutions, Inc.</td>
<td>ORPC</td>
<td>2013</td>
<td>Western Passage</td>
<td>Report</td>
<td>**</td>
</tr>
<tr>
<td>Physical and Environmental Data</td>
<td>Bathymetry &amp; 3D Hydrodynamic model</td>
<td>ORPC/NREL</td>
<td>Levi Kilcher, ORPC</td>
<td>2017</td>
<td>Western Passage</td>
<td>Report</td>
<td>**</td>
</tr>
<tr>
<td>Physical and Environmental Data</td>
<td>Sub-bottom Report/Geophysical Survey</td>
<td>ORPC/CR Environmental</td>
<td>ORPC</td>
<td>2013 (?)</td>
<td>Western Passage</td>
<td>Report</td>
<td>**</td>
</tr>
<tr>
<td>Benthic Community</td>
<td>Benthic Surveys</td>
<td>ORPC/IMER Associates</td>
<td>ORPC</td>
<td>2009</td>
<td>Harris Cove, Western Passage</td>
<td>Report</td>
<td>**</td>
</tr>
<tr>
<td>Plankton Community</td>
<td>Zooplankton surveys</td>
<td>UMaine-GBZ Lab</td>
<td>Louise McGarry &amp; Gayle Zydlewski</td>
<td>Oct 2018</td>
<td>Western Passage; plankton tow sites TBD</td>
<td>Raw Data</td>
<td>Plankton tows in conjunction with fish hydroacoustic surveys; species presence/absence.</td>
</tr>
<tr>
<td>Fish</td>
<td>Fish Datasheets - Citizen Science (pelagic and demersal fish species)</td>
<td>Citizen Scientists - recreational and commercial fishermen</td>
<td>Chris Bartlett</td>
<td>July - Fall 2018</td>
<td>Western Passage</td>
<td>Raw Data</td>
<td>GPS/location, gear type, fish species, total length, numbers per hours, buckets filled.</td>
</tr>
<tr>
<td>Fish</td>
<td>Active Hydroacoustic Surveys</td>
<td>UMaine-GBZ Lab</td>
<td>Louise McGarry &amp; Gayle Zydlewski</td>
<td>2009-2011, 2018</td>
<td>Western Passage</td>
<td>Raw and Synthesized Data</td>
<td>GPS locations, Acoustic profiles (echograms), fish presence/absence, densities of fish in water column.</td>
</tr>
<tr>
<td>Fish</td>
<td>Index Cards - Cod, Atlantic Herring, Mackerel, Lobster</td>
<td>Citizen Scientists - Commercial Fishermen</td>
<td>Chris Bartlett</td>
<td>July 2018-ongoing</td>
<td>Western Passage</td>
<td>Raw Data</td>
<td>Handed out to four commercial fishermen. Won't retrieve until the last Minke is sighted (~December 2018).</td>
</tr>
<tr>
<td>Marine Mammals</td>
<td>Index Cards - Minke Whales</td>
<td>Citizen Scientists - Commercial Fishermen</td>
<td>Chris Bartlett</td>
<td>July 2018-ongoing</td>
<td>Western Passage</td>
<td>Raw Data</td>
<td>Handed out to four commercial fishermen. Won't retrieve until the last Minke is sighted (~December 2018).</td>
</tr>
<tr>
<td>Marine Mammals</td>
<td>Marine Mammal Visual Observations (BIG EYES)</td>
<td>UMaine &amp; ORPC</td>
<td>Chris Tremblay</td>
<td>Nov 2017-ongoing</td>
<td>Bishop's Property/Dog Island</td>
<td>Raw &amp; Synthesized Data</td>
<td>Survey data includes visual observations using BIG EYES (species, group number, swim direction, behavior, bearing and distance to animal) and environmental conditions (weather, beaurof scale, visibility).</td>
</tr>
<tr>
<td>Marine Mammals</td>
<td>Passive Acoustic Monitoring (PAM) - Whales and Porpoises</td>
<td>UMaine-GBZ Lab</td>
<td>Chris Tremblay &amp; Gayle Zydlewski</td>
<td>Fall 2017; July 2018-2018, ongoing</td>
<td>Western Passage</td>
<td>Raw Data</td>
<td>Audio recordings on duty cycled low frequency and high frequency programmed units.</td>
</tr>
<tr>
<td>Birds</td>
<td>Sea &amp; Shorebird Surveys</td>
<td>ORPC/Center for Ecological Research and Maine Sea Grant</td>
<td>ORPC</td>
<td>2012-2014</td>
<td>Western Passage</td>
<td>Report</td>
<td>**</td>
</tr>
</tbody>
</table>
Figure A.1. Data Workshop Feedback Forms

Thank you for your time! We value your participation in today’s meeting and look forward to working with you on this project.

To help us better plan for the future, we were hoping you could take a few minutes to provide us with some feedback. Any input you may have about the meeting, your participation, or the research is greatly appreciated!

Your thoughts about the meeting...

1. How effective was the meeting? Please rate on a scale of 1-5 (1 being the lowest score and 5 being the highest). Please circle the appropriate response.

   1     2     3     4     5

2. Please add any other thoughts about the meeting (scheduling, location, logistics, content, etc.):

About the research...

3. Do you think we missed something in our discussion that is important to your agency/organization or the project? Please be as specific as possible.

4. Any other thoughts on how to make our research more useful for you/your agency?

About your participation...

How often would you like updates on the project (please check)?

Monthly___
At scheduled meetings___
Other__________________________

What is the best way to contact you? Email_____ Phone_____ in-person______

THANK YOU! We appreciate your time and look forward to hearing your thoughts, ideas, and questions.
Figure A.2. Data Workshop 2- Data Café Raw Data Example (Nautical Chart with Handwritten LEK)
Figure A.3. Data Workshop 2- *Data Café* Raw Data Example (Citizen Science Fishing Datasheets)

<table>
<thead>
<tr>
<th>Location</th>
<th>Gear type</th>
<th>Hook size</th>
<th>Total fishing time</th>
<th>Time start</th>
<th>Time end</th>
<th>Species</th>
<th>Length (mm)</th>
<th># individuals</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandhills</td>
<td>Fluke</td>
<td>1.0</td>
<td>11:00-13:00</td>
<td>11:00</td>
<td>12:00</td>
<td>Flounder</td>
<td>250</td>
<td>5</td>
<td>Fresh Fish</td>
</tr>
<tr>
<td>Deep River</td>
<td>Trawl</td>
<td>2.5</td>
<td>12:00-14:00</td>
<td>12:00</td>
<td>13:00</td>
<td>Cod</td>
<td>900</td>
<td>3</td>
<td>Fish, Seal</td>
</tr>
</tbody>
</table>

Date: 7-24-18
Captains: Brian (H2R1), # crew: 2
Weather: Fog, 75°F, 10-20 knots, vessel: Trawler, # passengers: 10
Tide: Flood and ebb
Sea temp: 53°F
(1) Table Host Guidelines

⭐ Your role is to observe, ensure participants are recording ideas, and re-direct discussion as needed (using prompt questions on card #2).
⭐ Welcome participants to the table.
⭐ **Important:** make sure key insights are recorded! Remind participants to note key ideas on the paper provided and **to be as specific as possible.**
   ○ Encourage everyone to participate.
   ○ If one person is dominating the conversation, try to make space for quieter participants to talk.
⭐ When a new round begins, briefly share key insights from previous group (written on the paper). Encourage participants to link ideas between tables for deeper conversation!

(2) Table Host Prompt Card

⭐ Start with **primary** data example. Switch to **secondary** data example ~ halfway through round (this is flexible, don't force a switch if conversation is still ongoing about primary data example).
⭐ Allow participants to review data for a couple minutes before discussing!
⭐ In general, if a statement is made about data utility, make sure to ask **why** and encourage other participants to chime in. Example questions:

1. What are your initial impressions on this data format?
2. After reviewing, how usable is this data format? How/ why not?
3. Any comments on scale? Source of data?
4. Access: Have you seen these data? Do you have ready access to this data?
5. Can you give an example of where they may have used these data/information?
6. Are you able to use this data to make a decision on the example scenario?
7. How useful was this in your decision-making? Why or why not?
APPENDIX B

Figure B.1. Flyer to Recruit Participants for the June 2019 Community Meeting at Sipayik

We are looking to better understand fish, marine mammals, and birds in the Western Passage area in Passamaquoddy Bay.

Please join us to discuss:

• Incorporating your knowledge
• Local fishing initiatives
• Other collaborative opportunities

Wednesday, June 12, 2019
6-7:30pm @ the Bingo Hall
Food and refreshments will be provided!

Questions? Contact:
Chris Johnson
Sipayik Environmental Department
207-904-7366

Gabriella Marafino
University of Maine
gabriella.marafino@maine.edu
Figure B.2. Research Team Discussion Prompt for the June 2019 Community Meeting at Sipayik

Discussion Leaders – Please cover the following:

- What does fishing mean to you(r family) and your community (now and historically)?
  *Note: We want to specify that we aren’t just asking about commercial fishing!

- What makes Western Passage and Passamaquoddy Bay so valuable to you and/or your community?
  *Prompt examples: ways that fishing could be valuable (food, recreation, income, cultural, etc.).

- What do you think should be documented about the Western Passage and Passamaquoddy Bay region?
  - What HISTORICAL information can you share? PINK (or light color)
    *Example prompts:
    - Where would you go to find [fish, marine mammals, birds]?
    - On an average day on the water, what would you expect to see?
    - Any variation by seasons?
    - When did you observe this (general timeline)?
  - What CURRENT information can you share? – BLUE OR BLACK
    *Specifically, what CHANGES have you seen more recently?
    - Any changes in where you would go to find [fish, marine mammals, birds]?
    - Any changes in what you see in an average day on the water?
    - When? Where?

- Is there a written source for this information?
  - Can it be shared?
  - How can it be shared?

- If not written, are there any stories (oral histories) about this information
  - If yes, would you or others in the community be willing to share these stories at another time?
    *Explain that these stories are another important source of knowledge that can help inform our understanding of the area- we might be able to extract useful data from those!

- What new projects would you like to see done that could be of use to you and/or your community?
Figure B.3. Feedback Form for Community Meetings at Sipayik

Thank You for Coming Today!

Before wrapping up and heading home we have just a few more questions:

Name: ____________________________________________

Affiliation to Western Passage and/or Passamaquoddy Bay region: _______________________

How effective was the meeting? Please rate on a scale of 1-5 and circle the appropriate response (5 being the most effective):

1  2  3  4  5

Please add any other thoughts about the meeting (scheduling, location, logistics, content, etc.)

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Would you be willing to help us collect fish data for the project we discussed today (Circle one)?

Yes  No

If yes, do you plan to pick up datasheets and a fish measuring board from: (circle one)?

Chris Johnson  Chris Bartlett

__________________________________________________________________________

What is the best way to contact you?

Phone Number: ___________________________ Email: ____________________________

If you have any additional comments, please write them on the back of the page.

Thank You Once Again for Coming!
Figure B.4. Flyer to Recruit Participants for the September 2019 Community Meeting at Sipayik

Community Meeting

We are looking to better understand fish, marine mammals, and birds in Western Passage and Passamaquoddy Bay.

Please join us to discuss:

- An overview of work done this summer, including an online map of local knowledge
- Sharing stories with community members and researchers
- Opportunities for future collaboration

Questions? Contact:

Chris Johnson
Sipayik Environmental Department
207-904-7366

Gabriella Marafino
University of Maine
gabriella.marafino@maine.edu

Thursday, Sept. 19, 2019
6-7:30pm @ location TBD
Food and refreshments will be provided from 5:30-6pm!
Figure B.5. Research Team Discussion Prompt Cards for the September 2019 Community Meeting

Instructions for GIS Leaders-
1. After welcoming the group, start with a basic introduction to ArcGIS Online.
2. Describe how this is an interactive map and show how to pan, zoom in/out, click on points for more information.
3. Briefly show the list of datasets on the map (left hand side of screen).
4. Allow each participant to spend some time with the map.
5. Important: We don’t want participants to feel put on the spot. If they seem very uneasy or unsure about wanting to manipulate the map, the GIS leader can take over for them.

Please cover the following discussion points:
- What are your initial thoughts? Was this what you were expecting?
- Use “little” prompts:
  ○ How was that to use?
  ○ Was that easy to find?
- Check-ins: we want to be responsive to them!
  ○ Was this what you were expecting?
  ○ Did we fall short in anything?
- What information/combination of datasets is most interesting to you?
- Would you or others in your community use this map?
  ○ Are you most interested in using one dataset or combining multiple datasets together?
- Is there one format that is more useful than the other?
  ○ Interactive vs. printed map?
  ○ Computer vs. phone?

Instructions for Notetakers:
- Record answers along with questions that the discussion leader asked (for context).
- Make note of verbal & non-verbal actions (pauses/uneasiness/uncertainty).
- What information format are participants most often interacting with?
APPENDIX C

Figure C.1. 2019 Citizen Science Fishing Datasheets Template

PLEASE RETURN TO: Chris Bartlett at the Eastport Port Authority Office

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Fishing Time</th>
<th>Species</th>
<th>Total Length [mm] *tip of the snout to end tip of the caudal fin</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
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</table>

<table>
<thead>
<tr>
<th>Date:</th>
<th>Captain:</th>
<th>Vessel:</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tide:</td>
<td>Weather:</td>
<td>Gear Type, Hook Size:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Crew:</td>
<td># Passengers:</td>
<td># Fishing:</td>
</tr>
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</tbody>
</table>

2018 Datasheet for Recreational Fishermen
BIOGRAPHY OF THE AUTHOR

Gabriella Marafino was born in Washington, D.C. on August 17, 1992. She was raised overseas in England, Germany, and Russia, where she graduated from the Anglo-American School of Moscow in 2010. She attended George Mason University and graduated in 2015 with a bachelor’s degree in Biology and a minor in Applied Conservation Studies. She worked for two and a half years at the Smithsonian Environmental Research Center in Edgewater, MD. She then moved to Maine and started the Ecology and Environmental Sciences graduate program at the University of Maine in the summer of 2018. After receiving her degree, Gabriella will be starting as a 2021 John A. Knauss Marine Policy Fellow with the NOAA Budget Office, Division of Formulation and Communications. Gabriella is a candidate for the Master of Science degree in Ecology and Environmental Sciences from the University of Maine in December 2020.