Developing a Community-Based Environmental Monitoring Program for Butter Clams in Metlakatla Territory

by
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Abstract

Community-based environmental monitoring (CBEM) offers locally adapted and culturally relevant methods that Indigenous peoples, and others, can use to lead or participate in natural resource decision-making. Explicitly incorporating community values and local and Traditional Knowledge into monitoring programs can provide social, cultural and environmental benefits. In collaboration with Metlakatla First Nation, I designed and tested a monitoring protocol for butter clams (*Saxidomus gigantea*), which are highly valued by Metlakatla people. The CBEM protocol for butter clams supports Metlakatla's efforts to track and manage cumulative effects by collecting baseline data on butter clams in Metlakatla territory. This research demonstrates that CBEM is an effective approach for collecting data that will be used to inform local environmental decision-making. Based on this initial application of the CBEM protocol, I make recommendations to inform Metlakatla's approach to monitoring additional environmental components, and to guide other Indigenous communities seeking to develop community-based approaches to monitoring.

Keywords: community-based environmental monitoring; cumulative effects; intertidal clams; environmental decision-making; Indigenous Knowledge

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List of Acronyms

BC	British Columbia
CBEM	Community-Based Environmental Monitoring
CBM	Community-Based Monitoring
CEM	Cumulative Effects Management
CI	Condition Index
EA	Environmental Assessment
FSC	Food, Social and Ceremonial
GI	Growth Index
LK	Local Knowledge
SK	Scientific Knowledge
TEK	Traditional Ecological Knowledge

Chapter 1. Introduction

1.1. Research Context:

1.1.1. Managing socio-ecological and cultural systems amid increasing development and environmental change

Natural resource development and global environmental change are negatively affecting the ecological, social and cultural systems on which humans depend (IPCC, 2014). An enduring challenge facing society is how to manage trade-offs between the benefits and adverse impacts of development. In order to make wise choices, decision-makers require reliable methods for gathering data on historical and current baseline conditions in socio-ecological systems, and for monitoring changes in those systems over time.

Community-based environmental monitoring (CBEM) – environmental monitoring involving community members as participants – has been recommended as a locally adapted and culturally relevant approach for Indigenous peoples to lead or participate in natural resource decision-making. In this research, I collaborated with Metlakatla First Nation to design and test a CBEM program for butter clams (*Saxidomus gigantea)*, a highly valued ecosystem component for Metlakatla people. This CBEM program will provide baseline and ongoing monitoring data to inform planning and management by Metlakatla of their traditional territory.

1.1.2. Community-based approaches to environmental monitoring and management in Indigenous communities

CBEM is an approach where individuals, community groups and/or non-governmental organizations are key participants in monitoring activities (McKay & Johnson, 2017). Other terminology in the literature includes participatory environmental monitoring (Turreira-García et al., 2018), citizen science (Aceves-Bueno et al., 2015), community-based observing networks (Alessa et al., 2016), community-engaged research

(Adams et al., 2014), locally-based monitoring and public participation in scientific research (Danielsen et al., 2014). While related, these terms represent different formulations of community-engaged monitoring. For example, community-based observing networks are made up of observers with specific skills and experience related to the local area, who use their perspectives to make assessments. Conversely, citizen science typically engages community members as data collectors but refrains from gathering participants' perspectives and opinions (Alessa et al., 2016). In this study, I use CBEM as an umbrella term that refers to any environmental monitoring involving non-professional, local participants (e.g., community members who are not accredited as scientists).

Increasingly, CBEM is being adopted as a means for Indigenous peoples to lead or participate in assessment and decision-making, particularly with respect to environmental impact assessments (EAs) and the cumulative effects arising from development projects (McKay & Johnson, 2017a; Wiseman & Bardsley, 2016). Indigenous-led CBEM is a response to the gaps and failures of conventional monitoring programs that have often overlooked the perspectives and knowledge of Indigenous communities by not providing meaningful opportunities to participate in research, monitoring or mitigation activities (Ritts et al., 2016; McKay & Johnson, 2017a). Incorporating Indigenous values, Traditional Ecological Knowledge (TEK) and local knowledge (LK) can increase the success of monitoring programs and help to ensure that monitoring efforts are relevant to the community's needs and values (Adams et al., 2014; McKay & Johnson, 2017a). It is well documented that combining multiple knowledge systems (TEK, LK and scientific knowledge [SK]) into monitoring has resulted in new insights into, and understandings of, environmental systems, and improved management of natural resources in Canada (Alessa et al., 2016; Atlas et al., 2017; Ban et al., 2017; Berkes, M., Berkes, H., & Fast, 2007; Gearheard et al., 2011; Gérin-Lajoie et al., 2018; Housty et al. 2014; Mantyka-Pringle et al., 2017; Polfus, Heinemeyer & Hebblewhite, 2014; Suffice et al., 2017; Tengo et al., 2014; Trembley et al., 2008).

Indigenous peoples in Canada have constitutionally protected rights to lands and resources within their traditional territories. Provincial, territorial and federal governments have a legal obligation to consult and accommodate Indigenous people on matters of resource extraction and development that may affect those rights (Government of Canada, 1982). However, despite their legal rights, Indigenous communities remain disproportionately affected by adverse environmental effects from development (Mantyka-Pringle et al., 2017; Mitchell & D'Onofrio, 2016). Indigenous-led CBEM can play a role in ensuring that non-Indigenous decision-makers are aware of the interests and concerns of local Indigenous peoples (McKay & Johnson, 2017a).

In recent years there has been progress toward improved engagement with Indigenous communities in Canada, as a result of greater recognition of Indigenous rights in new legislation (e.g., BC's *Declaration on the Rights of Indigenous Peoples Act* [SBC 2019, ch. 44]), case law (e.g., *Tsilhquot'in Nation v. British Columbia*, 2014) and policy agreements (e.g., Recognition and Reconciliation of Rights Policy for Treaty Negotiations in BC, 2019). Decision-making authority is also shifting more to Indigenous governments through co-management and government-to-government arrangements (Adams et al., 2014). Indigenous-led CBEM can play a role here as well, by directly involving communities and community knowledge in decision-making at the local scale and beyond.

1.1.3. CBEM and cumulative effects in the traditional territory of Metlakatla First Nation

Metlakatla First Nation (Metlakatla) are an Indigenous people whose traditional territory is located on the Pacific Coast in northwestern British Columbia. In 2014, in response to an unprecedented increase in the number of industrial development projects proposed within Metlakatla territory – primarily liquid natural gas facilities and port expansion projects –Metlakatla leaders decided to develop a Metlakatla-made cumulative effects management (CEM) program so that they could better understand and manage the potential impacts of these developments on their community (Zeeg & Kwon, 2017). Cumulative effects assessment involves identifying and assessing the combined effects (past, present and future) of human activities and natural processes on a resource or valued component of the socio-cultural or biophysical environment (Gunn & Noble, 2011; Jones, 2014). Valued components are the features of the human and natural environment that individuals and groups of people consider important (British Columbia

Environmental Assessment Office, 2013). Understanding and monitoring the impact of cumulative effects on valued components is critical for protecting and maintaining those values in the face of uncertainty and change.

Typically, major resource development projects in British Columbia (BC) require a provincial or federal environmental assessment (EA) before they are approved. Within these EA processes, cumulative effects are usually assessed only as part of the EA of each individual project (McKay & Johnson, 2017). In addition, such assessments often fail to consider the values and priorities of local Indigenous communities (Lawe et al., 2005; O'Faircheallaigh, 2007). The Metlakatla CEM Program was instituted by Metlakatla leaders due to their concerns about the failures of traditional EA to address the combined impacts of proposed developments on the aspects of life Metlakatla value most.

Metlakatla values are the foundation of the Metlakatla CEM Program (detailed in section 3.3). The Metlakatla CEM Program is centered on five pillars of values: 1) cultural identity; 2) governance; 3) social/health; 4) economic prosperity; and 5) environment (MSS, 2019). For each pillar, the working group that developed the Metlakatla CEM identified valued components and their corresponding condition indicators (indicators that track the condition of a value), based on community-based research on values and indicators (MSS, 2019). Butter clams were identified by Metlakatla as a high-priority valued component of the environment, and population density (measured as # individuals/m^2), was selected as the corresponding condition indicator (MSS, 2019).

Baseline data are required to assess the condition of a valued component and to monitor changes over time, but when the CEM program was developed, Metlakatla lacked good data on butter clam populations in Metlakatla territory. My research, conducted in collaboration with Metlakatla, sought to close the data gap by developing and then testing a comprehensive butter clam monitoring plan, using a CBEM approach. Linking monitoring data to decision-making is key to successful CBEM (McKay & Johnson, 2017a; 2017b). Accordingly, the Metlakatla CEM Program has identified tiered management triggers and associated management strategies to link monitoring results for butter clams and other valued components with the implementation of mitigation and management strategies designed to protect those values (MSS, 2019).

Aside from meeting monitoring objectives for butter clams under the Metlakatla CEM Program, the CBEM program developed in my research will generate butter clam monitoring data that could be applied in project-based EAs, risk assessment and project consultation (Kouril, Furgal & Whillians, 2016), stock assessment for food, social and ceremonial (FSC) purposes, restoration initiatives, traditional and cultural revitalization efforts, and local and regional conservation, marine use and planning initiatives.

1.1.4. Designing an Indigenous-led community-based environmental monitoring program for butter clams in Metlakatla territory

Goals and objectives for the Metlakatla butter clam CBEM program were derived from the Metlakatla CEM Program and through discussions with the local Metlakatla community and Metlakatla Stewardship Society managers. The broad desired goal for butter clams in the Metlakatla CEM Program is to protect and improve the health and abundance of bivalve populations for continued harvesting by Metlakatla First Nation (MSS, 2019). The Metlakatla butter clam CBEM program is designed to collect population data on butter clams in Metlakatla territory and monitor changes in these populations over time, including changes arising from the adverse cumulative effects of industrial development and other activities. The CBEM data will not only provide a better understanding of how butter clam populations are changing over time but will inform local environmental decision-making by Metlakatla Stewardship Society managers.

While there are other examples of collaborative Indigenous-led CBEM programs in Canada (Atlas et al., 2017; Ban et al., 2017; Berkes, M., Berkes, H., & Fast, 2007; Gearheard et al., 2011; Herman-Mercer et al., 2018; Herrmann et al., 2014; Housty et al., 2014; Gérin-Lajoie et al., 2018; Lawe, Wells and Cree, 2012; Ratelle et al., 2018; Thompson et al., 2019; Trembley et al., 2008; Wilson et al., 2017;), scholars and practitioners have called for more case studies that explore the successes and challenges of Indigenous-led CBEM, to add to the growing knowledge in this field (Conrad and Hilchey, 2011, Johnson et al., 2015). Specifically, more examples are needed of CBEM programs where the data are not only collected, analyzed and interpreted by the Indigenous community, but the community also has decision-making authority (Johnson et al., 2015). The Metlakatla CBEM program provides such an example. Indigenous community members, managers and planners have authority over the program, and it incorporates community values and objectives. Non-Indigenous collaborators (including me) have contributed to the design and implementation of the program, but decision-making authority is vested in Metlakatla managers. Collaborative Indigenous-led CBEMs reported in the literature often engage community members strictly as data collectors, without allowing those members' perspectives and local expertise to shape the purpose and format of the program or interpretation of the data (Turreira-García et al., 2018).

Guided by principles for effective CBEM from the literature (Conrad & Hilchey, 2011; Kouril, Furgal & Whillans, 2016; McKay & Johnson 2017a; 2017b; Thompson et al., 2019), the Metlakatla CBEM program attempts to maximize opportunities for social, cultural and environmental benefits while addressing a baseline data gap required for management of bivalves in Metlakatla territory. Lessons learned and recommendations from this study should also inform Metlakatla's approach to CBEM of additional valued environmental components identified in the Metlakatla CEM Program and may offer guidance to other Indigenous communities embarking on CBEM in their territories.

1.2. **Overview of Research Objectives**

The goals of this research are to design a CBEM program for butter clams that incorporates the values, knowledge and objectives of Metlakatla First Nation, and to implement the program to collect baseline data on butter clams. To reach these goals, the primary research objectives are to:

1. Design and implement a bivalve monitoring protocol to collect baseline data on butter clams on representative beaches in Metlakatla territory, guided by current knowledge and key principles from the field of CBEM.
2. Incorporate Metlakatla values and multiple knowledge systems (TEK, LK and SK) into the design and implementation of the monitoring protocol.
3. Use the monitoring data to assess the condition of butter clam populations on the selected beaches.

4. Refine the monitoring protocol based on implementation experience and provide Metlakatla First Nation with training and resources to continue the community-based bivalve monitoring program autonomously.
5. Inform future approaches for establishing the baseline condition of valued environmental components, by Metlakatla or other coastal First Nations, by assessing the challenges and benefits of a CBEM approach to monitoring and making recommendations to address the challenges.

1.3. Situating Myself

I am a Settler Canadian of European descent, predominately English and Scottish. I was born in the small, rural town of Havelock, which is located in southern Ontario. While I was not raised with this knowledge, I now understand that the area where I grew up is in Haudenosaunee, Huron-Wendat and Anishinaabek territories, and part of the Williams Treaty. My upbringing was characterized by a deep appreciation for nature and a lot of time spent outdoors. It was my lifelong interest in environmental issues that led me to pursue this master's degree in resource and environmental management and planning.

In 2014, I lived in Vancouver but spent some time in Prince Rupert and the north coast region of BC. I was concerned about the dramatic rise in proposed liquid natural gas projects in the area and how cumulative effects from those projects may impact local ecosystems and communities. As someone from a small town, I empathized with rural communities who were facing the potential for dramatic changes to the places they call home. I was compelled to engage in this environmental issue because it reflects a common challenge facing society—reconciling the environmental, economic, social and cultural trade-offs of development. I also recognized that environmental issues are inextricably linked to Indigenous rights. I developed this understanding after moving to BC and learning the meaning of 'unceded' territories and how social and political systems of governance relate to Aboriginal legal rights, sovereignty and environmental issues. The recognition that protecting the environment and supporting Indigenous peoples' rights are complementary actions was further informed by studying environmental issues in university and after becoming politically engaged in opposing the Enbridge Northern Gateway pipeline in BC. I learned by listening to Indigenous leaders and community members about the ways in which their sovereignty and environmental rights were being threatened by development projects proposed in their territories.

I was motivated to work with and take direction from the Metlakatla First Nation for this research because they are on the forefront of the proposed development on the north coast and their ways of life and their sovereignty are directly tied to the health of the land and water. Although my research contributes but a small piece of a much larger effort, helping to advance Metlakatla's work to manage and protect their environment in the face of uncertainty offered a rewarding outcome for my research labour. Beyond that, I hope this research can be useful to other communities who seek a community-based approach to environmental monitoring and decision-making.

1.4. Report structure

This report has five remaining chapters. The second chapter provides background on the academic and grey literature related to CBEM, including the trends, challenges and opportunities discussed in the literature, and the practices being applied on the ground. Chapter two also discusses the application of CBEM in Indigenous communities. The third chapter provides an overview of Metlakatla First Nation and the Metlakatla CEM Program. The fourth chapter describes the research methods and results and is organized into six parts: 1) case study objectives; 2) designing the Metlakatla butter clam CBEM program; 3) pre-survey and bivalve survey protocol design; 4) implementation of the Metlakatla butter clam CBEM protocol; 5) key results from the 2018 butter clam surveys; and 6) overview of the data collected during the 2019 surveys. Chapter five discusses the findings from this study, including lessons learned, limitations of the research and recommendations for future research.

Chapter 2. Community- Based Environmental Monitoring

2.1. Trends in Community-Based Environmental Monitoring

CBEM is recommended as "an effective method for engaging in dialogue, cooperation and tracking environmental change" (McKay & Johnson, 2017a). Interest in community-based monitoring (CBM) continues to rise, both in scholarly literature and in applied practice. In a recent review of academic and grey literature on CBM, Kouril, Furgal & Whillans (2016), identified an increasing trend in CBM research and practice over the last thirty-five years. Approximately 83% of all CBM literature they reviewed was from the field of environmental science, though CBM is applied across diverse disciplines from public health to international development to education (Conrad & Hilchey, 2001; Kouril, Furgal & Whillans, 2016). In the field of environmental science, monitoring of water quality, biological impacts of global climate change, biodiversity, land-use and species-at-risk are some of the most common applications of CBEM discussed in the literature (Conrad & Hilchey, 2011; Dickinson et al., 2012; Herman-Mercer et al, 2018; Johnson et al., 2015).

Much of the literature on CBEM, in the Indigenous context in particular, is focused on how to improve the application of CBEM in practice. In particular, studies have examined how to engage the community better throughout the whole monitoring process, from design to end-use of the data (Mckay & Johnson, 2017a). Turreira-Garcia et al., (2018) found that in a majority of CBEM programs, citizens' involvement was primarily limited to data collection, whereas the design of the monitoring projects and the analysis and use of the data was done by 'professionals'(e.g., land managers, foresters).

CBM has been applied on every continent except Antarctica, with North America having the most CBM initiatives (Kouril, Furgal & Whillans, 2016). Indigenous populations are well represented in CBM. Close to twenty percent of the CBM literature reviewed by Kouril, Furgal & Whillans (2016) was from research in an Indigenous community or group of communities. Relevant to the Canadian context, Métis, First Nation and Inuit populations represented 6.4% of the CBM in peer-reviewed literature, and 16.2% of the CBM in grey literature (Kouril, Furgal & Whillans, 2016). The remainder of this paper focuses on CBM in an environmental context and I will refer to it as CBEM.

Rising interest in CBEM approaches has been attributed to a number of trends, including growing public awareness of environmental degradation and global climate change, concern over the effectiveness of monitoring by governments, recognition of TEK, and even the increasing use of smartphone technology (Andrachuk et al., 2019; Conrad & Hilchey, 2011; Ward-Fear, Pauly & Vendetti, 2019). In some cases, CBEM has been undertaken in response to a failure by a government body to address or acknowledge an environmental concern (see Ban et al., 2017). Local citizens take on the task of monitoring a component of the ecosystem that would otherwise not be monitored because it is in their best interest to do so (Conrad & Hilchey, 2011). In Indigenous communities, Indigenous peoples are expanding the use of CBEM programs as a strategy for asserting sovereignty over their territories, in parallel with increasing legal recognition of Indigenous rights (Wilson et al., 2018). With regard to development projects in Indigenous territories in particular, CBEM provides a process for the community to voice concerns and frame their perspectives on development projects, and to assess and monitor subsequent cumulative effects (McKay & Johnson, 2017).

Given the ubiquity of digital technology, use of devices like smartphones and tablets has greatly increased in CBEM (and in citizen science projects, in particular) as an affordable, portable and relatively easy way to collect and share environmental data over a large spatial scale and to upload data and communicate in real time (Andrachuk et al., 2019; Kipp et al., 2019). Utilizing mobile technologies for CBEM also has its challenges, including ensuring data quality, managing data and the high costs associated with developing smartphone applications. While these challenges may hinder the utilization of mobile technologies, overall the use of these technologies is influencing environmental monitoring methods and is playing an increasingly bigger role in CBEM (Andrachuk et al., 2019).

A number of recent studies have comprehensively reviewed CBEM programs to identify key elements, factors contributing to success, sources of failures, benefits and challenges, and to provide recommendations to communities and practitioners. An important component of any CBEM program is the level of involvement, influence and decision-making power of the community. Researchers have found a positive relationship between how much decision-making authority the community has and how much they benefit from the CBEM program (Kouril, Furgal & Whillans, 2016; McKay & Johnson, 2017a; Wiseman & Bardlsey, 2016). A typology of community participation, developed by Kouril, Furgal and Whillans (2016), (adapted from Danielsen et al., 2009) identifies, in order from least inclusive of community members to most inclusive, four categories of community participation:

1) externally driven monitoring with local data collectors;

2) collaborative monitoring with external analysis and interpretation;

3) collaborative monitoring with local analysis and interpretation; and

4) autonomous local monitoring (no involvement of external parties).

Reviews of CBEM programs reveal many collaborative CBEMs in practice but few that had local analysis and interpretation, and no autonomous programs in published literature (Ho, Eger & Courtenay, 2018; Kipp et al., 2019, Lam et al., 2019; Turreira- garcía et al., 2018). It is likely that autonomous monitoring programs are happening in practice, especially in Indigenous communities where informal environmental monitoring is often a way of life, but this approach is not represented in published literature (Kouril, Furgal & Whillans, 2016).

Similarly, Conrad and Hilchey (2011), describe a spectrum of community involvement in CBEM resulting from differences in the governance structure of the monitoring program (adapted from Lawrence, (2006)). They use the terms 'consultative/ functional' (top-down approach), 'collaborative' (multi-party approach) and 'transformative' (bottom-up approach) to describe types of CBEM governance structures. Many CBEM programs will not fall neatly into just one of these categories, but assessing the ways in which participation, objectives and governance (e.g., decision-making and power relations) influence CBEM outcomes is a current theme in the literature (Conrad & Hilchey, 2011).

2.2. Benefits of CBEM

CBEM utilizes the knowledge and capacity of local citizens to advance collective understanding and improve the effectiveness of natural resource monitoring, management and decision-making (Aceves-Bueno et al., 2015; Conrad & Hilchey, 2011; Danielsen, Burgess & Balmford, 2005; 2010, McKay & Johnson, 2017a). Results from CBEM programs not only inform local management actions but may have impacts beyond the local scale, such as enhancing regional environmental management or supporting the development of provincial or national environmental health policies that directly affect local communities (Ho, Eger & Courtenay, 2018; Ratelle et al., 2018).

Involving the community in monitoring means there are many eyes for observing and a diversity of perspectives and experiences to enrich and expand the collective understanding of environmental issues (Dicknson, 2012; McKay & Johnson, 2017a). When monitoring is locally adapted and relevant to the community, greater success can be achieved by all stakeholders because collective knowledge of environmental issues is improved. In this way, the knowledge generated by CBEM may be considered a shareable public good (Conrad & Hilchey, 2011; McKay & Johnson, 2017a; Triezenberg et al., 2012). Moreover, when monitoring is of value to the community, it can strengthen community buy-in and increase local compliance with management decisions (Aceves-Bueno et al., 2015; McKay & Johnson, 2017a; Thompson et al., 2019).

CBEM can be more cost effective than conventional professional monitoring, thus increasing the sustainability of monitoring in the long-term. Studies have shown that data collected by non-professionals can be as reliable as professionally collected data, particularly when there has been a process of training, data validation and calibration (Conrad & Hilchey, 2011; Danielsen, Burgess & Balmford, 2005; Herman-Mercer et al., 2018). For spatially extensive or long-running monitoring initiatives, such as the Christmas Bird Count – a citizen science program which has been collecting data on bird populations since 1900 (Audobon, n.d.) – CBEM tracks environmental change over large spatial and temporal scales that would be otherwise be infeasible.

CBEM can benefit local people and society at large by increasing scientific literacy, inspiring citizens to become environmental advocates, providing education and experience and building social capital (Aceves-Bueno et al., 2015; Alessa et al., 2016; Conrad & Hilchey, 2011; McKay & Johnson, 2017a). CBEM also contributes to democratization of environmental monitoring and management because of its inclusiveness, representativeness, accessibility and transparency (Conrad and Hilchey, 2011; Danielsen, Burgess & Balmford, 2005). Beyond benefitting the individual and community, collaborative CBEM can build trust and relationships across sectors (community, industry, government, academia) and improve communication between parties (McKay & Johnson, 2017a).

2.3. Challenges of CBEM

A practical challenge of CBEM is developing methods that are scientifically rigorous yet operationally feasible. In a literature review, Conrad & Hilchey (2011) found that data credibility is a well-documented challenge for CBEM. Many scientists and policy makers are hesitant to accept CBEM data despite evidence that community-derived data can be of the same quality as professional data (Herman-Mercer et al. 2018; Johnson et al., 2015). Decision-makers have criticized CBEM for being potentially biased (toward an environmentalist agenda), incomplete, non-comparable or lacking in quality, leading to a perception that data credibility is low (Conrad & Hilchey, 2011). If decision-makers question the validity of the data, it will limit the degree to which it can influence environmental and resource management decisions (Conrad & Hilchey, 2011; McKay & Johnson, 2017 b; Wilson et al., 2018).

For the data to be credible and reliably used for decision-making (especially beyond the local scale), methods should adhere to scientific standards of ecological monitoring (Burgos et al., 2013). To further mitigate data quality problems, the use of non-professionals in monitoring programs requires training, quality assurance and quality control measures, and efforts to reduce the potentially high turnover of participants, particularly if they are volunteers (Conrad & Hilchey, 2011; Johnson et al., 2015). However, the level of data quality needed may depend on the goals and objectives of monitoring. Herman-Mercer et al., (2018), suggest that the precision of the data simply needs to match the level of precision required for management decision-making; in some circumstances the costs of increasing the level of precision may outweigh the benefits of having additional certainty.

Even with high quality data, it may be difficult to get data and results into the hands of the appropriate decision-makers; if the governance structure of the CBEM program is not tied to decision-making, the application and impact of the work will be limited (Brower, 2016; Conrad & Hilchey, 2011).

Another challenge for CBEM program design is effectively incorporating multiple forms of knowledge. Despite evidence which shows that monitoring and management regimes that include multiple knowledge systems can achieve better resource management outcomes and social benefits (Aceves-Bueno et al., 2015; Conrad & Hilchey, 2011; Danielsen, Burgess & Balmford, 2005; Danielsen et al., 2010; Polfus, Heinemeyer & Hebblewhite, 2014), ecological research and monitoring is still largely influenced by the western-scientific paradigm that dominates resource management and conservation in Canada (Adams et al., 2014). Researchers and practitioners may not know how to appropriately gather TEK or LK, or may lack the resources or relationships to do so; the process of accessing and using TEK can be a project on its own (Huntington, 2000). Incorporating multiple evidence bases into monitoring requires an interdisciplinary approach and supportive partnerships. As such, using a multiple evidence-based approach requires additional time and financial resources that can exceed that which is typically required in conventional scientific monitoring (Asselin, Leblanc & Gauthier, 2018; Polfus, Heinemeyer & Hebblewhite, 2014).

Some scholars caution against simply 'integrating' TEK with SK because it may disadvantage Indigenous peoples and result in power imbalances. Instead, a 'bridging' of different knowledges is recommended (Lertzman, 2010; Mantyka-Pringle et al., 2017). Mantyka-Pringle et al., (2017) recommend 'bridging' TEK and SK by building a political power-neutral method for the co-production of knowledge. In their study of developing a Baysian belief network for assessing ecosystem health, Mantyka-Pringle et al., (2017) used nuanced methods (multiple modalities), meaningful involvement of Indigenous peoples and expert opinion from people with various backgrounds (e.g., Elders, social and natural scientists, government).

Other common challenges for CBEM programs include limited funding, technical and human resources (Aceves-Bueno et al., 2015; Conrad & Hilchey, 2011; McKay & Johnson, 2017b).

2.4. Recommendations from the literature

In recent studies by McKay and Johnson (2017a; 2017b), recommendations for improvement of CBEM were gathered from local industry, government and Aboriginal people engaged in CBEM approaches in Canada. The studues identified four key criteria of effective CBEM: 1) efficacy of environmental monitoring; 2) social cohesion or relationships; 3) ability to inform decision-making; and 4) effectiveness of CBEM for Aboriginal communities. Recommendations for effective CBEM agreed upon by all parties (industry, government and a First Nation) could be grouped under one of the four criteria including requiring well-defined methods and data confidence, improving cross-sector communication, identifying decision maker's objectives and including TEK and baseline information. Other common recommendations for successful CBEM are community leadership and the use of innovative technology (Kipp et al., 2019).

Indicator selection is also an important part of the CBEM process and Ho, Eger & Courtenay, (2018) recommend that practitioners work to improve approaches for identifying, refining or prioritizing candidate indicators and indicators that link environmental status to human health, particularly in Indigenous contexts (Kipp et al., 2019)

Based on a review of literature on citizen science and CBEM, Conrad and Hilchey (2011) suggest that moving from a less collaborative to a more collaborative approach can improve environmental monitoring outcomes overall (Conrad & Hilchey, 2011). Studies of CBEM suggest that project designs that engage community members in CBEM and include them in decision-making processes achieve better social and environmental outcomes (Brower, 2016; Conrad & Hilchey, 2011; Danielsen et al., 2010). Despite evidence showing the importance of community involvement, however, many CBEM programs exclude local people from decision-making and instead vest that authority in external parties (Johnson et al., 2015; McKay & Johnson, 2017a, 2017b; Turreira-Garcia et al., 2018).

Scholars have expressed the need for more published reports on CBEM case studies both in Indigenous and non-Indigenous contexts. There is a demand for better documentation and evaluation of the successes and challenges of CBEM programs in published reports, to better compare studies and facilitate learning among practitioners (Burgos et al., 2013; Conrad and Hilchey, 2011; Danielsen et al., 2009; Kouril, Furgal and Whillans, 2016). The fact that publishing is typically of more interest to external researchers and collaborators than to community members may explain the limited number of published case studies on community-led CBEM. Additionally, issues of data ownership or the publication of sensitive data or TEK/LK may also deter communities, particularly Indigenous communities, from publishing or otherwise sharing their data (Johnson et al., 2015). Case studies from community-led collaborations are rarely published, and cases of autonomous CBEM were not represented in the literature at all (Gérin-Lajoie et al., 2018; Kouril, Furgal & Whillans, 2016). Conrad and Hilchey, (2011) call for wider publication of case studies specifically illustrating the use of CBEM-derived data by decision-makers, or failures to link data collection with decision-making. Gaining a better understanding of the barriers to connecting data with decision-making may inform better CBEM design and implementation processes.

2.5. **CBEM in an Indigenous context**

As researchers, industry and government institutions move toward adopting more collaborative approaches to monitoring and management in Canada, especially in light of recent developments regarding legal recognition of Indigenous rights, it is likely that the number of examples of Indigenous-led CBEM programs will rise. Indigenous peoples' cultures, traditions and ways of life are inextricably linked to the lands and waters of their territories. In response to environmental degradation and contemporary environmental and political challenges, Indigenous peoples are expanding the use of CBEM programs as a strategy for asserting sovereignty over their territories (Wilson et al., 2018).

In the context of environmental decision-making and CBEM, Indigenous communities in Canada differ from non-Indigenous communities in three key ways: 1) Indigenous communities are disproportionally exposed to environmental harms (Mantyka-Pringle et al., 2017; McKay & Johnson, 2017a; Mitchell & D'Onofrio, 2016) 2) Indigenous peoples have a legal right to be consulted on proposed development projects (Gimenez, 2019); and 3) TEK is a " cumulative body of knowledge and beliefs, evolving by adaptive processes and handed down through generations through cultural transmission" (Berkes, 1999, pg. 8) and is commonly applied in Indigenous CBEM (Alessa et al., 2016; Ban et al., 2017; Gérin-Lajoie et al., 2018; Kouril, Furgal & Whillans, 2016; Parlee, Geertsema & Willier, 2012). These differences are discussed below.

Indigenous peoples in Canada are disproportionately affected by adverse environmental impacts resulting from development projects, a phenomenon known as environmental racism (Mantyka-Pringle et al., 2017; McKay & Johnson, 2017a; Mitchell & D'Onofrio, 2016). Despite potential environmental, social, and cultural harms that development projects may inflict, affected Indigenous communities do not always have the opportunity to engage deeply in project review or the related monitoring and management activities (McKay & Johnson, 2017a; Mitchell & D'Onofrio, 2016). However, CBEM is being adopted as a way of meaningfully including local Indigenous peoples in assessment, decision-making and long-term monitoring of the impacts from the development of natural resources (McKay & Johnson, 2017a).

Indigenous peoples are legally entitled to be consulted when their constitutionally affirmed rights may be affected by adverse impacts from a project (Gimenez, 2019). However, the law does not provide complete details on how consultation must occur and how engagement should inform a decision (Gimenez, 2019). Consultation has been criticized by Indigenous peoples as coming too late in the project approval process, happening too quickly, failing to adequately address cumulative effects of natural resource development at a broader scale (including past damages), not accounting for historical and systemic environmental impacts and failing to resolve outstanding land claims (Gimenez, 2019). Consultation often takes place through an EA process (Gimenez, 2019). EA is the primary way in which Indigenous groups are given the opportunity to express their concerns and perspectives regarding a proposed development project and its impact on their ways of life (McKay & Johnson, 2017a). EA and the environmental decision-making process have been criticized for the level of discretion that is granted to the final decision-makers, and for poorly accommodating different knowledge sources such as TEK and LK, which are critical for the expression of Indigenous values (Gimenez, 2019).

In light of these challenges with the EA process, a promising development was the Province of BC's enactment of the *Declaration on the Rights of Indigenous Peoples Act*, in November 2019. The Act requires the provincial government to take measures to ensure that provincial laws are consistent with the United Nations Declaration on the Rights of Indigenous Peoples (Gunn & Donovan, 2019). A key part of the Act is the development of a framework for shared decision-making between the Province and Indigenous governments, which should affect provincial EA by giving Indigenous communities more involvement and decision-making authority (Gunn & Donovan, 2019).

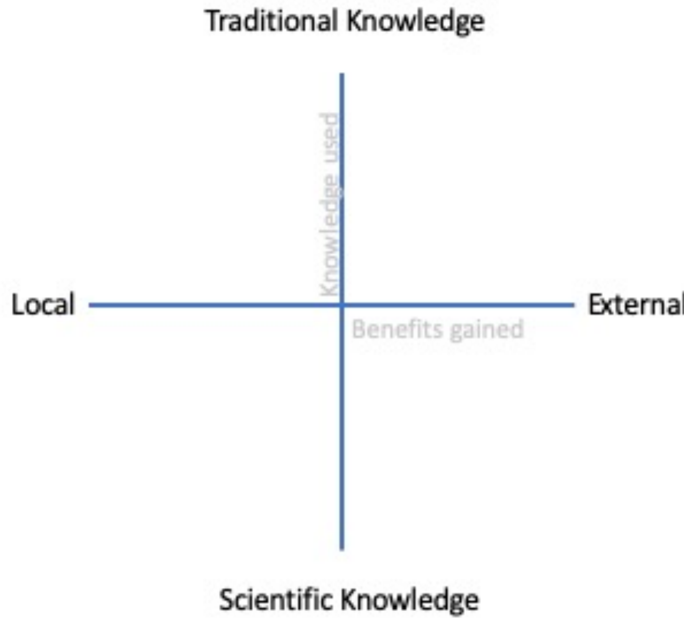
Indigenous peoples are intimately familiar with the environmental norms they have established in their traditional territories and have been interpreting environmental information for millennia in order to successfully hunt, fish, gather, travel safely and practice cultural activities, (Gérin-Lajoie et al., 2018; Johnson et al., 2015; McKay & Johnson, 2017a). TEK, passed down through generations, is the result of this deep understanding of local conditions and observations of environmental change. TEK also incorporates cultural and spiritual beliefs into Indigenous peoples' understanding of the natural world. TEK contributes to CBEM by revealing and filling gaps in SK, offering alternative explanations of observations and ensuring that environmental monitoring is relevant to local people, thereby informing a more comprehensive picture of environmental change (Gérin-Lajoie et al., 2018; McKay & Johnson, 2017a).

Given how Indigenous communities are situated, both in the context of ongoing development of natural resources in their traditional territories, and with respect to the valuable contributions of Indigenous Knowledge systems, Indigenous-led CBEM is increasingly being explored, particularly in the circumpolar North (Conrad & Hilchey, 2011; Hermann et al., 2014). There are published examples of CBEM in Indigenous communities, especially among Métis, First Nations and Inuit populations in Canada, in northern regions in particular. Kouril, Furgal and Whillans' (2016) review of the trends and key elements in CBEM shows that Inuit in the circumpolar north host the greatest number of Indigenous-CBEM programs reported in both grey and peer-reviewed literature (12.9% and 3.6% respectively). Popularity of CBEM in northern communities is unsurprising given that they are on the forefront of environmental impacts of climate change, including reduced ice flow, melting permafrost, and animal migration shifts that impact their way of life (Anisimov et al., 2007). Key elements that are common in successful northern Indigenous-led CBEM programs are: 1) incorporating TEK and LK; 2) ensuring adequate funding; 3) building capacity; 4) training; 5) setting agendas and negotiating vision and objectives; 6) offering compensation or other incentives; 7) obtaining feedback and practicing clear communication between parties; 8) using information and communication technologies; 9) identifying a local coordinator; 10) employing qualitative methods and; 11) using standardized and simple methods (Kouril, Furgal & Whillans, 2016).

Indigenous communities may decide to develop or take part in a CBEM program for a number of reasons. Communities may be inspired to take action because their daily lives are affected by climate change, or because of their dissatisfaction with the current management (or lack thereof) of a resource or environmental public good (Ban et al., 2017). In other cases, efforts to engage in traditional practices and establish renewed self-determination and management of natural resources have motivated a CBEM approach (Atlas et al., 2017), particularly because "self-determination in resource management requires approaches that are themselves self-determined" (Housty et al., 2014). CBEM programs have also emerged out of concerns over development projects and associated cumulative effects, or from augmentation of the consultation triggered by an EA (Lawe, Wells & Mikisew Cree, 2012; McKay & Johnson, 2017a).

Monitoring assessments conducted by Indigenous communities have focused on a wide variety of issues and objectives, including: large-scale environmental change and adaptive management (Berkes M., Berkes H., & Fast, 2007; Johnson et al., 2015 ;Trembley et al., 2008; Wiseman & Bardsley, 2016;); Indigenous food security (Lam et al., 2019; Ratelle et al., 2018); water quality (Burgos et al., 2013; Gérin-Lajoie et al., 2018; Herman-Mercer et al., 2018; Ho, Eger & Courtenay, 2018; Wilson et al., 2018); cumulative effects from development (McKay & Johnson, 2017a, 2017b; Parlee, Geertsema & Willier, 2012); human health impacts from climate change (Kipp et al., 2019); ecosystem status (Lyver et al., 2018); species conservation and changes to habitat (Herrmann et al., 2014; Housty et al., 2014); social, political and wildlife indicators related to harvesting of marine resources (Thompson et al., 2019); and fisheries management (Atlas et al., 2017; Ban et al., 2017; Savo, Morton & Lepofsky, 2017).

Wiseman & Bardsley classify Indigenous-led CBEM methodologies in terms of two spectrums (Figure 2.1). One spectrum represents the integration of TEK and ranges from full inclusion of TEK on one end of the spectrum, to the exclusive use of SK on the other. The second spectrum represents the party who benefits most from the monitoring, and ranges from local to external. Considering where a CBEM program falls along these two spectrums is helpful for predicting the likelihood that it will achieve positive outcomes for local communities. When portrayed as two intersecting axes the top left quadrant represents projects that have a high integration of TEK and empowerment of local communities, which would typically indicate the most positive outcomes for local Indigenous peoples. Conversely, CBEM programs falling in the bottom right quadrant, prioritize external interests and use SK as the dominant source of information. Understanding how the knowledge systems and program beneficiaries interact to determine outcomes is important when considering the design or evaluation of any Indigenous-led CBEM program.



Adapted from Wiseman and Bardsley, 2016.

Figure 2.1 Spectrum of types of knowledge and primary beneficiary of monitoring, used to typify CBEM programs.
CBEM programs can be placed anywhere within a quadrant to represent the level of Traditional Ecological Knowledge integration in the program and which party predominantly benefits. Programs falling within the upper left quadrant are most beneficial for Indigenous communities.

In Indigenous-CBEM, incorporating values, knowledge and perspectives of Indigenous peoples helps to ensure that the monitoring is locally relevant and of value to the community (McKay & Johnson, 2017a). One way to elucidate values and understand perspectives is to incorporate Indigenous Knowledge systems into CBEM design and implementation. LK and TEK are forms of Indigenous Knowledge and are commonly applied in Indigenous monitoring programs and other environmental studies. Definitions of each type of knowledge system vary slightly but are fundamentally similar across the literature. SK, also referred to as 'western science', is knowledge held by trained scientists and is largely quantitative, reductionist and centred on hypothesis testing (Asselin, Leblanc & Gauthier, 2018; Mantyka-Pringle et al., 2017). LK is predominately held by Indigenous peoples and is built on years of empirical evidence, but unlike TEK, LK does not incorporate values or beliefs (Adams et al., 2014). TEK is "…a combination of adaptively evolving practice, belief and knowledge of natural systems… transmitted culturally through generations over millennia" (Adams et al., 2014). TEK is a key strength of Indigenous communities' approach to monitoring and can effectively elucidate environmental changes, such as those caused by resource development and/or climate change (Parlee, Geertsema & Willer, 2012). Because TEK is passed down over generations, it can help identify what environmental conditions were like in the past and provide a better understanding of spatial and temporal trends and the general stability or instability of socio-ecological systems (Herman-Mercer et al., 2018; Wiseman & Bardsley, 2016). Some scholars refer to LK and TEK collectively as Indigenous Knowledge (Berkes, 1999), local and Traditional Ecological kkowledge (Thornton & Scheer, 2012), Indigenous ecological knowledge or local ecological knowledge (Aswani, Lemahieu, & Sauer, 2018;).

A recent review of global literature on LK and Indigenous ecological knowledge found a global trend of impoverishment of these knowledge sources; losses in knowledge are attributed to "globalization, modernization and market integration" (Aswani, Lemahieu & Sauer, 2018). Given the interconnectedness of cultural and biological diversity, losing these knowledge sources can have severe impacts on the environment, particularly in community-based conservation efforts (Aswani, Lemahieu & Sauer, 2018). However, in studies where there was a concerted effort to maintain traditional practices and where these knowledge sources were valued, persistence of these types of knowledge was reported (Aswani, Lemahieu & Sauer, 2018).

It is well established that applying TEK and LK in conjunction with SK, enhances collective understanding of socio-ecological systems and can improve environmental monitoring and management outcomes (Houstey et al., 2014; McKay & Johnson, 2017a; Thompson et al., 2019; Wiseman & Bardley, 2016). Adams et al., (2014) explain that "when a knowledge system and worldview does not separate people from place, western science cannot disregard the cultural influence that permeates the ecosystem in which research occurs." Tengo et al., (2014) call this a 'multiple evidence base' approach and recognize that applying LK, TEK and SK together provides new insights, innovations and complementarities. In other words, the whole is greater than the sum of its parts. Taking a multiple evidence-based approach to collaborative projects is increasingly called for in planning, research, monitoring and conservation to protect marine resources and the environment (Thornton & Scheer, 2012). Researchers suggest that when there is a higher integration of TEK with SK in CBEM programs, there is greater success for all parties involved (Wiseman & Bardsley, 2016), not least because utilizing these formal (scientific) and informal (local) knowledge systems helps reduce uncertainty in environmental decision-making (Ostrom, 1990). In Indigenous CBEM, incorporating values and perspectives of Indigenous peoples helps to ensure that the monitoring is locally relevant and of value to the community, (McKay & Johnson, 2017a).

2.5.1. Benefits of CBEM to Indigenous peoples

Employing CBEM in Indigenous communities can provide tangible improvements in environmental conditions. Case studies in the literature illustrate that CBEM can increase the abundance of economically or culturally important species (Atlas et al., 2018; Ban et al., 2017; Groesbeck et al., 2014), influence environmental health policies (Ratelle et al., 2018), advance governance objectives and self-determination (Hermann et al., 2014; Wilson et al., 2018), monitor adverse environmental impacts from development (Herrmann et al., 2014) and improve adaptive management (Alessa et al., 2016). CBEM can build the capacity and skills of individuals, engage community members in the scientific process, and generate relevant data that can be used at the local scale for management decisions (Gérin-Lajoie et al., 2018; Hermann et al., 2014). Participation of youth in CBEM can inspire a connection to the land, help reduce the loss of LK and TEK (Aswani, Lemahieu & Sauer, 2018) and even increase the interest of students in science, leading to higher levels of high school completion and university enrollment (Gérin-Lajoie et al., 2018). However, youth from remote Indigenous communities often have to leave their community to pursue educational or work opportunities, meaning that youth are generally underrepresented in Indigenous CBEM programs (Gérin-Lajoie et al., 2018)

Including multiple evidence-based knowledge in CBEM can build trust between parties, which is especially important for Indigenous communities who historically have been systematically marginalized, especially in research. Recognizing TEK as being as valuable as western SK is a long overdue acknowledgement that makes space for Indigenous communities to “regain control and ownership of their knowledge that has historically been appropriated through centuries of colonization and reintroduced as anecdotes from non-Western others” (Alessa et al., 2016, p. 95). Combining TEK with SK can provide Indigenous communities with knowledge that is valuable for governance as well as environmental objectives (Adams et al., 2014), but Indigenous Knowledge holders must hold equal authority with scientists when collecting, validating and co-creating knowledge (Thompson, 2019).

With respect to CEM, Indigenous-led CBEM has emerged as an effective approach for monitoring valued components and considering cumulative effects. Indigenous-led CBEM can provide a locally adapted and culturally relevant method for Indigenous communities to lead, or participate in, natural resource decision-making and management (McKay & Johnson, 2017b).

2.5.2. Challenges of CBEM in an Indigenous context

Most of the challenges associated with CBEM that were discussed in section 2.2.2 are common for CBEM in Indigenous contexts as well (e.g., difficulty retaining volunteers, inexperience of non-experts with scientific protocols, funding and logistical issues), (Conrad & Hilchey, 2011; Gérin-Lajoie et al., 2018).

Specific to Indigenous-led CBEM is the application of TEK, which is not always easy to access, and which may be overlooked and under-appreciated by external partners. Inadequately acknowledging and utilizing TEK can result in missed opportunities for enhanced understanding of the socio-ecological system being monitored, empowering local people, improving the effectiveness of environmental management and conservation and reducing uncertainty in environmental decision-making (Johnson et al., 2015; McKay & Johnson, 2017a).

In many cases, external partners (industry, government, researchers) have their own agendas that dictate research objectives and they fail to adequately include the values and interests of the community (McKay & Johnson, 2017a). Where the community is not a full participant throughout the CBEM process, mistrust between stakeholders may develop and the relationship building that is key to successful collaborative CBEM will be strained. Success of Indigenous-led CBEM can be impeded when decision-making authority is vested in people and institutions outside of the community, which lessens the impact of monitoring and limits the application of the results (Johnson et al., 2015).

Indigenous communities are often located in rural areas where internet connectivity and telecommunication can be weak, making the adoption of some web-based technologies, or the sharing of knowledge and data more difficult than in well-serviced areas (Kipp et al., 2019).

2.5.3. Recommendations from the literature

Key recommendations for developing CBEM programs with Indigenous communities that aim to maximize the benefits to the community and to society as a whole include: 1) increasing the integration of TEK and co-production of knowledge; and 2) supporting meaningful community participation from design to data interpretation and decision-making (Wiseman and Bardlsey 2016; and see Figure 2.1). Based on recommendations from industry, government and Indigenous peoples, McKay and Johnson (2017a; 2017b), identified four fundamental components to consider when developing or improving an Indigenous-led CBEM program: 1) efficacy of environmental monitoring; 2) ability to inform decision making; 3) social cohesion or relationships; and 4) effectiveness of CBEM for local communities (Table 2.1).

Table 2.1 Key recommendations for effective development or improvement of Indigenous-led CBEM.

Key components in the development or improvement of a collaborative Indigenous-led CBEM program, as recommended by representatives from industry, government and a First Nation	
Key components of CBEM	**Examples**
Efficacy of environmental monitoring	- defined methods - community driven - locally adapted - data confidence - communicate results - include cumulative effects - supported (financially & politically)
Social cohesion and relationships	- establish trust - build relationships - develop partnerships - ongoing cross-sector communication - information sharing - mutual respect
Ability to inform decision making	- identify decision-makers objectives - consult decision-makers prior to program establishment - promote awareness and understanding of program
Effectiveness of CBEM for Indigenous communities	- link with culture - focus on local issues - include TEK and baselines - include community values - use a multiple evidence-based approach - build capacity for community participation - meet industry and government standards - maintain continuity through political shifts

Adapted from McKay & Johnson, (2017a)

Published examples of collaborative Indigenous-led CBEM that demonstrate the incorporation of TEK are needed. Similarly, more case studies that explore how monitoring data informs decision-making and whether decision-making power is held by the community, shared with the community or withheld from the community, would be beneficial for providing effective approaches or identifying gaps to be addressed in practice (Conrad and Hilchey, 2011, Johnson et al., 2015). With consent from the community, more case studies could be documented publicly so the knowledge generated from monitoring *and* from the CBEM process itself can become a shareable public good. Sensitive information or data that communities do not wish to be in the public domain could be omitted from the results or have identifying characteristics removed prior to publication. Still, there may be hesitation from some community groups to publish results.

The literature also recommends CBEM approaches to address specific environmental issues. For example, Kipp et al., (2019) call for more CBEM programs that connect monitoring of environmental impacts from climate change to health and well-being and suggest the use of integrated environment-health indicators to do so. This is particularly important in Indigenous-led CBEM because Indigenous worldviews recognize environment health and human well-being as inextricably linked. Cumulative impacts from development is another significant area in which CBEM approaches could make positive contributions and improve upon the status-quo. Current cumulative effects monitoring is typically a siloed approach that is conducted and assessed on a project-by-project basis, rarely considers all past or future impacts, and inadequately includes community values and perspectives (McKay & Johnson, 2017a). CBEM approaches can be more effective at documenting, preventing and mitigating impacts through cross-sector collaboration and provide an opportunity to empower the community in the process (McKay & Johnson, 2017a).

Finally, more research funding should be directed to programs that explicitly acknowledge and value Indigenous perspectives, priorities and concerns, although this does seem to be an increasing trend that reflects progress being made in the recognition of Indigenous rights (Kouril, Furgal & Whillans, 2016).

Chapter 3. Metlakatla First Nation and Cumulative Effects Assessment

3.1. The Metlakatla First Nation

The Tsimshian are Indigenous peoples who have traditionally lived in the Nass and Skeena river region, in what is now northwestern BC. Metlakatla members are descendants of the nine tribes of the Coastal Tsimshian; today Metlakatla and Lax Kw'alaams are the two distinct First Nations that belong to the Coast Tsimshian group (Metlakatla Governing Council (MGC), 2015).

Metlakatla means 'salt water pass' in Sm'algyax, the language of Metlakatla people (Metlakatla First Nation, 2016). Today, there are very few Metlakatla members who are fluent in Sm'algyax because, like many Aboriginal languages, these tangible forms of culture and group identity were almost entirely exterminated through the residential school system and are now critically endangered (Truth and Reconciliation Commission (TRC) of Canada, 2015). Residential schools were a systematic government and church-sponsored attempt to destroy Aboriginal culture and language by forcibly removing Aboriginal children from their homes in an effort to assimilate them until they no longer existed as distinct peoples (TRC, 2015). Today, language teachers are working to bring the language back to the community in Metlakatla and Prince Rupert (MGC, 2015). Despite the legacy and continuation of colonization, Tsimshian culture persists and Metlakatla members "continue to enjoy their inherent rights and freedom to harvest traditional food, practice traditional ceremonies and honour their history and lineage" (MGC, 2015).

Metlakatla has an extensive traditional territory, covering approximately 20, 000 square kilometers of the Great Bear Rainforest, including roughly 2,575 km of coastline (Figure 3.1) (MGC, 2015). Metlakatla Village, the Nation's current home community, is located 7 km northwest of the city of Prince Rupert and is accessible only by boat (Figure 3.2). As of 2019, there were 986 registered Metlakatla members with 89 on-reserve members living in Metlakatla Village and many more living in nearby Prince Rupert (Indigenous and Northern Affairs Canada (INAC), 2019).

Figure 3.1 Map of Metlakatla territory

Figure 3.2 Map showing location of Metlakatla village on the north coast of BC

Metlakatla's territory is richly endowed with terrestrial and marine resources, including abundant fresh water, that together support important populations of salmon, trout and other fish, diverse ecosystems and healthy wildlife populations (MGC, 2015). As a coastal community, Metlakatla has traditionally been and remains a marine-oriented community with reliance on the marine environment for food, livelihood and cultural practices. Livelihoods are largely based on participating in both subsistence harvesting activities (e.g., fish, shellfish, seaweed) and jobs in the formal economy such as commercial fisheries, tourism, marine transportation, port-related employment and other resource industries in the region (e.g., forestry) (MSS, n.d.).

Metlakatla people have been stewards of their territory for thousands of years and their connection to the land, waters and resources is part of their Tsimshian cultural heritage, which manifests in their language, spiritual beliefs and stewardship responsibilities (MGC 2015). Coast Tsimshian people have always engaged in annual subsistence activities that many Metlakatla families still participate in today. The annual "round" includes practices such as fishing for eulachon on the Skeena and Nass river in the early spring, seaweed gathering, herring spawn collection, halibut fishing and cedar bark collection in late spring and early summer, salmon fishing and berry picking in the summer and then food preservation, shellfish harvesting, hunting and fishing in the autumn and winter months (Halpin & Seguin, 1990). Metlakatla people are responsible to future generations for preserving, protecting and enhancing their land, waters, resources and heritage (MGC, 2015).

The Metlakatla First Nation has four main governing departments: Metlakatla Governing Council, Metlakatla Development Corporation; Metlakatla Treaty Office; and Metlakatla Stewardship Society, which supervises the Metlakatla Stewardship Office. The Metlakatla Governing Council is the governing body of the Band elected by Metlakatla membership and is comprised of an elected chief and six councillors who serve four-year terms (MGC, n.d.). In February of 2019, Metlakatla members removed election provisions that had previously been under the jurisdiction of the *Indian Act* and ratified a custom Election Code. The Metlakatla Election Code extends voting rights to off-reserve Metlakatla members, allows voting in Prince Rupert and Metlakatla and permits mail-in ballots (MGC, n.d.).The Governing Council also oversees public works, financial management, reserve land use and management, community planning, implementing the Land Code, by-laws and disputes, and social, health and education services.

The Metlakatla Development Corporation is the business arm of the Metlakatla First Nation and has a mandate to grow its business base through joint ventures, to identify new business opportunities consistent with principles of sustainable eco-based resource management, to maintain and strengthen existing business and to build skills and capacity in the community (MDC, n.d). The Metlakatla Treaty Office is the department responsible for inter-governmental matters including treaty negotiations. At the time of writing, Metlakatla recently advanced to stage 5 of the 6-stage treaty process with the provincial and federal governments (BC Treaty Commission, 2019).

The Metlakatla Stewardship Society is the department most directly associated with this CBEM study. The work of the Stewardship Society is wide reaching, including aquatic resource management (through Metlakatla Aquatic Resources), land and marine use planning, Metlakatla Coastal Guardian Watchmen, EA and project applications, protected areas and conservation, cultural heritage and, most relevant to this work, cumulative effects management (MGC, n.d.).

3.2. Development in Metlakatla Territory

According to BC's Major Projects Inventory, there are currently 34 large development projects (valued at $15 million or more) proposed for the North Coast region of BC, about half as many as were proposed just a few years ago (BC Ministry of Jobs, Trades and Technology [BC JTT], 2019). These projects include private and public construction projects designated as proposed, under construction, completed or on hold. Of these projects, 15 are located within Metlakatla territory. Another six projects, all LNG related, are located just outside of Metlakatla territory but could potentially affect Metlakatla resources because of related shipping activity or other effects. Numerous other industries, projects and activities occur on and near Metlakatla territory, such as forestry, mining, aquaculture, small hydroelectric projects and oil and gas development, but are not accounted for in the Major Projects Inventory because they are valued at less than $15 million each. The North Coast region has been the target of immense investment interest for a number of years. The large number of proposed development projects in Metlakatla territory prompted Metlakatla leadership to ask what the cumulative impacts of these projects would be on the things Metlakatla people value, and what the community could do to better understand and manage those impacts (Kwon and Zeeg, 2017). In 2014, these questions led Metlakatla to begin developing a comprehensive and Metlakatla-made CEM Program.

3.3. The Metlakatla Cumulative Effects Management Program

The Metlakatla CEM Program is an Indigenous-led resource management system for monitoring the condition of Metlakatla values over time. By linking monitoring data to decision-making, the CEM Program supports Metlakatla managers in responding to cumulative change in Metlakatla territory (MSS, 2019). The overarching goal of the Metlakatla CEM Program is to protect, preserve, and/or improve the status of things Metlakatla people care about most (i.e., valued components).

3.3.1. Values

The Metlakatla CEM Program uses a four-step approach (Figure 3.3; MSS, 2019). Step one is identifying Metlakatla people's priority values and determining the associated condition indicators for each value. Step two involves assessing the current condition of each priority value (establishing a baseline). Step three is establishing management triggers, a series of markers that reflect increasing levels of concern about the condition of a value (Figure 3.4). Step four is the monitoring, management and mitigation stage. At the core of the initiative is the identification of the values of Metlakatla members. Input from members was combined with knowledge from subject matter experts to select values and indicators to meet selection criteria identified through research on best practices for CEM (Kwon & Zeeg, 2017). The CEM Program focuses on five pillars of values: Cultural Identity, Governance, Social/Health, Economic Prosperity, and Environment. Metlakatla decided to launch the CEM Program with a pilot project focused on four high-priority values: FSC activity; housing; employment; and butter clams (MSS, 2019).

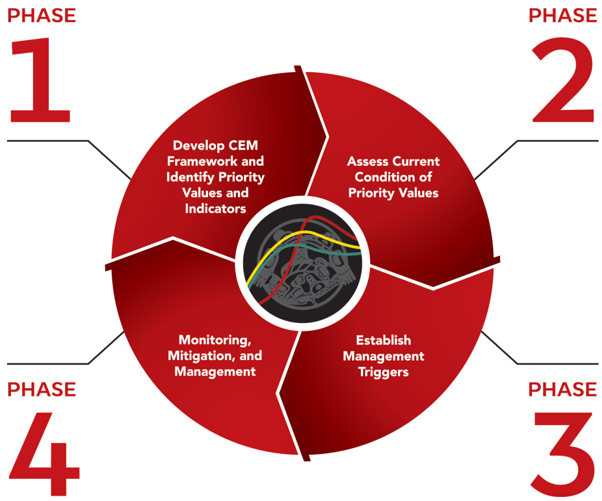


Figure 3.3 Phases in the Metlakatla Cumulative Effects Management Program
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Butter clams were chosen as a priority environmental value in the Metlatkatla CEM Program for the following reasons:

- **Important traditional resource:** Intertidal clams were repeatedly identified as a top traditionally desired, harvested and consumed resource by Metlakatla members (Fediuk & Thom, 2009).
- **Important historical and cultural resource:** Historically, clams were actively managed in Metlakatla Territory through the use of ‘clam gardens’, cultural remnants of which are visible today.
- **Important linkages to foreshore rights and title:** Evidence of clam gardens suggest that clams were an important resource for people in the territory and the existence of these sites can potentially be used to support claims of Aboriginal rights and title to intertidal and submerged lands in British Columbia (BC; Brown & Mildon, 2010).
- **Sensitive to marine pollution and contamination:** Bivalves are also important from a cumulative effects perspective because they are highly sensitive to marine pollution and contamination, both chemical and biological, and are excellent indicators of water quality and intertidal beach ecosystems (King & Day, 2014).
- **Important for other species:** Ecologically, bivalves play an important role in the energy flow of an ecosystem due to their position in the food web (Pellegrin et al., 2007).
- **Potential economic opportunities through shellfish aquaculture:** Intertidal clams also have the potential to provide a significant source of income for

Metlakatla with the increase of shellfish aquaculture and the potential increase of recreational clam diggers in the north coast region (MSS, 2016).

- **Management priority for Metlakatla and feasible to implement monitoring and management plans:** Clam survey methodologies already exist and clams are generally sessile and easy to locate, count and identify. Metlakatla also has a mandate (shared with the Department of Fisheries and Oceans Canada) to manage FSC fisheries in the territory and can do so by setting and enforcing harvesting allocations, directing harvesting activity, restoring habitat, and implementing other measures.

The broad desired goal for butter clams in the Metlakatla CEM Program is to protect and improve the health and abundance of bivalve populations for continued harvesting by Metlakatla First Nation (MSS, 2019).

3.3.2. Indicators

When determining what indicators to measure, the Metlakatla CEM working group focused on measuring the overall condition of the value, rather than the source(s) of impact (stressors) from individual projects or activities (MSS, 2019). Stressors can be additive (cumulative effect is the sum of the effects of individual stressors), synergistic (cumulative effect is greater than the sum of effects of individual stressors) or even antagonistic (cumulative effect is less than the sum of the effect of individual stressors) (Piggott, Townsend, & Matthaei, 2015). Because there are multiple stressors putting pressure on a value at any given time, monitoring the effect of each stressor is resource intensive and may not generate a full picture of how the stressors are collectively affecting the value; focusing on the condition of the value is a way of monitoring the outcome of the cumulative stressors on the value (MSS, 2019). When changes to the value are observed, further investigation of stressors may be required.

For the butter clam value, the CEM working group chose population density (measured as # individuals/m^2) as the condition indicator because it is a "common measure of population condition for bivalve species, and because bivalve population densities are specific to the time, place and species" (MSS, 2019, p.47). Stressor indicators for butter clams were identified as contaminant levels (chemical and biological), harvest levels and changes to intertidal beach habitat (MSS, 2019).

3.3.3. Management triggers and actions

Each value in the Metlakatla CEM Program has a broad desired goal, a set of tiered management triggers and a set of potential management actions that are linked to specific triggers and management zones (standard, cautionary and critical zones (Figure 3.4; MSS, 2019). Management triggers are a series of increasing thresholds that reflect increasing degrees of concern about and change in the condition of the value being studied (Kwon, 2017). The management trigger concept (Figure 3.4) supports CEM in the following ways: 1) it provides a process for linking data to decision-making; 2) it allows the community and decision-makers to determine thresholds of acceptable change in a value; and 3) it presents a proactive and precautionary approach to monitoring and management (MSS, 2019).

Figure 3.4 The Metlakatla CEM Program's management triggers concept.
The tiered management triggers concept depicts increasing levels of impacts with corresponding increases in development projects over time. Management actions are triggered if a value's condition transitions from one zone to another. Management actions are implemented to maintain or restore the value of a condition and return it to a more acceptable zone. Reprinted with permission, from the Metlakatla CEM Program Synopsis: Methods, Results and Future Direction of a First Nations-led CEM program. 2019.

Management actions in the CEM Program were designed to be effective and implementable. Linked to the tiered management triggers, associated management actions provide clear guidance to managers about when it is time to intervene and what action(s) should be taken (MSS 2019).

Chapter 4. **Designing and Implementing the Metlakatla Butter Clam Monitoring Protocol**

4.1. **Case Study Objectives**

The primary objective of this study is to design and implement a bivalve monitoring protocol with and for Metlakatla First Nation, to collect baseline data on butter clams on representative beaches in Metlakatla territory. Guided by current knowledge and principles from the field of CBEM, this study aims to maximize benefits to the Metlakatla community by explicitly incorporating Metlakatla values, perspectives and knowledge. Using the data collected with the bivalve monitoring protocol, a preliminary estimate of the condition, or status, of butter clam populations on the surveyed beaches can be made. Testing the monitoring protocol provides an opportunity to refine and improve the methods so that future iterations of butter clam monitoring are successful and can be implemented by Metlakatla autonomously. Recommendations from this study may inform future approaches for establishing baseline condition of valued environmental components by Metlakatla or other coastal First Nations.

This study fulfills a key step in the Metlakatla CEM Program (Figure 4.1). Population density is identified in the Metlakatla CEM Program as the condition indicator for butter clams.

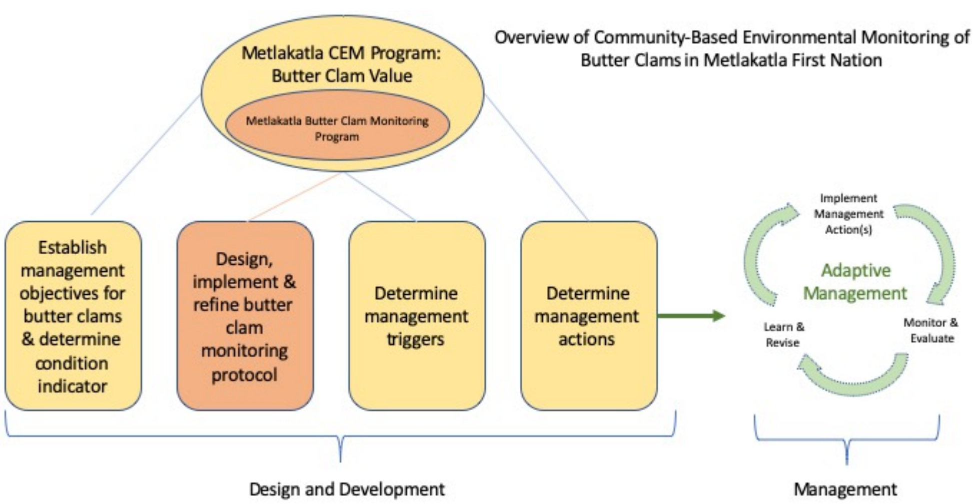


Figure 4.1 Process diagram of the Metlakatla butter clam community based environmental monitoring program.

The Metlakatla butter clam monitoring protocol is nested within the Metlakatla CEM Program. The orange box represents activities undertaken in this study.

Following recommendations from the literature, a program design objective for the Metlakatla CBEM was to select methods that were scientifically robust yet practical and affordable, given the scarcity of financial and human resources in small communities like Metlakatla.

4.2. Designing the Metlakatla Butter Clam Monitoring Protocol

The Metlakatla butter clam monitoring protocol is the key component of the CBEM program. The protocol sets out detailed methods for planning and conducting intertidal butter clam surveys and data analysis. The protocol uses the Sm’algyax word for butter clam, “sa’mx”, to reflect the cultural importance of butter clams to Metlakatla people, and to be consistent with the recent efforts of the Metlakatla Aquatic Resources department to incorporate the Sm'algyax name for species in management documents and reports.

4.2.1. Gathering information

I began by conducting a literature review to identify relevant information from the fields of CBEM, cumulative effects monitoring and management, molluscan biology and ecology, field survey methodologies and protocol development. The review included academic literature, government and non-governmental reports and manuals, and relevant Metlakatla and regional planning documents.

The Metlakatla CEM Program reports provided the overarching direction for this work by specifying goals and objectives and documenting the process through which Metlakatla and its partners developed the CEM Program. Understanding the development process, including the identification of valued components, the design of the management triggers and the rationale for choosing butter clams as the environmental valued component, was important for establishing the context for this study and for situating this work within the CEM Program framework.

Next, I consulted with Metlakatla staff, SFU researchers and marine biologists to draw on their expertise and obtain guidance for the development of the Metlakatla protocol. Specifically, close communication with Metlakatla Stewardship Society and other Metlakatla staff members helped to ensure that the design of the Metlakatla protocol would be practical, achievable and aligned with the larger goals of Metlakatla and the CEM Program.

Knowledge gained through the literature review and informal interviews with experts informed my selection of clam survey methods and helped me expand upon conventional bivalve survey methodologies to better incorporate the values, goals and perspectives of Metlakatla and produce a Metlakatla-made protocol.

4.2.2. Defining the scope and scale of the butter clam surveys

After reviewing Metlakatla CEM Program documentation and meeting with Metlakatla Stewardship Society staff and the project team for this study, I scoped the work plan to clearly articulate the goals and objectives and establish reasonable expectations for the breadth of data that could be collected in one survey season (the time available for the initial trial of the protocol).

An initial decision was made by Metlakatla managers to limit the geographic scope of the study to beaches located on the foreshore of "Indian Reserve" lands within Metlakatla's territory. Beaches outside of IR lands may be surveyed in future years but were out of the scope of this project.

The literature review indicated that butter clam surveys require a tide of no more than 1.0 m above chart datum (Gillespie & Kronlund, 1999). Logistically, appropriate tide depth also needs to coincide with suitable daylight hours for field work. These constraints result in a survey season typically occurring between June-October on the western coast of Canada (Gillespie & Kronlund, 1999). Conducting intertidal bivalve surveys over the summer months is challenging for Metlakatla because Metlakatla Stewardship Society staff and resources are busy at that time of year with other field work. We were able to obtain boats and equipment for the surveys from other Metlakatla departments. Rather than rely exclusively on Metlakatla technical staff or external consultants to complete the work, and in an effort to follow principles of CBEM, community members and summer students from various Metlakatla departments were recruited as paid participants. Involving community members in data collection is standard practice in most collaborative CBEM programs.

I consulted the opinions of several marine biologists, a manual for intertidal clam surveys issued in 1999 by the Department of Fisheries and Oceans Canada (Gillespie & Kronlund, 1999), as well as the summary report from a pilot clam survey conducted by Metlakatla in 2017 (Kwon, 2017), to determine how many beaches could reasonably be surveyed in a single season, considering resources and logistical constraints. I determined that three beaches could realistically be surveyed in 2018. The selection of specific beaches is discussed in the next section.

Based on the information I gathered in the literature review and my interviews with marine biologists, I estimated the extent of biological data collection required to reliably assess the condition of butter clams. The objective was to select bioindicators (see section 4.3.5) that are scientifically informative yet relatively simple and affordable to assess. Condition index (CI), (measured as wet tissue weight/shell length) and growth index (GI), (measured as total shell length/age) were selected as the main bioindicators, in addition to data typically collected on bivalve individuals (length, height, whole weight). The reasons for these choices are explained in s. 4.3.5 below.

This study focuses on the 2018 field season and preparations for the following two years (2019-2020), for which funding has been committed.

4.2.3. Selecting Beaches

Metlakatla territory has numerous large beaches (greater than 5ha) that support, or may support, bivalves. Developing a process for evaluating and selecting beaches for monitoring was an important step in designing the Metlakatla protocol.

Surveying beaches from a broad area of the coastal territory to gather data that are spatially extensive was agreed upon by the research team as a longer-term goal of the CBEM program. Spatially extensive data will provide Metlakatla managers with baseline data on beaches that have a range of characteristics, allowing comparison of results between beaches with distinct attributes (e.g., a harvested beach and an unharvested beach) or similar attributes (e.g., comparable substrate and/or habitat characteristics). Because stressors to bivalve populations change spatially across the territory, having baseline data from different areas will be informative for Metlakatla managers with respect to monitoring and management of cumulative effects. Despite this longer term goal, my study was limited to surveying only three beaches and it was not expected that those beaches would represent the full spatial extent that will eventually be surveyed.

Evaluating candidate beaches

I coordinated a meeting with Metlakatla Aquatic Resources and other Metlakatla Stewardship Society technical staff to review and evaluate a long list of candidate beaches according to a set of evaluation criteria (Table 4.1) and to select three beaches for the 2018 surveys. The criteria for evaluation were selected based on the goals and objectives of the study, as well as professional and practical advice from Metlakatla technical staff familiar with the area, including one Metlakatla member who has substantial long-term LK of the area. Where possible, TEK (gathered from Metlakatla's Traditional Use Studies) was reviewed to identify areas of historical and cultural importance. We also reviewed available information on ShoreZone classification (Port of Prince Rupert, n.d.), relevant information from Metlakatla's Community Harvest Plan (MSS, 2017), and knowledge about butter clam habitat and survey methods from the literature.

Table 4.1 Summary of evaluative criteria used in beach selection.

Criteria	Options	Data Source
Located in Metlakatla IR	Yes/No	Metlatkatla Land Use Plan (MLD, 2019.)
Included in Community Harvest Plan	Yes/No	Community Harvest Plan (MSS, 2017)
Proximity to Metlakatla Village	Walkable Somewhat close boat access Boat access	Google maps
Current status of beach	Open/Closed	Community Harvest Plan (MSS, 2017)
Close to Pollution Tracker sample site	Yes/No	PollutionTracker Report (Oceanwise, 2018)

Criteria	Options	Data Source
Beach Type: Harvested	Yes/No/Lightly/Historically/ Unknown	MSS technical team opinion
Beach Type: Unharvested	Yes/No/Lightly/Historically/ Unknown	MSS technical team opinion
Beach Type: Modified	Yes/No/Unknown	MSS technical team opinion
Beach Type: Contaminated	Yes/No/Unknown	MSS technical team opinion
Beach Type: Uncontaminated	Yes/No/Unknown	MSS technical team opinion
Beach size	< 5ha >5ha	ArcGIS
Shore type	rocky sediment rocky + sediment other	ShoreZone (Port of Prince Rupert, n.d.)
Wave exposure	semi-exposed exposed semi-protected very protected	ShoreZone (Port of Prince Rupert, n.d.)
Biophysical qualities	island nearshore stream channels exposed forested megafauna present dominant plant species	Google maps, ShoreZone (Port of Prince Rupert, n.d.), MSS technical team opinion

For the initial set of beach surveys (conducted in 2018), the project team prioritized surveying beaches that are located within Metlakatla IR lands and that are identified in the Community Harvest Plan (MSS, 2017). The project team wanted to include a harvested beach, an unharvested beach and a modified (clam garden) beach to represent different types of clam beaches in the territory. The project team defined *harvested* as any beach that has been harvested a minimum of one time per year during every harvest season in the last 10 years. An *unharvested* beach is a beach with no reported harvesting for a minimum of 20 years (the estimated maximum lifespan of a butter clam). Identifying beaches as harvested or unharvested was hampered by the lack of reliable data on harvesting effort. Nearly all clam-bearing beaches in Metlakatla territory were harvested in the past, but as a consequence of declines in harvesting activity within the community, many beaches are now considered unharvested (W. Beynon, personal conversation, May 18, 2018).

The rationale for selecting a harvested beach is that FSC harvest areas are meaningful to the community and it is important for the Metlakatla Stewardship Society and Metlakatla Aquatic Resources to better understand butter clam population health and dynamics where FSC harvest takes place. If harvesting pressure, or other stressors, increase in the future, data from harvested beaches can inform decisions about whether annual catch limits should be established and what those limits should be. Metlakatla Stewardship Society was also interested in exploring the practice of intentional harvesting of a beach to maintain healthy clam populations and increase productivity. Regular harvesting is recognized by coastal First Nations as a way of improving clam productivity and is thought to reduce overcrowding, maintain suitable habitat and keep sediments aerated (Lepofsky et al., 2015). However, to properly test this hypothesis on Metlakatla beaches, a study designed specifically for that purpose would be required, which is beyond the scope of the present project.

The rationale for choosing an unharvested beach is that there are a number of beaches listed in the Community Harvest Plan that are currently closed to harvest but that may be re-opened in the future. This would provide an opportunity to compare data from the same beach under unharvested and harvested conditions to see if there are observable changes in productivity that could be correlated to the change in harvest pressure. Unharvested beaches that support bivalves also represent another general beach type and surveying a variety of beach types was identified by the project team and Metlatkalta Stewardship Society staff as an objective of the 2018 surveys.

The rationale for choosing a modified beach is that some Metlakatla members and leaders had expressed interest in exploring clam garden restoration. Gathering baseline data prior to restoration efforts will allow for analysis of population effects pre- and post-restoration. Modified beaches also represent a beach type that the project team wanted to include in the surveys because they are historically important and there was interest from Metlakatla Stewardship Society in potentially restoring a clam garden beach in the future. A population survey prior to potential restoration could be useful. Clam garden locations were identified from Metlakatla's Traditional Use Study, Spatial Geo-Database by Metlakatla Stewardship Society staff who then utilized ESRI ARCPro to filter for sites that best fit the criteria for the surveys (criteria described below). After a long-list of potential sites was developed, I collaborated with Metlakatla's Culture, Language and Heritage Coordinator to identify areas of interest to their department related to significant archeological sites. This process narrowed our selection of candidate sites to three clam garden beaches from which one was chosen based on our observations at low tide. The beach that was selected is adjacent to an important archeological site, which provided us an opportunity to collect a contemporary dataset for a historically significant site. The beach also had a visible wall, a distinct and relatively small survey area due to physical features (stream, rocks and treeline), and was in close proximity to a regularly harvested beach that was currently open to harvest (suggesting that the clam garden beach could potentially be opened if it proved to be relatively productive).

4.3. Pre- and Full- Survey Protocol Design

4.3.1. Review of existing protocols

I developed a comprehensive Metlakatla survey protocol to detail the methods for implementing the butter clam surveys, which were based on best practices and recommendations from peer-reviewed and grey literature review, clam survey protocols from other coastal Indigenous groups, and interviews with experts. The Metlakatla protocol generally follows the organizational structure recommended by the U.S. Fish and Wildlife Service (2013), which includes the following components: 1) Introduction; 2) Sampling Design; 3) Field Methods and Sample Processing; 4) Data Management and Analysis; 5) Reporting; 6) Personnel Requirements and Training; 7) Operational Requirements; and 8) References. Other clam survey protocols follow a similar structure but differ in their level of detail, which reflects the intended audience, ranging from simple checklists for community volunteers to technical methods for professionals. For Metlakatla, the survey lead is expected to have scientific training but the participants administering the protocol will vary in their level of experience. To accommodate this range of skills and experience, I wrote a detailed protocol with limited use of jargon and non-essential academic language but retained essential mathematical and scientific explanations. I created abbreviated field notes that were adapted from the detailed protocol and are meant to be referred to by technicians in the field, or the lab, in an effort to ensure the methods are followed consistently, even if the person has received little training.

In the existing protocols I reviewed, pre-survey methods for determining the bivalve population boundaries on the beach were similar, though I found no explicit direction for including LK or TEK in that process. I incorporated gathering of LK and TEK into beach selection and pre-surveys. Local harvesters and knowledge holders were part of the discussions about beach selection and Traditional Use Studies were referenced for locations of clam garden and harvesting sites. LK was shared by local harvesters, knowledge holders and Elders who I talked with during the pre-survey work, which informed the sample area boundaries and helped determine areas of low and high clam density for the purposes of stratifying the sampling area. LK also helped identify location-specific characteristics relevant to surveying, including when and how specific areas of the beach flood, where local hazards existed (e.g., wildlife, rocks to avoid when landing the boat). TEK and LK was included as a way of ensuring that Metlakatla values, such as important traditional and contemporary harvesting sites, are considered, and for obtaining practical information about local sites that were relevant to surveying.

Data analysis in the protocols I reviewed typically included length and weight relationships, length and weight frequencies and abundance and biomass estimates. I did not find any clam survey protocols that recommended a growth index or condition index, possibly because existing protocols are primarily concerned with stock assessment. I included habitat and biological health assessments (including substrate classification, condition index and growth index) in the Metlakatla protocol to reflect that Metlakatla's values and objectives go beyond stock assessment to determining the condition of a population as a whole.

4.3.2. Choosing an appropriate sampling methodology

I reviewed the literature to determine which sampling methods are used for intertidal bivalve surveys and found that stratified random sampling, simple random sampling and stratified two-staged sampling were the most common. Quadrat area and sample depth varied depending on the target species or on the sampling method used. Existing clam survey protocols varied in their methods largely because of differences in the objectives of the surveys, spatial context, target species, or resources available to carry out the surveys (Critser & Hosley, 2018; Ha-ma-yas Stewardship Network, n.d.; Gillespie & Kronlund, 1999; Norgard et al., 2010). Whatever the objectives, defining the appropriate spatial context and choosing a sampling method that ensures that the "breadth of inference of the results is known" is critical to the success of the survey (U.S. Fish and Wildlife Service, 2013).

The Metlakatla protocol was largely adapted from Gillespie and Kronlund's (1999) *A Manual for Intertidal Clam Surveys* (the Gillespie & Kronlund manual), a standard and comprehensive reference for intertidal bivalve studies on BC's coast that is the protocol followed by DFO. Probability sampling is the statistical basis for the survey methodology described in the manual (Gillespie & Kronlund, 1999). The recommendation of Gillespie and Kronlund (1999), is that survey areas larger than five hectares should be sampled using a stratified two-stage sampling method, and survey areas smaller than five hectares should be sampled using a stratified random sampling method. However, since 1998, stratified random sampling is the sampling protocol used by DFO's Marine Ecosystems and Aquaculture Division's (MEAD) regardless of beach size (Bigg, 2015).

The stratified random sampling method separates the clam population on a beach into non-overlapping units, referred to as strata, and uses random sampling within each stratum. A benefit of stratified random sampling is that it provides more precise variance estimates of the mean or total than if the whole area was surveyed by simple random sampling, a method often used for smaller beaches (Gillespie & Kronlund, 1999). Population density can differ markedly between strata, so stratified random sampling ensures the sampling units within a single stratum are as similar as possible, thereby reducing variability within the stratum. Because each stratum is randomized independently, problems that occur in the field (sampling errors) are confined to one stratum (Gillespie & Kronlund, 1999). The rationale for choosing stratified random sampling over stratified two-stage sampling method was three-fold. First, while the Gillespie & Kronlund manual (1999) recommends stratified two-stage sampling for survey areas greater than five hectares, this is not a hard and fast rule, but a suggestion. Stratified two-stage sampling increases the complexity, time and effort required to conduct the surveys while increasing the precision of the estimates by a relatively small degree. Second, there was statistical code for producing density, abundance and biomass estimates from stratified random sampling-derived data that was available for use by Metlakatla. This code was used to analyze the Department of Fisheries and Oceans' Seal Island butter clam survey dataset (M. Bigg, personal conversation, May 28, 2018). The Seal Island dataset is thought to be the longest running intertidal bivalve study in BC (26 surveys over 73 years) and was analyzed by Michelle Bigg, a Department of Fisheries and Oceans intertidal biologist who contributed expertise to this study (Bigg, 2015). Third, many of the potential survey beaches in Metlakatla territory have a survey area of approximately five hectares; using the same sampling methodology across all clam surveys would standardize Metlakatla's methods and make them easier to implement and the data easier to analyze and compare over time. For these reasons, stratified random sampling was chosen as the sampling methodology for the Metlakatla protocol.

For butter clam surveys, Gillespie and Kronlund (1999) recommend using a quadrat size of 100cm x 100cm and digging to a minimum sample depth of 30 cm. The recommended sampling rate is 10 quadrats per hectare with a minimum of 10 quadrats per stratum, to adhere to statistical sampling theory (Gillespie & Kronlund, 1999). I used these parameters in the Metlakatla protocol.

4.3.3. Designing pre-survey methods

A pre-survey is a reconnaissance of the selected beaches to gather data required to generate the survey maps. The goal is to identify the location and extent of the clam population for the purpose of delineating the survey area perimeter, and noting areas of high and low density, or other important features, for stratification. By validating or correcting the initial assumptions that were based on desktop analysis, the survey lead is able to better prepare for the surveys and to generate useful survey maps. For example, a pre-survey provides the opportunity to find a landing area for the boat at low tide, determine how long it takes to walk from the landing area to the survey area, note which areas flood first when the tide is coming in or collect waypoints for areas that cannot be sampled due to permanent flooding, boulders, or other obstacles.

Pre-surveys require a tide of not more than 1.0 m above chart datum to expose as much potential butter clam habitat as possible so that the area can be mapped accurately. Pre-surveys are typically designed to be conducted during the lowest tide series of the first available month with appropriate corresponding daylight hours (usually June). A key aspect of the pre-survey method is to include a staff member, or hire a community member, that has LK of the area. It saves time and focuses survey effort more efficiently if someone on the team can identify prime clam habitat and areas of high (or low) productivity. In our experience, LK also helped identify hazards and characteristics of the beach that may not otherwise be obvious (e.g., potential wildlife conflicts, which section of the beach floods first).

I developed a pre-survey procedure with detailed step-by-step instructions on implementing pre-surveys, including planning, desktop analysis, budget and schedules, hiring participants and sourcing equipment. The pre-survey procedure details how to determine the location and bounds of the clam populations on the beach, how to sketch and note important beach features that will aid in stratification and how to collect waypoints. The procedure also covers how to input the waypoints into a global information software system, such as ArcMap or QGIS, and generate a map of the survey area.

Pre-surveys typically only need to be done once. After a survey map has been made for a particular beach, it will be used for all subsequent surveys at that location (barring major changes to the locations of clam populations or the physical structure of the beach). It is important that the same area is surveyed each time, so that data can be compared over time.

4.3.4. Designing full-survey methods

The Metlakatla protocol includes detailed instructions on how to plan and execute full butter clam surveys. I developed brief field notes to aid technicians if they are unsure of the methods while in the field or lab. Photos and diagrams of the methods, work-flows and procedures accompany the text to provide visual aids and improve understanding of the methods.

The goal of the full survey is to collect the data required to generate estimates of mean population density (the butter clam condition indicator identified in the CEM Program), abundance, and mean biomass, and to gather observations on substrate and general habitat characteristics. Although butter clams are the target species for the surveys, any and all clams that are collected in the quadrats are identified, bulk weighed and counted. Non-butter clam species are returned to the beach after bulk counts and weights have been recorded. A sub-sample of butter clams, chosen at random and representing every stratum, is retained for further bio-sampling (discussed below). Remaining butter clams are returned to the beach. As per Gillespie & Kronlund (1999), 200 butter clams are retained for bio-sampling from a survey area of five hectares or less, and 500 clams are retained for a survey area larger than five hectares.

Collecting data on the non-butter clam species provides information on the diversity and relative proportions of other clam species inhabiting the survey area. This helps generate a fuller picture of the relative abundance and size of the intertidal clam community at each beach, including other harvested species such as cockles and native littleneck clams. A caveat is that the survey methods were designed specifically to sample butter clams, so inferences from the data on other clam species should take this into consideration. Aside from gathering data on the CEM Program condition indicator (population density) and other key population information, survey data may also enable managers to observe trends in the locations and abundance of clam populations as locations and elevations of particular habitats change due to climate change (i.e., sea level rise and/or warming waters) or other stressors such as wakes from large ships, development or other shoreline modifications, for example. Identifying and recording all clam species may also help detect invasive species.

The Metlakatla protocol uses a stratified random sampling method and a sampling rate of 10 quadrats per hectare with a minimum of 10 quadrats per stratum, as recommended by the Gillespie and Kronlund (1999) manual. Some methods in the Gillespie and Kronlund (1999) manual were outdated. For example, I replaced the use of reference lines and measuring tapes for locating quadrats, as recommended in the manual, with the use of GIS software and handheld global positioning system devices in the Metlakatla protocol.

The Gillespie and Kronlund (1999) manual recommends that all clams are bagged and taken back to the lab to be processed, live, if possible and frozen and processed later if necessary. Other protocols suggest doing all of the bio-sampling (weighing and measuring of individual clams) on the beach (Ha-ma-yas Stewardship Network, n.d) if possible. Because of Metlakatla's large beaches, the short tide window (4 hours) and the fact that some beaches are highly productive, it was not feasible to conduct all the bio-sampling on the beach was not feasible. However, the Metlakatla protocol stipulates that, to the extent possible, bulk weighing and counting of clams takes place on the beach so that all clams except the butter clams required for bio-sampling can be returned to the beach in an effort to minimize clam mortality.

4.3.5. Designing bio-sampling and data analysis

Intertidal clam surveys in coastal BC typically target commercially significant species for stock assessment (Gillespie & Kronlund, 1999; Ha-ma-yas Stewardship Network, n.d.; J. Carpenter, personal conversation, November 27th, 2018; Point No Point Treaty Council, 2019). Metlakatla's primary interest was in obtaining mean population density and mean biomass data to help inform management actions according to the CEM Program management triggers. Population density and biomass data can also be used to set annual catch limits, should this become a priority for Metlakatla in the future. For the purposes of better understanding cumulative effects, I included substrate classification in the Metlakatla protocol to better understand the relationship between substrate type and clam population density.

Table 4.2 presents the parameters that are measured in the Metlakatla protocol. During the review of existing protocols, similarities were found regarding the type of biological data collected. Existing protocols usually include measurements of shell length, height and whole animal weight, data which are also collected in the Metlakatla protocol. Depending on objectives, capacity and existing data on the populations, the protocols that I reviewed differed in whether or not they include aging of clams, growth rate analysis (which requires age and length-at-annulus data) and thickness measurements. None of the protocols I reviewed measured the tissue weight, although tissue weight was measured in many of the academic studies I reviewed on assessing condition of clams using bio-indicators. The Metlakatla protocol includes clam aging, growth rate analysis and tissue weight measurements. The rationale for including these measurements, despite the added costs (time and labour), was that they provide crucial population data that are required to more fully assess the condition of clams in the territory (see Table 4.2).

Table 4.2. Summary of parameters and data required to measure each one

Location	Parameter	Data Collected	Measurement Units
Field	**Biomass**	Bulk weight of clams[1]	Kg/m^2
	Population Density and Abundance	Bulk counts of clams[1]	# $clams/m^2$
	Habitat characterization/quality	Substrate characterization	Visual % cover
		Beach profile	Metres (slope)
Lab (bio-sampling)	**Length-weight relationship**	Shell length and whole animal weight. Shell length is measured as the greatest linear distance between anterior and posterior margins of the valve.	Mm/g
	Frequency of Length	Length	# of clams/mm
	Age-length relationship	Age (# of annual rings, called annuli) and total shell length	Age/mm
	Age- weight relationship	Age and whole animal weight	Age/g
	Age frequency	Age	# of clams/age
	Age-class structure	Age	# clams per age-class Juvenile (1-3 yrs) Mature (4-8 yrs) Legal (9-15yrs) Senile (16+ yrs)

Location	Parameter	Data Collected	Measurement Units
	Condition Index (a.k.a Condition Factor)	Wet tissue weight/shell length	g/mm
	Growth Index (a.k.a development index or length-to-age ratio)	Length of shell/age	Mm/years
	Growth rate (von Bertalanffy growth model)	Length-at-Annulus	Mm/years
	Shell morphology	Qualitative description of symmetry	Observed symmetry
		Shell height- measured as greatest linear distance from umbo to ventral margin of valve	mm

[1]Bulk weight and counts are per species and age class (legal and sub-legal) for Butter and Native Littleneck clams. Butter clam legal size is ≥63mm and Native Littleneck clam is ≥38mm. All other clam species can be bulk weighed and counted with no age class separation

Samples are collected live and then frozen prior to bio-sampling. The rationale for freezing is that there may be occasions when the bio-sampling cannot be completed within the two-day post-collection survival window. In an effort to keep methods consistent, the clams are frozen. Processing the clams frozen means that Metlakatla has the opportunity to conduct all the field work, then freeze the samples and bio-sample at a later date. Building in the flexibility to execute the field sampling at one time and the bio-sampling at another time will be beneficial to Metlakatla's scheduling and staffing constraints.

Clam aging methods

While measuring clam length, height and weight is straightforward, determining the age of a clam is more difficult. Aging is done by interpreting the concentric rings on the outside of the shell. Aging butter clams is especially challenging because they have numerous concentric rings on the valves, many of which do not represent annual growth. Annual growth lines (called annuli) appear where growth has gradually slowed in the winter and then gradually recovered in the spring. Disturbance lines caused by a storm event, reproduction or predation attempt, in contrast, are characterized by rapid decrease in growth and rapid recovery (Hallmann et al., 2009). The challenge is that disturbance lines and annuli look very similar and it takes experience to differentiate them. Annuli also get increasingly difficult to identify the older the clam gets, meaning that the younger the clam, the more likely it is to be aged correctly. Typically, people who are experienced with aging clams learned by watching others or by simply practicing on their own. None of the protocols I reviewed, or experts that I talked with, had followed a particular method for aging other than visually inspecting the valves, and they did not otherwise validate their age data. The only ways to validate age are through stable oxygen isotope sclerochronology or carbon dating, methods which require specialized expertise and equipment, making them too expensive for standard stock assessment surveys (M. Bigg, personal conversation, June 28, 2018).

For the Metlakatla protocol, I developed a low-cost method for increasing the accuracy of age estimates. This involves first separating the valves of a group of 10-15 shells (each valve is labelled with the clam's unique serial number during bio-sampling). With the first half of the valves (i.e., one side of each clam shell), the technician ages the clam using the naked eye (the conventional method) and uses a pencil to mark the annuli on one valve. Next, the other half of the corresponding valve for the same clam is sawn in cross-section (across the annuli), using lapidary equipment. After the valves have been cross-sectioned, and without referring to the age determined using the naked eye, the technician views the cross-sectioned shell using a dissecting microscope and observes the growth lines that are now visible in cross-section. It is easier to distinguish the growth lines in a magnified cross-section than in the un-sawn valve with the naked eye. I developed tips for interpreting the growth lines both in cross-section and by the naked eye, which I determined after a review of sclerochronology and bivalve physiology literature, and through conversations intertidal bivalve biologists. I collected magnified photos of cross-sections done by other researchers that had labelled annuli (which were validated using stable oxygen isotope analysis) from academic papers and used these images as training guides on how to interpret growth lines. (Bassett, Andrus & West, 2018; Cannon & Burchell, 2017; Hallmann et. al, 2009; Sea et. al, 2018).

After the cross-section aging is complete, each clam now has an age assigned by two different methods, 1) naked-eye and 2) cross-section analysis. The two ages are compared, and the technician can see what the variance is between the two methods. The learning comes from comparing both valves of the shell (the intact valve and the cross-sectioned valve); the technician improves their ability to recognize what rings actually constitute an annuli, using the cross-sectioned valve as a reference. The obvious limitation with this approach is that both methods are ultimately still unvalidated. While the annuli on the cross-sectioned valve are typically easier to see and identify, without validating the age with chemical analysis, subjectivity and error are inherently present. In my experience, after four ‘rounds’ of aging 10 clams per round (using both methods), I observed increasing agreement between ages I assigned using both methods. By the fourth round, the average difference in age between the two methods was less than one year. The Metlakatla protocol suggests that the technician follow this two-method approach until they reach an average difference between the two methods of less than one year. When that benchmark is met, the technician is ready to age using only the naked eye technique.

Although imperfect, this approach is an affordable way to improve aging accuracy. Accuracy in aging is important for a number of reasons. First, these baseline data can help establish the mean age at which a butter clam reaches both sexual maturity and legal harvest size in Metlakatla territory, which may be slightly different than butter clams elsewhere in the region. Establishing these essential life history stages is important for understanding and tracking changes in population demographics, which may inform stock assessment or cumulative effects management, for example. Second, age is a parameter in many biological indicators including growth rate and growth index. If these indicators are to be reliably compared between beaches, consistent aging methods are required.

Biomarkers

The Metlakatla protocol is innovative because it includes assessment of two biomarkers, CI and GI. According to Benford et al., (2000 pg. 120), biomarkers are “…any series of biochemical or molecular responses to compounds that have entered an organism, reached sites of toxic action and are exerting an effect on the organism”. Biomarkers are widely used in aquatic studies as predictive tools for ecotoxicity analysis and reliable indicators of ecosystem health (Blaise, Gagné & Burgeot, 2017). While there is a battery of biomarkers that can be utilized in aquatic studies and with bivalves in particular, many of these require the use of expensive equipment and highly technical expertise. For Metlakatla's purposes, CI and GI biomarkers were chosen because methods to assess them were affordable and did not require extensive expertise or specialized equipment, yet they still provide reliable information on animal health and water/sediment quality (Blaise, Gagné & Burgeot, 2017).

Many studies have been done to establish CI for bivalves to provide an indication of the general physiological health and growth of the animal (Blaise, Gagné & Burgeot 2017; Velez et al., 2015). Shellfish farmers commonly use CI as an indicator of the quality of their products and because it is significantly correlated with standing stock biomass (Filgueira et al, 2014; Orban et al., 2002). Typically, CI is defined as the ratio of wet or dry weight of the tissue to the weight of the shell or whole animal (De Montaudouin et al., 2010; Mann, 1992; Martínez-Gómez et al., 2017; Velez et al., 2015). However, some CI discussed in the literature use a ratio of tissue weight to length (Benali et al., 2015; Blaise, Gagné & Burgeot 2017; Blaise et al., 2002) or dry tissue weight x100/shell cavity volume (Mann, 1992). For the purposes of the Metlakatla protocol, a CI using the wet tissue weight/length was used. Tissue weight was used rather than whole animal weight because sand and rocks are often trapped inside the shell, resulting in an overestimation of weight (Blaise, Gagné & Burgeot 2017). Another advantage of collecting tissue weight in addition to the whole animal weight is that shell weight can then be estimated (whole weight- meat weight = shell weight), although a caveat is that there is a possibility of overestimation of whole weight, due to rocks and sand, in this calculation of shell weight. Tracking changes to shell weight over time may be useful for inferring impacts from ocean acidification. This is not yet a calculation that is required in the Metlakatla protocol, though the data are there should Metlakatla wish to determine shell weight. Wet tissue weight was chosen over dry tissue weight because the costs of added equipment and resources required to dehydrate the tissue did not seem to elicit sufficient additional benefit (F. Gagne, personal conversation, March 19th, 2018).

After a decade long study looking at the effect of contamination on *Mya arenaria* (soft-shell clam), Blaise, Gagné & Burgeot (2017), recommend using GI, the ratio of length to age, as an indicator of growth when comparing clam populations. Specifically, Blaise, Gagné & Burgeot (2017) assessed GI in clams collected from sites with known contamination and sites that were considered relatively ‘clean’. They found that GI significantly correlates with numerous effects-related biomarkers while being relatively easy to measure, which provides a strong rationale for using GI as an indicator of population health. The Metlakatla protocol uses GI to compare clam biodata from different beaches, or the same beach over time, to assess whether there are stressors (contamination or otherwise) that are impacting growth. While GI can help identify changes within or between populations, it cannot determine the source of the stressor(s) that are causing the differences, which is a more complex issue to resolve.

CI and GI, while easy and relatively inexpensive to assess, were shown by Blaise, Gagné & Burgeot (2017), to correlate with eight other effects-related biomarkers "…providing even more support for their relevance and use for water quality assessments from an eco-epidemiological perspective". For example, there have been observed correlations between CI and GI and biomarkers such as oxidative metabolism, immunosuppression, genotoxicity and population metrics (e.g. population density), (Blaise, Gagné & Burgeot, 2017). Studies have shown CI values will fluctuate depending on seasonal factors such as food availability, temperature and the reproductive cycle (Benali et al., 2015; Blaise et al., 2002; Filgueira et al., 2014). In the Metlakatla protocol I recommend collecting samples from a particular site during the same month each year to reduce variation caused by these fluctuations.

4.3.6. Exploring community benefits

Based on examples from the CBEM literature I designed the Metlakatla protocol to involve community members in ways that should provide additional community benefits, such as: increasing scientific literacy and developing skills of Metlakatla members; utilizing existing skills and capabilities within Metlakatla Stewardship Society and expanding that internal capacity; investing in monitoring tools and equipment; increasing members’ participation and employment within the CEM Program; increasing member’s interest in clam harvesting; and incorporating Metlakatla values, LK and TEK to make monitoring as relevant to Metlakatla people as possible. A key benefit of the

Metlakatla protocol is providing opportunities for members to learn from each other and from researchers, during field and lab work, community harvest days, meetings and training sessions. In particular, cross-generational learning between youth (e.g., summer students) and older Metlakatla harvesters, knowledge keepers and Elders should have positive benefits like helping maintain Indigenous Knowledge systems and traditional practices (Aswani, Lemahieu & Sauer, 2018). Youth participation and engagement was an important element of the Metlakatla protocol design because of the positive effects it can have on those who participate, including increasing interest in science and improving rates of high school completion (Gérin-Lajoie et al., 2018).

4.4. Testing the Protocol

The following section outlines the process that was followed to test the Metlakatla protocol and survey three beaches in Metlakatla territory during the summer of 2018. Beyond the goal of collecting baseline data on butter clam populations at three beaches in the territory, the testing phase allowed us to field-test the methods to reveal any areas of the protocol that needed change or improvement. Lessons from the 2018 surveys contributed to refining the Metlakatla protocol for the 2019 surveys.

4.4.1. Hiring and Training

In total, seventeen Metlakatla staff members, one Metlakatla contractor, seven Metlakatla summer students, eight other Metlakatla members, two SFU researchers and an SFU faculty member were involved in some capacity over the course of the 2018 clam surveys. Twelve of the twenty Metlakatla members who participated were under the age of 25 years old.

I delivered a training presentation for the participants who were hired to help conduct the field surveys and bio-sampling. The training was held in Metlakatla Village and was open to anyone who was interested in participating in the surveys. The purpose of the training was to ensure participants were familiar with the objectives and methods of the Metlakatla clam monitoring protocol. The training also provided background on the CEM program and the broader context of the butter clam surveys. The training was delivered using a PowerPoint presentation, which can be updated and used in subsequent years by Metlakatla.

4.4.2. Overview of the 2018 surveys

The Metlakatla protocol designed in this study was initially implemented from June through September 2018. Pre-surveys were conducted during the lowest tide series in June 2018. Three beaches were pre-surveyed, an unharvested beach (Beach 1), a harvested beach (Beach 2) and a modified beach (Beach 3). One full bivalve survey was then conducted on each of these beaches. These bivalve surveys were conducted during the lowest tide series of the month during the months of July, August and September 2018. Due to time and resource constraints, Beach 2 was partially surveyed during the low tide cycle for August and the survey was completed during the low tide cycle for September. Ideally, each time a beach is surveyed, the survey should occur during the same month. This minimizes variability in mass caused by reproductive cycles, which fluctuates throughout the summer months, although the precise measure of that variability is not known. Quayle and Borne (1972) report that in BC, butter clams spawn from April to October. Exact timing of gametogenesis and spawning in bivalves is influenced by a number of exogenous factors (temperature, food supply, light, salinity) and endogenous factors (neuro-endocrine cycles and genotype) and is different for each species (Gosling, 2003). Without developing a histological assessment of the reproductive cycle or analyzing squash preparation of gonads, precise timing of butter clam spawning in Metlakatla waters is unknown.

Although surveying Beach 2 over the course of two tide cycles was not ideal, I considered it to be acceptable for two reasons. First, variability in weight caused by individual reproductive cycles is not identified in the literature as a fundamental concern but, rather, a consideration for reducing uncertainty of the data. Second, the 2018 data represents one year in an ongoing and long-term survey effort; over the long-term, any minor errors in weight measurements due to the timing of sampling in 2018 should be negligible.

Table 4.3 below summarizes the 2018 survey effort. In total, 3,989 clams (all species) were counted in the field and bulk weighed. Of that total, 3,052 (77%) were butter clams. Of the total number of butter clams counted and weighed on the beach, 1,970 (65%) were above the size threshold established by DFO regulations for legal harvest (≥63mm) and 1,082 (35.5%) were sub-legal (<63 mm).

Shell length, height, total weight and wet tissue weight measurements were collected for 1,252 individuals, the sub-sample of the population that was retained for bio-sampling (approximately 500 butter clams retained from beaches over five hectares) and approximately 200 butter clams retained from beaches smaller than five hectares). Of the 1,252 butter clams retained for biological sampling, 1109 butter clams were aged (damaged shells were excluded from aging). Length-at-Annulus measurements were taken on 150 butter clams (50 per beach) to determine growth rate using the von Bertalanffy growth model (Gillespie & Kronlund, 1999).

Table 4.3 Summary details for the 2018 butter clam surveys

Beach	Dates (2018)	Tide (m)	Survey Area (ha)	# of Strata	# Quadrats Sampled
1	Aug 10	0.8	5.1	4	52
	Aug 11	-0.03			
	Aug 12	-0.33			
	Aug 13	0.07			
2	Aug 14	1.08	5.9	5	62
	Sept 10	0.22			
	Sept 11	0.4			
	Sept 12	0.75			
3	July 14	-0.15	1.6	2	16

4.4.3. Communication and Reporting

Ongoing communication about the activities related to the butter clam surveys, both internally with the project team and Metlakatla staff members, and with the greater Metlakatla community, was an important step in the implementation of this study. Because the work was being completed with the help of multiple Metlakatla departments, clear communications about scheduling, equipment use, and personnel availability was typically done by me with the help of a Metlakatla contractor and liaison who was on the project team. Having one key person located in Prince Rupert who could liaise with Metlakatla staff and community members was critical to the success of the surveys, particularly because I was located in Vancouver and travelled only periodically to Prince Rupert and Metlakatla Village.

I communicated with Metlakatla community members about hiring opportunities, training sessions and post-survey updates in a number of ways: posting on official Metlakatla First Nation Facebook pages; putting up posters in the band office; emailing individuals who had expressed interest; phoning and text messaging; and through word-of-mouth/in-person conversations. Using a variety of communication channels was important for reaching membership, because some were located in Metlakatla and some in Prince Rupert, and to account for differences in communications preferences that members have. In many cases, text messaging was the most reliable form of communication and was preferred by many of the participants in this study. One of the most successful ways to share information about the butter clam survey work, including recruiting members to work on the surveys, was member-to-member conversations; it was common for a community member who was hired for a survey to inform and recruit other friends or family members to participate.

Providing regular updates about the monitoring work increased awareness of this study and of the CEM Program more generally. I made an effort to consistently refer to the Metlakatla clam survey protocol as being a part of the Metlakatla CEM Program, which reinforced the importance of this work and situated it within the broader context of CEM. Posting photos and reporting accomplishments to the Metlakatla Facebook pages ensured that the community was regularly informed of how the work was progressing, prior to any final results being shared. While not every Metlakatla member is on Facebook, the Metlakatla First Nation Facebook page is where a lot of important information from Metlakatla departments is disseminated to the community. When communicating about the monitoring work or the CEM Program, I emphasized that the Metlakatla protocol was a Metlakatla-driven program and a research collaboration between SFU and Metlakatla. If communications and implementation were not thoughtful, community members could mistake this work as being driven by SFU researchers and not by Metlakatla's priorities. To avoid this type of misunderstanding, we presented this work as a Metlakatla-made program designed to meet goals that were developed with, and by, the community.

A short post-participation survey, administered by the Metlakatla project team via SurveyMonkey, was sent to 13 Metlakatla staff and members who participated in the beach surveys. The survey asked about their experiences with the clam surveys. Responses from nine individuals revealed numerous positive outcomes from participation in the butter clam surveys. For instance, all respondents said they enjoyed their experience and would do it again. Sixty-three percent of respondents indicated that the clam surveys were the first time they had dug for clams and 67% of respondents indicated that participating in the project motivated them to go harvesting in the future. All survey respondants indicated that participating in the clam surveys got them thinking about why and/or how clams are important to Metlakatla people ‘a great deal’ or ‘a lot’ (options were ‘a great deal’, ‘a lot’, ‘a little’, ‘not at all’). A total of 89% of respondents said that participating made them feel more connected to Metlakatla territory. All respondents answered that the clam surveys were important for Metlakatla’s CEM Program. When participants were asked if they had become “extremely interested”, “very interested”, “somewhat interested”, “not very interested” or “not at all interested” in the Metlakatla CEM program by doing the clam survey work, all participants said they were “extremely interested”, “very interested”, or “somewhat interested”.

Negative or neutral responses were typically about scheduling (e.g., early start times, working on weekends) and the physically demanding nature of the work. One participant commented that, ideally, they could keep and eat the clams that are harvested. However, the survey season does not correspond with harvest season as the risk of bio-toxins is high during summer months. Another participant noted that some of the youth were complaining that they did not want to be there and that it was difficult to find people for the work.

Since community participation is an important objective of CBEM and of the Metlakatla protocol, we wanted to understand the experience of those who participated so that improvements can be made and opportunities explored. For example, the positive response to the clam digging experience motivated our research team to organize a subsequent community clam dig which attracted over a dozen people.

After preliminary results of the butter clam monitoring surveys were analyzed, I presented a summary of the results at a Metlakatla community meeting in March 2019. The purpose of the meeting was to present butter clam survey results and provide an opportunity for community members to ask questions, share concerns and otherwise engage with the project team. The high number of attendees (approximately 40) and active engagement of meeting participants illustrated that the community values having the space and time to be informed of activities, progress, results and to have the opportunity to contribute their perspectives.

A key deliverable of this study was a detailed final report for Metlakatla Stewardship Society that provided an overview of the CBEM program and included: 1) an introduction to the goals for the butter clam project and how the project objectives align with the Metlakatla CEM Program; 2) a literature review covering topics such as establishing baselines, ecological survey methodologies, bivalve biology and habitat, and assessing condition of bivalves; 3) a summary of the process and design of the Metlakatla protocol; 4) the butter clam survey results; 5) a discussion of the results; 6) reflections and lessons learned; and 7) limitations and recommendations for future research.

4.4.4. Refinement of protocol

Testing the Metlakatla butter clam monitoring protocol during the summer of 2018 provided the opportunity to field test the methods and see what worked and what did not. After these tests, refinements were made to the Metlakatla butter clam monitoring protocol in order to:

- make directions clearer,
- consolidate data sheets and make data input more efficient,
- add detailed instructions on how to age clams,
- include more photos to show specific methods,
- include beach profiling (measuring slope) in the pre-survey methods.

The Metlakatla protocol is a living document with the intention that it will be refined, as needed, to accommodate changing conditions, priorities and objectives and to reflect Metlakatla's increased experience and knowledge in the area of bivalve monitoring and cumulative effects.

Using the Metlakatla protocol developed in this study, pre-surveys of four new beaches were conducted in 2019. The four beaches included two lightly harvested beach (beaches 4 and 7), and two historically harvested beaches (beaches 5 and 6). Full surveys were conducted during the lowest tide series of the month, from July through September 2019, on beach 2 (for the second year) and beaches 4, 5, and 6. A full survey of beach 7 is planned for 2020. The 2019 surveys are beyond the scope of this study and the data analysis is not included in this paper.

4.4.5. Lessons learned

Overall, the 2018 butter clam surveys were implemented successfully, providing Metlakatla with a baseline data set for butter clams from three beaches in the territory. Reflections on the key lessons learned are summarized below and can be used as a reference for future work by Metlakatla in collecting baseline data for biophysical values, and by other Indigenous communities attempting similar work. This information was provided to Metlakatla in a final report, to assist with future iterations of the Metlakatla butter clam CBEM program.

Complementarity of Scientific and Traditional Ecological Knowledge

Complementarity of SK and TEK is well established and there are many studies that demonstrate the benefits of using a multiple evidence-based approach (see Chapter 2 of this report). In this Metlakatla case study, local knowledge and TEK informed the beach selection process, helped the survey team locate clam populations and areas of low and high density in the field and informed the study's objectives. There is more opportunity to connect scientific methods and TEK in the butter clam monitoring work, including in the establishment of a historical baseline for clam populations in the territory and in the setting of management actions.

During the community meeting at which survey results were shared, one community member raised concerns that in her view the work was heavily focused on collecting SK which produced results that simply reinforced what was already known by the local community (i.e., local knowledge). This is a criticism sometimes levelled at researchers working with Indigenous communities and to me it indicated that in my approach or my delivery of the results I had not been sufficiently alert to this potential concern. Indigenous communities, like Metlakatla, are often barraged by researchers and consultants who want to work with the community, or by proponents seeking consultation on a project. Collaborations can be a burden, or may even cause harm to the community. In many Indigenous communities, there is a legacy of researchers, proponents and consultants (typically settlers) not listening or responding to the community's concerns, not following the community's protocols or ignoring basic ethical research practices (Jasmin & Lynch, 2017; Smith, 2013). If the community was disappointed, or even harmed, in the past, it is easy to see why there might be skepticism or resistance to the next researcher that comes along. Even if no direct harm has been caused, research fatigue can set in and the community's tolerance for yet another data collection or knowledge gathering exercise might be low (Jasmin &Lynch, 2017).

Although the critical comments came from only one Metlakatla member, they highlight a frustration many Indigenous peoples and groups have expressed, which is that SK is often given more weight and value than TEK in academia and the public realm (Nicholas, G. 2018). It is not uncommon for Indigenous Knowledge to be 'discovered' and reframed in scientific terms, an undermining of the value and credibility of the Indigenous peoples who held that knowledge already. While the present study was designed to use TEK and SK to produce robust data that would be important to the community, the way that I communicated the results left at least one person (and potentially others) questioning the validity, and perhaps the importance of this work. In hindsight, I should have better communicated to Metlakatla members how SK and TEK are used complementarily in this study and how, used appropriately, the application of local and Traditional Knowledge can enhance ecological research (Adams et. al, 2014). Describing how the data will remain with the community and describing concrete applications for the data produced in this study may have better allayed the member's concerns.

Recognition of how I, a Settler researcher who is external to the Metlakatla community, am situated within this study and within the community is also critical. Although this work is a collaboration between an external research institution (SFU) and Metlakatla (leadership, technical staff and members), co-presenting the results of the study with a Metlakatla member or staff person would have offered a more powerful representation of the community role within this work. Reflecting on why some community members may be skeptical, fatigued or uninterested in this work, practicing good research ethics (specifically as a white Settler in an Indigenous community), and accepting responsibility for how this work is received by the community, was an important lesson from this experience. By taking a more reflective approach, practitioners like myself can achieve better scientific outcomes (more rigorous and effective data collection) that gains from Indigenous Knowledge, while also benefiting the community by enhancing local conservation and management efforts (Jasmin & Lynch, 2017).

Recommendations:

- Practice engaged and reflective research that acknowledges common pitfalls and the legacy of poor research ethics.
- Become familiar with existing frameworks and principles which guide collaborative efforts toward enhanced community-based resource management (Adams et al., 2014; Jasmin & Lynch, 2017).
- Using appropriate and thoughtful methods, collect TEK to inform a historical baseline on the condition of butter clams in Metlakatla territory, to supplement the results of this study of current conditions (e.g., qualitative interviews with harvesters, knowledge holders and/or elders).
- Ensure Metlakatla members (within the CEM working group or otherwise) have the opportunity to contribute LK, TEK and other ideas to potential management actions for bivalves under the CEM program (e.g., hold a community workshop or meeting to gather input).
- If changes to the clam populations are detected, consult LK and TEK holders when attempting to determine or verify causes (e.g., key informant interviews).
- Increase community participation in the butter clam monitoring work through organized community clam digs to provide informal opportunities for the passing on of LK and TEK between members, and to increase interest in the traditional practice of clam harvesting. Make a concerted effort to recruit youth.
- Communicate to researchers and Metlakatla members the value of using a MEB approach. Create opportunities to share the ways in which TEK, LK and

SK complement one another in this work (e.g., specifically address this topic during community meetings where progress and/or results are being reported).

Surveys are resource intensive and hiring and retaining participants can be difficult

Even with a well-designed survey protocol in hand, planning and carrying out the Metlakatla protocol requires significant time, money and labour. Currently, Metlakatla Stewardship Society does not have the internal capacity to execute the surveys without external support or hiring additional personnel. This is partly due to the timing of the surveys, which coincide with many other resource-intensive activities that are a high priority for MAR (e.g., the food fish program).

Hiring members for short-term (4-5 days) work is challenging. The work can be difficult and requires early start times and hard physical labour often in poor weather. Because the workdays are dictated by tides, this means they often occur on weekends when staff and community members are less available. People who join for one survey often do not come back again because they find other full-time employment or because of personal scheduling conflicts.

The Metlakatla butter clam monitoring protocol should eventually be led completely by Metlakatla. To get to that point, capacity of Metlakatla staff and members should be incrementally developed with experience over time. An important lesson is that building internal capacity takes time, planning and stable funding.

Recommendations:

- Hire Metlakatla summer students for the surveys. They are typically more available than regular staff and the field and lab work provide an opportunity for learning.
- Pay a relatively high hourly wage to make up for the fact that there is only a few days' work per month.
- Conduct the field work during the low-tide windows but freeze the clams and bio-sample them during winter months when Metlakatla Stewardship Society staff may be available.
- Consider developing a 'field school' for high school students where they perform the field and bio-sampling work each summer, supervised by a Metlakatla staff member, in exchange for school credit. 'Learning by the Sea' is a southern BC example, or the 'Science Land Camps' in northern Quebec referenced in Gérin-Lajoie et al. (2018). Such an initiative could incorporate

cultural and traditional teaching by elders and provide cross-generational learning opportunities for participants.

Quality control is critical

The survey lead is accountable for ensuring quality control through every stage of data collection and recording. Given the high turn-over of participants, and the spontaneous addition of new participants who have not received the full training, methods in the field should be supervised closely throughout each day (e.g., ensuring that diggers are digging deep enough, recording data properly). Fatigue and being cold and wet can increase the incidence of errors and personal injury when in the field. Anticipating problems, identifying hazards and having a plan to address them will help to mitigate preventable errors or injury.

Bio-sampling requires numerous people and there are many opportunities for human error to spoil the data. Ensuring each person has been properly trained on how to use the equipment (e.g., recording measurements to the appropriate number of significant figures, measuring the correct parts of the shell) is critical. Periodically (e.g., at the end of each day or at the end of the survey) data that have been recorded should be reviewed and cleaned. The survey lead should check the data for anomalies, missing data, transcription errors and review photos and identify any unidentified clams.

Recommendations:

- Ensure each participant has been trained in the methods, either by attending a formal training session or by receiving detailed instructions in the field.
- Pair up inexperienced participants with experienced ones.
- Provide condensed field notes to each digging team and bio-sampling team so they can reference the methods at any time.
- The survey lead should make periodic rounds observing the technicians at work and answer any questions they have.
- Ensure participants are appropriately dressed for the weather; provide snacks and encourage workers to take breaks when needed.

Butter clam monitoring provides added value to the community

Aside from collecting data for CEM purposes, potential benefits of monitoring butter clams include: short-term employment of members; promotion of the CEM program; relationship building between Metlakatla and other organizations and partners (e.g., SFU, DFO, other First Nations); equipment purchases and upgrades; methods and design frameworks that can potentially inform data collection for other species; opportunities for Metlakatla staff and members to learn and practice clam harvesting; cross-generational learning between elders and youth/students; and building skills within MSS and the community.

Recommendations:

- Recognize and celebrate community benefits resulting from CBEM. Report these benefits to the community, to leadership and in annual reporting documents in order to capture the full value of this work.
- If resources allow, organize an annual community clam dig where Metlakatla staff arrange the boat, equipment and prior biotoxin testing so that members have an opportunity to harvest at least once per year. This would also provide an opportunity to interact with staff who are involved with the surveys so that informal discussions about butter clams, the CEM program, and survey results can take place.

Communication is important for community support

As discussed above, communication and reporting are integral to the implementation of the Metlakatla protocol. Communication about what is being done and why it is important is critical for ensuring that support for this project, and the wider CEM Program, continues to build within the Metlakatla community. As determined through the feedback survey from clam survey participants, discussing the work and situating it within the broader CEM context made participants feel like they were part of a team, that they were contributing to advancing Metlakatla's CEM objectives, and that the work they had done was valuable.

Recommendation:

- Allocate resources to communication purposes, including community meeting(s).
- Ensure that a Metlakatla staff person, preferably a champion of the CEM program and related projects, is present at community meetings in order to respond to member's questions and concerns.

Inter-departmental cooperation is critical

To accomplish the 2018 clam surveys, people from many departments within Metlakatla were involved. Each individual's contribution helped ensure the success of the surveys. Collaboration was required for planning (e.g., beach selection), equipment use (e.g., boats), personnel, scheduling, budgets and other miscellaneous coordination. As the work continues, communication between departments will be necessary to ensure things run smoothly, and that scheduling and personnel conflicts are avoided.

Recommendations:

- Ensure clear lines of communication between departments to minimize scheduling conflicts, communicate successes and challenges, and maximize opportunities for collaboration.
- Assign a dedicated person to be the survey lead and to liaise between departments.

4.5. Key results from the 2018 surveys

The data analysis and plotting of results was done in 'R,' a programming language and software system for statistical computing. The R code was originally derived from a script used by intertidal clam biologist Michelle Bigg (Department of Fisheries and Oceans) for the Seal Island long time-series data and adapted to fit the data analysis needs of Metlakatla. For example, new R code was written for Metlakatla to include analysis of growth index, condition index, and inclusion of wet tissue weight for weight-related analysis. The R script for data analysis was written to be as user-friendly as possible and is an important component of the Metlakatla butter clam CBEM program that will be used for subsequent survey data analysis.

4.5.1. Population density, abundance and biomass estimates

Table 4.4 below provides an overview of the density, abundance and biomass results from the 2018 surveys. With longer time-series data, and if survey precision is good, it should be possible in the future to test for significant differences between historic and recent mean population estimates.

Table 4.4 Summary of key results from the 2018 butter clam surveys.

Beach	Size Class	Mean Density (clams/m2	SE	CI95	Total Abundance (clams)	SE	CI95	Mean Biomass (kg/m2)	SE	CI95	Total Biomass (kg)	SE	CI95
Beach 1	Sublegal	6.78	0.87	1.74	137,811.10	30,638.77	61,453.60	0.12	0.03	0.06	4,170.54	1,083.20	2,172.63
	Legal	11.44	1.85	3.72	295,878.90	65,473.34	131,322.90	1.18	0.25	0.49	41,602.21	8,670.05	17,389.92
	Total	18.22			433,690.00			1.30			45,772.75		
Beach 2	Sublegal	10.73	2.36	4.72	366,597.60	80,693.51	161,356.60	0.48	0.12	0.22	16,496.86	3,739.59	7,477.78
	Legal	19.88	2.41	4.83	679,213.00	82,472.57	164,914.10	2.78	0.30	0.59	95,076.21	10,091.92	20,180.04
	Total	30.61			1,045,810.60			3.26			111,573.07		
Beach 3	Sublegal	1.02	0.42	0.90	17,238.00	7,058.21	15,138.35	0.02	0.02	0.04	380.30	288.52	618.80
	Legal	2.34	1.53	3.28	39,546.00	25,839.28	55,419.74	0.21	0.12	0.26	3,625.05	2,082.56	4,466.65
	Total	3.36			56,784.00			0.23			4,005.35		

Key population data are reported as estimates of mean density, abundance, mean biomass and total biomass for each of the three beaches surveyed. Data are reported by butter clam class size: sub-legal (<63mm) and legal (≥63mm). Total (sub-legal + legal) estimates are also provided. Standard error (SE) and 95% confidence intervals (CI95) are included.

4.5.2. Length and weight data

Data from all beaches showed that the shells with maximum length (103 mm) and maximum total weight (392.3 g) were both recorded from beach 2. For comparison, maximum length recorded on the south coast at Seal Island was 115 mm in 1976 (Bigg, 2015). Surveys on the north coast of British Columbia by Gillespie and Bourne (2005), recorded lengths typically below 90 mm. Longer shell lengths on beach 2 could be attributed to more favourable growing conditions (e.g., better food availability, warmer temperatures) and longer-lived butter clams than other places on the coast where Gillespie and Bourne (2005) surveyed.

Figure 4.2 illustrates the frequency of length measurements at each surveyed beach. Beach 1 and beach 2 are left skewed, meaning most butter clams fall into larger shell length categories. Beach 3 is right skewed, meaning most clams fall into smaller shell length categories.

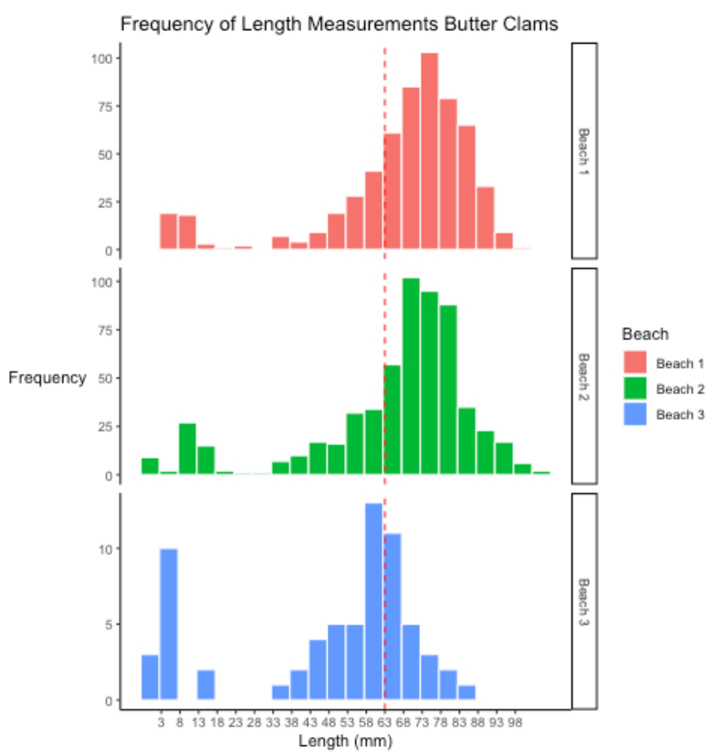


Figure 4.2 Frequency of length measurements at each of the three beaches surveyed. The dotted red line represents legal size (≥63mm).

To better understand the relationship between wet tissue weight and shell length, I plotted the wet tissue weight (g) and the shell length of each butter clam that was bio-sampled at each beach (Figure 4.3). The data were plotted using the ggplot2 package in the R software program. The geom_smooth function was used to derived fitted power trend lines for the wet tissue weight to shell length relationship at each beach. The slope of the curves indicates the rate of increase of wet tissue weight in relationship to the increase in shell length. A fitted line can be used to estimate the value of one parameter (e.g., wet tissue weight) given the value of the other parameter (e.g., shell length).

Results show that the length and weight relationship for butter clams from beach 1 is similar to that for beach 2. Butter clams from beach 3 show smaller shell lengths and smaller tissue weight than beach 1 and beach 2. This is consistent with other results that suggest non-ideal growing conditions at beach 3. Poor substrate and proximity to a fresh water stream (reducing salinity) may be contributing to poor growth.

Figure 4.3 Fitted power trend lines showing the relationship between wet tissue weight and shell length at each beach.

4.5.3. Age data

Collecting age data provides important information about population demographics/age classes, growth rates, recruitment and mortality. Understanding population dynamics can help managers estimate potential effects of harvesting (or other stressors) on the population. There is an inherent survey bias toward large clams because they are easier to find.

Quayle and Bourne (1972) studies have estimated that butter clams in BC reach maturity at 38 mm length and approximately 3 years of age. Data from the butter clams sampled in the Metlakatla surveys were analyzed to see if those butter clams also reach 38mm around 3 years of age. Table 4.5 shows the mean length, age and weight (total and wet tissue weight) for butter clams at each of the surveyed beaches in Metlakatla territory. Because few of the sampled butter clams were exactly 38mm in length, and to account for measurement error, all sampled butter clams which measured between 35mm and 41 mm were grouped together and their mean age, mean total weight and mean wet weight were determined. Results from beach 1 and beach 2 are similar to those reported by Quayle and Bourne (1972), though data from beach 3 show that it takes butter clams from that beach over twice as long (6.33 years) to reach 38mm. This result could be attributed to variety of factors that inhibit growth including poor substrate and proximity to a freshwater stream. It is also possible that beach 3, like many clam gardens along BC's coast, has not been harvested or tended since the late Holocene (Groesbeck et al., 2014). Regular harvesting is thought to reduce overcrowding, maintain suitable habitat and keep sediments aerated (Lepofsky et al., 2015). Not harvesting a clam garden site may lead to a decrease in productivity, although this theory is offered as a suggestion and is not yet substantiated.

Table 4.5 Mean length, age and weight of butter clams at maturity

Beach	Mean Length (mm)	Mean Age (years)	Mean Total Weight (g)	Mean Wet Weight (g)
1	37.3	3.0	13.1	5.55
2	38.2	3.45	14.7	6.06
3	39.7	6.33	36.5	11.4

Quayle and Bourne (1972) also report that butter clams in the Prince Rupert area reach legal-size (63 mm) at approximately nine years of age. Data from the butter clams sampled in the Metlakatla surveys were analyzed to see if those clams also reach 63 mm around 9 years of age. Table 4.6 shows the mean length, age and weight (total and wet tissue weight) for butter clams at each of the surveyed beaches in Metlakatla territory. Because few of the sampled butter clams were exactly 63 mm in length, and to account for measurement error, all sampled butter clams which measured between 60 mm and 66 mm were grouped together and their mean age, mean total weight and mean wet weight were determined.

Both beach 1 and beach 2 show that the sampled butter clams reach legal size at 7.84 years and 8.12 years respectively, slightly earlier than the Quayle and Bourne (1972) estimates. These results could be attributed to good habitat conditions (e.g., substrate, slope) or factors such as abundant food availability or harvesting activity. Butter clams from beach 3 reach legal size around 11.1 years of age, taking longer than both beach 1 and beach 2, and the Quayle and Bourne (1972) samples. These data are consistent with the data from Table 4.5, showing that beach 3 takes substantially longer to reach a particular age than the other two beaches which is likely attributable to the poor substrate, proximity to a freshwater stream or lack of harvesting activity, among other possible factors that could limit growth.

Table 4.6 Mean length, age and weight of sampled butter clams at recruitment to legal size (63 mm).

Beach	Mean Length (mm)	Mean Age (years)	Mean Total Weight (g)	Mean Wet Weight (g)
1	63.4	7.84	68.5	27.5
2	63.3	8.12	71.4	30.3
3	62.2	11.1	76.1	28.5

Butter clams with shell lengths of 60 mm to 66 mm were used to account for measurement error and the fact that few butter clams were exactly 63 mm in length.

Based on the information derived from Table 4.5 and Table 4.6 and from Qualye and Bourne (1972), age classes were determined to be: juvenile (ages 1-3); mature (ages 3-8), legal size (ages 9-15) and senile (age 16+). Figure 4.4 shows the results of grouping the sampled butter clams for each beach according to these age classes. Beach 1 and beach 2 are dominated by legal-sized butter clams, with a large majority of the remaining population measuring at sub-legal size, but still reproductively mature (Figure 4.4). This suggests that under favourable circumstances, beach 1 and beach 2 will have healthy numbers of butter clams recruiting into the legal-size class over the next five years. Beach 3 had fewer butter clams overall but the butter clams that were sampled were all reproductively mature and a majority were in the legal-size class.

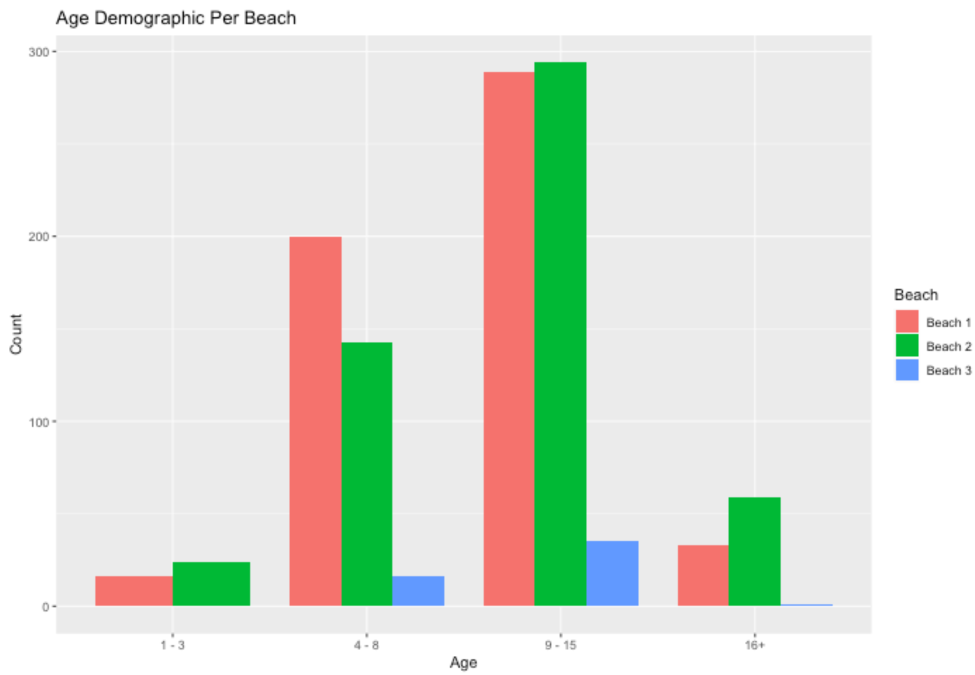


Figure 4.4. Age demographics of sampled butter clams from each beach. Age classes are separated into juvenile (1-3 years), mature (4-8 years), legal (9-15 years), senile (16+ years). These age class bins were informed by Quayle and Bourne, (1972) and the data from Table 4.6 and 4.7.

4.5.4. Growth Curves (von Bertalanffy model)

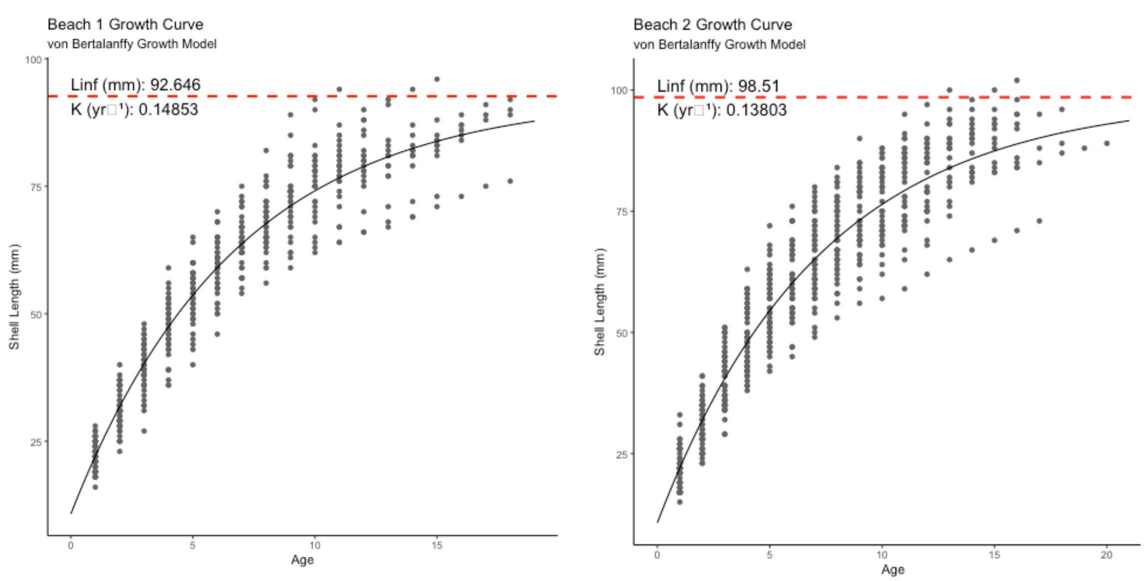
The von Bertalanffy growth equation (Figure 4.5) best describes the relationship between growth (length) and age in bivalves and fish (Gosling, 2003) and was the model used to determine growth rate in this study. Growth rates are typically used to determine how long it takes for a bivalve to reach legal size (Gillespie & Kronlund, 1999). Comparing growth rates spatially and temporally also provides information about the relative condition of populations. A growth rate can be estimated using total length at age, or length-at-annulus measurements. The latter incorporates historic information by detailing the length at each year of age, and was the method used in this study (Gillespie & Kronlund, 1999).

$$\boldsymbol{L_{t} = L_{\infty} \, (1 - eK^{\,(t-t_0)})}$$

Figure 4.5 Von Bertalanffy equation

Lt is the mean length at age *t;* $L\infty$ is the asymptotic mean length-at-age; *K* is the Brody growth rate co-efficient (yr -1) which represents the exponential rate of approach to the asymptotic length (Schnute & Fournier, 1980); and t_0 is a modelling artifact that represents the time or age when mean length was zero (Ogle, 2013).

The von Bertalanffy growth curves (Figure 4.6) were created by first estimating the parameters of the von Bertalanffy equation ($\boldsymbol{L\infty}$, $\boldsymbol{K}$ and $\boldsymbol{t_0}$) by optimizing the negative log likelihood function calculated on each beach's length-at-annulus dataset. These optimal parameters were then used to calculate the growth model for each respective beach. The results of the von Bertalanffy growth model curves suggest that butter clams from beach 2 reach a higher mean asymptotic length at a slightly slower rate than butter clams from beach 1, which have a slightly higher rate of growth, but reach a lower mean asymptotic length. Butter clams from beach 3, as expected given the other results, have a slower growth rate and a much lower mean asymptotic length.



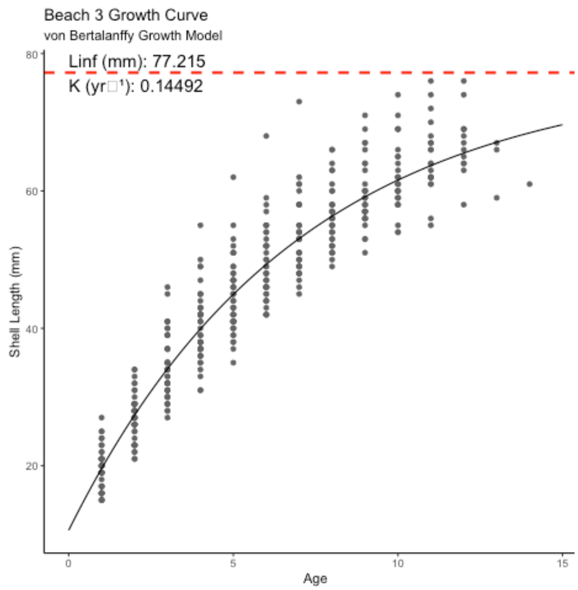


Figure 4.6 Von Bertalanffy Growth Models
Fitted curves for L_∞ (mm). $L\infty$ is the asymptotic mean length-at-age. K (yr -1) is the Brody growth rate co-efficient and represents the exponential rate of approach to the asymptotic mean length-at-age.

4.5.5. Growth Index and Condition Index

GI and CI are useful biomarkers for long-term monitoring studies on beaches with known differences (e.g., one with exposure to pollution sources and one with no known or apparent sources of pollution). As Metlakatla surveys additional beaches and obtains longer time series data (providing more informative estimates of the biomarker values), comparison of CI and GI can be done using a statistical analysis (e.g., a *t* test) to test significant differences between locations. GI provides insights into effects that are linked to growth inhibition (Gagne et al., 2007). CI is used to assess environmental contamination, a key stressor for bivalves in Metlakatla territory.

Table 4.7 Growth Index

Beach	Growth Index (GI) Mean (shell length/age)
1	8.17
2	7.74
3	6.67

GI is calculated for each beach by dividing shell length by age (mm/yrs) for each butter clam in the sample and then taking the mean of those results.

Table 4.8 Condition Index

Beach	**Condition Index:** **Mean (wet tissue weight (g)/shell length [mm])**
1	0.54
2	0.56
3	0.34

CI is calculated for each beach by dividing wet tissue weight by shell length (g/mm) for each butter clam in the sample from that beach and then taking the mean of those results.

GI and CI values provide a relative comparison between the condition at different beaches (spatial comparison) or between the condition at different points of time on the same beach (temporal comparison). The values reported in Tables 4.7 and 4.8 represent only three beaches in the territory and only one year of data collection. Therefore, results related to the condition of the butter clams sampled in 2018 should be considered preliminary. As more beaches are surveyed, Metlakatla managers will develop an understanding of the range of values that reflect a healthy clam population (e.g., from a reference beach) and the range of values that reflect a relatively less healthy population (e.g., from a contaminated beach).

Consistent with other the other results from the 2018 surveys, beaches 1 and 2 have similar GI and CI values, while beach 3 values are notably lower. A lower CI value for beach three is not likely to be due to biological contamination problems because of its relative proximity to beach 2, which is a beach that is regularly tested for biological contamination and open to harvest. However, there are many other factors that influence growth (tissue weight and shell length) that could be contributing to low GI and CI values at beach 3. Factors potentially affecting growth include: substrate; lack of harvesting/clam garden tending; food availability; salinity; and water temperature. Any of these factors, alone or cumulatively, could be impacting butter clams at beach 3.

Chapter 5. **Discussion**

In collaboration with the Metlakatla First Nation, this research study successfully achieved its primary objective (see section 1.2), which was to design and test a butter clam monitoring protocol to collect baseline data on bivalve populations in Metlakatla territory. The Metlakatla butter clam monitoring program was designed to incorporate elements of successful CBEM models in an Indigenous context. The goal of Metlakatla's butter clam CBEM program is to inform environmental decision-making and resource management in a time of unprecedented environmental change and impacts from human activities in Metlakatla territory. The CBEM program and the data it gathered on butter clams are important components in the Metlakatla CEM framework (Figure 4.1).

Like many other Indigenous-led CBEM programs in Canada, (Gearheard et al., 2011; Gérin-Lajoie, 2018; Housty et al., 2014; Thompson et al., 2019), this study sought to bridge SK and Indigenous Knowledge systems (TEK and LK) and incorporate community values and priorities to better inform study objectives, design and implementation (research objective number two). Although TEK and LK did inform the design and implementation of this research, there is much more room for explicitly bridging multiple knowledge systems, especially in establishing a historical baseline of the condition and abundance of butter clams in Metlakatla territory. I anticipate that as the Metlakatla butter clam CBEM program develops and community support for this work grows, there will be more opportunity for TEK and LK systems to be applied.

Assessing the baseline condition of the butter clams surveyed on beach 1, beach 2 and beach 3 is the third objective of this research study. All of the data collected and analyzed contribute to an assessment of the overall condition of butter clams from the surveyed beaches. These preliminary results show that beach 2, the harvested beach, is in good condition relative to the other beaches surveyed and relative to other (limited) data from beaches in the region. Beach 2 had the highest mean density, the biggest clams (length and weight), a healthy population demographic, robust growth rate and relatively high GI and CI values compared to the other beaches surveyed. Although I did not test for the influence of harvesting on productivity and growth, the literature suggests that regular harvesting on beach 2 may be strongly influencing the results. Field notes from the survey also indicate that there is ideal substrate on beach 2. Evidence of the abundance of shells from dead butter clams also confirm that beach 2 is highly productive. Predation may also be helping to remove older clams, make room for new recruits, aerate the soil and maintain a healthy habitat, producing a similar effect as harvesting on the populations, though this is a personal hypothesis that has not been tested in the literature.

The condition of butter clams at beach 1 also seems relatively good. The main difference observed between beach 1 and beach 2 is the mean density of butter clams, which is notably lower on beach 1. It is possible (but unconfirmed) that historic and present harvesting at beach 2 accounts for some of this difference. Otherwise, beach 1 and beach 2 share similar results in terms of length and weight models, age demographic, growth rate and GI and CI values.

The butter clam population at beach 3, as has been discussed, seems to be in relatively poor condition. This assessment is based on the low mean density, poor growth rate and low GI and CI values reported from the 2018 data.

Achieving research objective number four, the butter clam monitoring protocol developed in this study was refined based on lessons learned from the testing of the protocol in 2018. The updated protocol was implemented in 2019. Additional surveys are being planned for 2020. In this way, this study has achieved the final research objective of providing Metlakatla Stewardship Society with training and resources to continue the butter clam CBEM program. It is my hope that this work will inform Metlakatla's approach to monitoring additional valued environmental components in the future.

As a case study, my research presented an opportunity to explore an Indigenous-led collaborative CBEM that explicitly incorporates the values, goals, constraints and characteristics of a coastal First Nation. Recommendations from this study may offer direction to other Indigenous communities on the design and implementation of Indigenous-led CBEM, particularly those initiatives with a focus on cumulative effects management.

5.1. Drawing from principles of successful CBEM

A summary of the recommended features of CBEM programs from the literature can be found in Table 5.1. A more detailed description of the most important elements that make up the Metlatkatla butter clam CBEM program follows.

Table 5.1 Key features of successful CBEM programs

Key Elements for effective, successful and sustainable CBEM			
Key Element	**Short Description**	**Source**	**Included in Metlakatla CBEM ?**
Community-driven	Include community values, perspectives, LK	McKay & Johnson, 2017b	Yes
Support	Adequate funding, capacity, resources,	McKay & Johnson, 2017b; Kouril, Furgal & Willans, 2016	Mostly
Defined methods	Credible, accepted by decision-makers, consistent, simple and standardized	McKay & Johnson, 2017b; Kouril, Furgal & Willans, 20162016	Yes
Data confidence	Accurate and reliable for decision-making	McKay & Johnson, 2017b	Yes
Reporting	Results reported to participants/partners/ Community/decision-makers	McKay & Johnson, 2017b	Yes
Cumulative impacts	Consider cumulative effects from development projects and explicitly monitor	McKay & Johnson, 2017b	Yes
Partnerships	Can increase credibility and allow for data and resource sharing	McKay & Johnson, 2017b Kouril, Furgal & Willans, 2016	Yes
Communication	Ongoing and clear to build trust, encourage buy-in, build relationships	McKay & Johnson, 2017b; Kouril, Furgal & Willans, 2016	Yes
Trust	Trusting relationships lead to acceptance of data, compliance, and information sharing.	McKay & Johnson, 2017b	Yes
Linked with culture	Include TEK, LK and Indigenous values	McKay & Johnson, 2017b; Kouril, Furgal & Willans, 2016	Yes
Influence	Can result in better management by local people of resource	McKay & Johnson, 2017b	Yes

Key Elements for effective, successful and sustainable CBEM (Cnt'd)			
Key Element	**Short Description**	**Source**	**Included in Metlakatla CBEM ?**
Policy & Legal support for CBEM	Mechanisms to support local resource management and decision-making	Danielsen et al., 2009	Somewhat
Local decision-making as a management objective	Local people empowered to make decisions as an objective of management. Data linked to decision-making.	Danielsen et al., 2009; Kouril, Furgal & Willans, 2016	Yes
Community members have vested interest	Natural resources are part of local way-of-life, local people are interested in monitoring and management	Danielsen et al., 2009; Kouril, Furgal & Willans, 2016	Yes
Capacity building	Training and skills building of community members	Kouril, Furgal & Willans, 2016	Yes
Clear objectives and understanding of methods, costs, etc.	Before beginning monitoring, to ensure program is relevant to community	Kouril, Furgal & Willans, 2016	Yes
Compensation for participation	Incentives or compensation for contributions	Kouril, Furgal & Willans, 2016	Yes
Evaluation	Determining value of the CBEM to ensure goals are met	Kouril, Furgal & Willans, 2016	No
Information and communication technologies	For collecting and accessing data (Global Positioning System, Global Information System, internet, etc.)	Kouril, Furgal & Willans, 2016	Somewhat
Linking data to decision-making	Data leads to decision-making which leads to action	Kouril, Furgal & Willans, 2016	Not yet
Local coordinator	Champion of monitoring program, liaises between partners	Kouril, Furgal & Willans, 2016	Yes/No (not permanent)
Qualitative methods	Exploring social & cultural aspects through interviews, workshops, etc.	Kouril, Furgal & Willans, 2016	Somewhat

5.1.1. Adopting a collaborative but locally driven approach to CBEM

The Metlakatla butter clam CBEM program uses an approach that closely fits the 'collaborative CBEM with local data analysis and interpretation' classification described by Kouril, Furgal and Whillans (2016). This type of approach to CBEM accounts for roughly 20.2% of examples in the published literature (Kouril, Furgal & Whillans, 2016), and is particularly suitable when local people have a vested interest in resource use and monitoring outcomes (Danielsen, et al., 2009), which is the case for the Metlakatla community.

The main aspects of a collaborative CBEM with local data analysis and interpretation are:

- Local community and experts are the data collectors and end-users of the data;
- Involves community in data collection, analysis, interpretation and in management decision-making;
- Incorporates TEK/LK; and
- External support may assist in facilitation and training (Kouril, Furgal & Whillans, 2016).

Metlakatla's butter clam CBEM program is a collaboration primarily between the Metlakatla community (MSS managers as well as Metlakatla members) and external researchers (SFU graduate students and faculty members). PollutionTracker was also involved indirectly with this research. PollutionTracker is a contaminant monitoring program that aims to determine the relative state of pollution in coastal BC. PollutionTracker partnered with Metlakatla to take sediment, crab and mussel samples from a site near Metlakatla Village and to analyze it for a suite of contaminants that are of concern for marine health (Metlakatla First Nation, 2019). The location of the sampling site was taken into consideration during beach selection for this study; having contaminant data near butter clam survey sites will provide useful information about potential exposure to contaminants, which are a key stressor to bivalves.

Metlakatla is well positioned to lead a CBEM program because of supportive community leadership, existing partnerships and collaborations, internal expertise and capacity, and departmental policies and mandates that support conservation and environmental stewardship. Metlakatla Stewardship Society staff provided guidance and direction throughout this study and their involvement helped to ensure that decisions and deliverables served Metlakatla's interests. For example, Metlakatla Stewardship Society staff identified important FSC harvesting beaches as priority places to monitor, helped researchers communicate about the process and results to the community, and helped to coordinate field work around important events in the community.

Metlakatla members were encouraged to participate by being offered a wage, training and experience. Building skills and capacity of community members is a key benefit of collaborative CBEM, cited in the literature (Kouril, Furgal & Whillans, 2016; McKay & Johnson, 2017a). Youth are typically underrepresented in CBEM programs (Gérin-Lajoie et al., 2018), but in this study, summer students were recruited and hired as data collectors and trained in scientific methods. Inter-generational learning took place when summer students were paired with older Metlakatla members in the field, so that informal teaching could take place about traditional practices, plant and animal identification and even translations of marine species names into Sm'algyax, the traditional language of Metlakatla people. Inter-generational knowledge transmission is more common in CBEM than in conventional scientific monitoring because it "engages and involves community members as local experts" (Gérin-Lajoie et al., 2018, p.394).

Creating opportunities for community members to benefit from involvement in CBEM can increase the impact of monitoring efforts in foreseeable and in unanticipated ways. According to a post-participation survey, participation in the butter clam monitoring field work increased community members' interest in the Metlakatla CEM Program and in harvesting practices more generally. When monitoring is valued by the community, it strengthens community buy-in and can increase local compliance with management decisions (Aceves-Bueno et al., 2015; McKay & Johnson, 2017a; Thompson et al., 2019).

5.1.2. Using methods that are scientifically rigorous yet practical to implement

An objective of this research was to develop a values-based CBEM program that is both scientifically rigorous and operationally feasible. Data must be credible enough to be accepted by decision-makers and resource users (McKay & Johnson, 2017b; Wilson et al., 2018). At the same time, Metlakatla (like other small communities), face real constraints on funding and resources, so they must balance the trade-offs between more precise and substantial data and the actual quality of data required for management purposes. Herman-Mercer et al., (2018), suggest that the precision of the data simply needs to match the level of precision required for management decision-making. For example, choosing bio-indicators (GI and CI) that are easy and affordable to measure but provide reliable information that has been verified in the literature, was a way of obtaining quality data using the skills and equipment that Metlakatla already had, or could easily acquire.

5.1.3. Using multiple evidence bases to enhance understanding

Metlakatla Stewardship Society staff and Metlakatla members contributed expertise, TEK and LK to the process of survey site selection and data collection. Using multiple evidence bases (TEK, LK and SK) to enhance understanding of complex socio-ecological systems is effective not only with respect to environmental/conservation outcomes (Aswani, Lemahieu & Sauer, 2018; Berkes M., Berkes H., & Fast, 2007; McKay & Johnson, 2017b;), but also for social well-being (Kipp et al., 2019; Parlee, Geertsema & Willier, 2012; Wiseman & Bardsley, 2016). For example, a Metlakatla elder participated in all the field work and informally shared TEK and LK with other participants about how and where to harvest shellfish and other marine species, unusual or expected observations of the local ecosystem and how traditional practices have changed over time. This study provides an opportunity to maintain TEK and LK by revitalizing the traditional practices for harvesting shellfish and by engaging youth (Aswani, Lemahieu & Sauer, 2018). Incorporating Indigenous values into a CBEM program (including TEK and LK) improves Indigenous peoples' ability to actively and effectively participate in local resource management and decision-making that affects their ways of life (Danielsen et al., 2009; Johnson et al., 2015).

5.1.4. Building and maintaining trusting relationships

At the beginning of this study, I was a new researcher and unknown to the Metlakatla community. However, there was an existing good relationship between Metlakatla and SFU that had existed for several years and had a foundation of mutual trust and respect. Because of this pre-existing relationship, building rapport, trust and collaboration came more easily to the people involved in my study than if the relationship was new. Building trust and developing respectful and collaborative research partnerships is essential to the success of collaborative CBEM (Adams et al., 2014; Kouril, Furgal & Whillans, 2016; McKay & Johnson, 2017b). In particular, as a non-Indigenous researcher working with and within an Indigenous community, it was incumbent upon me to understand the legacy of past unethical research practices that have caused harm to Indigenous peoples and to follow engaged, reflective and respectful research practices (Jasmyn & Lynch, 2017).

5.1.5. Connecting CBEM to CEM

McKay and Johnson (2017b), include the consideration of cumulative effects of resource development as a key element of successful CBEM because cumulative effects represent an urgent and prevalent issue. Canadian environmental laws and regulations are criticized for not adequately addressing cumulative effects at the local scale, yet there are no standards or guidelines on how to address cumulative effects within CBEM, even in cases where industry, communities and government are already working together (McKay and Johnson, 2017b). The Metlakatla butter clam CBEM program and the Metlakatla CEM Program will contribute to examples of programs that link CBEM and CEM by establishing baselines, monitoring changes to valued components over time and using that monitoring data to inform EA and project consultations.

5.1.6. Using monitoring data to inform decision-making

A key characteristic of the Metlakatla butter clam CBEM program is that all materials, methods and data remain with, and are managed by, Metlakatla. Data and knowledge generated in the Metlakatla butter clam CBEM program will be used by Metlakatla managers for decision-making. In the literature, there is a lack of published accounts of CBEM where the data collected are explicitly used by the local community for decision-making. Lack of published data may be a result of communities being less motivated by publishing than researchers, or being concerned over sharing sensitive data; the lack of case studies in the literature does not necessarily mean these examples do not exist (Kouril, Furgal & Whillans, 2016).

CBEM programs are often evaluated based on whether monitoring data informs decision-making. Metlakatla are the primary users of the data for decision-making in the Metlakatla butter clam CBEM program, which is uncommon based on the literature. The data collected in Metlakatla's CBEM program will contribute to better understanding of baseline conditions on the north coast of BC. The management actions that Metlakatla take in response to these data may influence external resource managers and decision-makers—flipping the status quo of decision-making where First Nations rarely have full decision-making authority, but, rather, their perspectives are merely considered in the decision-making of external "experts" (Kouril, Furgal & Whillans, 2016). Research has shown that CBEM not only produces meaningful data for decision-making but can be an expression of Indigenous governance by incorporating traditional and cultural perspectives and concepts of stewardship and responsibility to protect the environment (Wilson et al., 2018).

5.1.7. Ensuring data quality

A common concern raised, particularly by scientists and Settler governments, with CBEM is the accuracy, precision and reliability of data collected by non-professionals (Conrad & Hilchey, 2011; Herman-Mercer, 2018; Wilson et al., 2018). Decision-makers often disregard CBEM data despite evidence that shows that when non-professional data collectors are trained, they can collect quality data that are comparable to professional data sets (Wilson et al., 2018). While Metlakatla managers are the primary decision-makers who will use the CBEM data, numerous external organizations and governments who work with Metlakatla on various environmental, conservation and resource management initiatives will need to be convinced to accept the data as credible and reliable.

To mitigate concerns and instill confidence in the data, Metlakatla's CBEM was designed to use rigorous and defensible scientific methods that met or exceeded the standard methods of the Department of Fisheries and Oceans Canada and were supported in peer reviewed literature. Quality control was addressed through training programs and on-site supervision by me, the lead researcher, throughout the field sampling and bio-sampling work. A new method for aging clams was developed to improve accuracy of an inherently subjective aging process. Redundancy was built into the data collection procedures by using hard copy data sheets to record the data and then digitally scanning them and filing both the hard and digital copies for reference. Data were then transferred to a master excel sheet by me and cleaned and reviewed for any errors.

5.1.8. Building adaptive capacity

Adaptive capacity is the ability of a system to adjust to stress and maintain function or thrive in the face of change (McCarthy et al., 2005). Adaptive capacity is a fundamental component of resilient socio-ecological systems and is dependent on effective monitoring systems and support of the local community (Aceves-Bueno et al., 2015; Thompson, et al., 2019). The Metlakatla CBEM program should enable responsive management of butter clam populations in Metlakatla territory and build adaptive capacity by establishing baselines and using an iterative approach to monitor and manage butter clams. The Metlakatla CBEM program is iterative in that it monitors bivalve populations over time, uses the monitoring data to inform management actions (according to the Metlakatla CEM Program management triggers) and then continues to monitor and implement management actions based on how conditions are maintained, improved or degraded.

5.2. Research limitations

The research presented in this study has several limitations that should be considered, especially when applying these methods in other communities. The research is situated in the context of the Metlakatla First Nation and its territory and reflects the specific goals and values of this community. Although aspects of the process design and general experiences (challenges and successes) may be suitable and informative for application in other coastal First Nations communities, the Metlakatla butter clam CBEM was designed and implemented with Metlakatla's specific goals, objectives, values, constraints and opportunities in mind. For example, the Metlakatla CEM Program identified butter clams as a priority valued component, determined the condition indicator for butter clams (population density), and set high level goals for maintaining healthy bivalve populations in Metlakatla territory. The Metlakatla CEM Program also helped to galvanize Metlakatla leadership, staff and community members around environmental monitoring and management in Metlakatla territory. The Metlakatla CEM Program provided direction and clarity to this study, making the job of designing a CBEM simpler, cheaper and quicker. In the absence of pre-existing plans or guiding programs, other communities would have additional work to do in the beginning to identify goals, priorities and objectives to inform the design of an effective CBEM program and may potentially need to generate buy-in from leadership, community members and collaborators. Methods for beach selection, including specific criteria for evaluating candidate beaches, is another example of a component of this work that was specifically designed with Metlakatla's needs in mind.

The results of the 2018 butter clam surveys should be considered preliminary. Although baseline condition estimates are discussed at the beginning of this chapter, no determinative conclusions can be drawn from one year of data. According to the IUCN (2018), a minimum of ten years of data should be collected before determining the status of a population. Ten years of population data should smooth out some of the 'noise' of natural variability within a population caused by factors such as poor recruitment or high mortality related to abiotic and biotic factors such as temperature, predation, salinity or air exposure (Dame, 2012). Consequently, the condition estimates for butter clams on the beaches surveyed in 2018 are made with low confidence and should be confirmed over time. While the three beaches surveyed in 2018 may be broadly representative of other beaches on the territory, factors that influence bivalve population health vary spatially and temporally; more information is needed to increase the confidence of the estimates about the condition of bivalves in Metlakatla territory.

5.3. Recommendations and Future Research

A critical next step for the Metlakatla CEM Program is to determine how the knowledge gained from this study will be integrated into resource management decision-making and the governance structure of Metlakatla First Nation. Ensuring that the CBEM program is “institutionalized within the existing management structures and linked to the delivery of ecosystem goods or services” will increase the probability of success in the long term (Danielson, Burgess & Balmford, 2005).

The following are my recommendations for improvements or future research related to butter clam CBEM in Metlakatla territory:

1. Develop a more comprehensive method for evaluating the success of the Metlakatla butter clam CBEM program. The key elements of effective and sustainable CBEM programs, as reported by McKay and Johnson, (2017b) and Kouril, Furgal and Whillans (2016) which are summarized in Table 9, could be used as starting place for identifying evaluative metrics.

2. Integrate the Guardian Watchmen program and the Metlakatla butter clam CBEM program so that Metlakatla can “enhance its monitoring with the observations of land and sea users” by incorporating shellfish harvesters’ landings, observations and experiences (Thompson, et al., 2019).

3. Gather TEK on the historic conditions of bivalves in Metlakatla Territory. Qualitative interviews with community members, information gathering from Metlakatla’s Traditional Use Studies and archeological studies can be used to develop a historical baseline. Historical baselines help to prevent shifting baseline syndrome and enhance understanding of how population trends have changed over time. Shifting baseline syndrome can be defined as “a gradual change in the accepted norms for the condition of the natural environment due to lack of past information or lack of experience of past conditions” (Soga & Gaston, 2018). One of the best ways to guard against shifting baseline syndrome, protect biodiversity and enhance socio-ecological system health is by incorporating LK and TEK into monitoring and management regimes (Gatti et al., 2015; Thornton & Scheer, 2012).

4. Explore how participation in the Metlakatla butter clam CBEM program affects participants’ perceptions of environmental advocacy, interest in clams and clam harvesting, and understanding of cumulative effects

management. Use this knowledge to enhance the program and maximize benefits to the community.

5. Develop a web-based application for Metlakatla members to access data summaries and annual reports related to this work.
6. Consider publication of this work to add to the limited literature on Indigenous-led CBEM case studies, particularly cases where the data collected directly influences local resource management and decision-making (Conrad & Hilchey, 2011; Kouril, Furgal & Whillans, 2016). If work is published, pursue co-authorship between researchers and Indigenous participants (see Ward-Fear, et al., 2019).
7. Make a concerted effort to involve youth in CBEM initiatives, revitalization of traditional practices, and TEK and LK dissemination, to help preserve Indigenous Knowledge. When cultural knowledge and practices are lost, LK and TEK are devalued and young people are more likely to become disengaged, which results in a further erosion of culture and loss of Indigenous Knowledge (Aswani, Lemahieu & Sauer, 2018). Where Indigenous Knowledge is lost or eroded, ecological systems are more likely to also be degraded (Aswani, Lemahieu & Sauer, 2018).
8. Utilize the knowledge gained in this study for purposes beyond the Metlakatla butter clam CBEM and the Metlakatla CEM Program, including: monitoring other biophysical values of importance to the community; restoring clam habitat using LK and TEK; increasing Metlakatla members' interest in traditional harvesting practices; and building relationships between government, researchers and the community.

5.4. Conclusion

My research demonstrates that an Indigenous-led, collaborative CBEM can be effectively implemented to collect baseline data for monitoring cumulative effects and other impacts on an important marine species, butter clams. This study demonstrates that good program design and meaningful community input can provide social and cultural benefits to community participants. By developing a methodology for bridging community values, TEK, LK and SK into a monitoring framework, I incorporated key aspects of effective CBEM identified in peer reviewed and grey literature.

This study adds to the growing body of work that explores the challenges and opportunities of Indigenous-led, collaborative CBEM. This research is innovative in that it is nested within a community-led CEM framework designed to manage cumulative effects from development. Continuation of the Metlakatla butter clam CBEM is required to evaluate its effectiveness in the long-term and to obtain a reliable estimate of the condition and stability of butter clam populations in Metlakatla territory. A next step is to identify further processes for linking monitoring data to decision-making within institutional and governance structures of Metlakatla First Nation. Although this case study illustrates the unique experience of Metlakatla First Nation, the elements of CBEM design that were incorporated to maximize benefits and reduce common failures of Indigenous-led CBEM may be applicable to other Indigenous communities seeking a community-based approach to environmental monitoring.

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