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Monitoring salmon aquaculture waste: The contribution of First Nations' rights, knowledge, and practices in British Columbia, Canada

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Abstract

British Columbia's current approach to monitoring salmon aquaculture waste is disconnected from political and legal trends towards the recognition of Aboriginal rights in Canada. Drawing on insights from collaborative monitoring in northern Canada and interviews with 23 Kwakwaka'wakw clam-diggers and cultural specialists (2006–2007), preliminary directions for integrating First Nations' values, knowledge and stewardship practices into marine environmental monitoring are identified. Kwakwaka'wakw monitoring practices include the use of qualitative individual, community and population scale indicators and the integration of traditional knowledge as baseline data about the healthy conditions of traditional food resources.

Keywords: Indigenous monitoring; Traditional knowledge; Aquaculture; Marine pollution; First Nations

1. Introduction

Salmon farming is part of a dramatic global transition in seafood production from wild harvesting to aquaculture. While aquaculture has been suggested as a way to reduce pressure on wild fisheries and provide alternate economic development options in coastal regions, in many parts of the world adverse environmental and social impacts have been documented [1–5].

On the west coast of Canada, salmon farming has led to a substantial public controversy [6,7]. Environmental groups and First Nations governments are working at the front lines of resistance to the top-down imposition of the salmon farming industry and its impacts, and as the key voices in advocating for alternative technologies and management practices. First Nations have the most at stake in decisions about the development of the salmon aquaculture industry, as virtually all salmon farming operations in British Columbia (BC) fall within their traditional territories [6]. Arguably, the Kwakwaka'wakw people whose traditional territories encompass the Broughton Archipelago, northern Johnstone Strait and southern Queen Charlotte Strait, have faced the most significant impacts of salmon farming with 37 tenures in the Kwakwaka'wakw Sea.[1] They are also amongst the strongest voices of resistance [6,8]. The Kwakwaka'wakw have highlighted many concerns about environmental impacts from salmon farms including predation on the wild juvenile salmon from escaped farmed Atlantics, sea lice infection transfers to juvenile wild salmon from farmed salmon, competition effects and potential genetic hybrids between wild salmon and escaped farmed Atlantics, harassment and killing of wild predators by salmon farm operators and pollution from farm wastes affecting traditional food sources [9].

While concerns related to escaped farmed salmon and sea lice have dominated the media and have been the focus of many scientific studies and reports [10–12], research and media attention about the impacts from fish farm wastes have emerged more slowly. Only a handful of scientific studies have considered the environmental impacts of the wastes produced by salmon aquaculture [2,13]. However,

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[1]Living Oceans Society. 2004. Map of salmon farms, clam beds and pink salmon rivers in the greater Broughton Archipelago. Accessed June 14, 2007 from: 〈http://www.livingoceans.org/maps/file_info/thumbs2/th_ff_brough_clam_pink_1.jpg〉.

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First Nations have continued to voice concerns about salmon farm waste polluting marine waters, affecting their traditional food resources, and in turn, their health [14,15]. Wastes from salmon farms include fish feces, unconsumed feed pellets, antibiotics in medicated fish feed, dead fish carcasses and hazardous wastes such as petroleum products, paints and cleaning products.[2] These wastes, the problems that they pose, and how they could be monitored, are the focus of this paper. Preliminary directions for how Kwakwaka'wakw knowledge, indicators and epistemologies[3] could play a role in marine environmental monitoring of the impacts of waste from salmon aquaculture are suggested.

A large body of research supports the assertion that sustainability is more likely achieved when indigenous stewardship practices, traditional ecological knowledge (TEK), and wisdom are recognized, respected and integrated into broader management schemes [16–19]. Management systems that seek to integrate local knowledge provide greater likelihood of buy-in by the local resource users, and are more adapted to local environmental conditions. However, TEK goes beyond providing detailed observations of particular localities and resources, but also provides "philosophies and methods of acquiring and communicating knowledge that can help us to achieve a better, more sustainable relationship with our environment" [17, p. 1285]. Attempting to understand and integrate local knowledge systems (or epistemologies) will provide a greater opportunity for understanding and applying other components of TEK such as knowledge about the environment, knowledge about past and current use of the environment, and culturally based values about the environment [20].

Furthermore, incorporating a diversity of processes that generate learning, meaning, knowledge and experience of ecosystem dynamics, helps to build social sources of resilience in dealing with complex adaptive systems [21]. Complexity is present in the current context and debate surrounding salmon aquaculture in BC, and issues of value, equity and social justice desperately need to come to the surface, including the nature and sources of knowledge relevant for salmon farm regulatory decisions [7]. At the same time, there is a growing recognition that the conventional scientific approaches may be insufficient in the face of complexity [22]. Problems of complex adaptive systems involving human use and impacts often cannot be separated from issues of value, equity and social justice. As a result, complex systems require participatory approaches in which scientists and managers need to work with local people, and recognize local ways of knowing.

Research suggests that, incorporating local and indigenous management practices leads to more effective and sustainable environmental management. However, in Canada, federal and provincial governments are also facing legal challenges to state controlled top-down resource management as a result of recent Supreme Court of Canada decisions on Aboriginal rights and title. While new policy directions have emerged to address this changing legal context, such as BC's "New Relationship" policy, there is a disconnect between the legal rights and stated goals and the actual implementation of these rights and goals in a practical sense, such as in marine environmental monitoring. First Nations' social and cultural institutions, such as indigenous monitoring practices, are generally not recognized in a practical sense by the state [8]. This paper considers how collaborative monitoring might be implemented in a way that respects the nature of Aboriginal rights and fulfills the stated goals of the BC government to achieve a "New Relationship" with First Nations. Following a review of the current monitoring protocol in BC, the goals and characteristics of Kwakwaka'wakw approaches to monitoring are explored, the two systems are compared, and suggestions made for how these approaches might be integrated.

2. Methods

This analysis emerges from the author's masters thesis research on Kwakwaka'wakw clam stewardship practices. Chain-referral sampling was used to identify the interviewees considered to be experts on this topic. In total, 23 interviews were completed in 2006–2007, 17 in the community of Alert Bay/Yalis on Cormorant Island, five in the community of Gwa'yasdams on Gilford Island, and one in Vancouver. Most interviewees were involved in clam-digging and fishing, both before and after the introduction of fish farms in the area. Interviews were semi-structured, conducted in people's home, band offices, or local restaurants, taped and later transcribed. Review of policies, management plans and regulations from provincial and federal agencies as well as local First Nations and tribal councils, provided further data. The author attended several resource management meetings during the time spent in the community, as well as a multi-stakeholder clam bed meeting for the area. This meeting brought together First Nations, government, industry and academic representatives to specifically discuss research and monitoring of potential impacts from fish farm wastes on clam beds in the Broughton Archipelago. A quasi-grounded theory approach was used to analyze interview transcripts and research notes.

3. British Columbia's approach to marine environmental monitoring

The salmon aquaculture industry in BC started in the 1970s with small-scale farming of Pacific species. However, as economic pressures changed, and industry knowledge regarding Atlantic salmon grew, the Pacific species were

[2]Department of Fisheries and Oceans website. Fact sheet: Waste Management. Accessed June 15, 2007 from: 〈http://www.dfo-mpo.gc.ca/aquaculture/sheet_feuillet/waste_e.htm〉.

[3]The nature and validity of knowledge.

increasingly replaced with Atlantics and the ownership of aquaculture sites was increasingly consolidated [23]. As a response to the concerns about the impacts from the growing industry, in 1995 a moratorium on granting new salmon aquaculture tenures was established. The provincial ministers responsible for aquaculture management at the time[4] requested that the BC Environmental Assessment Office (EAO) conduct a review of the adequacy of current methods and processes used to regulate and manage the industry in the province. As a part of this review, public meetings were held in First Nations communities most affected by salmon aquaculture. Many concerns were voiced about the impacts of fish farm waste polluting marine waters, often by First Nations using traditional clam-digging and fishing spots [14]. These concerns have been echoed in more recent inquiries and academic studies [6,8,15].

The recommendations from the salmon aquaculture review [23] included the development of performance-based waste management standards. As a result, a technical science advisory group was established with representatives from the provincial and federal government[5] and the salmon aquaculture industry to assist in developing a monitoring program based on a set of chemical and physical indicators.[6] The following parameters are measured as a part of the new protocol for marine environmental monitoring; free sulfides, redox potential (Eh), total volatile solids or total organic carbon, sediment grain size and copper or zinc concentration. Two biological analyses, species richness and abundance of infauna[7] and epifauna[8] *may* be required only if a chemical requirement has not been met. Sampling station locations are at the perimeter of containment structures, 30 m from zero meter station, at the perimeter of the tenure and at reference stations anywhere from 0.5 to 2.0 km from the facility. To determine whether the farm wastes are having an environmental impact, statistical analyses are performed to compare baseline and reference data with the operational data [24].

According to the provincial government, the purpose of these new standards is to allow the industry to manage their aquaculture operations to maximize production while ensuring the assimilative capacity of the surrounding area is not unduly affected.[9] The goal of "maximum production" asserted here by the provincial government, and the interpretation of "unduly affected" and "surrounding area" by a technocratic science-based decision process, excludes First Nations values and goals, and chooses environmental standards and indicators at a chemical and physical scale that are meaningful only within a specific scientific worldview. In 2002, these environmental standards and monitoring protocol were formalized in the Finfish Aquaculture Waste Control Regulation introduced under the BC *Environmental Management Act*, and were the final policy piece required for lifting the moratorium on new finfish aquaculture sites.[10]

4. Recognizing Aboriginal rights

Three years after the Finfish Aquaculture Waste Control Regulation was introduced, an all-party committee of members of the BC Legislative Assembly was appointed to conduct an inquiry into aquaculture in BC.[11] The second report of the Special Committee on Sustainable Aquaculture (SCSA) was released on May 2007 and its foremost recommendation is that the BC ministries currently responsible for salmon aquaculture management[12] adhere to the principles of the new relationship, a government-to-government relationship with First Nations peoples founded on respect, recognition and reconciliation of Aboriginal rights and title [25]. The third goal in the New

[4]BC Minister of Environment, Lands and Parks (MELP) and the BC Minister of Agriculture, Fisheries and Food (MAFF).

[5]In addition to implementing the waste management regulations through the Ministry of Environment, the province is also responsible for issuing aquaculture operating licenses through the MAFF, and leasing Crown land through Land and Water British Columbia, Inc. [7]. At the federal level, the Department of Fisheries and Oceans (DFO) is the lead agency on aquaculture development. In addition, the federal government is responsible for broader regulations regarding fish products, therapeutic drugs and vaccines, importation and inter-provincial movement of fish and eggs, conservation and protection of wild-fish stocks and fish habitat and navigational safety [7]. Some stakeholders are concerned that DFO's legitimacy as a regulator and enforcer of the federal *Fisheries Act* is compromised by its formal support of the industry [15]. Given its jurisdiction over protection of wild-fish stocks and fish habitat, the federal government has the power to be more actively involved in marine environmental monitoring of the impacts of the salmon aquaculture industry.

[6]British Columbia, Ministry of Land Water and Air Protection. Aug 28, 2001. Salmon Farming Monitoring Report: Backgrounder. Accessed June 14, 2007 from: 〈http://www2.news.gov.bc.ca/nrm_news_releases/2002WLAP0091-000335.pdf〉.

[7]Animals that live within the substrate.

[8]Animals that live on top of the substrate.

[9]British Columbia, Ministry of Land Water and Air Protection. Aug 28, 2001. Salmon Farming Monitoring Report: Backgrounder. Accessed June 14, 2007 from: 〈http://www2.news.gov.bc.ca/nrm_news_releases/2002WLAP0091-000335.pdf〉.

[10]BC Ministry of Environment, Environmental Protection Division. Industrial Waste: Agriculture and Aquaculture–Finfish Aquaculture Waste Control Regulation. Accessed July 1, 2007 from: 〈http://www.env.gov.bc.ca/epd/epdpa/industrial_waste/agriculture/aqua_home.htm〉.

[11]The BC Legislative Assembly Special Committee on Sustainable Aquaculture (SCSA) completed two reports reviewing the management and sustainability of the industry. The SCSA Final Report Volume 1 [19] made some very strong recommendations, which have the potential to influence the problems with the current finfish aquaculture waste management. Most notably, the committee has recommended a shift to closed containment technology to be implemented in the next 5 years (Recommendations 1.1–1.3). However, the technology proposed is considered to be "flow-through" allowing exchange of some micro-organisms and waste between the farmed and marine environment. Whether or not these new recommendations will have an impact on the marine wastes depends on two factors: (1) if and when the recommendations are implemented and (2) to what extent the shift to closed containment technology includes barriers to waste material flowing into marine waters.

[12]BC Ministry of Agriculture, Fisheries, and Food (MAFF) and BC Ministry of Environment (MoE).

Relationship document explicitly identifies a commitment to "ensure that lands and resources are managed in accordance with First Nations laws, knowledge and values" [26, p. 2]. This goal reflects the Supreme Court of Canada definition of Aboriginal rights as *sui generis*—they are unique and must be defined according to Aboriginal custom and practice, including traditional Aboriginal law [27].

Given this context and the importance of the resource economy in BC, a major challenge for Canadian governments and First Nations is how to bridge the disconnect between legal rights and stated goals, and their practical implementation in resource management. In order to "ensure that lands and resources are managed in accordance with First Nations laws, knowledge and values", as outlined in the New Relationship document [26, p. 2], and underscored by the legal definition of Aboriginal rights as *sui generis*, integration of First Nations knowledge and values must be done in conjunction with a meaningful engagement with the First Nations knowledge systems, going beyond simple insertion into western science-based management. As Berkes et al. [28] state, "documenting this knowledge is only the first step; learning to engage with indigenous processes of knowing is the bigger challenge" (p. 159).

5. Results and discussion

The current management system for salmon aquaculture is far from one of co-management where First Nations values, knowledge and stewardship practices are integrated in a way that respects the political commitments of the New Relationship and the *sui generis* nature of Aboriginal rights. Many steps would need to be taken to move towards "complete co-management" [29]. For example, in the salmon aquaculture context there are no formal management institutions to co-ordinate and implement resource management decisions, such as are established in northern Canada through comprehensive land claims agreements. Glimmers of potential progress in this direction may come from the BC treaty process, and the Aboriginal Aquatic Resources and Oceans Management (AAROM) program.[13]

However this paper focuses specifically on how the current monitoring protocol for fish farm wastes might change or broaden if Kwakwaka'wakw values, knowledge and stewardship practices, embedded within cultural knowledge systems, were meaningfully integrated. In focusing on the specifics of monitoring I must acknowledge two concerns. First, integrating Kwakwaka'wakw values, knowledge, and stewardship practices into marine monitoring is difficult without other processes and institutions in place that would lead towards more complete co-management. Second, it is not possible to predict what this type of monitoring system would look like specifically, given the importance of a participatory policy and planning process [30]. However, it is useful to consider what a monitoring system might look like if it seeks to integrate First Nations' values, goals, knowledge, stewardship practices and epistemologies, to imagine different possibilities, and to try to learn from experience elsewhere, particularly in northern Canada.

5.1. Goals: monitoring what matters

Regarding fish farm waste impacts, First Nations have repeatedly stressed concerns about the importance of protecting traditional clam beaches, and have indicated that other resources have not been affected to the same extent as clams [14]. Concerns include declining stocks and quality, contamination of beaches and associated losses of access to clams for food and income and health risks [14]. Kwakwaka'wakw traditional harvester and clam-digger, Brian Wadhams[14], describes the following:

> You know when you talk about the feces and the waste that comes out of that [fish farms], it has to go somewhere. And when you look at the mainland inlets [Broughton Archipelago] you got a real strong tidal flow and you know they assume that the waste is just going to drop to the bottom and settle there, but the tidal flow in there is so strong, you are starting to see the cumulative effects and the far-field damages that are going on out there now. I mean, the beaches from when I was a little boy, I looked at all those beaches and how beautiful, like when you see sand and it is so white and fresh smelling. Today, you walk on those beaches and its smells like the sewer. Those are the changes that we are seeing.

Currently, cumulative and far-field impacts of salmon farm wastes are not monitored. Instead, the protocol for marine environmental monitoring attempts to address impacts on a site-by-site basis[15]. While there has yet to be any scientific research into the connection between

[13]One of the stated objectives of the AAROM program is to "encourage the establishment of collaborative management structures that contribute to integrated ecosystem/watershed management and planning processes". Department of Fisheries and Oceans. Aboriginal Aquatic Resources and Oceans Management program website. Accessed June 26, 2007 from: 〈http://www.pac.dfo-mpo.gc.ca/tapd/aarom_e.htm〉.

[14]Interviewees quoted directly in this paper chose to have their name included to give credit for their contribution.

[15]An independent Science Advisory Group (SAG) was tasked with reviewing the Finfish Aquaculture Waste Management Regulations, and had the following to say about cumulative effects: "With regard to substances released from aquacultural operations, the SAG offers the view that the approaches being entertained and that seem feasible as part of a regulation under the Waste Management Act theoretically have the potential to address waste related impacts of aquaculture on a site-by-site basis. The regulation, however, would lack the structure, the focused interest in, and the power to detect, monitor and manage cumulative effects of multiple aquacultural operations in a larger defined coastal ecosystem". (p. 2). Letter report of the independent Scientific Advisory Group regarding the B.C. Aquaculture Waste Control Regulation, December 5th. 2001. Accessed June 19, 2007 from: 〈http://www.env.gov.

salmon farm wastes and impacts on clams and clam beaches on the west coast of Canada, in the Bay of Fundy on the east coast, Robinson et al. [13] have determined a far-field linkage of salmon farms to the inter-tidal zone using zinc–lithium tracers. Furthermore, concerns of local fisherman in the Bay of Fundy are similar to those of Kwakwaka'wakw fishers. The concern regarding salmon farming most frequently mentioned by local lobster fisherman in the Bay of Fundy is the possibility that salmon wastes, diseases or disease therapeutics might impact the marine environment [31].

Clams are a staple resource in the Kwakwaka'wakw economy and all the traditional village sites are located close to productive clam beds [32]. Clams are served at potlatches and feasts, and are also seen as a reliable backup resource in case of failure of other food sources, including the supermarkets of the cash economy [32]. Beyond this, clam-digging, as with other traditional resource harvesting, plays a role in renewing cultural norms, values and institutions, including traditional stewardship practices. As put by Weinstein and Morrell [32, p. 22]:

> …subsistence is an integrative activity. It connects individual activity with family and group welfare, and these in turn with direct experience of the state of resource animal populations and environmental quality. Resource harvesting is the connector between environment, communities, human history and individual and family life.

In addition to the importance of clams for food, clams play an important economic role, both in the past and today. In Kwakwaka'wakw trading networks, dried smoked clams, called *Ku'matsi* in the Kwak'wala language, are an important item [32,33]. In addition, harvest of clams for the commercial market has become an increasingly important source of income in the winter months.

Gerwing and McDaniels [6] attempt to characterize First Nations fundamental values and objectives for decisions related to salmon aquaculture in their traditional territories. Monitoring impacts of existing fish farm facilities and conducting research in partnership were identified as First Nations objectives tied to the values of good governance and fostering learning [6]. Collaborative monitoring of impacts from fish farm wastes on clams and clam beaches is one way to broaden the current monitoring regime to start to incorporate some of the values and objectives of First Nations people. However, collaborative monitoring that begins to recognize and respect the *sui generis* rights of First Nations people would have to go beyond incorporating values and goals and consider First Nations stewardship practices, including the sites and signs that are used to monitor change in the environment, and the knowledge system in which these are embedded.

5.2. Signs and signals of change

Many different types of indicators can be used for environmental monitoring in the development of management targets (or ecological standards) and to determine strategies for achieving objectives [30,34]. While indicators for monitoring environmental quality are often thought to be in the realm of Western science only, much evidence demonstrates the importance of indigenous monitoring in the north. As Berkes et al. [28, p. 152] describe,

> Many indigenous experts do recognize and monitor various environmental signs and signals. These may be related to changing seasons, abundance of animals, noting unusual patterns and extremes, and noting condition and quality of animals. Such "indicators" may be chosen on the basis of shared culture and values of a given group, and reflect the knowledge and experience of current and previous generations. This accumulated experience with the environment may be used to detect long-term trends. Evaluation of indicators over time allows users to receive feedback from the ecosystem, enabling them to assess various aspects of it.

The specific signs and signals of environmental quality that indigenous hunters, gatherers, or fishers monitor fit within a context of holistic understanding. This holistic understanding is connected with an epistemology that may be very different from the often linear, well-defined, cause-and-effect connections used to generate and validate knowledge in Western science. For example, among the Inuit and in many other northern cultures, systematic generalizations regarding cause-and-effect relationships are in general regarded negatively [35]. According to the Inuit worldview, making simplifications and generalizations of complex phenomena is "childish" and "without sense" [35]. Ultimately, in order for First Nations values, knowledge and stewardship practices, such as environmental monitoring, to be incorporated appropriately into current management strategies, the system in which these values, knowledge and practices are embedded, must be recognized and respected [17].

The challenges of a holistic worldview and a western one that emphasizes cause-and-effect relationships comes across as Kwakwaka'wakw traditional harvester, Brian Wadhams, expresses frustration with management based solely on science:

> You know, science is a great thing, but the tunnel vision of science is unbelievable. I've been dealing with science for quite sometime now, just understanding how science works, and the lack of transparency of science, it doesn't have the broad picture, it is a tunnel vision where it doesn't look anywhere else but through a microscope and this is what really confuses me when I see different

(*footnote continued*)
bc.ca/epd/epdpa/industrial_waste/agriculture/sag/pdfs/scien_advis_group_rev_dec01.pdf⟩.

> changes like the clam beds. When you see changes to one portion of the system, everything changes along with it. And that's what frightens me; those are the kinds of things you learn over time. If you interfere with one fishery, the food chain is such a delicate system where everything relies on each portion of it. Herring is a good example, it is the main food chain for most of the fisheries that we have, like salmon, cod, halibut, and if you tamper with that portion of it, you are going to affect the whole system, so that is the balance that you are throwing out of whack.

Scientific and traditional knowledge are each developed through different modes of knowledge production that in turn reflect unique worldviews. Attempting to understand and incorporate both approaches to building knowledge not only leads to more resilient and adaptable environmental management, but also begins to address the legal and political requirements of Canadian governments.

In Berkes et al. [28] review of the role indigenous monitoring in the Canadian north, ways in which the selection and use of indicators is influenced by the particular holistic epistemology of indigenous people are highlighted. Drawing upon this research in the north I explore the following aspects of environmental monitoring; scale of observations, qualitative vs. quantitative, number and specificity of indicators and short vs. long time series, in relation to examples of Kwakwaka'wakw monitoring of clams and clam beaches.

5.3. *A Kwakwaka'wakw approach to monitoring*

The difference between a more holistic approach to generating and validating knowledge about the environment and one that emphasizes cause-and-effect relationships manifests itself in the approach taken towards resource management, including several aspects of monitoring. For example, the scale at which observations are made is often different. Whereas Western science-based monitoring often focuses on the chemical, biochemical, and cellular levels, local observations and traditional knowledge instead focuses on individual, population and community levels [36]. Table 1 summarizes the Kwakwaka'wakw indicators used to assess clam and clam-beach health at different scales.

At the individual level, food quality is an important category of indicator in Kwakwaka'wakw environmental monitoring and clam-diggers suggest the following "signs" are used to assess clam health; thickness, strength and color of clam shell, size of clam compared to shell size, flesh color, taste and smell of clam. Examples from the north suggest that these types of signs are read continuously and cumulatively by traditional resource users, establishing a norm on the health of an animal, and creating a reference that tells them when an animal is not well and should not be eaten [37,38]. For instance, in the Canadian Artic Contaminants Assessment indigenous hunters and fishers were adept at detecting abnormal body conditions, abnormal taste and consistency, parasitism, body fat content and abnormal behavior [37]. In northern BC, the Haisla First Nation and Eurocan Pulp and Paper Co. have entered into a long-term agreement in which Haisla participate in the sensory (taste and smell) evaluations of eulachon tainted by effluent from a pulp and paper mill on the Kitimat River [39].

Table 1
Kwakwaka'wakw indicators used to monitor the health of clams and clam beaches

Scale of indicator	Indicator examples
Individual	Thickness of shell Strength of shell Color of shell Mussel size to shell size ratio Flesh color Taste Smell
Population	Clam abundance Regeneration time Abundance of small or immature clams Annual time of spawning
Community	Hardness of beach substrate Color of beach substrate Presence/absence of other organisms

In addition to indicators related to individual clams, Kwakwaka'wakw clam-diggers note population scale changes on clam beaches. For example, diggers monitor clam abundance through both a visual survey of beaches and the amount of effort and time that is put in to dig a certain amount. Furthermore, diggers monitor how quickly the beaches are regenerating:

> They [clam-diggers] used to be able to go out one tide, skip another tide, then go back one tide after that. So basically 5–6 weeks between digging and they would come back in that time so you could go dig again. But they notice now that they can't do that anymore.[16]

Other population scale indicators include abundance of small or immature clams on a beach, and annual timing of spawning. At the community level, Kwakwaka'wakw clam-diggers note overall environmental quality of the beach, such as the substrate hardness and color and the presence or absence of other organisms, such as mussels and sea lettuce. Elder and hereditary chief, Arthur Dick recounts the importance of monitoring the sea lettuce changes in relation to clams:

> The clams have their own cycle. And, when the green seaweed, they call it *Ulva*, when they start growing and floating around we quit digging clams… and my granny used to say the clams are no more good, we're not going

[16] Personal Communication with Robert Mountain, Local Stewardship Coordinator, Musgamagw Tsawataineuk Tribal Council, Alert Bay, BC.

> to take any more. And when we saw this green stuff disappearing and when the last one was going out and we couldn't see them floating around up top… when they're gone that's when we could start digging clams again.

In addition to presence and condition of sea lettuce as an indicator of the timing for clam-digging in the seasonal round, other types of indicators are used to determine when to stop clam-digging such as the presence of "milky" clams during spawning. Research with indigenous hunters and fishers in the Canadian north suggests that a more holistic worldview favors a large number of less specific (and perhaps multi-causal) indicators used simultaneously as a suite [28]. This approach gives the community feedback on many aspects of the environment by providing holistic snapshots on a continuous time scale, and allows for flexibility to modify indicators with changing conditions [28]. While traditional monitoring of sea lettuce was connected with the timing for clam-digging in the seasonal round, the amount and timing of sea lettuce presence is adapted as an indicator of changing environmental quality, as described by Arthur Dick:

> The fish farms have showed up now and this green stuff starts growing, and what happens is the entire beach gets covered with it whereas before it was just little patches… and this stuff stays so much longer that the beach is always wet and it depletes the oxygen. And you go to these beaches and you can actually see cockles flip themselves up to lay on top of the green *Ulva*, just because they don't get the oxygen to survive.[17]

5.4. Comparing monitoring approaches

Not only do the above examples of Kwakwaka'wakw environmental monitoring suggest different scales, numbers and specificity of indicators than are currently used for monitoring impacts from fish farm wastes, they are also of a qualitative nature, result in data gathered over a long time period, and are measured against different environmental standards or baselines. Table 2 compares the goals and characteristics of Kwakwaka'wakw monitoring to the current technical monitoring approach of the BC government.

Whereas the BC protocol for marine environmental monitoring calls for quantitative measurement of free sulfides, redox potential (Eh), total volatile solids or total organic carbon, sediment grain size and copper or zinc concentration, Kwakwaka'wakw clam-diggers use a gradient of descriptions of color, size, strength, hardness, abundance, smell and taste to measure environmental change. Karjala et al. [30] suggest that these types of qualitative indicators are based on held values embedded in traditional worldviews, philosophies, ethics, beliefs and rules of proper conduct on the land. While these indicators may be culturally "embedded" in a significant way, studies with northern indigenous people working with scientists in the area of contaminants have found that indigenous hunters are using indicators quite comparable to those in ecotoxicology, except in a qualitative way and at a different scale of measurement [37,38].

Table 2
Comparison of the goals and characteristics of Kwakwaka'wakw monitoring and the current government of BC Protocol for marine environmental monitoring

	Kwakwaka'wakw monitoring	BC monitoring protocol
Key goal of monitoring	Maintain healthy subsistence resources	Maximize production while ensuring the assimilative capacity of the surrounding area is not unduly affected
Scale of indicators	*Individual* (i.e. Food quality-taste and smell of clam) *Population* (i.e. Overall clam abundance or abundance of immature clams) *Community* (i.e. Presence/absence of other organisms on clam beach)	*Chemical* (i.e. Copper or zinc concentration) *Physical* (i.e. Sediment grain size)
Type of indicators	Qualitative	Quantitative
Type of data	Diachronic (long time series)	Synchronic (short time series)
Number and specificity of indicators	Larger number, less specific	Smaller number, more specific
Baseline standards	Traditional knowledge passed down through generations	Nearby reference station measurements

Kwakwaka'wakw monitoring of environmental conditions, as with other indigenous peoples, is based on day-to-day intimate contact with the environment over long periods of time, and is passed down from generation to generation through oral history and through experiential education. This type of diachronic information (long time series) is needed to establish a baseline for small areas, and is different from the synchronic data (short time series) that science is good at collecting over large areas [28]. The current "baseline" used as an environmental quality standard against which to measure environmental change with regard to fish farm wastes is based on measurements taken before the fish farm is established, or in the case of pre-existing fish farms, measurements from a nearby reference station[18] [24]. However, in order to take into consideration cumulative impacts of fish farms that have

[17]The potential for salmon farm wastes to affect the distribution and growth of *Ulva*-dominated algal mats, and in turn the population dynamics of soft-shell clams, has also been identified by researchers studying the Bay of Fundy on the east coast of Canada (Robinson et al., 2005).

[18]Most farms in the Broughton Archipelago were in place prior to the implementation of the Protocol for Marine Environmental Monitoring. Growth of salmon aquaculture in the area today is mostly through intensification and expansion of existing farms.

been active in the area since the early 1970s, Canadian governments must recognize that First Nations traditional knowledge is a source of baseline data prior to aquaculture development. This baseline data can provide alternate environmental quality standards with which to compare current conditions. The most powerful monitoring would use both types of data and standards, giving a more complete picture on temporal and spatial scales [28].

6. Conclusion

This paper suggests that the nature and approach to environmental monitoring of fish farm wastes could be altered and broadened to integrate the values, knowledge and stewardship practices of First Nations people. Access to healthy traditional food sources is of high value to First Nations people, and therefore environmental monitoring of fish farm wastes must include monitoring far-field and cumulative impacts on traditional fishing and clam-digging sites. Impacts on clams and clam-beach ecosystems continue to be emphasized by First Nations, suggesting monitoring of clam beaches as a potential first step. Monitoring practices of Kwakwaka'wakw clam-diggers include the use of a large number of less specific qualitative individual, community and population scale indicators and the integration of Kwakwaka'wakw traditional knowledge as baseline data about the normal and healthy conditions of clams and clam beaches. The nature and validity of knowledge—epistemology—is influenced by a holistic understanding of the environment and is reflected in the Kwakwaka'wakw approach to monitoring. Sites and signs of change in the environment are read continuously, cumulatively, and over long time periods. The resulting knowledge, holistic pictures of the state of health of the environment, is different in nature from the results of science-based monitoring. There are many challenges to integrating traditional knowledge and stewardship practices with science-based marine environmental monitoring. However, the "single most serious limitation is the difficulty in translating indigenous knowledge and science into forms that are mutually intelligible, in ways that make it accessible to decision-makers" [28, p. 159]. Therefore, in working towards an aquaculture management system that goes beyond participation of First Nations, to one that begins to integrate different values, laws, knowledge and ways of knowing, decision-makers themselves must include holders of First Nations epistemologies.

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