Marine Biotoxin Workshop

PROCEEDINGS
HELD OCTOBER 24-25, 2016
NORTH VANCOUVER BC

RECOMMENDATIONS, EVALUATION AND PRESENTATION SUMMARIES

Can seals predict human illness?

Integrating wildlife and environmental information with shellfish marine biotoxin data for public health purposes.

MARCH 2, 2017
MARINE BIOTOXIN WORKSHOP COMMITTEE

This workshop was made possible through funding and sponsorship from:

BC Centre for Disease Control
An agency of the Provincial Health Services Authority

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http://www2.gov.bc.ca/gov/content/health

Reference: BC Centre for Disease Control and First Nations Health Authority, 2017. Proceedings of the Marine Biotoxin Workshop: Recommendations, Evaluation and Presentation Summaries. 38 pp.

Abbreviations

AGRI	Ministry of Agriculture
ANTHC	Alaska Native Tribal Health Consortium
ASP	amnesic shellfish poisoning
BC	British Columbia
BCCDC	BC Centre for Disease Control
CFIA	Canadian Food Inspection Agency
CSL	California sea lion
DA	domoic acid
DFO	Fisheries and Oceans Canada
DSP	diarrhetic shellfish poisoning
EC	Environment Canada
ELISA	enzyme linked immunosorbent assay
FNFNES	First Nations Food, Nutrition and Environment Study
FNHA	First Nations Health Authority
HA	Health Authorities
HAB	harmful algal bloom
MoH	Ministry of Health
NOAA	National Oceanic and Atmospheric Administration (US)
NZ	New Zealand
ORR	observe, record, report
ppm	parts per million
PSP	paralytic shellfish poisoning
RMS	regional monitoring system
SST	sea surface temperature
TDI	tolerable daily intake
VIU	Vancouver Island University

Organizations referenced at the workshop

ANTHC – Alaska Native Tribal Health Consortium http://anthc.org/

BC Centre for Disease Control shellfish map http://maps.bccdc.org/shellfish/ and
Marine Biotoxin Workshop http://www.bccdc.ca/health-info/food-your-health/fish-shellfish/marine-biotoxin-workshop

BC Salmon Farmers Association http://bcsalmonfarmers.ca/

Citizen Science Program http://marinesurvivalproject.com/research_activity/list/citizen-science-program/

Coastal First Nations Regional Monitoring System http://coastalguardianwatchmen.ca/

DFO Fisheries and Oceans State of the Pacific Ocean Annual Reports http://www.dfo-mpo.gc.ca/oceans/publications/index-eng.html and
Shellfish harvest area opening and closures subscription (Fishery Notices) http://www-ops2.pac.dfo-mpo.gc.ca/fns_reg/index.cfm

FNFNES First Nations Food, Nutrition and Environment Study http://www.fnfnes.ca/

HAMP Harmful Algal Monitoring Program https://www.facebook.com/Harmful-Algae-Monitoring-Program-216356751718929/

LEO Local Environmental Observer Network https://www.leonetwork.org/en/

Microthalassia http://www.microthalassia.ca/

NOAA National Oceanic and Atmospheric Administration (US) http://www.noaa.gov/

Oceans Network Canada http://www.oceannetworks.ca/

ORHAB Olympic Region Harmful Algal Blooms http://www.orhab.org/

Phytoplankton – Citizen Science Program https://www.facebook.com/CitizenSciencePhytoplankton/

Strait of Georgia Data Centre (phytoplankton data) http://sogdatacentre.ca/

SEATOR Southeast Alaska Tribal Ocean Research http://www.seator.org/

SOUNDTOXINS https://www.soundtoxins.org/

Vancouver Aquarium Marine Science Centre https://www.vanaqua.org

WARRN West – Wildlife Algal Toxins Research & Response Network for the US West Coast
https://www.nwfsc.noaa.gov/research/divisions/efs/warrnwest/

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Executive Summary

On October 24-25, 2016, a workshop was held to discuss the implications of marine biotoxins in shellfish, an important food resource for coastal First Nations communities and wildlife. Approximately 75 representatives from First Nation, public health, environmental monitoring, research and regulators met to discuss the effects of climate change and harmful algal blooms (HABs). Challenges and emerging issues were discussed in the context of impacts on food security for First Nation, human and wildlife health. Twelve presentations focused on domoic acid (DA), a marine biotoxin of concern along the British Columbia (BC) coastline. DA was detected at increasing levels in shellfish in 2015, and implicated in human and animal illnesses in 2016.

BOX 1: TEN KEY RECOMMENDATIONS: A CALL FOR ACTION
(in no particular order)

1. **Identify champion(s) to lead the process**
2. **Create a network of contacts interested in this issue**
3. **Create a centralized location for resources**
4. **Plan future workshops**
5. **Create a summary report with key outcomes and recommendations**
6. **Identify funding and conduct pilots**
7. **Improve First Nations community awareness**
8. **Develop a comprehensive monitoring system for environment, wildlife and health**
9. **Improve communications for monitoring results, education, and risk**
10. **Research chronic low dose exposure to DA and create risk guidance**

Presentations discussed health issues faced by marine mammals eating DA contaminated shellfish and fish, and highlighted the increasing occurrence of DA poisoning (amnesic shellfish poisoning – ASP) in marine mammals. Human health impacts included new research suggesting memory loss and learning impairment from chronic low-dose DA exposure. However, dietary changes to reduce or eliminate DA reversed the effects of chronic low-dose exposure in mice.

Ten key recommendations were made by participants (Box 1). Two recommendations focus on the need to establish phytoplankton monitoring in First Nation communities and to improve communications at all levels, particularly risk communication to First Nation. To move phytoplankton monitoring forward, funding needs to be identified and secured, and pilot tests conducted. Guidance can be sought from established organizations in Washington and Alaska that have existing programs in place for tribal communities. To keep this initiative moving forward, there was consensus that champions and leads in agencies and communities need to be identified, and networks of interested people connected and informed. Suggestions to accomplish this included the creation of a steering committee or community-of-practice to guide this work and a central location for resources. Plans for future workshops and improving First Nation awareness and involvement through local meetings with trusted experts and elders would allow for meaningful engagement. Policy options for addressing these issues were pinpointed, including how and with whom to share information, and identifying the needs of communities.

The most important risk communication issue to be addressed is to create shellfish consumption advice for First Nation communities and their most at risk populations – elders, pregnant and breastfeeding woman, and children. This advice needs to cover the risks of consumption of various shellfish and fish

species. Engaging partners from the First Nation community, First Nations Health Authority (FNHA), BC Centre for Disease Control (BCCDC), Health Canada, First Nations Food, Nutrition and Environment Study (FNFNES) representation, Canadian Food Inspection Agency (CFIA), and Ministries of Health and Agriculture is urgently required. Participants agreed that further research and collaboration regarding the potential for adverse health effects associated with at-risk populations chronically exposed to low-doses of DA (i.e. below the 20 ppm Canadian maximum level for DA in bivalve shellfish edible tissue), is necessary to fully understand the potential health effects, in particular as it pertains to First Nations communities in British Columbia. This workshop was an important first step towards discussing the issues surrounding marine biotoxins in key First Nation food sources. A one health approach that includes understanding the impact on wildlife and the environment from DA exposure will help protect the health of people.

Workshop objectives

In British Columbia (BC), toxins associated with phytoplankton or algal blooms are fairly common. Harmful algal blooms (HAB) that affect the growth of shellfish and fish may lead to massive die-offs. When contaminated fish and shellfish are ingested by humans and wildlife, illness may result. For example, blooms of *Alexandrium* spp., which produce saxitoxin, are common year-round in BC waters. Saxitoxin accumulation in shellfish can lead to paralytic shellfish poisoning (PSP) upon consumption. Butter clams contaminated with saxitoxin have caused serious PSP illness and death in BC First Nations (Disease Surveillance, Vol 1(1) Sep 22, 1980).

In 2015, however, high levels of domoic acid (DA), a neurologic toxin, were reported in shellfish from BC coastal waters where it had never previously been detected. In areas of Haida Gwaii in past years, DA has been detected at low levels of no concern to human or animal health. 2015 was the first year where high DA levels were recorded on the east coast of Vancouver Island and Saanich Inlet. Typically present in California, higher DA levels in BC shellfish are being attributed to warming ocean waters. DA is a naturally occurring toxin produced by diatoms (*Pseudo-nitzchia* spp.). High DA levels in shellfish causes amnesic shellfish poisoning (ASP) which can be harmful or even fatal to humans. The high levels seen during 2015 led to the closure of commercial shellfish beds and the imposition of restrictions on self-harvesting. Foods of concern included razor clams, which retain DA toxin for a much longer period compared to other bivalves, and Dungeness crabs, which accumulate toxin in the hepato-pancreas rather than in the meat when they feed on razor clams.

Given the high DA levels in BC shellfish growing areas and new information suggesting health effects from chronic exposure and especially to vulnerable populations, there is concern that populations in BC who self-harvest shellfish and/or consume large quantities of shellfish may be at risk from toxic exposure. In Canada, the Canadian Shellfish Sanitation Program (CSSP) aims to protect Canadians from the health risks associated with the consumption of contaminated bivalve molluscan shellfish (for example, mussels, oysters and clams) by ensuring commercially harvested shellfish do not exceed guidelines for DA, saxitoxin, and other shellfish biotoxins. Under this program, only shellfish that meet food safety and quality standards reach domestic and international markets. The CSSP also provides marine biotoxin monitoring in support of community harvest plans for various First Nations communities along the BC coastline. However, while the CSSP supports the monitoring and management of harvest areas and maintains a biotoxin surveillance program of commercial shellfish and some First Nation

growing areas, the program does not address all self-harvesting areas. Further, risks of DA in other food sources e.g. invertebrates and planktivorous fish, remain unknown. To better understand gaps in existing monitoring programs and the potential health risks to self-harvesters, particularly First Nations who consume higher amounts of shellfish and marine foods, the BCCDC and FNHA convened a multi-stakeholder workshop to initiate discussion on the topic.

In the absence of year-round and broad-based monitoring of shellfish along BC's coasts, an alternative approach is to utilize information about marine wildlife mortality or illness events that may have been caused by marine biotoxins. Data could be gathered by agencies and institutions focusing on the marine environment, and by coastal communities. This approach fits the 'One Health' concept; that is, a collaborative effort of multiple health science professions, working to attain optimal health for people, domestic animals, wildlife, plants, and our environment.

Specific objectives of the workshop were to:

- explore potential sources of data on environmental factors, wildlife mortality events or unusual findings that may be associated with marine biotoxins, or other hazards of public health relevance;
- discuss potential avenues for collaboration between organizations and communities that collect such data, including data-sharing agreements, which would allow the subsequent development of suitable indicators for these hazards derived from this data.

Agenda

Five Key Questions Raised on the Workshop Agenda

1	How aware are we of the risks posed by marine biotoxins?
2	How can communities be better informed about that risk?
3	What are the opportunities for monitoring and data sharing?
4	How can we further the use of traditional knowledge?
5	What information is available about shellfish poisoning in BC? Is information complete and accessible?

Discussion topics

- Recognize useful environmental indicators as predictors for human and wildlife health risks.
- Identify traditional/current diets of First Nations most likely to be impacted by harmful algal blooms (HABs).
- Describe testing methods for clinical and wildlife toxicity assessments.
- Consider if current monitoring programs for HABs are meeting needs of self-harvesters.
- Propose methods to create or enhance environmental monitoring networks.
- Recommend how to optimize risk communication to self-harvesters.
- Identify opportunities for data sharing and collaboration.
- Reflect on evidence to propose reducing exposure via traditional diets for First Nation populations most at risk, such as during pregnancy.

Session – Day 1	Presenter	Title of Presentation
Opening	Gloria Nahanee Squamish Nation Elder	Welcoming and lunch
	Dr. Pablo Romero-Barrios Linda Pillsworth Mark Matthew	Welcome and introductions
Why are we concerned about marine biotoxins?		
Afternoon	Dr. Tom Kosatsky	Overview: populations impacts and recent observations
	Ross Wilson	Importance of shellfish and marine foods to nutrition and traditional diet of First Nations
	Dr. Reza Afshari	Domoic acid exposure among the First Nation population in BC
Environmental impacts and current monitoring		
Mid Afternoon	Dr. Ian Perry & Dr. Angelica Peña	Recent environmental conditions in southern BC marine waters, and unusual algal blooms
	Open discussion	Monitoring of marine biotoxins in BC shellfish
	Open discussion	Facilitated discussion to review our questions, gaps, and needs of community research, industry and public health
Session – Day 2	**Presenter**	**Title of Presentation**
Dietary exposure to biotoxins in the community and environment		
Morning	Dr. Laurie Chan	The importance of shellfish in the traditional diet of First Nation Communities: findings from the First Nations Food, Nutrition and Environment Study
	Dr. Kathi Lefebvre	Environmental exposure risks and effects of domoic acid in marine mammals and humans
	Open Discussion	Facilitated discussion
Environmental and wildlife impacts		
Mid Morning	Dr. Martin Haulena	Epidemiology and clinical signs associated with acute and long term effects of domoic acid toxicity in marine mammals along the west coast of North America
	Nicky Haigh	Phytoplankton sampling and its role in marine biotoxin monitoring
	Dr. Vera Trainer	An unprecedented toxic algal bloom linked to anomalous ocean conditions and implications for First Nations health
	Open Discussion	Facilitated discussion
Networks in the community		
Afternoon	Lara Hoshizaki	Coastal First Nations Regional Monitoring System
	Svetlana Esenkulova	Monitoring of harmful algal blooms in the Strait of Georgia by the Citizen Science Program
	Linda Pillsworth	Local Environmental Observer Network: the eyes, ears and voice of environmental change
	Panel Discussion	Community environmental monitoring networks
Mid Afternoon	Break-out groups	Group reflection and prioritization
	Gloria Nahanee Squamish Nation Elder	Adjournment and closing prayer

Full summaries of each presentation are available in Appendix1 Discussions and speaker presentations during the workshop.

Organizations represented and participants in the workshop

The aim of the workshop was to include representatives of organizations with an interest in either the impact of marine biotoxins (on the health of consumers or wildlife) or on harvesting of shellfish for human consumption. Representatives of 35 organizations participated in the workshop (Figure 1), divided into those working in the public health area, environmental health, wildlife, regulatory bodies and First Nations.

Figure 1. Workshop attendees October 2016.

Participants attended the workshop from the full length of BC's coastline, with a concentration of participants attending from the southeast coast of Vancouver Island and inland as far as Prince George (Figure 2). There was also participation and presenters from Washington State and Ottawa.

Figure 2. Map of British Columbia's coastline showing home locations of workshop participants. Push pins indicate where participants attended from. Top right and bottom left insets show details of the areas.

Workshop activities and discussions

As reflected in the workshop agenda, presenters covered a wide range of topics. Summaries of the presentations given, question and answer sessions and discussions that followed, can be found in Appendix 1. The information provided by these presentations helped to stimulate the open discussions held after each session.

In the final group discussion held on the second day of the workshop, participants were asked to identify and prioritize the main issues related to how marine biotoxins can affect the health of shellfish consumers, specifically self-harvesters. To guide the discussion, participants were asked three questions:

1. How can we keep the discussion going beyond this workshop?
2. What should we do next and who should do it?
3. What are you going to bring back to your community or agency?

Answers to the first two questions were documented by each discussion group (Figure 3), and collected at the end of the workshop. Answers are summarized, grouped by the first two question themes. The last question was posed to stimulate self-reflection; thus no answers were recorded.

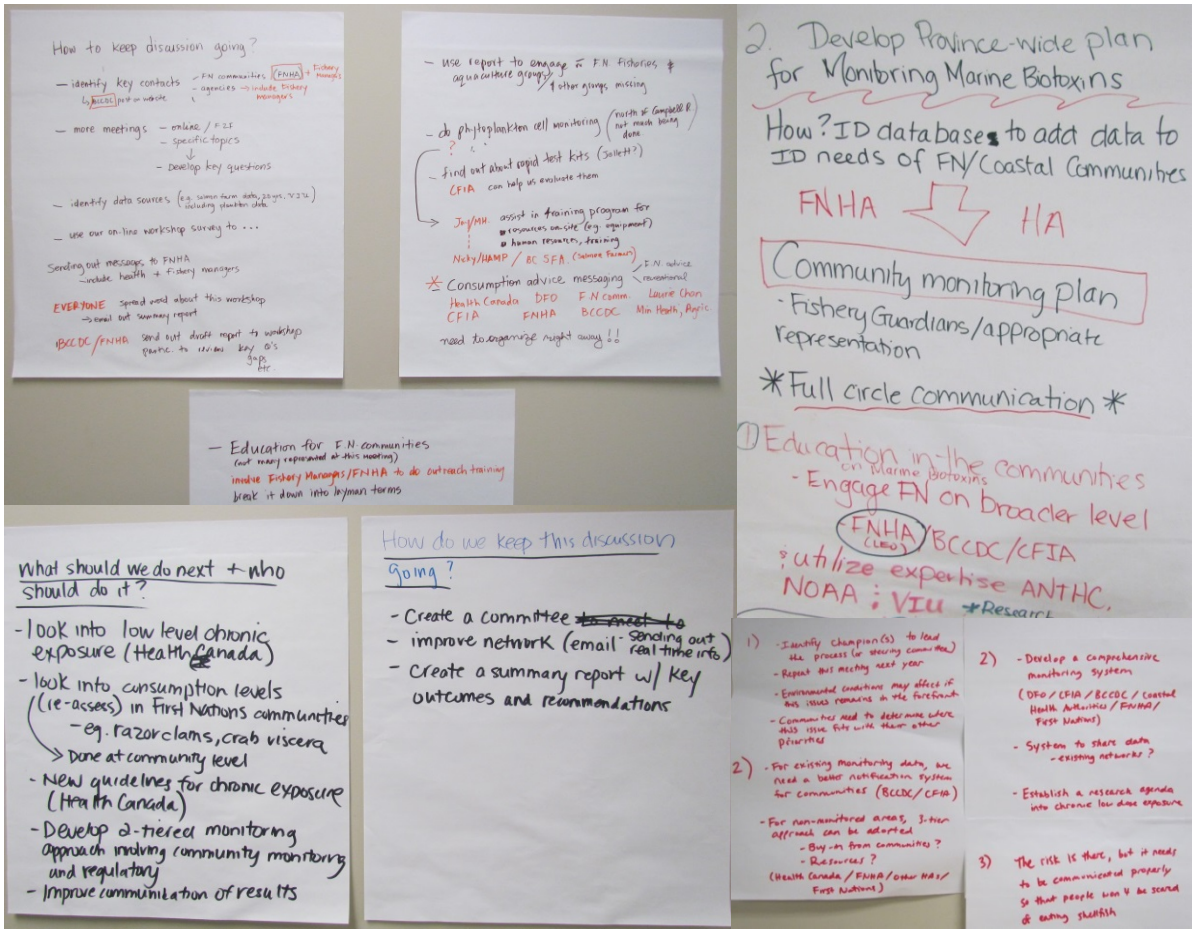

Figure 3. Record of discussion and ideas.

Ten key recommendations to keep this discussion on our agenda

(in no particular order)

1. Identify champion(s) to lead the process

A steering committee or a community of practice should be created. This group could provide the lead and a point person, and bring together representatives from different groups. A flow chart should be developed to identify the roles of participants and agencies, and their respective responsibilities and activities (i.e., who does what, who would like to do more, and who should do more).

2. Create a network of contacts interested in this issue

Creation of such a network would allow information to be sent to network members in real time and provide networking opportunities. Community updates could include webinars, newsletters, health notices or advisories, and information on future workshops or follow-up reports. It was specifically mentioned that First Nation communities, including fishery managers, should be included in the network, as well as representatives from the Department of Fisheries and Oceans (DFO). Feedback from this workshop and from the feedback survey should be broadly distributed to inform First Nation, health, fishery managers, and other network contacts about the main issues identified and the recommendations put forward by participants.

3. Create a centralized location for resources

Multiple organizations, both community-driven and institute-led, were represented at the workshop. However, many participants did not know of, or had not heard of, these organizations and were unaware of the resources available. Hence, a centralized location for all North American Pacific coast biotoxin-related resources is needed. This could include a repository of monitoring program data, and could be used to track and follow-up on the aforementioned needs and priorities. It could also be used to identify data sources (e.g. Vancouver Island University [VIU] 20 year salmon farm plankton data) and provide information on how and where to access this data. Other data sources could include information from the LEO Network, SEATOR, ORHAB, SOUNDTOXINS, etc. (see page 4 for links to these organizations).

4. Plan future workshops

Repeating the workshop next year, or conducting more regular meetings to address specific topics. Meetings could be held on-line or face-to-face, and address specific topics or key questions.

5. Create a summary report with key outcomes and recommendations

A summary report (this report) would be shared with workshop participants to reach a consensus on recommendations. It could be used to engage fisheries and aquaculture groups, and other groups that did not attend the workshop, and to spread the word about the topics covered during this event.

6. Identify and secure funding; conduct pilot studies

Grants and other sources of funding need to be identified and secured to further our goals and build upon current efforts. Pilot studies and actions could be implemented first at the ground level to see what works in BC, and then implemented on a wider scale if successful. Long-term funding is required from multiple sources for different projects, and should strategically build upon current projects.

7. Improve First Nations community awareness

First Nation communities require further education and awareness on shellfish poisoning and marine biotoxins. They also need to determine where this issue fits with their other priorities. Communities should be engaged on a broader level. This engagement should include FNHA, BCCDC, CFIA, and VIU, and should utilize the expertise of the Alaska Native Tribal Health Consortium (ANTHC) and the US National Oceanic and Atmospheric Administration (NOAA).

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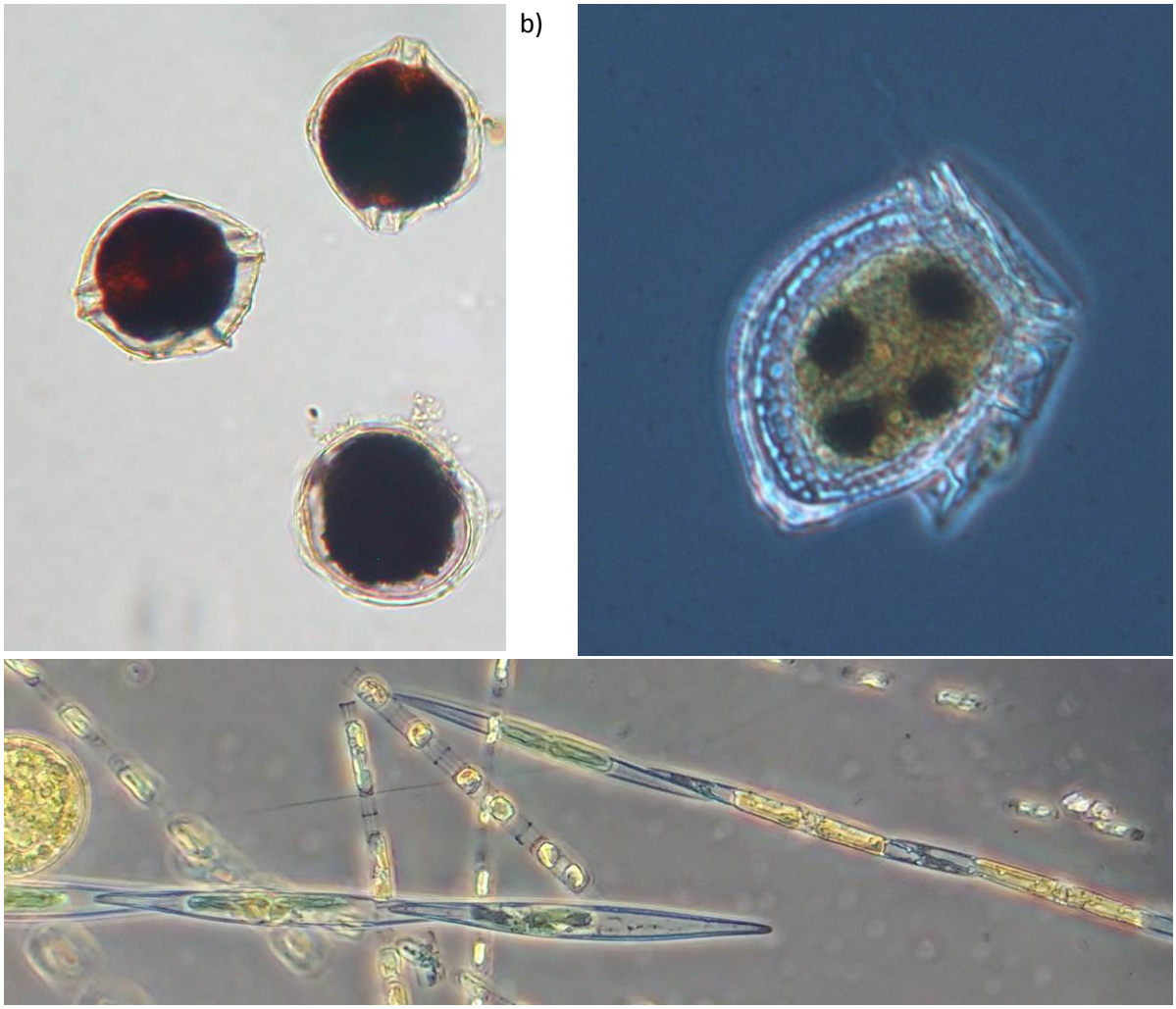


c)

Figure 4. Harmful algae a) *Alexandrium catenella*, b) *Dinophysis acuminata*, and c) *Pseudonitzschia pungens* and *P. australis*. Pictures courtesy of Microthalassia Consultants Inc.

RECOMMENDATIONS FOR NEXT STEPS AND WHO SHOULD BE RESPONSIBLE

8. Develop a comprehensive monitoring system for environment, wildlife, and health

The majority of comments involved the idea of developing a comprehensive monitoring system. This would include different types of monitoring activities, such as phytoplankton monitoring, wildlife morbidity monitoring and investigation, health monitoring of First Nation and coastal communities, and community monitoring plans. Organizations identified to lead the process included the BCCDC, CFIA, coastal HAs, DFO, First Nation, and FNHA.

Issues to consider when designing a monitoring system included:

- What do we need to enable monitoring? We need to collect information on existing resources available to help build local monitoring and planning, such as:
    - Identify who, where, what, when…
    - For community information resources, assess knowledge gaps and outstanding questions
- Developing a province-wide plan for monitoring marine biotoxins, including:
    - Explore policy options
    - Identify a database to hold data
    - Identify the needs of First Nation and coastal communities. Community monitoring plans need to include:
        - Fishery guardians or appropriate representation
        - Full circle communication is important
- Developing a better notification system for communities for existing shellfish biotoxin monitoring data (BCCDC/CFIA lead suggested)
- Conduct phytoplankton cell monitoring. This is required in areas north of Campbell River where very little shellfish biotoxin testing is carried out. For non-monitored areas, a 2/3-tier approach[1] can be adopted, involving community monitoring and regulatory agencies. Requirements for phytoplankton monitoring include:
    - Buy-in from communities
    - Pooled resources and commitment from FNHA, other HAs, First Nations, and other agencies or institutions
    - Need to identify what resources (e.g. equipment) are required on-site to conduct monitoring. A representative from Marine Harvest indicated that they could provide advice on what would be needed to do this.
    - Need to identify what training and human resources are needed to conduct monitoring. Experts from HAMP at VIU and the BC Salmon Farmers' Association currently conduct monitoring for harmful algae, and could provide advice on these requirements.
- Explore rapid test kits to detect biotoxins

[1] Phytoplankton monitoring in harvesting areas, combined with the use of rapid tests looking for biotoxins in water when phytoplankton is detected, and testing in shellfish when the toxin is detected in water.

- CFIA can assist to evaluate rapid test kits
- Wildlife morbidity event investigations (DFO lead suggested)
- Assess who is exposed in coastal communities (BCCDC/FNHA lead suggested)
  - Establish a monitoring program by conducting anonymous sampling e.g. surveys

9. Improve communications for monitoring results, education, and risk

Improved communication was a topic that featured prominently, covering different areas. It was acknowledged that FNHA should play an important role in communicating with respective First Nation communities.

- Improve communication of monitoring results to First Nation and recreational self-harvesters. There is a need for a system to share data – could existing networks be used?
- Education and awareness for First Nation communities (many First Nation communities were not represented at the workshop)
  - Involve fishery managers and FNHA to do outreach training
  - Ensure simple messaging
- Develop effective risk communication. Consumption advice messaging for First Nation and recreational harvesters should be organized as soon as possible (DFO, First Nation community, FNFNES, CFIA, FNHA, BCCDC, MoH, AGRI, Health Canada (refer to post-workshop comment)). This advice should cover risk of chronic toxicity related to different seafood species: the risk is there, but it needs to be adequately communicated so that people are not scared of eating shellfish.

10. Research chronic low-dose exposure to DA and create risk guidelines

Establishing a research agenda to investigate chronic low-dose exposure to DA, and developing new guidelines to address chronic exposure was another important step identified. This work should include:

- Re-assessing shellfish consumption levels in First Nation communities at the community level (e.g., razor clams, crab viscera)
- Assessing risk from consuming small fish (e.g. sardines, anchovies) that are known to contain biotoxins (both consumption patterns and levels of biotoxins in these fish).

Recommendations from the survey responses

Following the workshop, all participants were invited to complete a survey. The survey consisted of ten questions. Responses were received from 26 participants (35% of workshop attendees) representing all invited sectors (see Figure 5).

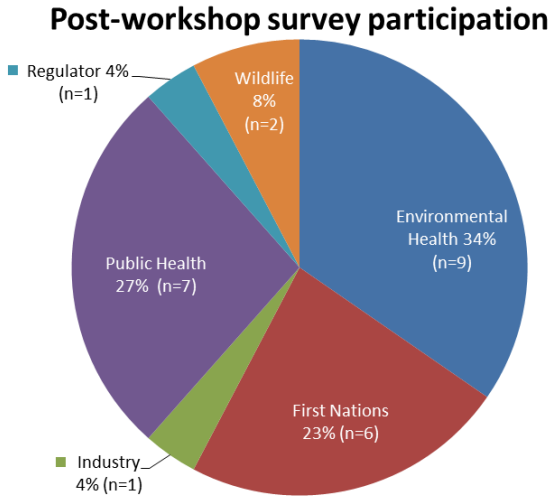


Figure 5. Respondents to the post-workshop survey, broken into sectors

What participants learned at this workshop

Over 80% of survey respondents felt their learning goals and workshop objectives were met. Presentations were informative and useful, and 100% of respondents agreed that learning and networking at the venue was a good experience (Figure 6).

All respondents (100%) agreed that community networks, data sharing improvements, and informing communities about biotoxin risk could be improved.

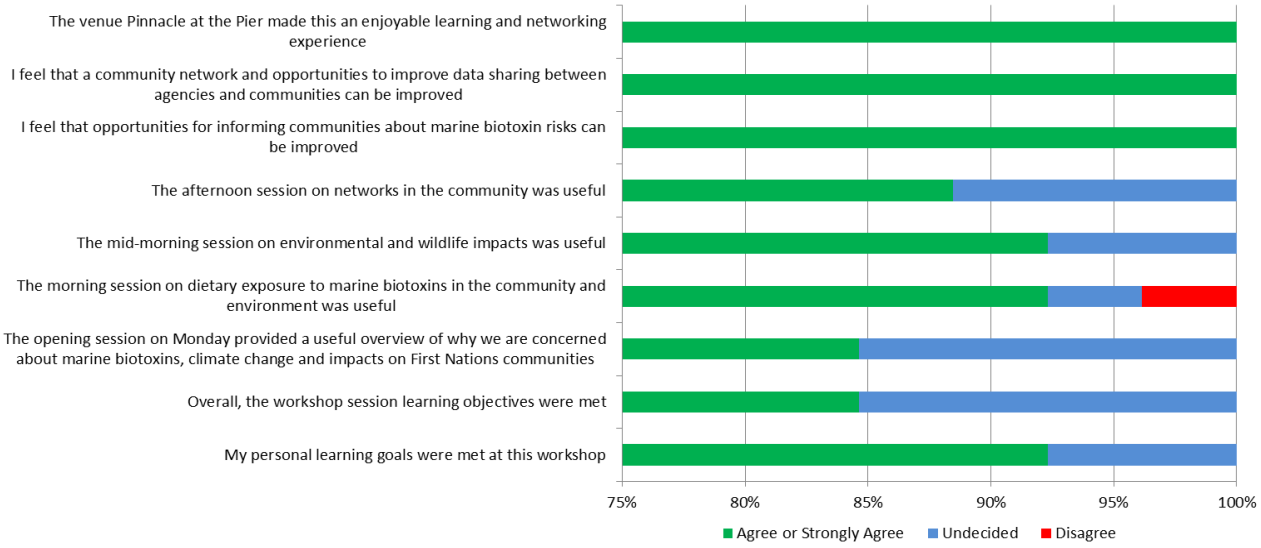


Figure 6. Responses indicating the usefulness of the workshop to participants.

A majority of respondents (65%) reported improved understanding of marine biotoxins, in particular DA. Approximately 35% of participants learned low doses of DA affect memory and behaviour, but recovery from chronic low doses is possible. Dr. Kathi Lefebvre's mouse video resonated with the audience.

Forty-two percent (42%) of respondents reported learning about First Nation activities, such as the Watchmen programs, and the need for First Nation to be more actively involved in shellfish management. They learned the importance of shellfish food security, health, and the importance of foods eaten by First Nations.

Thirty-eight percent (38%) of respondents reported a need for phytoplankton monitoring through citizen science programs and First Nation monitoring, and learned that not all First Nation areas are monitored under the current biotoxin monitoring system. Twenty-seven percent (27%) of respondents learned what species of shellfish and fish are most at risk for biotoxins; that razor clams retain DA for the longest time compared to other shellfish species; that retention times for biotoxins differ between shellfish species; that salmon are not at risk, but some smaller fish that eat plankton (anchovies and sardines) are at higher risk compared to other fish that feed on zooplankton (e.g. herring and eulachon).

What participants said they could take back to their agency or community

Fifty-four percent (54%) said they would share the information internally with their agency or community and encourage more communication. Specific items to be shared included the workshop presentations, the shellfish testing and site closure information distributed by the CFIA and DFO, and the on-line BCCDC mapping service that interprets DFO shellfish closures. Thirty-eight percent (38%) will be bringing back awareness of shellfish consumption and DA risk to their community or agency, specifically mentioning the risk to elders, those with kidney disease, and pregnant women/women with infants. A few participants noted the need for a more comprehensive biomonitoring program and that First Nations may need to do phytoplankton monitoring (15%). Others noted the need to incorporate environmental monitoring of wildlife strandings (such as sea lions) to provide early risk indicators (8%).

What participants said was the most important collective priority to move forward with now

The majority (46%) stated faster and improved access to existing monitoring data was needed, identifying local laboratories to conduct testing e.g., in Prince Rupert (n=3), timely communication to all interested parties, and better data sharing. Improving risk communication messaging was the priority for 23% of survey respondents, focusing on educating at-risk groups (e.g. pregnant women), communities, and the public. A further priority was the specific need for realistic consumption advice that included food access issues. Improved collaborations, coordinated surveillance efforts and a need for focused training for First Nation (by the HA or using Alaskan training materials) was also a priority.

Opportunities for informing communities about marine biotoxin risks

Half of respondents identified the need for centralized resources, either online or in a data warehouse. Resources are currently scattered among many programs, sites, and authorities. Community education could be in the form of posters, pamphlets, bulletins, or e-mails. Ideas for informing communities included messaging to students to take home to families and signing up to receive DFO shellfish reports. Forty-two percent (42%) of respondents identified the need to deliver information directly to First Nation communities through local meetings and workshops, by involving elders, community leaders, and community health members (23%).

Describe how a community network and opportunities to improve data sharing can be achieved

Most respondents (56%) again identified a need for centralized networks and information sharing (e.g., a ‘HUB’), which should include Washington data sources. More engagement and improved communications (30%) with all parties and particularly including First Nations was important. More meetings, education, and training programs could achieve this (23%). Specific ideas included

incorporating chemical contaminants into the discussion, and providing appropriate context and interpretation to any shared biotoxin information to discourage harvesting from closed areas.

What research opportunities are needed?

The effects of low level, long-term (chronic) DA exposure to human health requires further investigation (38%), followed by the need for more environmental baseline monitoring of shellfish, water, wildlife sample collections, and in general examining the health of our oceans (34%). Potential projects included conducting long-term monitoring of human health using voluntary and confidential urine sampling, and a pilot project to assess rapid response test kits for biotoxins.

The need to test more species to determine what foods are impacted by toxins (20%), including sea urchins, snails, crabs, small fish such as anchovies and sardines, and the length of time biotoxins are retained in these species and in shellfish, needs to be investigated and shared. A smaller number of respondents identified a need to research more effective ways to communicate risk to communities and determine if message delivery is working, and to look at fish and shellfish consumption patterns –what First Nation are eating regularly, and ask elders their traditional knowledge about when to abstain from eating shellfish.

Action Statements

Participants were asked to rank ten action statements. Based on their top two choices, the creation of shellfish consumption advice, and advice specific to pregnant women and children who eat shellfish regularly, were the most important priorities for action identified (Figure 7). Three actions were ranked equally for the third key action. Establishing phytoplankton monitoring in First Nation communities; increasing funding to change the focus on shellfish monitoring towards First Nation communities as a priority and commercial interests second; and to improve stakeholder communications.

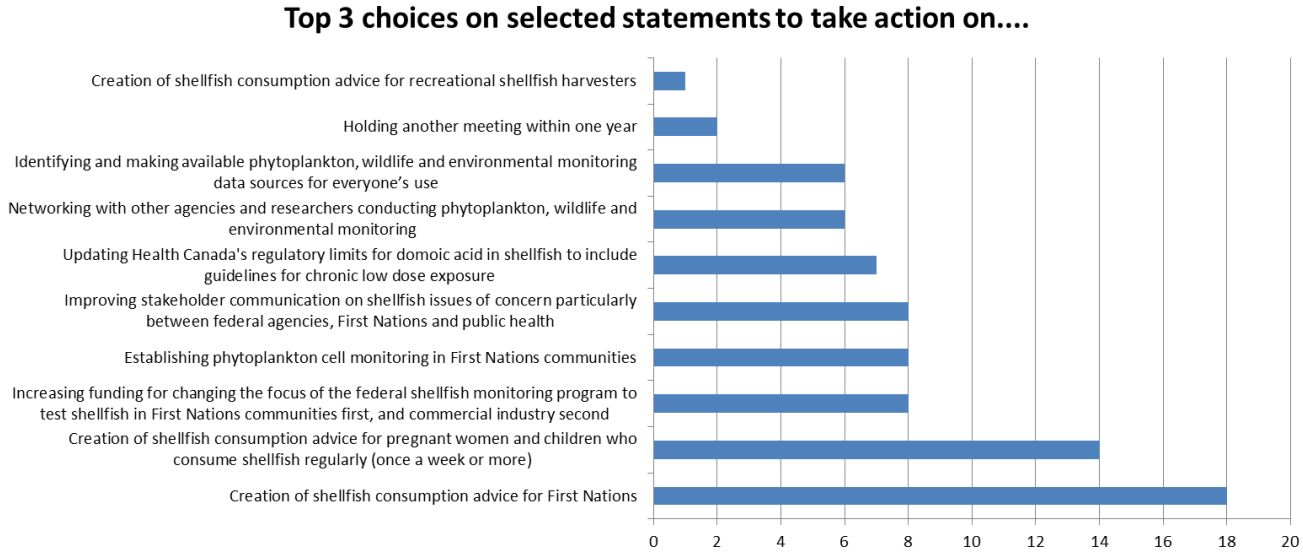


Figure 7. Responses to "The top 3 actions to take".

Other comments about the workshop

Most participants thanked the organizers and the fantastic facilitator for a great workshop. Klecko klecko (*thank-you* in Nuu-chah-nulth). More First Nation participation and more discussion were noted. One participant felt the government only cared about commercial shellfish interests and not the people. A similar comment was to put the people first and commercial interests last. Another comment was that the workshop was less about assessment and management of risks of sub-acute chronic exposure to DA, and more about the overall toxins management program and its effectiveness.

Appendix Discussions and speaker presentations during the workshop

Day 1 October 24, 2016

Opening statements and welcome

Welcome Ceremony with Gloria Nahanee, First Nation Elder, Squamish

Elder Gloria was very thankful for the work that this meeting is trying to accomplish. She sang a gratitude song for the food we were about to eat and some attendees had a great time dancing their interpretations of the animals in the song. Elder Gloria's niece helped attendees with dance interpretations on stage. This was quite fun and light hearted.

Lunch followed and afterwards introductions were made around the room. Everyone was excited about the workshop and about having a platform to discuss the goals for the workshop. Introductory statements by the facilitator, Mark Matthew (FNHA), and co-hosts Dr. Pablo Romero-Barrios (BCCDC) and Linda Pillsworth (FNHA) were made to set the stage for the presentations and discussions.

Mark shared responses from the pre-workshop questionnaire, the agenda, and goal to facilitate this group and bring us to a place of action. The pre-workshop key themes included: needs for collaboration, monitoring, research, and risks.

Pablo spoke about the context for the workshop. In 2015, there were elevated levels of DA observed. This year, two incidents of suspected amnesic shellfish poisoning (ASP) occurred in BC. This leads us to believe DA and consequently ASP is an emerging issue. We would like to have a more inclusive, one health approach, bringing together wildlife and human health risks, environmental monitoring and surveillance programs, public health, regulators, First Nation, and industry. The most important outcome is the collaboration of ideas from everyone in the room.

Linda reflected on Gloria Nahanee's words of "take care of our Earth and it will take care of you". Looking at the importance of shellfish to First Nation, it behooves us to act on the issues surrounding coastal communities' relationship with shellfish. She felt that the Mount Polley Mine incident reinforced how important it is to look at diet, cultural, physical, and mental health concerns for food resources affecting First Nation communities. Monitoring systems that best support communities will do two important things: (1) mitigate the health risk, and (2) provide food security.

Speaker Presentations

Responses captured during the audience questions and group discussion following each presentation and during group discussions were provided by speakers and workshop participants in a plenary setting.

Dr. Tom Kosatsky, Director of Environmental Health Services, BC Centre for Disease Control
Overview: population's impacts and recent observations

A "one health" approach is important. Consuming shellfish is a matter of life and culture, and we are grateful to work with people committed to this – looking at the health of the environment and whole earth – because by protecting the environment we protect ourselves. This issue is important to me because I was involved in the first ASP outbreak in Canada in 1987.

In this (1987) outbreak, consumption of farmed PEI mussels identified 99 cases of illness. People began arriving in the emergency departments with odd neurological symptoms, severe headaches, and/or had nausea, vomiting, and diarrhea. Sudden and complete memory loss occurred in 25% of cases, and tragically there were 3 deaths. These occurred within days of eating mussels. Brain components involved with memory were missing ("burned out") in deceased patients and in experiments with mice. DA was the toxin found to be responsible. We are made up of amino acids, and DA is like an amino acid, affecting glutamic acid and neural responses. HABs had occurred off PEI and the mussels had picked DA up. The investigation looked at who was ill, the ratio of men to women, and ages of the cases. In this outbreak, older cases suffered more severe symptoms and memory loss. Males were more likely to be ill, cases were likely to be older, and have kidney disease. Higher concentrations of DA in mussels meant higher dose levels, correlating to likelihood of neurological symptoms. All of this data was based on the intensive investigation of only 10 of the 99 cases ill.

Based on only these ten cases, some assumptions were made to set a market limit. Based on information collected from the 1987 outbreak from the person with the neurologic symptoms from the lowest exposure, limits were set at 10 times below the safety margin – 20mg/kg. This limit is based on the average amount of shellfish eaten (250g or 9oz), which is not very much for a feast during a single meal. Also, this is based on a single, non-compounding, meal. For example, where separate, unrelated lunch and dinner meals of 250g are consumed, and without roll-over between times, assuming the first DA dose is eliminated before the next dose is eaten.

Conclusion: this is imperfect regulatory legislation. The system in place assumes all shellfish beds are monitored and that people's health is protected. Is this risk management working? While there have been no outbreaks since 1987 aside from gastroenteritis reports in Washington in 2001, there have been marine mammal deaths. Grattan recently published[2] studies showing that in tribal communities, people who ate more razor clams (greater than 15 per month) had their short term recall ability affected, and performed poorly on memory and depression scores. We need to look at long-term

[2] Grattan, L.M., C. Boushey, K. Tracy, V.L. Trainer, S.M. Roberts, N. Schluterman, and J.G. Morris, Jr. 2016. The association between razor clam consumption and memory in the CoASTAL cohort. Harmful Algae 57: 20-25

consumption effects, marine life, public education, and current market limits. Can we better manage this risk?

Audience questions and group discussion

Q: How often do we need to sample clams and how long does the toxin stay in clams? On site sampling where communities harvest should be considered. This is the strategy in Alaska.

A: DA can vary significantly from one shellfish species to another and even vary in different parts of the clam (selective accumulation). Levels can go up and reduce in a matter of weeks, unsure how long it completely stays there. There are no good studies on the persistence of DA in humans although some studies have been done in animals. Repeated dosing has shown repeated harm and death of brain cells over time.

Q: Could the DA finding in the 1987 outbreak have been a red herring, and could there have been something else occurring?

A: No, it was DA, but there could also have been multiple toxins causing illness.

Ross Wilson, Metlakatla First Nation. Importance of shellfish and marine foods to nutrition and traditional diet of First Nations - perspectives from Metlakatla

Metlakatla have a community harvest plan and 900 members. Their relationship with seafood has never been lost and continues to this day. They harvest butter clams and cockles in a large area out into Hecate Straight near the Haida territory (harvest areas 3, 4, 5 and the lower Skeena River). The razor clam industry is a very important export industry to Haida Gwaii. They have partnerships with many organizations (EC, CFIA, DFO) to decide on appropriate shellfish harvesting periods. In the fall and winter harvest months, collection of biomonitoring samples occur weekly; in non-harvest seasons samples are bi-weekly. Three consecutive low (toxin) samples are needed before harvesting. Metlakatla are involved with sampling, have beach patrols, and ensure that sampling occurs during the harvest periods. Public notices are issued advising on toxin levels. Stewardship of the program is with the Metlakatla people. Concern from the community about shellfish safety is high. Several areas are closed due to sewage contamination (Prince Rupert pumps sewage into water) or other sanitary closures, which could be addressed to allow for more harvest locations. A new sewage treatment facility has assisted in opening access close to the community.

An internal challenge is that some members won't share where they harvest. Catch monitoring is difficult: individuals want to keep good locations secret or individuals who hold title within their own territory don't want to disclose to non-members or even other Metlakatla members. Pristine locations in the nation are of high interest to the general public. The public wants beaches that are viable and healthy, but First Nation members do not want to give up their food, social, ceremonial rights under the Constitution Act (section 35).

Research needs are to (1) identify all viable clam beaches (a difficult task), and (2) review clam gardens (Lo ki'we) archaeology and middens. There is evidence of mariculture and seasonal villages, based on strategic areas to find canoe accessible areas. In 2016 there was a clam garden project at Dundas Point to rehabilitate this site.

Metlakatla has guardian watchmen. At 3:00 a.m. people are harvesting clams – are they there legally? The option for ORR (observe record report) is not real-time. First Nations want the authority to enforce regulations like DFO. First Nations have the responsibility and authority to patrol their own beaches. Guardians have had many serious incidents, being threatened by clam rakes, and are concerned of more serious threats. Metlakatla want to work with DFO to resolve issues.

Ross expressed his thanks for Tom's presentation – their elders love clams, and razor clams, and DA risks need to be known. Other issues need to be investigated too: there's more port activity, huge traffic, LNG, tankers with oil and bitumen, and logs. We need to work on a plan to ensure safety of the area. It is important to look at research into areas where communities eat. The recent Bella Bella spill is an issue that needs to be addressed from a shellfishery standpoint. There are other resources aside from shellfish in Haida Gwaii. This year, the seaweed bloom (fishery) lasted less than a week. They noted an increase in water temperature, divers usually need wet suits but this year was so warm they were wearing t-shirts. The herring roe was a short season too – the kelps were suffocated so the herring couldn't spawn. [*Macrocyctis* was covered in bryozoa, herring unable to find suitable substrate: multiple impacts.]

Audience questions and group discussion

Q: How do HA support individual community risk assessments?

A: Local testing is a big challenge, getting samples to CFIA could be a unique opportunity.

Dr. Reza Afshari, Toxicologist, BC Centre for Disease Control. Domoic acid exposure among the First Nation population in BC

What is amnesic shellfish poisoning? This is diagnosed by gastrointestinal symptoms and to a lesser extent by neurologic symptoms. ASP with gastrointestinal symptoms alone could only be 'diagnosed' if the gastrointestinal patient could be shown to be exposed to DA, or be linked to a case with neurological symptoms. There is likely under-reporting of shellfish illness.

Myths surrounding domoic acid (DA)	Facts about domoic acid (DA)
Storing shellfish rapidly destroys DA	No, DA remains in food for a long time. In one study, one-quarter of the toxin remained 180 days after storing shellfish.
DA is destroyed by boiling and cooking	No, DA is resistant to boiling and cooking
DA is destroyed when exposed to stomach acid	No, DA survives in stomach acid
DA occurs only in the summer.	No, DA can occur in the winter as well as the summer. The 1987 outbreak in Canada occurred in Nov-Dec.
DA at any level in shellfish is considered to be toxic.	No, DA at levels below 20ppm is considered safe. DA at very low levels is frequently reported, and is not a reason to avoid eating shellfish. High levels (20 ppm and over) are reported less frequently, and are the reason not to eat shellfish.
Amnesic shellfish poisoning (ASP) is common.	No, ASP is rarely reported as an illness in developed or developing countries.

Other risk factors need to be looked at besides being elderly and individuals with kidney problems e.g., the risk in pregnant women (breast milk/amniotic fluid transmission), consuming multiple shellfish meals per day, and chronic low dose exposure are important. The First Nation population at risk has increased in recent decades because of population growth (more pregnancies and more neonates), and an aging population with increasing kidney disease. In addition, the portion size and frequency of consumption of shellfish is higher amongst First Nation populations. Current regulations and testing are only sufficient for the "commercial use", not self-harvesters, which is a matter of concern in regards to "inequity in food toxicities". As shellfish self-harvesting is more common among First Nation populations, they should receive more attention. We need to share more information, have more effective education, and consider re-evaluating regulations.

Audience questions and group discussion:

Q: Where is the closest lab for shellfish testing?

A: In Vancouver.

Q: Is there statistical data to support the idea of an increased population risk in First Nation?

A: Yes, the province has collected health data to support this both with an aging population and increased cases of diabetes (renal dysfunction). When people age there are fewer brain cells and older kidneys take longer to clear out toxic substances, so elderly people are at higher risk. To draw conclusions from one outbreak in 1987 is difficult, but using the data from multiple studies from many disciplines, we can begin to paint a picture of the impact of DA on people.

Dr. Ian Perry, Senior Research Scientist, Fisheries and Oceans Canada. Recent environmental conditions in southern BC marine waters, and unusual algal blooms

Overview of recent ocean conditions – what has been going on?

1. **Warming global climate**: 2015 was warm, and 2016 looks like it may be even warmer. The "blob", and El Niño event in 2015; August 28 there was a huge storm that was the end of the blob and start of El Niño. Up until 2012 our ocean was cooler but the North Pacific marine heat wave (aka the blob) area is bigger than BC and Alberta combined. In Jan 2014 it was cool along the coast but by Jan 2015 all along the coast was very warm water.
2. **Unusual phytoplankton events**: After the Aug 28th storm, trophic levels changed. There was a shift from large, northern zooplankton to smaller, southern zooplankton. We also saw many southern animals (fish) in our waters in 2015. Harmful algae are characterized as a) toxin producers; b) possibly non-toxic to us, but potentially harmful to birds and the gills of fish (mechanically harmful, spiny); and c) high biomass producers, which can deplete oxygen levels in the water. There were poorer fish food types, e.g., copepods, and more gelatinous zooplankton which are also poor fish food. There were exceptional phytoplankton blooms of *Pseudo-nitszchia* spp. from May-Sept 2015, spanning the coastline from California to Alaska. On August 19, 2016 a coccolithophore bloom in the southern Strait of Georgia turned the water white-green. This had never been seen before, and was not a health hazard. In Saanich Inlet, there was also bright green water from blooms. (Note that there is generally a lag of 12 months in the water from offshore to the Strait of Georgia.)

3. **Possible futures:** Theoretically, any type of bloom could occur at any time of the year. There is a lack of structured monitoring. We need a long-time series of phytoplankton monitoring. The responsibilities for monitoring of HABs in Canada is "scattered" and industry dependent, and it's very convoluted how the pieces fit together. Is this global warming? Maybe. Things will be more variable and less predictable at least, and include changes in temperature, nutrients, chemistry. Difficult to say what the future will look like, but it is likely that we can expect increases in expansion of HABs both spatially and temporally.

   Annual "State of the Pacific Ocean" and "State of the Oceans Report" from DFO is available online. Are there any indications before the blooms occur? Yes, in a way. There are areas/habitats and environmental conditions where/when certain species bloom. What may happen in the future? Fish don't seem to be impacted by DA. Marine mammals are impacted by eating filter feed fish. Toxins tend to depurate in fish muscle tissue quickly (may not be the case in periods of extended exposure), and tend to be present at higher concentrations in fish gut compared to muscle tissue.

Audience questions and group discussion

Q: Is CFIA data on biotoxins available?

A: Yes, but it is very difficult to get hold of historical data unless individuals have been recording it from the weekly reports themselves. Areas get closed based on either high or no results (testing) in that area, or the area is difficult to access.

Q: Are fish affected?

A: Fish do not appear to be affected by DA; however, marine mammals feeding on fish (e.g. sardines, anchovies) can be affected. When DA levels are high in prolonged blooms, and DA is high in the gut, it crosses into muscle tissue. In 2015, most DA was found in the fish gut, not in edible fish tissues.

Q: How fast does DA spread? What causes blooms to come ashore?

A: This cannot be predicted without conducting offshore sampling. It varies depending on whether narrow inlets or bays.

Q: Why don't communities get this information? They are the last to know.

A: There is a need to support local information access.

Open Discussion and Questions

A representative from Tsartlip First Nation shared the impacts that a lack of monitoring and dissemination of results has on First Nation communities. The existing harvest area monitoring locations do not cover all sites for which the community would like to harvest from, particularly for a community that is challenged by unemployment and food security. This message carried emotion throughout the room and reinforced why participants are here today.

Hartley Bay First Nation participates in community monitoring of shellfish biotoxins and they see great diversity in biotoxin levels between adjacent sites. In one beach you can have high results and five kilometers away levels are low. Taking a sample doesn't tell you if it's toxic; often samples do not make

it to the Vancouver lab. It would be great to have a laboratory in Prince Rupert. The community does not have a dedicated program for shellfish; this work is all off the side of their desks.

Vera Trainer (NOAA) emphasized modelling a community-based monitoring program in BC after the Alaskan tribal monitoring network that involves monitoring of phytoplankton (with some basic training and access to microscopes). The west Alaskan coastline is such a vast area, it cannot all be monitored. Phytoplankton monitoring is used as an early warning system. The Sitka Tribe of Alaska has their own testing lab, which is integrated into State monitoring. This is important outreach and provides early warning of blooms.

Klaus Schallie (former CFIA Shellfish and Aquaculture Specialist) shared that a Canada-wide complete monitoring program might not be feasible, so there is a need for community-based monitoring. There are some areas where First Nations live that are monitored for biotoxins in mussels. The monitoring program analysis results indicate that the presence of the ASP toxin is very fleeting in other species of shellfish. California has much more frequent blooms of *Pseudo-nitzschia* spp. and there are many observations of marine mammals and birds being affected, although no cases of human poisoning from DA are known to have occurred in California.

Q: What species are important to First Nation?

A: First Nation representatives shared the following key species: butter clams, cockles, manila clams, littleneck clams, oyster, razor clam, scallops, blue/California mussels. The species are variable depending on the area. It is also important to consider other foods, such as crab, herring, sardines, and anchovies.

Other comments: There are challenges with getting samples to the CFIA Vancouver testing lab from remote sampling locations. For example, weather can delay transport for a week and thus samples do not reach the lab. To resolve this, a testing lab in Prince Rupert would greatly enhance service to these remote locations in the Central and North Coast.

Q: Where is monitoring currently carried out and how do we (First Nation, general public) access results?

A: Everyone can sign-up for the e-mailed harvest area opening and closure status updates available from the DFO website [link: http://www-ops2.pac.dfo-mpo.gc.ca/fns_reg/index.cfm], although reports of marine toxins monitoring data are not available to the general public. Monitoring is typically based on mussels, used as a sentinel species. Due to finite resources, areas where there are no active commercial fisheries are not consistently monitored. For example, in some areas of the North and Central Coast and Barkley Sound, areas are sampled before opening a geoduck fishery for commercial harvest in order to ensure the safety of this product. The association submitting these samples receives the results for their samples in order to inform their harvest plans. The majority of clam licenses (70%) are owned by First Nations, which provides economic support for those communities. However, in areas with no monitoring, possibly due to a lack of commercial harvesting or under harvest closure orders, those resources shouldn't be harvested or eaten due to the associated unknown risks. One participant noted that parks are rarely, if ever, cleared by DFO for harvesting, especially in recreational areas. The decision [of where to sample] does not fall within the means of any of the workshop attendees. More involvement from stakeholders is needed. Dialogue and action are necessary to address the lack of

biotoxin monitoring for First Nation communities. The current monitoring system doesn't cover all First Nation areas and they need this information because these are the foods they rely upon.

Q: How can we set up community-based monitoring?

A: Phytoplankton monitoring can be used as an early warning at the community level, as in Alaska. Rapid analysis tests (used in US coastal states) will only give a presence/absence result, and will not tell you actual levels. The rapid tests can't be used to open beds (shellfish tests needed) but could be used to close them.

In 2016, BCCDC created a user-friendly interactive shellfish harvesting map to better assist the public in accessing harvest closure areas. A demonstration of the BCCDC website shellfish harvesting map was provided. The BCCDC Shellfish Harvesting Map can be accessed at: http://maps.bccdc.org/shellfish/. The site includes a clam dictionary to assist in identifying clam species.

Day 1 - Tabletop summaries centered around three themes.

(1) Testing and monitoring shellfish resources

- Identify where key gaps in monitoring exist, and identify where First Nation are harvesting.
- Using coastal tracker or coastal guardian.
    - Need for an App or an addition to existing App such as "Coast Tracker" to easily communicate results to First Nation stakeholders.
    - Use "Coastal Guardian" or "Coast Tracker" tools for community level monitoring.
- Improved sampling strategies, risk-based, screening, point of use testing (microscope).
- Conduct more shellfish biotoxin monitoring in First Nation traditional harvesting areas.
- Conduct more comprehensive sampling of offshore blooms.
- Create a [phytoplankton] community-based monitoring program for early warning of HABs.
- Assess the viability of reopening the Prince Rupert lab to assist in preparation of samples and shipping to CFIA Burnaby laboratory for analyses. Local labs would enable faster reporting.
- First Nations should be doing community monitoring because they are better positioned in intertidal areas. DFO's monitoring strength is in the offshore areas.
- Dedicated, supported sampling programs for First Nation communities through local labs with real-time reporting.
- Survey who is harvesting what, where and when to direct research and monitoring. Create surveys to help guide sampling and include questions to identify who is harvesting and consuming, and who is at risk.
- We will never be able to test every beach on our coastline, so how do we solve this? Rapid ELISA? Create mobile testing for algae? There is a big need for rapid test kits or similar early warning systems.

(2) Communication and education

- Need to create a means of user-friendly communication of biotoxin results and harvest area closures. For example, using maps showing areas where monitoring does, or does not, occur. Increase the clarity, frequency, and public availability of CFIA results and areas, and clarifying the responsibilities of DFO and CFIA. Better communication and data access from CFIA, DFO, and Environment Canada regulatory agencies.
- Ensure stakeholders have access to data.
- Informed risk communication that is empowering.
- Capacity building. Each community needs access to microscopes, training, and other workshops.

(3) Human health risks

- Need for a risk assessment of chronic exposure in high-risk populations e.g. pregnant and breast feeding women and their infants.
- Conduct human surveillance at community level of DA and other potential toxins to better understand the health effect of chronic exposure.
- More research into who is at risk: First Nation communities, recreational harvesters, others?
- Look at the DA risk of other species e.g., eulachon, sardine, herring, anchovies, crab, and others.

Day 2 October 25, 2016

Mark gave a great summary of yesterday's work.

Dr. Laurie Chan, Professor, University of Ottawa. The importance of shellfish in the traditional diet of First Nation Communities: Findings from the First Nations Food, Nutrition and Environment Study

The BC portion of this study occurred in 2008-2009 and represented a true partnership with First Nations. Similar studies are occurring across Canada for other representative First Nation communities. In BC, the data was aggregated into five eco-zones that represented 21 communities. For each community, individual data was reported, but was not shared to protect confidentiality. The objectives of this study were to find out: What are people eating? How balanced is their diet? Is the food safe (e.g., mercury, water-borne illnesses)? The project was comprised of five activities – 1) food frequency interview; 2) collect "country food" for analysis of contaminants; 3) conduct water sampling for trace metals; 4) examine surface water for pharmaceuticals; and 5) analysis of results.

The top five traditional community foods eaten in BC were: moose, salmon, deer, trout, and elk. The top five traditional seafood eaten were: salmon, clams, crabs, oysters, and mussels (in that order). Coastal First Nation consumption rates of clams (66%) and crabs (59%) are higher than for all BC First Nation (25% clams and crabs). Oysters are a good source of zinc in the diet and contribute 20% of nutrients. Salmon is an important protein source. There were low background levels of contaminants in all seafood groups examined. Seaweed has high levels of arsenic while moose liver and kidney is high in cadmium; consumption of these should therefore be limited. Food security is an issue in BC with 41% of First Nation

reporting food insecurity issues compared to 15% in the general BC population. Overall, 91% of First Nation participants would like to eat more traditional food.

Conclusion: traditional food is a healthy source of nutrition, but is not always available. The full study can be found online at www.fnfnes.ca.

Audience questions and group discussion:

Q: Was the data collected at one time or over a period?

A: Data were collected mostly in the fall. Many of the samples came from the freezers of participants.

Q: Portion size/time of year: can you use an average?

A: For the purpose of this study, it was the best way to see the big picture. Eating traditional food is healthy, and more traditional food should be eaten.

Q: Do First Nations eat the crab viscera?

A: Yes, crab liver is eaten.

Dr. Kathi Lefebvre, Research Biologist, NOAA. Environmental exposure risks and effects of domoic acid in marine mammals and humans

Kathi is the program lead for the Wildlife Algal Toxins Research and Response Network for the US West Coast (WARRN-West). This overview is to learn about the health effects of DA on marine mammals. In the past, DA was not considered to be as big of a problem for marine mammal health as it has been in Central California. But when 900 marine mammals were studied, low levels of saxitoxin and DA were detected, demonstrating that DA is in the food web. The regulatory limit for DA in shellfish is 20ppm or 20,000ng/g. In the studies, we looked at ng/g levels using ELISA (enzyme linked immunosorbent assay). Pacific walrus had the highest DA levels seen at 6,000ng/g (before the bloom of 2015), followed by bowhead whales at 359ng/g. Seventeen of 25 bowhead whales contained detectable DA – these animals were hunted (not sick) for harvest and food. There is a traditional practice of eating walrus viscera and organs so this is of concern. Sea lions are known to eat anchovies that can have dangerously high levels of DA and that result in seizures and death in sea lions. DA levels as high as 182,000 ng/gram have been documented in feces of sea lions exhibiting seizures.

With acute DA exposure, there will be serious effects and damage in the brain and hippocampal connectivity, causing many marine mammal strandings. Learning deficits using water mazes have shown smaller hippocampi and permanent brain damage. [Peter Cook et al (2015) *Algal toxin impairs sea lion memory and hippocampal connectivity*. Science. Vol.350(6267):1545-7]

We wanted to study the effects of low level, repetitive DA exposure. First Nation communities in the Pacific Northwest eat razor clams weekly over their lifetime, and these clams are an important dietary component. To mimic this exposure we used a mouse model, and determined the amount of dose that would cause a visible physical reaction in mice - a “hind leg tremor”. We then took a value that was less than half of that to find a dose that did not generate visible symptoms (0.75 ppm DA), and injected mice once a week for 6 months to mimic weekly dietary exposure. The treated mice and control mice

(without DA exposure) were trained to find the exit to a water maze. A video demonstrated that exposed mice were unable to find the exit while control mice could find the exit to the maze. This demonstrated visibly the inability of mice to learn after chronic low-dose DA exposure affecting spatial memory, learning deficits, and hyperactivity. However, if these same mice were fed a normal diet (with no DA exposure) for 9 weeks, they recovered, showing chronic low-dose DA effects are reversible in mice. We also looked at the combined effect of DA and old age – mice were dosed with DA for 9 months from 3 months of age to 12 months of age, followed by a recovery period of no toxin exposure. Mice were tested (by maze) at 18, 24, and 28 months, and no differences to controls were seen ($p>0.05$).

On October 7, 2016, a first ever educational warning was sent out advising no more than 15 clams should be eaten each month over a one year period. When clams exceed 20ppm, the harvest area is closed. However, a household survey found there is a subset of people who are chronically exposed to DA who eat more than expected, or are younger/smaller than the average person, and thus consume above the TDI (tolerable daily intake) based on their size and consumption habits.

Audience questions and group discussion:

Q: Do we (BC/Canada) need to have an advisory on chronic exposure as well as acute?

A: No, we don't have at the moment. In Washington State (WA) they have long periods of time when toxin levels are above normal and that is an issue for chronic exposure.

Q: What are 15 clams in terms of weight (grams)?

A: The value assigned was 45g and can range between 40-90g depending on the clam species.

Q: What about other clam species? Do we need specific language around each type of species?

A: The ability for shellfish to retain biotoxins differs greatly from species to species, so yes language needs to be created to address this. Scallops also retain toxin for a long time. While mussels release toxins over a few weeks, razor clams take months to release toxin. In WA, crabs eating razor clams with high levels of toxin also become a problem. WA had their first crab fishery closure this year due to DA levels. Crab meat is typically negative for DA, but the viscera can contain very high levels of DA. This can be a problem when the hepatopancreas is eaten. The species eaten by First Nations are not generally ones that retain toxin.

Q: How do mouse and monkey or mammal studies compare?

A: Many studies on fish show a lot of toxin goes to the bile (compared to the brain). In mammals, the half-life is short, but the damage is done, and the animals will keep seizing for a long time.

Q: What about using juvenile or fetal organisms?

A: This aspect has not been examined yet, but investigation of *in utero* exposure is planned. It is difficult to estimate food exposures in marine mammals and marine mammal variability. By the time samples have been collected (e.g. stranded mammal), there is the possibility that the toxin concentration in the feces has decreased. There could also be dietary differences. Marine mammals are consuming massive amounts of seafood, and on average, humans don't eat that much. However, this is an early warning.

Marine Harvest provided an observation that fish are behaving abnormally when *Pseudo-nitszchia* spp. is present. We are not testing marine mammals systematically because DFO has a limited mandate and resources to deal with stranded animals.

Dr. Martin Haulena, Staff Veterinarian, Vancouver Aquarium. Epidemiology and clinical signs associated with acute and long-term effects of domoic acid toxicity in marine mammals along the west coast of North America

Martin described his earlier career in California and the nightmare of DA. The first documented cases of DA exposure in marine mammals started in 1998, during an El Niño year. "Tick", a healthy pregnant California sea lion (CSL) was diagnosed with comas and seizures – it took a long time to figure out it was DA. DA is a neurotoxin produced by several algae, in particular *P. australis*. It binds to the CA3/4 of the hippocampus causing neurological symptoms. Urine is the most reliable sample for diagnosis as DA disappears in blood. Marine mammals showed signs of recovery after this incident. However, in 2002, Tick came back, seizing again and many females aborted pups. Today, there are multiple factors clearly showing the link between these symptoms and *P. australis*. In 2002, the recurrent stranding of known CSL showing multiple symptoms was observed. Common symptoms included abortion and still-birth. Normally you cannot approach a sea lion, but they were listless and rocking. Now they have a "DA protocol" to assess CSL. What occurred in 1998 was not an isolated incident. Now, there are more years with acute DA outbreaks in CSL than without. CSL symptoms: repeated stranding, flipper chewing, aggression. The long-term effects of DA exposure are showing up on necropsy. They look for the typical differential issues: gunshot, *Toxoplasma*, *Neospora*, *Sarcocystis*, conduct blood work, MRI (shrinking of hippocampus), radiographs. Note: damage from DA is not always seen on MRI. CSL don't always show outward seizures when exposed to DA, but they do show abnormal neurological activity when using EEG. It will show subclinical seizure activity, and if the CSL is acting weird, lethargic or isn't looking/acting normally and if there is epileptiform activity, the diagnosis is DA. Furthermore, tracking studies have shown CSL can get confused as to their normal migration patterns.

Audience questions and group discussion:

Q: What is the best tissue to sample and how long does it last?

A: Urine and feces are best. Almost always, animals that have been exposed and die do not have any measurable DA in their system anymore. Can detect brain lesions, but only in fresh mortalities (the brain decomposes fast).

Q: What is the population effect on animals?

A: CSL are in a good state of recovery from the last two El Niño events; however, the sea otter is more vulnerable. It is a benthic forager and eats a lot of crab and abalone.

Q: Why are females most affected?

A: Females are actively foraging near haul-out sites because they are about to give birth. These sites are closer to bloom areas, thus they are exposed to higher levels of DA.

Q: Are there case control studies for non-affected animals?

A: Yes, those data exist.

Nicky Haigh, Manager, Harmful Algal Monitoring Program, Vancouver Island University. Phytoplankton sampling and its role in marine biotoxin monitoring

Nicky describes harmful algae in BC as (1) Alex (*Alexandrium)* the dino (dinoflagellate), (2) "*PN the Aussie and gang"* are toxic (*P. australis*), but not all are toxic, and (3) dastardly *Dinophysis. Alexandrium* spp. cause PSP, *Pseudo-nitszchia* spp. cause ASP, and *Dinophysis* spp. cause DSP. We have always had shellfish toxins in BC. The 1940's led to routine monitoring in BC for PSP, followed by monitoring in 2011 for DSP after an outbreak. Monitoring for all three (PSP, ASP, DSP) is done by CFIA by analysis of shellfish flesh samples. However, there is no routine monitoring of phytoplankton as part of the monitoring system for shellfish. Fish are affected by algae too; they can die. After a very bad 1997 with *Heterosigma*, the Harmful Algae Monitoring Program (HAMP) was born (1999). The HAMP mandate: analysis of weekly phytoplankton samples, institute industry standards for sampling phytoplankton, education about harmful algae and their monitoring, and to offer support during bloom events. Education is done via on site workshops or via online courses: www.microthalassia.ca Onsite sampling is great because it can be done immediately, and as Nicky says, "It's not rocket science." Many fish farmers are also looking at harmful shellfish algae because they like to harvest shellfish recreationally.

New Zealand (NZ) monitoring is thought to be the best model in the world [Rhodes, Smith & Moisan, *Shifts and stasis in Marine HAB monitoring in New Zealand.* Environ Sci Pollut Res Int. 2013 Oct;20(10):6872-7]. NZ shellfish toxin issues began in 1993. They use a compound approach of phytoplankton monitoring and analytical (biotoxin) analysis at 100 sites. There are two streams: recreational (government funded) and commercial (funded by industry). The model for recreational sites is to first monitor for phytoplankton, once detected, shellfish are collected and tested for biotoxins. Shellfish testing determines when an area is opened or closed. Phytoplankton sampling costs less money, is fast, but may have false positives and some species may vary in toxicity. By comparison, biotoxin monitoring is slower, more expensive, but gives you the actual toxin numbers. Limited training is needed on phytoplankton identification, which can help create community-based monitoring and could be a great first line of defense. Phytoplankton analysis would require knowledge, basic equipment, training, and commitment to ongoing sampling.

Audience questions and group discussion:

Q: In regards to false positives, how often do potential harmful species shut down an area?

A:Always be conservative. Expert [microscopy specialists] or knowledgeable individuals can help eliminate false positives.

Q: How frequently should sampling occur and over how big of an area?

A: Weekly sampling is best. Plankton is patchy, so one needs to consider how representative an area is. When viewing harmful algae there are threshold values of cell concentrations that you need to see before you take the next step. This will trigger the collection of shellfish for biotoxin testing, or you can do rapid Enzyme Immunoassay (EIA) tests. Test sites and then choose shellfish harvesting sites over a period of time to determine sites of importance.

Q: Is there any correlation between coastal and pelagic (deep ocean) sites?

A: No. There is much variability, but blooms are happening mostly in the inlets.

Dr. Vera Trainer, Supervisory Oceanographer, Marine Biotoxin Program, Northwest Fisheries Science Center. An unprecedented toxic algal bloom linked to anomalous ocean conditions and implications for First Nations health

The blooms seen in 2015 in Washington State were like looking at pure cultures grown in the laboratory (i.e., optimum). The zooplankton net drags were clogged by super long 3-celled chains. There were economic issues: crabbers were on food stamps, over $23 million was lost in revenue to the Dungeness crab industry. Annually this industry has a $180 million value. Where should a line be drawn? All sardines and anchovies showed some level of DA. The blob persisted from Sept. 2014- March 2015, and spring upwelling fueled the bloom after warmer sea surface temperature (SST) and three storms (wind) which pushed the bloom inshore. Razor clams retain DA much better than mussels. Are large scale closures the "new normal"?

In 2015, we saw levels of DA from cell samples higher than ever previously recorded. Canada did not experience as much *P. australis* compared to Washington State. There is a strong correlation between *Pseudo-nitszchia* blooms and El Niño years (Pacific Decadal Oscillation). With a little bit of a lag, El Niño forecasting may offer an early warning system. The theory preceding the bloom was the blob: warm SST allowed for a low snowpack and drought. This caused nutrient depletion and good conditions for toxic algae. *Pseudo-nitszchia* is like a sponge and sucks up all the nutrients, and is very resilient to environmental stressors. It is rare to see such a bloom in the springtime; however, the blob was an unusual incubator, providing a natural experiment for global warming. The Grattan paper[3] demonstrated some cognitive learning and memory function loss in super consumers i.e., high level coastal consumers in Washington of >15 razor clams/month. There is a strong need for: (1) monitoring of harmful algae, toxic, and environmental parameters; (2) rapid and effective communication of results; and (3) outreach and education. In the Philippines, Indonesia, and Guatemala they hold classes in seafood safety – and it works to monitor for harmful algae. A tiered monitoring strategy is effective in Washington State and Southeast Alaska. Examine phytoplankton cells over periods, when toxic cells are seen in phytoplankton, use rapid kits to test shellfish and seawater. ORHAB monitors 24 sites weekly www.soundtoxins.org. The state provides microscopes and presence/absence of the 3 algae of concern is mapped (in stoplight format) for *Alexandrium, Pseudo-nitszchia* and *Dinophysis*. BC is welcome to use the Washington database or use it as a model. SEATT (Southeast Alaska Tribal Toxin) http://www.seator.org/ and microthalassia.ca have a lot of online resources available.

Audience questions and group discussion:

Q: What is the impact of the advisory limit and how was it decided?

[3] Grattan, L.M., C. Boushey, K. Tracy, V.L. Trainer, S.M. Roberts, N. Schluterman, and J.G. Morris, Jr. 2016. The association between razor clam consumption and memory in the CoASTAL cohort. Harmful Algae 57: 20-25

A: The advisory limit is not a lot (of food) for First Nation communities, so yes it has a big impact on economics and on the nutrition of tribal communities. The advisory is 15 razor clams per month, and the quota for allowed harvest is 100 clams. More studies on the economic impacts are still to come.

Q: Is environmental data being collected as well as cell densities?

A: Yes, at least temperature and salinity. These programs are very popular and very effective.

Lara Hoshizaki, Coastal First Nations Regional Monitoring System

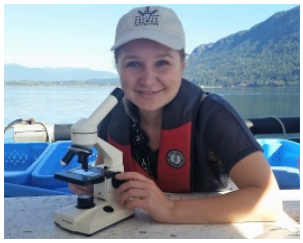
Coastal Guardian Watchmen and other technicians working for their respective Nation's Stewardship Offices collect and upload monitoring data using the CoastTracker app to a centralized database located on a server in BC. The Regional Monitoring System (RMS) offers methods for standardized data collection, field cards/CoastTracker, online data management system, data for planning and decision making, and support. The data is owned and used by the Nation's that collect it. What is monitored? Patrol effort, wildlife and prawn/crab trap sightings, tourists and their activities, impacts to cultural and ecological sites (can turn off GPS feature for privacy), suspicious activities, spawning salmon, tsunami debris, stream habitat, and photos. How? Via Samsung tablets (don't need Wi-Fi for the app), and then web access to the database. Potential uses for the data include marine use plan implementation, land use plan implementation, fisheries management, referral responses, to support conservation, and reports to communities. The app is easy to adapt and is user-friendly. Authorized users can access data online. http://www.coastalguardianwatchmen.ca/

Audience questions and group discussion:

Q: Can this be used in southern BC/Vancouver Island?

A: Yes, it can be used; it just depends on the organizations who would like to use it (if they see a benefit of using it). There is potential for collaboration for specific projects.

Svetlana Esenkulova, Monitoring of harmful algae via citizen science program with DFO and Pacific Salmon Foundation



This 3-year program is a collaboration between the Pacific Salmon Foundation, Ocean Networks Canada, and the DFO. Sampling of the Strait of Georgia is done every 2 weeks between February and October by "citizen scientists" (trained members of the coastal community). Water properties and specific samples are measured and collected at ~80 sites in the Strait: conductivity, temperature, depths, salinity, and phytoplankton. At selected sites nutrients, zooplankton and chlorophyll samples are also collected. This provides unique data on the entire Strait at a resolution that was never possible before. Based on the analysis of thousands of phytoplankton samples we witnessed very different phytoplankton dynamics (timing and composition) in 2016 versus 2015. For example, cells of *Alexandrium* spp. (PSP causing species) started to appear earlier and were much more abundant in 2016 than 2015; areas with less turbulent waters (for example, semi enclosed Cowichan Bay) appear to be affected the most.

You can find the Phytoplankton - Citizen Science monitoring project on Facebook https://www.facebook.com/CitizenSciencePhytoplankton/; phytoplankton data at http://sogdatacentre.ca/ and environmental data at http://www.oceannetworks.ca/

Audience questions and group discussion:

Q: Who are the volunteers?

A: They are mostly folks who have their own boat: retired or recreational fishermen. The program provides training on board the boat and a QA/QC person from the Pacific Salmon Foundation comes out to ensure protocols are being followed properly.

Q: Is there an opportunity to expand the monitoring area?

A: Not according to the mandate of the Pacific Salmon Foundation. For the moment it is restricted to the Georgia Strait.

Linda Pillsworth, Manager Environmental Public Health Services, First Nations Health Authority. Local Environmental Observer (LEO) Network: the eyes, ears and voice of environmental change

Canada is becoming wetter, warmer, and stormier. We need to monitor weather, landscape, biota, and public health; and communicate with other regions. The Alaska Native Tribal Health Consortium (ANTHC) uses a one health approach via a google based platform (app). This is concentrated in Alaska, but there is the potential for expanding. Anyone can register: First Nation observer, First Nation expert, wildlife expert, or agency. The system links local observers with local experts and discipline experts. It is user friendly and contains public facing and internal pages, and it utilizes photos and videos. The BC coordinator is Dr. Tom Okey, UVIC, www.leonetwork.org. The next steps for implementation in BC are to get the app into communities and conduct initial training workshops in Victoria and getting the right experts involved. FNHA environmental health officers will be trained. The Marine Biotoxin Network Project has been created on the LEO network as a potential mechanism to support future networking and observations.

Audience questions and group discussion:

Q: Do you have any guide sheets?

A: No, not yet.

Q: How do we preserve privacy?

A: Each Nation needs to decide whether they want public vs. community site sharing – it is a protected network. Events may be marked as general area, and not for a specific point like some of the other available networks.

Q; Is LEO Network compatible with CoastTracker?

A: This needs to be investigated, we don't want to reinvent the wheel.

Q: Are there any examples of information that was collected that led to action?

A: Yes. For example, deer with hair loss; individuals were able to access experts who gave answers and relieved worries in the community (this was deer hair loss syndrome, which is of no threat to humans).

Day 2 – Poster Board Questions

A question board was made available during the workshop to pose additional questions and were answered by knowledgeable experts in the room.

Question	Answered
Has DA been tested for in herring or eulachon species?	No. These are NOT planktivorous fish so there is a reduced risk – they feed on zooplankton. The biotoxin level would need to be very high for the toxin to go into reproductive organs or roe. Anchovy and sardines feed on phytoplankton and that is why they are at greater risk from biotoxins.
Is there anything that can be done to break up blooms?	No. Algae are really big picture, climate change is a big driver, which is difficult for individuals to do anything about. Some individuals are spraying clay, but it is very controversial. There may be naturally occurring bacteria or viruses that may control algae blooms.
Should we be testing crab?	Crab is tested sometimes when there are high levels of DA in shellfish. The muscle tissue does not hold toxins; however, crab hepatopancreas may contain DA and saxitoxin. Crab testing is based on average consumption rates of crab viscera (which needs to be addressed). Crab closures can be very difficult because the area is so much bigger than shellfish. It was suggested that if 1000ppm or higher in shellfish/crab, it should not be consumed
Why are First Nation and recreational shellfish areas not funded for biotoxin testing? How do we get funding for this?	No answer to this (this was a question added to the on-line survey following the workshop).
Is it feasible for FNHA to fund a pilot project in Metlakatla First Nation for biotoxin and phytoplankton monitoring?	Metlakatla has been used for pilots for studies on fish lice in the past because of its size and proximity to an urban area.

The remaining poster board recommendations, questions and comments are listed below, grouped by similar themes that arose during the workshop open discussion:

(1) Monitoring

- Implement phytoplankton monitoring programs in coastal communities and provide training, equipment, and employment.
- Count and identify phytoplankton cells in shellfish harvesting areas and link to existing environmental data.
- Connect sampling information to reduce redundancy.

- Share data more widely.
- Include paid sampling.
- Monitor big ships that travel through central coastal waters.
- How could we work around protecting harvesting site identification while providing adequate monitoring?
- Are the quick tests that measure for toxicity in the water simply presence or absence tests? Or can they be designed to only detect the toxin at a certain concentration?
- In PSP 'hot spots', are blooms associated with any environmental or anthropogenic factors (pollution, run-off, temp, etc.)?
- How can First Nation access the rapid testing kits? What would an average testing cost to test clams (manila) once a week/month not including labour?
- Is there an effort to collect all sources of marine environmental data, plankton monitoring, fish/shellfish health data etc. (i.e., DFO offshore and Bayne Sound carrying capacity IOS, CFIA, Universities, Hakai Institute, local community data shellfish farm/fish farm monitoring, etc.)?
- Would there be a benefit to industry paying for commercial monitoring and the current government funded model shift to be protective and consider First Nation and recreational harvesters, thus increase geographic coverage?
- What is the residency of DA in other shellfish/bivalve species of importance in food, social and ceremonial (FSC) fisheries/commercial/recreational, i.e. butter clams, scallops, geoduck?
- Is testing done in the winter months on shellfish - clams, crab, mussels?
- Would there be a benefit to having the Canadian Shellfish Program in one federal department and not spread across DFO, CFIA, and EC?

(2) Next steps

- Create a network of government agencies as First Nation industry and develop a plan of action for a mandate to be informed.
- Have another session with more First Nations because there are only about 5-8 nations of about 200 in BC at this workshop. Maybe make a connection with BC First Nation fisheries and health managers for further awareness.

(3) Education and communication

- Develop a program to provide information on biotoxins to First Nation institutions.
- Education and outreach at the school level. Teach kid's microscope use and species identification or maybe a mobile teaching unit that takes the message home.
- Education, networking, communication.
- Effective risk communication in communities. What does it look like and how do we do it?
- How can we connect, share, and disseminate information?

(4) Health risks

- Understand and provide advice on health risks associate with chronic low-dose exposure of DA (especially in at-risk groups such as pregnancy or breast feeding).
- Are there other vulnerable people or groups with language barriers or cultural practices that harvest in high risk areas? What is being done to assess these situations?
- What about linkages between microplastics & HABs?
- Do First Nations harvest planktivorous fish (sardine, anchovy) for food?
- Do multiple toxin types change symptom profiles, or complicate and increase risk?

Closing Ceremony with Gloria Nahanee, First Nation Elder, Squamish

Post-workshop comments

Comments received on this report from our workshop participants were incorporated into the body of this report. However, some comments we felt should stand alone and are noted below.

- Health Canada's Bureau of Chemical Safety, Food Directorate, continues to be committed to reviewing any new scientifically sound information that becomes available relating to the potential low-dose toxicity of DA. They are also available, upon request, to review information and support the development of consumption advisories or other risk management approaches relating to seafoods containing elevated concentrations of DA, which would support any decisions of the appropriate authority(ies) that are leading the development and implementation of any such risk management approaches.
- While coast-wide plankton monitoring would be wonderful to implement, the extreme length and complexity of our coastline would make this a very expensive undertaking. In addition, many parts of the coast are subject to extremely variable and often dangerous conditions. Taking routine samples of plankton and shellfish from monitoring sites will be costly and occasionally very hazardous! California has a great program and it is largely done by volunteers in coastal communities. But their coastline is relatively simple and well populated; nothing like our coast.
- While I think it is important and useful to raise the issues of potential chronic hazards of low dose long-term exposure to DA in the diet, I think it is also important to recognize that research in this regard is nascent, and that this public health impact is not yet firmly understood or universally recognized. While useful in terms of drawing the need for research and regulatory opinion in this area (which the report does mention), it may be viewed as a bit inconsistent to suggest an urgent need for risk management actions, when the risk intelligence may not be complete.
- Emphasis in the workshop was on DA, however PSP is a much more common and dangerous toxin on our coast. Blooms occur regularly all over the coast while DA is normally only detected on the outer coastal areas. PSP is retained at dangerous levels in most species of bivalve shellfish longer than DA, and much longer in butter clams and the viscera of scallops.

- The Canadian Shellfish Sanitation Program has another major requirement for harvesting shellfish for human consumption. In addition to toxin monitoring, there is the issue of a sanitary survey to ensure that the growing waters do not have unacceptable levels of pathogenic bacteria and viruses. If First Nations health is the major consideration for increased toxin monitoring, will the water quality requirements also be addressed?
- Observing marine mammals, birds or other organisms in and around the marine environment can be useful.
    - As an indicator of acute toxicity, observing affected animals (sick, dying or dead) should trigger an investigation that could include any or all of the following: tissue samples of the affected animals; necropsies of dead animals; analysis of indicator organisms such as bivalves, crustaceans (e.g. crabs), etc. for the presence of marine toxins; plankton monitoring to determine if species known to be capable of producing marine toxins (e.g. PSP, ASP, DSP) are present and their abundance.
    - As an indicator of chronic exposure to marine toxins, necropsies of dead animals from areas known for frequent harmful algal blooms (HAB's) could be conducted with results compared to the same or similar species in areas not generally associated with these blooms.
    - On the other hand, these are not as reliable as a monitoring program that analyzes samples of an indicator species for the presence of marine toxins or a plankton monitoring program to detect the presence of species associated with HAB's.

Acknowledgement is given to the organizers of the Marine Biotoxin Workshop Committee Members (left to right):

Linda Pillsworth, Gethsemane Luttrell, and Mark Matthew of First Nations Health Authority
Lorraine McIntyre and Pablo Romero-Barrios of the BC Centre for Disease Control
Tamara Russell of the Harmful Algal Monitoring Program at Vancouver Island University

Figure 8. Marine Biotoxin Workshop Committee Members.

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