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## Norovirus Outbreak Stakeholder Survey Results

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## Executive Summary

A norovirus outbreak beginning in November 2016, linked to BC harvested oysters, and affecting more than 300 people, was finally declared over six months later on May 11<sup>th</sup> 2017. The Environmental Transmission of Norovirus to Oysters working group (ETNO) was formed to identify potential causes of environmental contamination. ETNO reports to the Outbreak Investigation Coordination Committee (OICC). As part of this work, ETNO conducted a stakeholder survey containing 20 possible hypotheses for the recent outbreak. The survey consisted of two exercises, and allowed participants the option of providing a rationale for the answers chosen.

Responses were received from 27 participants. Respondents were categorized into two broad groups: (1) all respondents who self-identified as belonging to either the OICC or ETNO groups were grouped into one category (internal), and all other respondents were categorized as external. Responses were analysed together and separately by these two respondent groups.

Overall, the hypotheses identified as most and least likely by internal and external groups were similar.

The hypotheses identified as being most likely to have caused the outbreak included (in no particular order):

- local waste water treatment plants (WWTP) near shellfish farms
- multiple metropolitan WWTPs
- single WWTPs
- land runoff
- other sewage outfalls near shellfish farms
- other single point sources

The hypotheses identified as being least likely to have caused the outbreak (in no particular order):

- agricultural sources
- contamination at the processor plant
- contamination during distribution
- contamination at the restaurant/retail level
- wildlife carriers
- BC ferries
- cruise ship traffic

Amongst the hypotheses identified as most likely, rationales were often strongly polarized. However, as hypotheses became less likely to have caused the outbreak, rationales tended to be more cohesive.

All other hypotheses grouped between the most and least likely hypotheses. While these and the least likely hypotheses cannot be ruled out as possible causes of the outbreak, they may be considered as lesser priorities until the most likely hypotheses have been fully investigated.

## Introduction

On November 17<sup>th</sup> – 19<sup>th</sup> 2016, the 20<sup>th</sup> Annual Clayoquot Oyster Festival was held in Tofino. Following this event, more than 100 people became ill with norovirus. It was suspected that oysters harvested in local shellfish farms were linked to this cluster of illness. Unfortunately, in the months following, additional norovirus illness was reported linked to oysters harvested from other shellfish farm sites on both the west and east coasts of Vancouver Island and the Gulf Islands. Illnesses were predominantly reported in the lower mainland area of Vancouver; however, additional illnesses were reported in Alberta and Ontario. All illnesses were linked to BC harvested oysters. An investigation involving federal and provincial health authorities was launched to explore the cause of contamination.

On May 11<sup>th</sup> 2017, the Public Health Agency of Canada (PHAC) declared the outbreak over. As reported on the PHAC website, “a total of 331 clinical cases of gastrointestinal illness linked to oysters were reported in three provinces: British Columbia (230), Alberta (42), and Ontario (59). No deaths were reported... All individuals who became ill did report eating oysters in the 12 to 48 hours prior to their onset of illness.” (<http://www.phac-aspc.gc.ca/phn-asp/2017/outbreak-norovirus-eclosion-eng.php>, accessed May 18<sup>th</sup> 2017).

As part of this investigation, the Environmental Transmission of Norovirus to Oysters working group (ETNO) was formed to identify potential causes of environmental contamination. ETNO was initiated as a sub-group reporting to the Outbreak Investigation Coordination Committee (OICC) that is chaired by PHAC. Terms of reference arising from ETNO’s working group include:

- to assess proposed hypotheses;
- to propose steps needed to understand and manage risks;
- to review existing literature and discuss plausible pathways of norovirus contamination in BC oysters and shellfish sources in the winter of 2016/2017.

## Methods

To help address these terms and best direct resources, the working group identified 20 possible hypotheses that could explain the outbreak. Members of the working group then conducted a stakeholder survey including these hypotheses in order to elicit feedback on which hypothesis seemed most likely to have contributed to the norovirus illnesses. The survey was created using the Checkbox Survey, Inc. tool that is hosted on the Vancouver Coastal Health Authority site. The survey link was distributed via e-mail on April 19<sup>th</sup>, 2017 and participants were asked to provide a response by May 5<sup>th</sup>, 2017. All responses were anonymous and housed on a secure BCCDC database server.

Participants were asked to complete two exercises to assess the hypotheses: (1) choose a response most in keeping with their opinion on whether the hypothesis caused all, most, some or none of the norovirus illnesses associated with the outbreak and to provide a rationale for each choice, and (2) to provide a rank order of the most likely hypothesis using a drag ‘n drop exercise. Certain responses were excluded from the analysis: those who chose “I can’t say” for all 20 hypotheses and those who did not complete the drag ‘n drop exercise. Results from the survey were analysed in Excel.

### Who participated?

The survey was sent from BCCDC to approximately 39 people from the OICC and ETNO. Recipients were free to distribute the survey to others with relevant expertise. A total of 27 respondents completed the survey. Of these, 16 respondents identified as being part of the OICC and/or the ETNO groups, while 11 respondents were external to these groups.

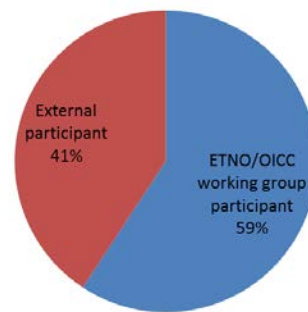


Figure 1. Survey respondents

From the OICC/ETNO groups, most respondents identified themselves with public health (n=10). Of the external respondents, food safety and public health were equal, with 7 respondents in each. Respondents could select more than one area of expertise, and at least one respondent had experience in all listed categories.

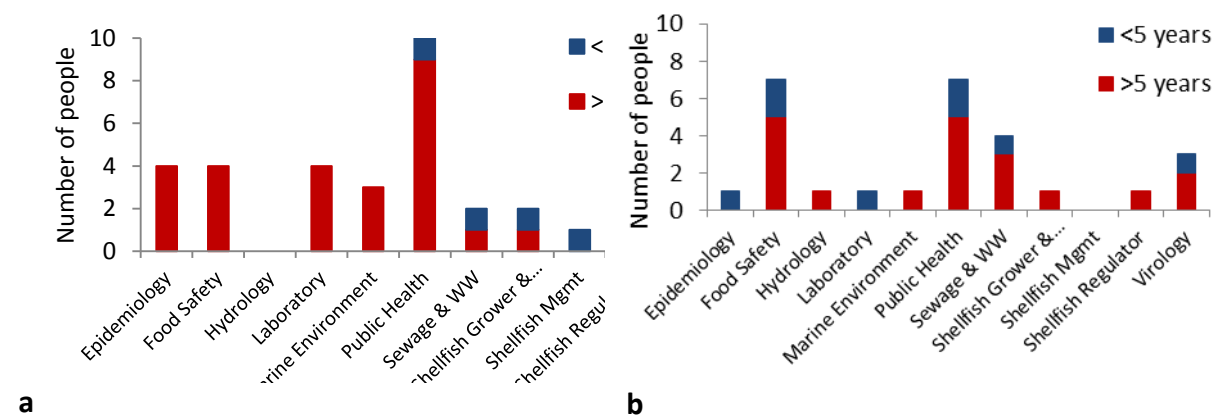


Figure 2. Areas of expertise respondents identified from a) the OICC/ETNO groups and b) external respondents.

## Results

The hypotheses chosen by stakeholders to have caused all, most, some, or none of the norovirus illnesses, including the option for “I can’t say” are displayed in Figure 3. Of the 27 respondents, six selected “I can’t say” for all hypotheses. For analyses purposes, these responses were removed. Five of these six were external respondents and one from was an OICC/ETNO member. Results are based on 21 responses, 15 from the OICC/ENTO group, and six external respondents. The “all” and “most” categories were combined due to a low number of responses in some cases in each category, and to improve visualization of data.

Combined responses: When both the OICC/ETNO and external responses were combined, the plausible hypotheses most often selected in the “all & most” category were multiple waste water treatment plants (WWTP n=6, 28.6%), followed by local WWTP, single metropolitan WWTP, and land runoff and discharge (all n=3, 14.3%).

The least likely hypotheses, as inferred from responses in the “none” category, were contamination at the processor plant, during distribution, at the restaurant/retail level, and in wildlife carriers, with just over half of respondents indicating none of the contamination could have been caused by these routes (n=11, 52.4%). Other hypotheses also considered highly unlikely to have been the cause of contamination were cruise ship traffic, BC ferries, and agricultural sources (n=10, 47.6%). Ill shellfish farm workers was the only other hypothesis that stood out, with 9 responses (42.9%) in the “None” category.

Many respondents answered “I can’t say”, stating rationales such as “no data to substantiate this hypothesis”. Other unexplained events had a high percentage of responses in this category (n=15, 71.4%), as did wet storage contamination (n=13, 61.9%), agricultural sources, and community sources (n=10, 47.6%).

Eight to ten hypotheses grouped between the most (all or most) and least likely (none) hypotheses. Many respondents chose “some” for the hypotheses indicating these could have been responsible for part of the contamination that caused the norovirus outbreak.

OICC/ETNO responses: The hypotheses identified as most likely from this group were: multiple metropolitan WWTPs [n=6, 40%], single metropolitan WWTP, local WWTPs near shellfish farms, and land runoff and discharge [all n=3, 20%]. Three hypotheses had a single respondent mark the “all & most” category (wildlife carriers, other unexplained events, exposure to community sources of norovirus). Many hypotheses had a large number of responses in the “some” category e.g., commercial boats, other single point source events (n=8, 53.3%), local WWTP, and other sewage outfalls near shellfish farms (n=9, 60%).

The least likely hypotheses as per the “none” category, were wildlife (n=11, 73.3%); BC ferries, ill shellfish farm workers, processor plant, and restaurant/retail (n=9, 60%); and cruise ship traffic, agricultural sources, and distribution (n=8, 53.3%). Thus, almost half of the hypotheses have strong weighting towards being unlikely causes of the norovirus contamination. A high number of respondents answered “I can’t say” for other explained events (n=10, 66.7%) and wet-storage contamination (n=9, 60%).

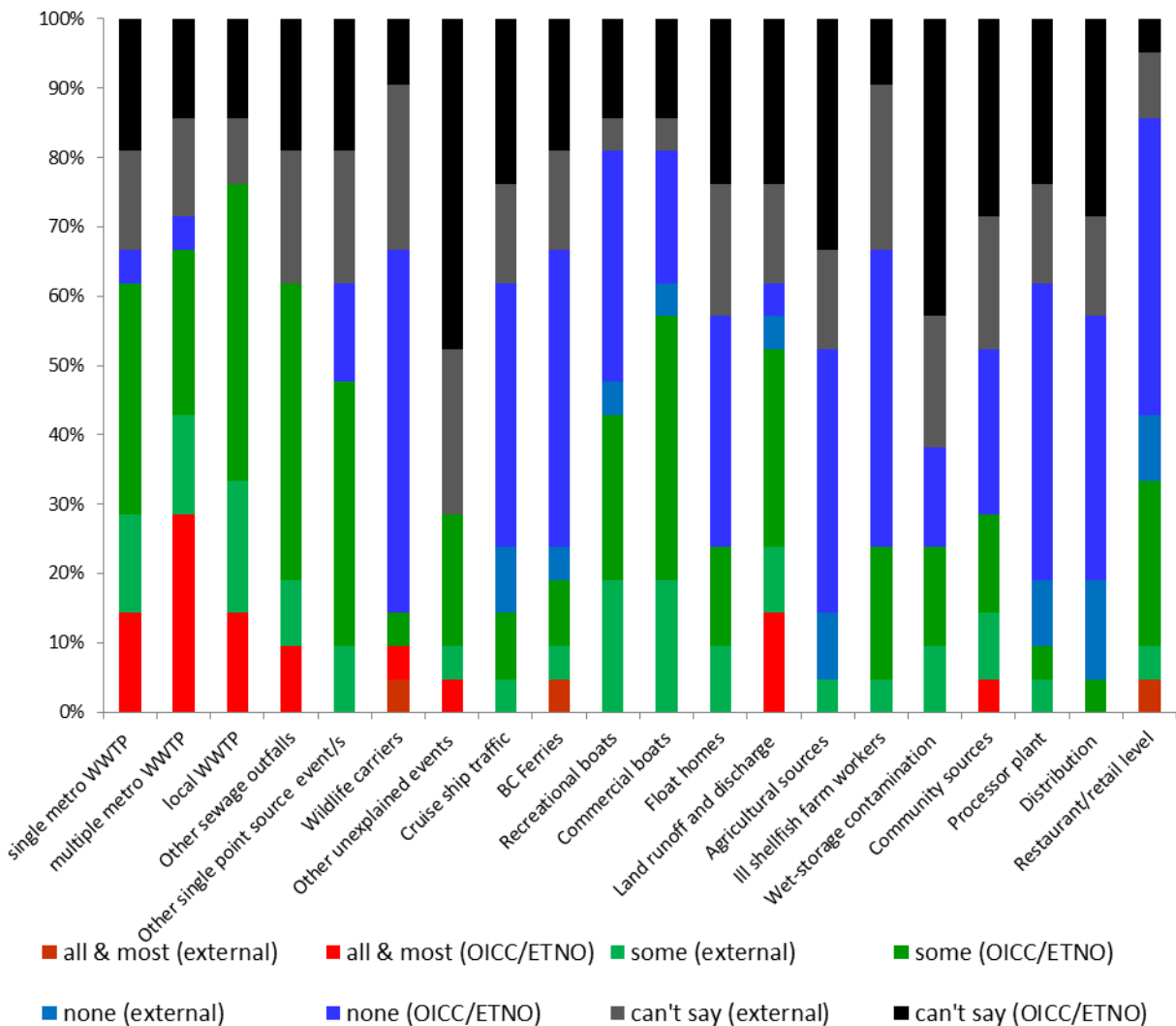


Figure 3. Combined (OICC/ETNO and external, n=21) responses to the 20 plausible hypotheses.

**Table 1. Top 5 most likely hypotheses as identified by OICC/ETNO members**

Hypothesis	All & Most (%)	Some (%)	None (%)	Can't say (%)
Multiple metropolitan WWTP	6 (40)	5 (33.3)	1 (6.7)	3 (20)
Single metropolitan WWTP	3 (20)	7 (46.7)	1 (6.7)	4 (26.7)
Local WWTP near shellfish farms	3 (20)	9 (60)	0 (0)	3 (20)
Land runoff/discharge	3 (20)	6 (40)	1 (6.7)	5 (33.3)
Other sewage outfalls	2 (13.3)	9 (60)	0 (0)	4 (26.7)

External responses: Of the six external respondents whose answers were analysed, the majority responded with “I can’t say”, “none”, or “some”. Very few responses were in the “all & most” category – wildlife carriers, BC ferries, and contamination at the restaurant/retail level (n=1 response for each hypothesis). Five of six respondents answered “I can’t say” with regards to wildlife. Half of the responses for BC ferries, and two of six responses for contamination at restaurant/retail level were “I can’t say”.

There were no clear unlikely hypotheses in this group because of the small number of respondents and the preference for responding with “I can’t say” (i.e., eight of 20 hypotheses had four or five respondents check this category). Half of respondents answered “none” for contamination during distribution. Other hypotheses had only zero, one, or two responses in the “none” category.

### Drag ‘N Drop Results

In this exercise, respondents were asked to rank all 20 hypotheses from most to least likely to explain all or most of the illness/contamination. Depending on where hypotheses were placed in the ranked list, they were given a score from 1-20, with a score of one given to the most likely hypothesis and a score of 20 given to the least likely hypothesis. These scores were summed across all respondents for each hypothesis, and then overall score was ranked. A lower overall score indicates a higher ranking.

Combined responses: The top six most likely hypotheses causing contamination of oysters with norovirus were the same between the combined, OICC/ETNO, and external groups, although the order of ranking was slightly different (Table 3). The six most likely hypotheses included local WWTP, multiple metropolitan WWTP, other sewage outfalls, land runoff, single WWTP and other single point sources. Unlikely hypotheses included community sources of norovirus, agricultural sources, and contamination at the processor plant, during distribution, or at the restaurant/retail level. The two groups of respondents varied slightly on what the unlikely hypotheses were, as detailed below.



**Table 3. Responses from the OICC/ETNO members, external respondents, and combined responses.**

	Combined		OICC/ETNO		External	
	Total score	Rank	Total score	Rank	Total score	Rank
Local WWTP	40	1	31	1	49	2
Multiple metro WWTP	54	2	52	2	56	3
Other sewage outfalls near shellfish farms	60	3	57	3	63	5
Land runoff and discharge	69	5	75	4	63	4
Other single point source event/s	62	4	79	6	44	1
Single metro WWTP	74	6	78	5	69	6
Other unexplained events	99	7	106	7	91	12
Commercial boats	105	8	126	8	84	9
Recreational boats	112	9	133	9	90	11
Wet-storage contamination	121	10	168	14	73	7
Ill shellfish farm workers	123	11	152	10	93	13
Float homes	126	12	157	11	95	14
Cruise ship traffic	127	13	163	12	90	10
Wildlife carriers	135	14	192	17	78	8
BC Ferries	140	15	175	15	105	18
Community sources	141	16	167	13	114	19
Agricultural sources	141	17	178	16	103	16
Restaurant/retail level	158	18	217	20	99	15
Processor plant	160	19	215	19	104	17
Distribution	163	20	209	18	117	20

OICC/ETNO responses: Three responses were incomplete for this section and were therefore excluded, 13 responses were used in the analysis. The top six most likely hypotheses identified by this exercise are the same as those identified in the first section of the survey, and the same as the combined and external responses in this section. Three of the five least likely hypotheses identified through this exercise align with results given by this group in the previous section. The five least likely hypotheses in the previous section included BC ferries and ill shellfish farm workers.

External respondents: Eight responses were included in the analysis. Three responses were excluded as respondents did not complete the section fully. The top six most likely hypotheses identified here differ from this groups' answers in the previous section of the survey: wildlife carriers, BC ferries, and contamination at the restaurant/retail level were listed as causing all or most of the contamination. However, the top six responses do align with the combined and

OICC/ETNO responses. The five least likely hypotheses as identified by the external respondents were similar to OICC/ETNO members, but also included BC ferries and exposure to community sources of norovirus. No bottom hypotheses were able to be clearly identified via the previous exercise for this group.

## Rationales

Most respondents provided a rationale for their answers during the first half of this survey. Upon reviewing these rationales, it was apparent that many strong opinions exist about certain hypotheses, and that viewpoints were often polarized (e.g., very strong wording agreeing with the hypothesis as the cause, to certainty that it could not be the cause). By contrast, the hypotheses that had little support (i.e., least likely hypotheses) showed cohesion in terms of rationales provided. A selection of rationales is provided below that summarize the overall responses for selected hypotheses, with a focus on the most and least likely hypotheses identified by the survey. The full list of rationales is provided in Appendix 1.

### *Most likely hypotheses*

*Single WWTP:* This hypothesis had a quite polarized response e.g., "... I believe it is unlikely that this outbreak has been caused by any single event at one or multiple WWTP." This conclusion is "based on the fact that the genogroup profile of the event switched from GI to GII over time... suggests... multiple time points in which human waste was being discharged." In comparison "I strongly believe that the outbreak was caused by human sewage discharged into the ocean and contaminating oysters." However, the overall sense from the rationales provided was that a single WWTP couldn't be responsible for such a geographically dispersed outbreak.

*Multiple WWTP:* A greater number of respondents provided rationale that suggested this hypothesis was more plausible compared to a single WWTP, however questions still remained about the geographic dispersion of the affected areas. "The volume of effluent from all metropolitan WWTPs is too significant to not be a factor." "I have difficulty seeing the virus being transported so far away from the source." "I think the dispersed landfills identified in the single tag clusters points to multiple contamination events/locations..."

*Local WWTP:* About half of the rationales here suggested respondents did not think this hypothesis could be a possible cause; however, this was identified as one of the most likely hypotheses for further investigation through the other parts of the survey, highlighting the polarity of opinions. Some respondents were under the impression that all WWTPs have control measures in place to filter viruses from effluent; however the working group has learned from experts that this is not the case. "When Environment Canada staff conduct the growing area surveys, they look

at real and potential sources of contamination. The growing areas near these facilities are normally classified as prohibited (to harvesting shellfish) based on discharge volume, currents, tides etc...”

*Other sewage outfalls:* Many respondents thought this could be a likely hypothesis, but lacked specific details about outfall locations at sites relevant to this outbreak. “I do not know the location of the local sewage outfalls nor their proximity to the locally affected areas, but it is possible that some of the infection has arisen via this route...” “There are regulations for how far shellfish farms must be from outfalls, although it’s unknown whether these distances are sufficient to allow norovirus die-off, especially in cooler weather and with increased rainfall.”

*Land runoff and discharge:* Rationales for this hypothesis were quite polarized. “Not likely because too small of a population for the odd runoff/discharge with norovirus to affect such vast oyster harvest areas.” “There were a lot of unplanned dumps in Baynes, heavy storms and, of course, septic is an ongoing problem.”

*Other single point sources:* Rationales suggested this was an unlikely cause, although this hypothesis remained among the most likely hypotheses. This is perhaps due to the non-specific nature of this particular hypothesis, which could encompass a number of potential transmission routes.

### *Least likely hypotheses*

*Wildlife carriers:* There was a clear sense that wildlife could not be the source of contamination due to differences between human and animal norovirus genotypes, which matched its placement in the unlikely hypotheses. “Norovirus is generally host restricted; the genogroups of norovirus that infect humans (GI, GII, GIV) should not infect agricultural animals. While there are some reports that norovirus is detected in animals, they are usually not amplifying the virus.” However, this group was still split, with a few respondents feeling very strongly that wildlife could be cause. “Strong correlation between affected areas and haul out sites for sealions...” “Noroviruses are in the calicivirus family and there are documented incidents where there was transmission from marine mammals to terrestrial animals such as pigs...”

*Contamination during distribution/during processing:* Overall both of these hypotheses were considered not likely. “There was very little clustering of illness by processor, retail or restaurant.” “If this was true, then one processor/distributor/store would have been linked to most illnesses.” “Multiple processors were implicated in contaminated product. For this (hypothesis) to be true, there would need to have been a simultaneous loss of control at multiple processors.”

*Contamination at the restaurant/retail level:* “For this hypothesis to hold true, there would need to have been a simultaneous loss of control at dozens of locations across multiple provinces.”

*Agricultural sources:* This was identified as a less likely hypothesis, and the rationales tended to reflect this. ...”remote areas implicated, there is little or no agricultural activity in these areas.”

*BC Ferries:* The majority of respondents said it was not possible due to BC Ferries having “regulations in place for discharge”; however one respondent felt this could be a likely cause of the outbreak.

*Cruise ship traffic:* Clear responses indicating that this outbreak occurred outside of cruise ship season.

### **Others**

*Recreational boats:* Most respondents provided rationales that stated there was very little recreational boating at this time of year.

*Commercial boats:* Some indecisiveness was apparent here. However this respondent summed it up well: “Only major commercial traffic during this time is the herring fishing at the end of February, far after the outbreak was well under way.”

*Float homes:* Float homes were deemed unlikely by most. “There are regulations that float homes be a certain distance from shellfish farms, and that sewage treatment be done strictly on such homes.” But one rationale queried this overall thought. “Issues in False Creek recently point to live-aboard vessels as a problem.”

*Ill shellfish farm workers:* “Per 2010 outbreak, it would be very evident there was a single confined in time and space problem. This was not the case.” “Would not be so widespread if it was caused by ill workers.”

*Exposure to community sources:* “Some of the outbreak genotypes were only found in this outbreak, never in the community...”

## Conclusion

The hypotheses identified as most likely in no particular order:

- Local WWTPs near shellfish farms
- Multiple metropolitan WWTPs
- Other sewage outfalls near shellfish farms
- Land runoff
- Other single point sources
- Single metropolitan WWTPs.

The least likely hypotheses identified from this survey, in no particular order, are:

- Agricultural sources
- Contamination at the processor plant
- Contamination during distribution
- Contamination at the restaurant/retail level
- Wildlife carriers
- BC ferries
- Cruise ship traffic.

All other hypotheses cannot be disregarded as possible causes of the norovirus outbreak, but they perhaps warrant less investigation until the more likely hypotheses have been fully investigated.

## Recommendation

We recommend expending available resources investigating the top six most likely hypotheses, as bullet-pointed above.

## Appendix 1.

Full rationales as provided in the survey. Not everybody provided a rationale for every hypothesis. Hypotheses are presented in the order they appeared in the survey.

### 1. Single Metropolitan WWTP

There is no data to substantiate this hypothesis.
to wide spread to be caused by one point source. However, it can not be ruled out as a possibility to have caused some cases.
it is my belief that the original outbreak in Lemons inlet was due to waste water discharge.
I don't have the most current knowledge of this outbreak but have repeatedly heard that a number of areas are implicated, not all on the same part of our coast and some are remote with little human habitation, activity or anthropogenic inputs (sewage, garbage disposal sites, etc.)
I strongly believe that the outbreak was caused by human sewage discharged into the ocean and contaminating oysters. The only source of sewage large enough to cause this would be from sewage plants. I am not clear whether this would be from one or multiple sewage plants as I don't know enough about how much norovirus is found in sewage and how likely it is for sewage from one plant to contaminate so many geographically disparate sites.
Information on currents/survivability of norovirus and whether one area could account for all impacted harvest areas
This source seems most probable from municipal sewage because of large population with some part of the population typically disposing of norovirus in diarrhea &/or vomit into sewage that is disposed of in the ocean. As the population of municipality gets larger than likely larger dosing of norovirus in the sewage effluent.
It is possible that sewage discharge from a treatment plant has caused contamination in some oysters but the spread of the affected areas suggests that it is unlikely all affected areas have been contaminated by one treatment plant.
Norovirus is evidently associated with human activities. It has resistant to harsh treatment conditions. Norovirus has been reported to be present in discharges of municipal wastewater treatment plants. However, depending on the location of the plant, some of those close to shore are likely the ones to cause direct contamination of oysters. Some of those far away from the shore may not expose direct risk for contamination since the levels of noroviruses and especially infectious viruses are decreased as the viruses carried by river stream to sea are reduced if discharge sites are very far away from the shores.
Contaminated oyster sources are too diverse.
Don't know enough about waste water treatment plants to comment. I will state that I believe it is unlikely that this outbreak has been caused by any single event at one or multiple WWTP. I draw this conclusion based on the fact that the genogroup profile of the event switched from GI to GII over time. This suggests to me that there was multiple time points in which human waste was being discharged. The fact that GII (the most prevalent genotype in community cases) happened later in the season suggests at least a second output.
Largest inputs of virus come from the largest sources. Evidence on whether norovirus can travel is unclear - it is possible. Evidence of norovirus survival is better established, and it is environmentally tough and able to persist in dark, cold, lower salinity conditions - we had all of these this past winter.
Sewage is a likely source in this outbreak given the number of different genotypes that were detected. Sewage discharge of raw sewage or minimally treated sewage (i.e. primary treatment) from a single plant could contribute to some of the illness. However, given the geographic range of this outbreak, more than one WWTP is likely to be involved
I don't know that it was a metropolitan treatment plant so much as the result of many plants and septic and other sources
This is plausible, given that we don't know the behaviour of norovirus in plumes in this particular water system. Without researching how far NV can travel in BC waters this hypothesis can't be written off entirely.
I don't know any of the issues related to effluent flow patterns
While I am sure some contamination has come from individual metro WWTP, I strongly doubt a single plant is responsible for all contamination due to the distances involved.
wide geographic distribution of implicated harvest sites

## 2. Multiple metropolitan WWTP

There is no data to substantiate this hypothesis.

same possibility as above

This is far from the first time that our shellfish growing areas have been subjected to very heavy rainfall which may cause some WWTP's to overflow or discharge untreated waste water. It defies logic that this would happen in a number of areas, not close to each other, at the same time. When I was the CFIA's Shellfish & Aquaculture Specialist, I was responsible for recommending sanitary and marine toxin closures. Some of these were seasonal (usually based on rainfall or vessel traffic) and some of them were based on rainfall triggers (e.g. the Baynes Sound Management Plan.) I don't have detailed knowledge regarding this event but am asking if there were any reports of WWTP failures in any of the areas implicated with illnesses related to consumption of oysters.

Same as above

Information on currents/survivability of norovirus and whether one area could account for all impacted harvest areas

This source seems most probable from multiple municipal sewage sources because of large population with some part of the population typically disposing of norovirus in diarrhea &/or vomit into sewage that is disposed of in the ocean. As the population of municipality gets larger than likely larger dosing of norovirus in the sewage effluent.

It is possible that sewage discharge from multiple treatment plants has caused contamination in some oysters but the spread of the affected areas suggests that it is unlikely all affected areas have been contaminated by treatment plants alone.

Norovirus was frequently detected in the discharge of wastewater treatment plants. As mentioned above, if discharges from multiple plants are either close to the shores or go to one river ending at sea, the levels of norovirus are increased. Chance of infection of oysters will be increased.

Some of the harvest locations are very remote

See comment above.

Largest inputs of virus come from the largest sources. Evidence on whether norovirus can travel is unclear - it is possible. Evidence of norovirus survival is better established, and it is environmentally tough and able to persist in dark, cold, lower salinity conditions - we had all of these this past winter.

Sewage is a likely source in this outbreak given the number of different genotypes that were detected. Given the geographic range of this outbreak, more than one WWTP is likely to be involved. Sewage, rather than boats, float homes etc...are a likely source given the volume of human waste that is discharged and the expected concentration of norovirus in the water.

I think the disperse landfills identified in the single tag clusters points to multiple contamination events/locations, possibly linked to rainfall? However, I don't think it's likely that there were failures at multiple water treatment plants; I think it's more likely that high rainfall caused some non-regulated sewage overflow (this may be what is discussed below as "other sewage outfalls" - but I'm not clear on what those would be - I am definitely not a water treatment/sewage expert!)

This is plausible, given that we don't know the behaviour of norovirus in plumes in this particular water system. Without researching how far NV can travel in BC waters this hypothesis can't be written off entirely.

Volume of effluent from all metropolitan wastewater treatment plants is too significant to not be a factor.

As above

i have difficulty seeing the virus being transported so far away from source i am assuming that by metropolitan you are talking vancouver or victoria ?

### 3. Local WWTP near shellfish farms

There is no data to substantiate this hypothesis.
As for all of these three prior questions, I am sure that control measures are in place to deal with virus loads at the treatment plants.
When Environment Canada staff conduct the growing area surveys, they look at real and potential sources of contamination. The growing areas near these facilities are normally classified as Prohibited (to harvesting shellfish) based on discharge volume, currents, tides, etc. I believe there is also an onus on operators of WWTP's to notify when they are discharging inadequately treated effluent. I don't have detailed knowledge regarding this event but am asking if there were any reports of WWTP failures in any of the areas implicated with illnesses related to consumption of oysters.
I don't see a clear difference between this option and the last 2. However, even though discharge close to a farm could definitely contribute to local contamination, this would not explain the geographically dispersed affected areas.
Would not likely be able to account for the full geographic spread of the outbreak and norovirus identification.
The closer a local waste water treatment plant is to a shellfish harvesting area the more likely this could be the source of the norovirus, especially from larger sewage treatment plants because of larger dosing of norovirus from larger associated population.
I do not know the location of the local waste water treatment plants nor their proximity to the locally affected areas, but it is possible that some of the infection has arisen via this route, especially considering the amount of rainfall experienced throughout the winter and spring.
The rationales are as above. Of course, it is also depended the treatment technologies that the plant are using.
Not all sources of oysters are located near shellfish farms
The areas of geographic dispersion are numerous. Local WWTP could only contaminate local shellfish beds.
This is possible for some clusters, but given the geographic range, cannot explain all clusters.
Without knowing how NV behaves in BC waters, we can't write this off.
Not sure what is meant by the term local wastewater treatment plants. Is it Ministry of Environment regulated treatment plants?
The NoV had to get in there somehow and it comes from human sewage, regardless of the mode of transport.
this seems more possible as the dilution and transport of the virus would be less difficult



## 4. Other sewage outfalls near shellfish farms

There is no data to substantiate this hypothesis.

again it is possible

I can't see why other sources of sewage would result in norovirus contamination, all at the same time in numerous locations on our coast. In the traceback and investigation of these illnesses, did all the implicated areas have sewage outfalls and / or WWTP's? Even the remote areas?

This may have contributed to some of the outbreak but I believe we would have learned of an inadvertent outfall if it had occurred and we did not.

Would not likely be able to account for the full geographic spread of the outbreak and norovirus identification.

Definitely possible

It is possible if the said sewage outfall is likely to contain norovirus. The larger the population utilizing this outfall than the more likely this could be associated with norovirus.

I do not know the location of the local sewage outfalls nor their proximity to the locally affected areas, but it is possible that some of the infection has arisen via this route, especially considering the amount of rainfall experienced throughout the winter and spring.

If sewage is related to human wastes, the risk is high. If sewage is likely associated with animal waste, it may not be so.

Septic system discharge could relate to some of the illnesses

Have read about some CSO this past season, possible that has contributed.

Unclear if this means combined sewage overflow or stormwater or both? With high rainfall in the fall, this certainly is strong possibility.

Please see rationale above.

Seems possible that the combination of heavy rainfall with various non-point sources of sewage/runoff could have contributed to several contamination events. Without knowing the specific geography of each land file and nearby runoff/streams/density of septic tanks, this is difficult to know. There are regulations for how far shellfish farms must be from outfalls, although it's unknown whether these distances are sufficient to allow norovirus die-off, especially in cooler weather and with increased rainfall.

Again I'm not sure what types of outfalls these would be. MoH legislation does not allow outfalls. MoE legislation does but they would be captured in the question above. Are these float homes, barges, float camps, resorts, industrial camps, any and all unregulated discharges.

It's possible that local septic tanks could be leaking and contaminating water/oysters.

what sewage outfalls ?

## 5. Other single point source contamination events near shellfish farms

There is no data to substantiate this hypothesis.
possible but the widespread nature suggests a transient vector such as sealions to me
Did all of the areas implicated in illnesses from oysters receive abnormally high rainfall during the current outbreak? Our coast has many areas that routinely get a lot of rain, e.g. parts of the West Coast of Vancouver Island and this doesn't seem to have happened previously.
I believe rainfall and subsequent flooding may have contributed to a contamination event or events, but flooding itself would not cause contaminate. You need a source of norovirus.
Would not likely be able to account for the full geographic spread of the outbreak and norovirus identification.
Definitely possible
Not as likely one fish boat or a couple malfunctioning septic systems in the same area would be the likely source of the norovirus. As it would be smaller volume and it is not as likely that there would be norovirus in the sewage effluent.
It is possible but it is not clear where the infection would come from if not from sewage, waste water or agricultural run off.
The same as above
Why this year and not other years? Have been through single point source contamination events before. This is different.
This may account for some illness from oysters at a specific geographic site.
please see rationale above.
Seems possible that heavy rainfall in autumn played a role however i dont know what other single point sources exist.
Might be site specific as some sites appear to be in areas where there would be limited fecal material washed into the marine environment as a result of flooding.
Seems unlikely.
could be failing septics and high rainfalls causing sewage in lagoons to be discharge at a much more rapid rate --ie little or no settling

## 6. Wildlife carriers

There is no data to substantiate this hypothesis.

Strong co-correlation between affected areas and haul out sights for sealions. Timing of migration to Vancouver island and BC coast affected areas also coincides with Sealions. I have also witnessed, displacement of local seal populations to less favorable haul out sights when sea lions are in areas, and subsequent fecal contamination levels increasing in the shellfish in the secondary areas now populated with the displaced seals. You can also go to the affected areas and see up to 20 sealions hauled out on oyster rafts.

Based on recent weather and the amount of run off due to rain. I think sewage grey water was discharged into the marine environment. I believe wildlife became infected and due to the Herring spawn and the fact that these animals were following the herring the outbreak was spread over a much larger area.

This is an area that needs to be looked at very closely. Noroviruses are in the calicivirus family and there are documented incidents where there was transmission from marine mammals to terrestrial animals such as pigs. [https://wwwnc.cdc.gov/eid/article/4/1/98-0103\\_article](https://wwwnc.cdc.gov/eid/article/4/1/98-0103_article) The 2004 outbreak was preceded by reports of sporadic illnesses implicating oysters in Oregon, then Washington and then we had the outbreak in BC. This seemed to coincide with the northward migration of California sea lions. Maybe this was only a coincidence but we still were unable to explain why there were illnesses in remote growing areas with little or no human residents or activity. Also, the number of illnesses reported were more or less proportional to the volume of oysters being harvested which may or may not indicate similar levels of contamination from norovirus. I'm not a virologist or epidemiologist so this is a WAG (wild ass guess) on my part.

The genotypes seen in this outbreak are carried by humans.

I don't feel they could be a source of the outbreak and ability to transport would be minimal

Definitely possible

It is possible that wildlife carriers could account for some of the spread of infection, however this is the same every year and does not result in the extensive outbreak we are currently experiencing.

As my knowledge, there is no any evidence that human norovirus illness can be caused by animal species.

Norovirus genogroups are host specific and there are no documented cases in the literature of wildlife being carriers of Human norovirus.

The evidence suggests they are not a source.

Norovirus is generally host restricted; the genogroups of norovirus that infect humans (GI, GII, GIV) should not infect agricultural animals. While there are some reports that norovirus is detected in animals, they are usually not amplifying the virus.

all science presented seems to indicate that noro particles are human-generated and that animals are not the source. That seems to be supported by the fact that the increased sea lion population did not increase levels of noro-related illnesses

I am not a veterinarian, but I do not think birds carry norovirus. The sea mammals, possibly?

Little evidence to support this hypothesis. Sea animals such as sea lions and porpoises have been demonstrated to carry non-human strains of norovirus. Unless we had microbiological evidence that animals in BC waters are indeed carrying human strains, this is implausible.

Sea lions could be carriers...

un proven to be even possible

## 7. Other unexplained events

There is no data to substantiate this hypothesis.
Again possible, this extremely wet fall could have contributed. In addition low UV levels would hamper deactivation of the viruses.
I'm not a virologist and have no knowledge of the viability of norovirus in the marine environment or any environment outside of a host.
I don;t know enough about this.
Definitely possible
Not sure about the survivability of norovirus in sediment?
No knowledge of this subject.
Norovirus can be survived and still possess infectious in well water for 2 years. There is unknown about in sediments.
I believe this year's event was most likely caused by a perfect storm of weather conditions. The outbreak started right after landfills were re-opened after sanitary closures for heavy rainfall and also right around the time the temperatures dropped. Whether it was trapped in the sediment or some other phenomena, I believe it was something unique about climate conditions this year that allowed norovirus to persist longer than normal in the marine environment. The source of the human waste output could be any of the theories listed in this survey, but the key difference between this year and other years I believe is the weather conditions.
There is not enough evidence to say ya or nay.
I think low temperature could be a phenomena that could explain the persistence.
I don't know enough about this, other than that it is an under-researched area.
There's always a possibility but without having any data it's impossible to say.
transfer of virus from human contact with oysters during or after the shucking process

## 8. Cruise ship traffic

There is no data to substantiate this hypothesis.
There is no real cruise ship traffic during the implicated time period. The cruise period starts in May - Aug with sailing from Vancouver to Alaska....this one can be ruled out.
The outbreak occurred at the time of the year when there are no cruise ships on our coast. Also, none of these go to the West Coast of VI where there were implicated harvest sites (is true?) Also, were there any reports of noro illnesses in Washington State from their oysters? Seattle is also a major cruise terminal.
Some areas of contamination are so remote that this would be highly unlikely.
Would not explain temporal or geo trends
I thought cruise ships had standards around disposal at sea.
You would think that we would be receiving reports of cruise ships with norovirus outbreak if this was the case.
If Cruise ships discharge infected effluent into the ocean, then this could contaminate oysters. However, I am unaware of any local cruise ships affected by a norovirus outbreak on board. Also over the winter period most if not all of the cruise lines have ceased operation, and are only now starting cruises again.
If there was outbreak (often occurrences) in the cruise ship, the levels of noroviruses are very high in liquid waste of the ship. If it is discharged without adequate treatments, there is high risk for oyster contamination.
This time of year very little cruise ship traffic. genotypes different in 2004.
No cruise ship traffic at this time of year.
It was not cruise ship season, but that's not to say that they don't contribute to the overall problem.
I think it was explained on an OICC call that it is not possible for vessels to discharge sewage without being docked.
It is possible this could play a role in areas with heavy ship traffic, given that Canadian regulations allow ships to discharge waste under certain circumstances. In combination with water currents/intense rainfall, it seems possible. It would be useful to have a record of all ship discharges mapped with water currents and shellfish farms.
Seems unlikely due to timing of outbreaks when cruise ships were not in BC waters
Not cruise ship season
i am not aware of any curse ship traffic in the correct time frame

## 9. BC Ferries

There is no data to substantiate this hypothesis.
Nope, treatment on board and area affected were no where near ferries in some cases (tofino?)
Can't say but I doubt it. No BC Ferries on the West Coast of VI. And this goes for all of the points questioning human waste as a source of the illnesses. Was there such a high number of noro illnesses in the general population at the time (e.g. in schools, senior and assisted living facilities, etc.) that would be the source of norovirus in WWTP's, sewage outfalls, failing septic systems, ferries and other vessel discharges such that the growing areas would be contaminated?
same as above
Would not explain temporal or geo trends
I thought BC Ferries pump to an offshore treatment facility rather than direct discharge to the ocean.
I understand BC Ferries does no sewage discharges to the ocean; all is discharged on land for treatment.
If BC Ferries discharge infected effluent into the ocean, then this could contaminate oysters. However, I am unaware of any BC Ferry affected by a norovirus outbreak on board. If they discharge 3 miles from shore, that would limit the number of affected areas. BC Ferries are also in the process of discharging their effluent at a new processing centre, but it is not clear how many ferries this plant serves.
Likely. It needs to have a well-designed study to approve this statement.
need to hear from BC ferries. they have contributed to issues in past years.
I suspect BC Ferries doesn't accidentally discharge waste and I believe this was already discussed and discarded as a possibility.
From all information gathered, they don't dump raw...but...I don't have enough information to make a call.
It is possible this could play a role in areas with heavy ship traffic, given that Canadian regulations allow ships to discharge waste under certain circumstances. In combination with water currents/intense rainfall, it seems possible. It would be useful to have a record of all ship discharges mapped with water currents and shellfish farms.
too small of a discharge and not all areas had Ferries
BC Ferries have regulations in place for discharge.
closed systems are in use

## 10. Recreational boats

There is no data to substantiate this hypothesis.
Almost no chance of this as well, low recreational usage this time of year, if you were sick with Noro you wouldn't go out on a boat. Anyone going out on a boat fishing or cruising would be far enough from shore that this would not be a factor.
There's very little marine traffic on our coast at that time of the year. Certainly not a lot of recreational boaters, sailboats, etc. Not compared to other times of the year when the weather is better and also sport fishing for salmon is best.
same as above
Would not explain temporal or geo trends
Not likely because too small of a population for the odd boater with norovirus to affect such vast oyster harvest areas.
Recreational boats will discharge effluent into the ocean, but in small quantities. The people using the facilities on board these boats would need to be shedding the virus. It is possible some are affected, but the extensive outbreak seems to suggest this is not the only source.
Unlikely. It also depends whether there is a direct discharge of human wastes to sea.
More likely/probable than BC Ferries or cruise ships.
It is not high season for boating, but there could be waste discharged into the water by vessels that contain a marine toilet/holding tank. This would represent a relatively small contribution of waste from a limited number of individuals.
Absolutely! They and commercial fleets contribute to the issue. NO one should be dumping raw without consequences.
Same as above, if perhaps slightly less likely.
Possible for some influence but late fall winter is low season for recreational boaters
Few recreational boats around at this time of year.
we see v little winter recreational traffic

## 11. Commercial boats

There is no data to substantiate this hypothesis.
Only major commercial traffic during this time is the herring fishing at the end of Feb, far after the outbreak was well under way.
This outbreak started well before the busiest fishery in the winter and spring period, the roe herring fishery. Other fisheries are usually well away from shellfish growing waters (e.g. trawlers don't operate near shore).
same as above
Would not explain temporal or geo trends. perhaps a more likely source for some isolated areas.
Not likely because too small of a population for the odd commercial boater with norovirus to affect such vast oyster harvest areas.
Commercial boats will discharge effluent into the ocean, but in relatively small quantities and often in open sea. The people using the facilities on board these boats would need to be shedding the virus. It is possible some are affected, but the extensive outbreak seems to suggest this is not the only source.
See above.
Herring fishing occurring in some of the areas, waste discharge possible but I can't say.
More likely/probable than BC Ferries or cruise ships.
As above, there could be waste discharged into the water by vessels that contain a marine toilet/holding tank. This would represent a relatively small contribution of waste from a limited number of individuals.
Same as above.
Possible contributor as there are few marinas that have sewage pump out facilities
Possible that e.g. herring fleet caused some contamination, but not across all areas.
plausible as they discharge raw sewage but realistically unlikely as there is again not much happening in the nov--feb period in our area



## 12. Float homes

There is no data to substantiate this hypothesis.
I don't know what the number of float homes is in the areas implicated for illnesses. I imagine this is being looked at by Environment Canada, DFO and the industry.
same as above
Would not explain temporal or geo trends
Not likely because too small of a population for the odd float home with norovirus to affect such vast oyster harvest areas.
Most floathomes are served by marinas and do not discharge into the water. Some liveaboard boats will discharge effluent into the ocean, but in relatively small quantities. The people using the facilities on board these boats would need to be shedding the virus. It is possible some are affected, but the extensive outbreak seems to suggest this is not the only source.
Float homes were not located near all oyster harvest locations
Issues in False Creek recently point to live-aboard vessels as a problem. Do we know how controlled this is?
I am unaware of the density of float homes in this area. I have heard, however, that many of these remote site do not contain float homes.
It's cumulative...
Possibly?
There are regulations that float homes be a certain distance from shellfish farms, and that sewage treatment be done strictly on such homes (although don't know if NV is tested for during inspections of such homes)
Some possibility but would include all floating structures in this category such as work camps, resorts aquaculture.
Are there any float homes in these areas at this time of year?
unlikely due to regulations in force covering float homes

### 13. Land runoff and discharge

There is no data to substantiate this hypothesis.
possible
Unless there was a major noro outbreak at the time of the outbreak, I can't see that this would be a likely source (sick people vomiting and / or defecating away from toilets in large numbers?)
as mentioned earlier, rain, flood, runoff could all contribute to contamination of the ocean and farms by sewage.
This is not something I know enough about to comment on how it might occur or impact the shellfish harvest areas.
Definitely possible
Not likely because too small of a population for the odd runoff/discharge with norovirus to affect such vast oyster harvest areas.
There has been extensive rainfall over the winter and early spring. There is the possibility that this rainfall has caused flooding and runoff from septic tanks and other localised sources of effluent. It is possible this run off is linked to the infection of local oyster harvest areas.
There is no direct association. It depends whether there is untreated human wastes in runoff and whether the runoff goes to sea.
possible but some of the oyster harvest locations were remote.
I am uncertain about local control for these sources, and feel they could have contributed to this outbreak
Septic tank discharge or overland flow related to sewage lagoons could explain some contamination, but would be a relatively small contribution given the volume of waste produced (vs sewage, for example).
There were a lot of unplanned dumps in Baynes, heavy storms and, of course, septic is an ongoing problem.
I'm not sure if this is similar to the "other sewage outfalls above".
Seems possible that the combination of heavy rainfall with various non-point sources of sewage/runoff could have contributed to several contamination events. Without knowing the specific geography of each land file and nearby runoff/streams/density of septic tanks, this is difficult to know.
There are significant numbers of properties with onsite sewage disposal systems. There is a mix of old systems and newer systems but maintenance and monitoring is essentially up to the individual owners.
could be failing septics and high rainfalls causing sewage in lagoons to be discharge at a much more rapid rate --ie little or no settling

## 14. Agricultural sources

There is no data to substantiate this hypothesis.
Unlikely but possible
If there are indeed remote areas being implicated, there is little or no agricultural activity in these areas. It also raises the issue of whether there could be an animal reservoir or vector for the norovirus.
The genotypes seen in this outbreak are carried by humans.
Would not explain temporal or geo trends
Definitely possible
I am not sure about sources of Agriculture with norovirus?
There has been extensive rainfall over the winter and early spring. There is the possibility that this rainfall has caused flooding and runoff from agricultural land which is contaminated with animal excrement. There could also be some localised flooding of slurry pits on farms which then contaminates local fresh water sources and finds its way to the ocean. It is possible this run off is linked to the infection of local oyster harvest areas.
Noroviruses from animal sources could infect oysters but will not cause human illness. It requires a further studies to provide evidence about animal noroviruses in oysters.
The source of the norovirus was a human source, this link would be weak
Animal norovirus genotypes do not infect humans.
Norovirus is generally host restricted; the genogroups of norovirus that infect humans (GI, GII, GIV) should not infect agricultural animals.
Unless there was human waste as well (from farm proper), all information gathered says it's not the animals.
The timing of the outbreak would not coincide with the spreading of manure on crop land, in my opinion. While I am not in BC and do not know the coastline well, I expect that there aren't a lot of grazing animals near the harvest areas... but I'd be interested in hearing what BC agriculture may suspect. I know that human noroviruses have been isolated from cows and pigs, so it's theoretically possible.
Without knowing if agriculture uses human sewage for fertilizer, it's hard to know. Bovines don't carry human NV strains.
Published literature states this is unlikely to cause human NoV
un realistic

## 15. Ill shellfish farm workers

There is no data to substantiate this hypothesis.
unlikely- with the heightened sensitivity of the outbreak I would think they would stay home.
I would certainly hope that our shellfish industry has come a long way beyond this being a possibility. There was a multi-state outbreak from norovirus some years ago when several sick oyster harvesters in the Gulf of Mexico (Louisiana or Mississippi) vomited and defecated into the harvest areas.
There have been no reports of ill farmers, processors or food handlers. A single or a few ill individuals could not explain even a small proportion of the human illnesses seen in this outbreak which spanned several months and multiple provinces.
Would not explain temporal or geo trends. Has not been reported in any investigation steps.
Definitely possible
We have not received any reports of ill shellfish workers with norovirus.
It is possible some shellfish workers have shed the virus, either in the harvesting areas, or at the collection and purification locations but it should be obvious to the harvesting company, and it is hoped that they would have measures and rules in place to prevent this risk.
If some of workers have norovirus infection and outbreak, it could happen if there is lack of disease control system in the place.
The sources are so varied and occurred over long periods, would not be able to account for all FBIs
Per 2010 outbreak, it would be very evident there was a single confined in time and space problem. This was not the case this year.
There is strong evidence from the outbreak that it was not related to contaminated farm fish workers.
It is definitely possible, but no investigations pointed to a single source illness at farms.
A small proportion, possibly.
Seems implausible given the geographic spread of contaminated sites...
Possible this had some influence
Would not be so wide spread if it was caused by ill workers. And who goes to work when you're struck ill with NoV? Impossible to work if you're ill with this virus.
it is a possible scenario but unlikely to be a large factor due to widespread nature of the problem

## 16. Wet-storage contamination during distribution or retail

There is no data to substantiate this hypothesis.
possible if the lots are not separated and the water not maintained I guess.
Is it known that there was wet storage involved in some of the oysters implicated? At the shellfish processor, distributor, restaurant or retail level?
there was very little clustering of illness by processor, retail or restaurant.
Would not explain temporal or geo trends. Has not been reported in any investigation steps.
Definitely possible
not sure about possible contamination at wet-storage location.
It is possible that the wet storage is a source of contamination, and this could affect multiple batches of oysters from different harvesting areas - making it look like these harvesting areas are the source of the contamination. This is also possible if the wet storage equipment is not functioning properly (filters, UV light) during purification, and further when there is comingling of batches of oysters. In the oyster harvesting areas themselves, it is also possible that relaying batches from marginally contaminated areas to clear areas has spread the infection, especially if the marginal areas are more heavily contaminated than expected.
See above
sources and cold chain too varied
Perhaps some of the lots of oysters could have become contaminated at this point, however this would not explain how all of the contamination occurred given that not all oysters were wet-stored at the same place.
If this was true, then one processor / distributor / store would have been linked to most illnesses.
I believe there was limited wet storage in this outbreak, but I am not an expert in this field.
Again...it's a possibility but my instincts say it's broader than that, especially because investigations did not point to single source.
Dont know this process well enough to comment.
I don't know enough about this.
if water can transport the virus (yes) regular levels of uv have little impact on the virus then yes this is a possible scenario

## 17. Exposure to community sources of norovirus

There is no data to substantiate this hypothesis.
unlikely
It's possible that some of the illnesses implicating oysters were actually contracted from community sources. What about the people preparing (shucking, plating) and serving the oysters? Has this been investigated?
This outbreak occurred during the norovirus season. Although all measures were taken to exclude community-acquired cases from the outbreak case count, it is possible that some cases were acquired in the community. However, this should not be considered a source of the outbreak but rather a small amount of case misclassification.
Would not explain temporal or geo trends. Has not been reported in any investigation steps. This would not have caused contamination of the oysters. A very small number of our counted clusters may have been associated with community illness and oyster consumption was incidental but I feel this is a small number and can not be specifically identified.
maybe, but not likely
Not sure?
Don't think so.
Only illnesses linked to raw and cooked oyster consumption were included. Community sources of potential infection were not included in the case counts.
Some of the outbreak genotypes were only found in this outbreak, never in the community, suggesting that this is not related to the community sources.
There were sick folks everywhere and noro is very contagious. This had to be a factor, especially because of the scope.
I think there are likely a few clusters that are attributable to community sources and just happened to have been exposed to oysters; but I think it would be a very small proportion of the reports.
It seems that this outbreak is firmly connected to oyster consumption, in which case it would be strange if all food establishments were contaminated from community sources. Originally the norovirus infecting the oysters may have come from the community, however HOW is what we are interested in. (sewage seems most likely)
It's always possible but again I don't think this could cause all contam across such a large area
logic being that as the alberta study showed viral levels rise in ground water when illness levels rise in the general population however if this was the case why did we see higher levels this year compared to normal its a great shame we do not have accurate figures to show the infection rate in the general population was the rate in oyster eaters higher than in the general population --if so by how much ?

## 18. Contamination or loss of control at the processor plant

There is no data to substantiate this hypothesis.
The widespread nature of the outbreak suggests other wise. In addition the shell acts as a barrier to contamination.
I doubt it as handling is minimal for this product, only washing, grading and packing. As above, I hope our industry wouldn't allow ill personnel to work with the oysters.
There was no evidence of large clustering by processor to support this hypothesis. It is possible that a small number of oysters were contaminated post harvest. However, until the oysters are opened, the risk of such contamination is very low.
Would not explain temporal or geo trends. Has not been reported in any investigation steps.
Definitely possible
It is possible that the processing plant is a source of contamination, and this could affect multiple batches of oysters from different harvesting areas - making it look like these harvesting areas are the source of the contamination. This is also possible if the processing equipment is not functioning properly (filters, UV light) during purification, and when there is comingling of batches of oysters. In the oyster harvesting areas themselves, it is also possible that relaying batches from marginally contaminated areas to clear areas has spread the infection, especially if the marginal areas are more heavily contaminated than expected.
The same as above
Multiple processors were implicated in contaminated product. For this to be true, there would need to have been a simultaneous loss of control at multiple processors.
If this was true, then one processor / distributor / store would have been linked to most illnesses
There is strong evidence from the processing plants were not responsible for OB.
Investigations showed no proof of this. Not to say it couldn't or didn't happen, but...no proof in this outbreak.
I doubt this, given that there are contaminated oysters associated with multiple processing facilities.
Not sure if all contaminated oysters were processed at same plant? If not this seems unlikely.
I don't know enough about this
v unlikely

## 19. Contamination or loss of control during distribution

There is no data to substantiate this hypothesis.
The widespread nature of the outbreak suggests other wise. In addition the shell acts as a barrier to contamination.
It's packed product at that point with almost no contact with people, no wet storage.
There was no evidence of large clustering by distributor to support this hypothesis. It is possible that a small number of oysters were contaminated post harvest. However, until the oysters are opened, the risk of such contamination is very low.
Would not explain temporal or geo trends. Has not been reported in any investigation steps.
Definitely possible
It would be possible if batches of oysters were transferred together in the same bulk container. If they were not combined then contamination would be unlikely.
The same as above
The oysters were found to be positive at the harvest location, dry holding of oysters it would be unlikely to have cross contamination. The only place were cross contamination is likely would be if there was wet storage.
The number of different distributors that have been linked to contaminated oysters suggests this is not the case. For this hypothesis to hold true, there would need to have been a simultaneous loss of control at multiple distributors.
If this was true, then one processor / distributor / store would have been linked to most illnesses
There is strong evidence that transport was not responsible for OB.
I doubt this, given that there are contaminated oysters associated with multiple distribution routes.
Can't comment.
I don't know enough about this
v unlikely apart from the wet storage issue



## 20. Contamination or loss of control at the restaurant/retail level

There is no data to substantiate this hypothesis.
The widespread nature of the outbreak suggests other wise. In addition the shell acts as a barrier to contamination.
What about the people preparing (shucking, plating) and serving the oysters? Has this been investigated?
There was no evidence of large clustering by restaurant to support this hypothesis. It is possible that a small number of oysters were contaminated at the restaurant level by an ill foodhandler. However, no such evidence was uncovered by EHOs during restaurant inspections occurring after a case notification.
Would not explain temporal or geo trends. Has not been reported in any investigation steps. Restaurant investigations have not identified any issues.
Definitely possible.
It would be possible for the oysters to become contaminated in a restaurant setting, either by oysters being stored together in the same water or by an infected food handler. However this would likely be investigated if numbers of customers all recalled eating oysters at the same restaurant.
The same as above
live tank holding or display and the potential for public handling, contaminating water etc
The sheer number of different restaurants/retailers that have been linked to contaminated oysters suggests this is not the case. If all or even a majority of the illness cases purchased from the same restaurant/retailer, this may be somewhat plausible. For this hypothesis to hold true, there would need to have been a simultaneous loss of control at dozens of locations across multiple provinces.
If this was true, then one processor / distributor / store would have been linked to most illnesses
There is strong evidence that the restaurants were not responsible for OB.
There were sick folks everywhere and noro is very contagious. This was most probably a contributing factor.
As with the community acquired option, I think it's possible that there are a few clusters that were associated with contamination at the restaurant level by unwell staff, but again a very small proportion.
Seems unlikely given the sheer number of clusters in this particular year.
Multiple farms and restaurants involved. Could not possibly be due to all involved restaurants losing control.
according to european studies someone who has suffered from norovirus continues to shed the virus for up to 8 weeks after the illness occurred 67 % of the population is shedding the virus at any one time therefore it is almost certain that some contamination happened this way why was the presence of norovirus found in so few oysters at the farm ? why were there virtually zero illness reports from the bc oysters sold into the U.S.? the illness reports recently from a problem in washington state show that they have a good reporting system in place

## Additional Hypotheses

Please list any additional hypotheses that we may have missed. Please provide a rationale.

By having an option for "Other unexplained events or phenomena" you have the hypotheses covered. However, I find it impossible to distinguish/determine different probabilities for the contribution of any variety of sources. The estuarine environment is too complex to make any conclusions for a given outbreak without data. For "outbreaks in general" there may be some value to guessing at the main contributing sources so that we can at least do our best to target risk management action which is focused - but from what I understand - this survey is specific to a given outbreak and I do not feel comfortable guessing in this context. I have not completed the ranking section as a result of this (no extra value could be extracted for your team based on my responses).

Since much of our product is exported to the US, have there been illnesses reported in Washington, California, Nevada or other states that get our halfshell oysters? If not, that's a real puzzle! Are the retailers and restaurants keeping accurate records as to where the oysters they sell and serve are from? Inaccurate records could implicate harvest sites that weren't the source of the product. While I was still CFIA shellfish specialist, whenever we invited the restaurant association to participate in discussing outbreaks (norovirus and vibrio) the response, if any, was half-hearted and token at best. I hope that's not the case here.

In summary, the points are 1) whether there is a source of human viruses nearby; 2) whether there is an access of human norovirus to sources of alive or growing oysters; 3) whether there is presence of adequate treatment methods and technologies applied to human wastewater treatment plants.

Septic tanks contributing to runoff.

adverse publicity created over reporting of illness by people who contracted the infection in a regular general way by person to person transfer and then blamed oysters they had eaten



