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National Capital Region

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Science Advisory Report 2021/038

EFFECTS OF FINFISH AQUACULTURE ACTIVITIES ON HARD SEABED ECOSYSTEMS IN BRITISH COLUMBIA AND ADVICE ON MONITORING PROTOCOLS

Net-pen along the coast of British Columbia (photo credit: DFO).

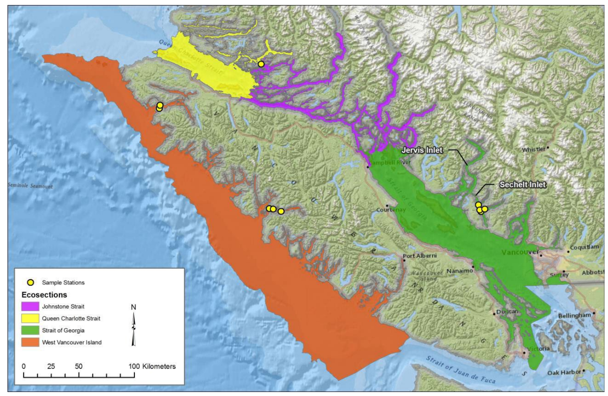

Figure 1. Location of video survey transects in, Queen Charlotte Strait (yellow), Johnstone Strait (purple), Strait of Georgia (green) and West Vancouver Island (orange).

Context:

Fisheries and Oceans Canada (DFO) is responsible for the regulation and management of the aquaculture industry in British Columbia (BC), and throughout Canada under the Aquaculture Activities Regulations, defining the conditions under which an aquaculture operator may deposit organic material under s.36 and s.35 of the Fisheries Act. Under the Aquaculture Activities Regulations, and previously as a condition of licence, the Pacific aquaculture industry is required to conduct seafloor monitoring of finfish aquaculture sites. The measurement of redox and sulphide from sediment samples is an accepted standard practice for soft-bottom seabeds. However, past monitoring practices involving grab sampling for redox and sulfide analyses have presented challenges at aquaculture sites located over hard bottom substrates. Section 10(2) of the Aquaculture Activities Regulations allows for visual monitoring instead of sediment grab samples if it is not possible to obtain benthic substrate samples. The protocols are outlined in the regulations and associated monitoring standard. Two research projects were initiated to assess and provide recommendations on the current approaches to hard seafloor monitoring around aquaculture facilities and provide advice on the development of future management approaches.

Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

October 2021

SUMMARY

- Video survey data collected between 2008 and 2011 by the finfish aquaculture industry in British Columbia (BC) and by Fisheries and Oceans Canada's Pacific Region Aquaculture Management, as part of their audit program, were analyzed in order to address questions related to changes in benthic epifaunal distributions, to assess differences associated with finfish aquaculture organic loading, and to provide advice on potential additional indicator species and sampling design for the purposes of site monitoring. Video data were collected around peak production at finfish aquaculture sites in Jervis Inlet, Sechelt Inlet, Queen Charlotte Strait, Johnstone Strait and Western Vancouver Island. These sites represent a variety of fine sediment, mixed sediment and hard-bottom seabeds. Baseline (pre-farm) surveys were not used in this analysis and therefore pre- and post-farm epifaunal differences were not assessed.
- *Beggiatoa*-like bacteria were observed on 36 of the 44 farm transects (82%) and Opportunistic Polychaete Complexes (OPCs) were observed on 17 of 44 farm transects (39%). None of the reference transects assessed had visible *Beggiatoa*-like bacteria or OPCs.
- In some instances, an inverse relationship was observed between *Beggiatoa*-like bacteria and OPCs within the near-field zone of the netpen systems, where the percent coverage trend for *Beggiatoa*-like bacteria had an offset-peak and showed low percent coverage while OPC had high percent coverage. The relationship between OPCs and *Beggiatoa*-like bacteria are likely complex. When *Beggiatoa*-like bacteria were visible in farm transects, the trends in terms of percent coverage along the length of the video transect (i.e., distance away from a farm) were variable (constant, offset-peak, or declining trend with distance from farm).
- Overall, *Beggiatoa*-like bacteria are responsive to changes in benthic oxic state associated with organic loading. However, it appears that *Beggiatoa*-like bacteria may exhibit a peak in abundance based on the optimal oxic-anoxic gradient and sulfide concentrations, and therefore in high organic loading areas should be used in combination with other sensitive visual indicators (e.g., OPCs) for hard bottom monitoring.
- *Beggiatoa*-like organisms and OPCs are currently accepted indicators of organic enrichment although their respective relationships to changes in epifauna are not established.
- There are currently no additional indicators or measures of benthic community changes associated with hard bottom finfish aquaculture sites in BC that can be used as part of a weight-of-evidence approach.
- Observations of epifauna from video surveys were qualitatively compared to reference transects for farms without accounting for substrate type. Broadly speaking there were differences in the epifauna seen between the farm transects and the reference transects, but, whether these are due to organic loading associated with farm activities or differences in substrate type or oceanographic conditions, cannot be assessed at this point. Finer scale, substrate-matched analyses would be required in order to assess for differences in epifauna taxa distribution or abundance between reference transects and farm transects. The use of baseline (pre-farm) survey data would allow for analysis of benthic community change over time and production cycles.

- The potential for additional species-specific, biodiversity, or substrate indices would require further research and assessment. Since some epifaunal taxa demonstrate depth preferences, any further research investigating the use of changes in epifaunal taxa distribution as an indicator should incorporate this aspect into the survey design.
- Detection and visual estimation of the percent coverage of *Beggiatoa*-like bacteria and OPCs from video segments becomes less accurate and precise as their percent coverage decreases. Continuous video segments or increasing the number of frames assessed may increase the accuracy and precision.
- While technological improvements have been made in recent years, advice on methods to visually monitor organic enrichment from finfish aquaculture summarized in Wildish et al. (2005) remain applicable. Further consideration of integrating technological advances, such as additional geo-referencing data, to improve the location of the ROV position during surveys is recommended.

INTRODUCTION

A robust and practical benthic environmental monitoring program is one that reliably captures quantitative information regarding changes to an existing natural population. Soft-bottom monitoring programs associated with aquaculture activities typically deploy a grab mechanism in subtidal settings to assess geochemical indicators representative of benthic organic enrichment (e.g., pore-water sulfide) and/or trace-elements that may reflect anthropogenic influences (e.g., sediment zinc, copper). Biological responses of infauna to these abiotic indicators can be established and used to develop management thresholds. However, these conventional soft-bottom techniques are not feasible with hard-bottom seafloors that are characterized by rocky textures, steeply-sloping grades, which lack fine sediments and infauna. Although some studies have used video and still-photo imagery of mixed or hard-bottom seabeds in association with aquaculture sites across Canada, there is a paucity of analysis of information on this topic given the diversity of the Canadian coastline.

In order to apply a rigorous and practical visual monitoring tool, it is important to consider the complexity of both the substrate and epifauna diversity that will be assessed. Recruitment, settlement and establishment of biofilms and epifaunal rely on the interaction among hydrodynamics, bathymetry, substrate conditions, and primary production.

Visual monitoring tools, such as ROV-video, towed video, and drop-camera photos have been used for surveying mixed and hard-bottom substrates in deep-water settings around finfish aquaculture sites in both Newfoundland and Labrador (NL) and BC. These tools have been used to quantify primary biological indicators of benthic organic enrichment on various substrates on seabed surfaces, such as *Beggiatoa*-like bacteria and Opportunistic Polychaete Complexes (OPCs). Generally, these indicator species can tolerate anoxic sediments characterized by high levels of pore-water sulfide, are capable of responding quickly to changing environmental conditions, and have previously been associated with organic loading associated with aquaculture activities.

Since there are epifaunal community structure changes with depth, in particular the change from macrophyte dominated communities in the shallow euphotic zone to invertebrate dominated communities at greater depth, the effects of aquaculture activities on hard seabed ecosystems also vary with depth.

In support of evaluating the environmental monitoring standard associated with the *Aquaculture Activities Regulations*, Fisheries and Oceans Canada Aquaculture Management asked for science advice regarding benthic monitoring tools and sampling design to assess impacts associated with biological oxygen demanding deposits from finfish aquaculture sites over mixed and hard-bottom seabed.

To address the request for advice, the following questions were considered:

1. What is the usual benthic community structure found in un-impacted environments that are similar to salmon aquaculture sites where it is not possible to obtain benthic substrate samples in British Columbia?
2. What are the changes on benthic communities and the benthic substrate from increased BOD generated from finfish aquaculture facilities in the Pacific Region? Changes may include biochemical, biological and other observable (e.g., gas bubbles, uneaten feed, bareness, etc.) impacts.
3. What sampling design, data collection, and technical specifications are required to allow for differentiation between impacted and un-impacted benthic substrates using visual monitoring tools?
4. Are there additional indicators or measures of benthic community changes associated with finfish aquaculture BOD deposits that can be used as part of a weight-of-evidence approach for assessing impacts?

ASSESSMENT

The assessment of the video surveys conducted included analysis of the percent coverage of *Beggiatoa*-like bacteria and OPCs as well as the appearance of off-gassing, barrenness and presence of epifauna taxa. Other physical or chemical changes were not assessed, nor were other ecosystem interactions such as predation, competition nor community structure.

Distribution of Benthic Taxa at Reference Sites

Data from video records collected at 22 reference sites in Jervis Inlet, Sechelt Inlet, Queen Charlotte Strait, Johnstone Strait and Western Vancouver Island from 2008-2011 were analyzed. Reference sites approximately 1000 m from finfish aquaculture sites that are characterized as mixed or bedrock seabeds were used to summarize the typical distribution of benthic epifauna taxa found in un-impacted environments with similar physical characteristics as finfish farm sites located in these regions. A community analysis was not completed.

Based on the video assessment, three general categories of seabed substrates were defined (fine substrate, mixed substrate and rock wall substrate). Within a given transect there can be a range of these substrates and associated distribution of taxa. The presence of hard surfaces provides attachment points for many sedentary (e.g., giant plumose anemone (*Metridium farcimen*), orange cup coral (*Balanophyllia elegans*)) and motile epifauna.

The epifauna observed for fine sediment seabeds include vertically structured suspension feeders and deposit feeders, such as marine polychaetes (various species), mud stars (unidentified) and sea urchins (*Stronglyocentrotus* spp.). Other taxa observed included shrimp (unidentified), squat lobster (*Munida quadrispina*), crabs (unidentified), giant nudibranchs (*Dendronotus iris*), opalescent nudibranchs (*Hermissenda crassicornis*), flatfish (unidentified), pricklebacks (unidentified), and ronquils (unidentified).

The epifauna associated with mixed substrate seabeds in BC is diverse given the complexity of substrate. The epifauna that were observed as part of this analysis were limited to taxa that could be visually identified (i.e., larger than 2 cm), including giant plumose anemones (*Metridium farcimen*), tube-dwelling anemones (*Pachycerianthus fimbriatus*), sabellid worms (unidentified), serpulid worms (unidentified), giant California sea cucumbers (*Parastichopus californicus*), brittle stars (unidentified), vermillion stars (*Mediaster aequalis*), and sea urchins (spp.).

Bedrock wall substrates can have up to 90° slopes, provide a large surface area for attachment of taxa and usually support a community based on glass sponges, such as the boot sponge (*Rhabdocalyptus dawsoni*) and cloud sponge (*Aphrocallistes vastus*) (Leys et al. 2004), as well as giant plumose anemones, painted anemones (*Urticina crassicornis*), snakelock anemones (*Anemonia viridis*), creeping pedal sea cucumbers (*Psolus chitinoides*), giant California sea cucumbers, serpulid worms (spp.), sea urchins (spp.) and dorid nudibranchs (spp.). Squat lobsters frequent the sponge communities. The fish community associated with the references sites with rock wall substrates consisted of rockfish (unidentified), greenling (unidentified), and lingcod (*Ophiodon elongatus*). In some cases, bedrock wall substrates have benches with additional substrate-type, including shell-hash, sediments or skeletal-sponge-matrix. The latter is made up of dead sponge spicules and forms a soft mesh in between bedrock crevices or on rock wall benches.

In addition to the influence of the substrate type on the epifauna taxa distribution, depth, and oceanographic conditions, particularly tidal currents, also influence the nature of the benthic epifauna distribution, making it difficult to generalize for the whole coast of BC.

What are the changes on benthic epifauna distribution and the benthic substrate from increased BOD-matter generated from finfish aquaculture facilities in the Pacific Region?

The video survey data used for this analysis and, where possible, benthic grab samples collected by industry and Aquaculture Management as part of the audit program were typically collected around peak production at finfish aquaculture sites in Jervis Inlet, Sechelt Inlet, Queen Charlotte Strait, Johnstone Strait and Western Vancouver Island. While these sites represent a variety of mixed and hard-bottom seabeds, grab samples were obtained from some sites at either 0 m, 30 m or 125 m from cage edge. These sites represented mixed sediment types and contained a combination of compliance stations that were both soft and hard-bottom. Baseline (pre-farm) surveys were not analyzed, so a comparison of pre- and post-farm epifaunal differences was not completed.

For finfish aquaculture facilities, the predicted BOD-matter footprint generated from depositional models was used as a predictor of the organic loading at the site.

Reference transects are ideally chosen to be at similar depths and similar substrate-type as farm sites. However, the variability (e.g., substrate-type, seabed slope, oceanographic, etc.) between reference and farm sites made it difficult to directly compare epifauna.

These relationships have inherent uncertainty associated with them as no pre-farm, peak production, and recovery data were analyzed which would have allowed for a full assessment of changes associated with farm-mediated activities.

In contrast to reference sites where no *Beggiatoa*-like bacteria and/or OPCs were detected, 36 of the 44 farm transects assessed had visible *Beggiatoa*-like bacteria, and 17 of 44 farm transects had visible OPCs. When *Beggiatoa*-like bacteria were visible, the trends in terms of percent coverage were variable (constant throughout the length of the transect, offset-peak, or declining trend).

Similar to some previous studies, *Beggiatoa*-like bacteria were not always visible in the near-field environment (up to 40 m from cage edge), with *Beggiatoa*-like bacteria observed and increasing a short-distance away, followed by a decline with distance from the netpen system (e.g., Brooks et al. 2004; Hamoutene et al. 2014).

In some instances, an inverse relationship was observed between *Beggiatoa*-like bacteria and OPCs within the near-field, up to 40 m from cage edge, where *Beggiatoa*-like bacteria showed low abundance while OPC had high abundance. The relationship between OPCs and *Beggiatoa*-like bacteria are likely complex. Overall, while *Beggiatoa*-like bacteria are responsive to changes in benthic oxic state associated with organic loading, it appears that *Beggiatoa*-like bacteria may exhibit a peak in abundance based on the optimal oxic-anoxic gradient and sulfide concentrations, and therefore should be used in combination with other sensitive indicators (i.e., OPCs).

Observations of epifauna from video surveys were qualitatively compared to reference transects for farms without accounting for substrate type. Broadly speaking there were differences in the epifauna seen between the farm transects and the reference transects, but whether these are due to organic loading associated with farm activities or differences in substrate type or oceanographic conditions could not be assessed. The epifaunal abundances were averaged for the transect, without taking into account the organic loading gradient that can be anticipated from cage edge to approximately 150 m from cage edge. Finer scale, substrate-matched analyses would be required in order to assess for differences in epifauna taxa distribution or abundance between reference transects and farm transects. The use of baseline (pre-farm) survey data would allow for analysis of benthic community change over time and production cycles.

Comparisons between farm and reference sites were limited due to the assumption that reference sites are representative of pre-farm epifaunal species distributions.

Requirements for Sampling Design, Data Collection and Technical Specifications

Image Capture Considerations

The effect of camera orientation [forward-facing vertical tilt (traditional orientation) and downward-facing] on the ability to visually detect both primary epifaunal indicators (*Beggiatoa*-like bacteria and OPCs) as well as sessile and motile epibenthic organisms for different substrate types was assessed. Images from ROV transects with paired cameras, along a single transect line with the ROV camera oriented in different directions, and at discrete stations at 30 m and 125 m from cage edge were also compared.

The data presented suggest that video surveys on mixed and bedrock substrates require consideration of which taxa are being assessed to determine appropriate camera angle. In general there is fairly good agreement in the ability to detect *Beggiatoa*-like bacteria between the images captured regardless of the camera angle and substrate type. *Beggiatoa*-like bacteria are more often detected on fine substrates than in mixed or bedrock substrates.

Colour calibration may influence the captured image, but was not assessed. The influence of different lighting and/or camera quality on the ability to detect *Beggiatoa*-like bacteria in video images was not analyzed, but remains a knowledge gap.

Drop Camera Drift Surveys

Drop camera drift video surveys require sufficient drift periods and spatial frequency to adequately describe taxa distribution along impact gradients and reference locations. Analysis would be required to determine these requirements. Additionally, an analysis of drop camera images in comparison to ROV camera images taken along the same transect would allow for the determination of the utility of this technology to differentiate between un-impacted and impacted benthic communities.

Survey Positioning

For the different survey strategies reported, although a starting location and a target end location were geo-referenced, the actual ROV operations proceeded along defined compass bearings. In the absence of active geo-referencing, the spatial extent of video segments that were subsequently analyzed (typically by 2 m or 4 m sections) were calculated by extrapolation of distance travelled by the ROV from elapsed time on the video at the current ROV speed over ground.

Current operational protocols in BC for ROV-based seabed video surveys do not require active geo-referencing of the survey path of the survey vehicle. Further consideration of integrating additional geo-referencing with the aim to improve the location of the ROV position during surveys is recommended.

There are several acoustic positioning technologies available for use on ROVs and on other visual monitoring approaches (diver-deployed video, drop/drift systems, towed vehicles) (reviewed in Wildish et al. 2005). These technologies are relatively mature (i.e., in regular application for marine ROV survey work for well over a decade), and allow for real-time positioning of the survey vehicle in the field, both relative to the surface support vessel, as well as by derived geographic position. For field operations these systems can thus provide an additional guide for ROV pilots to execute a specific survey operation, and can also be used to input preplanned geo-referenced transect paths for the ROV to follow.

For post-processing of video imagery the derived ROV positions can be subsequently displayed within Geographic Information Systems (GIS) from which defined transect sections can be selected by reference to the Global Positioning System (GPS) timecode recorded along with the positional data. Some commercial acoustic positioning systems also provide the means for recording the derived vehicle positions onto the recorded video stream, either as on-screen video overlay or as an embedded signal (e.g., on the video audio track or as a closed captioning data stream).

The addition of geo-referencing data will enhance the metadata already collected (e.g., GMT time stamp, date stamp, compass bearing, and depth).

Survey Design Considerations

Given the mosaic nature of the seabed, acoustic-based area interpretation of seabed characteristics in addition to continuous seabed imagery along linear transects, as is currently required, continues to be supported (Wildish et al. 2005).

The ability to detect and accurately visually estimate *Beggiatoa*-like bacteria and OPCs from video segments decreases with decreasing percent coverage and increasing patchiness.

Continuous video segments or increasing the number of frames assessed may address some of this variability.

Since some epifauna taxa exhibit depth preferences, ROV surveys that maintain a single depth contour that spans the farm system and extends in the dominant and subdominant current directions may avoid this confounding factor. Therefore, reference video surveys that maintain a depth contour and, where possible, match the substrate type of the farm transects will provide a stronger comparison with near-field video surveys.

Collection of baseline data that characterizes the site, representing where survey transects will be conducted allow for direct pre-farm and farm site analyses.

Additional Indicators of Benthic Epifauna Distribution Changes

The studies did not characterize epifaunal differences between paired farm and reference transects, and there was a lack of data presented to directly assess changes due to organic loading from finfish aquaculture farms. An initial analysis of additional potential indicator taxa, waste feed and farm fish feces, gas bubbles, barrenness, and substrate colour was undertaken. Based on this initial analysis, waste feed and farm fish feces were detected in the near-field (within 40 m), and while visible over fine substrate, detection of these wastes was not easily discernable particularly at mixed substrate sites. Substrate colour was not easy to characterize, and gas bubbles and barrenness were not apparent. There remains uncertainty regarding the applicability and robustness of any of these additional indicators in BC.

Further research would be required to investigate the applicability of any potential additional indicators to contribute to a weight-of-evidence approach. A potential secondary taxon that may bear further consideration may be the giant plumose anemone (*Metridium farcimen)*, as an initial assessment suggests that they align with density gradients of primary indicators and/or waste pellet estimates. However, the organic enrichment levels that giant plumose anemones are tolerant to would also need to be assessed. Taxa that may be indicators of the transition between oxic states could be investigated (e.g., species of: sea urchins, brittle stars, tube dwelling anemones, nudibranchs, shrimp, etc.).

Sources of Uncertainty

While initial results suggest that there may be an increasing trend in abundance and richness of epifauna with increasing sediment hardness, further analysis is required to confirm this trend.

The percent cover or presence of *Beggiatoa*-like bacteria and OPCs as indicators of benthic enrichment leading to deleterious habitat impacts and/or their relationship to epifauna have not been established. This linkage is key to the development or recommendations of sampling designs to detect specific changes that are associated with management objectives.

Variations in colour of the underlying substrate influence the ability to detect *Beggiatoa*-like bacteria in video images.

Several factors associated with the detection of *Beggiatoa*-like bacteria and porewater sulfides need further research to establish upper and lower limits or relationship, including the presence of *Beggiatoa*-like bacteria over time.

Recovery processes are poorly understood. Farms produce a pulse effect, and the effect of the timing of fallowing will affect biological recovery. The percent cover or presence of *Beggiatoa*-like bacteria and OPCs can be variable within a production cycle, and the relationship between these indicators and current farm production level, cycle, and potential cumulative effects is not always clear.

Documented changes in benthic epifaunal distributions cited in the two working papers occur over sub-metre to several-metre scales and so inherently the analyses require close consideration of spatial resolution.

As research progresses related to additional indicator species, a conceptual model to inform survey design that takes into account the habitats and conditions in which these taxa may be expected to be found should be considered. There may be other conceptual models that could inform sampling designs to evaluate impact gradients (Vandermeulen 2005).

Current operational protocols in BC for ROV-based seabed video surveys do not require active geo-referencing of the survey path. This was considered both a significant source of uncertainty for determining spatial patterns of benthic diversity in relation to aquaculture site location, and an opportunity for improvement in overall survey protocols.

CONCLUSION

The distribution of benthic epifauna found on hard-bottom seabed locations near finfish aquaculture sites in BC is highly variable but some generalizations within an ecoregion can be made associated with both overall substrate type (fine, mixed, or rock wall) and depth.

Of the 44 farm transects assessed, *Beggiatoa*-like bacteria and/or OPCs, were observed in 36 and 17, respectively. In contrast, none of the reference transects assessed had visible *Beggiatoa*-like bacteria or OPCs.

In locations where *Beggiatoa*-like bacteria were visible, the trends in terms of percent coverage were variable (constant throughout the length of the transect, offset-peak, or declining with distance from the farm). Whether this variability is related to variability in the substrate type (fine or mixed, rock wall or rock wall with benches, etc.) was not investigated.

In some instances, an inverse relationship was observed between *Beggiatoa*-like bacteria and OPCs within the near-field zone of the netpen systems, where the percent coverage trend for *Beggiatoa*-like bacteria had an offset-peak and showed low percent coverage while OPC had high percent coverage. The relationship between OPCs and *Beggiatoa*-like bacteria is likely complex.

Overall, while *Beggiatoa*-like bacteria are responsive to changes in benthic oxic state associated with organic loading, it appears that *Beggiatoa*-like bacteria may exhibit a peak in abundance based on the optimal oxic-anoxic gradient and sulfide concentrations, and therefore should be used in combination with other sensitive indicators, such as OPCs.

Observations of epifauna from video surveys were qualitatively compared to reference transects for farms without accounting for substrate type. Broadly speaking there were differences in the epifauna seen between the paired locations, but whether these are due to organic loading associated with farm activities or differences in substrate type or oceanographic conditions was not assessed. Finer scale, substrate-matched analyses would be required in order to assess differences in epifauna taxa distribution or abundance between reference station and farm transects.

The sampling design, data and technical requirements to capture video images that allow for differentiation between impacted and un-impacted benthic communities are dependent on which indicators of change are being detected.

For primary indicators of benthic enrichment (*Beggiatoa*-like bacteria and OPCs), standard forward-facing cameras and downward-facing cameras produce similar results.

The ability to detect and accurately visually estimate *Beggiatoa*-like bacteria and OPCs from video segments decreases with decreasing percent coverage and increasing patchiness. Continuous video segments or increasing the number of frames assessed may allow for more accurate estimates of *Beggiatoa*-like bacteria and OPCs.

Since some epifaunal taxa exhibit depth preferences, reference video surveys should maintain a depth contour and match the substrate type of the farm transects where possible to provide a strong comparison with near-field video surveys.

Current operational protocols in BC for ROV-based seabed video surveys do not require active geo-referencing of the survey path of the survey vehicle. Further consideration of integrating additional geo-referencing with the aim to improve the location of the ROV position during surveys is recommended.

Further analyses of different video capturing methodologies (sampling design, data and technical requirements, image analysis) are required.

An initial analysis of other potential indicators (e.g., waste feed, feces, gas bubbles, and barren seabeds) was completed; however, there remain remains uncertainty regarding the applicability and robustness of any of these additional indicators in BC.

Further research would be required to investigate the applicability of any potential additional indicators to contribute to a weight-of-evidence approach. Potential additional indicators that may warrant further investigation include Giant plumose anemones as this species may tolerate organic enrichment and was observed to co-occur with *Beggiatoa*-like bacteria and OPCs at some farm sites. Other taxa that tend to occur at the transition between oxic states could also be investigated (e.g., sea urchins, brittle stars, tube dwelling anemones, opalescent nudibranchs, shrimp, etc.).

In order to provide advice on changes associated with finfish aquaculture generated BOD-matter on the hard-bottom seabed benthic community, substrate-matched community analyses are required. The use of baseline (pre-farm) survey data from the aquaculture site would allow for analysis of benthic community change over time and production cycles.

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SOURCES OF INFORMATION

This Science Advisory Report is the product of a national science peer review meeting on the effects of aquaculture activities on hard seabed ecosystems and advice on monitoring protocols held in Vancouver, B.C., March 1-2, 2016. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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