Salmon Aquaculture Environmental Monitoring Data Report

Results of Sampling Program for Year 2002

by

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Executive Summary

This data report contains salmon aquaculture farm site monitoring data collected by the B.C. Ministry Environment (formerly Ministry of Water, Land and Air Protection) to provide the necessary background scientific data to support the development of a new fish farm waste control regulation. The data were collected from May to September, 2002. One of the recommendations of the provincial Salmon Aquaculture Review (SAR, 1997) was the development of a performance-based waste management regulation to protect the marine environment. The sampling program undertaken by the ministry and the B.C. aquaculture industry was initiated at the direction of the Regional Waste Manager, Vancouver Island Region. Objectives, instructions and protocols for this program can be found in the ***Aquaculture Information Request and Interim Monitoring Program*** document dated May 29, 2000.

A total of 18 farms were sampled in 2002. Of these, only three farms were sampled for benthic invertebrates. In general, the sampling gradient included 0, 30, 60, 100 m distant and two reference sites. However, depending on local conditions, the actual distances sampled varied. Some sites had samples only near the edge of the net pens, or at 0 and 30 m distant. Biotic and geochemical effects were noted at varying distances from the farm.

All sites had measurements of free sulfides as well as redox measurements. The inclusion of both types of measurement tended to best predict biotic effects. Biotic and geochemical effects were noted at varying distances from the farm. Table 1 summarizes sediment geochemistry measurements and basic biology (species richness and abundance of *Capitella capitata* complex). Substrates were primarily silt or silty sand, although very few sites had actual sediment particle size analyses. Some sites had varying mixtures of gravel, wood debris or terrigenous material, shell debris and rock/cobble. Only 2 sites were noted to have some gravel and generally coarser or mixed substrates.

In a number of farm locations, sediment geochemistry (redox and free sulfides) appeared to be within a range expected to support "normal" benthic communities. However, a number of near-field samples, particularly within 30 m of the edge of net pens, had redox levels below zero (suggesting anoxic sediments or patches) and/or sulfide levels well above background levels (<250 to 350 μM) for natural sediments which do not experience any unusual enrichment sources. Those sample locations which had an impoverished biota also tended to have unusual sediment geochemical conditions, suggesting a cause/effect relationship.

However, there are a few exceptions to this pattern. The samples with redox values below 0 did not always have an impoverished biota. Such conditions can occur frequently in natural sediments where there is limited bottom current and/or natural organic deposition. Under fish farms, negative redox values may occur only in the near-surface layer where rapid organic deposition is occurring. Thus, the sub-surface sediments may be oxygenated and allow reasonable biotic growth. However this condition is expected to be uncommon. More likely, spatial and temporal patchiness of fish farm depositions make on-the-spot redox measurements highly variable. Thus, there may be patches of anoxia with are not extensive enough to inhibit biological growth, but may cause variability in geochemical sampling results.

Other exceptions to the common pattern can be seen in the sulfide measurements. In addition, high sulphide levels (>1000 – 1700 uM) in the data did not necessarily coincide with negative redox levels measured in sediments. The production of hydrogen sulfide by bacteria such as *Beggiatoa* spp. is dependent upon the presence of low levels of oxygen as well as elemental sulfur. Thus the oxic/anoxic interface may be sub-surface, so that a surface redox sample may be positive, with high sulfide production below the surface allowing diffusion of hydrogen sulfide into the near-surface layer. Such conditions are ideal for the proliferation of opportunists such as *Capitella capitata* complex, or where sulfide is more moderate, a more functionally diverse assemblage which is physiologically adapted to tolerate the sulfidic conditions. In addition, patchiness of sampling probe deployment may also cause highly variable results in sediment geochemistry samples.

Table 1 shows that mild to strong anoxia (redox value <0) was found at 16 of the 18 farms at varying distances, with strong anoxia evident only in two farm sites. Sulfide levels above what might be considered background levels (determined to be > 250 to 350 μM) occurred at 16 sites, with moderate to high levels (>800 μM) noted at 2 sites. Levels for total volatile solids (TVS) were found to be less informative indicators of organic accumulation than redox or sulphide measurements, but tended to correlate with the two. This finding was consistent with that reported for organic enrichment in sewage deposition areas by Burd, 2000, 2003. The presence of wood fibre debris may have been a confounding factor. If thick enough, this could cause redox decline and biotic compromise outside the influence of the farm wastes.

In cases where sulphide levels were high, there was usually some biotic compromise evident (note Hardy Bay is an exception). In addition, biotic effects were usually evident at 0 m regardless of sediment redox and sulphide levels, suggesting other unmeasured factors may be important.

The presence of a high proportion of *C. capitata complex* was variable. Although only 3 sites had biological data, several sites included field notes which suggested dense aggregations of *C. capitata*. However, without field collections, the identity of this worm is in question. These are noted in Table 1. In total, 6 of 18 sites showed enhancement of this opportunistic organic enrichment indicator. Because of the lack of data, it is not possible to determine if this species was abundant at other locations.

Enhancement of this polychaete occurred either at locations nearest the farm, or to 30 m distant. *C. capitata* can be high where sulfide levels are extreme but require some oxygen in sediments, in addition to elevated sulphide levels for reproduction and recruitment (c.f. Burd 2003).

Of the three sites with biological samples, moderate to extreme impoverishment in terms of species richness was noted at 0 and 30 m from the farm. Of the three farms, no enrichment of abundance was noted at sampled stations. There was insufficient biological data to comment on any other trends. The biotic diversity index (Shannon-Weiner) tended to follow the pattern of species richness, whereas the Simpson's index was somewhat erratic.

The sediment particulate copper levels were well below the provincial guidelines (PEL = 108 μg/g copper) for 15 of the 18 farm sites, and was near or over the limit in 3 farms. Zinc was near or over the provincial guidelines (PEL = 271 μg/g) at 11 of 18 farm sites.

Table 1. Summary of farm site characteristics for 2002.

Farm Site	Anoxia	sulfides	substrate	*C. capitata*	Species Richness	Zinc/Copper
Arrow Passage	not evident	moderate at 0-30 m SSE	mixed with rocks	n/a	n/a	Cu low; Zn moderate
Bawden Point	moderate all stations	high at 0 m	sandy silt	moderate at 30m	impoverished 0-30 m	low
Centre Cove	severe all stations	high to 30 m	fine, black	n/a	n/a	Cu, Zn over limit
Cypress Rocks	not evident	high at 0 m	silty sand/wood	n/a	n/a	low
Cyrus Rocks	moderate all stations	moderate at 0 m NW	silt	n/a	n/a	Cu low, Zn near limit 0 m NW
Hohoae Island	moderate 0 m E	low to moderate	silt sand/gravel	n/a	n/a	Cu, Zn moderate to high
Kent	strong 0-30 m	low to moderate 0 m	silt	n/a	n/a	low
Larsen	not evident	high at 0 m	silt/cobble	moderate at 30 m	impoverished 0-30 m	low
Midsummer Island	mild at 0 m	moderate 0 m	silt	n/a	n/a	Cu low, Zn near limit to 60 m
Orchard Bay	moderate 0-20 m	very high 0 m	silt	high 0 m	n/a	low
Rant Point	moderate 0,60 m SW, 5 m SE	very high 0 m SW	silt	n/a	n/a	Cu low, Zn moderate 0 m
Raynor Group	mild-moderate 0-30 m	very high 0 m SSE	silt	n/a	n/a	Cu low, Zn at limit 30 m
Ross Passage	mild 30 m SSW	moderate-high 0-30 m	muddy sand, rocks	high 0 m	n/a	Cu low, Zn limit or over 0 m to 30 m N
Shaw Passage	moderate 0-60 m SW, 30 m E	low	sandy silt	n/a	n/a	Cu at limit 30 m SW; Zn > limit 0-30 m SW
Sir Edmund Bay	mild-moderate all stations	high 0 m SE	sand, cobble	high 0-30 m E	moderate 0,30 m	Cu low, Zn high 0 m E
Swanson Island	mild 30-100 m	low	silty sand	n/a	n/a	low
Upper Retreat	mild at 30 m	low-moderate 0-30 m	silt	n/a	n/a	low
Westside	moderate 0 m SSE	high 0 m SSE	silt	high 0 m E	n/a	Cu low, Zn moderate 0 m E

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