Salmon Aquaculture Environmental Monitoring Data Report

Results of Sampling Program for Year 2000

by

Cindy Wright[1], Bernie Taekema[2], Brenda Burd[1], and Eric McGreer[2]

[1]Ecostat Research Ltd.
1040 Clayton Rd., RR #1
Sidney, B.C.
V8L 5P6

[2]Ministry of Environment
Environmental Protection Division,
Environmental Quality Section
2080A Labieux Road
Nanaimo, B.C.
V9T 6J9

March, 2007

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

Executive Summary

This data report contains salmon aquaculture farm site monitoring data collected by the B.C. Ministry of 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 during the summer and fall of 2000. 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.

An interpretation of the data in this data report has been previously presented by McGreer *et al.*, 2002. Results of the industry's sampling program can be found elsewhere in Brooks, 2001.

A total of 32 farm sites were monitored in the 2000 cycle. In general, the sampling gradient included 0, 30, 60, 100 m locations along a transect from the edge of the net-pen structure, and a reference site. However, depending on local conditions or logistical constraints encountered in the field, the actual distances sampled varied. Some sites had samples collected near the edge of the net pens, or at 0 and 30 m only.

Most sites had measurements of free sulfides as well as redox measurements. All sites had at least one of these two types of measurements. Two sites were missing redox measurements, and five sites were missing sulphide measurements. The inclusion of both types of measurement tended to best predict biotic effects. In cases where sediment redox was not available, the presence of black coloured surface sediments was a good indicator of surface anoxia in sediments, and *Beggiatoa* mats were a good indicator of anoxic surface sediments with overlying low oxygen water (i.e., the oxic/anoxic interface was right at the sediment surface).

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 sandy with only one muddy site (Bare Bluff), and some with varying mixtures of gravel and mud. About 7 sites were noted to have some gravel and generally coarse substrates. Except for the muddy site, these substrates would not be expected to experience anoxia unless the overlying water mass was anoxic.

Table 1 shows that mild to strong anoxia (redox value <0) was found at 20 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 µM) occurred at 22 sites, with moderate to high levels (>800 µM) noted at 16 sites. Levels for Total

Organic Carbon were found not to be reliable indicators of organic accumulation or enrichment. This finding was consistent with that reported by Burd, 2000.

The presence of wood fibre debris was a confounding factor. If thick enough, this could cause redox decline and biotic compromise outside the influence of the farm wastes (c.f. Lutes Creek).

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 which 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 sulphidic conditions. In addition, patchiness of sampling probe deployment may also cause highly variable results in sediment geochemistry samples.

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* was variable. Thirteen of the sites showed no enhancement of this opportunistic organic enrichment indicator. Of the remaining 19 sites, enhancement of the polychaete occurred mostly at locations nearest the farm. In cases where sediment sulfides were very high (>1000 µM), and sediment redox was less than about -70 mV, *C. capitata* were usually rare or absent. *C. capitata* could be high where sulfide levels were extreme but sediments were oxygenated (c.f. Jervis, Koskimo). *C. capitata* require some oxygen in sediments, in addition to elevated sulphide levels for reproduction and recruitment (c.f. Burd 2003).

Based on total and mean taxa number, seven sites showed no evident biotic impoverishment at any distance from the farm. A clear gradient towards the farm site of increasing impoverishment based on species richness was noted in 6 of the farm sites. Enrichment of both abundance and species richness was noted at only 1 site. Of the remaining sites, all showed impoverishment nearest the farm site, with variable impoverishment evident 30-100 m away. One site (Blunden Pass) showed extreme impoverishment from 0-150 m relative to the reference site. This site showed anoxia to 100 m but no sulphide measurements were taken. There were some indications of degraded conditions (slight to moderate odour and black layer in sediments), but it was not extreme enough to suggest such extensive biotic degradation. The reason for the extensive impoverishment is therefore unknown.

The biotic diversity indices (Shannon-Weiner and Simpson's Index) were not very informative except in cases of extreme biotic degradation or opportunistic enhancement.

The sediment particulate zinc and copper levels were well below the provincial guidelines (271 µg/g zinc and 108 µg/g copper) for 20 of the farm sites. Zinc was near the limit in 6 farm sites and over the limit in 6 farm sites. Steamer Point had particularly high zinc levels (>780 µg/g). Copper levels were only elevated in 2 farm sites, and values were less than 200 µg/g in all cases.

Table 1. Summarized descriptions of basic geochemical and biotic measurements for farm sites, 2000.

Farm Site	Anoxia	sulfides	substrate	Presence *C. capitata*	Species Richness effects	zinc/copper (ug/g)
Arrow Pass	moderate-100 m	not sampled	sandy	abundant 0 m	impoverished 0 m	low
Bare Bluff	not sampled	moderate at 0 m	muddy	abundant 0 m	impoverished 0 m	low
Bawden Pass	strong to 30 m	very high 0m, high to 60 m	sandy	abundant 60 m	slight impoverished to 100 m	Zn near limit
Belcher Point	none (0 m sampled only)	low at all stations	sandy	few	not evident	low
Bell Island	none	moderate at 0 m	sandy	abundant 0 m	impoverished 0 m	low
Bickley Bay	none	low at all stations	sandy	abundant 0, 30,100 m	not evident	low
Blunden Pass	moderate to 100 m	not sampled	sandy mud	none	0-150 m extreme?	Zn near limit
Burdwood	moderate-mild 5, 35 m	high at 0 m	sandy mud	moderate 5,35 m	not evident	Zn near limit
Cecil Island	mild 0-60 m	not sampled	muddy sand	moderate 0-30 m	impoverished 0-30, enrich. 60 m	Zn over limit
Center Cove	moderate to 100 m	moderate to 100 m	mud to sand	few	impoverished to 100 m	low
Coal Harbour	mild 100 m, R1	high at 0 m	mud to sand	abundant 60 m		Zn high >400
Cypress Hrbr.	moderate 0 m	not sampled	sandy	abundant 0 m, mod 30m	gradient 0-100 m	Low
Cyrus Rocks	strong 0 m, mild to 60 m	high at 0 m	muddy sand	few	gradient 0-100 m	Low
Dunsterville	moderate 0-60 m	high at 0 m	sandy	abundant 0-30 m	gradient 0-100 m	Low
Hardy Bay	none	high at 0 m	gravelly sand	abundant 0 m	not evident	Zn near limit, Cu >130
Hecate F4	none	low at all stations	sandy gravel	none	not evident (0, 30 m only)	low
Hohoae	moderate to 60 m	high 0,60 m, moderate 30 m	sand & gravel	few 0, 30 m	impoverished 0-60 m	Zn high >300
Indian Bay	not sampled	high to 100 m	sandy mud	abundant 30 m	moderate impoverishment to 60 m	Zn near limit
Jervis Cove	none	high at 0 m	sandy	abundant 0 m	impoverished 0 m	low
Koskimo Bay	marginal 0, 100 m R1	high at 0 m	gravelly sand	abundant 0 m	impoverished 0 m	Zn near limit
Lees Bay	moderate 0 m, marginal 30-60 m	high at 0 m	mixed sand	abundant 0 m	impoverished 0 m	low
Lutes Creek	none	high at 0-30 m	muddy sand	abundant 0-30 m	slight impoverished 0 m	low
Mahatta West	moderate-mild 0-160 m	moderate 0-30 m	muddy sand	few 30 m	may be slight to 160 m	low
Orchard Bay	none	high 0-30 m	muddy sand	abundant 0 m	impoverished 0 m	low
Power Bay	moderate 35 m only	moderate at 5 m, high 3 5m	sandy	very abundant 35 m	slight impoverishment to 60 m	Zn over limit
Rant Point	moderate0-30 m	high at 0 m	sandy mud	none	gradient 0-R1	low
Ross Passage	moderate 60 m only	low at all stations	gravelly sand	abundant 12 m	gradient 12-60 m	low
Simmonds Point	none	moderate at 0 m	sand	few	gradient 0-60 m	low
Sir Edmund Bay	moderate 60 m only	not sampled	gravelly sand	few	impoverished To 60 m	low
Steamer Point	none (0m sampled only)	low at all stations	muddy sand	none	not evident	Zn 780, Cu 177
Upper Retreat	moderate 0-30 m N, SW, 60 m SW	high 0m N, SW, 30 m N	muddy sand	few	impoverished 0-30 SW, N, 60 m N	Zn over limit
Young Pass	none	moderate at 0 m	sandy	few	not evident	low

This page left blank