IMPACTS OF WOOD DEBRIS ACCUMULATION ON SEABED ECOLOGY IN BRITISH COLUMBIA ESTUARIES

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ABSTRACT: The accumulation of wood debris near logbooms has important and long-term impacts on benthic ecology. Typically infauna is less diverse and sediments are often anoxic. Neither the extent of these influences nor their duration is well known. We have undertaken seafloor surveys in two similar bays on the British Columbia North Coast near Kitimat. Clio Bay has been used for logbooming for many decades, while Eagle Bay has never been used. In Clio Bay, we identified several thousand partially decomposed logs and a mean surface area coverage of about 40 % bark debris to a depth of 60 m. In contrast, there was virtually no bark debris on the Eagle Bay seafloor. Epifaunal communities proved to be a better indicator of habitat differences between the two bays than porewater redox potential. Large benthic predators such as Dungeness crabs and sunflower seastars are more abundant in Eagle Bay. There are some organisms, however, which prefer wood accumulations (e.g., squat lobsters, holothurians). We have shown that impacts can last many decades and even centuries.

SOMMAIRE: L'accumulation de bois près des pannes de troncs a des impacts importants sur l'écologie du fond marin. Typiquement, la faune est moins diverse et souvent le sédiment est anoxique. On ne sait pas très bien ni l'étendue de ces influences ni leur durée. Nous avons fait des levées du fond marin dans deux baies similaires sur la côte nord de la Colombie-Britannique près de Kitimat. La baie Clio a été utilisée depuis longtemps pour l'entreposage des troncs en pannes; la baie Eagle n'a jamais été utilisée à cette fin. Dans la baie Clio nous avons identifié plusieurs milliers de troncs entiers et une concentration moyenne de morceaux d'écorce de 40 % jusqu'à une profondeur de 60 m. Dans la baie Eagle, il n'y a presque pas de matière organique terrestre au fond. La faune benthique est plus diverse dans la baie Eagle et les animaux comme les crabes Dungeness et les étoiles de mer y sont plus nombreux. D'autre part, il y a quelques organismes qui préfèrent les accumulations de bois (par exemple les holothuriens). Nous avons démontré que les impacts peuvent durer quelques dizaines d'années et peut-être même des siècles.

1. INTRODUCTION

Temporary storage of harvested logs in estuarine areas has been a common practice in many parts of eastern and western Canada for nearly two centuries. While the practice has been severely curtailed in eastern Canada in recent years, the handling, storage and marine transportation of logs are still extremely important in British Columbia. The reasons for using estuaries and coastal waters for these activities in British Columbia relates to the remoteness and rugged character of most of the coast, and the logistic difficulties associated with of land-based transportation routes. Estuaries are preferred sites for temporary storage because they are commonly adjacent to areas accessible by local logging roads and because of their low salinity which inhibits the development of shipworms (teredos, *Bankia setacea*) which are highly destructive to wood.

Effects of log handling activities on marine ecosystems have been the focus of previous research (e.g., Levy et al. 1982; Duval and Slaney 1980) but most have concentrated on infaunal and intertidal epifaunal communities. Many studies have documented effects such as reduced concentrations of porewater dissolved oxygen, increased elevations of interstitial reducing conditions and changes to infaunal communities dominated by opportunistic taxa (Pease 1974; Conlan and Ellis 1979; Jackson 1986). Several intertidal investigations have examined abundance changes of several small crustacea important in juvenile salmon diets (e.g., Levy et al 1989; Stanhope et al. 1987; Stanhope and Levings 1985; Sibert 1979; Sibert and Harpham 1979; McGreer et al. 1984). Most previous work on subtidal epifauna has been qualitative and limited to relatively small areas or small sample sizes (e.g., McDaniel 1973, Pease 1974, Conlan 1977, O'Clair and Freese 1988, Williamson et al. 2000).

The aims of the present study, carried out as part of the "Coasts Under Stress" project funded by the Social Sciences and Humanities Research Council and the Natural Sciences and Engineering Research Council of Canada are to:

(a) develop techniques for the identification of wood debris accumulations;
(b) document the extent of wood debris accumulation in areas near logbooming sites;
(c) characterize the physical and chemical characteristics of sediments in areas of wood debris accumulation compared to unimpacted sites;
(d) determine the impacts of wood debris on epifaunal taxa in these estuarine areas; and,
(e) make preliminary recommendations for policy related to logbooming site selection, operation and abandonment in the future.

2. STUDY AREA

Several estuaries on the North Coast of British Columbia near Douglas Channel were selected for investigation, including those 1) currently used for logbooming, 2) previously used for various time periods and 3) never been used. Exposure and seabed morphology were also considered during site selection.

In this paper we report some preliminary findings from two morphologically similar bays, Clio and Eagle, located near Kitimat (Fig. 1). Clio Bay has been actively used as a log handling site for several decades whereas Eagle Bay has never been used for that purpose. Both bays are very similar in size (approximately 1.6 km^2), shape, depth and orientation.

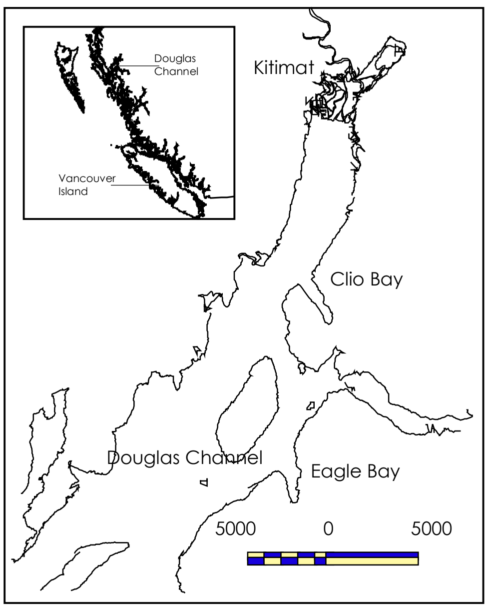

Fig.1 Location map of North Coast area of British Columbia showing Douglas Channel and Eagle and Clio Bays.

3. METHODS

The seafloor was mapped using a combination of techniques including sidescan sonar, echosounding, video imagery and sampling.

A fully scale-corrected 390 kHz EG&G model 260 sidescan sonar system was used to map seafloor substrate and accumulations of whole logs on the seafloor. Line spacing was 100 m with a 200 m swath width, providing complete acoustic imagery of the seafloor. Concurrently, 200 kHz narrow-beam echosounding data were acquired, coupled with a Quester Tangent QTC-View system for acoustic classification of the seabed.

Ground-truth and epifaunal information was provided by a towed seabed video system (Seabed Imaging and Mapping System; Harper et al. 1998, 1999). The video camera "wing" is towed approximately 1-2 m above the seafloor at speeds of 1-1.5 knots, yielding about 15 line kilometres of imagery per day. Video line spacing was 100 m. The imagery was interpreted by a geologist and a biologist, with classified data on substrate and biota entered in a custom database; mapping was carried out using ArcView GIS software.

Grab samples and cores were acquired in early May of 2001 and 2002 and late September 2001 using a Ponar grab sampler and a large-diameter (10 cm) gravity corer. Samples were described in the field, and porewater reduction/oxidation (redox) potential was measured 0.5cm below the sediment/water interface with an Accumet AP62 metre and an Orion platinum electrode. Subsamples were collected for laboratory analysis and washed through a 1 mm mesh sieve for infaunal constituents and wood debris concentrations. In the laboratory, grainsize analysis was undertaken using a 2-m settling tube for sand and a Sedigraph for muds; organic matter was removed prior to analysis where necessary using hydrogen peroxide. Total organic C and N were determined using a CHN analyzer.

4. RESULTS AND DISCUSSION

Clio Bay was found to have a significantly higher terrestrial organic content in the sediments and on the seafloor than Eagle Bay. Large areas of Clio Bay were found to exhibit very high concentrations of whole logs, in some instances as stacks up to 10 m high above the seafloor. Based on sidescan sonographs (Fig. 2) and seafloor video imagery (Fig. 3), we estimate that this bay contains several thousand partially decomposed logs which have sunk beneath log booming sites.

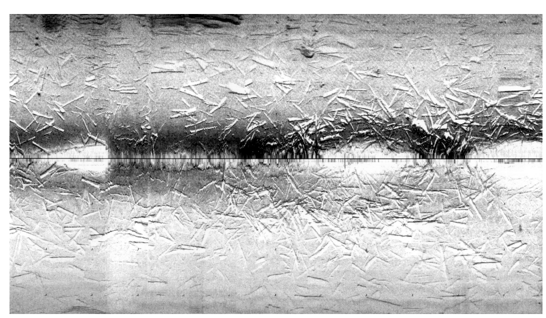

Fig. 2 Sidescan sonograph from Clio Bay showing dense concentrations of whole logs on the sea floor.

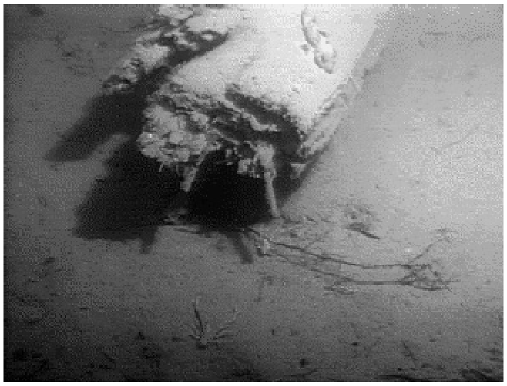

Fig. 3 Photograph of partly decomposed whole log on the sea floor.

As the central woody material in the logs deteriorates, in large part through the destruction by teredos, a tube of bark often remains for some time (Fig. 3). Eventually this more resistant bark material collapses and forms a layer of coarse debris within the sediments, often up to several tens of centimetres in thickness. This bark debris is easily recognizable in video imagery and can be quantified. In Clio Bay seafloor bark coverage reach more than 80 percent locally and average about 40 percent in the areas surveyed (Fig. 4). In addition, much of the sediment in Clio Bay consists of fine (about 1 mm) disseminated wood.

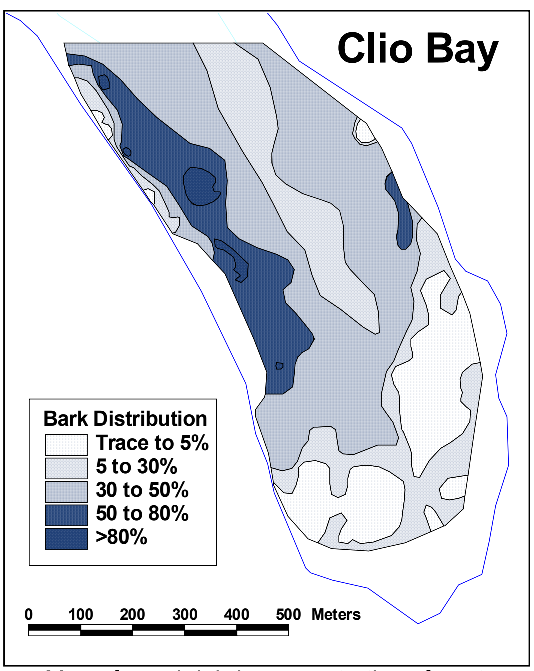

Fig. 4 Map of wood debris concentrations from towed seabed video imagery in Clio Bay.

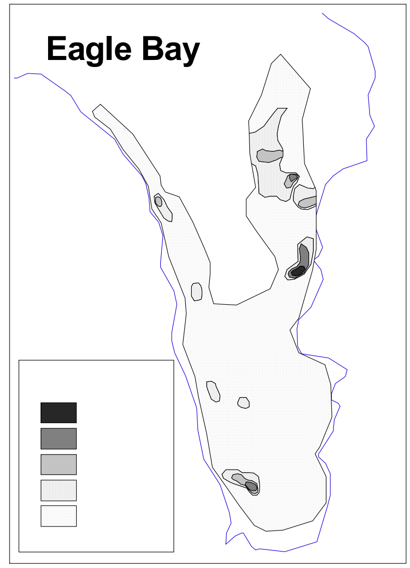

Fig. 5 Map of wood debris concentrations from towed seabed video imagery in Eagle Bay.

In contrast, Eagle Bay displays organic contents of less than 10 percent on average with only small, highly localized occurrences of more than 50 percent (Fig. 5).

C/N ratios in recent sediments largely reflect the source of organic matter. C/N ratios of about 7 (i.e., Redfield ratio) in estuarine areas are associated with marine organic matter whereas values in excess of this are usually indicative of some terrestrial contribution. Bornhold (1978) describes C/N ratios from a wide range of British Columbia marine environments; in general, fjord sediments ranged from about 6.85, for Saanich Inlet and Quatsino Sound, to 14.3 near Kitimat (Douglas Channel). The latter reflects a contribution of about 18 percent terrestrial plant material. Mean Clio Bay C/N ratios were nearly double and significantly greater than those from Eagle Bay (Tab. 1, $t=6.71$, $P<0.0001$). Based on the C/N ratios, mean terrestrial organic carbon contribution was 67% in Clio Bay and 32% in Eagle Bay.

Table 1. Mean carbon to nitrogen ratios (C/N) and percentage of terrestrial organic carbon (and 95% confidence limits) of sediments from Clio and Eagle bays, British Columbia, collected in May and September 2001

	C/N		% Terrestrial C	
Bay	Mean	95% CL	Mean	95% CL
Clio	39.5	5.05	67.0	6.55
Eagle	21.5	2.66	31.7	6.04

Porewater redox conditions are often cited as a useful surrogate for interstitial habitat conditions and infaunal community health (Whitfield 1969; Pearson and Stanley 1979; Davies et al. 1998; Brooks 2001). Predominance of reducing conditions (i.e., negative redox potential) are indicative of low dissolved oxygen concentration, conditions usually associated with sediments subjected to anthropogenic organic loading. However, in our study, near-surface redox conditions did not reliably distinguish Clio and Eagle bay sediments (Table 2). Redox values remained relatively consistent in Clio Bay, but Eagle Bay sediments showed considerable interseasonal variation. Oxidizing conditions dominant in spring shifted to autumn reducing conditions. Seasonal changes in settling organic matter quantity associated with spring phytoplankton bloom die-off and terrestrial melt-water run-off high in organic matter likely account for the observed redox potential variation.

Table 2. Mean reduction/oxidation (redox) potentials measured 0.5cm below the sediment/water interface of sediments collected from Clio and Eagle bays, British Columbia, in May and September 2001.

	Redox Potential (mV)			
	May		September	
Bay	Mean	95%CL	Mean	95%CL
Clio	-55.71	24.37	-30.50	23.69
Eagle	176.25	63.6	-55.91	62.03

Epifaunal communities differed substantially between Clio and Eagle bays. Initial examination of towed seabed videos suggests that large benthic predators avoid wood-dominated habitats. Dungeness crabs (*Cancer magister*), for example, were observed five times more often in the unimpacted Eagle Bay (Fig. 6) than in Clio Bay. Similarly sunflower seastars (*Pycnopodia helianthoides*) were twenty-five times more abundant in Eagle Bay than in Clio Bay. Further, both species were several-fold less abundant in wood-dominated habitats in Clio Bay than in non-wood habitats in that bay. The reduction of infaunal prey species in wood habitats previously documented by several authors (e.g. Pease 1974; Conlan and Ellis 1979; Jackson 1986), may account for low predator abundance in these habitats.

Some species, however, displayed a positive correlation with wood debris abundance. Squat lobsters (*Munida quadrispina*), some anemones (*Metridium* spp.) and holothurians (*Parastichopus* spp.) are all more abundant in Clio Bay than in Eagle Bay. Squat lobsters in particular show a high degree of association with sunken logs and coarse wood debris (Fig. 7). The increased abundance of squat lobsters, and anemones is likely related to the substrate that coarse wood provides for attachment and the availability of crevices (especially around whole logs) for evasion of predators. In addition, both these taxa are planktivorous and thus do not rely on a healthy infaunal community as a food source. Wood-dominated habitats may support elevated microbe populations providing an abundant food source for holothurians.

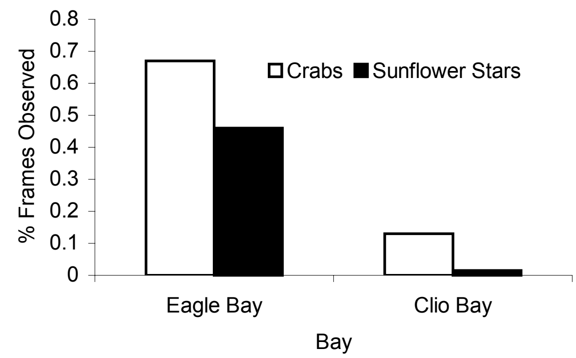

Figure 6. Percentage of towed video frames from Clio and Eagle bays (British Columbia) where Dungeness crab (*Cancer magister*) and sunflower seastars (*Pycnopodia helianthoides*) were observed.

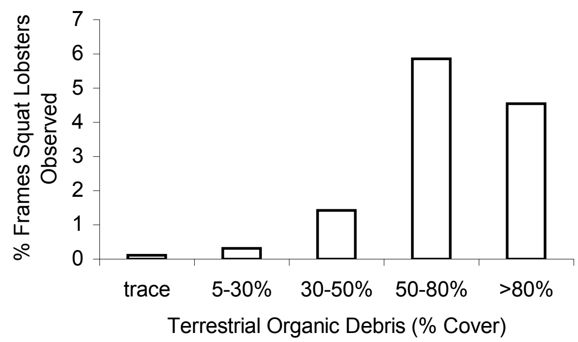

Figure 7. Percentage of towed video frames within each terrestrial organic debris surface area coverage category in Clio Bay where squat lobsters (*Munida quadrispina*) were observed.

5. CONCLUSIONS

Wood debris accumulation associated with log handling is extensive in Clio Bay. This is reflected in significantly higher seabed bark coverage and C/N ratios in Clio Bay relative to Eagle Bay. Despite this, porewater redox potentials were not a reliable indicator of habitat quality due to interseasonal variability of Eagle Bay sediments. Epifaunal communities appear to be a more useful indicator of habitat differences since large benthic predators avoid wood accumulations, while these habitats may be preferred by squat lobsters, some anemones and holothurians.

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