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Deep-Water Bark Accumulation and Benthos Richness at Log Transfer and Storage Facilities

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ABSTRACT: A small, manned submersible was used to determine the extent of bark accumulation and its effects on the epifaunal macrobenthos at depths from 20–130 m at log transfer facilities (LTFs) and log rafting facilities (LRFs) in Dora Bay, Prince of Wales Island, Alaska. Continuous videotaping from an external fixed camera was conducted along 6 transects located near LTFs and LRFs and along 3 transects in a similar, adjacent area not used as an LTF or LRF. Bark and woody debris accumulations and kinds and numbers of organisms were recorded by depth for 3 general habitat types (steep, rocky; moderate incline, cobble; flat, silty) with and without bark. Bark accumulation was found to 40-m depth on 6 dives, and to 70-m depth on 3 dives. Of 91 taxa observed during the study, most (69 species) were found on rocky, bark-free habitat; significantly reduced species richness was found in all bark-dominated habitats. Bark and debris from LTFs appeared to be displaced down slope into adjacent, deeper areas; this is the first published account of bark and woody debris accumulation below 20-m depth. In suitable habitats, manned submersibles or remotely operated vehicles appear to be useful tools for monitoring bark accumulation and investigating the effects of logging facilities.

INTRODUCTION

Southeast Alaska has supported commercial timber harvest since the early 1900s. Harvest increased dramatically in the 1950s following the signing of exclusive timber contracts with Ketchikan Pulp Company and Alaska Pulp Company (Selkregg 1974). A second dramatic increase occurred in the early 1980s, when Native corporations initiated logging operations. The majority of harvested timber has been transported in the water in large log rafts to processing locations or to transfer locations for export. Rafts are generally formed near log transfer facilities (LTFs) and are often temporarily left at log raft storage facilities (LRSs) in route to pulp and saw mills and shipping export facilities. Various methods, designs, and guidelines attempt to minimize impacts at these facilities on marine resources (Faris and Vaughn 1985; LTF Guidelines Technical Committee 1985). All LTFs and LRSs result in bark loss to some degree (Robinson–Wilson and Jackson 1986), and the bark often accumulates in extensive benthic deposits (Schultz and Berg 1976).

LTF guidelines (LTF Guidelines Technical Committee 1985) have been used by the timber industry since 1986 to answer state and federal agency concerns regarding compliance with the Clean Water Act. These guidelines and state and federal permits require that certain siting criteria are followed and that annual monitoring for bark accumulation is conducted at all active LTFs. Requirements include (1) selecting sites in areas that have the least productive intertidal and subtidal zones, (2) minimizing the log bundle speed at water entry, (3) limiting the zone of bark deposit (ZOD) to 1 acre, and (4) annual monitoring of bark accumulation. Monitoring requires permanent transects and measurements of areal extent, thickness, and percent

Authors: BEN KIRKPATRICK is a habitat biologist with the Alaska Department of Fish and Game, Habitat and Restoration Division, P.O. Box 240020-0020, Douglas, AK 99824. THOMAS C. SHIRLEY is a professor with the Juneau Center School of Fisheries & Ocean Sciences, University of Alaska Fairbanks, 11120 Glacier Highway, Juneau, Alaska 99801. CHARLES E. O'CLAIR is a research biologist with the Auke Bay Fisheries Laboratory, National Marine Fisheries Service, 11305 Glacier Highway, Juneau, AK 99801-8626.
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coverage of bark debris from mean high water to approximately 20 m below mean lower low water. To date, no study has been conducted to determine the regional effectiveness of the guidelines in minimizing impacts to the marine environment.

Considerable research near LTFs has documented distribution patterns of bark accumulation within the depth range of required monitoring (≤20 m), as well as biological effects including reduced abundance of benthic infauna (Pease 1974; Jackson 1986), reduced diversity of benthic epifauna and macroalgae (Schultz and Berg 1976; Conlan & Ellis 1979), reduced fitness and survival of bivalves (Freese and O'Clair 1987), and reduced fecundity and increased egg mortality in Dungeness crab (O'Clair and Freese 1988). These studies report negative effects on the marine environment, but also point out a need for more research to fill information gaps, elucidate mechanisms of impact, replicate key studies upon which specific guidelines are based, and examine more carefully topics of research for which results are presently inconclusive. The complexity of the marine ecosystem in Southeast Alaska often confounds the analysis of logging effects. Many of these studies should be replicated to better quantify benthic impacts from logging activities in shallow marine waters. However, funding for such research has not been available.

Though not completely quantified, the negative effects of bark accumulation are fairly well established in shallow water ≤20 m (Tetra Tech 1996), and therefore facility owners and resource managers have been inclined to site LTFs adjacent to deeper waters (>20 m), where possible, assuming that impacts will not be as great on the deeper benthos (CH_2M Hill 1982). However, there is scant literature on bark dispersal, accumulation patterns and biological impacts in deeper water (>20 m) on which to base that assumption.

We designed a feasibility study using a manned or remotely operated submersible, to determine if bark accumulations in deeper water were visually identifiable. If so, then the study would determine the feasibility of contrasting habitat use by benthic organisms in bark-dominated areas versus bark-free areas. We hope this feasibility study will stimulate further research to better quantify the impacts of bark accumulation on deep-water benthos.

Dora Bay, located on the south side of Cholmondelay Sound on southern Prince of Wales Island, Alaska, was selected as the site for this study. It is approximately 4 km long by 1.5 km wide and is oriented southwest to northeast (Figure 1). Steep submarine slopes near the shore descend to a relatively flat, deep (80 to 120 m) basin in the middle. The topography of the land surrounding the bay mirrors the rugged configuration of the marine bottom.

Since 1985, Dora Bay has been used by private native corporations as a central log storage and transfer location for southern Southeast Alaska. The first logging support facility in Dora Bay permitted by federal and state agencies was a single-point moorage system with an associated LRS. It was designed for transferring logs from rafts onto a log ship. In 1986 an LTF/LRS and a float camp were permitted on the west side of Dora Bay. In 1987 an LTF/LRS and float camp were permitted on the east side of Dora Bay. In 1989 a second ship mooring facility and temporary float camp were permitted. The steep nearshore terrain in Dora Bay results in a limited area <20 m in depth, which minimizes the area for which monitoring of bark accumulation and benthic impacts is required.

This rapid development of facilities in Dora Bay was not without controversy. A substantial commercial shrimp harvest, frequent humpback whale sightings, seal haulouts and pupping areas, and 4 nearby salmon streams were the primary issues raised by nearby private property owners and resource agencies during the public review in the permit process. Increased vessel traffic and human activity and direct and indirect impacts to the food chain through bark accumulation were the primary concerns related to these developments. The combination of steep submarine terrain, multiple logging support facilities, and public controversy favored Dora Bay as a location for the study of deep-water bark accumulation.

METHODS

Field Investigations

The Delta Oceanographics 2-person research submersible (Figure 2) was used to make 9 dives, ranging from 24 min to 114 min, in Dora Bay on July 3 and 4, 1997. Continuous videotape from an external fixed camera recorded each dive and included depth, time, water temperature, and observer comments. The support vessel tracked the submersible's location and provided GPS/GIS-compatible navigation information. Additionally, external fixed and internal hand-held 35mm cameras provided photographs. A manipulator arm was capable of probing the bottom to determine the thickness of bark deposits and the thickness of sediment if present covering bark deposits.

We conducted 6 dives in portions of Dora Bay that were suspected to have bark accumulations, such as near LTFs, LRSs, and ship mooring areas. Three dives were conducted in adjacent areas with similar terrain, far enough away from the surface facilities that no bark accumulation was expected but near enough that the habitats observed were probably comparable to the bark-covered habitats prior to the construction of the logging facilities. Straight-line transects were difficult to execute because of the rugged terrain. A general course was given by a scientist on the bridge of the support vessel who tracked the course of the submersible and communicated course corrections to its crew. The submersible crew attempted to maintain depths of ≥20 m.

Bark and debris accumulations were generally easy to identify visually. Random probing with the manipulator arm did allow bark depth to be estimated, but did not reveal any hidden bark accumulations. Bark depth measurements could be useful in future studies, but was not measured in this study. When bark coverage was >50% of an area it was designated “bark-dominated,” and all species noted were considered within bark-dominated habitat. When bark coverage was <50% it was considered to be “bark-free,” and species were considered within a bark-free habitat even if scattered bark was present. Highly motile species, such as fish, that moved over areas where bark was present and therefore could be “exposed” to bark-covered habitat were considered to occupy bark-dominated habitat, whereas sedentary species, such as sponges, that were attached to rock in a clean area surrounded by scattered bark accumulations were considered to occupy bark-free habitat.

We divided the benthic substrate into three general types: (1) level with a predominately silty substrate, (2) moderate incline slope with a predominately cobble substrate, and (3) steep with a predominately rocky substrate. These 3 substrate types were further categorized as bark-dominated or bark-free, for a total of 6 habitat types.

Analysis

The videotapes from the 9 submersible dives in Dora Bay were examined to determine bark accumulation areas and depths, to list animal species observed and their relative abundance, and to record the general habitat types where the species were observed. This involved reviewing the videotapes and listening to the observer’s comments. This semiquantitative analysis was done on site with the observer, to the extent possible, and upon return to Juneau.

Two statistical tests were conducted to determine if the presence of bark is related to the distribution of species within habitats. McNemar’s test (Conover 1980) tested the null hypothesis that within a given habitat type a species is as likely to be found in bark-dominated areas as in bark-free areas. This analysis compares the number of species found in bark-free areas with the number found in bark-dominated areas. Second, Friedman’s 2-way analysis of ranks (Conover, 1980) tested whether the distribution of abundance differed among all 6 habitat-bark combinations and then determined which combinations specifically differ. For this analysis, the abundance was ranked from 1 (not present) to 5 (abundant) by category, then an analysis of variance was performed with species as blocks and habitat-bark combinations as factors. Both of these analyses assume that each species does not influence the distribution of other species. Although this is probably not true, strong interactions have yet to be demonstrated for the species included in this study (Paine 1980), and strong interactions would probably be necessary for one species to have a significant effect on the distribution of another species for the purposes of this analysis. Also, neither analysis compensated for the different amount of area surveyed for each habitat-bark combination, so that a species-area effect may have some influence. Finally, a subjective appraisal of abundance may be biased if the observer has preconceived notions about the effect being studied.

RESULTS

Bark and debris accumulations were noted primarily on inclines and steep terrain. Little bark was noted on the level terrain, which was generally at the greatest depths and the greatest distance from surface facilities.

Habitat Differences

A diverse benthic community exists in Dora Bay below 20 m depth. On the 9 dives 8 animal phyla were identified and 90 taxa were identified, 74 to species and 13 to genus or family (Table 1). Commercially harvested species were observed, including dock shrimp, Alaskan pink shrimp, coonstriped shrimp, spot shrimp, Tanner crab, California sea cucumbers, Pacific halibut, red urchins, and several rockfish species (Table 1). It should be noted that this study only sampled epifauna and did not consider infauna.

Although the distribution of bark was modified by local topography and currents, bark-dominated areas were generally associated with surface logging facilities (Figure 1). Bark and debris accumulations were visibly noted in the 3 general habitat types (Figure 3)

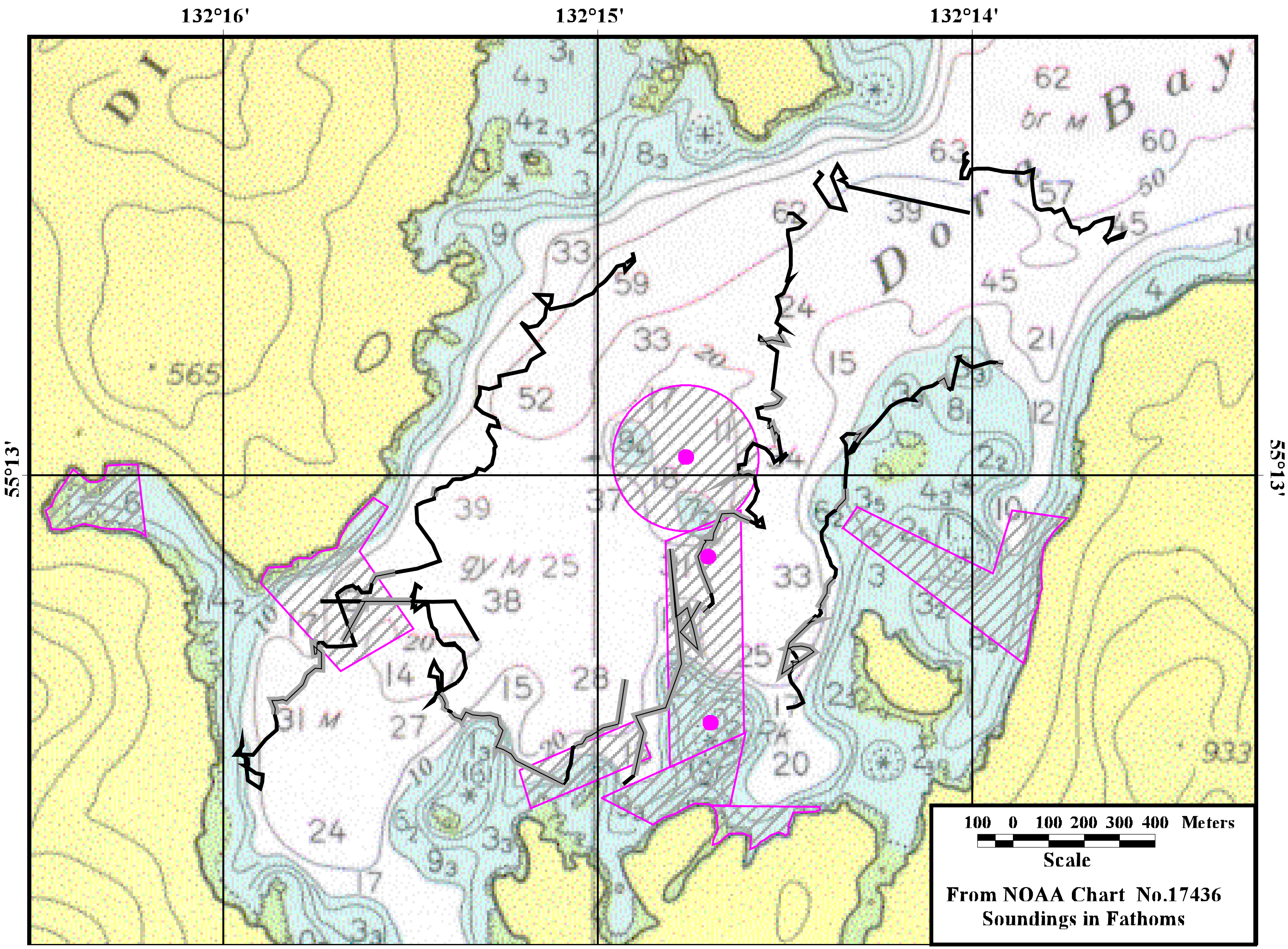

Figure 1. Submersible transects in Dora Bay, Prince of Wales Island, Alaska, July 1997.

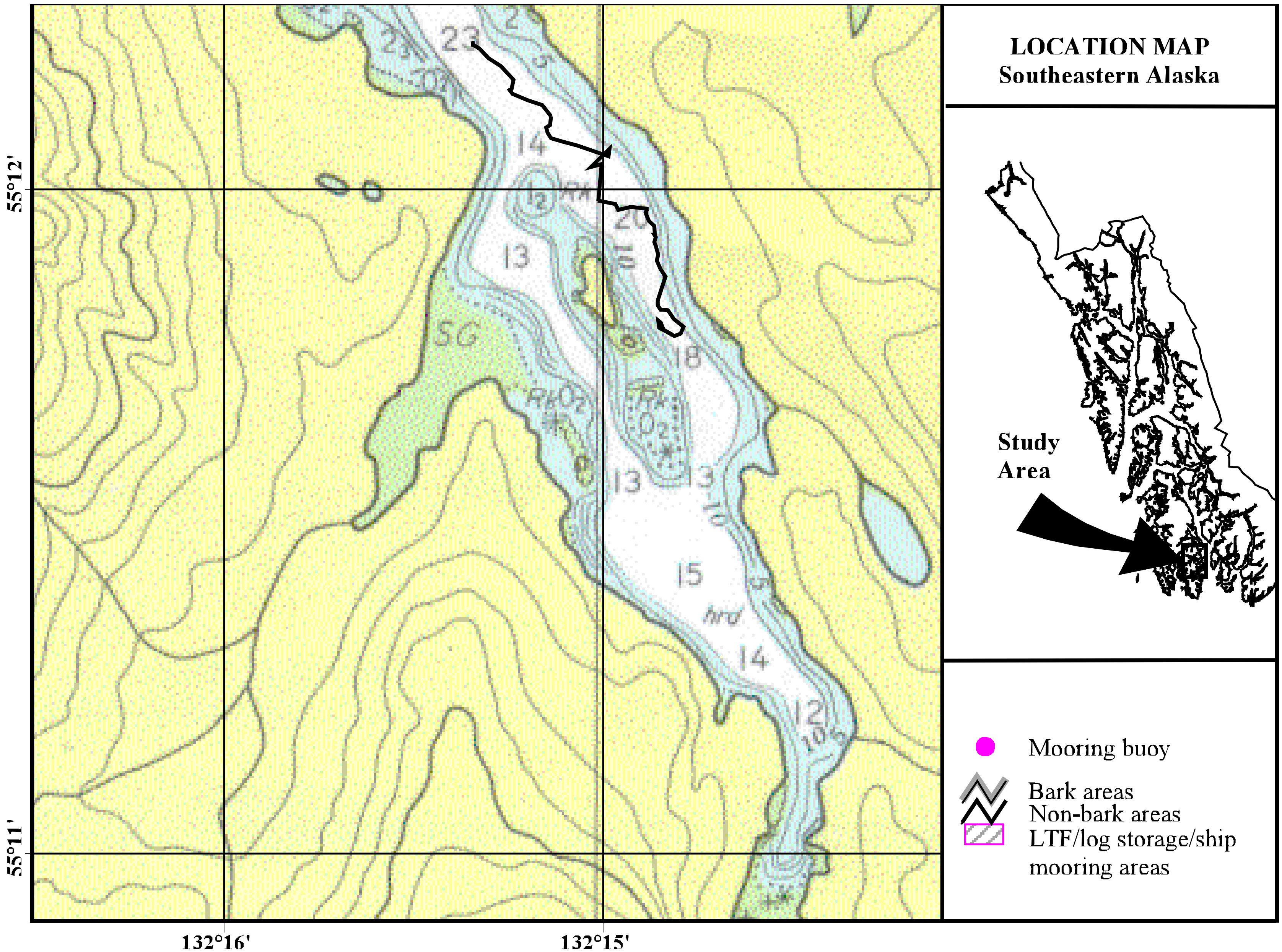

Figure 1. (continued).

and throughout the range of depths to >70 m (Figure 4).

The steep, rocky, bark-free habitat contained the most diverse taxonomic assemblage, including 68 of the 90 identified taxa (Figure 3). Many organisms were found almost exclusively on this habitat, such as the anemones, epibenthic worms, gastropods, and brachiopods. In addition, most of the sponges, sea stars, tunicates, and rockfish were only found in this habitat. By comparison, the steep, rocky bark-dominated habitat was fourth in species richness, following the 3 bark-free habitats; only 18 taxa were recorded on these areas. Sea stars and sea cucumbers had the greatest species richness, accounting for half the species recorded in this habitat. Five species of fish were observed.

The moderate incline, cobble, bark-free habitat was second in species richness with 36 taxa (Figure 3); crabs, sea stars, brittle stars, and sea cucumbers were the most common invertebrates, and 9 species of fish were noted on this habitat. The bark-dominated counterpart of this habitat had much lower species richness. Only 13 taxa were observed on this habitat, primarily sea cucumbers and sea stars and 7 species of fish.

Figure 2. Delta Oceanographics submersible in Dora Bay, Prince of Wales Island, Alaska, July 1997.

The flat, silty, bark-free habitat was third in species richness with 25 taxa (Figure 3). This habitat tended to be located toward the center of Dora Bay and was found at the greatest depths. Areas with no apparent bark accumulation had high densities of some shrimp and fish species. These high densities were noticeably absent in the bark-dominated counterpart, but bark in this habitat type was encountered during <1% of the bottom time, presumably because it was furthest removed from the surface facilities.

Solid waste disposal is specifically prohibited according to the federal and state permits under which these facilities operate. Large quantities of solid waste were observed in all areas containing bark accumulations. Cable was the most abundant item noted; it was present in all bark accumulation areas, often in large quantities. The cable observed was mostly in the form of short pieces, but longer pieces and whole coils were present. Beverage cans and sunken boom logs were common; work implements and household items were also noted.

Bark-Dominated vs. Bark-Free Areas

The number of species was highly significantly different between bark-dominated and bark-free areas within habitat type (McNemar's test). Table 2 displays the distribution of species for each habitat, along with the chi-square value and the *P*-value from the test. Compared to bark-dominated habitats, more taxa were present in all bark-free habitats. The distributions of taxa abundance were highly significantly different (Friedman's test, $P<0.0001$) among the 6 habitat-bark combinations, but of greater interest is the pair-wise comparison of means of the ranks (Table 3). All bark-free habitats had significantly greater mean ranks than their respective counterparts with bark.

DISCUSSION

Reduced benthic infaunal and epifaunal diversity and abundance have been documented in shallow-water (<20 m) bark accumulation areas by several authors (Pease 1974; Schultz and Berg 1976; Conlon and Ellis 1979; Jackson 1986). Although this study was not rigor-

Table 1. List of species observed during submersible dives, number of transects where the species were encountered, and relative abundance by 6 habitat types (r = rare, u = uncommon, c = common, and a = abundant); in Dora Bay, Alaska, July 1997.

			Habitat Type					
			No Bark			Bark		
Scientific Name	Common Name	# Transects Occurring On	Level (Silt) 25%	Incline (Cobble) 14%	Steep (Rocky) 26%	Level (Silt) <1%	Incline (Cobble) 19%	Steep (Rocky) 16%
Porifera								
Aphrocallistes vastus	Cloud sponge	3			U			
Cliona sp.		1			R			
Leucandra heathi	Spiny vase sponge	3			A			
Polymastia pacifica	Aggregated nipple sponge	4			C			
Porifera, unidentified	Sponges	4	R	U	A			U
Cnidaria								
	Unidentified Jellyfish	4		U	C			
Anthozoa								
Virgularia sp.	Sea Whip	1	R					
	Anemones							
Cribrinopsis fernaldi	Crimson anemone	3			U			
Epiactis sp.	Sea anemone	2			R			
Metridium giganteum	White Plumed anemone	1	R					
Pachycerianthus fimbriatus	Tube dwelling anemone	3			U			
Stomphia coccina	Swimming anemone	2			R			
Urticina crassicornis	Sea anemone	1			R			
Mollusca								
Gastropoda								
Prosobranchia	Snails							
Fusitriton oregonensis	Oregon triton	2			R			
Opisthobranchia	Nudibranchs							
Archidoris montereyensis	Monterey sea-lemon	1			U			
Archidoris odhneri	White night doris	3			U			
Tochuina tetraquetra	Giant orange tochui	1			R			
Nudibranchia, unidentified	Nudibranch	1			U			
Bivalvia								
Chlamys rubida	Reddish scallop	5	R	U	C			U
Crassedoma giganteum	Giant rock scallop	1		U				
Mytilus trossulus	Blue mussel	2		U			U	
Tresus nuttallii	Pacific gaper	1	C					
Cephalopoda								
Rossia pacifica	Squid	1	R					
Annelida								
Polychaeta								
Myxicola infundibulum	Sabellid worm	3			A			
Pseudochitonopoma occidentalis	Serpulid worm	1			A			
Serpula vermicularis	Serpulid worm	4			A			
	Serpulid worms – no id	1			A			

– *continued* –

Table 1. (continued)

Scientific Name	Common Name	# Transects Occurring On	Habitat Type: No Bark: Level (Silt) 25%	No Bark: Incline (Cobble) 14%	No Bark: Steep (Rocky) 26%	Bark: Level (Silt) <1%	Bark: Incline (Cobble) 19%	Bark: Steep (Rocky) 16%
Arthropoda								
Crustacea								
Malacostraca	Mysids	3	A		C			
Decapoda								
Caridea	Shrimp							
Pandalus danae	Dock shrimp	4	U	R				
Pandalus borealis	Alaskan pink shrimp	7	A			U		
Pandalus hypsinotus	Coonstriped shrimp	6	C		R			
Pandalus platyceros	Spot shrimp	6	C		A	U		
Anomura	Crabs							
Acantholithodes hispidus	Spiny lithode crab	2		U	U			U
Lopholithodes foraminatus	Brown boxcrab	1		R				
Munida quadrispina	Squat lobster	7	C	C	C	C		
Paguridae, unidentified	Hermit crabs	5		U				
Brachyura	Crabs							
Chionoecetes bairdi	Tanner crab	3	C	R			R	
Hyas lyratus	Pacific lyre crab	2		U	U			R
Oregonia gracilis	Graceful decorator crab	3		R				
Telmessus cheiragonus	Helmet crab	1			R			
Brachiopoda								
Terebratalia transversa	Lamp shells	3			C			
Echinodermata								
Asteroidea	Sea Stars							
Ceramaster patagonicus	Cookie star	3			U			
Crossaster papposus	Rose star/ snowflake star	2			U			
Dermasterias imbricata	Leather Star	1			R			
Evasterias troschelii	Mottled star	4		U	U			U
Gephyreaster swifti	Sea star	6		U	C			
Henricia leviuscula	Blood star (white)	8		U	C		R	R
Lethasterias nanimensis	Sea star	3		U	U			
Mediaster aequalis	Vermilion star	3			C			
Orthasterias koehleri	Rainbow star	3			C			
Pisaster ochraceus	Purple/ Ochre star	2		R	C			U
Pteraster tesselatus	Cushion star	3			U			U
Pycnopodia helianthoides	Sunflower star	7		C	C		C	C
Solaster dawsoni	Dawson's Sun star	3		U	U			U
Stylasterias forreri	Fish eating star	4		C	C			U
Ophiuroidea	Brittle Stars							
Ophiuroids	Unidentified Brittle Stars	3	C	C	C		C	
Ophiura sarsi	Brittle Star	2	R		C			
Echinoidea								
Strongylocentrotus franciscanus	Red urchin	3		R	U			

– continued –

Table 1. (continued)

			Habitat Type					
			No Bark			Bark		
Scientific Name	Common Name	# Transects Occurring On	Level (Silt) 25%	Incline (Cobble) 14%	Steep (Rocky) 26%	Level (Silt) <1%	Incline (Cobble) 19%	Steep (Rocky) 16%
Holothuroidea								
Cucumaria piperata	Sea cucumber	3		C	U			
Parastichopus californicus	California sea cucumber	8		A	A		C	A
Psolus chitonoides	Slipper sea cucumber	4		U	A			C
Chordata								
Urochordates								
Ascidia paratropa	Glassy tunicate	3			U			
Boltenia villosa		1		C	C			
Didemnum sp.	Tunicate- compound	1			U			
Halocynthia aurantium	Sea peach	5			U			
Halocynthia igaboja	Tunicate	2			C			
Pyura haustor		1			C			
Styela sp.		1			C			
Vertebrata								
Cottid	Sculpin	2		R			R	
Hemilepidotus hemilepidotus	Red Irish lord	2	R					
Hexagrammos decagrammus	Kelp greenling	7		U	U		C	
Hexagrammos stelleri	Whitespotted greenling	1		U				
Hippoglossus stenolepis	Pacific halibut	7	C	U		U	U	
Hydrolagus colliei	Spotted Ratfish	2	C					
Lumpenus sagitta	Snake prickleback	7	A	U	U		U	
Microgadus proximus	Pacific Tomcod	4	U					
Myoxocephalus polyacanthocephalus	Great sculpin	1		R				
Platichthys stellatus	Starry flounder	2	C					
Pleuronectid, unidentified	Flatfish	1	C					
Lepidopsetta bilineata	Rock sole	3	U				U	
Sebastes caurinus	Copper rockfish	1			U			
Sebastes ciliatus	Dusky rockfish	1			R			
Sebastes maliger	Quillback rockfish	7	R	U	A			C
Sebastes melanops	Black rockfish	1			C			
Sebastes nigrocinctus	Tiger rockfish	4			U			
Sebastes reedi	Yellowmouth rockfish	1			R			R
Sebastes ruberrimus	Yelloweye rockfish	3		U	U		U	U
Sebastes nebulosus	China rockfish	2			U			
Sebastes sp.	Unidentified Rockfish	1			A			C
Zoarcidae	Eelpout	9	A	C	U		C	U

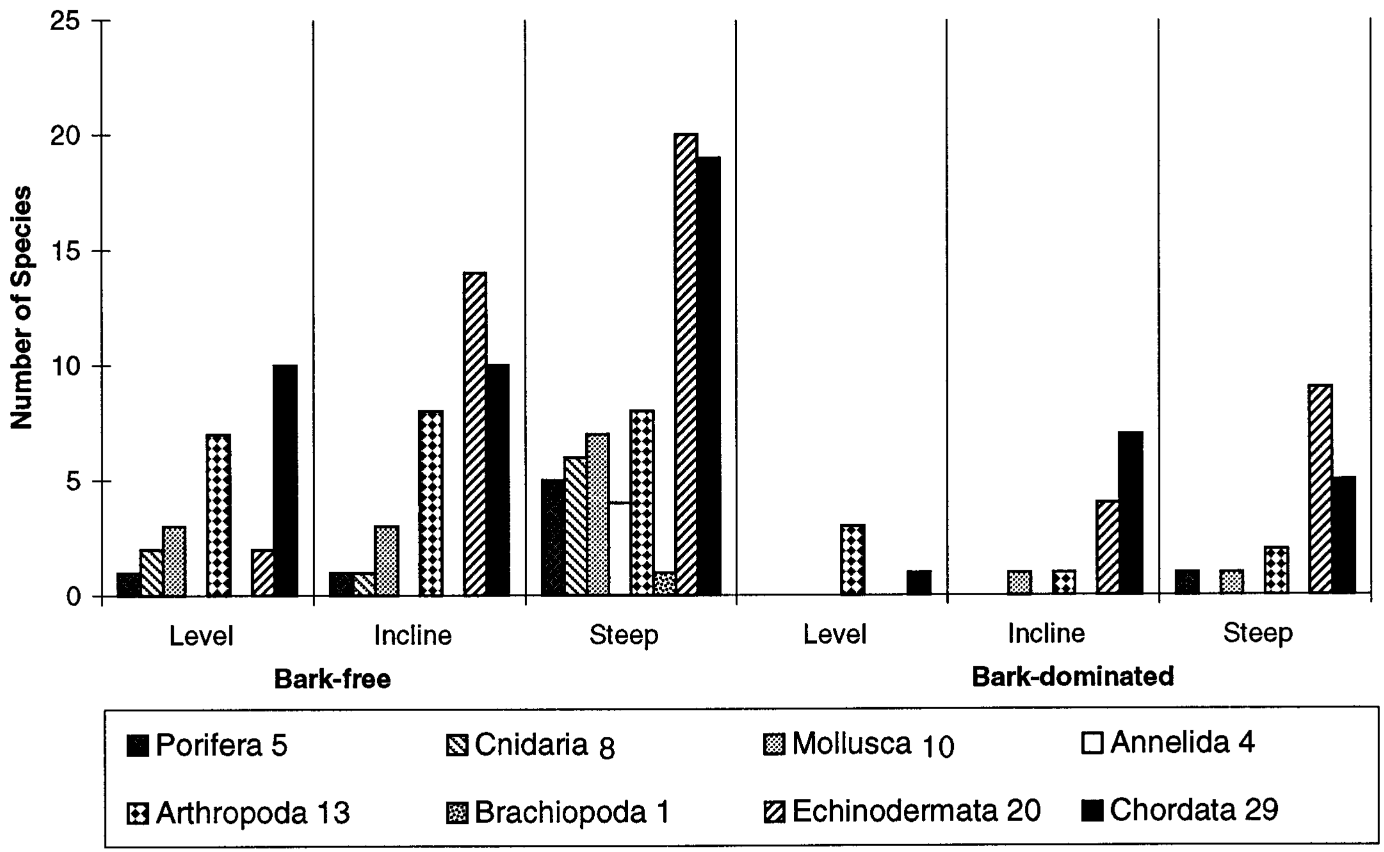

Figure 3. Distribution of number of species by phylum observed in bark-free and bark-dominated habitats in Dora Bay, Prince of Wales Island, Alaska, July 1997.

Table 2. Results of McNemar's test comparing number of species in bark-free versus bark-dominated areas by substrate type.

		Bark-Dominated				
Substrate: Level						
		Present	Absent	Total	X^2	p-value
Bark-free	Present	4	21	25	21.00	<0.0001
	Absent	0	66	66		
	Total	4	87	91		
Substrate: Incline						
		Present	Absent	Total	X^2	p-value
Bark-free	Present	12	24	36	23.04	<0.0001
	Absent	1	54	55		
	Total	13	78	91		
Substrate: Steep						
		Present	Absent	Total	X^2	p-value
Bark-free	Present	18	51	69	51.00	<0.0001
	Absent	0	22	22		
	Total	18	73	91		

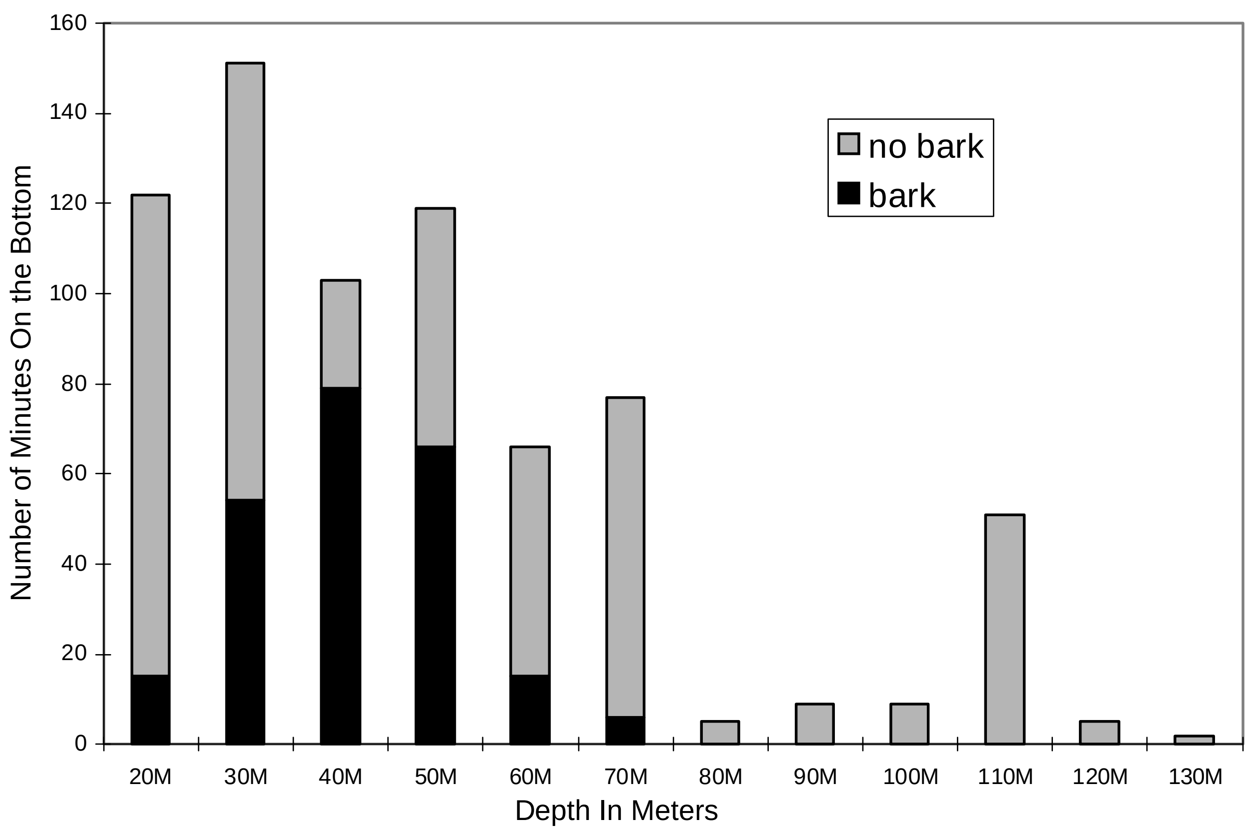

Figure 4. Amount of time submersible spent on bottom by bathymetric depth in July 1997.

Table 3. Comparison of mean ranks of habitat-bark type derived from Friedman's 2-way analysis of variance. Habitat-bark types with the same grouping letters are not significantly different at the 0.05 level (the least significant difference in mean ranks is 0.2766).

Grouping		Mean Rank	Habitat-Bark Type
	A	2.8571	Steep, Bark-free
	B	1.8022	Incline, Bark-free
C	B	1.6593	Level, Bark-free
C	D	1.4286	Steep, Bark-dominated
E	D	1.3077	Incline, Bark-dominated
E		1.0989	Level, Bark-dominated

ous enough to quantify the reduced abundance on a scale more exact than the ordinal scale, it corroborates these findings. We also found reduced species richness in areas with bark extending to depths >70 m, which is well below the approximately 20-m depth above which bark monitoring is required.

Reduced species richness was noted in all bark-dominated areas. Certain phyla including Porifera, Cnidaria, Mollusca, Annelida, Arthropoda, and Brachiopoda were notably absent from bark-dominated areas. These phyla included 41 of the 90 taxa observed overall. Several taxa appeared to be little affected by bark accumulation including: sea cucumbers, especially *Parastichopus californicus*, and several sea stars. These species were observed even in areas with heavy bark accumulation. Several fish species were also observed in bark-dominated areas; because of their mobility, we could not determine if the fish were utilizing the bark-dominated areas in some way or simply swimming across them.

Current federal and state permits for operating LTFs require monitoring for bark accumulation to a depth of approximately <20 m, which is considered standard, safe scuba survey depth. In Dora Bay, bark accumulations at depths of at least 40 m were found on 6 of 9 dives, and 3 dives recorded significant bark accumulations at 70-m depths. Our results indicate that the dive surveys conducted for the 2 LTFs (Alaska Commercial Divers 1994) grossly underestimated the areal extent of bark accumulation. These 2 surveys also indicated that bark accumulation was decreasing during periods of LTF inactivity. In areas near steep submarine slopes, similar to Dora Bay, it is likely that the bark is displaced down slope and will accumulate in deeper areas adjacent to the monitoring area, essentially expanding the impacts from shallow water into deep water. Schultz and Berg (1976) and Freeze et al. (1988) found that accumulations of bark and wood debris persisted up to 26 years.

If there is adequate visibility under water, submersibles (manned or remotely operated) appear to be a useful tool for monitoring bark accumulation and determining the effects of this accumulation on benthic communities in deep water near logging facilities. Use of this tool should aid facility owners and resource managers in making decisions that are more informed when considering locations and designs for LTFs and LRSs, to better quantify impacts from existing facilities to the benthic infauna, and to improve monitoring of compliance with permit stipulations. This study also indicates there is a need to monitor solid waste disposal. Currently, permit stipulations do not require solid waste be noted during bark surveys or removed in a timely fashion.

This study was designed to be a preliminary study, not a quantitative analysis of bark accumulation impacts. Statistical analyses conducted with this report are only indicators of the effect bark accumulation is having on Dora Bay. Future studies of the impact of bottom bark deposits on benthic communities must rigorously quantify benthic biota. For biota that are observed in substantial numbers, density estimates could be made with line transects to detect species distribution patterns relative to depth, substrate, and location (Zhou and Shirley 1996, Thompson 1992).

The present study has shown that there are significant impacts occurring to benthic habitat in water >20 m. Because there is currently no monitoring of deeper sites, we have little knowledge of bark distribution in deep water at other bays with logging facilities in Southeast Alaska, and we have little understanding of the impacts of bark deposits on the deep benthos. Monitoring impacts at some level at greater depths is needed, as well as further investigations designed to quantify the impacts of bark accumulation on deep water habitat.

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