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Effects of Log Dumping and Rafting on the Marine Environment of Southeast Alaska

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ABSTRACT

The extent of water-dependent log handling and storage facilities in southeast Alaska is summarized, along with the available literature on the environmental impact of these facilities. Field studies were conducted at 16 sites and correlated with laboratory studies of leaching rates and toxicity of the four major wood species harvested in southeast Alaska. Significant effects on water quality are believed to occur only under unique conditions and were observed at only 2 of the 16 study sites. Bark deposits with a high demand for oxygen were observed at all active and abandoned log dumping sites. The abundance of benthic infauna was noticeably reduced in bark covered areas and intertidal raft storage areas. The laboratory studies demonstrated that oxygen demanding organic compounds rapidly leach from logs in water, but precipitate in salt water. The wood leachates are toxic to pink salmon fry in the laboratory but probably have little effect on fish in the natural environment. Further studies are needed to further quantify the environmental impact of water-oriented log handling practices.

Keywords: *Logging rafts, fish management, water quality.*

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EFFECTS OF LOG DUMPING AND RAFTING ON THE MARINE ENVIRONMENT OF SOUTHEAST ALASKA

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by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Background

Southeast Alaska is basically a system of islands convoluted with numerous bays and estuaries (Fig. 1). Because of the water-oriented geography and lack of roads, most commercially harvested timber in Southeast Alaska is stored and transported on its marine waters.

The water-dependent log handling and storage facilities in Southeast Alaska are of four types (State of Alaska, 1971):

1) Sale area dumping sites
2) Sale area raft collecting and storage sites
3) Winter raft storage sites
4) Mill storage and sorting sites

Logs are introduced into the water at the sale area dumping sites by a variety of methods. Usually, they are bundled with steel bands while still on the logging truck, then lifted and lowered into the water with an A-frame crane (Fig. 2). In some logging operations the log bundles are slid or skidded into the water; in others individual logs are either lifted, slid, or skidded into the water and bundled there.

The log bundles are then collected into rafts of approximately 70 ft by 550 ft and 300 to 600 thousand board feet (bd ft). The rafts remain at the sale area raft collecting and storage sites until they are towed to either the mill storage and sorting sites or the winter raft storage sites. The mill storage and sorting areas are usually in deep water located near the processing mills. Here logs are kept for only a short time, as they are usually processed soon after arriving. The winter storage sites are often intertidal areas near the heads of estuaries. Here the log bundles ground at low tide and receive freshwater from inland streams (Fig. 3). Logs kept at the winter storage sites are usually in excess of the demand from summertime processing at the mills and are drawn upon gradually during the winter and spring. Intertidal areas are chosen for extended log storage because grounding at low tide and the relatively low salinities minimize infestation by marine wood-boring organisms, known as "teredos" (*Bankia setacea*). Most logs in Southeast Alaska are handled and stored at

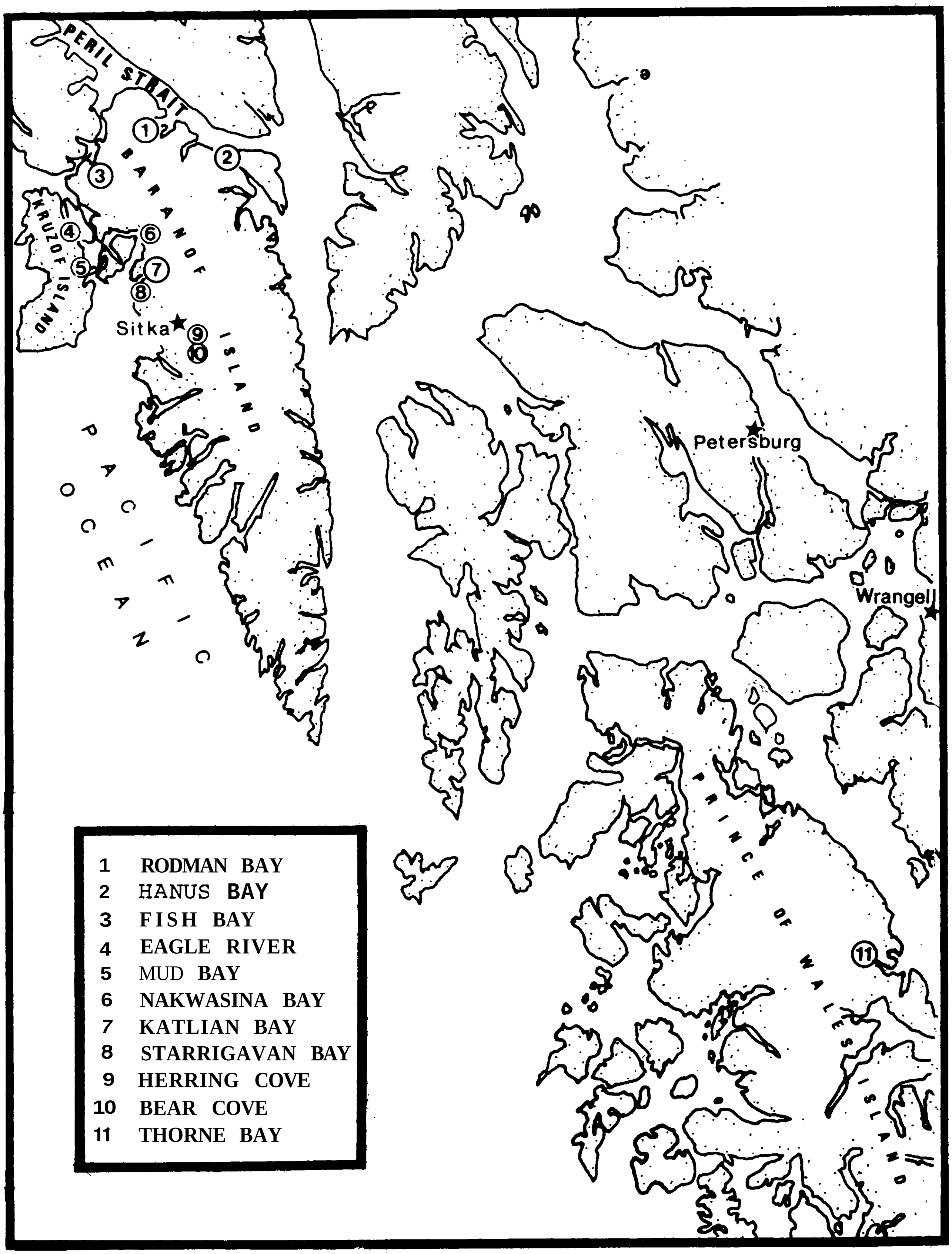

Figure 1. Study sites in Southeast Alaska.

Figure *2.* Active log dump at Thorne Bay.

Figure 3. Intertidal raft storage at Fish Bay.

the heads of bays and estuaries for protection from teredos and from stormy weather.

Scope of the Problem

Approximately 60 individual logging companies operate within Southeast Alaska (State of Alaska, 1971). They supply timber to two large pulp mills and approximately 18 smaller saw mills in Southeast Alaska. In 1970, they harvested 560 million bd ft of timber, 70% of which was hemlock (*Tsuga heterophylla*), 25% spruce (*Picea sitchensis*), and 5% red and yellow cedar (*Thuja plicata* and *Chamaecyparis nootkatensis*) (State of Alaska, 1971). A total of 650 acres (approximately 1 sq mi) of water was used for the storage and handling of that timber. Since some of the logging companies move their operations to new areas each year, a large area of water has been used for log handling and storage in Southeast Alaska,

The literature on the effects of log dumping and rafting on the marine environment of Southeast Alaska is very scanty, In 1970, investigators from the Auke Bay Biological Laboratory of the National Marine Fisheries Service described the extent and impact of bark debris at one active dumping site, three abandoned dumping sites, an active raft storage area, and two control areas (U.S. Fish and Wildlife Service, 1970). SCUBA divers made subjective observations on the amounts of bark, wood debris, and other debris on the bottom, as well as the relative numbers and types of large benthic organisms in the area. Drastic depletion of benthic organisms was observed at three dumping sites, along with thick beds of bark and organic debris, and scattered steel bands and cables, A less used dumping site had an insignificant amount of debris and appeared to have a normal population of benthic organisms. At the active raft storage area the benthos was apparently unaffected except directly under the rafts, where shading had apparently inhibited the growth of algae on the bottom. Three other active dumping sites were investigated in 1967 by Ellis (1970). Despite their use for as long as 12 years, they had no accumulation of bark and debris; however, strong currents were measured there at the time of investigation.

Schaumburg (1973) investigated the environmental impact of the freshwater-oriented log handling practices of Oregon and concluded that:

1) significant quantities of bark are dislodged during log dumping and rafting activities;

2) bark deposits exert a small, but measurable, chemical and biological demand for oxygen from overlying waters;

3) organic compounds leach from logs when stored in water;

4) log leachates exert a chemical and biological oxygen demand;

5) log leachates add color-producing substances to the water; and

6) Douglas fir leachate is acutely toxic to rainbow trout and chinook salmon fry in freshwater,

A task force of the Pacific Northwest Pollution Control Council (1971) recently evaluated the environmental impact of log dumping and storage in public waters. It made a number of recommendations for abatement of ill effects, most of which differ from present practices in Southeast Alaska. The task force has been criticized by industry representatives for reaching tentative conclusions on the basis of limited scientific data. Rational decisions can be made regarding alternative log handling procedures only after the environmental impact of the present methods is known in greater detail.

Project Objectives

1) To determine the effects of log dumping and rafting on the water quality of Southeast Alaska by measuring the concentration of organic log leachates, biological oxygen demand, dissolved oxygen, and hydrogen sulfide in the water at varying distances from log dumping, log rafting, and control sites.

2) To determine the effects of log dumping and rafting on benthic organisms in Southeast Alaska by making a comparative survey of the kinds and relative abundances of benthic organisms associated with log dumping, log rafting, and control sites.

3) To determine the relative leaching rates of hemlock, spruce, red cedar, and yellow cedar logs in sea water.

4) To determine the toxicity of hemlock, spruce, red cedar, and yellow cedar log leachates to organisms found at log dumping and log rafting sites.

5) To evaluate the economics of log towing vs log barging.

6) To make recommendations for further study.

MATERIALS AND METHODS

Field Studies

Study Sites and Sampling Stations

Studies of water quality and benthic fauna were conducted during the summer of 1972 at the locations shown in Fig. 1, belonging to six categories of facilities (Table 1); hereafter referred to by the abbreviations given in Table 1, as follows:

1) active log dumping site
2) abandoned log dumping site
3) sale area log raft collecting and storage site
4) winter raft storage site
5) mill storage and sorting site
6) control site

The active log dumping sites were selected on the basis of age and the amount of timber that had been put into the water. Information on the log dumping activity at the study sites is compiled in Table 2. The abandoned log dumping sites were chosen to include varying ages of disuse (Table 2), but were easily identified from the presence of old cribbing and miscellaneous debris. At least one site representing each of the three categories of rafting sites was studied (Table 1). Information on the log rafting activity at the study sites is compiled in Table 3. Three control sites were selected (Table 1), on the basis of comparative similarity in physical and chemical characteristics, such as depth, bottom type, salinity, temperature, etc., with the rafting and dumping sites. It was assumed that the control sites had never been used for log handling.

Table 1. Site abbreviations and classifications

Site location	Type of facility	Abbreviation[1]
Hanus Bay	Active dump	HD
Mud Bay	Active dump	MD
Thorne Bay	Active dump	TD
Eagle River	Abandoned dump	ED
Katlian Bay	Abandoned dump	KD
Nakwasina Sound	Abandoned dump	ND
Starrigavan Bay	Abandoned dump	SD
Rodman Bay	Abandoned dump	RD
Thorne Bay	Sale area raft collecting and storage	TR
Fish Bay	Winter raft storage	FS
Rodman Bay	Winter raft storage	RS
Bear Cove	Mill storage and sorting	BR
Herring Cove	Mill storage and sorting	HR
Katlian Bay	Control	KC
Rodman Bay	Control	RC
Thorne Bay	Control	TC

[1]These abbreviations hereafter are used in reference to sites.
First letter of abbreviation = First letter of site location.
Second letter of abbreviation = First letter from type of facility.

Table 2. Log dumping activity at study sites[1]

Site	Method of dumping	Total years active	Years of disuse	Amount dumped (MMBF)[2]	Percent of total board feet dumped: Hemlock	Spruce	Cedar
TD	A-frame crane	10	0	550	70	25	5
MD	A-frame crane	7	0	210	70	30	0
HD	A-frame crane	1	0	8	70	30	0
SD	Slide ramp	3	1	7	85	14	1
ED	A-frame crane	1	2	27	70	30	0
RD	A-frame crane	7	5	162	70	30	0
KD	A-frame crane	6	7	113	41	59	0
ND	A-frame crane	2	11	37	38	62	0

[1]Personal communication with Mr. Allen Aitken of the US Forest Service.
[2]MMBF = million board feet.

Table 3. Log rafting activity at study sites[1]

Site	year rafting began	Total years active	Normal storage (rafts)	Percent composition of rafts: Hemlock	Spruce	Cedar
TR	1962	10	60	70	25	5
HR	1965	7	6	60	40	0
BR	1965	7	10	60	40	0
FS	1959	13	40	60	40	0
RS	1969	3	40	60	40	0

[1] State of Alaska, Department of Environmental Conservation, Water Quality Control Section, 1971.

The locations of the sampling stations are shown in Figs. 4 through 10. A linear series of four stations perpendicular to the shoreline, at increasing distances from the dumping site, were sampled at all active and abandoned dumping sites, with one station at each of the lateral boundaries of the dumping site (for example, see Fig. 8). A varying number of stations were sampled at different rafting sites. At least one station near the center of a raft storage area was always sampled, along with other stations around the perimeter of and at a distance from the rafts (for example, see Fig. 7). A linear series of stations was sampled at the control sites (for example, Fig. 4).

Water Quality

Sampling. Water samples were collected at the surface and just above the bottom at each station. The bottom samples were collected utilizing a van Dorn bottle. Two methods were used to sample the surface waters at each station. A 2-ft column of water was sampled by placing the van Dorn bottle several inches below the surface, and the top 1 to 2 inches of surface water was sampled by slowly filling a BOD bottle at the surface. The surface water samples collected using the van Dorn bottle are hereafter referred to as "van Dorn surface" samples, while the surface water samples collected using a BOD bottle are hereafter referred to as "surface" samples.

Analysis of Water Samples

Salinity and Temperature. Measurements were conducted with a Kahlsico hydrometer kit immediately after collection of the samples. Salinity was measured with hydrometers accurate to ±0.5 ppt, and temperature with a mercury thermometer accurate to ±0.1 C.

Dissolved Oxygen. The azide modification of the Winkler method was used and the procedures outlined by the American Public Health Association (APHA) et al. (1971, pp. 477-481) were followed. Accuracy of determination was to ±0.1 ppm. The dissolved oxygen concentration (DO) measurements were converted to percent oxygen saturation with a nomograph, using the data on temperature and salinity.

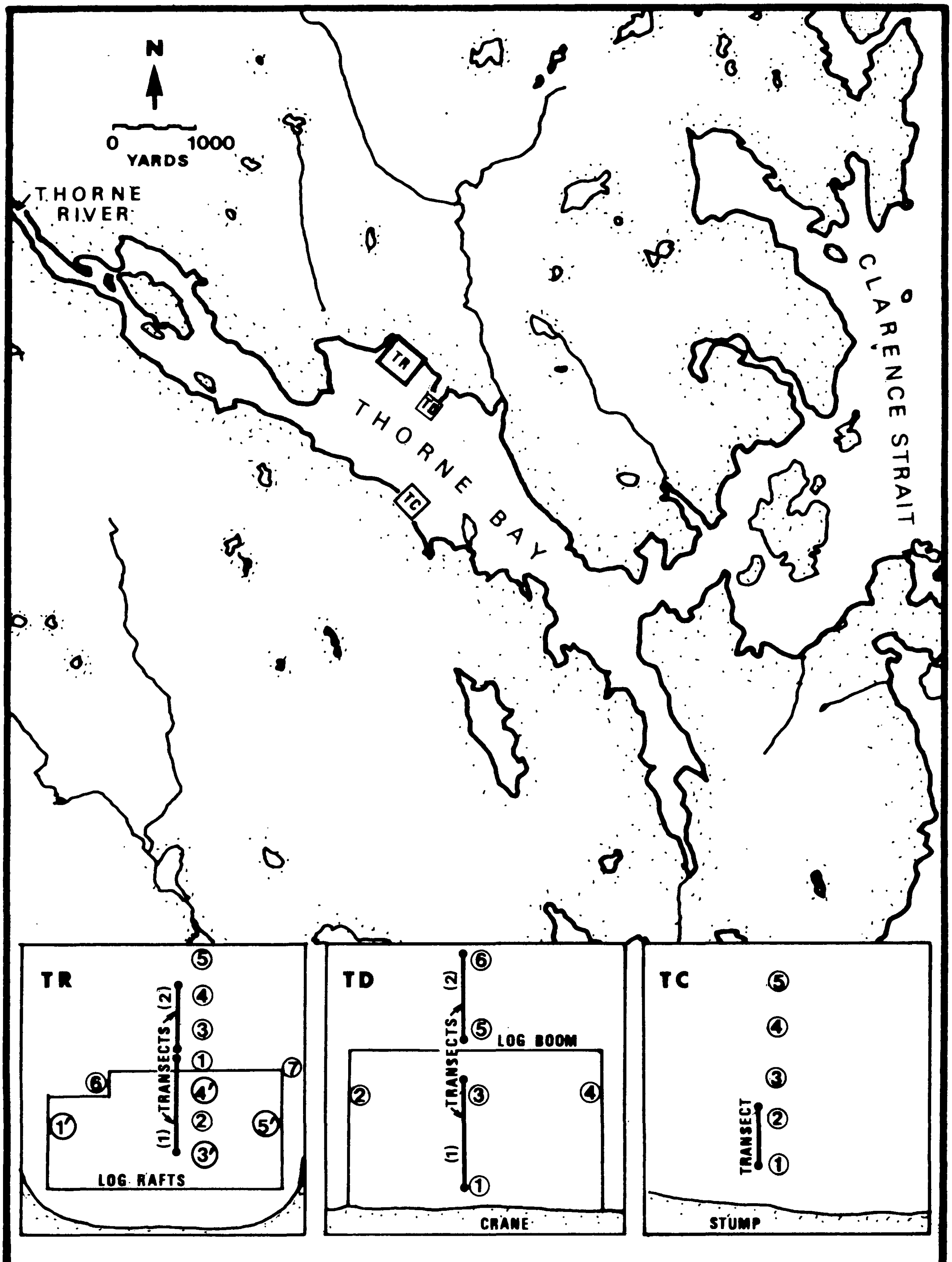

Figure 4. Thorne Bay sampling stations (stations 1',2,3', 4',5' sampled 7/19/72).

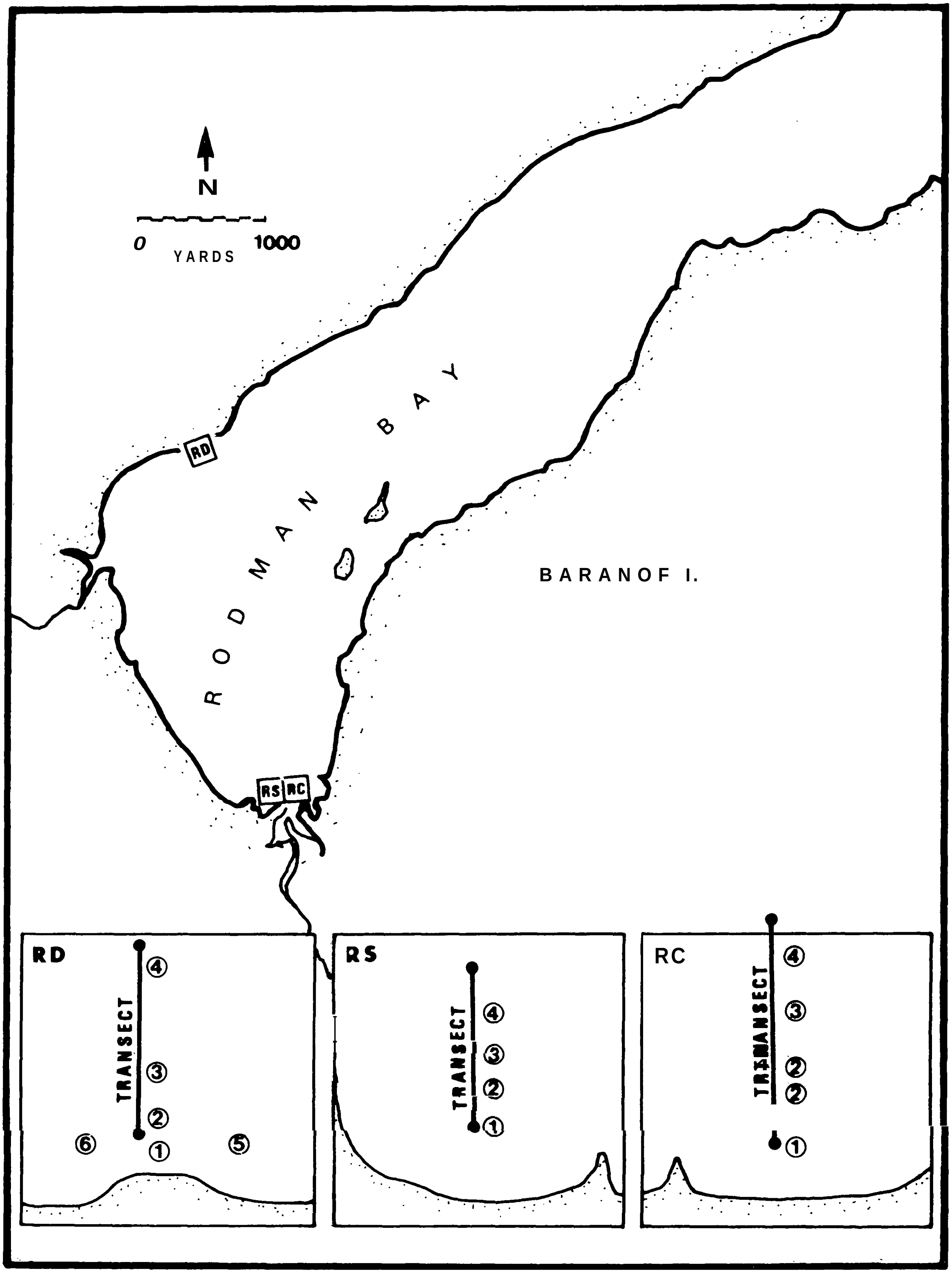

Figure 5. Rodman Bay sampling stations.

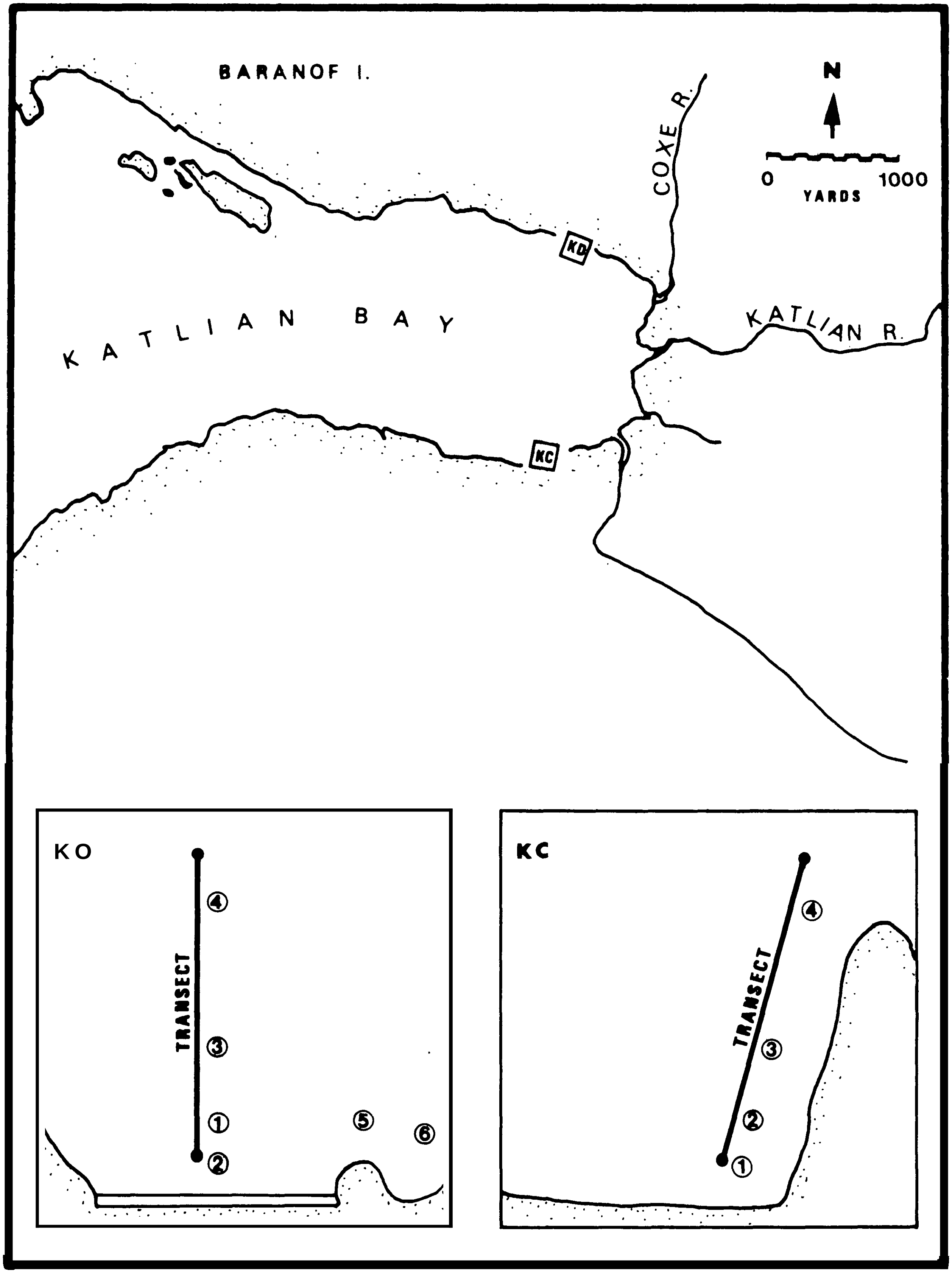

Figure 60 Katlian Bay sampling stations.

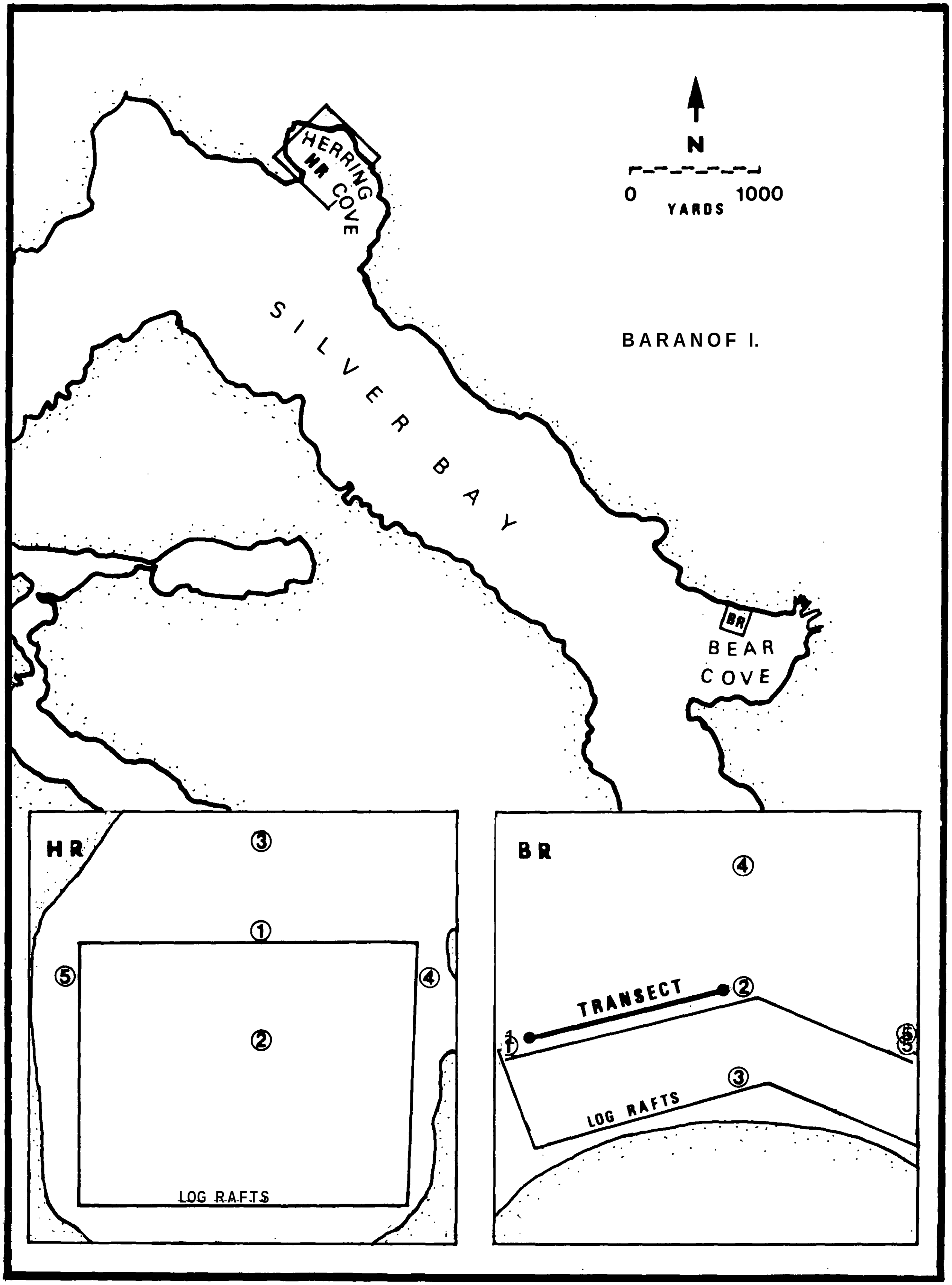

Figure 7. Herring Cove and Bear Cove sampling stations.

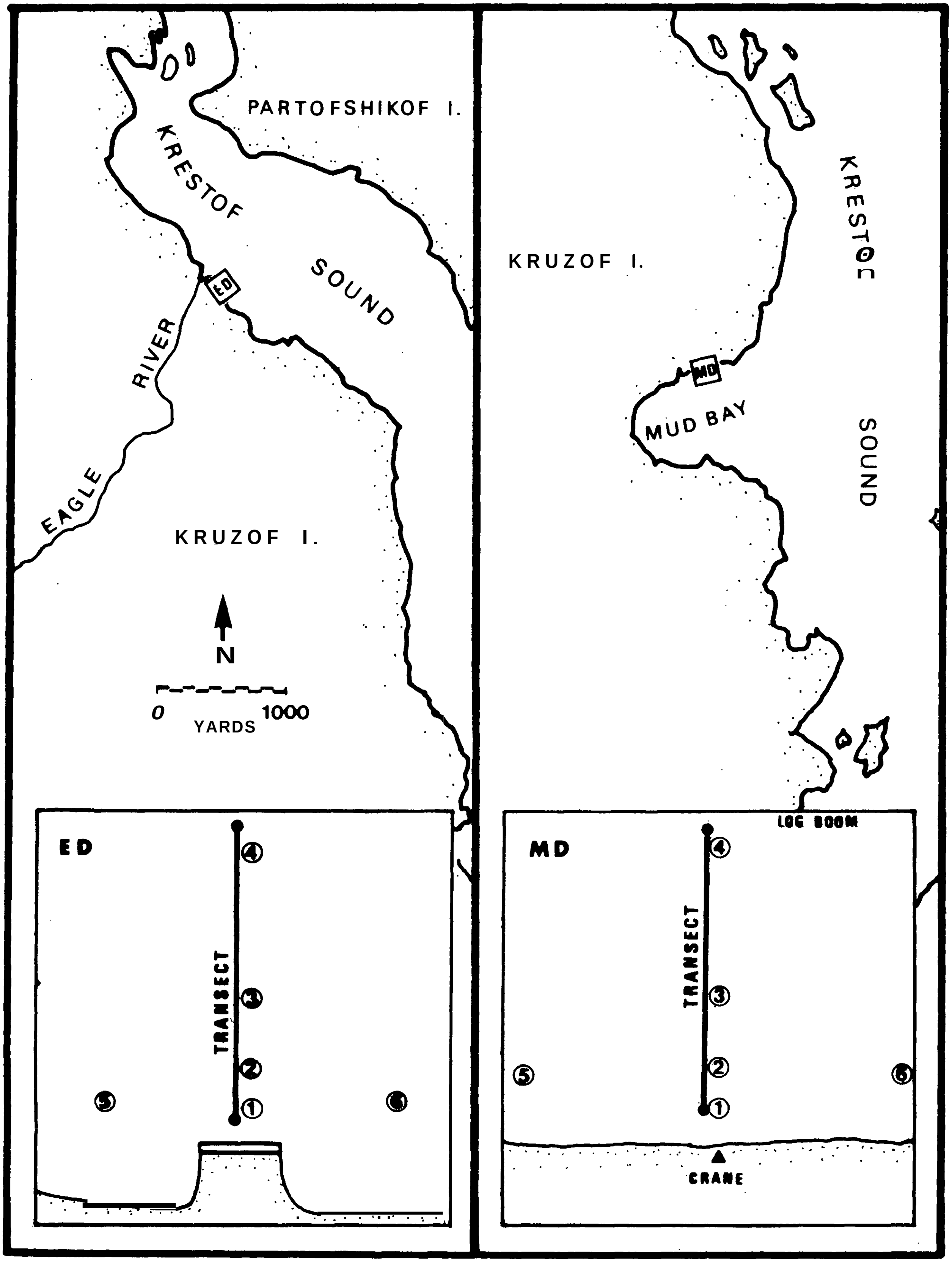

Figure 8. Eagle River and Mud Bay sampling stations.

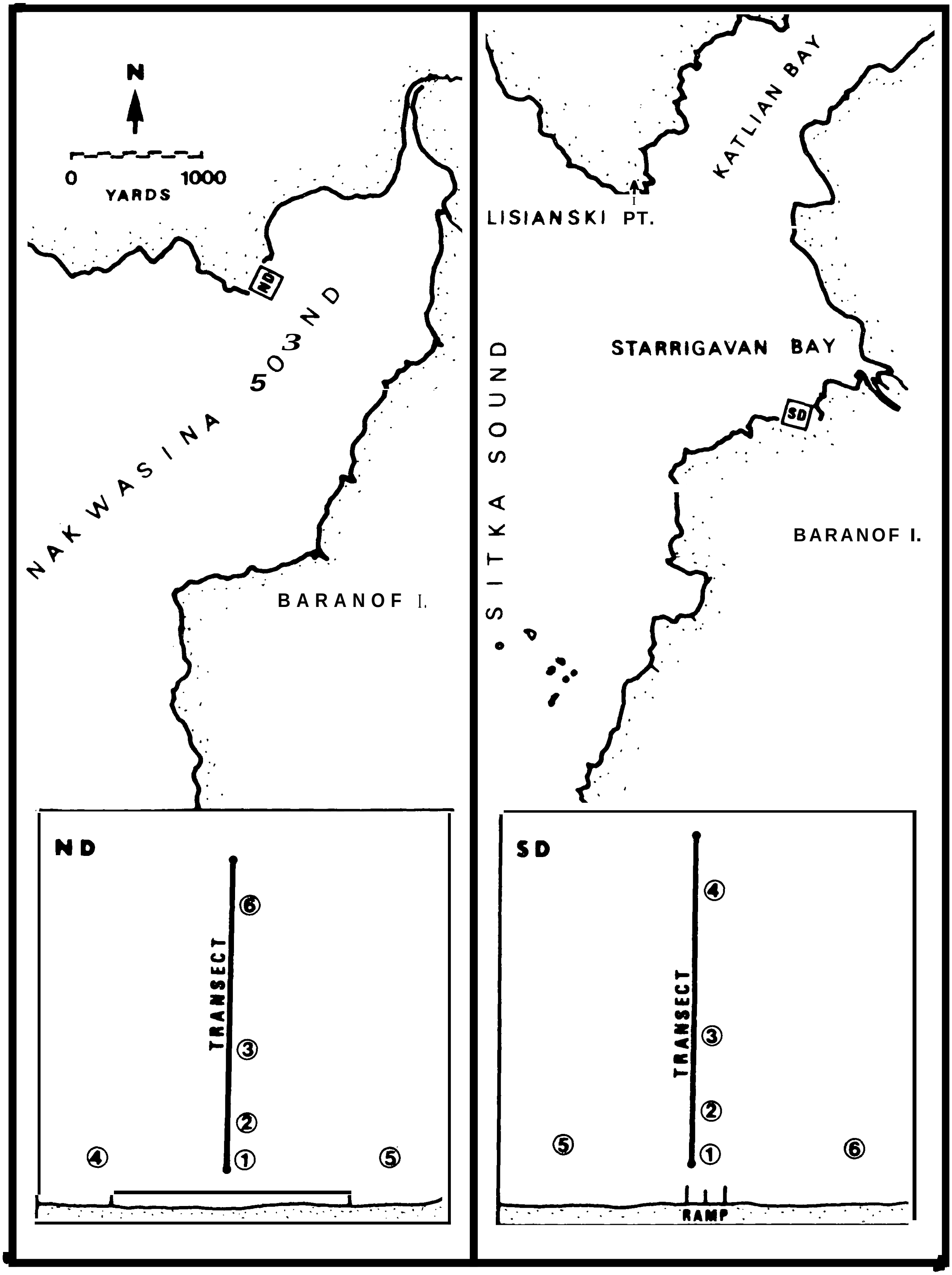

Figure 9. Nakwasina Sound and Starrigavan Bay sampling stations.

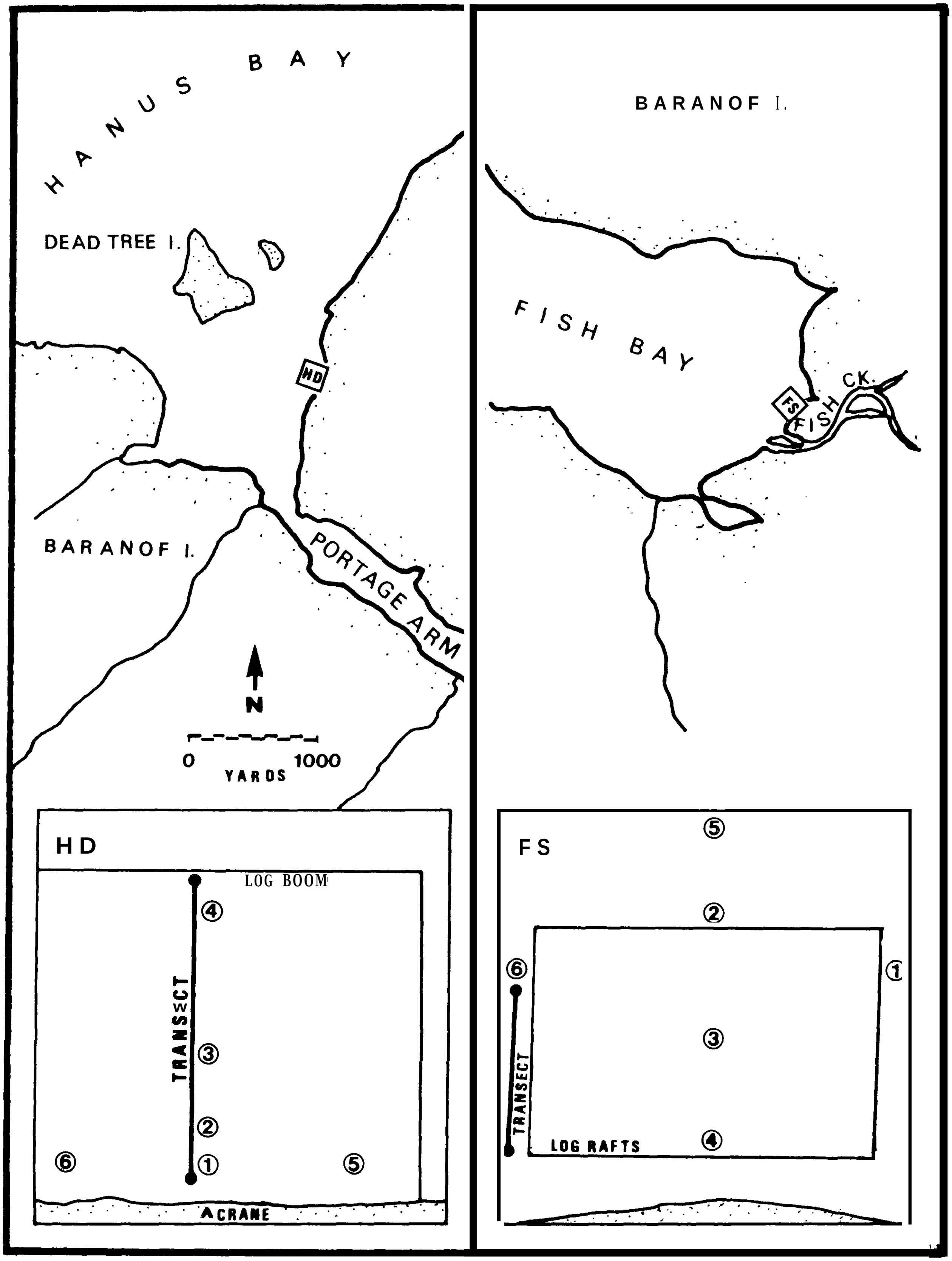

Figure 10. Hanus Bay and Fish Bay sampling stations.

Total Leachate Concentration. Total leachate concentration is hereby defined as the concentration of all chemical compounds leached from a log in water. The total leachate was obtained through a freeze-drying process (see bioassay section of Methods and Materials). A large proportion of the total leachate is composed of hydroxylated aromatic compounds. The proportion of these compounds was measured by means of a portable Hach Chemical Co. (Hach) tannin and lignin field test kit, employing the colorimetric tyrosine method. The procedure is a modification of that outlined in APHA et al. (1971, pp. 346-347). The treated samples were compared visually with standards supplied with the kit. Sea water produced precipitates with the addition of the reagents, thus samples were allowed to settle for one-half hour before comparison with the standards.

The Hach kit reads on a relative scale of 1-15. On the assumption that the hydroxylated aromatic compounds constitute a constant proportion of the total leachate, we converted the readings to mg/l hemlock, spruce, red cedar, and yellow cedar freeze-dried extract (FDE) using standard curves. The precision of the method was not calculated but was good. The accuracy could not be calculated because there are no primary standards for the complex leachate compounds

Hydrogen Sulfide. Analysis was conducted immediately after collection of samples. Concentrations were measured with a portable Hach field test kit. The Hach kit measures within a range of 0.1 to 5 ppm.

Biochemical Oxygen Demand (BOD). A Hach manometric BOD apparatus was used. This apparatus is a simple modification of the Warburg and Sierp standard-type manometric apparatus. Five samples can be analyzed at one time. The samples were incubated at approximately 25 C. Only samples run at the same time were compared, since the incubation temperature was not rigorously controlled.

The BOD of sea water samples was found to be below levels detectable by the manometric apparatus. The relative BOD of the bottom deposits was measured at some sites as follows: Bottom samples were collected by SCUBA divers using a Plexiglas coring cylinder 6 inches long and 3 inches in diameter. In each BOD run, each core sample was mixed with 100 ml of sea water from the corresponding van Dorn surface sample. A 244-ml subsample of the mixture was then incubated in the BOD apparatus for two to three days and the BOD's were recorded at intervals of time. The accuracy of the method is unimportant since only relative values were compared.

Benthic Communities

SCUBA Transects. The large benthic plants and animals at each site were identified and enumerated by a SCUBA diver swimming along a transect line 220 ft long and marked at 10-ft intervals. The locations of transects are shown in Figs. 4 through 10. No transect was run at Herring Cove because of poor visibility. The transect line was pulled taut and anchored at both ends. A line on one end extended up to a buoy, and a line on the other end extended up to the boat. The diver swam along the transect line identifying and recording all plants and animals observed within 3 ft of the transect line, a total area of 1,320 sq ft. One diver made all observations along transects so that all transects were equally biased.

The diver also recorded the bottom sediment composition along the transect at 10 ft intervals.

van Veen Grab Samples. Two samples of the benthic infauna at each sampling station were taken with a 0.03-m^2 van Veen grab sampler (see Figs. 4 through 10). Immediately after collection the fine sediment was separated by means of a 1-mm-mesh sieve. All material greater than 1 mm was put into plastic bags and preserved with 10% Formalin. Sorting was done later in the laboratory.

The total abundance of infauna was calculated for all stations, but because of time and expense limitations, species identification and calculation of diversity indices were limited to nine of the fifteen study sites, representing the six categories in Table 1. Only the mollusks and polychaetes were identified to species and used to calculate the diversity indices, since they represent 80% of the total number of individuals. The other organisms were identified to either phylum, class, or order.

The species diversity index indicates whether some species are more affected by environmental change than others, and species identifications show which species, if any, are affected. Species diversity was measured by the Shannon-Wiener information function (H), because it is relatively independent of sample size (Sanders, 1968).

$$H = -\sum_{r=1}^{s} P_r \log_2 P_r$$

where s = total number of species, and P = observed proportion of individuals that belong to the r^{th} species (r = 1, 2, ..., s). It should be emphasized that only the polychaete and mollusk species were used in the calculation of H, and H would be different if all species were used. However, Sanders (1968) indicates that 80% of the species are sufficient for a good relative index.

Laboratory Studies

Leaching Rate Experiment

Log Sections. Log sections of the four species of timber commercially harvested in Southeast Alaska (hemlock, spruce, red cedar, and yellow cedar) were used. All were obtained from trees cut near the Forestry Sciences Laboratory at Juneau, Alaska. The hemlock and spruce log sections were cut on October 5, 1972, and the red and yellow cedar sections were cut on October 10, 1972. One log section approximately 12 inches in diameter (cut from a tree approximately 12 inches in diameter) and 12 inches long of each of the four species was tested, along with another log section of each species (except spruce) approximately 24 inches in diameter (cut from a tree approximately 24 inches in diameter) and 12 inches long. The spruce section was not tested because it was larger than 24 inches in diameter and would not fit in the testing tank. The volume of the log sections, in bd ft, was measured by displacement. The bark was left completely intact on all log sections. The ages of the 12-inch-diameter sections were: hemlock, 180 yr; spruce, 85 yr; red cedar, 160 yr; and yellow cedar, 200 yr. Those of the 24-inch sections were: hemlock, 290 yr; red cedar, 350 yr; and yellow cedar, 430 yr.

Experimental Design and Equipment. Each 12-inch-diameter log section was completely submerged in a tank containing 80 liters of 20 ppt sea water, each 24-inch-diameter log section was completely submerged in a tank containing 140 liters of 20 ppt sea water. One control tank contained 80 liters of 20 ppt sea water. All tanks were made of epoxy-coated plywood and lined with epoxy-laminated fiberglass. The log sections were held submerged with the wood grain oriented vertically by means of nylon cord tied to eyelets in the bottom of each tank. The water in all tanks was stirred at a constant rate with electrically-driven stainless steel impellers. The sea water was synthesized using "Instant Ocean," a commercially manufactured mixture of chemicals closely approximating the chemical composition of sea water. To prevent bacterial growth (Schaumburg, 1973, p. 11), we added 25 ppm mercuric chloride to the water in all tanks. Water temperature in all tanks was held at 12 ±1 C by submerging the tanks in a larger tank of temperature-controlled water. The salinity value of 20 ppt and temperature value of 12 C were chosen since they are the mean values of all the van Dorn surface samples collected in Southeast Alaska. The experiment had to be terminated on the 21st day because the cooling unit malfunctioned.

Chemical Analyses. At various intervals of time 200-ml water samples were withdrawn from the surface waters of each tank; care was taken not to include visible suspended and floating wood debris. The water samples were analyzed as follows:

Temperature and Salinity. Water temperature in each tank was measured with a mercury thermometer accurate to ±0.1 C, and salinity with a Goldberg T/C refractometer, Model 10423, accurate to ±0.5 ppt. The water temperature in all tanks remained at 12 ±1 C and the salinity at 20 ±1 ppt throughout the experiment.

Chemical Oxygen Demand (COD). Analysis was by the dichromate reflux method as outlined in APHA et al., 1971 (pp. 495-499). We modified the amount of mercuric sulfate added to the sample to 1 g to complex the chloride ions present, as indicated in APHA et al., 1971 (p. 497). The method will oxidize 95-100% of most organic compounds except straight-chain aliphatic compounds, aromatic hydrocarbons, and pyridine. In this study, the COD was probably measuring the wood sugars and side-chain compounds of the hydroxylated aromatic compounds, but not the hydroxylated aromatic compounds. The standard deviation is approximately ±10%, because of the large amounts of chloride ion present. We recorded the results as mg COD per liter to provide an absolute measure of COD in the water and converted then to grams of COD per board feet to provide a relative measure compensating for small discrepancies in the ratio of wood to water. The measurements from the 12-inch-diameter log sections were not directly compared with those from the 24-inch-diameter log sections because of the drastic difference in the ratio of wood to water.

Total Leachate Concentration. The method used was similar to the method described in the section on water quality except that the concentration of hydroxylated aromatic compounds was measured by a simple modification of the colorimetric tyrosine method outlined in APHA et al., 1971 fpp. 346-347). The modification included reducing the sample size by 50%, and centrifuging the sample after adding the reagents, and thereafter using only the supernatant solution. Light absorption was measured in l-cm cuvettes with a Bechnan Model 2400 DU spectrophotometer, at a wave length of 700 mμ. The readings were converted to mg/l hemlock, spruce, red cedar, and yellow cedar freeze-dried extract (FDE) by the use of standard curves for an absolute measure of the concentration of total leachate in the water. The precision was very high. We also converted the measurements to grams of total leachate per board foot to provide a relative measure compensating for small differences in the ratio of wood to water. Again, the measurements from the 12-inch-diameter sections were not compared with those from the 24-inch-diameter sections.

pH. Measurements were made with a Brinkman-Metrohm Model E-300 pH meter having an accuracy of ±0.1 pH units.

Bioassay Study

Test Animals. Pink salmon (*Oncorhynchus gorbuscha*) fry of the size indicated in Table 4 were used in all bioassay tests. They were from eggs and sperm sent to the Quinault Indian Reservation on September 23, 1972, from Lovers Cove Creek, South Baranof Island, Alaska. Pink salmon were chosen as test organisms because the adults are a highly important commercial species abundant throughout Southeast Alaska. Furthermore, the fry

Table 4. Size of pink salmon fry used in the bioassay study

	Salt water	Freshwater
Mean live weight (grams)	0.54	0.84
Sample size for weight	60	107
Mean standard length (mm)	37.0	41.6
Sample size for length	86	250
95% confidence interval (length)	$37.0 \geq \bar{X} \geq 36.2$	$42.1 \geq \bar{X} \geq 41.1$
Range[1] (length)	1.58	1.65
Condition factor[2]	1.07	1.16

[1]Range $= \frac{\text{Length of longest fish}}{\text{Length of shortest fish}}$.

[2]Condition factor $= \frac{\text{Mean live weight}}{(\text{Mean standard length})^3} \cdot 100{,}000$.

spend varying periods of time (up to 2 months) in bays during their seaward migration and frequent the heads of bays in the vicinity of log rafts for short periods.

Test Solutions. Well water with the alkalinity and hardness shown in Table 5 was used as dilution water in all test solutions. One series of freshwater bioassays was made with well water, and one series of sea-water bioassays was made with 20 ppt "Instant Ocean" *(see leaching rate experiment section of Methods and Materials)* in well water. Test concentrations were prepared with freeze-dried extract (FDE). The FDE of each wood species (hemlock, spruce, red cedar, and yellow cedar) was prepared from a 1-inch-thick cross section cut from the end of each 12-inch-diameter log section before it was used in the leaching rate study. The section was cut into thin wood shavings with a jointer, and the wood shavings were then soaked in distilled water for 4 days, in the approximate ratio of 1 kg of wood shavings for every 6 liters of distilled water. The wood shavings were then separated from the water by means of a series of four Tyler screens (minimum aperture size 0.208 mm) and, finally, Whatman No. 4 filter paper. In an attempt to prevent the loss of steam-volatile compounds during the freeze-drying process, the water solution was run through a petroleum ether extraction process. The yield of ether extract was negligible, and it is believed that the steam-volatile compounds were not effectively removed but were probably still present in the FDE. The water solution was freeze-dried in a Vir-Tis Co. Repp model freeze-dryer, and the resulting lightweight brown powder was redissolved in various test concentrations.

Table 5. Quality of dilution water used in the bioassay study

Alkalinity (mg/l $CaCO_3$)			CO_2 acidity	EDTA hardness (mg/l $CaCO_3$)	
Bicarbonate	Carbonate	Hydroxide	(mg/l CO_3)	Total	Calcium
44.7	0	0	5.24	60.0	32.7

Experimenta Design and Equipment. The genera procedures outlined by Doudoroff et al. (1951) and APHA et al. (1971) were followed in the bioassays. The fish were acclimated to test conditions more than 10 days before testing in both fresh and sea water. All tests were made in 5-gal glass aquaria, with 10 fish per 10 liters of test solution. A control tank was used with each series of tests. The freshwater test solutions were aerated with a controlled amount of compressed air, but the sea-water test solutions were not aerated. The concentration of dissolved oxygen remained above 5 ppm in all test solutions. Temperature was kept at 9 ±1 C by the system described in the leaching rate experiment section of Methods and Materials. All tests were continued for 96 hr, during which period the test solutions were not changed. The temperature and salinity, total leachate *(see leaching rate experiment section of Methods and Materials)*, and dissolved oxygen of the test solutions were measured every 24 hr during the 96-hr tests. Dissolved oxygen was measured with an oxygen meter accurate to ±0.2 ppm.

Statistical Methods. The relative toxicity of each wood species was evaluated by the methods outlined by Sprague (1969). Median lethal times (LT_{50}'s) were calculated from hourly observations of percent mortality plotted on log-probit paper. The LT_{50} at each concentration was plotted on semilog paper and lines were fitted by eye for calculation of the threshold toxicity concentration (incipient LC_{50}) for each wood species in freshwater and sea water.

RESULTS

Field Studies

Water Quality

Salinity and Temperature. Normal summer estuarine temperature and salinity regimes existed at all study sites. Salinities generally increased and temperatures generally decreased with depth. The measurements at all sites are summarized in Tables 6 and 7.

Table 6. Salinity (ppt) of water samples collected at all study sites

		Surface					van Dorn surface					Bottom				
Site	Date	Max.	Station	Min.	Station	Mean	Max.	Station	Min.	Station	Mean	Max.	Station	Min.	Station	Mean
TC	7/25	23.5	2, 4	22.5	3, 5	23.0						30.0	5	29.0	3, 4	29.4
TC	8/5	1.5	3, 5	1.0	1	1.3	19.5	3	5.5	1	12.5	29.5	1-5	29.5	1-5	29.5
TD	7/22	22.5	2, 4	22.0	1,3,5,6	22.2						28.0	3,4,5	24.5	1, 2	26.7
TD	8/4	15.0	2	6.0	6	10.9	20.5	6	16.0	3	19.0	30.0	3	27.0	1	28.8
TR	7/17	26.5	4	13.0	2	22.9						30.0	1,2,3,6	29.0	3	23.7
TR	7/19	20.0	1',2,3'	15.5	5'	18.9						28.0	1'	24.5	5'	26.4
TR	8/3	23.0	1, 3	21.5	2	22.2	24.0	1, 5	22.5	2	23.4	29.5	1	27.5	2, 3	28.1
KD	8/9	17.5	2	2.0	5	7.5	16.0	3	3.0	5	11.2	33.0	4	29.0	2	31.0
SI!	8/10	25.0	2	15.0	6	21.2	28.0	2,3,5	25.5	6	27.4	31.5	3, 4	33.0	6	30.9
KC	8/12	9.5	3	5.0	4	7.5	18.0	3	11.0	2	13.9	33.0	3	31.0	1	32.1
MD	8/18	28.5	2	25.0	5	26.7	29.0	2	26.0	6	27.3	32.0	1	29.5	2	31.2
ND	8/19	25.5	5	3.5	1	10.3	28.0	1, 5	25.0	4	27.1	32.0	3, 6	29.5	3	30.9
FS	8/21	13.0	6	8.0	3	10.7	22.5	1	17.0	3,4,5	18.6	31.5	1, 5	17.0	4	25.4
Hi?	8/23	16.0	1	7.5	5	11.7	25.5	4	15.0	2	20.9	33.0	1, 2	26.5	5	31.5
BR	8/29	11.0	1	8.0	2, 5	9.2	24.0	1-4	22.0	5	23.6	32.0	4	31.0	2,395	31.3
ED	8/31	25.5	3	14.5	6	18.6	27.5	2-6	27.0	1	27.4	30.0	4, 5	27.5	2,3,6	28.5
RC	9/1	0.5	1	2.5	4	4.6	27.0	1, 4	25.0	3	26.4	27.0	1	28.5	2-4	28.1
RD	9/1	24.0	2	13.5	1	16.7	27.9	1	19.5	6	23.9	30.0	2-5	28.0	6	29.6
RS	9/2	9.0	1	5.5	2	7.6	23.0	4	18.5	1	20.5	26.0	4	18.5	1	22.4
HD	9/2	28.5	1	27.0	5	27.8	29.5	4	27.5	3	28.5	30.0	2, 3	28.5	6	29.5

Table 7. Temperature (C) of water samples collected at all study sites

Site	Date	Surface Max.	Station	Min.	Station	Mean	van Dorn surface Max.	Station	Min.	Station	Mean	Bottom Max.	Station	Min.	Station	Mean
TC	7/25	14.0	1	13.5	2-5	13.6						10.5	1,3,4	10.0	5	10.4
TC	8/5	14.0	1, 5	13.9	3	14.0	14.0	1	13.1	2	13.6	10.2	1	10.0	5	10.1
TD	7/22	16.3	6	15.5	3	15.9						14.4	1	11.2	2	12.2
TD	8/4	14.2	6	13.7	3	13.9	13.8	1	13.5	2,3,5,6	13.6	12.8	1	10.5	3	11.0
TR	7/17	16.0	6	11.5	1	13.4						10.1	3-5	9.5	1.5	9.9
TR	7/19	18.8	5'	14.5	1'	15.5						14.3	5'	11.4	1'	12.7
TR	8/3	14.5	3	14.0	1-2,4-6	14.1	14.0	3	13.8	4-6	13.9	11.8	2	11.4	5	11.6
KD	8/9	9.7	3	7.9	5	8.9	11.2	3	8.0	5	9.9	12.9	2	9.1	2	11.4
SD	8/10	15.7	6	13.7	1	14.4	14.0	6	13.2	2,3	13.4	13.5	6	11.9	3	12.6
KC	8/12	12.0	2,4	10.8	3	11.5	13.5	3	12.4	1	12.8	12.0	1	8.9	3	10.1
MD	8/18	14.0	5,6	13.2	3	13.6	13.6	6	12.9	2,3	13.2	12.1	2	9.8	5	10.5
ND	8/19	16.7	1	13.1	3	14.8	15.0	2	13.0	6	13.7	12.1	4	3.5	3	10.9
FS	8/21	16.6	6	13.4	1	14.5	14.5	6	13.5	2	13.8	14.5	6	10.3	5	12.9
HR	8/23	15.1	2	10.6	5	12.9	14.2	2	13.3	4	13.7	13.7	5	8.2	1	10.0
BR	8/29	10.9	3	9.9	1	10.4	11.8	4	10.2	1	11.3	12.0	3	10.9	4	11.5
ED	8/31	13.8	6	12.2	4	13.0	12.2	1-6	12.2	1-6	12.2	12.5	6	11.4	3	12.0
RC	9/1	10.5	1	9.5	2	9.9	11.7	1	11.6	2-4	11.6	11.5	1,2	11.4	34	11.4
RD	9/1	12.1	5	11.8	6	11.9	11.9	4,5	10.8	2	11.6	11.4	6	10.2	4	10.8
RS	9/2	15.1	1,2	14.7	3	15.0	14.1	1	13.0	4	13.5	14.1	1	13.3	4	13.6
HD	9/2	11.6	6	11.2	3,5	11.3	11.3	1,4,6	11.2	2,3,5	11.2	11.3	6	11.0	2-5	11.1

Each site was visited at a different date and time. Therefore, water samples from each site were collected at a different tidal stage. The variation in tidal stage accounts for much of the variation between sites in the values of water quality parameters, especially in the surface and van Dorn surface samples. The salinities of the surface samples ranged from 1.0 ppt to 28.5 ppt while those of the van Dorn surface samples ranged from 3.0 ppt to 29.5 ppt and those of the bottom samples ranged from 17.0 ppt to 33.0 ppt. The temperatures of the surface samples ranged from 7.9 C to 18.8 C while those of the van Dorn surface samples ranged from 8.0 C to 14.5 C and those of the bottom samples ranged from 8.2 C to 14.5 C.

Dissolved Oxygen. The State of Alaska's minimum standard DO for coastal waters is 6 ppm. As seen in Table 8, DO's below 6 ppm were measured at two of the study sites (HR and TR). The minimum DO's of the surface, van Dorn surface, and bottom samples collected at the Herring Cove raft storage site were at or near 0 ppm, and the minima of the surface samples collected at the Thorne Bay raft storage site on July 17, 1972, and July 19, 1972, were well below 6 ppm. The mean DO's of the surface, van Dorn surface, and bottom samples collected at HR were all 6 ppm or lower, and thus indicated that raft storage affected the DO of the entire cove (Fig. 7). Concentrations below 6 ppm at TR were limited to the surface samples taken within the log rafts (Fig. 4).

Concentrations at all study sites other than HR and TR were above 6 ppm (Table 8). However, oxygen saturation values below 80% were measured from bottom samples collected at the two oldest active dumping sites (TD and MD), at two recently abandoned dumping sites (ED and RD), and at two raft storage sites (FS and HR) (Table 9). Oxygen saturation values of bottom samples from all other sites were above 80%, and oxygen saturation values of surface and van Dorn surface samples from all sites except TR and HR were near 100%.

Total Leachate. Measurable concentrations were found only at the Herring Cove and Thorne Bay rafting sites (Table 10), at all stations and depths in Herring Cove but only in the surface samples within the log rafts at TR. Total leachate concentration decreased with increasing depth at Herring Cove.

Table 8. Dissolved oxygen (ppm) of water samples collected at all study sites

		Surface					van Dorn surface					Bottom				
Site	Date	Max.	Station	Min.	Station	Mean	Max.	Station	Min.	Station	Mean	Max.	Station	Min.	Station	Mean
TC	7/25	9.7	1	9.3	5	9.5						8.4	3	7.8	2	8.0
TC	8/5	9.5	1-5	9.5	1-5	9.5	9.5	3	9.0	5	9.3	7.9	3	7.7	5	7.8
TD	7/22	10.1	6	9.5	1	9.7						9.7	6	7.0	4	8.4
TD	8/4	9.6	24	8.0	1	9.2	9.7	6	9.2	1	9.5	9.9	1	8.0	2	8.6
TR	7/17	8.9	45	0.7	2	6.9						8.5	5	7.5	1	8.0
TR	7/19	6.8	3'	4.3	1'	5.4						9.7	5'	8.5	2'	8.9
TR	8/3	10.1	6	7.0	1	8.9	10.4	5	8.2	3	9.7	9.2	2,4	8.3	5	8.3
KD	8/9	12.0	5	11.5	1-3	11.6	11.0	5	10.5	3	11; 2	9.6	2	8.3	4	9.0
SD	8/10	10.4	4,6	9.6	3	10.0	10.2	6	9.4	1	9.8	10.0	6	8.7	4	9.2
KC	8/12	11.6	2,3	11.4	1,4	11.5	11.4	1,4	9.3	2	10.8	0.9	4	8.7	1,2	8.8
MD	8/18	10.4	2,3	10.0	6	10.2	10.8	1	10.2	24	10.4	10.2	2	6.8	3	8.0
ND	8/19	12.6	4	10.3	1	11.3	11.7	2	11.1	6	11.4	10.8	4	8.1	2	8.8
FS	8/21	10.0	6	9.5	3	9.7	9.8	6	6.5	4	8.4	10.3	2	8.4	5	9.4
HR	8/23	9.7	3	0.0	?	6.0	3.4	4	0.0	2	1.2	4.5	4	0.1	1	1.5
BR	8/29	10.3	4	9.6	15	9.9	8.4	4	8.1	5	8.2	7.8	1	7.0	5	7.5
ED	8/31	11.2	6	9'.7	3	10.2	9.6	5	8.6	3	9.0	9.7	6	6.2	5	7.8
RC	9/1	10.8	1	9.4	4	10.2	9.6	1,4	9.0	3	9.4	9.2	1	7.8	4	8.C
RD	9/1	10.5	2,3,5,6	10.0	14	10.3	10.5	6	9.5	4	10.0	9.5	2,6	7.0	3	9.1
RS	9/2	10.7	23	10.5	1	10.6	12.6	2	11.0	1	11.5	13.2	4	11.0	1	12.4
HD	9/2	10.0	3	8.2	5	9.0	9.9	3	5.9	4	8.5	9.6	6	0.2	2	8.9

Table 9. Oxygen saturation (%) of water samples collected at all study sites

		Surface					van Dorn surface					Bottom				
Site	Date	Max.	Station	Min.	Station	Mean	Max.	Station	Min.	Station	Mean	Max.	Station	Min.	Station	Mean
TC	7/25	108	1	102	5	104.6						90	3	84	5	86.8
TC	8/5	109	3	91	1,5	97.0	101	3	93	5	96.0	85	3	83	5	84.0
TD	7/22	116	6	108	1,3	111.1						108	1	77	4	30.3
TD	8/4	101	2	82	1	94.2	104	6	99	4	101.3	110	1	85	3	92.7
TI?	7/17	97	4.5	7	2	75.4						91	5	80	1	86.3
TR	7/19	75	3'	47	1'	59.8						109	5'	93	1',2	98.6
TR	8/3	111	6	78	1	97.8	115	5	91	3	107.2	101	4	90	2.5	95.3
KD	8/9	112	2	102	5	105.0	108	6	97	4	103.7	109	2	89	4	100.2
SD	8/10	113	6	108	1.3	110.5	115	6	106	1	110.7	115	6	99	3	104.5
KC	8/12	112	2	108	1,4	109.5	117	3	92	2	110.0	98	1	96	2.4	96.2
MD	8/18	118	2	112	4,6	114.5	121	1	115	2-4	116.5	115	2	7s	3	88.7
ND	8/19	130	4	107	1	117.5	131	1	123	6	129.5	120	4	88	3	96.8
FS	8/21	111	2	97	1,3	102.5	106	6	69	4	90.4	114	2	69	4	97.2
HR	8/23	95	3	0	2	59.0	38	4	0	2	14.2	49	4	1	1	16.6
BR	8/29	97	4	90	1,5	92.6	90	4	84	1,5	86.4	87	5	80	1	83.4
ED	8/31	117	6	103	1	107.7	105	5	94	3	99.3	108	6	72	4	86.0
RC	9/1	101	1	84	4	93.0	104	1.4	97	3	101.7	100	1	86	4	94.0
RD	9/1	111	2	101	1	104.7	110	1,3	100	4	107.0	105	6	74	3	94.3
RS	9/2	109	34	108	1,2	108.5	137	2	118	1	124.2	148	4	118	1	136.2
HI)	9/2	107	3	88	5	98.3	106	3	65	4	92.8	104	6	90	2	98.2

Table 10. Total leachate as ppm FDE in water samples collected from stations at TR and HR

Site	Date	Type of FDE total leachate measured as:	Surface stations 1	2	3	4	5	van Dorn surface stations 1	2	3	4	5	Bottom stations 1	2	3	4	5
TR	7/17	Hemlock		60													
TR	7/17	Spruce		70													
TR	7/17	Red cedar		36													
TR	7/17	Yellow cedar		114													
HR	8/23	Hemlock	40	75	40	20	70	40	40	20	20	30					10
HR	8/23	Spruce	50	85	50	30	75	50	50	20	30	45					15
HR	8/23	Red cedar	25	45	25	15	40	25	25	10	15	20					10
HR	8/23	Yellow cedar	80	135	80	50	125	80	80	45	50	70					40

Hydrogen Sulfide. Measurable amounts were found only at Herring Cove. A concentration of 4.0 ppm was measured in the van Dorn surface sample from the middle of the log rafts at station 2 and concentrations of 0.5 ppm were measured in the bottom samples from stations 1 and 2. The bottoms of the logs in the rafts at Herring Cove were covered with a white film, believed to consist of magnesium and calcium sulfides; and the whole cove smelled of hydrogen sulfide.

Benthic Deposits

Biochemical Oxygen Demand. The data for the control, dumping, and rafting sites at Thorne Bay are plotted in Fig. 11, and the data for the Starrigavan Bay dumping (SD), Katlian Bay dumping (KD), and Katlian Bay control (KC) sites are plotted in Fig. 12. Values were higher at the active and abandoned dumping sites sites than at the rafting and control sites. Also at SD, which had been abandoned only one year before sampling, the value was quite high; and the value at KD, which had been abandoned for seven years, was only slightly higher than that at KC.

Composition. Benthic bark deposits were observed at all active and abandoned dumping sites, whereas only scattered bark was observed at the raft storage sites and little or no bark at the control sites.

The visual observations of sediment composition along transects at all sites are compiled in Table 11. The thickest bark layer was found at the Thorne Bay dumping site, where 550 MMBF of timber has been dumped during the last 10 years. A 2-3 inch bark layer was found at the Hanus Bay dumping site, which had been active for only one year.

The bark-covered areas at the dumping sites varied in size. At the oldest active dumping sites, TD and MD, the bark-covered area extended out for a radius of at least 200 ft from the point of introduction of log bundles into the water. At the abandoned dumping sites, the bark-covered area only extended out for a radius of about 50-75 ft. Scattered patches of white powder were observed on the bark at many of the dumping sites. This white powder was probably either magnesium or calcium sulfide. Miscellaneous debris, such as metal bands and cables and wood shavings from boom-stick boring operations, was also seen scattered on top of the bark-covered area at many of the dumping sites.

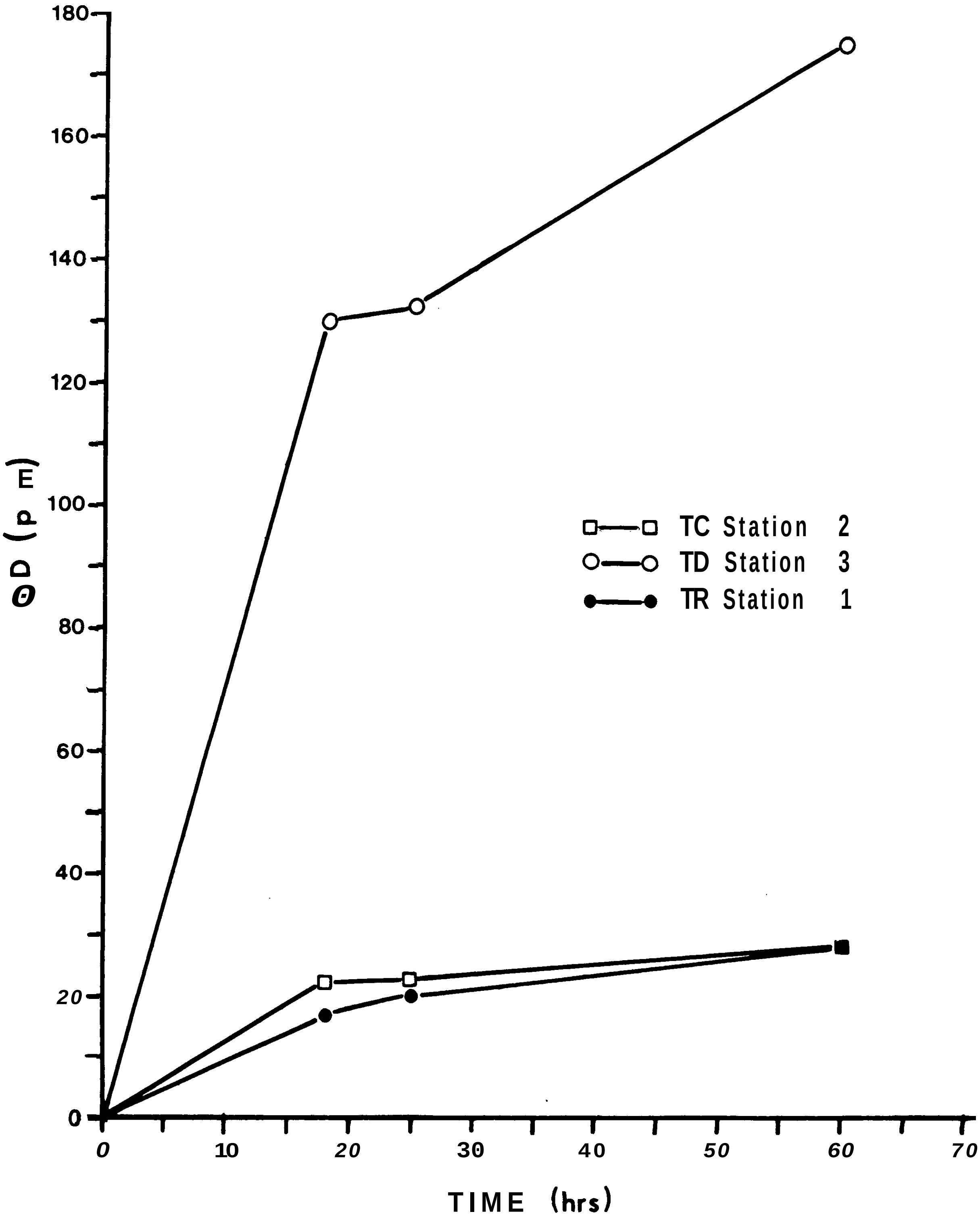

Figure 11. Sediment sample BOD's (run 8/1/72 to 8/4/72).

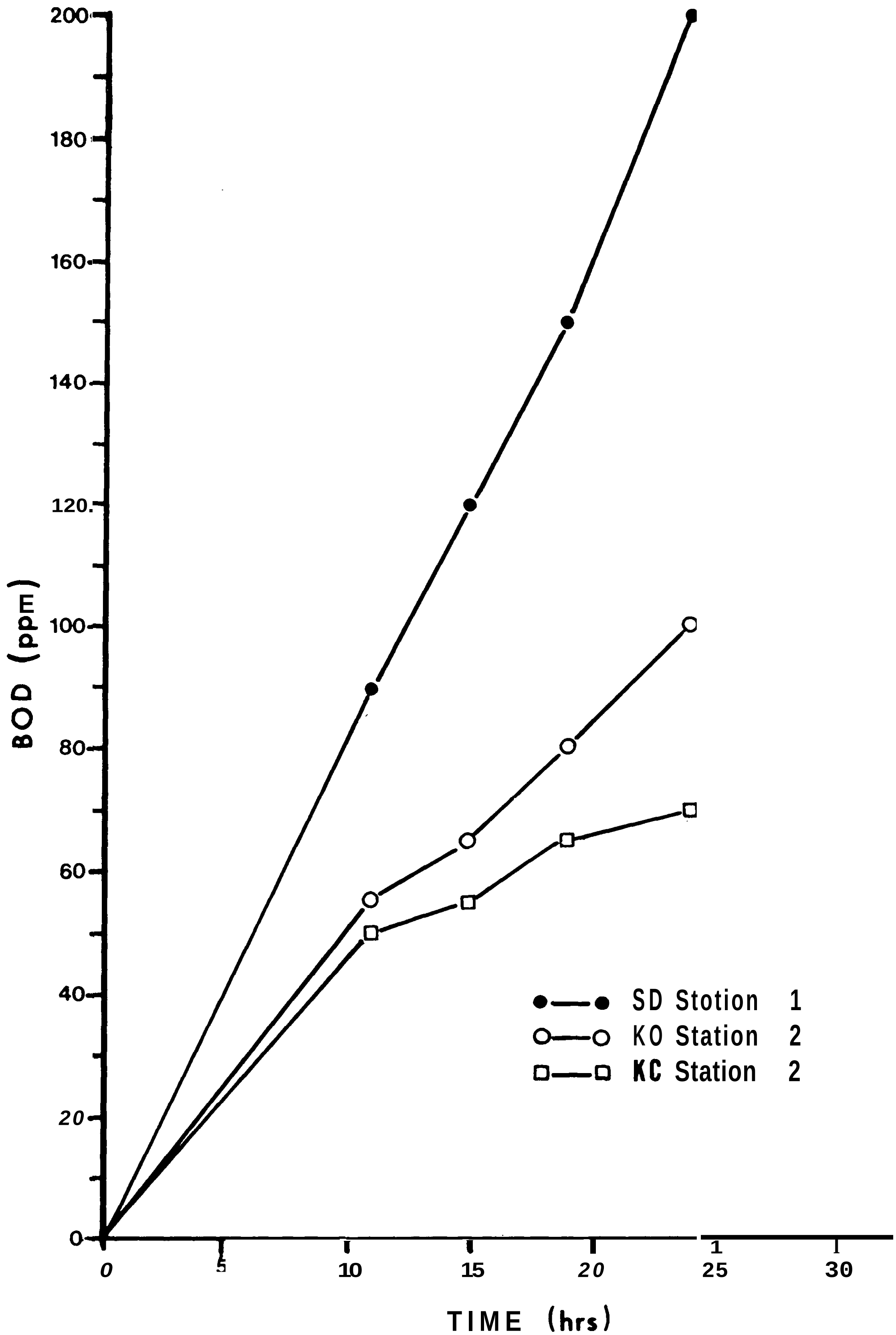

Figure 12. Sediment sample BOD's (run 8/14/72 to 8/16/72).

Table 11. Sediment composition at study sites from observations made along the SCUBA transects

Site	Sediment composition
TC	Scattered bark on layer of soft silt over gravel
TR	Thin layer of bark on soft silt over gravel
TD	Bark layer 2-3 ft thick with scattered patches of white powder within the log boom area, becoming soft silt outside log boom
KD	Bark layer within a radius of 50 ft of the dump site, becoming fine sand and silt farther from the dump site
SD	Bark layer extending about 100 ft from the dump site, becoming coarse sand
KC	Silt with rock outcrops
MD	Bark 1–2 ft thick with large rock outcrops
ND	Bark layer with some silt extending about 75 ft from the dump site (patches of white powder), becoming silt
FS	Scattered bark over sand and gravel
HR	Logs felt by divers but visibility too poor to run transect
BR	Mixed bark and silt with occasional rock outcrops, patches of white powder and scattered sunken logs
ED	Bark and silt mixture 1–2 ft thick extending 50 ft from dump site (patches of white powder), becoming sand and gravel
HD	2–3-inch layer of bark over gravel extending 75 ft from the dump site (few patches of white powder) becoming sand and gravel
RD	Bark and gravel mixture extending 50 ft from the dump site, becoming silt
RC	Sand and gravel
RS	Compacted sand and gravel (looked and felt like sandstone) with scattered bark

Only scattered bark was observed at the raft storage sites. They were widely distributed, however, as evidenced by scattered bark deposits at the Thorne Bay control site 1,000 yd from the log dumping and rafting area. The bottom sediment at the Rodman Bay intertidal raft storage site was extremely compacted from the weight of log bundles grounding at low tide. Large depressions were apparent, in which the sand and gravel were compacted to the consistency of sandstone. The sediment under the log rafts at the Fish Bay intertidal raft storage site was not observed because log rafts were present when the site was studied.

Benthic Communities

Epifauna Along Transects. The epifauna observed at most dumping and rafting sites was similar in type and abundance to the epifauna at the control sites. The types and abundances of organisms observed along the transects are summarized in Table 12. The epifauna at the Thorne Bay active dumping site (TD1, *see* Fig. 4) was greatly reduced in abudance as compared to all other sites; only mobile predators were present. The abundance of benthic epifauna at the Mud Bay active dumping site appeared to have been unaffected, but most of the organisms observed were on rocks jutting above the bark layer.

The benthic epifauna was more abundant at TD2, TR1, and TR2 than at TC (Fig. 4). The difference resulted from an increase in the abundance of attached forms, such as tunicates *(Ascidia)* and anemones (*Metridium*).

The numbers of epifaunal species at the Fish Bay intertidal raft storage site (FS) and the Rodman Bay intertidal raft storage sites (RS) were slightly less than the number of species at the Rodman Bay intertidal control site (RC). More clam species, including the commercially important little-neck clam (*Protothaca staminea*), were found at RC than either FS or RS. Eel grass (*Zostera*) was also found at RC but not FS and RS.

Infauna Sampled with the van Veen Grab. The abundance of benthic organisms (infauna) collected at each sampling station are compiled in Table 13. Abundance was noticeably lower at some of the stations at the Thorne Bay and Mud Bay active dumping sites (TD and MD) as well as most of

Table 12. **Organisms** observed along **SCUBA** transects at study sites

	Site																
	TD1	TD2	TR1	TR2	TC	KD	KC	SD	MD	ND	FS	BR	ED	RD	RS	RC	HD
Phylum Chordata																	
Class Ascidiacea (Tunicates)																	
Ascidia paratropa (Huntsman, 1912)		5	11	75	6												
Cnemidocarpa finmarkiensis (Kiaer, 1893)					1				9	2							
Corella willmeriana (Herdman, 1898)									1			A					
Class Osteichthyes **(Fish)**																	
Pleuronectidae (Flatfish)		2	1			7			1	12				3			1
Scorpaenidae (Rockfish)	3											P					
Pholidae and Stichaeidae **(Blennies)**																	P
Cottidae (Sculpins)																	1
Phylum Arthropoda																	
Class Crustacea																	
Cancer magister (Dungeness crab) (Dana, 1852)		2								1			1				
Cancer oregonensis (Dana)														2			
Hyas lyratus (Spider crab) (Tilesius)		3	6	7	1			1				1		15			
Telmessus cheiragonus (Horse crab) (Dana, 1851)													2				4
Balanus sp. **(Barnacle)**											A				P	P	
Pagurus sp. (Hermit **crab)**		4	1		3			5	1	10			2	A	1		8
Oregonia **sp.** (Decorator crab)						1											
Pandalus **sp.** (Shrimp)		1										4		38			3

Table 12. Organisms observed along SCUBA transects at study sites - continued

	Site																
	TD1	TD2	TR1	TR2	TC	KD	KC	SD	MD	ND	FS	BR	ED	RD	RS	RC	HD
Phylum Coelenterata																	
Class Anthozoa																	
Metridium sp. (Plumed anemone)		6		1	1					4			14	12			2
(Burrowing anemone)							2		3								
Phylum Mollusca																	
Class Pelecypoda (Bivalves)																	
Pecten *caurinus* (Weathervane scallop) (Could, 1850)				1	1												
Pecten hericius (pink scallop) (Could, 1850)			1	1	1		2					2					
Clinocardium nuttallii (Cockle) (Conrad, 1837)										1						A	
Protothaca staminea (Little neck clam) (Conrad, 1837)															S	A	
Saxidomus giganteus (Butter clam) (Deshayes, 1839)																3	
Schizothaerus nuttallii (Horse clam) (Conrad, 1837)													3			A	
Mytilus edulis (Mussel) (Linne, 1758)											P				A	A	
Class Gastropoda'																	
Acmea sp. (Limpet)											P						
Littorina sp. (Littorine snail)											A						
Hermiscenda crassicornis (Nudibranch) (Eschscholtz, 1831)		2			1		1										
Dirona albolineata (Nudibranch) (MacFarland, 1912)												1					
Class Amphineura (Chitons)																	
Tonicella lineata (Lined chiton) (Wood, 1815)												A					

Table 12. **Organisms observed** along SCUBA transects at study sites - continued

	TD1	TD2	TR1	TR2	TC	KD	KC	SD	MD	ND	FS	BR	ED	RD	RS	RC	Hi)
Phylum Echinodermata																	
Class Asteroidea (Starfish)																	
Pycnopodia helianthoides (20-rayed star) (Brandt, 1835)	1			1	3			14	1			1	5	3			8
Evasterias troschelii (Stimpson, 1862)	1		1					1									
Class Holothuroidea (sea cucumbers)																	
Parastichopus californicus (Stimpson, 1857)							4	25	20			3		8			
Eupentacta sp.		2															
Class Echinoidea (Urchins)																	
Strongylocentrotus drobachiensis (Müller)						6	75		6			2		1			
Strongylocentrotus franciscanus (Agassiz)								1									
Burrows		P	15	20	13	A	A								P	A	
Algae																	
Chlorophyta (Green algae)					A												A
Phaeophyta (Brown algae)					P						P		P	P			P
Rhodophyta (Red algae)												P					
Zostera (Eel grass)													A			A	
Number of species (not including burrows and algae)	3	9	6	6	9	3	5	6	8	6	4	1 0	6	9	4	6	8
Total abundance (not including burrows and algae)	5	27	22	86	18	14	84	27	42	30	A	A	27	A	A	A	A

P = Present in greater numbers than could be easily counted, but not abundant.
A = Abundant.

References: Anon., 1969
Light, 1970

Table 13. Abundance of benthic infauna in the van Veen samples from all sites

Site	Date	Abundance at stations[1] 1	2	3	4	5	6
TC	7/25	9	9	13	15	18	
TD	7/22	0	3	1	11	20	10
TR	8/3	8	11	10	14	16	8
KD	8/9	272	48	126	104	50	26
SD	8/10	14	117	32	21	100	-
KC	8/12	71	-	50	-		
MD	8/18	3	5	21	2	10	0
ND	8/19	13	53	64	21	10	30
FS	8/21	166	446	135	573	22	103
HR	8/23	-	-	0	21	26	
ED	8/31	47	80	29	>400	73	92
RD	9/1	5	14	41	38	43	207
RC	9/1	603	171	175	64		
RS	9/2	23	72	0	11		
HD	9/2	39	8	17	-	4	17

[1]Abundance of benthic infauna sampled with two 0.03-m^2 van Veen grabs.
Dash (-) = No sampled obtained (bottom too rocky, steep, etc.).

the abandoned dumping sites studied (KD, SD, ND, ED, and RD). Abundance was lowest at sampling stations located within the bark-covered areas (Table 11). The abundance of infauna at the Rodman Bay intertidal raft storage area (RS) was drastically reduced, from the numbers found at the control area (RC). No benthic organisms were found in the middle of Herring Cove (HR).

The polychaete and mollusk species and their abundance and diversity, along with the other phyla found and their abundances, in the samples from TR, TD, TC, HD, ND, KC, HR, and RC are compiled in Table 14. The lowest species diversity indices were measured at HR and RS. The abundance of the errant polychaete *Dorvillea rudolphi* lowered the diversity index at HR, and the abundance of the macoma clam (*Macoma balthica*) lowered the diversity index at RS. Most other pelecypods, including the commercially valuable little-neck clam (*Protothaca staminea*), were drastically reduced at RS, from the abundance at RC.

Species diversity was actually higher at TR and TD than at TC, because the abundance of polychaetes and mollusks was slightly lower at TR and TD, while the number of species at TR and TD was about the same as the number of species at TC. The same effect was seen at stations 2 and 5 at ND.

Laboratory Studies

Leaching Rate Study

Chemical Oxygen Demand. An increase was noted with time in all test tanks except the control, indicating that the compounds leached from wood in water are capable of creating a measurable demand for oxygen.

The COD leaching rates of the test log sections can be estimated from the steepness of the graphs in Fig. 13. The graphs of the absolute COD leaching rates are presented as a measure of the concentration of COD produced by the four wood species. After 21 days of leaching, COD concentrations of 210-560 mg/l were obtained. The relative COD leaching rates of the four wood species were compared, and they were found to be, in descending order; red cedar, yellow cedar, hemlock, and spruce.

Table 14. Organisms collected in the van Veen grab samples at selected study situ

		August 3, 1972						July 22, 1972						July 25. 1973									
		TR						TD						TC[2]					HD[3]				
	Ref. Code[1]	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	1	2	3	5	6
Phylum Annelida																							
Class Polychaeta																							
Subclass Errantia																							
Family Polynoidae																							
Harmothoë imbricata (Linne)	A																		2	3			
Harmothoë fragilis Moore	A																						
Family Sigalonidae																							
Pholoë minuta (Fabricius)	B		1										1									1	3
Family Phyllodocidae																							
Eteone longa (Fabricius)	B		2						1		1	1									1		
Phyllodoce groenlandica Oerstad	B																						
Family Pilargidae																							
Pilargis berkeleyae Monro	A																						
Parandalia fauveli	A																						
Family Syllidae																							
Syllis pulchra Berkeley and Berkeley	B																						
Family Nephtyidae																							
Nephtys caeca (Fabricius)	B																						
Family Goniadidae																							
Glycinde picta Berkeley	A				1												1						
Family Lumbrineridae																							
Lumbrineris bicirrata (Treadwell)	A				1					1													
Lumbrineris luti Berkeley and Berkeley	A	1	1	2	1	3	1				2	1	1			3	1						
Lumbrineris californiensis Hartman	A				2																		
Lumbrineris sp. 1	A																						
Family Dorvilleidae																							
Dorvillea rudolphi (delle Chiaje)	B																						
Subclass Sedentaria																							
Family Orbiniidae																							
Scoloplos armiger (Müller)	A			2							1	1				1					2		
Family Spionidae																							
Scolelepis fulginosa (Claparède)	A																						
Laonice cirrata (Sars)	A				1																		
Paraspio cirrifera Banse and Hobson	A																		1	33	5		2
Prionospio cirrifera Wiren	B																		1				
Prionospio malmgreni Claparède	B																			1	4		
Spiophanes bombyx (Claparède)	B																						
Family Cirratulidae																							
Cirratulus cirratus	A																						
Chaetozone setosa Malmgren	A																						
Tharyx multifilis Moore	A																						
Family Flabelligeridae																							
Pherusa papillata (Johnson)	A		1																				
Family Scalibregmidae																							
Scalibregma inflatum Rathke	B														1								
Family Opheliidae																							
Armandia brevis (Moore)	B																				2		
Family Capitellidae																							
Capitella capitata (Fabricius)	A																						2
Family Maldanidae																							
Praxillella gracilis (Sars)	A		1		1							1	1			2	2						
Praxillella praetermissa	A						2										5						
Family Sternaspidae																							
Sternaspis fossor Stimpson	B																						
Family Oweniidae																							
Owenia fusiformis delle Chiaje	B																		1				1
Family Pectinariidae																							
Pectinaria granulata (Linne)	B																						
Family Trichobranchidae																							
Terebellides stroemi Sars	B				1	1						1											
Trichobranchus glacialis Malmgren	B	2	1	1		3	1					1	2			2	1						
Family Terebellidae																							
Pista cristata (Müller)	B		1		2	2										1							
Family Ampharetidae																							
Amphicteis scaphobranchiata Moore	B	1														1	2						
Family Sabellidae																							
Laonome kroyeri Malmgren	A																						

		ND						KC[3]		HR[3]			RC				RS			
	Ref. Code[1]	1	2	3	4	5	6	1	3	3	4	5	1	2	3	4	1	2	3	4
Phylum Annelida																				
Class Polychaeta																				
Subclass Errantia																				
Family Polynoidae																				
Harmothoë imbricata (Linne)	A							3			1	2	3		3	3				
Harmothoë fragilis Moore	A										1									
Family Sigalonidae																				
Pholoë minuta (Fabricius)	B	1	2	2	3			23	6				2	4	13	7		1		
Family Phyllodocidae																				
Eteone longa (Fabricius)	B	3											6	8	2					
Phyllodoce groenlandica Oerstad	B			2				1	2			1								
Family Pilargidae																				
Pilargis berkeleyae Monro	A			1			1		1											
Parandalia fauveli	A		1																	
Family Syllidae																				
Syllis pulchra Berkeley and Berkeley	B								2							1				
Family Nephtyidae																				
Nephtys caeca (Fabricius)	B												4	25			1	2		
Family Goniadidae																				
Glycinde picta Berkeley	A		1	2												2				
Family Lumbrineridae																				
Lumbrineris bicirrata (Treadwell)	A		1			1														
Lumbrineris luti Berkeley and Berkeley	A		4				1	4	3					1						
Lumbrineris californiensis Hartman	A					1		6												
Lumbrineris sp. 1	A			1			1													
Family Dorvilleidae																				
Dorvillea rudolphi (delle Chiaje)	B										15	5								
Subclass Sedentaria																				
Family Orbiniidae																				
Scoloplos armiger (Müller)	A		3			3		2					6	4	30	3		1		
Family Spionidae																				
Scolelepis fulginosa (Claparède)	A		1										4							
Laonice cirrata (Sars)	A																			
Paraspio cirrifera Banse and Hobson	A													2						
Prionospio cirrifera Wiren	B																			
Prionospio malmgreni Claparède	B																			
Spiophanes bombyx (Claparède)	B													7	1					
Family Cirratulidae																				
Cirratulus cirratus	A											5								
Chaetozone setosa Malmgren	A															1				
Tharyx multifilis Moore	A								2					5						
Family Flabelligeridae																				
Pherusa papillata (Johnson)	A																			
Family Scalibregmidae																				
Scalibregma inflatum Rathke	B			1			1													
Family Opheliidae																				
Armandia brevis (Moore)	B												1		9	1				1
Family Capitellidae																				
Capitella capitata (Fabricius)	A								18					16	3	1				
Family Maldanidae																				
Praxillella gracilis (Sars)	A																			
Praxillella praetermissa	A																			
Family Sternaspidae																				
Sternaspis fossor Stimpson	B			3																
Family Oweniidae																				
Owenia fusiformis delle Chiaje	B	1	2		10		1		7				13	25	98	16		1		
Family Pectinariidae																				
Pectinaria granulata (Linne)	B		1											12	4	2				
Family Trichobranchidae																				
Terebellides stroemi Sars	B			1																
Trichobranchus glacialis Malmgren	B																			
Family Terebellidae																				
Pista cristata (Müller)	B		2		1		1													
Family Ampharetidae																				
Amphicteis scaphobranchiata Moore	B			3											3					
Family Sabellidae																				
Laonome kroyeri Malmgren	A													1	9	2				

Table 14. Organisms collected in the van Veen grab samples at selected study sites - continued

		TR (August 3. 1972)						TD (July 22, 1972)						TC[2] (July 25, 1973)					HD[3]					ND						XC[3]		KR[3]			RC				RS			
	Ref Code[1]	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	1	2	3	5	6	1	2	3	4	5	6	1	3	3	4	5	1	2	3	4	1	2	3	4
Phylum Mollusca																																										
Class Lamellibranchiata (Bivalves)																																										
Order Protobranchia																																										
Family Nuculidae																																										
Nucula tenuis Montague, 1808	C	1		1		3	1		1			6	2	1				4								4			3													
Family Nuculanidae																																										
Nuculana fossa Baird, 1863	C	1			2	1						1	1		2	1	1	4																								
Yoldia sp.	C						1																																			
Order Filibranchiata																																										
Family Mytilidae																																										
Mytilus edulis Linnaeus, 1758	C											1											1	1										1	116		1		2	4		
Order Eulamellibranchiata																																										
Family Montacutidae																																										
Mysella tumida Carpenter, 1864	C																		1								1								3	1	5	2				
Orobitella sp.	C		1																																							
Family Turtonidae																																										
Turtonia miniata Fabricius. 1780	C																																		190	6				1		
Family Lucinidae																																										
Lucinoma annulatus Reeve, 1850	C												1																													
Parvilucina tenuisculptus Carpenter, 1865	C			1	2		1				1	2	1																													
Family Thyasiridae																																										
Axinopsida sericatus Carpenter. 1864	C																								20	33		4	10							1		3				
Thyasira barbarensis Dall, 1889	C	1	1	1							1	2		1	1																											
Family Cardiidae																																										
Clinocardium nuttalli Conrad, 1837	C																																				1					
Serripes sp.	C																													4												
Family Veneridae																																										
Compsomyax subdiaphana Carpenter, 1864	C										1																			7	1											
Protothaca staminea Conrad, 1837	C																						3												3	4	6	2		1		2
Family Tellinidae																																										
Macoma alaskana Dall, 1900	E					1	1																																			
Macoma incongrua Martens, 1865	E															1						1			4				1					2		1	11	7				
Macoma nasuta Conrad, 1837	E																		1							3										1						
Macoma inquinata Deshayes, 1854	E																					1			1		1		2					1			4	1				
Macoma expansa Carpenter, 1864	E																											1														
Macoma balthica Liana, 1758	E																																		95	31	2		9	16		7
Family Hiatellidae																																										
Hiatella arctica Linne, 1767	C																																	4	1							
Family Pandoridae																																										
Pandora filosa Carpenter. 1864	C																1	1																								
Class Gastropoda																																										
Subclass Prosobranchia																																										
Order Monotocardia																																										
Littorina sitkana Philippi. 1845	C																																		1							
Lacuna carinata Gould, 1848	C																																		2							
Natica clausa Broderip and Sowerby, 1829	C																											1														
Oenopota harpula Couthouy, 1838	C																										1															
Oenopota kyskana Dall. 1919	C																												1													
Subclass Opisthobranchiata																																										
Order Tectibranchiata																																										
Sulcoretusa sp.	C													1				2							1		1															
Odostomia inflata Dall and Bartsch, 1907	C																																			1						
Class Amphineura																																										
Order Polyplacophora																																										
Lepidozona mertensii Middendorff, 1846	D																																			1						
Phylum Nemertinea		1	1	1							3										1		2	1	9	5	1		2		6			3	1	1 1	5	9		1		
Phylum Echinodermata																																										
Class Ophiuroidea (Brittle stars)				1																					1	3		2			1											
Class Holothuroidea (Sea cucumbers)						1					1	2					1																									
Class Echinoidea (Urchins)																														11			,									

43

Table 14. Organisms collected in the van Veen grab samples at selected study sites - continued

	August 3, 1972						July 22, 1972						July 25, 1973									
	TR						TD						TC[2]					HD[3]				
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	1	2	3	5	6
Phylum Arthropoda																						
Class Crustacea																						
Subclass Cirripedia																						
Order Thoracica (Acorn barnacles)								1					1									
Subclass Malacostraca																						
Order Nebaliacea																		2	1			
Order Amphipoda					1													18		1		
Order Isopoda																						
Order Cumacea																						
Order Tanidacea																						
Order Decapoda																					1	3
Phylum Echiuroidea																						
Abundance (Total number of individuals) at stations	8	11	10	14	16	8	0	3	1	11	20	10	9	9	13	15	18	39	8	17	4	17
Abundance of Polychaetes and Molluscs at stations	7	10	8	14	14	8	0	2	1	7	18	10			13	14		19	7	15	4	15
Number of Polychaete and Mollusc species at stations	6	9	6	10	7	7	0	2	1	6	11	8			9	8		6	3	5	3	6
Abundance of Polychaetes and Molluscs at sites			61						38						27					60		
Number of Polychaete and Mollusc species at sites			22						15						12					16		
Species Diversity (H) at sites				4.1						3.5						3.3				3.1		

	ND						KC[3]		HR[3]			RC				RS			
	1	2	3	4	5	6	1	3	3	4	5	1	2	3	4	1	2	3	4
Phylum Arthropoda																			
Class Crustacea																			
Subclass Cirripedia																			
Order Thoracica (Acorn barnacles)												1							
Subclass Malacostraca																			
Order Nebaliacea										3									
Order Amphipoda	6						7	1				127	10	1	1	3	17		
Order Isopoda												22				8	27		
Order Cumacea							2						1	2					
Order Tanidacea							1												
Order Decapoda		1		2							2	2	2				1		
Phylum Echiuroidea											8								
Abundance (Total number of individuals) at stations	13	53	64	21	10	30	71	50	0	21	26	603	171	175	64	23	72	0	11
Abundance of Polychaetes and Molluscs at stations	6	43	56	20	8	28	51	42	0	17	23	452	159	157	54	12	27	0	11
Number of Polychaete and Mollusc species at stations	4	13	12	7	5	13	8	9	0	3	8	16	21	18	16	3	7	0	4
Abundance of Polychaetes and Molluscs at sites			161				93			40				822			50		
Number of Polychaete and Mollusc species at sites			31				13			9				34			9		
Species Diversity (H) at sites			3.5					3.1		2.3				3.5			1.8		

[1] Reference Code:
A. Personal communication with Mrs. Katherine Hobson.
B. Berkeley and Berkeley, 1948, 1952; Banse and Hobson, in preparation.
C. Keen, 1963; Oldroyd, 1924; and Abbott, 1954.
D. Rice, 1971.
E. Dunnill and Ellis, 1969.

[2] Polychaete samples from stations 1, 2, and 4 lost before identification, but total number of polychaetes used in total abundance.

[3] No sample obtained from HD station 4, KC stations 2 and 4, and HR stations 1 and 2 (bottom too rocky, steep, etc.).

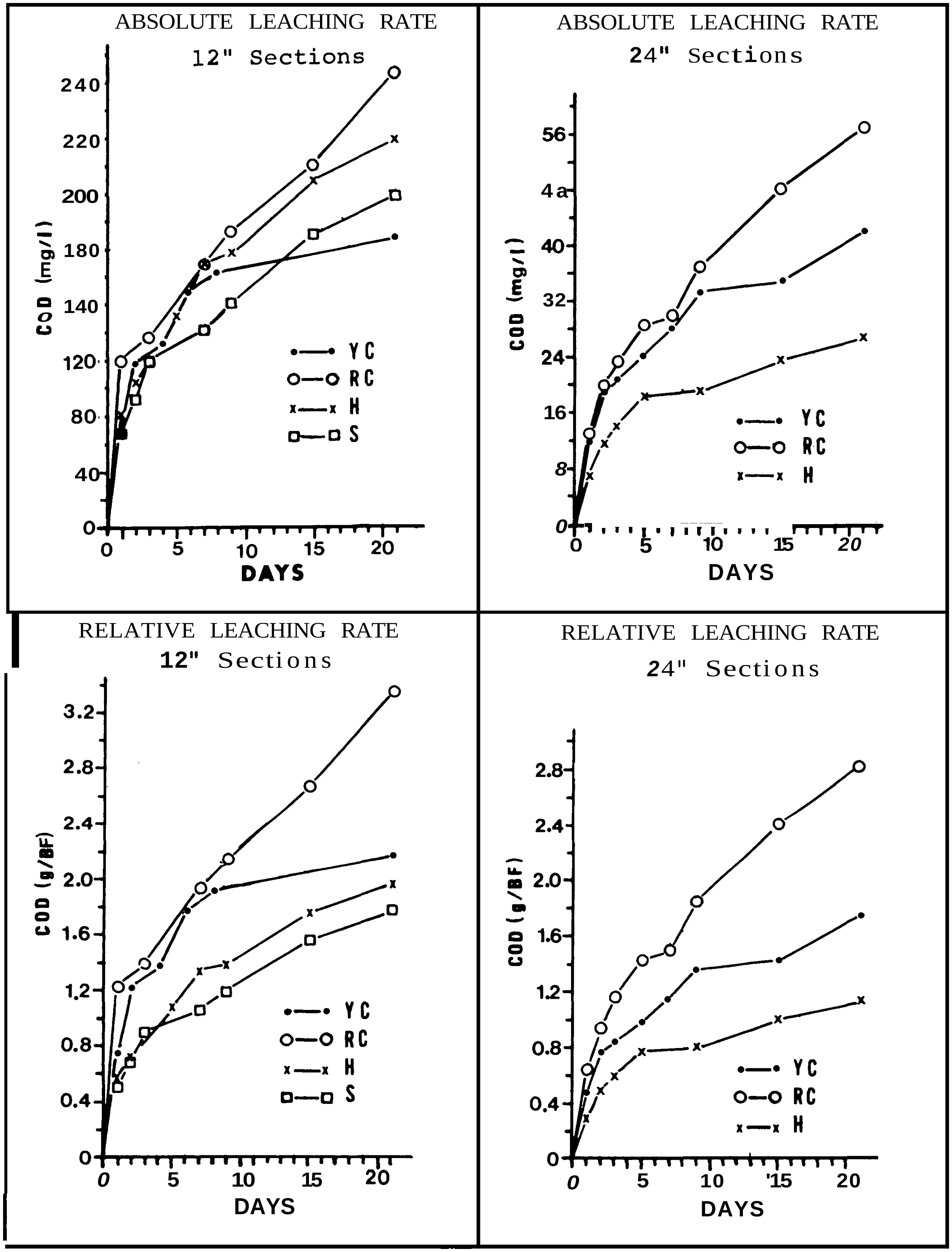

Figure 13. COD leaching rates of test log sections (YC=Yellow Cedar, RC=Red Cedar, H=Hemlock, S=Spruce).

Total Leachate. An increase was also noted with time in all test tanks except the control. The total leachate leaching rates of the test log sections can be estimated from the relative steepness of the graphs in Fig. 14. As can be seen in the absolute leaching rate graphs, concentrations of 90-250 mg/l total leachate were measured after 20 days of leaching. Relative total leachate leaching rates of the 12-inch log sections followed the same descending order that was found for the relative COD leaching rates, i.e., red cedar, yellow cedar, hemlock, and spruce. However, the descending order of the relative total leachate leaching rates of the 24-inch log sections was: red cedar, hemlock, and yellow cedar. The difference in relative total leachate leaching rates between young and old wood was probably due to a change in chemical composition with age.

A brown precipitate was observed in all test tanks except the control, indicating that part or all of the leachate slowly precipitated. Schaumburg (1973) also found that log leachates precipitate in salt water.

pH. The pH of the water was lowered by the leachate from all wood species (Table 15). The lowest pH, 6.3, was caused by the 24-inch red cedar section. The other wood sections lowered the pH to about 7.0, from the normal sea-water pH of 7.7-8.0. A slight increase in pH occurred in most test tanks near the end of the test period.

Bioassay Study

Spruce and red cedar were found to be the most toxic of the wood species to pink salmon fry in freshwater and yellow cedar was found to be the most toxic in sea water. All the wood species were found to be more toxic in freshwater than in 20 ppt sea water. No mortalities occurred in the controls. The LT_{50}'s at all concentrations in freshwater and 20 ppt sea water for all of the wood species are graphed in Fig. 15. The lethal thresholds for red cedar and spruce in freshwater are indicated by the sharp vertical breaks in the lines. The estimated lower threshold toxicity concentration for each wood species is indicated by the interception of the solid lines with the 96-hr axis (time limit of bioassays), and the estimated upper threshold toxicity concentration is indicated by interception of the broken vertical

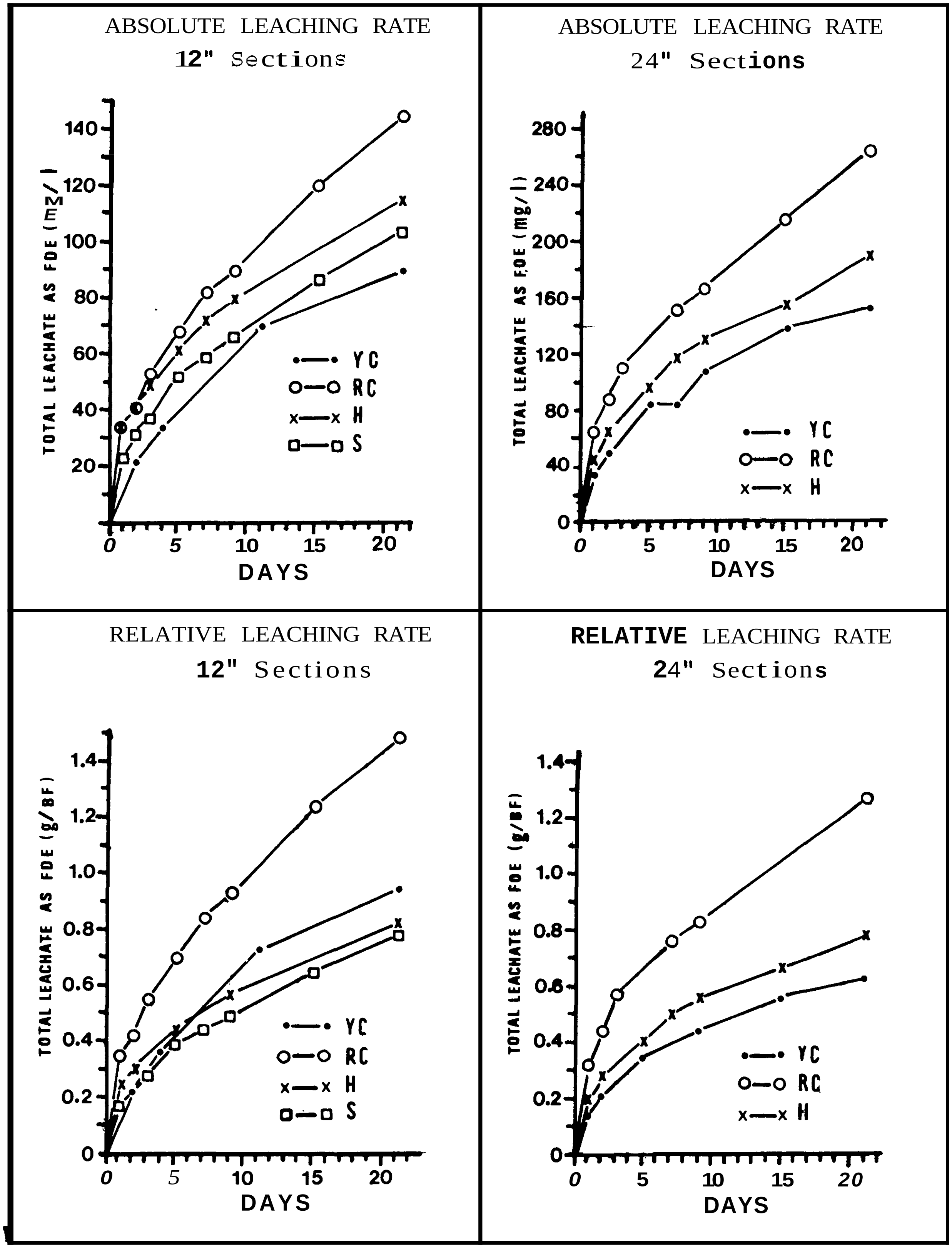

Figure 14. Total leachate leaching rates of log sections (YC= Yellow Cedar, RC=Red Cedar, H=Hemlock, S=Spruce).

Table 15. pH of the log sections in the leaching rate study

Day	Red cedar 12"	Red cedar 24"	Hemlock 12"	Hemlock 24"	Yellow cedar 12"	Yellow cedar 24"	Spruce 12"	Control
1	7.0	6.7	6.7	7.0	8.0	7.0	7.0	7.9
2	7.0	6.7	6.7	6.9	7.5	6.9	7.0	8.1
3	7.0	6.6	6.7	6.9		6.9	7.0	7.9
4					7.3			
5	7.0	6.6	6.7	6.9		6.9	6.9	7.9
6								
7	7.0	6.5	6.7	6.9		6.9	6.9	8.0
8								
9	7.0	6.4	6.6	6.9		6.8	6.9	8.0
11					7.0			
15	7.2	6.3	6.8	7.2		7.0	7.2	8.1
21	7.2	6.3	6.6	7.1	7.4	7.1	6.9	8.0

lines with the 96-hr axis. The ranges of the threshold toxicity concentrations for all wood species, estimated from Fig. 15, are summarized in Table 16.

The concentration of freeze-dried extract (FDE) and therefore its toxicity, declined rapidly in salt water because of its precipitation with sea-water ions and its oxidation. The concentration of FDE also decreased in freshwater, but more slowly than in sea water. Since no precipitate formed in freshwater, we assume the decrease of FDE resulted entirely from oxidation. This assumption is reasonable since the measurement of FDE depends on its reducing power.

Log Barging Versus Log Raft Towing

Some Forest Service personnel feel that log barging would cause less environmental damage than log raft towing, so we were requested to compare the economics of log barging as opposed to log raft towing.

The Alaska Lumber and Pulp Company supplied the following information about the cost of log barging and log raft towing operations to the Sitka mill.[1] Log barging requires a large initial capital investment and costs more per thousand bd ft/mi than log raft towing. On the other hand, it is faster and there is no loss of logs, as happens in log raft towing in bad weather, Loss of logs during the log raft towing operation is the major reason that some companies are barging logs.

The present system of log barging is at least as harmful to the marine environment as log raft towing, because logs are loaded onto the barge from the water near the sale area and unloaded into the water near the mill site. Thus, the logs are dumped into the water twice, and twice as much bark and wood debris enters the marine environment. This effect could be minimized by loading and unloading barges from land, but the feasibility and environmental impact of building dock facilities and the associated dry-land log storage facilities in Southeast Alaska are unknown.

[1]Personal communication with Mr, D. J. Theno.

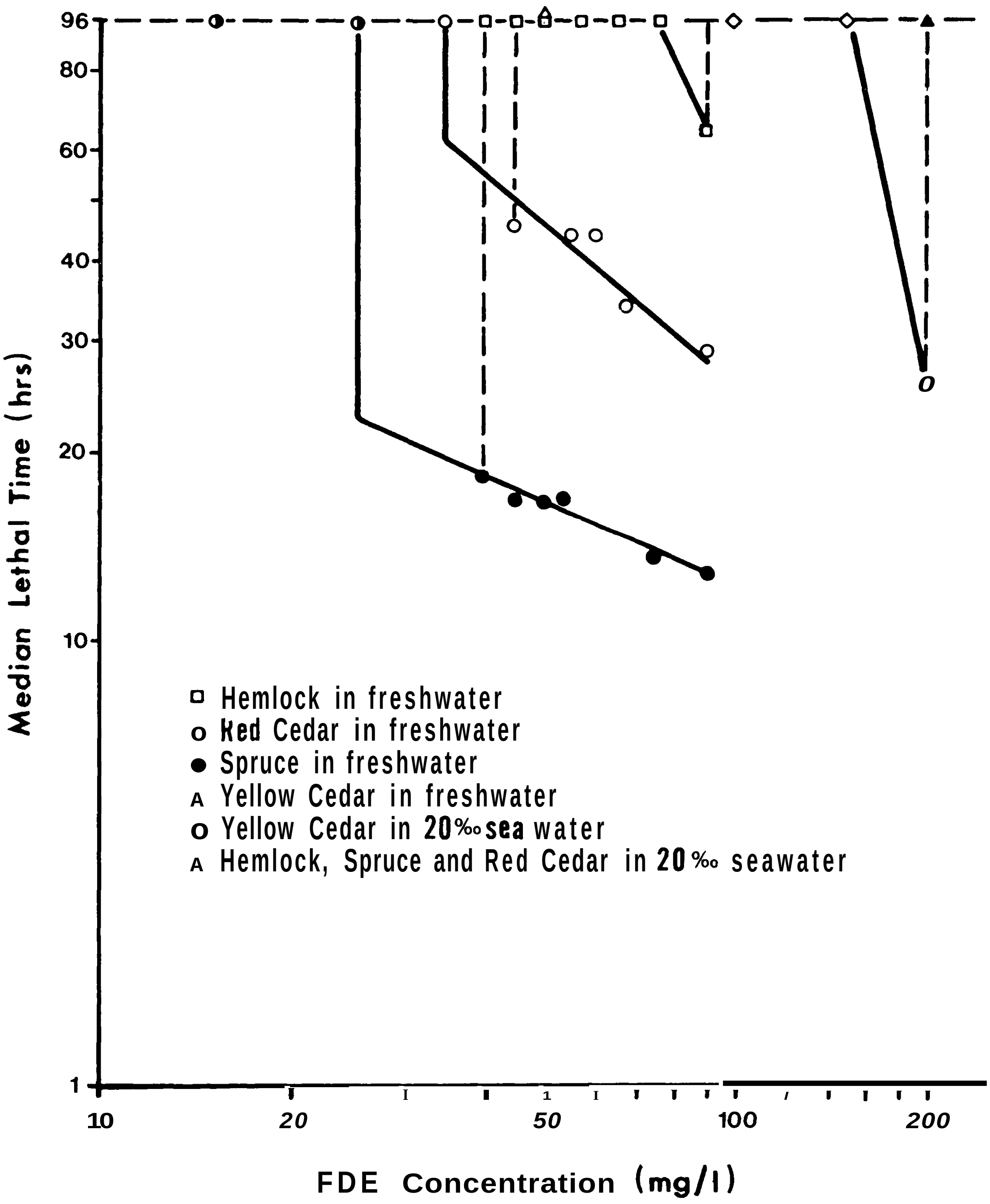

Figure 15, Threshold toxicity concentrations from pink salmon fry bioassay. Lower threshold toxicity estimate from intersection of solid lines with 96 hour axis (end of experiment). Upper threshold toxicity estimate from intersection of broken line with 96 hour axis,

Table 16. Summary of threshold toxicity concentrations from pink salmon fry bioassay

Wood species	Threshold toxicity concentrations (mg/l FDE) Fresh water	20 ppt sea water
Red cedar	35 < T < 45	T > 200
Yellow cedar	T > 50	150 < T < 200
Hemlock	75 < T < 90	T > 200
Spruce	25 < T < 40	T > 200

Where T = threshold toxicity.

DISCUSSION

The environmental impact of log dumping and rafting activity in Southeast Alaska can be broken down into three categories: (1) the impact of organic compounds that leach from logs when stored in water (total leachate), (2) the impact of benthic bark deposits, and (3) the impact of compacted sediment resulting from the intertidal storage of log bundles. These three categories will be discussed with reference to the following types of sites studied: (1) active log dump, (2) abandoned log dump, (3) sale area log raft collecting and storage, (4) winter raft storage, (5) mill storage and sorting, and (6) control.

The environmental impact of log leachates was observed at a sale area log raft collecting and storage site (TR) and a mill storage and sorting site (HR), and studied in the leaching rate study and bioassay study. It appears that the most serious impact of log leachates is their biological and chemical demand for oxygen. Schaumburg's (1973) laboratory studies demonstrated that log leachates have a measurable biological and chemical demand for oxygen, and the laboratory leaching rate study in this report confirms the high COD of log leachates. Also, the high leachate concentrations at TR and HR were measured in water samples with DO's under 6 ppm (Tables 8 and 10).

High leachate concentration and low DO are probably permanent conditions in Herring Cove, as evidenced by the buildup of sulfides from prolonged anaerobic bacterial action. However, the situation at Herring Cove is probably unique in that little tidal flushing occurs because of the restricted entrance (Fig. 7). Also, the surface and bottom of the cove are covered with logs; the bottom is covered with logs that sank after unbanding of log bundles. The last log bundles were unbanded in Herring Cove about 5 years ago, when a new system was developed to hoist whole log bundles into the pulp mill. It is also possible that some spent sulfide waste liquor from the pulp mill enters Herring Cove.

High leachate concentration and low DO appear to be only temporary conditions at the Thorne Bay rafting site, confined to a thin surface layer within the interspaces of the log rafts. The conditions appear to be temporary because low DO's were measured during only two of the three days that the site was sampled (Table 8), a high leachate concentration was measured on only one of the three days (Table 10), and no sulfides were found in the area. The conditions of high leachate concentration and low DO at TR developed after a rainfall, occurred only in a shallow layer of "fresh" water trapped at the surface between logs, and rapidly returned to normal after mixing of this water with underlying sea water. Although these conditions were found at neither of the other raft storage sites studied (BR and FS), the conditions probably develop in most log rafts after rainfall.

It is doubtful that the total leachate concentrations at HR and TR (Table 10) were toxic to pink salmon fry, since these were measured in saline water (Table 6) and the toxicities of the wood species tested *are* greatly reduced in 20 ppt sea water (Table 16). Also notice that the shortest LT_{50} in Fig. 13 is about 12 hr, meaning that it took the most toxic wood species (spruce) 12 hr to kill half the test fish. It is doubtful that fish would remain in an area of high leachate concentrations, a thin surface layer at most raft storage sites, for 12 hr before detecting the leachate and low DO without swimming away. Even though 6 ppm is the minimum DO standard for Alaskan coastal waters, most salmonids can survive much lower DO's for short periods, and many estuarine invertebrates can tolerate lower DO's for long periods. Therefore, it appears that log leachates are toxic but seldom kill pink salmon fry or other fish in Southeast Alaska. Since the log leachates precipitate and concentrate at the bottom of the estuaries, studies of toxicity of log leachates to benthic invertebrates such as Dungeness crabs would be more appropriate than studies of their toxicity to fish.

Benthic bark deposits were observed at all dumping sites (both active and abandoned). They had a higher BOD than the surrounding sediments. Schaumburg (1973) also concluded that bark deposits have a measurable BOD. The BOD of the bark deposits appeared to lower the DO of the overlying water slightly at sites with deep, recently deposited bark layers, as seen by the lowered oxygen saturation values of bottom water samples from TD, MD, ED, and RD. But the DO's of the overlying waters at all dumping sites were above 6 ppm, probably because of tidal flushing and low temperatures (Table 7). The abundance of epifauna was relatively unaffected at most dumping sites, also indicating that DO's in the water above the bark deposits were not drastically lowered. In fact, it appears that scattered bark increases the abundance of epifauna by providing a hard substrate for attached forms, as seen by the greater abundance of tunicates (*Ascidia*) and anemones (*Metridium*) at TD2, TR1, and TR2 as compared to TC (Fig. 4). The only decrease in abundance of epifauna was observed at TD1 (Fig. 4), the oldest and largest active dumping site in Southeast Alaska.

Abundance of infauna turned out to be a good indicator of changes in the benthic community. The bark deposits at all dumping sites caused a decrease in abundance of infauna. The infauna are probably affected by low DO's within the bark deposits caused by the BOD of the bark. It is also possible that leachates from the bark deposits are toxic to the infaunal organisms. Species diversity was not as affected as abundance, except at HR and RS, where H was noticeably low.

The major impact of intertidal raft storage is the compaction of the bottom sediments and crushing of the infauna from the weight of log bundles grounding at low tide. The sediments at RS were so compacted that the benthic infauna was almost eliminated (Table 13).

SUMMARY

The impact of log rafting and dumping activity on the water quality and benthic ecology at five log rafting, eight active and abandoned log dumping, and three control sites in Southeast Alaska was investigated during the summer of 1972. The relative leaching rates of hemlock, spruce, red cedar, and yellow cedar were investigated in the laboratory by immersion of log sections of each wood species in tanks of water for 21 days. Static 96-hr bioassays of log leachates from hemlock, spruce, red cedar, and yellow cedar were conducted in the laboratory with pink salmon fry in fresh and 20 ppt sea water. The following are the significant findings of the field, leaching rate, and bioassay studies:

1) High concentrations of log leachate and DO's below the State of Alaska's minimum standard for coastal waters were measured at two raft storage sites, Herring Cove and Thorne Bay. These conditions were permanent at the Herring Cove mill raft storage and sorting sites, where logs were unbanded, but the site is unique in that the cove has limited tidal flushing. The high leachate concentration and low DO at the Thorne Bay sale area raft storage site appeared in a shallow layer of "fresh" water within the interspaces of the raft for a short time after a rainfall. The conditions at Thorne Bay are believed to occur at most raft storage areas in Southeast Alaska.

2) A layer of bark covered the bottom within a radius of 50-75 ft at most abandoned dumping sites and within a radius of 200 ft at the two oldest active dumping sites studied.

3) The BOD of the bark layer at active and abandoned dumping sites was higher than that of the surrounding sediment, and the BOD decreased with increasing age of bark deposits.

4) The benthic epifauna was relatively unaffected by log rafting and dumping activity at most sites. However, a reduction in abundance was observed at the Thorne Bay log dump, the oldest active log dump studied,

5) The abundance of benthic infauna was noticeably reduced in the bark-covered area at all active and inactive dumping sites studied, but the species diversity was not affected.

6) The abundance of benthic infauna was reduced drastically at the Rodman Bay intertidal log storage area. Here, the bottom sediments were compacted to the consistency of sandstone from the weight of grounded log bundles.

7) In descending order of leaching rate, the wood species were: red cedar, yellow cedar, hemlock, and spruce.

8) The organic compounds leached from wood in water condense and precipitate in sea water,

9) All wood leachates were more toxic to pink salmon fry in freshwater than in 20 ppt sea water. Spruce was found to be the most toxic wood species in freshwater, and yellow cedar the most toxic wood species in 20-ppt sea water.

RECOMMENDATIONS

1) Log bundles should not be unbanded in the water without provisions for recovery of sunken logs.

2) Log bundles should not be stored in the intertidal zone where grounding will occur at low tide.

3) Studies should be undertaken to develop methods of introducing logs or log bundles into the water with less bark loss, such as debarking logs before dumping them, Studies should be made also of the feasibility and environmental impact of dredging bark deposits.

4) The feasibility and environmental impact of dry-land storage and barge transportation *(see Log Barging Versus Log Raft Towing section under Results)* of logs should be studied.

5) Further studies should be conducted on the toxicity of bark and wood leachates to marine benthic invertebrates such as Dungeness crabs and pandalid shrimp.

6) Further studies should be conducted at raft storage areas to determine the extent of oxygen depletion and total leachate concentration over a period of at least a year.

7) Study should be made of the benthic community before and after log dumping is started at a site, to further quantify its effects on benthic ecology.

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