ENVIRONMENTAL PROTECTION BRANCH
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

PULP MILL ENVIRONMENTAL IMPACT ASSESSMENT
RAYONIER CANADA LIMITED
WOODFIBRE DIVISION

Regional Program Report: 79-3

by

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ABSTRACT

In October 1976, the Environmental Protection Service initiated a program to assess the environmental impact of pulp and paper mills in British Columbia. With the co-operation of various other government agencies and the industry, EPS compiled relevant resource data and receiving environment monitoring information. After reviewing and evaluating the existing information the environmental quality of each area was assessed and the need for additional monitoring studies determined. This report represents the environmental impact assessment for the Rayonier Canada pulp mill at Woodfibre, Howe Sound, B.C.

RÉSUMÉ

Au mois d'octobre 1976, le Service de la protection de l'environnement a entrepris de'évaluer les répercussions mésologiques des fabriques de pâtes et papiers de la Colombie-Britannique. Aidé de l'industrie et de divers autres organismes gouvernementaux, il a réuni une documentation concernant les ressources ainsi que certains résultats de contrôles portant sur l'environnement affecté. Après avoir étudié ces données, le Service a évalué la qualité environnementale de chacune des régions et déterminé quelles seraient les études supplémentaires qui resteraient a réaliser. Ce rapport fait connaître les résultats ayant trait à l'évaluation des contrecoups imputables à la fabrique de pâte de la Rayonier Canada be Woodfibre sur l'environnement du détroit de Howe.

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SUMMARY AND CONCLUSIONS

Receiving water studies to date show that the environmental impacts from Woodfibre effluent discharges are confined to a relatively localized area adjacent to the mill and extend a short distance to the south. Good circulation and flushing in surface waters due to the Squamish River flow are largely responsible for minimizing environmental impact.

The installation of a submerged outfall and diffuser system discharging within the mixing zone will increase dilution and dispersion of mill effluent thereby improving water quality and intertidal conditions adjacent to the mill. As the disruptive influences on these habitats are reduced or eliminated by the diffuser system and in-plant pollution abatement measures, the pattern and degree of rehabilitation should be investigated. The impact on benthic organisms should be monitored if fibre deposits begin to build up in the poorly flushed areas of the inner basin.

Deep benthic communities in the Woodfibre area have not been adequately studied. These communities may be substantially depressed as a result of previous fibre build up at the base of the steep sloping topography adjacent to the mill and the restricted water exchange at depth. A recently completed bottom trawl study in Howe Sound by Environment Canada will be useful in defining deep benthic communities in relation to industrial operations. In this respect Pisces submersible observations in the Woodfibre area would be useful.

1 INTRODUCTION

The Rayonier Canada Limited pulp mill at Woodfibre, British Columbia is located approximately 5 km from the head of Howe Sound on the west shore (Figure 1). Being located in a deep cleft of the coastal mountains some distance from the Strait of Georgia, Woodfibre is subject to continental climatic influences. During winter, strong northerly winds frequently blow down the Squamish Valley from the interior. Strong southwesterly winds originating from Pacific storms are channelled toward the head of Howe Sound by the mountain barriers. Although not as strong as the "Squamish" winds, the southerly inflow winds occur frequently between October and March and are often of gale force. Woodfibre experiences the wet winter - dry summer precipitation regime typical of coastal British Columbia. The area has a mean annual precipitation of approximately 200 cm with an average winter snowfall of 140 cm. For a more detailed discussion of climatology refer to Hoos and Vold (1975).

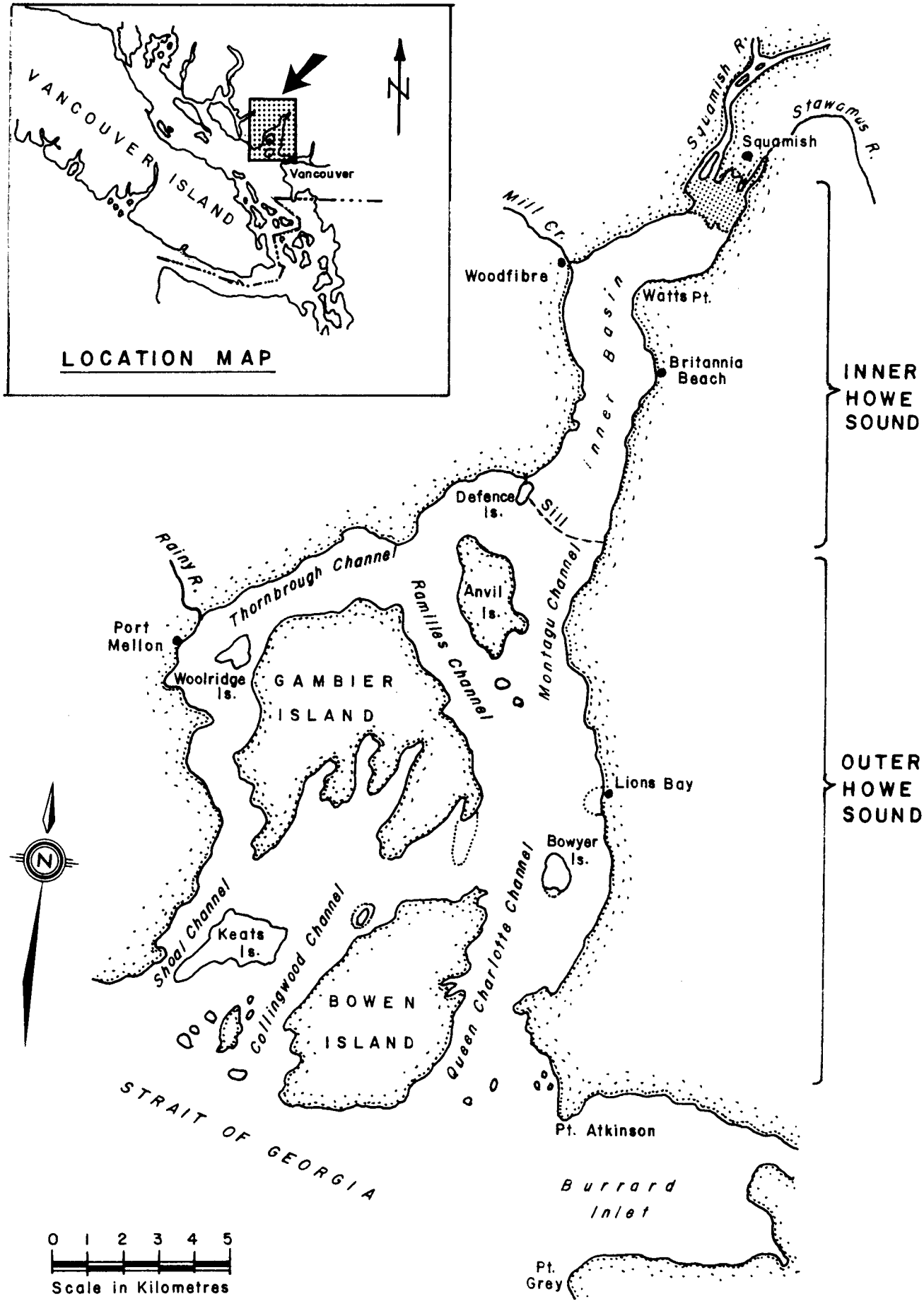

FIGURE 1 HOWE SOUND

2 MILL OPERATIONS

The Woodfibre pulp mill began operations in 1912 as an unbleached sulphite mill. In 1958, the mill was closed down for renovation to the present bleached sulphate (kraft) mill which began operations in 1961. In 1965, a new digester was installed which brought the mill to its present production rating of 600 air dried tons (ADT) per day of bleached kraft pulp. The mill manufactures pulp in a wide range of grades.

The wood chips required for the manufacture of pulp are purchased from Rayonier sawmills on the Fraser River or produced on site. Process water is piped from a lake approximately 1 km behind the mill site. Mill operations, including the sewer system, effluent characteristics, and pollution abatement facilities are discussed more fully by McLean and Tanner (1974).

3 EFFLUENT QUALITY

3.1 Government Regulations

Woodfibre currently discharges bleached kraft mill effluent (BKME) under a permit issued by the Pollution Control Board (P.C.B.) of the British Columbia Provincial Government. The permit, PE-1239 was issued on July 31, 1975 and amended February 9, 1977. Effluent characteristics stipulated are shown in Table 1 and outlined in a report on Pollution Control Objectives for the Forest Products Industry in British Columbia (1974). As an existing mill Woodfibre will be required by Federal Government Pulp and Paper Effluent Regulations (Environment Canada, 1971) to meet certain standards of biological oxygen demand ($B.O.D._5$), suspended solids (S.S.), and toxicity (Table 2).

The P.C.B. permit applies to a combined effluent from a large wood plant hydraulic barker, the chemical pulping process, and sanitary wastes, all of which will be consolidated into a single mill sewer. Effluent is presently discharged directly into surface waters of Howe Sound or Mill Creek through a series of outfalls with an estimated flow of 114 million litres per day.

3.2 Effluent Discharge

3.2.1 B.O.D. and S.S. Tables 3 and 4 show levels of B.O.D. and S.S. in Woodfibre mill effluent for 1976 and 1977 respectively. These measurements are taken routinely by Rayonier personnel and the results sent to the Federal and Provincial regulatory agencies.

3.2.2 Toxicity. In December 1975, an effluent monitoring program was initiated by Environment Canada to determine the range of toxicity associated with Woodfibre's mill effluent. Rayonier participated in the program by sending composite effluent samples on a regular basis to the E.P.S. bioassay laboratory in Vancouver for toxicity testing. The results appear in Table 5. Federal and Provincial toxicity requirements are given with Table 5 for reference. The program of toxicity testing was terminated by E.P.S. in December 1977.

TABLE 1 P.C.B. PERMIT REQUIREMENTS FOR EFFLUENT FROM THE WOODFIBRE MILL

Effluent Characteristics	Value
pH	6.5 - 8.5
Temperature	95°F
Floatable Solids	negligible
Total Suspended Solids	21 080 lb/day
Settleable Solids	2.5 ml/l
$B.O.D._5$	40 280 lb/day
Toxicity (LC_{50})	12.5%
Mercaptans	< 2.0 mg/l
Sulphides	< 1.0 mg/l
Residual Chlorine	< 0.1 mg/l

TABLE 2 FEDERAL EFFLUENT REGULATIONS FOR THE WOODFIBRE MILL

	S.S.	$B.O.D._5$
Kraft Pulping	7 lb/ADT	64 lb/ADT
Kraft Bleaching	6 lb/ADT	27 lb/ADT
Pulp Sheet Formation	2 lb/ADT	
Debarking	5 lb/ODT*	

* ODT - Oven Dried Tons.

Toxicity - 80% survival at 65% effluent concentration (v/v) over 96 hours, continuous flow testing.

TABLE 3 1976 EFFLUENT QUALITY RESULTS FOR RAYONIER CANADA LIMITED, WOODFIBRE MILL

Month	Flow x10 IG/D	BOD_5 LB/ADT	BOD_5 Tons	Suspended Solids LB/ADT	Suspended Solids Tons
January	19.9	62.0	15.19	218.0	53.41
February	13.6	32.6	5.62	77.4	13.35
March	14.2	31.5	5.67	138.6	24.95
1st Quarter	15.9	42.0	8.83	144.7	30.57
April	19.0	61.6	14.82	135.9	32.71
May	20.7	59.4	15.59	162.0	42.53
June	19.5	75.3	18.79	133.5	33.30
2nd Quarter	19.7	65.4	16.40	143.8	36.18
July	18.3	80.3	18.83	118.2	27.72
August	19.4	70.8	17.30	207.0	50.60
September	17.0	66.2	14.17	205.6	42.56
3rd Quarter	18.2	72.4	16.77	176.9	40.29
October	23.4	57.9	15.46	215.0	47.41
November	26.4	62.7	16.18	101.5	26.19
December	30.0	70.5	25.90	206.0	46.75
4th Quarter	26.6	63.7	19.18	174.2	43.45
Yearly Average	20.1	60.9	14.30	159.9	37.63

TABLE 4 1977 EFFLUENT QUALITY RESULTS FOR RAYONIER CANADA LIMITED, WOODFIBRE MILL

Month	Flow x10 IG/D	BOD_5 LB/ADT	BOD_5 Tons	Suspended Solids LB/ADT	Suspended Solids Tons
January	31.7	105.0	23.99	251	57.35
February	-	-	-	-	-
March	31.7	81.0	20.94	129.0	33.35
1st Quarter	31.7	93.0	22.47	190.0	45.35
April	31.7	81.7	17.61	145.1	31.26
May	24.6	67.3	15.99	109.9	26.09
June	26.7	67.0	14.20	183.0	38.80
2nd Quarter	27.7	72.0	15.93	146.0	32.05
July	27.1	63.3	16.36	72.2	18.66
August	28.1	102.0	23.82	161.0	37.59
September	29.2	-	-	90.3	22.79
3rd Quarter	28.1	82.7	20.09	107.8	26.35
October	28.5	79.76	19.76	109.3	27.27
November	29.6	104.0	27.04	180.0	46.80
December	24.5	59.0	14.51	130.0	31.98
4th Quarter	27.5	80.7	20.44	139.8	35.35
Yearly Average	28.8	82.1	19.73	145.9	34.78

TABLE 5 BIOASSAY RESULTS FOR RAYONIER CANADA LIMITED, WOODFIBRE MILL

Sample Date	% Survival Over 96 Hours, Static Testing Concentration (% V/V) Effluent						Sample pH
	100	65	45	32	12.5	5.6	
December 9, 1975	10	100	100	100	100	100	9.6
February 17, 1976	0	0	0	0	100	100	10.4
April 13, 1976	0	0	0	0	100	100	9.4
June 8, 1976	0	0	20	80	100	100	9.4
August 10, 1976	-	0	0	66	100	100	10.3
October 12, 1976	-	30	100	100	100	100	10.0
December 14, 1976	0	0	0	0	100	100	11.1
February 15, 1977	-	0	80	100	-	-	6.7
April 26, 1977	-	40	100	100	-	-	8.8
November 16, 977	0	0	0	60	-	-	7.8

Federal Bioassay Requirement - 80% survival in 65% (V/V) effluent concentration over 96 hours, continuous flow testing.

PCB Bioassay Requirement - 50% survival in 12.5 (V/V) effluent concentration over 96 hours, static testing.

3.2.3 Pollution Abatement Program. In order to bring Woodfibre mill into compliance with regulations several pollution abatement activities are underway. Rayonier plans the consolidation of several discharges into a total mill sewer which would have a submerged outfall and diffuser (Figure 2). In-plant chemical and fibre recovery facilities and bleach plant foam tanks are being installed. These works, as authorized in the P.C.B. permit are scheduled for completion by December 31, 1980. The feasibility of building a new bleach plant to replace two older plants is also being considered.

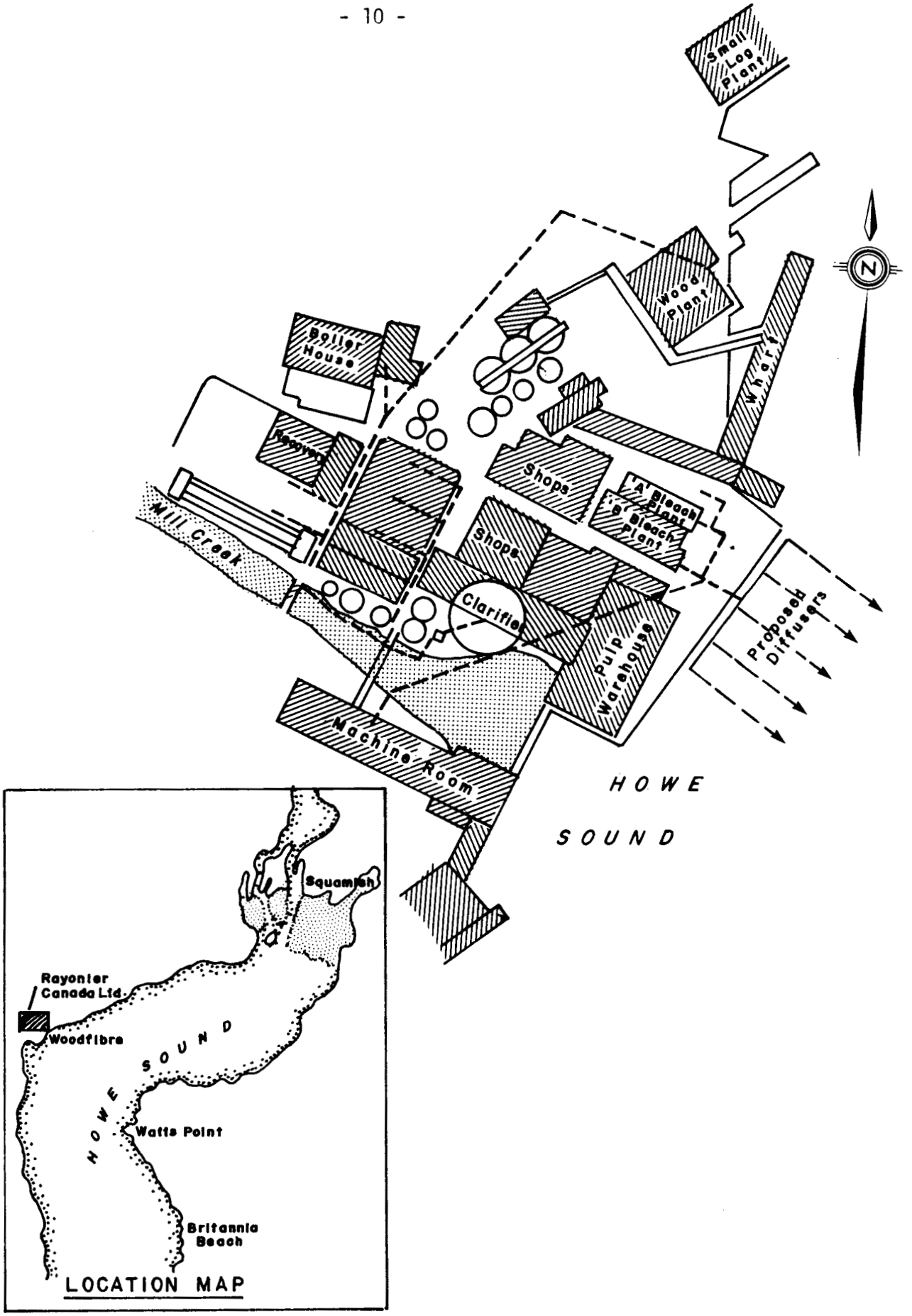

FIGURE 2 RAYONIER CANADA LTD., WOODFIBRE DIVISION

4 RECEIVING ENVIRONMENT

4.1 Oceanography

Oceanographic investigations in Howe Sound have extended over many years. In the late 1950's and the 1960's the area was monitored almost on an annual basis (Waldichuk et al, 1968) in view of the heavy industrialization in the Sound. More recently, current measurements and other oceanographic observations have been reported by Bell (1973, 1974) and currents in surface waters of upper Howe Sound by Pond (1973). A detailed review of oceanographic data for Howe Sound is presented in Environment Canada's Special Estuary Series (Hoos and Vold, 1975).

Howe Sound essentially contains two aquatic systems as a result of the relatively shallow threshold sill (61 metres) near the northeast end of Anvil Island (Figure 1). The area behind the sill, known as the upper basin or upper Howe Sound, is a true fjord reaching a maximum depth of about 290 metres and forms an estuarine system due to the influence of the Squamish River. The sill inhibits the regular flushing of the deeper waters in the upper basin. The lower basin (south of the sill) more closely represents a true Sound, being characterized by a broad body of water with scattered islands. The lower basin has a maximum depth of approximately 250 metres and empties directly into the Strait of Georgia.

Surface waters in the upper basin undergo changes in salinity, temperature, turbidity, and currents associated with variations in freshwater runoff. The main contributor of runoff water is the Squamish River which enters the system at the northwest corner of the upper basin. During freshet, May to September, stratification is most pronounced, while in the winter months when runoff is low, the stratification diminishes in surface waters, resulting in a uniformly mixed zone to a depth of about 10 metres.

Being a glacial melt river the Squamish has a high silt content which causes considerable turbidity and silt loading to the Sound, particularly during freshet. The Fraser River system also contributes silt to the Sound during periods of high runoff.

The two dominant factors affecting surface currents in upper Howe Sound are river runoff and wind (Pond, 1973). The current from the river discharge flows past Watts Point across from Woodfibre and then creates a counter-clockwise eddy between Britannia and the west shore of the Sound. The direct sweep of river water misses the foreshore at Woodfibre; however, a counter-current moving to the northeast sweeps along the Woodfibre shore in a clockwise eddy. This eddy tends to be entrained in the net outward flow created by the river and the area just north of Woodfibre appears to be relatively stagnant.

The seaward flow of river water and entrained saline water is replaced by a compensatory sub-surface current flowing upstream. The presence of the sill, however, inhibits deep waters originating in the Strait of Georgia from entering the inner basin behind the sill and exchanging with the waters confined there. This feature results in low dissolved oxygen in bottom waters behind the sill and occasionally a serious condition of anoxia develops. This phenomenon is presently being studied by Environment Canada (Pacific Environment Institute). Renewal of the deep waters behind the sill apparently occurs about once every three years (Bell, 1974) and appears to be due to a combination of strong, down channel winds and heavy runoff.

4.2 Impact Studies

4.2.1 Rayonier Studies. Between 1961 and 1972, Rayonier conducted a series of surveys in Howe Sound to determine receiving water quality with respect to mill effluent discharges (Denison and Tollefson, 1968, Tollefson et al, 1973). Although limited in scope, these studies tended to indicate that the effects of Woodfibre effluent were confined to an area adjacent to the mill. More extensive studies (Stoll, 1977; Tokar, 1978) were undertaken by Rayonier between 1975 and 1977 in compliance with a requirement of their P.C.B. discharge permit. These studies were concentrated at 13 stations in the upper basin (Figure 3) and included physical and chemical water quality measurements, plankton net hauls for standing crop determinations, and benthic grab sampling for invertebrate identification and enumeration and chemical analyses.

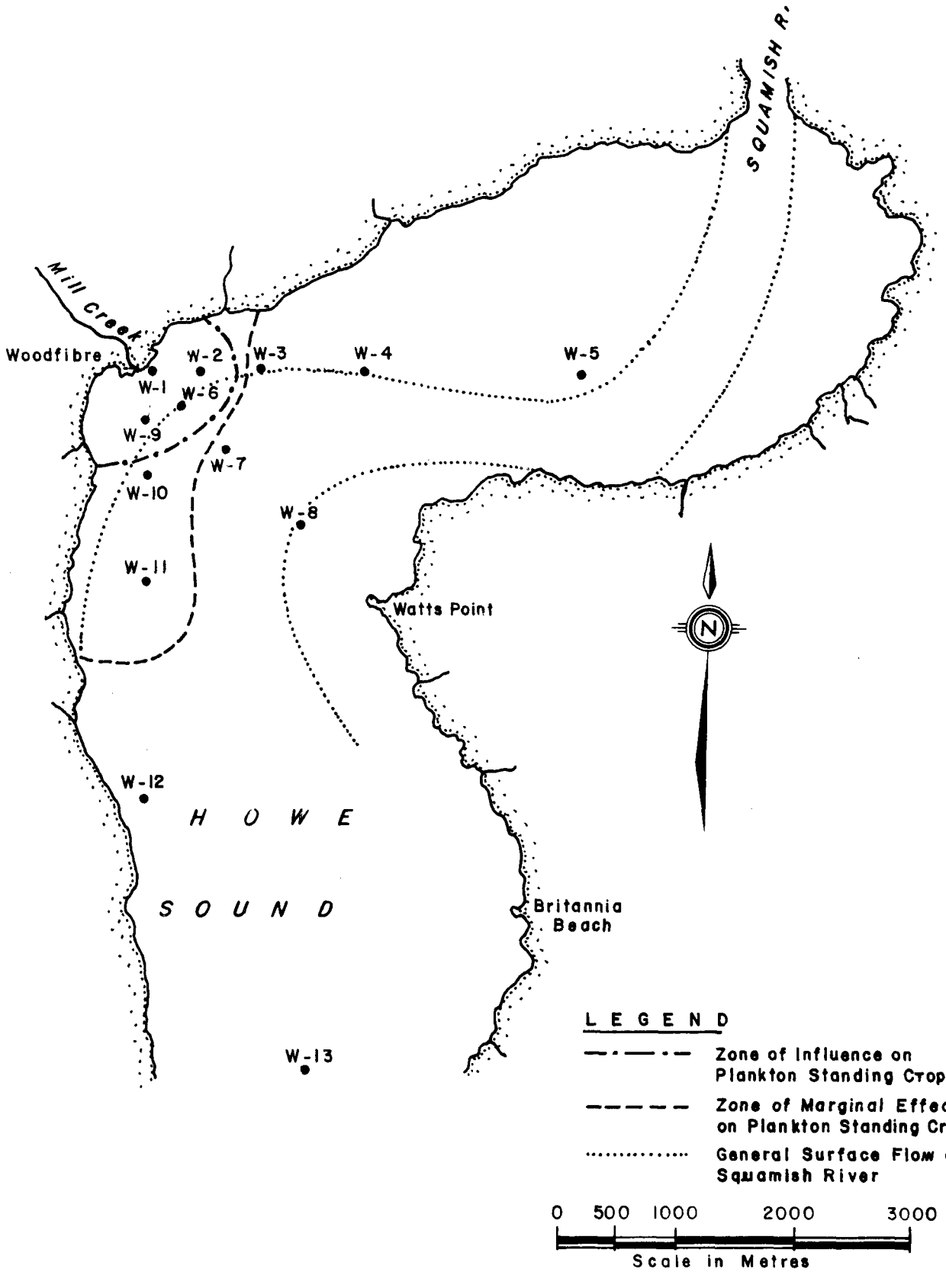

FIGURE 3 RAYONIER SAMPLING STATIONS AND MONITORING RESULTS (From Stoll 1977)

The Rayonier studies in 1976 showed a reduced species diversity and abundance of benthic invertebrates at stations W-1, W-6, and W-9 adjacent to the mill. In the 1977 studies no benthic life was found at these stations. Phytoplankton standing crop was depressed close to the pulp mill and in a southerly direction from the mill, as shown in Figure 3.

4.2.2 Phytoplankton Productivity. Stockner et al (1975) examined the relationship between BKME and phytoplankton production in waters adjacent to Woodfibre and the Port Mellon pulp mill in Howe Sound. Primary production in the Woodfibre area was 22% lower than at the control site; however, the total effect of Woodfibre and Port Mellon discharges on Howe sound production was calculated to be only 2 to 4%. The strong light attenuating properties of KME, as opposed to toxic substances in the effluent, were shown to be the major cause of reduced primary production. Stockner's data showed a similarity in density and species composition of phytoplankton populations between pulp mill and control stations. On this basis the author postulated that as the phytoplankton encounter effluent and reduced light conditions, they become metabolically inactive and remain quiescent until the light conditions improve.

This concept was substantiated by a later study (Stockner and Costella, 1976) which suggested that growth inhibition (toxicity) by substances in the effluent only occurred at effluent concentrations greater than 20% and that nutrients in the effluent could result in growth enhancement in regions of low effluent concentrations and good light conditions. The study also demonstrated that good water circulation and well flushed conditions are the most important physical factors reducing the impact of KME in coastal waters.

4.2.3 Benthic Studies. A SCUBA diving survey to determine the effects of solid pollutants on the shallow macro-invertebrate benthic fauna in Howe Sound was done by McDaniel (1973). Two stations were established near the Woodfibre mill, one about 0.8 km north of the main dock and the second approximately 1.6 km south of the main dock. The stations were characterized by steep, rocky dropoffs with sloping shelves

covered with fine silt deposited by the Squamish River. Although the organisms encountered were similar to those found on rocky substrates further to the south of Woodfibre the typical Balanus glandula/Mytilus edulis/Fucus sp. assemblage was more scraggly and intermittent.

Benthic diversity along transects from 0 to 30 metres depth was considerably less than noted at control stations near the mouth of Howe Sound. The reduction in diversity close to the mill could be due to many factors including low salinity, turbidity, and silt loading resulting from the Squamish River, and the build up of wood debris from log handling and storage. Other environmentally disruptive influences encountered by marine organisms in the vicinity of pulp mills were discussed by the author. These included water-borne wood fibres, chips and general plant wastes which may settle to the bottom forming extensive sludge beds of slowly decomposing wood which smother benthic communities and deplete overlying waters of oxygen. A recently completed bottom trawl study in Howe Sound (McDaniels et al, 1978), will be useful in defining deep benthic communities in relation to industrial operations.

The disruption of invertebrate beach communities by industrial operations in Howe Sound has been studied by Levings and McDaniel (1976). Data collected from a beach transect about 375 metres south of the Woodfibre sewer outfalls showed very depleted communities with only four invertebrate taxa recorded; namely nemerteans, oligochaetes, chironomid larvae, and a single species of amphipod. The beach area immediately adjacent to the mouth of Mill Creek (under the Woodfibre docks) was devoid of life.

The authors conclude that degradation of intertidal communities adjacent to the Woodfibre mill is due to toxic constituents in BKME. These have been shown to affect the growth and physiology of the pacific oyster, Crassostrea gigas (Pedlow, 1974). The authors also conclude that in terms of amount of waste and extent of disruption, log boom debris represents the most serious type of organic waste on Howe Sound beaches.

5 NATURAL RESOURCES

5.1 Fisheries Resource

A detailed discussion of fishery resources in Fisheries and Marine Service (F.M.S.) Statistical Area 28 (encompassing Howe Sound) has been prepared by F.M.S. (Knapp and Cairns 1978, F.M.S. Internal Report) and is presented in Appendix II. The following will be a brief summary of this information.

Howe Sound river systems contain steelhead trout, dolly vardon, char and four species of Pacific Salmon, i.e., pink, chum, coho and chinook. The salmon originate mainly from the Squamish-Stawamus River systems at the head of the Sound. Stocks of Howe Sound pink and chum salmon are harvested by net fisheries in the Strait of Georgia, Johnstone Strait, and Juan de Fuca Strait. Coho and chinook are caught commercially and by sport fishermen in the tidal waters outside Howe Sound and also provide a good sport fishery within the Sound, particularly since 1969 when the Sound was closed to commercial fishing.

The commercial herring fishery has been virtually non-existent in Howe Sound since 1970. The decrease in herring stocks has been attributed to loss of herring spawning habitat due to industrial development at the head of the Sound. Herring kills reported in Mamquam Channel at the head of the Sound were possibly due to low levels of dissolved oxygen or to hydrogen sulphide originating from decomposing wood debris on the bottom of the channel.

The commercial fisheries of groundfish and shellfish have been closed in the upper basin since 1970 due to mercury contamination from the F.M.C. chemical plant located on the Squamish delta. Most of the groundfish harvesting takes place outside Howe Sound or in the lower basin. Prior to 1970 large numbers of shrimp were reportedly fished in the upper basin; however, crab populations, although large, are not sufficient to support a commercial fishery. There has not been a mollusc fishery in Howe Sound since 1960.

5.2 Migratory Bird Resource

Howe Sound is generally recognized as a valuable habitat for migratory waterbirds throughout the year. The Squamish estuary is located between two important waterfowl areas, the Fraser delta and the Pemberton valley, and as such is a stop over for birds migrating between these areas. In addition to wintering and migratory habitat, Howe Sound sustains several breeding bird colonies. During most of the wintering and migration period, waterbirds can be found scattered along the shoreline with the largest concentration, numbering several thousand individuals of over 60 species, being found on the Squamish estuary. This estuary is the most important single area of habitat for dabbling ducks, geese and swans in Howe Sound. Smaller estuaries at the mouths of most creeks entering the Sound provide valuable habitat to dabbling ducks and other water-related birds. For additional information on migratory bird resource provided by the Canadian Wildlife Service (Trethewey, 1977, pers. com.) refer to Appendix I.

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APPENDIX I

MIGRATORY BIRD RESOURCES IN HOWE SOUND

APPENDIX I MIGRATORY BIRD RESOURCES IN HOWE SOUND (Canadian Wildlife Service, Trethewey, 1977 pers. com.)

Large flocks of several hundred western grebes are often seen in the deeper-water areas of the Sound, particularly in the Queen Charlotte Channel, Lions Bay to Britannia Beach and Britannia Beach to Squamish areas. Thornbrough Channel, into which the Canadian Forest Products, Port Mellon mill discharges its effluent, is known to support large numbers of wintering diving ducks. Thousands of diving ducks and other diving birds also winter among the islands of the southern part of the Sound, with those areas most favoured being: the eastern mainland shore from Point Atkinson to White Cliff Point; the eastern shoreline of Bowen Island in the vicinity of Deep Bay; the southern shore of Gambier Island; and perhaps most important, the fairly large area centering on the general area of the Pasley-Popham Island group and Barfleur Channel bounded on the west by Gower Point and Shoal Channel, on the north by the south shore of Keats Island, on the south by the open Strait of Georgia and on the east by the south-western shoreline of Bowen Island fronting Collingwood Channel.

Breeding bird colonies are located at:

1. Christie Islet, off the southern tip of Anvil Island
   -- glaucous-winged gull, pelagic cormorant, double-crested cormorant and pigeon guillemot.
2 Pam Rock, off the southern tip of Anvil Island
   -- glaucous-winged gull.
3. Whyte Islets, in Queen Charlotte Channel
   -- glaucous-winted gull.
4. Passage Island, in Queen Charlotte Channel
   -- glaucous-winged gull and pigeon guillemot.
5. Grace Islands, off the southwest tip of Gambier Island
   -- plunge divers, probably glaucous-winged gulls.

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APPENDIX II

CANADIAN FOREST PRODUCTS PULP MILL, PORT MELLON, B.C.
RAYONIER PULP MILL, WOODFIBRE, B.C.
FISHERIES RESOURCES OF FISHERIES AND MARINE SERVICE
STATISTICAL AREA 28 (Knapp and Cairns 1978, F.M.S. Internal Report)

The information presented in this document was collated solely for use within the Pacific Region (DFE) "Pulp Mill Review Process": a process designed to determine effluent characteristics, degree of treatment, and effects upon the receiving environment. This task was carried out to identify current and potential conflicts between aquatic resources and effluent disposal in order to priorize pollution abatement efforts.

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DEPARTMENT OF FISHERIES AND THE ENVIRONMENT
FISHERIES AND MARINE SERVICE

Canadian Forest Products, Port Mellon Pulp Mill
Rayonier, Woodfibre Pulp Mill
Fisheries Resources of Fisheries and Marine Service Statistical Area 28

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Resource Services Branch
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I INTRODUCTION

Howe Sound,a part of Statistical Area 28 (Figure 1), is enclosed by 75 miles of coastline and its 17 salmon spawning streams contain 46 linear miles of spawning grounds, 85% of which are found in the Squamish-Stawamus River systems at the head of the Sound. Two pulp mills are located on the western side of Howe Sound, Rayonier's Woodfibre mill near the head of the Sound, and Canadian Forest Products, Port Mellon mill opposite Gambier Island (Figure 2).(1)

II SALMONIDS

A. Stocks

Howe Sound river systems harbour steelhead and Dolly Varden (char) as well as four species of Pacific salmon *(Onchorynchus* sp*)*: coho, chum, pink, and chinook. Stocks mainly originate from the Squamish-Stawamus River systems at the head of Howe Sound. Chum and odd-year pink stocks provide the major harvest to the commercial fishery outside the Sound.(2) Coho and chinook provide a good sport fishery, particularly since 1969 when Howe Sound was closed to commercial fishing. Chinook stocks appear to have been decreasing since 1970 (Table I) while other salmon stocks have fluctuated widely from year to year. Stocks (Table I) were calculated from salmon escapement data because of inadequate commercial and sport fishing harvest data specific to Howe Sound. Proposed enhancement facilities for this area includes construction of a hatchery on the Cheakamus River capable of producing 45,000 chinook and 50,000 coho salmon, and 1,000 steelhead trout. In addition it would include a spawning channel for pink and chum salmon.(6)

B. Commercial Fisheries

Stocks of Howe Sound pink and chum salmon are largely harvested by net fisheries in the Strait of Georgia, Johnstone Strait, and Juan de Fuca Strait. Stocks of chinook

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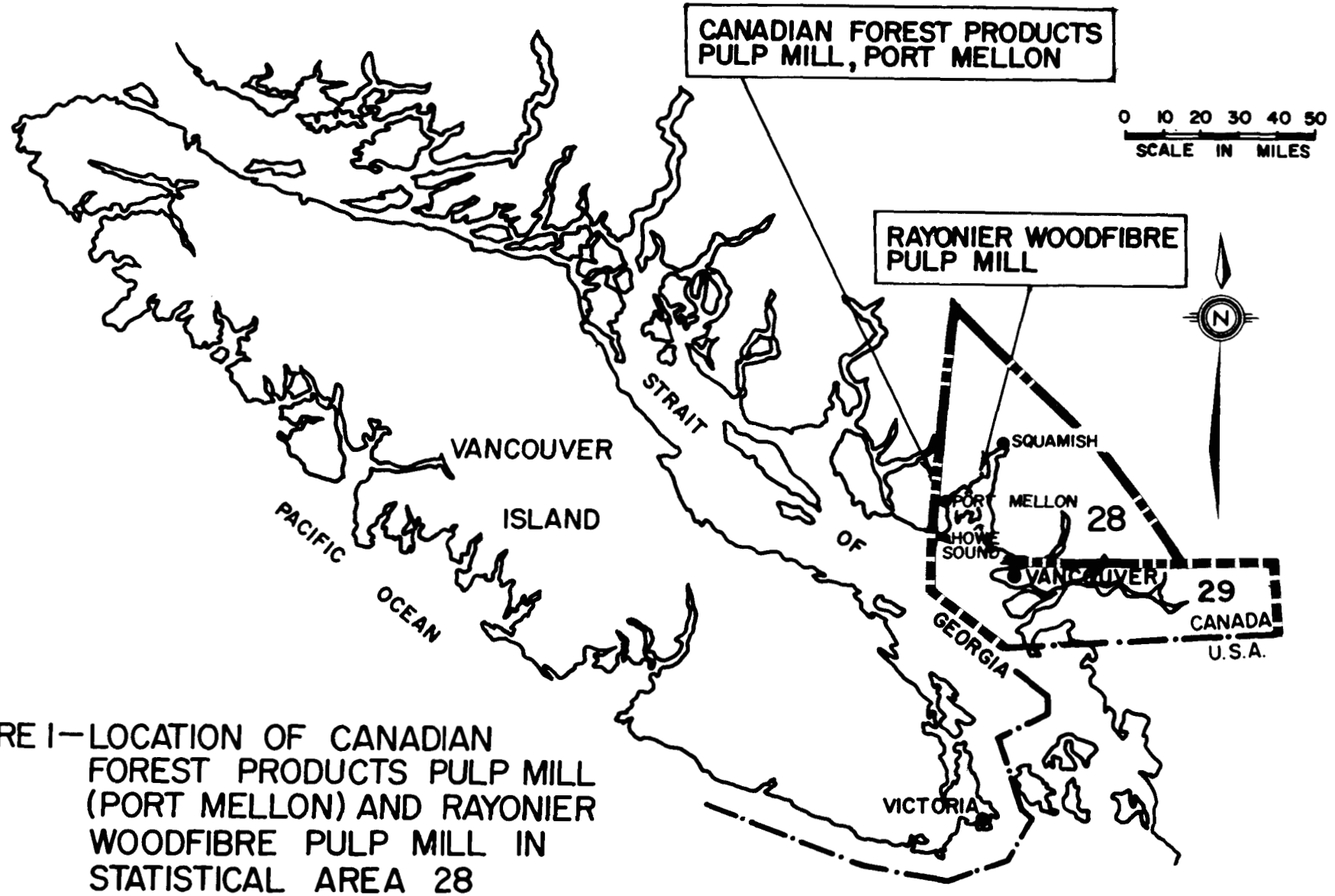

FIGURE 1—LOCATION OF CANADIAN FOREST PRODUCTS PULP MILL (PORT MELLON) AND RAYONIER WOODFIBRE PULP MILL IN STATISTICAL AREA 28

TABLE I

Estimates* of Mean Annual Total Stock** of Howe Sound Salmon(3,4,5,6)

YEAR	CHINOOK	COHO	CHUM	PINK Even/Odd
1956-59	92,500	71,500	161,000	0/673,000
1960-64	71,000	104,000	70,500	0/673,000
1965-69	102,000	56,000	94,500	0/240,000
1970	155,000	128,000	224,000	0
1971	56,000	120,000	66,500	120,500
1972	47,000	34,000	640,000	4,000
1973	69,000	110,000	471,000	690,000
1974	47,000	534,500	285,000	0
1975	12,000	225,500	68,500	125,000
1966-75	69,000	136,000	221,000	750/418,000

* Calculated from catch: escapement ratios. Chinook 5:1; Coho 4:1; Chum 2:1; Pink 5:1 (6)

** Stock = Escapement + Catch

and coho salmon are subjected to commercial and sport fisheries in tidal waters outside Howe Sound as well as sport fisheries within the Sound.(7)

The Available sport catch statistics include Area 29 (lower Fraser River and Gulf of Georgia, Figure 1) landings and are not specifically related to Howe Sound stocks. The combined sport-commercial harvest (Table II) was estimated using Howe Sound escapements (Table III) and accepted catch to escapement ratios. Based on coastwide information, these ratios are given as 5:1 for chinook, 4:1 for coho, 2:1 for chum, 5:1 for pink.(6)

C. Sport Fishery

i) Tidal

Tidal sport fishing in Howe Sound is concentrated in the early months of the year near Horseshoe Bay, the lower eastern portion of the Sound, Thornborough Channel and Halkett Bay (Gambier Island). In August, large chinook are caught off Britannia Beach. Catches of large chinook have also been reported off Woodfibre and Port Mellon mills.(7) Winter sport fishing for chinook salmon occurs at the head of Howe Sound.(1)

ii) Non-Tidal

A large non-tidal sport fishery occurs on the streams of the Squamish system. As an example, sport catch of 300 chinook, and 600 coho were recorded in 1972, a particularly poor year.(1) Sport steelhead yields for Squamish River streams, including the Stawamus, Squamish, Mamquam, and Cheakamus Rivers and Ashlu Creek are shown below:

ESTIMATES* OF SQUAMISH RIVER (AND TRIBUTARIES) STEELHEAD HARVESTS(9)

Years	Days Fished	No. Anglers	Catch	Catch/day
1975-76	8,098	2,115	1,907	0.235
1974-75	9,594	1,987	1,695	0.176
1973-74	10,703	2,279	1,349	0.126
1972-73	10,703	2,508	1,553	0.145

* Steelhead figures are obtained by a postcard system and estimates made form reported figures.

TABLE II

Estimated Mean Annual Sport and Commercial Harvest of Salmon(4,8)

YEAR	CHINOOK	COHO	CHUM	PINK Even/Odd
1956-59	74,000	53,000	79,500	0/538,000
1960-64	57,000	76,000	32,000	0/2,240,000
1965-69	81,500	39,000	45,000	0/191,000
1970	124,000	94,000	107,500	0
1971	45,000	87,500	29,000	95,500
1972	37,000	24,000	318,000	3,000
1973	55,000	80,000	235,000	551,500
1974	37,000	398,000	140,500	0
1975	9,000	166,000	32,500	99,000
1966-75	55,000	99,500	107,925	600/199,700

* Equals estimated stock (Table I) less total escapement (Table III) and Indian Food Fish Harvest (Table VIII).

TABLE III

Mean Annual Escapement to Howe Sound Streams(4,5)

YEAR	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD
1956-59	18,500	17,905	80,500	0/134,603	12,305
1960-64	14,200	25,900	35,800	0/560,705	13,400
1965-69	20,400	13,900	47,305	0/48,000	12,400
1970	31,000	32,000	112,200	0	8,200
1971	11,200	30,000	33,200	24,100	4,500
1972	9,500	8,500	320,100	750	22,600
1973	13,800	27,400	235,600	138,005	19,300
1974	9,300	133,600	142,600	0	26,300
1975	2,300	56,400	34,300	25,000	16,500

C. Escapement

In order to better relate the salmon spawning areas to the possible effects of the Port Mellon and Woodfibre pulp mills, Howe Sound salmon spawning streams were divided into four arbitrary areas (Figure 2); the Squamish-Stawamus system (Table IV), a mid-mill system, (McNab Creek, Table V), Port Mellon systems (Rainy River, McNair/Dakota Creek, Table VI), and Outer Howe Sound systems (Twin, Oulette, Mannion, Langdale, Williamson, West Bay and Long Bay Creeks, Table VII).

Howe Sound streams contain 46.5 linear miles of spawning grounds, 85% of which are found in the Squamish-Stawamus systems at the head of the Sound.(1,4) McNab Creek has 1.5 miles, the Port Mellon area streams have 1.5 miles and the outer Howe Sound streams have 4 linear miles of spawning grounds.

Timing of adult migrations to Howe Sound water systems depends upon the particular fish species, as shown in the following table and Figure 3 (Timing of Cheakamus River runs).

TIMING OF HOWE SOUND SALMON MIGRATIONS(4,5)

Species	Arrival In Streams	SPAWNING Begin	Peak	End
Chinook	mid-late June	mid-July	late Aug.	mid-Sept. - late Oct.
Coho	early Sept. - late Oct.	early Oct. - early Nov.	mid Oct. - late Nov.	early-mid Jan.
Pink	early Aug.	early Aug.	late Sept.	early-mid Oct.
Chum	early Nov.	mid-late Nov.	late Nov.	early Jan.

Seaward migrating juvenile salmon arrive in the estuaries in early spring depending upon environmental conditions (i.e. early freshet) and their residence time there varies according to the species.(10) Juvenile pink salmon leave the freshwater systems immediately after emergence in early spring and are out of the estuary by mid-April. Juvenile coho and chinook salmon spend up to one year in freshwater before migrating downstream to the marine environment. They are in the estuary from early April until mid-August, although chinook are at peak abundance in late June, and coho in late May and again in July. Chum salmon juveniles are present in the estuary from early April until July.(10)

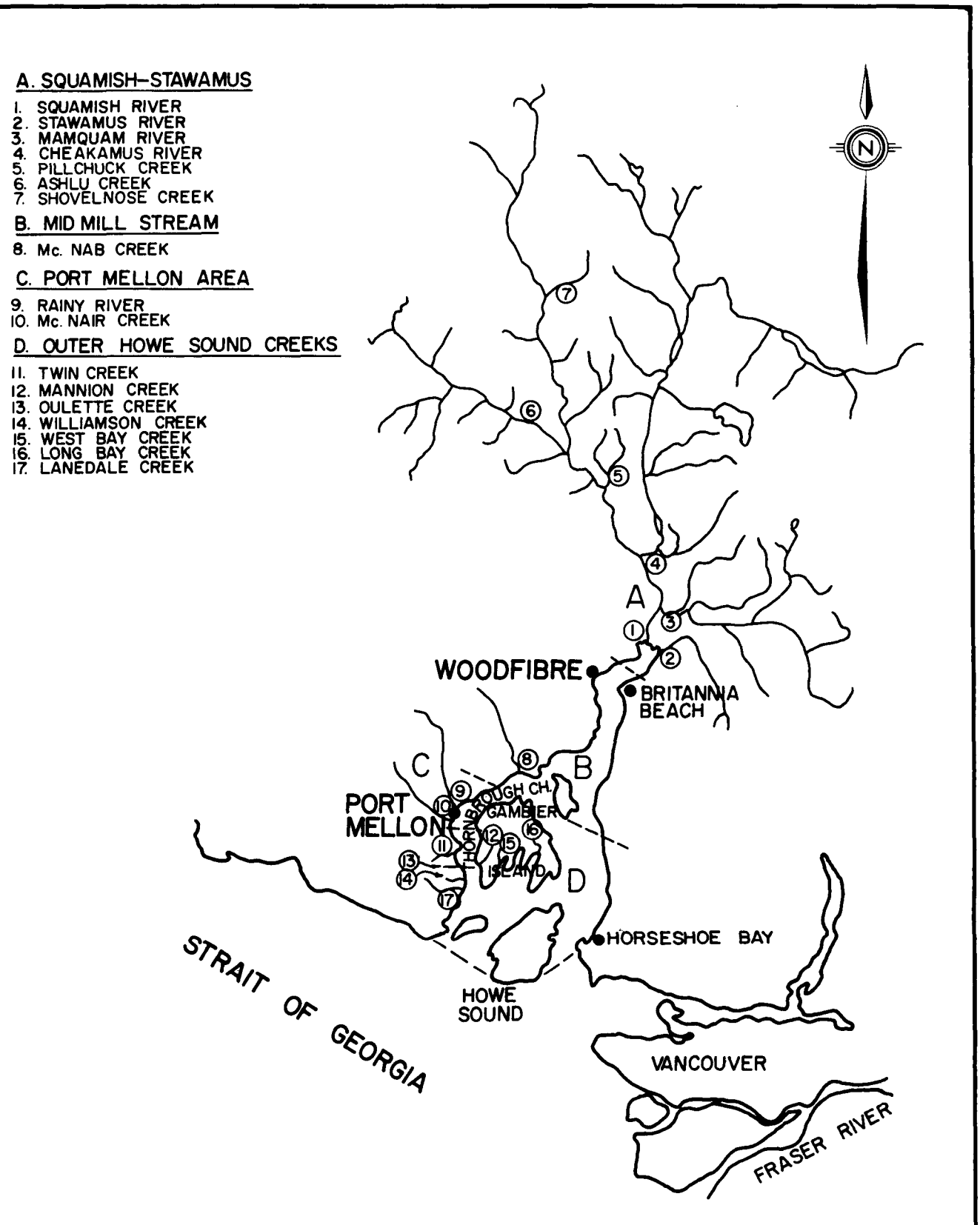

FIGURE 2–SALMON SPAWNING STREAMS OF HOWE SOUND

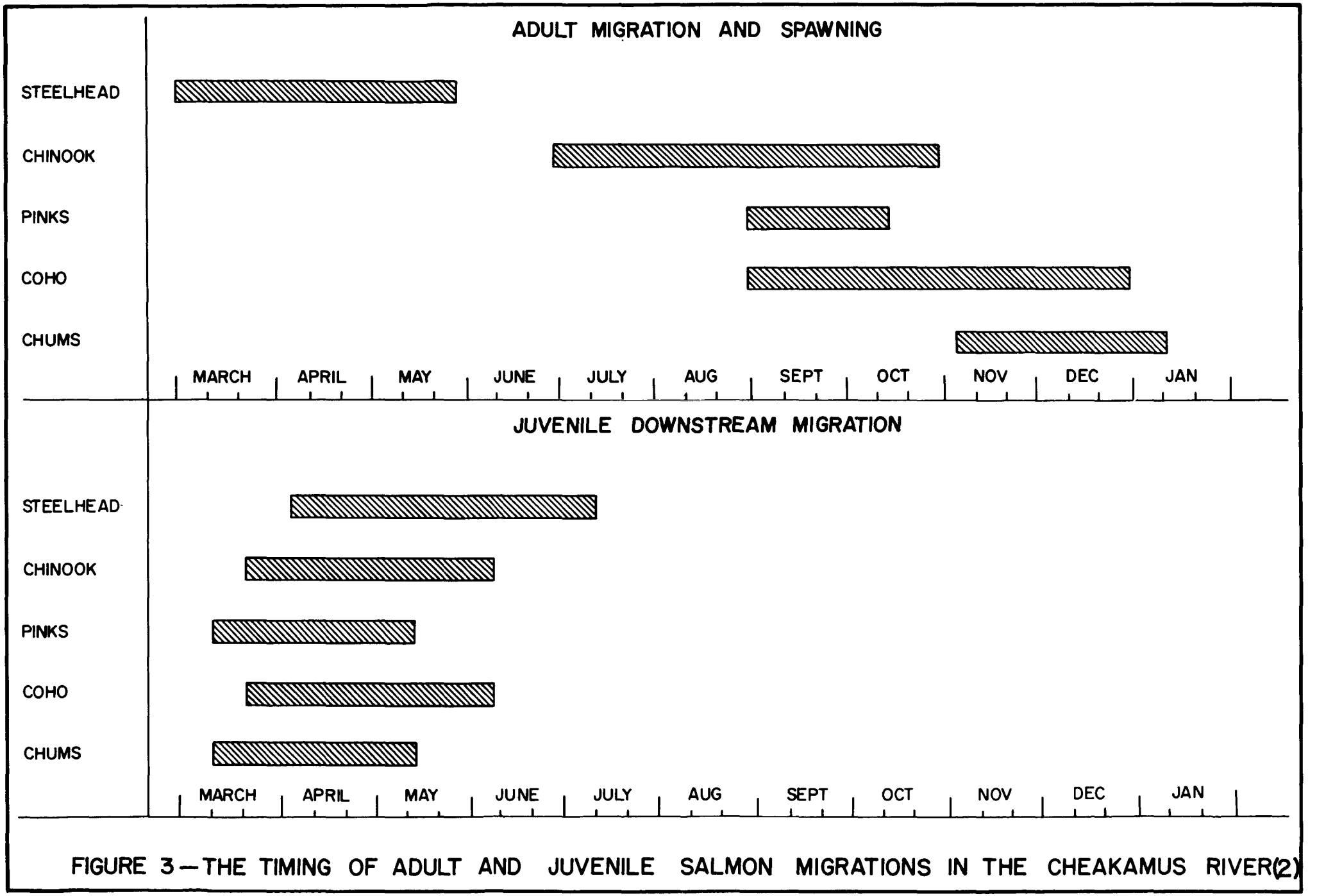

FIGURE 3—THE TIMING OF ADULT AND JUVENILE SALMON MIGRATIONS IN THE CHEAKAMUS RIVER(2)

TABLE IV

Mean Annual Escapements to the Squamish-Stawamus River Systems(4,5)

YEAR	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD
1956-59	18,500	18,900	80,409	0/134,300	12,300
1960-64	14,200	26,000	34,600	0/560,600	13,400
1965-69	20,400	14,000	44,000	0/48,000	12,400
1970	31,000	31,800	100,700	0	8,200
1971	11,200	29,800	23,200	24,100	4,500
1972	9,500	8,400	308,000	700	22,500
1973	14,000	27,000	225,400	138,000	19,300
1974	9,500	133,500	139,700	0	26,300
1975	2,500	56,300	31,500	25,000	16,500

TABLE V

Mean Annual Escapements to McNab Creek(4,5)

1956-59	0	200	0/250
1960-64	0	125	0/25
1965-69	0	200	0/25
1970	200	600	0
1971	150	150	0
1972	UNK	UNK	0
1973	350	350	0
1974	75	400	0
1975	25	50	0

TABLE VI

Mean Annual Escapements to the Port Mellon Area(4,5)

Rainy River

YEARS	CHUM	COHO	PINK	STEELHEAD
NO RECORDS PRIOR TO 1971				
1971	25	25	N/O	N/O
1972	25	25	N/O	25
1973	25	25	25	25
1974	25	75	N/O	25
1975	25	75	N/O	25
1976	N/O	N/O	N/O	N/O

McNair/Dakota Creeks

NO RECORDS PRIOR TO 1971				
1971	N/O	N/O	N/O	N/O
1972	10	N/O	N/O	N/O
1973	10	N/O	N/O	N/O
1974	35	25	N/O	N/O
1975	UNK	UNK	N/O	N/O
1976	N/O	N/O	N/O	N/O

TABLE VII

Mean Annual Chum Escapements to Outer Howe Sound Streams(4,5)

YEARS	TWIN	OULETTE	MANNION	LANGDALE	WILLIAMSON	WEST BAY	LONG BAY
1965-69		850			N/O	350	1,000
1967-76	*	1,500	*	*	1,400	1,200	1,500
1970	N/O	4,000	200	200	1,500	1,500	3,000
1971	N/O	3,000	100	50	3,400	2,200	1,100
1972	200	3,000	250	150	4,000	2,400	2,200
1973	150	1,500	750	75	2,200	1,800	3,000
1974	25	25	25	25	75	1,500	200
1975	N/O	200	400	25	25	1,600	200
1976	N/O	N/O	125	N/O	100	300	1,500

N/O = None Observed

* = No records Prior to 1970

Squamish-Stawamus Systems

The Squamish-Stawamus River systems produce 100% of the chinook, 99.8% of the coho, 95.8% of the chum, and almost 100% of the pink escapements to Howe Sound (Tables III, IV). If necessary, adults coming to this area could bypass the highest concentrations of effluent from the two mills by migrating along the eastern edge of the sound or by moving in the deeper waters beneath the effluent. The largest impact on the salmon stocks in this area is probably related to developments on the estuary itself (i.e. landfilling, dredging, dumping of industrial and municipal effluents, and storing log booms.)(10,11)

Primary production in marshlands and intertidal areas is very important to salmonid juveniles; benthic algae and sedges (grass-like plants) provide food (detritus or algae) for amphipods and other benthic invertebrates which are then preyed upon by fish. Of the 1,200 acres of the delta of the Squamish River, nearly 100 acres have been lost due to land filling and dyke construction.(10) Storing logs in Mamquam Channel has led to the accumulation of wood/debris causing physical "smothering" of benthic organisms and reductions in species diversity.(10)

Logging of the upper watersheds of the Squamish River system has resulted in flooding and the subsequent destruction of redds. This probably had an adverse influence on salmonid production in recent years. In 1973, floods destroyed 30 to 50% of coho and chum salmon spawn and up to 25% of pink and chinook salmon spawn.(7) In 1975, immense damage to pink and chinook spawning grounds resulted in losses of 80% of the salmon eggs.(7)

Systems between Port Mellon and Woodfibre

McNab Creek, located between the Woodfibre and Port Mellon pulp mills, has produced up to 600 chum (1970) and 350 coho (1973) (Table V). This creek has had diminishing stocks of pink salmon with none being recorded since 1969.(4,5) Adult salmon returning to this stream could, if necessary, avoid the worst concentrations of pulp mill effluent by migrating up the east side of Howe Sound and then through Ramillies Channel. There is, however, no evidence to suggest that the migrating salmon need to avoid the effluent. The mouth of McNab Creek is used for log storage. Such activity could have an adverse effect on salmon rearing.

Systems in the Port Mellon Area

Streams in the vicinity of Port Mellon produce only minor numbers of fish: 75 coho, 25 chum, 25 pink and 25 steelhead in 1974. These originate mainly from the Rainy River. (4,5) Adult and juvenile salmon may pass through high concentrations of effluent when arriving at or leaving waters adjacent to the Port Mellon pulp mill. The area around the mouths of Rainy River and McNair/Dakota Creek are used for log booming, which may have an effect on the rearing juvenile salmonids.

Historically the Rainy River was the most productive river in the Port Mellon Area. Records for 1924 to 1946, indicate that 7,000 chum and an equal number of odd-year pink salmon as well as 200 steelhead trout were common escapement to that stream.(4) In 1946 runs began falling off, presumably because houses for Port Mellon employees were being built on the banks of the river.(4) In 1954 the mill constructed a diversion dam and fishway, 3/4 of a mile upstream of the mouth. The Rainy River was not listed as a salmon spawning stream from 1947 to 1970. However, recent records (1971-1975) show some low returns of fish: 25-75 coho, 25 chum, 25 steelhead and a few odd-year pink salmon to the river. Only coho and steelhead have been reported above the dam where good spawning gravels are located. Below the dam where chum and pink salmon spawn poor spawning gravels are reported.(4) Recent observations have indicated that with adequate fish passage facilities fish stocks could be improved.(4)

Outer Howe Sound systems

Outer Howe Sound streams only produce chum salmon. The average annual total escapement to these streams has been 5,600 fish from 1967 to 1976. The mouths of all streams in the area are used as log booming or storage grounds which may have some adverse effect on juvenile salmon.(11)

D. Indian Food Fishery

Approximately 20 Indian families participate in the Howe Sound Indian food fishery. Fish are usually harvested using set nets in the Squamish River.(1) The harvest consists mainly of coho, chum and odd-year pink salmon with coho and chum being of greatest importance (Table VIII). Chinook harvests are low, although they have increased over the years. Harvests of other species such as steelhead and Dolly Varden char have fluctuated.(1)

III HERRING

Herring spawning takes place in Howe Sound (Figure 4)

TABLE VIII

Mean Annual Salmon Harvest by the Howe Sound Indian Food Fishery[7]

YEAR	DOLLY VARDEN	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD
1956-59	UNK	27	513	1,163	0/400	18
1960-64	UNK	170	2,100	2,860	0/3,000	28
1965-69	50	99	2,620	2,160	0/933	12
1970	UNK	125	2,200	4,800	0	0
1971	UNK	250	2,500	4,500	1,100	0
1972	UNK	547	1,379	2,112	0	3
1973	UNK	500	2,100	900	700	200
1974	UNK	360	2,870	2,250	0	25
1975	UNK	500	3,050	2,000	1,300	0
1966-75		258	2,360	2,606	0/880	28

UNK = Unknown

TABLE IX

Howe Sound Herring Catch, Spawners, Stock and Statute Miles of Spawn[12,13,14]

YEAR	CATCH	SPAWNERS	TOTAL STOCK	MILES OF SPAWN
	(Millions of Pieces)			
1956-59	<0.001	0.70	0.70	0.58
1960-64	0.20	27.7	27.90	2.61
1965-69	0.15	1.60	1.75	.56
1970	0.03	0.72	0.75	0
1971	0	UNK	UNK	.81
1972	0	0	0	0
1973	0	0	0	0
1974	0	UNK	UNK	.45
1975	0	0	0	0

* Catch calculated from commercial statistics (3) assuming 3,480 fish/ton.(14)

UNK = Unknown

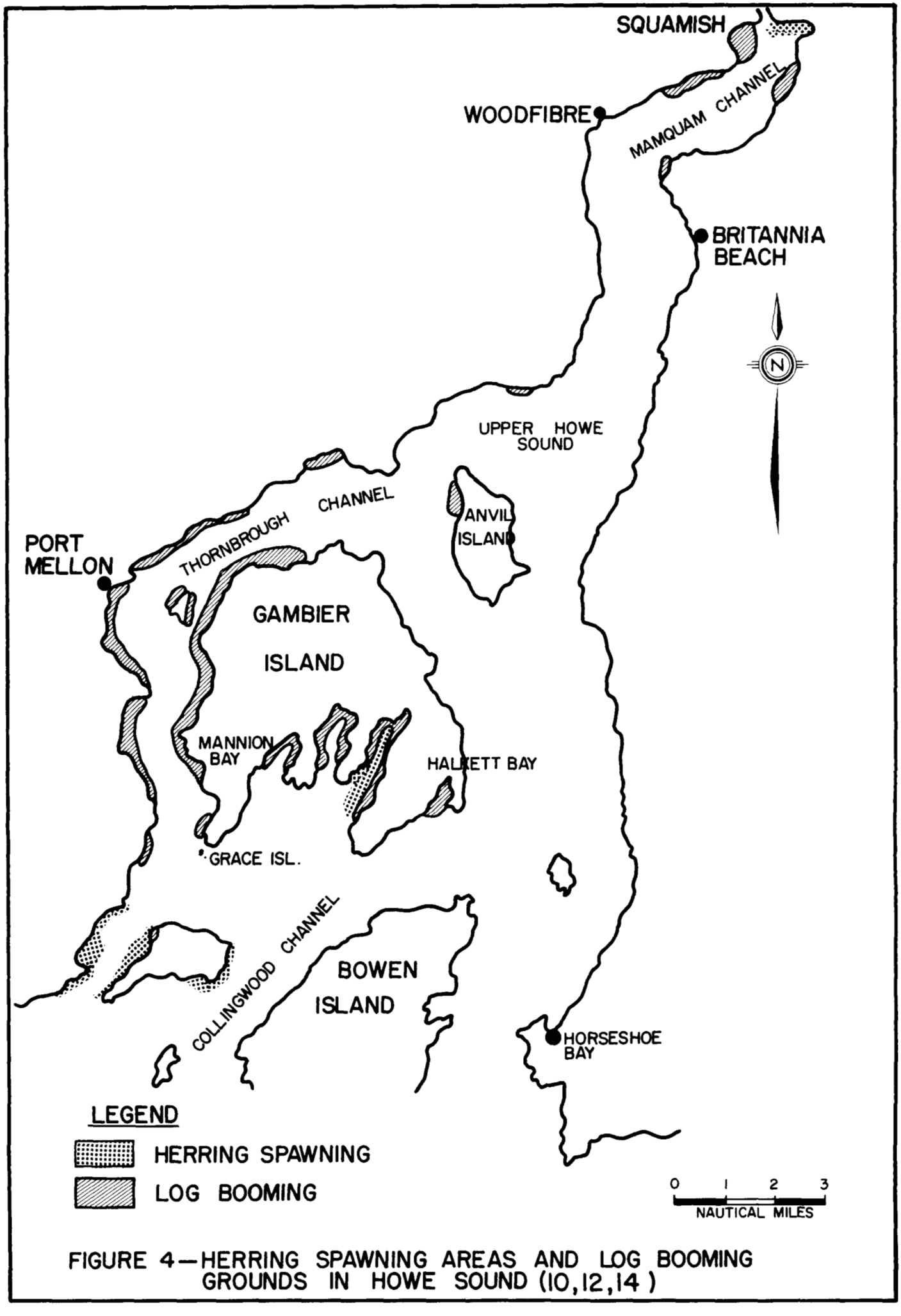

FIGURE 4—HERRING SPAWNING AREAS AND LOG BOOMING GROUNDS IN HOWE SOUND (10,12,14)

in mid-March. Egg deposition normally occurs within the shallow intertidal area where the eggs adhere to kelp, rockweed, eelgrass, rocks and other stable substrate. However, spawning has also been noted (to 1962) not only in eelgrass near Mamquam channel but also on creosoted dock pilings where vegetation was scarce (high mortality of eggs occurred on the creosoted pilings).(2) Historical herring spawning areas in Mamquam channel have been lost due to landfilling and log storage which resulted in displacement of spawning substrate.(2) Despite catches of all age groups and observations of large juvenile stocks in the Mamquam Channel area in 1969 no spawning occurred at this location.(2,10)

A commercial gillnet, herring fishery was conducted at the head of Howe Sound during the 1960's(1). Since a ban on harvesting herring for reduction purposes was in effect in the late 1960's and early 1970's, catch statistics for this period, reflects the bait, food, and roe fishery.(2) A small sport fishery is also conducted by jigging at the head of Howe Sound.(1)

Howe Sound herring stocks have been adversely affected by industrial development. Such development will eventually render the area unfit as a herring spawning area.(1) Herring kills have been observed on occassions when large numbers of herring are at the head of Howe Sound.(15) These mortalities may be due to low dissolved oxygen levels or by hydrogen sulphide evolving from wood debris on the bottom of Mamquam Channel.(10) Other herring kills were reported in 1968 and 1969 in the vicinity of Britannia Beach, but the cause was not discovered(1).

IV GROUNDFISH

Since 1970, upper Howe Sound (Figure 2) has been closed to commercial groundfish fisheries due to mercury contamination from the FMC chlor-alkali plant.(1) Most groundfish are now taken outside Howe Sound, although the occasional dragger works in the lower Sound.(16) The mean annual commercial catch is indicated in Table X.

V CRUSTACEANS

Since 1970, upper Howe Sound has also been closed to commercial shellfish harvesting due to mercury contamination.(1) Large populations of shrimp were reportedly fished in upper Howe Sound prior to the 1970 closure (Table XI).(10) Populations of shrimp are known off Grace and Gambier Islands, although they are not exploited.(10) Most shrimp fishing now occurs outside the Sound.(16)

TABLE X

Mean Annual Commercial Harvest of Groundfish and Other Non-Salmon Species (CWT) in Area 28, Including Howe Sound(3)

YEAR	FLOUNDER & SOLE	COD	SMELT	DOGFISH	NON-FOOD & OTHER FISH
1956-59	9.5	28.5	3.0	0	8.1
1960-64	.4	61.4	19.0	0	30.2
1965-69	14.6	14.0	40.6	38.2	4.0
1970	0	0	63	<.5	2
1971	0	2	0	0	2
1972	0	0	0	0	15
1973	0	10	0	1,740	<5
1974	0	0	0	170	10
1975	0	0	0	0	<5

TABLE XI

Mean Annual Commercial Harvest of Crustaceans, Shellfish and Molluscs (CWT) in Area 28, Including Howe Sound(3)

YEAR	SHRIMP & PRAWN	CRABS	C L A M S NATIVE LITTLENECK	BUTTER
1956-59	3,809	1,092	72.8	22.0
1960-64	2,356	1.092	2.6	.4
1965-69	2,136	738	0	0
1970	1,420	278	0	0
1971	1,109	273	0	0
1972	1,471	157	0	0
1973	1,450	330	0	0
1974	1,070	570	0	0
1975	1,090	1,670	0	0

Populations of crabs are relatively large, but not sufficient to support a commercial fishery (10,16). Commercial crab harvesting occurs outside Howe Sound and recreational prawn and crab fishing occurs near the entrance to the Sound.(10)

VI MOLLUSCS

There have not been any mollusc fisheries in Howe Sound since 1960. The harvest statistics (Table XI) are mainly for areas outside Howe Sound.(1) Oysters on Gambier Island have high levels of zinc and copper which are thought to have originated from Britannia mine.(10) The area of the mainland northwest of Gambier Island is an important oyster zone, while to the south of this is an area with commercially harvestable clams.(10)

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