Pollution

AN ASSESSMENT OF THE EFFECTS ON THE MORICE AND BULKLEY RIVER SYSTEMS OF A PULP MILL AT HOUSTON, B. C.

by

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FOREWORD

This report was written by Rick Kussat and Ken Peterson, respectively, of the Environmental Quality and the Economics Units, Northern Operations Branch.

This study was undertaken with the express purpose of assessing the economic and biological consequences of further development at Houston, B. C. It is hoped that this analysis will provide information necessary for decision-makers to formulate rational development plans which are in the public interest.

It should be noted that the contents of this report, while produced solely for the purpose of analyzing the Houston pulp mill development, is only a preliminary analysis which further field investigations might prove to be inadequate in future. Recent developments in both economic and bioassay studies might bring some of the conclusions contained in this report into question. Therefore, none of the report's contents or data should be used or referred to without clearance from the manager of the Northern Operations Branch.

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Rick Kussat

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I. INTRODUCTION

The Bulkley Valley Forest Industries Ltd. operation at Houston, B. C. is at present limited to a highly automated lumber mill with a production capacity of 270 million board feet annually. Plans for the forest products complex call for the construction of a plywood mill and a 750 ton capacity non-bleach pulp mill on the same site. Construction has not yet begun on the pulp mill, nor indeed, is it certain that the mill will be built as the parent firms (Bowaters Canadian Corp. and Consolidated Bathurst Ltd.) of BVFI have recently sold the lumber mill and all timber rights to Northwood Pulp Ltd. of Prince George, B. C. The Houston pulp mill project is thus now in limbo, but could be resurrected either by Northwood or by another company in the future.

The Fisheries Service of the Department of the Environment's concern with the Houston pulp mill proposal resides in the effect the effluent discharge from this mill would have on the Morice-Bulkley River system, specifically, the effect on salmon and steelhead trout which use the system spawning and rearing areas. Whether the BVFI pulp mill project goes ahead or not, it does not diminish this concern. A statement on the consequences of effluent discharge into the Bulkley River is essential at this time to emphasize the value of the system in its present state and to draw attention to the values that would be endangered by the proposed BVFI mill or any future pulp mill at Houston.

The first part of this paper identifies the geographic and biological aspects of the Bulkley River system and evaluates, in dollar terms, the commercial, recreational and Indian food fisheries of the Morice and Bulkley Rivers. Then, an assessment of the physical and chemical effects of effluent discharge is made, and finally, the net economic effect such chemical and physical changes would have on these fisheries is calculated.

II. GEOGRAPHIC AND BIOLOGICAL ASPECTS OF THE MORICE-BULKLEY RIVER SYSTEM

The Morice-Bulkley River drainage system, located in west-central British Columbia is one of the major tributaries of the Skeena River. The Morice River originates at Morice Lake and flows in a north-easterly direction approximately 53 miles to Houston where it joins the Bulkley River. From Houston, the Bulkley flows north-westerly for some 77 miles before it joins the Skeena River at Hazelton (Figure 1).

Morice Lake, the largest in the system, lies in the south-west corner of the watershed, and is bordered on the west by the Coastal Mountain Range. The Nanika River, a major salmon spawning tributary of the system, drains into Morice Lake on the east shore near the lake outlet (Figure 2). Nanika and Kidprice Lakes at the headwaters of the Nanika River are blocked to anadromous fish by a falls at the outlet of Kidprice Lake. On the west side of Morice Lake, the Atna River, which drains Atna Lake, enters the system.

Morice Lake is drained at the north-east end by the Morice River. The river is stable for the first 15 miles, but over the next 20 miles the river is characterized by a shifting bed and side channels which vary from year to year. From this point on to the Bulkley the river bed is again stable and very little shifting occurs. Numerous streams of varying size enter the Morice and Bulkley Rivers. Some of the more important ones that support salmonids are: Gosnell Creek, Thautil Creek, Lamprey Creek, Owen Creek, Telkwa River and Buck Creek (Figure 2).

The Morice and Bulkley Rivers, Morice Lake, Nanika River, Atna River and Lake and numerous other tributary streams provide spawning ground for all five species of Pacific salmon and rearing area for the three species whose life cycle includes a fresh water residence period. The system also supports steelhead trout. A brief

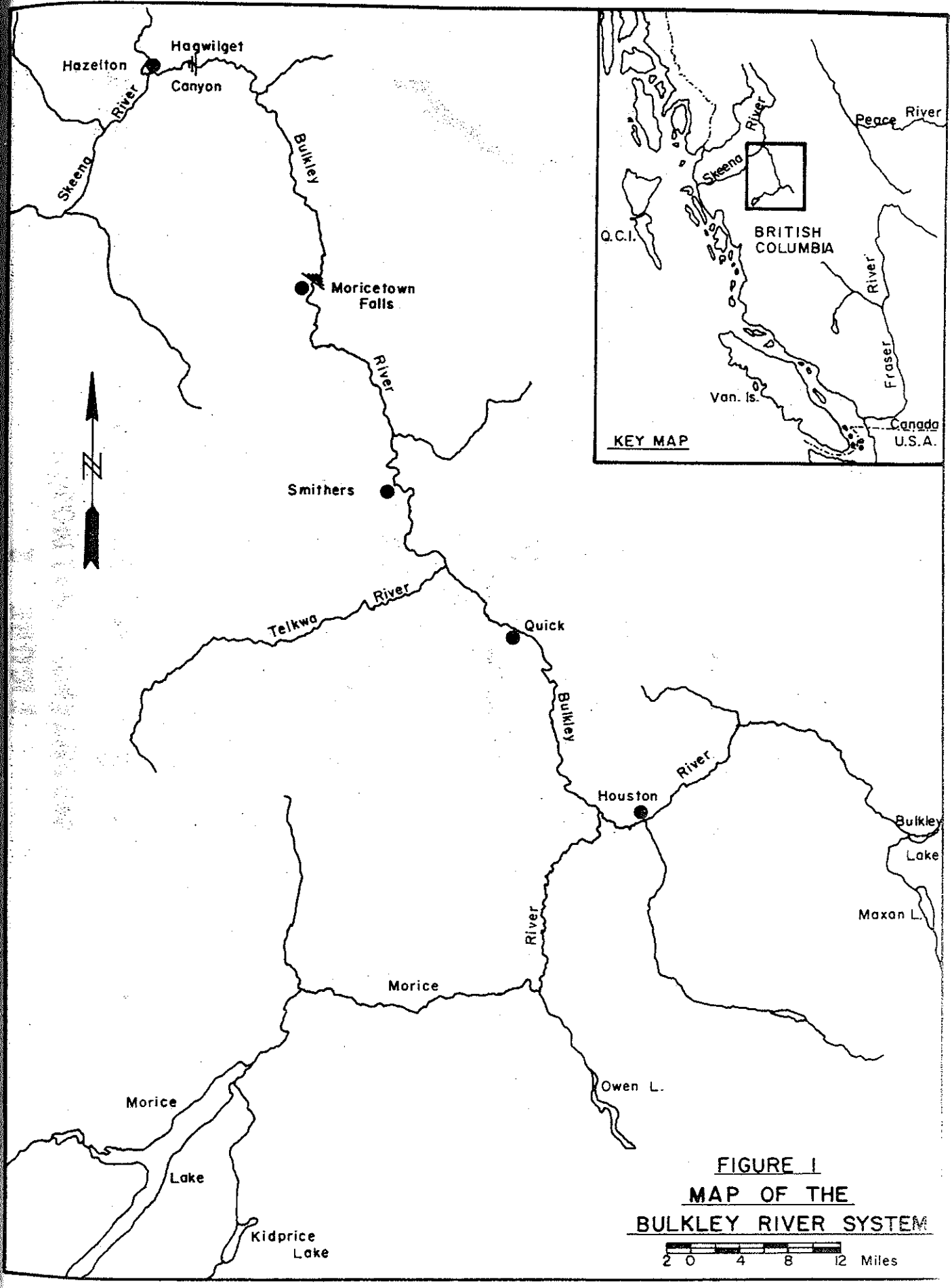
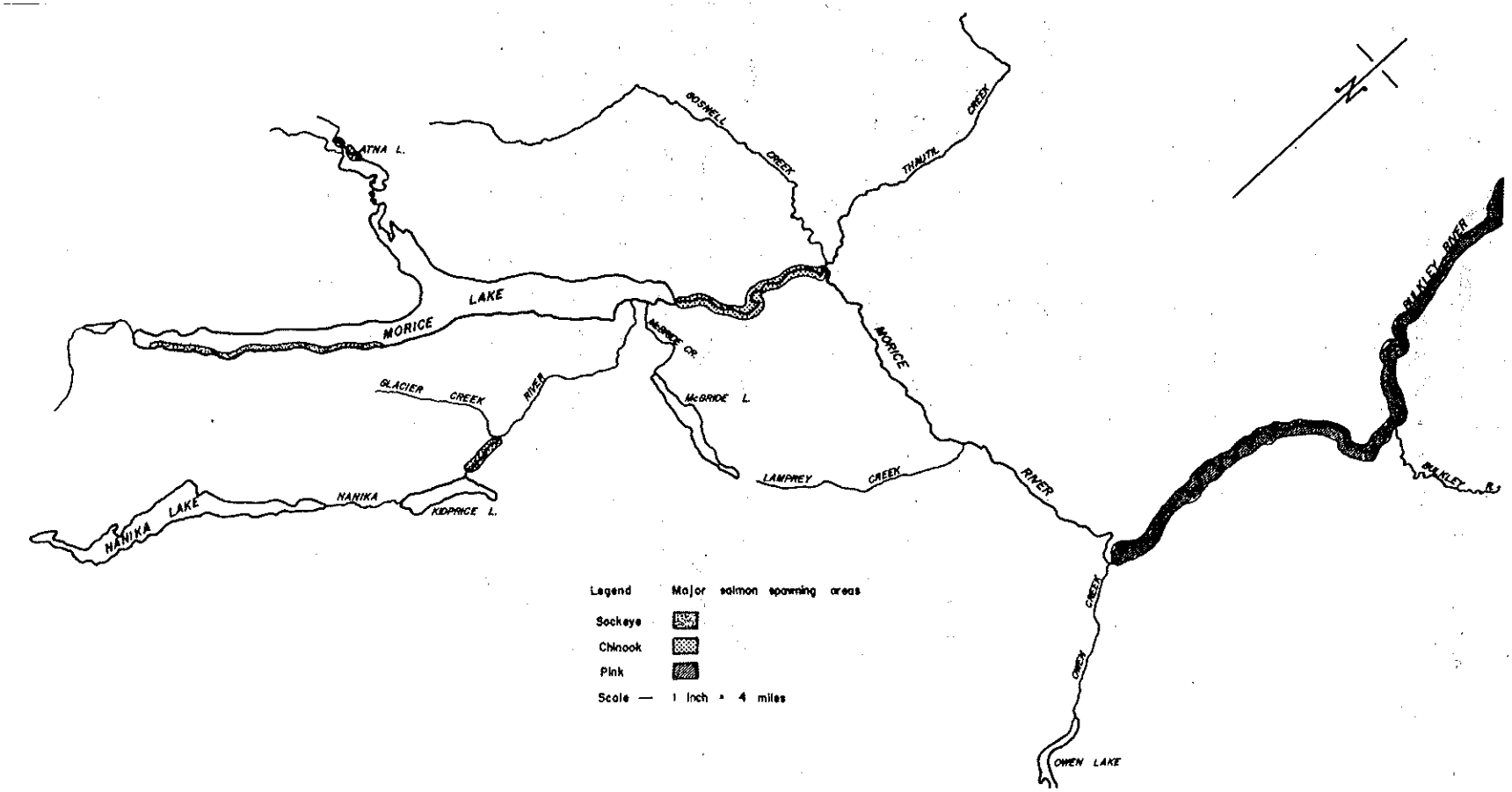


FIGURE 1
MAP OF THE
BULKLEY RIVER SYSTEM

FIGURE 2
IMPORTANT SALMONID
SPAWNING AREAS ON THE MORICE-BULKLEY RIVER SYSTEM



discussion of each of these six anadromous species that use the Morice-Bulkley system follows. Reference should be made to Figure 2, which shows the major spawning areas of the system.

Sockeye Salmon

Adult sockeye spawn from late August to early October in the Nanika River, Atna Lake and tributary streams, certain areas of Morice Lake, in the Morice River near the outlet, and in the upper Bulkley. The fry spend one to two years in Morice Lake before migrating to sea where they spend one to three years before returning. The two main age classes among Morice sockeye are 5_3's and 6_3's (in their 5th and 6th year as adults; two years in fresh water). This contrasts with the mixture of 4_2's and 5_2's (4th and 5th year as adults; one year in fresh water) which compose most of the Babine sockeye, the largest population in the entire Skeena system.

The annual sockeye escapement to the Nanika River, the principal sockeye spawning stream in the system, averaged approximately 50,000 during the period 1945-53. Escapement since that period has ranged from 1,000 to 10,000 fish annually. Development work including the construction of fishways at Moricetown Falls, the removal of a rock obstruction at Hagwilget Canyon on the Bulkley, and the construction of a temporary hatchery on the Nanika was undertaken to restore these stocks to their former levels. So far, these rehabilitation efforts have not brought the sockeye back to historic escapement levels, although there is no good reason to expect that these levels of abundance cannot be restored or even improved beyond their former levels, in future.

Chinook Salmon

Chinook salmon spawn mainly in the ten miles of the Morice River lying between the outlet of Morice Lake and Gosnell Creek during late August and September. Some of the fry migrate to sea the following

spring and some remain for one year in fresh water, migrating to sea in the second spring. The Morice River since 1951, has supported an average of 9,100 spawners annually, and remains one of the top ten producers of chinook salmon in British Columbia. The Bulkley accounts for a further 800 chinook spawners annually.

Pink Salmon

Pink salmon spawn in the lower twenty miles of the Morice River up to Owen Creek during late August and September. The following spring the fry migrate directly to sea returning as adults the next year. The Morice-Bulkley system has tremendous pink salmon producing potential, estimated to be in excess of 500,000 fish annually. The alleviation of obstructions at Hagwilget Canyon and Moricetown Falls has not resulted in any substantial increase in abundance, perhaps because Moricetown Falls still presents a severe impediment to pink salmon migration. Despite this, average annual escapement of 3,000 to 4,000 pink salmon have been observed.

Coho Salmon

Coho salmon are known to spawn in the Morice River and in nearly all accessible tributary streams of the system during October and November. No precise definition of the coho spawning areas has been attempted. Tagging studies indicate that the annual coho salmon escapement to the Morice-Bulkley system is in the order of 25,000 fish making this system one of the most important coho producers in British Columbia (Anonymous, 1964).

Chum Salmon

Little is known about the chum salmon spawning distribution

in the Morice-Bulkley system. The escapement has never been enumerated, but observations indicate that the population numbers only a few hundred fish.

Steelhead Trout

Adult steelhead are present in the Morice River during the period August to June. Spawning takes place during the winter throughout the entire Morice River; the largest concentration has been observed upstream from Lamprey Creek. No estimates are available on steelhead trout escapement, but the Morice River is known to be one of the major producers of steelhead trout in British Columbia.

III. ECONOMIC EVALUATION OF SALMON AND STEELHEAD FISHERIES ASSOCIATED WITH THE MORICE-BULKLEY SYSTEM

There are three distinct fisheries associated with the Morice-Bulkley system:

1. the commercial fishery off the mouth of the Skeena which depends upon salmon spawning in the Morice-Bulkley system for part of its total catch;

2. the Indian food fishery at Moricetown Falls on the Bulkley River which harvests part of the returning salmon population en route to the spawning areas of the Nanika and Morice;

3. the sport fishery on the Bulkley and Morice Rivers for salmon, steelhead and other species.

Each of these fisheries will be examined in turn, and each will be evaluated in dollar terms.

The Commercial Fishery

The sockeye, pink, chinook and coho salmon that spawn in the Morice-Bulkley system contribute to the commercial catch off the mouth of the Skeena River. The Morice-Bulkley system makes only a small contribution to the total sockeye and pink production of the Skeena, but it is an important producer of both coho and chinook salmon. Estimating the commercial value of these stocks requires calculating the proportion of the total catch composed of salmon destined for the Morice-Bulkley system.

Figures are available for the total catch, and total escapement by species of salmon destined for the Skeena system as a whole. Thus, if an estimate can be made of the escapement by species to the

Morice-Bulkley spawning areas, it should be possible to apply the catch to escapement ratio for the whole Skeena system and thus calculate the catch attributed to Morice-Bulkley bound salmon. The method used in this report is to combine the average of the best estimates made in recent years of the total number of spawners with the average number of salmon, by species, harvested en route to the spawning grounds.

The harvest of salmon in fresh water has three components: fish taken by sport fishermen; fish taken by the Indian food fishery; and fish injured, but not captured by the Indian food fishery (few, if any, of these survive to reach the spawning grounds) (Palmer, 1964). Table I shows by species, the estimated number of spawners (Anonymous, 1964), the estimated number of salmon harvested and the estimated total escapement to the Morice and Bulkley Rivers.

TABLE I

ESTIMATED AVERAGE ANNUAL ESCAPEMENT OF SOCKEYE, COHO, PINK AND CHINOOK SALMON TO THE MORICE-BULKLEY RIVER SYSTEM

	Sockeye	Coho	Pink	Chinook
Average no. spawners	7,700	25,000	3,500	9,900
Average no. caught by Indian food fishery	1,100	1,300	500	1,700
Average no. injured by Indian food fishery	1,650	1,950	750	2,500
Average no. caught by sport fishermen	-	500	-	500
Estimated average annual escapement	10,450	28,750	4,750	14,600

The average catch to escapement ratio over the five year period 1966 to 1970 for each species returning to the entire Skeena system is given in Table II. Applying these ratios to the estimated average annual escapement gives an estimated average annual catch of 12,000 sockeye, 67,900 coho, 7,900 pink and 32,400 chinook. Table II also shows the estimated annual landed and wholesale values of the commercial catch of the Bulkley and Morice River salmon. Based on an average 1972 landed value of $2.15 per sockeye, $2.45 per coho, $0.60 per pink and $7.15 per chinook, the average annual landed value of this part of the commercial fishery is $465,850. The wholesale value of the catch, which reflects more accurately the value to the British Columbia economy, is approximately double the average annual landed value, or $913,700. Converting the future stream of equal average annual wholesale values to a present value in 1972 (by discounting future values to the year 2,000 at 6 percent) gives a present discounted value of $12,490,000.

TABLE II

AVERAGE ANNUAL NUMBER OF PIECES AND VALUE OF THE COMMERCIAL CATCH OF SOCKEYE, COHO, PINK AND CHINOOK SALMON ATTRIBUTABLE TO THE MORICE-BULKLEY RIVER SYSTEM

	Sockeye	Coho	Pink	Chinook	Total
Total escapement	10,450	28,750	4,750	14,600	58,550
Catch/escapement	1.27	2.47	1.83	2.47	
Total catch	13,300	71,000	8,700	36,100	129,100
Average landed value	$2.15	$2.45	$0.60	$7.15	
Total landed value	$28,600	$173,950	$5,200	$258,100	$465,850
Total wholesale value	$57,200	$347,900	$10,400	$516,200	$931,700
Total discounted value to the year 2,000					$12,490,000

The Indian Food Fishery

Native Indians have been harvesting salmon and steelhead trout bound for the spawning grounds of the Morice-Bulkley River system for hundreds of years. They continue to do so as an aboriginal right although permits must be issued by the Fisheries Service, Department of the Environment, under the authority of the Canada Fisheries Act. Salmon are taken by Indians at scattered points along the Bulkley and Morice Rivers, but there is only one concentrated fishery where large numbers of fish are taken each year and that is at Moricetown Falls.

Moricetown Falls presents an obstacle to salmon migration which makes them vulnerable to the Indian fishery. The fish are delayed by the falls and collect at the base before ascending either the actual falls or the fish ladders installed by the Department of Fisheries in 1951. Indians take salmon with gaff hooks tied to long poles in what can be a spectacular performance as the fishermen stand rather precariously on rocks with nothing before them but a precipitous drop into turbulent water. The Indians turn some of the picturesque value of this operation into revenue as they run a small handicraft shop for the tourists who are attracted by the falls, by this spectacle and by the sports fishing in the same area. First, the value to the Indians of the food fishery is assessed and then the revenues they receive from tourists are discussed.

Table III shows the catch by species of salmon and steelhead trout by Indians at Moricetown Falls from 1956 to 1971. Nineteen-seventy-one and nineteen-seventy-two were poor years for the food fishery largely because of high water conditions during the peak migration periods. The gaff fishery is much more effective in low water because the salmon are delayed at the falls for longer periods. The slightly lower than average catch in the last few years might result from poor fishing conditions and restrictive regulations rather than serve as an indication that Indian fishing effort is decreasing.

TABLE III

ANNUAL CATCH OF SALMON AND STEELHEAD TROUT BY THE INDIAN FOOD FISHERY AT MORICETOWN FALLS

Year	Sockeye	Coho	Pink	Chinook	Steelhead	Total
1956	1,400	1,600	*	3,200	300	6,500
1957	200	500	*	2,400	100	3,200
1958	200	200	*	2,900	100	3,400
1959	600	1,300	1,000	2,500	300	5,700
1960	500	900	200	700	100	2,400
1961	2,100	1,200	1,200	2,500	600	7,600
1962	800	1,400	500	2,500	400	5,600
1963	2,300	1,400	1,600	2,600	500	8,400
1964	2,300	1,000	700	1,600	100	5,700
1965	1,500	3,200	1,100	1,400	200	7,400
1966	2,400	2,600	500	1,200	400	7,100
1967	800	2,000	200	1,000	200	4,200
1968	800	2,000	200	1,000	200	4,200
1969	500	800	500	500	100	2,400
1970	800	700	300	700	200	2,700
1971	200	300	300	300	100	1,200

* No estimates available.

The average catch by the Moricetown Falls food fishery over the years shown in Table III is calculated in Table IV. The landed value of these fish is also calculated in Table IV, using average value per fish as in Table II. The total landed value of $18,660 is then doubled to reflect wholesale value, a more appropriate measure of the value to the Indians. The average annual wholesale value of $37,320 represents a present discounted value (at 6 percent to the year 2,000) of $500,300.

TABLE IV

AVERAGE ANNUAL VALUE OF THE INDIAN FOOD FISHERY AT MORICETOWN FALLS

	Sockeye	Coho	Pink	Chinook	Steelhead	Total
Average annual catch	1,100	1,300	500	1,700	200	4,800
Average landed value/fish	$2.15	$2.45	$0.60	$7.15	$2.80	
Average annual landed value	$2,400	$3,200	$300	$12,200	$560	$18,660
Average annual wholesale value	$4,800	$6,400	$600	$24,400	$1,120	$37,320
Present discounted value to the year 2,000						$500,300

Access to the sport fishing areas below Moricetown Falls is largely controlled by the Indians. They charge fishermen $5.00 for a

season fishing permit and $1.00 for a daily permit. They also levy a $2.00 per night fee for campers who park on the reservation. Table V shows the total revenue received from these sources in 1971. Reports indicate that the coverage of fishermen and campers by the Indians is somewhat short of comprehensive. In addition, the prices charged are probably a good deal lower than those which maximize revenue. Both of these considerations indicate that the potential for revenue from fishermen and campers is much higher than the $1,071 collected in 1971, but there is no quantitative information available for estimating this potential.

TABLE V

REVENUE RECEIVED BY MORICETOWN FALLS INDIANS FROM SALE OF CAMPING AND FISHING PERMITS, 1971

Type of Permit	No. Sold	Fee	Total Revenue
Season fishing permit	61	$5.00	$305
Camping permit	236	$2.00	$472
One-day fishing permit	294	$1.00	$294
TOTAL			$1,071

Table VI shows estimates of the total revenue received by the Moricetown Falls Indians from 1967 to 1971. These include revenues from the sale of camping and fishing permits and revenues from the sale of handicrafts and so on, to tourists. The average annual revenue over the past five years was $2,200 which, when discounted, represents a present value of $29,493. The total value to the Indians of the

Moricetown Falls fishery, including the food fishery is in excess of $30,000 and the present discounted value using a 6 percent discounted rate and taking it to the year 2,000 is $529,793.

TABLE VI

ESTIMATED TOTAL ANNUAL REVENUE RECEIVED BY MORICETOWN FALLS INDIANS, 1967-1971

	1967	1968	1969	1970	1971
Estimated Total Revenue	$2,000	$2,000	$2,500	$2,500	$2,000

Average Annual Revenue $2,200

Present Discounted Value to the Year 2,000 .....$29,493

Calculating the value of the Moricetown Falls fishery in dollar terms does not tell the whole story. The food fishery is an integral part of the cultural heritage of the Moricetown Band and as such is of incalculable value to them. There is evidence that younger members of the Band attach less importance to the fishery as a way of life, viewing it more as sport, which suggests that as the cultural patterns of the Indians shift through time (as assumed here at least to the year 2,000) the fishery will be of declining significance. Nevertheless, for some time to come the food fishery will represent both past and future to many of the Moricetown Band, and no dollar calculation can adequately reflect this value.

The Sport Fishery

The Morice and Bulkley Rivers provide valuable sport fishing opportunities to residents and non-residents alike. Each year thousands of angler-days are spent on these rivers, particularly when coho and chinook salmon, and steelhead trout are running up the river. Resident populations of rainbow trout and Dolly Varden char also support a good deal of fishing effort each year, but the major attractions, especially for non-resident anglers are the anadromous species. Other lakes and streams of the Morice-Bulkley system provide few sport fishing opportunities at present, but this could change with improved access and facilities in more remote areas.

We pointed out above that the Morice and the Bulkley are two of the most important streams in British Columbia for both chinook salmon and steelhead trout. Table VII gives some interesting information on the rank[1] of the two streams from the point of view of the steelhead fisherman. In each of the five steelhead seasons from 1966-1967 to 1970-71 neither stream has ranked lower than eleventh in the province or third in the entire Northern Region as a producer of steelhead. The Bulkley was third in the province in 1966-67 (behind only the Vedder and the Thompson), and fourth in the 1970-71 season, the most recent for which statistics are available. The Morice River ranked fourth in 1969-70, and seventh in 1970-71, in the Province. The Northern Region contains other fine steelhead streams such as the Kispiox and the Zymoetz (Copper). Yet the Bulkley was the largest producer of steelhead for sport fishermen in three of the five years monitored and second only once. Similarly, the Morice ranked second in three of the five years, first once, and third just one time among all streams in the region.

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1. Data taken from Annual Steelhead Questionnaire Analyses published by the Fish and Wildlife Branch of the Department of Recreation and Conservation. Streams are ranked 1 for the most important, 2 for the second most important, and so on.

TABLE VII

THE RANK OF THE MORICE AND BULKLEY AS STEELHEAD PRODUCING STREAMS IN THE PROVINCE, AND IN THE NORTHERN REGION, 1966-67 to 1970-71

	BULKLEY		MORICE	
Year	Rank in Province	Rank in Northern Region	Rank in Province	Rank in Northern Region
1966-67	3	1	7	2
1967-68	7	2	6	1
1968-69	6	1	11	3
1969-70	6	3	4	2
1970-71	4	1	7	2

Steelhead trout are perhaps the severest test of anglers' skill, and are valued highly because of this. At a time when steelhead runs are declining on many of the streams in British Columbia, to the growing concern of steelheaders, the importance of the Bulkley and Morice steelhead fisheries cannot be overemphasized. Were comparable data available on the chinook salmon fisheries of the two streams it would almost certainly show a similar pattern. Chinook are the biggest and most highly prized of salmon amongst sport fishermen. Therefore, despite the fact that the Morice River is closed to sport fishermen, native chinook populations contribute to the fishing experience of sport fishermen in other Skeena River or coastal locations.

Calculating a dollar value for the sport fisheries of the Morice-Bulkley system presents several difficulties. Good information exists for the steelhead fishery, but only sketchy data are available

for the salmon sport fishery and the fishery for resident species. Nevertheless, sufficient data were on hand[2] to make credible estimates of value which are at the least, of correct order of magnitude.

Taking resident sport fishing first, Table VIII shows the total number of angler-days spent by resident fishermen on the Bulkley and Morice Rivers fishing for steelhead, salmon, and other species during the 1970-71 season. It also shows the value to the fishermen of this recreation. The value to British Columbia of resident sport fishing is the value that resident fishermen receive from their sport. The estimates of value, $15 per day of salmon and steelhead fishing, $6.50 per day of fishing for other species, are based on estimates made in other studies (Pearse and Laub, 1969) aimed specifically at discovering how much a day of fishing is worth to the fisherman.[3] To determine this, fishermen were asked how much they would have to be compensated in order to be as well off as if they had not fished in certain waters. It is important to point out that anglers would not need to be willing to pay these prices for such values to exist. Ideally, research into values pertaining strictly to the Morice-Bulkley system would have been carried out, but this was not possible given the time and budget considerations necessary for such a task. It is felt, however, that the values adopted for this study are rather conservative

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2. In addition to the Steelhead Questionnaire Analysis published by the Fish and Wildlife Branch, use was made of two study reports on the Economics of Wildlife Recreation done for the Fish and Wildlife Branch by Pearse Bowden Economic Consultants Ltd. No. 4 - "The Value of Non-Resident Sport Fishing in British Columbia", No. 5 - "The Value of Fresh Water Sport Fishing in British Columbia". Additional analysis was done by the Economics Branch of the Fisheries Service on some of the data collected by Pearse Bowden. Use was also made of reports on sport fishing submitted by field officers of the Fisheries Service.

3. Recent studies during the summer of 1972, conducted by the Northern Operations Branch, Fisheries Service, in the Yukon, have made information available which under preliminary analysis suggests that the value of sport fishing to sport fishermen visiting the Bulkley Valley area may be more than double the $6.50 and $15.00 used in this analysis.

because fish populations native to the Bulkley River area contribute to the total sport fishing benefits available in British Columbia. Using the unit values of Table VIII gives an estimate of $367,025 for the total value of resident fishing on the Morice and Bulkley Rivers during the 1970-71 season.

There is considerably less indeterminacy in calculating the value to British Columbia of non-resident sport fishing on the Morice and Bulkley Rivers. Direct benefits accrue through the expenditures of non-resident fishermen, and information on these is easily gathered. The measure of net benefits from non-resident fishermen's spending is the total of business profits from the sale of goods and services to these fishermen plus provincial government revenues from the sale of fishing licences, from liquor sales and from the gasoline and sales tax.

TABLE VIII

THE VALUE OF RESIDENT FISHING ON THE BULKLEY AND MORICE RIVERS DURING THE 1970-71 SEASON

	No. of Angler Days			Net Benefit Per Angler-Day	Total Value in 1970-71
	Bulkley	Morice	Total		
Steelhead	5,350	3,550	8,900	$15.00	$133,500
Salmon	7,500	5,750	13,250	$15.00	$198,750
Other Species	3,150	2,200	5,350	$ 6.50	$ 34,775
TOTAL					$367,025

Tables IX and X show the value of non-resident sport fishing on the Morice and Bulkley Rivers. The net benefits from out-of-province Canadian fishermen's spending are presented separately from those of non-Canadian fishermen because of the different scale of net benefits associated with each type of fisherman. The value to British Columbia of out-of-province Canadian steelhead and salmon fishing on the Morice and Bulkley Rivers is estimated to be equal to $10 per angler-day; the fishery for other species is estimated to be worth $3 per angler-day. Non-Canadian steelhead and salmon fishing is worth $12 per angler-day; other species are worth $5 per angler-day.

TABLE IX

THE VALUE OF OUT-OF-PROVINCE CANADIAN FISHING ON THE BULKLEY AND MORICE RIVERS DURING THE 1970-71 SEASON

	No. of Angler-Days			Net Benefit Per Angler-Day	Total Value in 1970-71
	Bulkley	Morice	Total		
Steelhead	1,000	200	1,200	$10.00	$12,000
Salmon	1,800	350	2,150	$10.00	$21,500
Other Species	500	100	600	$ 3.00	$ 1,800
TOTAL					$35,300

Table IX shows that out-of-province Canadian fishing on the Morice and Bulkley was worth $35,300 to the province in 1970-71, while Table X indicates that the fishery on these rivers was worth $66,800 in net benefits to British Columbia in 1970-71. Resident and non-resident fishing together was worth a total of $469,125 in 1970-71.

TABLE X

THE VALUE OF NON-CANADIAN FISHING ON THE BULKLEY AND MORICE RIVERS DURING THE 1970-71 SEASON

	No. of Angler-Days				
	Bulkley	Morice	Total	Net Benefit Per Angler-Day	Total Value in 1970-71
Steelhead	900	500	1,400	$12.00	$16,800
Salmon	3,000	1,000	4,000	$12.00	$48,000
Other Species	300	100	400	$ 5.00	$ 2,000
TOTAL					$66,800

Assessing the future values of sport fishing on the Morice and Bulkley Rivers requires that some assumptions be made about the growth of sport fishing on these rivers, and about the capacity of the streams to sustain this growth. The Fish and Wildlife Branch's statistics on steelhead fishing effort include resident and non-resident anglers together; thus, different aggregations are used for projections of sport fishing values than were used for the evaluation of sport fishing in the single year, 1970-71. However, since the projections are made on the dollar values themselves, this leads to the desired result: the future value of all sport fishing.

Table XI shows estimated future values of steelhead fishing, resident and non-resident together, of other resident sport fishing, including that for salmon, and of other non-resident sport fishing, including salmon on the Morice and Bulkley Rivers. The assumptions about future growth are different for each category. Steelhead fishing

TABLE XI

PRESENT CAPITALIZED VALUE OF THE SPORT FISHERIES ON THE MORICE AND BULKLEY RIVERS

$'000

Year	All Steelhead Fishing		Other Resident Fishing		Other Non-Resident Fishing	
	Future Value	1971-72 Present Value	Future Value	1971-72 Present Value	Future Value	1971-72 Present Value
1970-71	162		234		73	
1971-72	175	175	243	243	80	80
1972-73	189	179	253	238	87	82
1973-74	204	182	263	234	95	85
1974-75	221	186	273	229	103	87
1975-76	239	189	284	225	113	89
1976-77	248	185	295	221	123	92
1977-78	258	182	307	217	134	94
1978-79	268	178	320	213	146	97
1979-80	279	175	332	208	159	100
1980-81	290	172	346	205	173	103
1981-82	296	165	353	197	184	103
1982-83	302	159	360	190	195	103
1983-84	308	153	367	182	206	103
1984-85	314	147	374	176	219	103
1985-86	320	142	382	169	232	103
1986-87	327	136	389	162	246	103
1987-88	333	131	397	156	261	103
1988-89	340	126	405	150	276	103
1989-90	347	121	413	145	293	103
1990-91	354	117	421	140	310	103
1991-92	354	*1,839	421	*2,191	310	*1,614
Present Capitalized Value, 1971-72		$5,039		$6,091		$3,553

Present Value of All Morice-Bulkley Sport Fisheries $14,683,000

* Present value of annuities, equal to future values in 1990-91, from 1991-92 onwards. This follows from the assumption of zero growth after 1990.

has been growing on these streams at an 8 percent annual rate over the past five years. Other resident fishing has been growing at 4 percent annually, and other non-resident fishing has been growing at 9 percent over the past decade.

At some point in time pressure on the fish stocks, overcrowding at fishing sites, and so on, will eventually impose constraints on the growth of the sport fishery. It is difficult to determine just when the maximum size of the sport fishery on the Morice and the Bulkley will be reached because, for one thing, fishermen's attitudes towards crowding and catch success will inevitably change over time. For the purpose of this study it was assumed that sport fishing on the Morice and the Bulkley will undergo no further growth beyond 1990. It was further assumed that: steelhead fishing would continue to increase at 8 percent through 1975, fall to a 4 percent growth from 1976 through 1980, and grow at only 2 percent annually to 1990; other resident fishing would increase at 4 percent through 1980 and at 2 percent from 1981 to 1990; other non-resident fishing would continue to show a 9 percent increase through 1980, and then increase at 6 percent before falling to zero in 1990.

These assumptions of future growth are on the conservative side. Experience in the more densely populated areas of North America indicates that anglers will put up with a great deal of crowding and lower success rates for the opportunity to fish. Thus, conditions that would be intolerable to the current generation of British Columbia anglers may well be acceptable to their descendants. We are constrained, nevertheless, to make some assumptions about the capacity of fishing grounds and the ones made, while tending to underestimate the value of the sports fishery, are felt to be the best given the data available.

Forecasting[4] growth in this manner allows the calculation of

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4. The sports fishery differs from the commercial and Indian food fisheries in this respect because the latter were assumed to be constant in value over time, and thus no assumptions about growth were necessary.

a present discounted value in 1971-72 of the future stream of benefits British Columbians will enjoy from the sport fisheries on the Morice and Bulkley Rivers. The present value of steelhead fishing, discounted at 6 percent is $5,039,000. The present value of other resident fishing is $6,091,000 and the present value of other non-resident fishing is $3,553,000. Altogether the sport fisheries of the Morice and Bulkley Rivers represent a present discounted value, in 1971-72 of $14,683,000.

It is stated above that some of the assumptions required by the analysis led to a conservative estimate of the value of the sport fishery. There are, in addition, a number of other factors which do not lend themselves to measurement and which, therefore, by their omission also lead to an underestimation of value. For instance, option value, the value placed on the fishery by people who do not sport fish themselves but who wish to preserve the option to do so, or the enjoyment received by fishermen angling for fish native to the Bulkley Valley area in other locations on the coast, has so far resisted attempts at quantification. Economists agree that this value is important and may even overshadow the value placed on the fishery by those who use it. It would thus be a mistake to assume that only the values used in this paper reflect the absolute worth of the sport fishery to all British Columbians or Canadians. If the sport fishery is threatened in the future then all the values associated with it must be taken into account including those which are not calculable at present.

Summary of Values

The average annual value of the commercial fishery associated with salmon that use the Morice-Bulkley system for spawning is $913,700; the present discounted value of this fishery is $12,490,000. The average annual value of the Indian fishery at Moricetown Falls on the Bulkley River is $38,391; the present discounted value of this fishery is $530,000. The value of the sport fishery on the Morice and Bulkley

Rivers in 1971-72 is $469,125; the present discounted value of this fishery, taking future growth into account, is $14,683,000. The present discounted value of all the fisheries associated with the Morice-Bulkley river system is nearly $28,000,000.

IV. PHYSICAL AND CHEMICAL EFFECTS OF THE PROPOSED PULP MILL AT HOUSTON

In recent years biological surveys of stream conditions have been used extensively to assess the effects of pollution. Although universal indicator species do not exist, mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) nymphs are generally reported to be intolerant to organic wastes. The relative abundance of these forms in conjunction with physical-chemical water surveys will detect even minor deteriorations of the aquatic environment and reflect the effects of intermittent discharges which are often missed by periodic chemical water analysis.

Biological surveys on the Bulkley were initiated in 1965 when the Department of Fisheries was informed that a 750 ton per day unbleached kraft mill was to be constructed on the Bulkley River at Houston, B. C. Six sampling sites were established on the river: stations 1 and 2 upstream of the proposed mill site, and stations 3, 4, 5 and 6 approximately 2, 20, 38 and 80 river miles respectively, below. It was assumed that no significant effects of effluent discharge would be perceived beyond 80 miles downstream. Biological sampling at these stations consisted primarily of the collection of macro-invertebrates. Initially, wooden and metal one square foot trays were used to try to establish the kinds and numbers of benthos (organisms that live on or in the river bottom) present at the selected sites. The tray method was later replaced by the combination of a circular square foot sampler, used in the manner of the conventional "Surber" sampler, and nocturnal drift samplers.

The chemical and physical parameters monitored at each station included temperature, pH, dissolved oxygen, 5 day 20°C biochemical oxygen demand, total residue, conductivity, calcium ion, true color, and the presence of sulfide and chloride. Most of the tests were carried out in the field. Procedures requiring incubation

time or elaborate laboratory equipment were conducted in Vancouver.

RESULTS AND DISCUSSION

A. Biological

Many difficulties were encountered with the collection of macro-invertebrates, hence the use of different collecting techniques. The present data can only be reported qualitatively; however, it is interesting to note that 75 to 100 percent of the forms collected between 1966 and 1969 can be labelled sensitive to organic wastes. W. M. Beck, Jr. in 1966 published a "Biotic Index" in his paper, "Suggested Method for Reporting Biotic Data". Using this method, a grossly polluted situation in the Bulkley would yield a biotic index equal to zero, and clean water situations will be characterized by an index greater than 5. Figure 3 depicts the biotic index for the Bulkley at each of the six stations for October data collections of 1966, 1967 and 1968.

The values shown in Figure 3 indicate that in October clean river conditions existed at each of the six stations on the Bulkley over the three years monitored. The biotic index for station 6 was lower in 1966 and 1967 than the index for all other stations. However, it was postulated that the changed substrate and increased silt load of the river were responsible for the void of aquatic organisms, and thus the lower index does not indicate the presence of organic wastes in the lower portion of the river. The results of the biological sampling reflect pristine aquatic environmental conditions at the Bulkley and Morice sites studied.

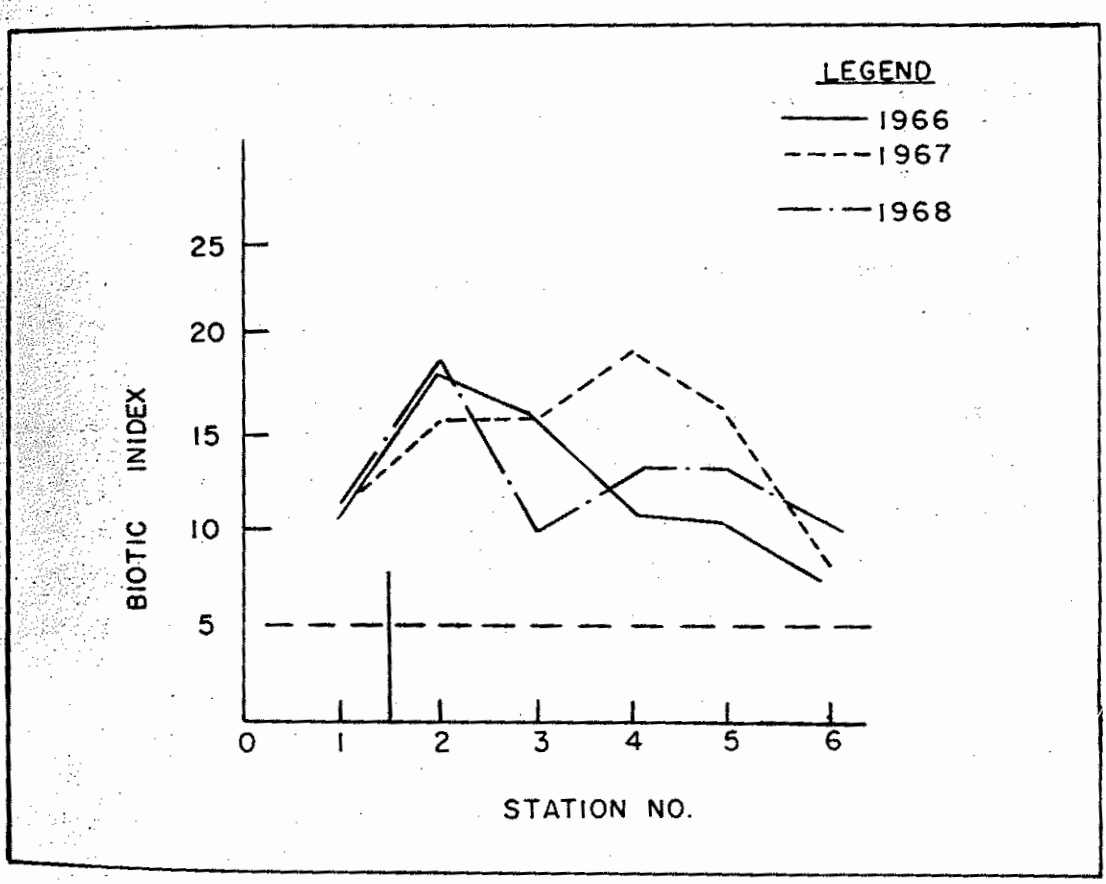
B. Chemical and Physical

The chemical monitoring program provided valuable base line data for the system. Measurement of chloride, biochemical oxygen

FIGURE 3

BIOTIC INDEX FOR BULKLEY TEST STATIONS

OCTOBER 1966, 1967 AND 1968



demand, sulfide, conductivity, and true color serve as indicators of minor changes in the receiving waters. Temperature, pH, dissolved oxygen, total residue, and calcium ion reflect the overall condition of the system and are generally altered only by major changes in the aquatic environment. The chemical information collected to date indicates that the waters can presently be classified as unpolluted.

In order to assess the possible effects on the aquatic environment of a pulp mill at Houston, B. C., the following assumptions were made:

1. mill capacity: 750 tons per day unbleached kraft

2. water consumption: 40,000 U. S. gal/ton = 28×10^6 US gal/day
   = 43.2 cfs

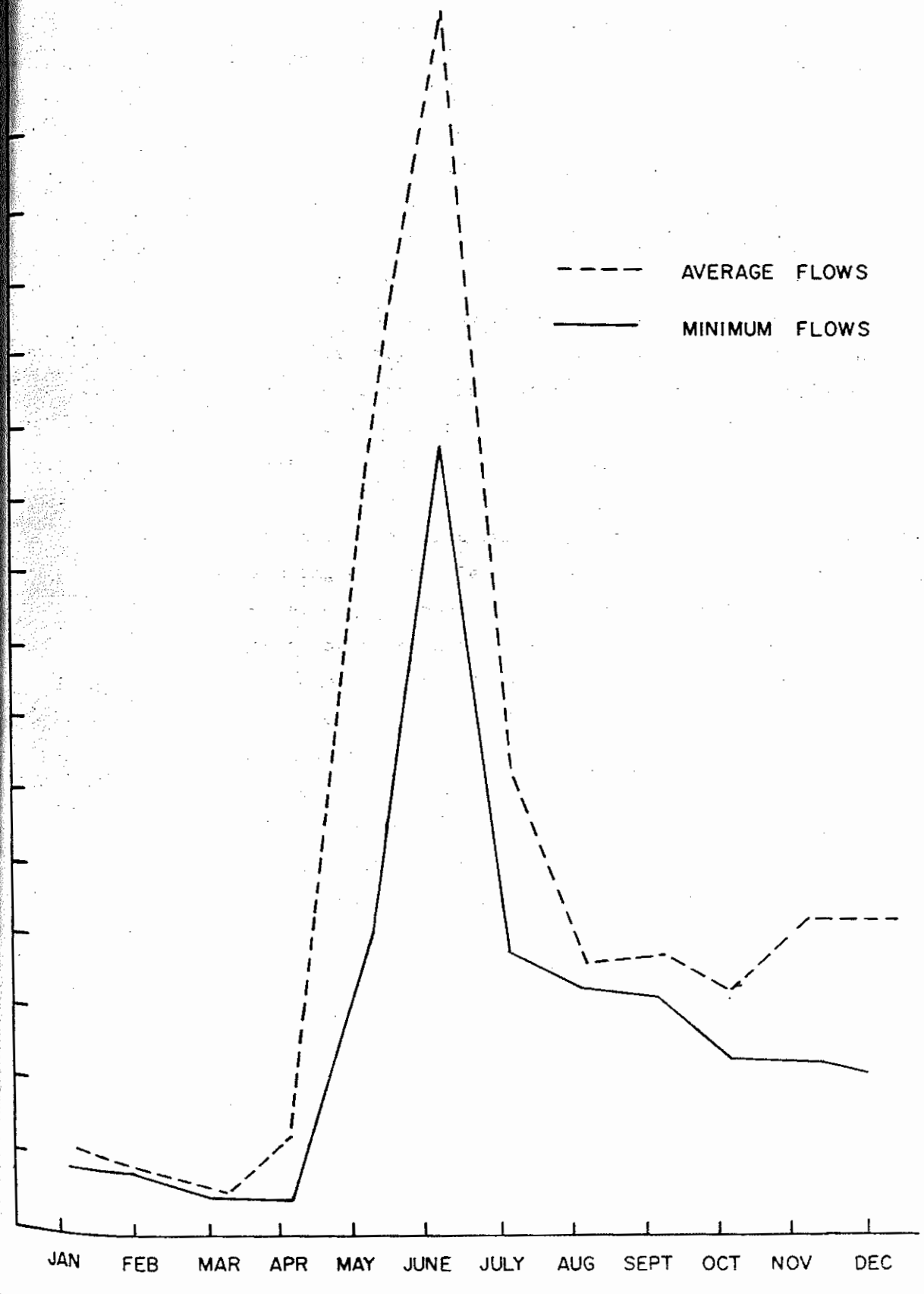
3. minimum of 5 day biological oxidation pond and all modern in-plant pollution abatement facilities.

River flows are recorded daily at Quick, B. C., and the monthly minima and averages for 1969 are shown in Figure 4. The low flows between January and April provide dilutions of less than 1:20 and these small flows cannot be relied upon to mask any unforeseen operational mishaps or deleterious effects, lethal or sub-lethal, on the aquatic biota.

Although the effluent may satisfy the acute fish toxicity tests, biochemical oxygen demand, and total suspended solids reductions required by regulatory agencies, sub-lethal effects of poorly diluted pulp mill wastes on the indigenous and anadromous fishes must also be considered as these stresses would undoubtedly affect certain phases of their life cycles. The effect of pulp mill wastes on the aquatic invertebrate forms would also have to be considered. With the minimal dilution afforded the effluent by the river water, these forms would be

FIGURE 4

1969 DISCHARGE RECORDS AT QUICK, B. C.



seriously threatened by the complex of chemicals discharged in pulping wastes. A reduction in aquatic invertebrates would then force the fishes to divert extra energy into searching for alternate food supplies, thus reducing their viability. These factors along with other taint and odor considerations (see Appendix I) would result in partial loss of the commercial fishery.

Also, it is anticipated that effluent discharge would change the color regime of the river, resulting in less light penetration and thereby decreasing the energy input into the ecosystem. Another effect on the river would be the formation of slimes in backwaters and slow reaches. This phenomenon has been reported downstream of existing pulp mills and is directly attributable to the introduction of high nutrient content wastes into the system. Both of these phenomena, color change and slime formation, would have an immediate adverse effect on the aesthetic and recreation values of the river.

One of the major problems of non-toxic effluent discharge will be the tainting of fish flesh. The degree of tainting would depend, of course, on the amount of water available for dilution. Recent experiments have indicated that dilutions in excess of 1:100 may be required to prevent tainting. Given the above assumptions about the amount of effluent and the historical flows of the river, it is estimated that the effluent from nine months operation would have to be stored and released during high flow periods to achieve dilutions in excess of 1:100. However, a 1:100 dilution would not be achieved during low water years necessitating the carryover of effluent into the next high water period. Logistics would suggest that this would be an untenable situation.

An additional consideration in determining the adequacy of river flows is the current investigation by the B. C. Energy Board into potential power developments on the Morice system. Annual diversion of

average flows of 1,100 cfs. from the Nanika River and 1,700 cfs. from Morice Lake have been proposed. The Department of the Environment has indicated that these figures are unacceptable for fish production. Furthermore, any reduction of flows will decrease the dilution capacity of the river and increase the detrimental effects of pulp mill wastes on the aquatic environment. In fact, the proposed diversion of 1,700 cfs. from Morice Lake and 1,100 cfs. from the Nanika River is equal to the average annual flow recorded at the outlet of Morice Lake between 1962 and 1967. If the diversion schemes are carried out, the effects of effluent discharge would have to be reexamined.

Summary of Physical and Chemical Effects

It is difficult to make a comprehensive assessment of the effects of pulp mill effluent discharge prior to the actual discharge of the waste. The effect of pulp mills on other rivers can be examined, but this can give little more than a qualitative guideline of what to expect because of the different physical and biological parameters associated with different streams. Thus, much of the research on the Bulkley would bear fruit only after discharge took place; an accurate assessment could only be made by examining the same parameters after a period of effluent discharge.

Nevertheless, the data are useful in that they demonstrate the pristine quality of the river in its present state. We can, in addition, make statements about some effects: color change, fish tainting, and slime formation, which would almost certainly occur from effluent discharge given the quality of effluent and the ability of the river to dilute it. At present modern pollution abatement facilities are not capable of removing color or coping with the tainting phenomenon from pulp mill wastes. Storage of effluent over a nine month period with subsequent metered release during high water periods is logistically unrealistic and also undesirable since it coincides with the peak of seaward migration of salmonids. Based on the dilution

requirements resulting from the recent fish tainting experiments it is obvious that a pulp mill on the Morice River would have a definite detrimental effect on the fisheries resource of the system.

Those are, moreover, among the most obviously noxious of the effects of pulp mill effluent and thus the effects most likely to have an immediate influence on the values we are considering in this report. We shall be able then to assess the net economic effect of pulp mill effluent on the commercial, sport and Indian food fisheries associated with the Bulkley and Morice Rivers.

V. ESTIMATED NET ECONOMIC EFFECT OF A PULP MILL ON THE FISHERY AT HOUSTON, B. C.

Predictions about the effects of effluent discharge on the fisheries of the Morice and Bulkley Rivers cannot, as pointed out above, be made in detail. A precise assessment of the net economic effect of effluent discharge on the fisheries is similarly restricted. Based on the qualitative statement of expected results in the preceding section however, an estimation of broad economic effects can be made.

If the anadromous species of the Morice-Bulkley system is wiped out by effluent discharge, then the value of all the fisheries dependant on these species would be lost. However, no such disaster is expected, but it should be remembered that the possibility does exist.

Of greater likelihood however, is the possibility that the pulp mill will cause some loss of the area's fish spawning, rearing, and production efficiency. This will result in either total or partial dissipation of the value of the commercial fishery. The total loss could amount to approximately $12,490,000.

The sport fishery and the Indian food fishery pose quite different problems. If, as expected, the salmon and steelhead are tainted by the effluent and if, as expected, the aesthetic values of the rivers deteriorate, then both fisheries would be seriously endangered. The Indian food fishery would be wiped out and the sport fishery, if not destroyed, would be reduced in both size and value.

Under these circumstances the total value of the Indian fishery would be eliminated, and thus amount to a loss of approximately $530,000. The sport fishery's value would be either completely or partially dispelled. The absolute magnitude of the loss to Canada because of deterioration of this area's sport fishery would depend upon the amount of effluent actually dumped into the river system and

and if it is treated. However, from the previous discussion on the sport fishery the loss can be estimated to be as high as $14,683,000.

Despite the need for precise analysis using data designed specially to analyze the total effects of the pulp mill, this preliminary review suggests that the loss when including all three segments of the fishery (i.e. Indian, commercial, and sports) can be estimated to be an amount of nearly 28 million dollars. Only a specially designed construction program and careful operation of the production process (to prevent spill and maintain minimum water levels) can ensure against either partial or total loss of this 28 million dollars to the people of Canada.

VI. SUMMARY

The commercial fishery, sport fishery and the Indian food fishery pose quite different problems. The economic effect of the Houston pulp mill on each of the three fisheries will ultimately depend on the type and amount of effluent discharged by the mill and its method of operation. However, according to the foregoing analysis, there is a distinct possibility that with low flow conditions in the Bulkley-Morice Rivers during salmon fry migration an accidental discharge directly into the river system could seriously impair the contribution of the Bulkley-Morice Rivers to the commercial fishery. Unless the Houston pulp mill is built to precise specifications with adequate safeguards against waste spillage, the total contribution of the Bulkley-Morice Rivers to British Columbia's commercial fishery could be totally eliminated. On the basis of the foregoing discussion this would amount to a total loss to the people of Canada of 12.5 million dollars.

Of less uncertainty is the potential loss of the Indian food and sport fisheries because of the Houston pulp mill. If, as is expected, the salmon and steelhead are tainted by the effluent coming from the mill the Indian food and sport fisheries would be all but eliminated. Therefore, the total loss to the Canadian people because of losing these two fisheries would be at least 15 million dollars.

When taken together the loss to the people of Canada because of establishing the Houston pulp mill will range between 15 and 28 million dollars.

Even a loss of these magnitudes fails to adequately deal with the optional, aesthetic and social values[5] (particularly the value to British Columbian Indians) which would more accurately reflect the real cost of establishing an uncontrolled pulp mill in Houston to the Canadian people.

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5. Existing economic theory prohibits precise economic evaluation of these intangible factors.

APPENDIX I

REPORT OF AN INVESTIGATION OF THE TAINTING OF THE FLESH OF SOCKEYE SALMON THROUGH EXPOSURE OF THE FISH TO PULP MILL EFFLUENT

S. E. Geiger

Introduction

In January, 1972, we were approached by Mr. W. Schouwenburg of the Environment Quality Unit, Northern Operations Branch, Fisheries Service, Department of the Environment, with a request for assistance. A new pulp mill had been proposed for construction at Houston, B. C. on the Bulkley-Morice River system, and earlier experience with a mill on the Kootenay River indicated that tainting of the flesh of fish in the Bulkley-Morice system could be expected to result from exposure to effluent from the new mill. Mr. Schouwenburg proposed that an experiment be carried out in which sockeye salmon would be exposed to a range of dilutions of pulp mill effluent like those to be expected in the Bulkley-Morice system when the new mill went into operation, and that after various periods of exposure, the fish be examined by a taste panel to ascertain whether or not their flesh became tainted. Field work was to be carried out by the Fisheries Service operations personnel, and taste panel examination by the Vancouver Laboratory of the Fisheries Research Board. The Director of the Vancouver Laboratory agreed to the proposal and the program commenced in February, 1972.

Procedure

Sockeye salmon (Oncorhynchus nerka) were obtained from the Fisheries Research Board of Canada, Nanaimo, B. C. and transported to Kitimat, B. C., where they were held in plastic tanks housed in a

building on the Eurocan mill site. The tanks held the following dilutions of pulp mill effluent: 4%, 2.2%, 1.8%, 1.3% and 0% - the latter constituting the control. At one week intervals, fish from each tank were killed, beheaded, gutted and frozen over dry ice. Each fish was individually wrapped in aluminum foil and each dilution group was placed in a separate, double plastic bag. The fish were shipped by air freight to the Vancouver Laboratory where they were held at -30°C until examined.

For examination, each group of fish was water-thawed at 22°C for 1½ hours in a separate container to avoid any possible cross-contamination between groups. The fish were weighed, measured (from the gill arches to the tail fork - the fish had been beheaded in Kitimat), flesh pH was determined, and then the fish were cut into standard sample pieces for cooking. The samples were cooked for 3 minutes (full oven) in a Westinghouse Microwave oven and served immediately to an experienced five member taste panel. The control samples were cooked separately to avoid any possibility of tainting during cooking. The panel was asked to rate the samples on a scale of 0-10 for odor, flavor, juiciness, tenderness and texture, using our usual organoleptic scoring system (copy enclosed). Five fish were used from each effluent dilution exposure group, so that each panel member tasted a different fish. This method was adopted to allow for any possible differences in effluent uptake resulting from size variation of the fish. Preliminary experiments indicated possible tainting was present in the control fish, and consequently, alternate controls were obtained directly from the Fisheries Research Board of Canada, Nanaimo, B. C., and were used in conjunction with the Kitimat controls throughout the experiment. The alternate control fish were from the same stock as the fish at Kitimat and had been kept in a fibreglass tank. The significance of differences between the exposed fish and both groups of controls has been calculated and is indicated in the tables.

After tainting of the exposed fish had been established by

the taste panel, fish which had been in the effluent dilution tanks for 13 days were transferred to fresh water to determine if the tainting would disappear. However, severe weather conditions in Kitimat resulted in loss of all fish except those previously exposed to the 4% dilution. These fish were kept in the fresh water tank for a 4 week period and were sampled every 6-7 days.

A separate experiment was conducted by Mr. W. Knapp at the West Vancouver Laboratory of the Fisheries Service to determine if any tainting had occurred from the plastic tanks used in Kitimat. Fish were held at the West Vancouver site in fresh water in plastic tanks like those used at Kitimat for a 3 week period, samples being taken twice weekly. As no tainting of these fish was detected by the taste panel, the results have not been detailed in this report.

Results

As is shown in Table I, tainting of exposed fish was perceived by the taste panel in the first week of testing, the degree of tainting being directly related to the concentration of effluent to which the fish were exposed. Statistically, the differences in odor and flavor of the exposed fish was more significant for the controls held at Nanaimo than those held at Kitimat, for although no statistically significant differences occurred between the scores for Kitimat and Nanaimo controls, the slight tainting detected in the Kitimat controls was reflected in greater variability and generally lower average scores for these fish. The slight tainting of the Kitimat control fish probably resulted from the location of the tanks at the Eurocan mill site. The Fisheries Service personnel on the site reported that pulp mill odor was noticeable in the building where the tanks were installed and it is likely that vapor from the mill reached the holding tanks. Certainly no tainting was detected in the control fish held at Nanaimo, nor in the others held in West Vancouver in the same kind of plastic tanks as were used in Kitimat. At 21 days, all exposed fish were found

to be extremely objectionable in flavor (bitter and acrid), and distinct "off" odors were reported. No significant differences were detected for tenderness, juiciness, and texture, and therefore these results and flesh pH values, to which they might have been related, are not detailed. In many instances, it was impossible, because of bad flavor, for the panel members to hold the samples in their mouths for a sufficient period of time to make these latter assessments.

Weight and length measurements of the fish have no significance to fish tainting in this experiment. They have been listed as an indication of the size of fish at the request of the Fisheries Service.

The recovery experiment (Table II) indicates that in fish previously exposed at the 4% level of effluent dilution, the flavor of the flesh improved slightly but was still objectionable at the termination of the work. The greater apparent recovery at the six day period may be related to size differences of the fish.

While our usual score sheet was used by the taste panel in making their evaluations, odor or flavor usually associated with spoilage were not detected at any time. The values given in the tables simply indicate the intensity of the unpleasant odor and flavor that were present and which can best be described as acrid and bitter.

In experiments to determine the T.L.M. (medium tolerance limit) of fish subjected to neutralized, filtered pulp mill effluents, the lowest concentration at which 50% death occurred (in 96 hours) was a 20% dilution (J. Davis, personal communication). In view of this, it appears from the present work that taste panel techniques might provide a sensitive and accurate tool which could be of great assistance in pulp mill pollution studies.

TABLE I

INFLUENCE OF EXPOSURE TO EUROCAN PULP MILL EFFLUENT ON ODOR AND FLAVOR OF SOCKEYE SALMON

Sampling		Weight of Fish		Length of Fish		Effluent Conc.	Duration of Exposure	Odor Score		Flavor Score	
Date	Location	Gms.		Cms.		%	Days				
1972		M[1]	S.D.[2]	M	S.D.			M	S.D.	M	S.D.
Feb. 7	Kitimat	71.08	12.55	16.50	1.24	0	7	7.60	1.34	6.60	2.41
	"	49.46	16.44	14.38	1.02	4.0	"	5.60 +	1.95	3.40 ++	2.51
	"	47.08	14.56	13.82	1.41	2.2	"	6.00 ++	1.00	4.00 ++	2.12
	"	57.71	13.99	15.10	1.10	1.8	"	7.40	1.34	4.90 +	2.40
	"	45.20	11.51	13.70	1.15	1.3	"	7.40	0.89	5.80 +	1.92
	Nanaimo	69.13	12.60	16.50	1.28	0	0	8.40	0.89	8.60	1.52
Feb. 14	Kitimat	56.77	16.68	15.00	1.64	0	14	7.20	0.84	6.60	2.07
	"	56.35	21.28	14.90	1.82	4.0	"	4.20 *+	1.92	1.60 **++	0.89
	"	61.96	19.00	15.55	1.59	2.2	"	4.40 **++	1.14	3.20 *++	1.10
	"	45.54	19.14	13.42	1.62	1.8	"	6.40	1.52	3.80 *++	1.48
	"	50.10	16.72	14.10	1.44	1.3	"	7.00	1.00	4.90 +	2.30
	Nanaimo	65.57	21.98	16.00	1.89	0	0	7.60	1.82	8.50	1.12
Feb. 21	Kitimat	62.66	15.27	15.64	1.10	0	21	7.40	2.30	7.00	2.00
	"	51.94	7.24	14.80	0.70	4.0	"	4.00 **++	2.00	1.60 **++	0.55
	"	38.58	4.67	13.42	0.44	2.2	"	4.80 ++	1.92	2.80 **++	1.30
	"	59.84	5.75	15.50	0.76	1.8	"	6.00	2.00	3.80 *++	1.92
	"	47.14	11.64	14.42	1.19	1.3	"	5.00 +	2.35	2.80 **++	1.92
	Nanaimo	63.54	21.97	15.50	2.18	0	0	8.00	0.71	8.40	1.14
Feb. 26	Kitimat	66.74	3.02	15.60	0.32	0	26	7.80	0.89	8.00	2.50
	"	56.36	15.55	15.00	1.56	4.0	"	3.60	2.41	1.60 **++	1.52
	"	63.20	11.99	15.34	1.17	2.2	"	3.80 **++	1.48	2.40 **++	1.52
	"	57.60	16.51	15.28	1.60	1.8	"	5.60 **+	1.14	4.20 *++	1.92
	"	50.46	7.48	15.00	1.03	1.3	"	6.00	2.83	4.50 ++	2.79
	Nanaimo	81.86	6.91	17.24	0.46	0	0	7.60	1.14	8.30	1.30

1 "M" denotes "mean"
2 "S.D." denotes "standard deviation"
* Significant at the 5% level - Kitimat control
** Significant at the 1% level - Kitimat control
\+ Significant at the 5% level - Nanaimo control
++ Significant at the 1% level - Nanaimo control

TABLE II

INFLUENCE OF TRANSFER TO FRESH WATER ON THE ODOR AND FLAVOR SCORES OF THE FLESH OF SOCKEYE SALMON PREVIOUSLY TAINTED BY EXPOSURE TO PULP MILL EFFLUENT

Sampling		Weight of Fish		Length of Fish		Duration of Recovery Treatment	Odor Score		Flavor Score	
Date	Location	Gms.		Cms.		Days	M	S.D.	M	S.D.
1972		M[1]	S.D.[2]	M	S.D.					
Feb. 14	Kitimat Test	56.35	21.28	14.90	1.82	0	4.20 ++	1.92	1.60 **++	0.89
Feb. 20	"	45.30	9.45	13.90	1.23	+6	5.40	2.70	6.40	2.41
Feb. 26	"	57.30	6.80	15.06	0.36	+12	5.00	2.45	5.20 +	2.17
Mar. 3	"	67.88	17.90	16.70	1.42	+20	5.20	1.79	3.40 ++	2.07
Mar. 11	"	69.18	12.46	16.70	1.30	+28	5.60	1.52	4.80 +	3.11
	Controls (0)									
Feb. 26	Nanaimo	76.02	27.38	16.30	1.79	-	7.20	2.17	8.30	0.84
Feb. 14	Kitimat	66.74	3.02	15.60	0.32	-	7.80	0.84	8.00	2.50

1 "M" denotes "mean"

2 "S.D." denotes "standard deviation"

* Significant at the 5% level - Kitimat control

** Significant at the 1% level - Kitimat control

\+ Significant at the 5% level - Nanaimo control

++ Significant at the 1% level - Nanaimo control

ORGANOLEPTIC ANALYSIS

Technique for scoring to be used in sensory evaluation of fish samples.

The terms used here are ones which have been used by:

1. Fisheries Research Board of Canada, Halifax Station.
   J. Fish. Res. Bd. Canada 7, 449-460 (1947-1950).

2. Torry Research Station, Aberdeen, Scotland.
   J. Sci. Food Agric. 4, 283-298 (1953).

3. Department of Food Science and Technology, University of California at Davis.
   Food Technol. 19, 238-245 (1965).
   Food Technol. 19, 1268-1272 (1965).

Odor

10. Fresh odor
9. Some loss of fresh odor - no off odor
8. Lack of odor
7. Just detectable off odor
6.
5. Increasingly strong off odors — e.g. cabbage-like odor
4.
3.
2. Distinctly noticeable ammoniacal or fishy (trimethylamine) and/or rancid odors.
1. Strong ammoniacal or fishy odors and/or stale or rancid odors (objectionable).
0. Very strong putrid (ammonia indole) and/or rancid odors (very objectionable).

Tenderness (force of bite)

10. Extremely tender (almost no force)
9. Very tender (very little force)
8.
7. Tender, flakes well
6. Moderately tender
5. Not tough, but only slightly tender (moderate force)
4. Slightly tough
3. Tough
2.
1. Very tough, rubbery (extreme force)
0. Extremely tough, leathery (almost impossible to bite)

Juiciness

10. Very juicy
9.
8. Juicy
7.
6. Moderately juicy
5. Moist
4. Slightly dry
3. Dry
2.
1. Very dry
0. Extremely dry

Flavor

10. Fresh, sweet flavors characteristic of species
9. Some loss of sweetness, still very good, natural flavor, no off-flavor

8. Good, slight sweetness, loss of flavor characteristic of species
7. Moderately good but neutral flavor, definite loss of flavor but no off-flavor
6. Absolutely no flavor, tasteless
5. Trace of off-flavors, some sourness, no bitterness, slightly fishy (trimethylamine)
4. Slightly poor, some off-flavors, some bitterness
3. Poor, strong bitter flavors, rubber-like and slight sulphide-like flavors, slight rancidity
2. Strong bitter flavors, not nauseating, stale (enough trimethylamine to be objectionable), or fairly strong rancidity
1. Very poor, strong bitter flavors, rancid, nauseating
0. Extremely poor, strong putrid flavors (sulphides), tasted with difficulty

Texture

10. Extremely fine
9. Very fine, mealy
8.
7. Fine
6. Moderately fine
5. Slightly fine
4. Slightly coarse
3. Coarse, fibrous
2.
1. Very coarse, stringy
0. Extremely coarse, hard

Under remarks, the panel member should give any special comments he has for this sample. In particular, appearance, rancidity and saltiness.

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