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SOCKEYE SALMON ENHANCEMENT FEASIBILITY STUDIES IN THE TRANSBOUNDARY RIVERS

February 1988

ABSTRACT

Enhancement opportunities for sockeye salmon are assessed for eleven transboundary lakes in the Stikine, Taku, and Alsek River systems. Using existing information and results from field studies undertaken in 1987, production potentials are developed from two analytical models. The first model is based on predicting adult sockeye production from the total euphotic volume of the system and the second, on determining potential smolt production from zooplankton (food supply) densities in the system.

Tuya Lake in the Stikine River system has the greatest production potential of the lakes studied. Its large size, the largest of the lakes studied, and the fact that presently there is no anadromous sockeye production due to a physical barrier preventing fish passage contribute to this potential. Tahltan Lake, in the same river system, is a potential source of broodstock. It appears capable of routinely supporting egg-takes without excessive removals from the wild stocks. The Tahltan stock is readily identifiable from other stocks in the system and could be targeted on by both U.S. and Canadian fisheries. Two enhancement scenarios are possible for Tuya Lake: 1) annual fry plants with harvest of all returns excluding broodstock and 2) removal of the outlet barrier so that a natural run could be established.

Tahltan Lake ranks third in potential enhancement production due to a relatively high euphotic volume and to relatively low fry densities and high zooplankton production. As this lake has been fertilized in the past several years without apparent increase in fry densities, fry implants or increased escapement may be needed to utilize the zooplankton production. The lake should be surveyed during a period of no fertilization to determine natural levels of fry and zooplankton densities.

Chutine and Christina Lakes in the Stikine River system have limited enhancement potential due to glacial turbidity and low zooplankton abundance.

Tatsamenie Lake in the Taku River system ranks second among the lakes studied for enhancement potential. It is a large lake with a large euphotic volume but presently has a low level of adult sockeye production. The rearing environment appears to be underutilized as evidenced by the moderate densities of zooplankton and low densities of fry. Low sockeye escapements to this lake in some years would limit egg-taking opportunities. Targeting the enhanced stock in the fisheries may be difficult and methods or opportunities for harvesting need to be studied.

The enhancement potentials of Trapper, Kuthai, and King Salmon Lakes in the Taku River system are moderate. Zooplankton densities are relatively high and current sockeye run sizes are very low or non-

existent so fry plants would seem to have the best potential of increasing production. Opportunities for targeting fishing effort on any of these stocks appear limited.

Little Trapper Lake has a low enhancement potential. The rearing habitat appears to be fully utilized and zooplankton density is low. Lake enrichment appears to be the best method for increasing productivity, but again, the small size of the lake limits total production.

Kennicott Lake is the smallest of lakes studied. Enhancement potential is estimated as low. Although there is at present no sockeye run and zooplankton densities are high, it is thought to be too shallow for successful rearing of sockeye fry.

Klukshu Lake in the Alsek River system is small and enhancement through fry plants is not recommended since fry recruitment already appears adequate (at least in 1987). This lake had the highest fry densities measured of the eleven lakes studied, while zooplankton densities were relatively low. Lake enrichment might increase production.

Approximate costs of major activities dealing with enhancement are summarized. Recommendations for further studies include: 1) determining growth rates of smolts reared under feeding conditions of 1987, 2) conducting further surveys of lake conditions for prospective candidates for enhancement to look at annual variations, 3) identifying methods of stock identification for enhanced stocks, 4) determining the marketing value of enhanced fish dependent on where they are caught, and 5) disease and parasite analysis.

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INTRODUCTION

In April, 1987, the Transboundary Technical Committee prepared a report summarizing known enhancement opportunities for salmon in the transboundary rivers. The report concluded that sockeye salmon would show the greatest benefits from enhancement, at least in the short term, and, therefore, emphasis was placed on this species both in that report and the present one. The 1987 report reviewed existing information and then rated eleven lakes in the Taku (Fig. 1), Stikine (Fig. 2), and Alsek (Fig. 3) watersheds for enhancement potential. Tahltan Lake in the Stikine River system ranked highest followed by Klukshu Lake in the Alsek system and Tatsamenie Lake in the Taku system. These conclusions were based on very limited information and it was, therefore, recommended that additional field studies be undertaken to provide a firmer foundation on which to develop enhancement plans for the transboundary rivers.

Surveys of physical and biological conditions in the same eleven lakes were made in the summer and fall of 1987 and results are presented in this report. Based on the information collected, two models were developed to predict enhancement potential of sockeye salmon in these lakes. This report also 1) discusses enhancement techniques most likely to be successful for each system, 2) presents estimates of major costs involved in enhancement, 3) looks into broodstock availability, 4) discusses harvest strategies of enhanced stocks, and 5) makes recommendations for further research.

ENHANCEMENT POTENTIALS

Analytical Models

Eleven sockeye salmon nursery lakes in the Stikine, Taku, and Alsek Rivers were surveyed in the summer and fall of 1987 to determine the density of rearing juvenile sockeye salmon in relation to carrying capacity. These lakes vary greatly in size (1.2-30.6 km^2), euphotic zone depth (1.9-20.2 m), and total phosphorous content (4.7-40.0 ug/L) (Table 1).

Two models utilizing different criteria were used to determine enhancement potential. Model I relates observed total adult production from rearing-limited sockeye systems to euphotic volume (the volume of lake water contributing to phytoplankton production; 1 EV unit = 1 million cubic meters). The observed adult production from nine Alaskan sockeye systems considered to be rearing-limited is plotted against euphotic volume (Fig. 4). The relationship appears linear, therefore, the resulting regression line (adults = 29.7 + 1.81 EV) is used to predict potential adult production from the transboundary river systems (Table 2). The enhancement potential of a transboundary lake is then

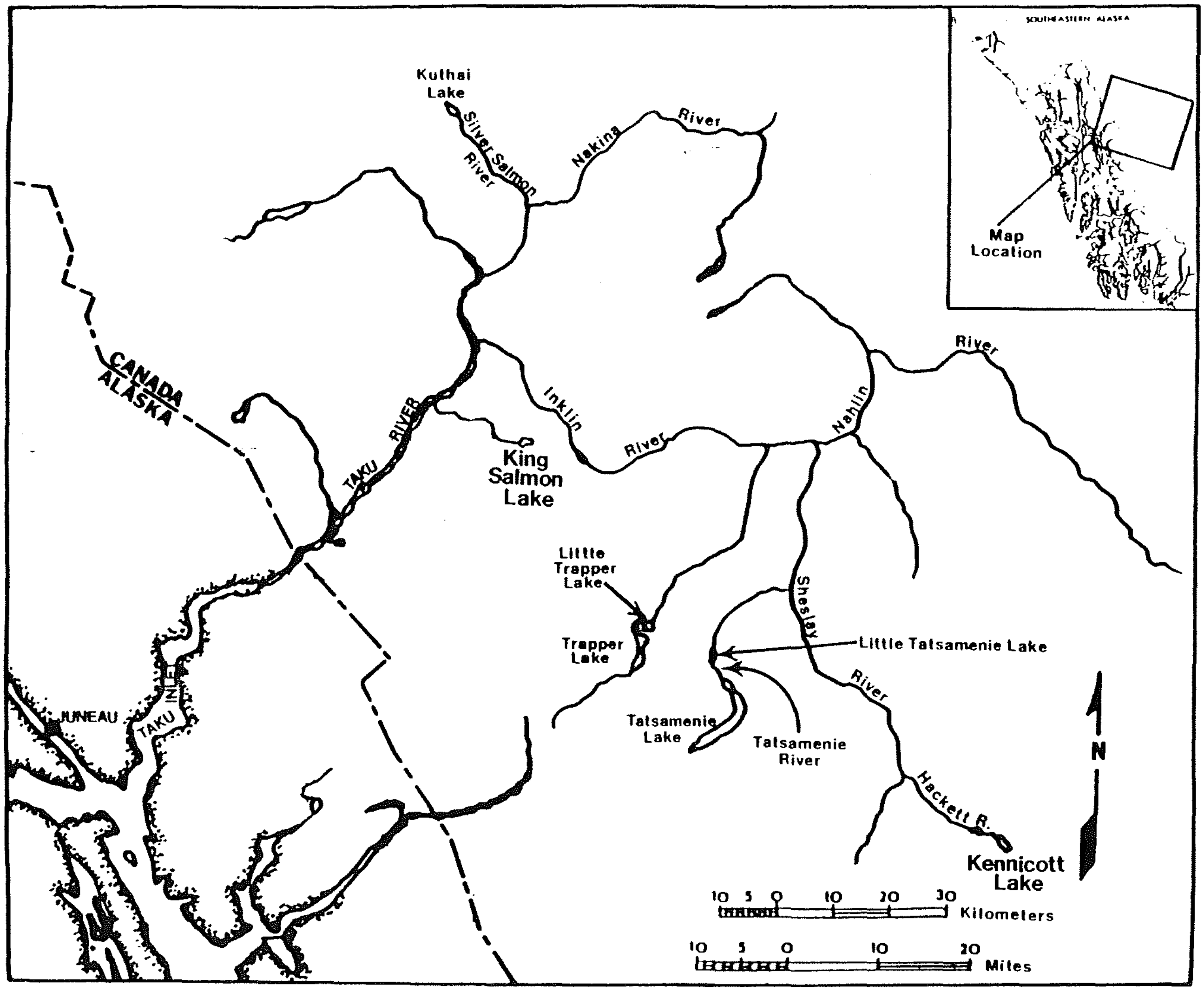

Figure 1. Taku River drainage.

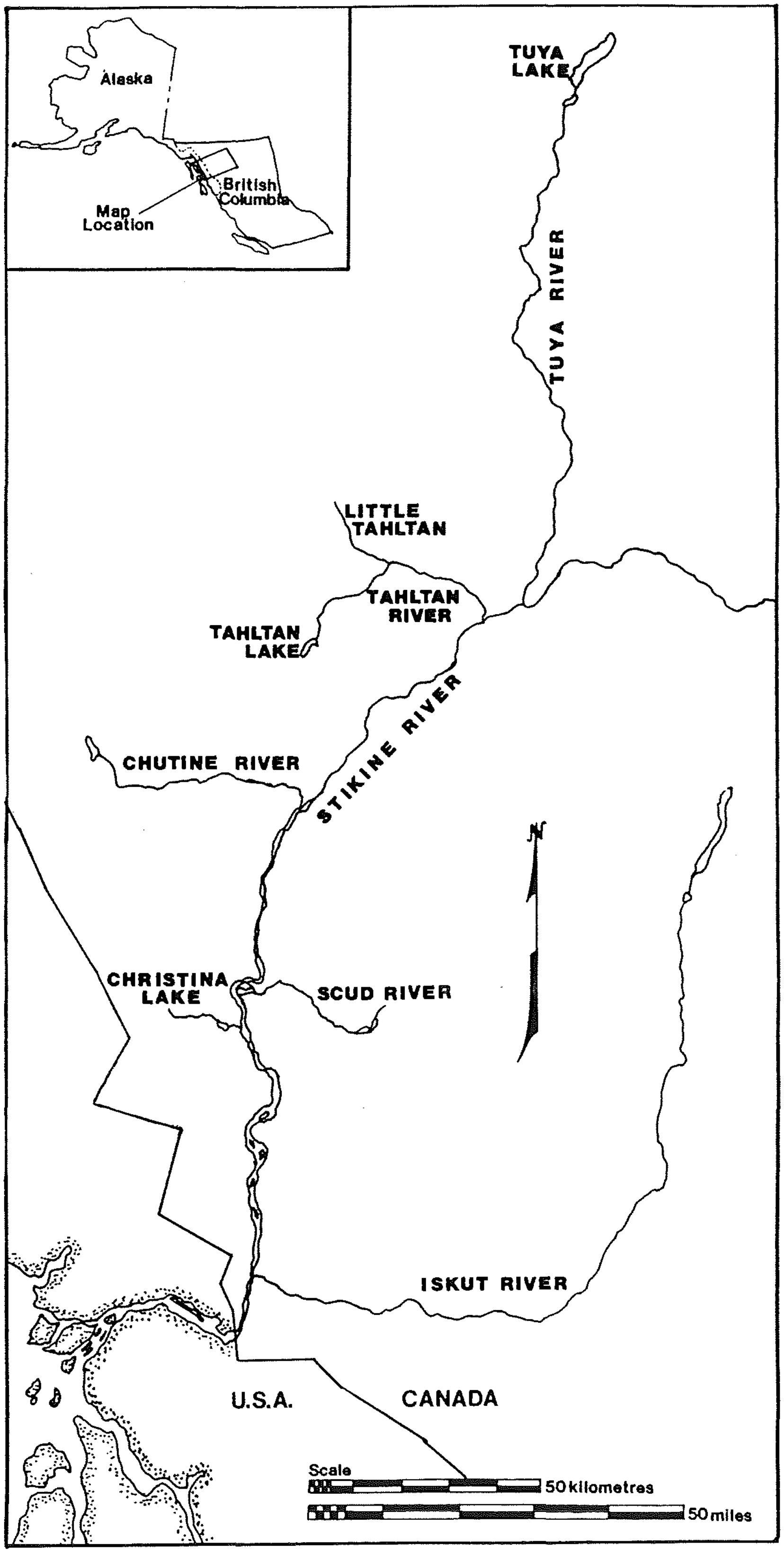

Figure 2. Stikine River drainage.

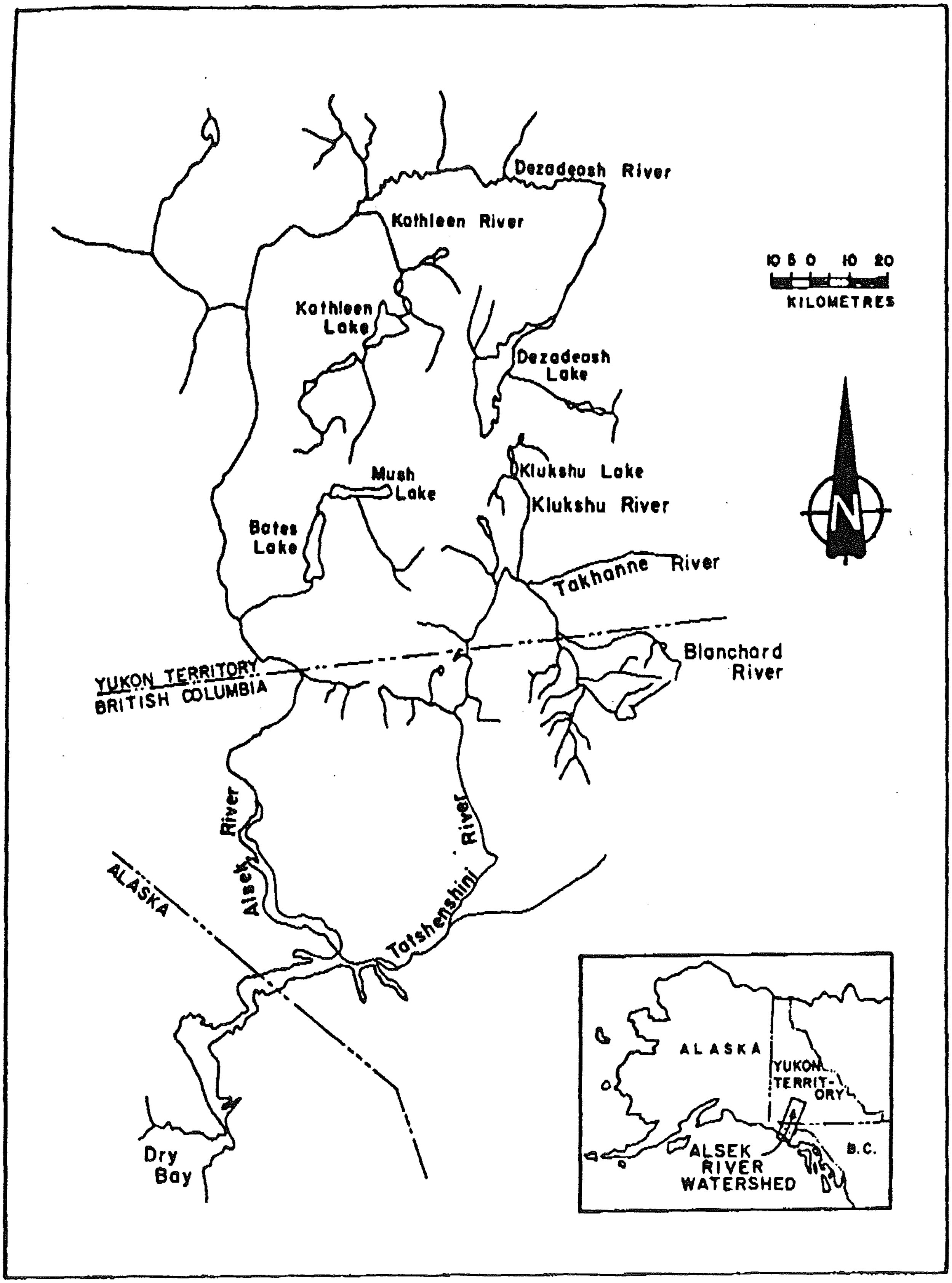

Figure 3. Alsek River drainage.

Table 1. Physical characteristics of sockeye salmon nursery lakes in the Stikine, Taku and Alsek River systems.

Category	Lake	Type *	Euphotic Depth (m)	Surface Area (sq.km)	Euphotic Volume (EV)**	Total Phosphorus (ug/L)
Euphotic Depth < 10 m	Chutine	G	1.9	6.5	12.4	40.0
	Christina	G	3.2	2.4	7.7	14.0
	Trapper	G	5.2	6.8	35.4	15.0
	Klukshu	C/G	7.5	1.6	12.0	9.0
Euphotic Depth > 10 m	L. Trapper	C/G	11.1	2.3	25.5	4.7
	Tatsamenie	C/G	12.8	15.8	202.2	6.0
	Tuya	C	13.3	30.6	407.0	9.0
	Kuthai	C	16.4	2.4	39.4	6.0
	King Salmon	C	17.7	1.6	28.3	5.5
Enriched	Kennicott	C	4.0	1.2	4.8	21.0
	Tahltan	C	20.2	4.0	80.8	11.0

* C = Clear, G = Glacial.
** EV = 1 million cubic meters.
*** Kennicott has not been enriched but is naturally very productive; the shallow euphotic depth is due to phytoplankton concentrations, not glacial silt.

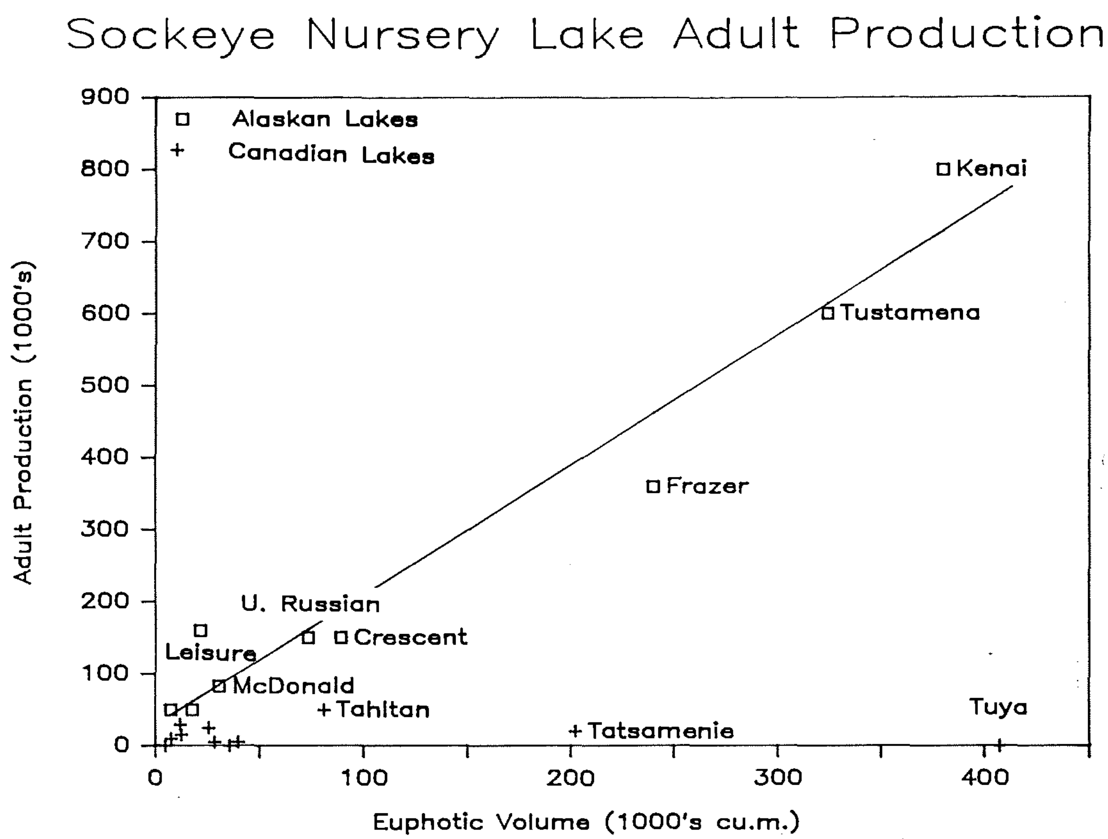

Figure 4. Adult sockeye production as a function of euphotic volume of nursery lakes; Alaskan lakes with full production capacity were used to determine regression line.

Table 2. Current and predicted levels (using model I) of adult sockeye production and resulting enhancement potential for the eleven transboundary sockeye nursery lakes.

Lake	Type *	Euphotic Volume (EV)**	Adult Production (thousands)		
			Current	Predicted	Potential
Tuya	C	407	0	764	764
Tatsamenie	C/G	202	20	394	374
Tahltan	C	81	50	176	126
Kuthai	C	39	5	100	95
Trapper	C/G	35	0	93	93
King Salmon	C	28	5	80	75
L. Trapper	G	26	25	77	52
Klukshu	C/G	12	30	51	21
Chutine	G	12	15	51	36
Christina	G	8	10	44	34
Kennicott	C	5	0	39	39

* C = Clear, G = Glacial.
** EV = 1 million cubic meters.

derived by subtracting the current adult production level from the predicted potential for adult production.

The second step under Model I is to determine whether the enhancement potential predicted for a lake would be best achieved by increasing fry concentrations or by lake enrichment. In twelve oligotrophic sockeye nursery lakes in Alaska when spring fry densities were at the carrying capacity of the system the resulting smolt production was on the order of 23,000 per EV and fry density for the preceding fall was on the order of 36,000 per EV (Koenings and Burkett 1987). Therefore, systems with fry densities in the fall of less than 36,000 fry per EV are candidates for increasing fry concentrations and those systems with greater fry densities in the fall are candidates for lake enrichment.

Model II assumes that maximum survival from eggs to smolts will be attained when there is a set balance between smolt size and numbers. This balance is achieved when a certain ratio of fry density to zooplankton (food supply) density is maintained. When zooplankton production limits the growth or survival of juvenile sockeye, a lake can produce many, small smolts or relatively few, large smolts. Existing evidence (Koenings and Burkett 1987) suggests that in rearing-limited systems the desired mean size of smolts is around 2 to 3 grams and that this size is attained when the density of usable zooplankton (>500 um in length) is maintained at about 5,000 zooplankters per cubic meter. This zooplankton density can probably be maintained under a grazing pressure from sockeye fry at densities in the fall ranging from 10,000 to 25,000 fry per EV in coastal British Columbia lakes (Stockner and Hyatt 1984, Hyatt and Stockner 1985) to 30,000 to 40,000 fry per EV in Alaskan lakes (Koenings and Burkett 1987). Enhancement potential ratings based on these ratios of fry density to zooplankton density are given in Table 3. This criterion measures enhancement potential per unit area, not per total system based on lake size. Zooplankton density versus sockeye fry densities based on numbers per volume (Table 3) are plotted in Figure 5 for both Canadian and Alaskan lakes. Suitable ratios of zooplankton to fry densities are indicated (very approximately) by the shaded region, referred to as the optimal zone. Fry additions (through increased spawning escapement or outplants) are recommended for those lakes that fall to the left of the optimal shaded zone, whereas lake enrichment (or decreased escapements) are recommended for lakes that fall to the right of the shaded zone. The relative distance from the optimal zone reflects only the relative potential for enhancement as the overall potential for enhancement also depends on lake size (Table 2). Furthermore, these results are assumed to represent feeding conditions for sockeye in 1987; conditions may vary annually, especially where spawning escapements, and hence fry recruitment, vary greatly from year to year as in Klukshu Lake.

Results

Both models (see Figs 4 and 5) suggest that Tuya, Tahltan and Tatsamenie Lakes can all support many more juvenile sockeye than they do at present. Because of its large size, Tuya Lake (64 fry /ha; 500

Table 3. Biological characteristics and enhancement potentials (using model II) of the eleven transboundary sockeye nursery lakes.

Category	Lake	Sockeye Fry Density (#/ha)	Sockeye Fry Density (#/EV)	Zooplankton Density (#/cu.m)	Enhancement Potential and Strategy
Euphotic Depth < 10 m	Chutine	9	500	2	poor
	Christina	68	2,100	13	poor
	Trapper	148	2,800	6,000	good, add fry
	Klukshu	7,500	100,000	1,000	good, enrich
Euphotic Depth > 10 m	L. Trapper	4,000	36,000	300	good, enrich
	Tatsamenie	1,400	10,900	9,500	modest, add fry
	Tuya	64	500	14,000	good, add fry
	Kuthai	330	2,000	15,000	good, add fry
	King Salmon	1,300	7,300	19,000	good, add fry
Enriched	Kennicott	0	0	25,000	poor
	Tahltan	1,600	7,900	37,000	good, add fry

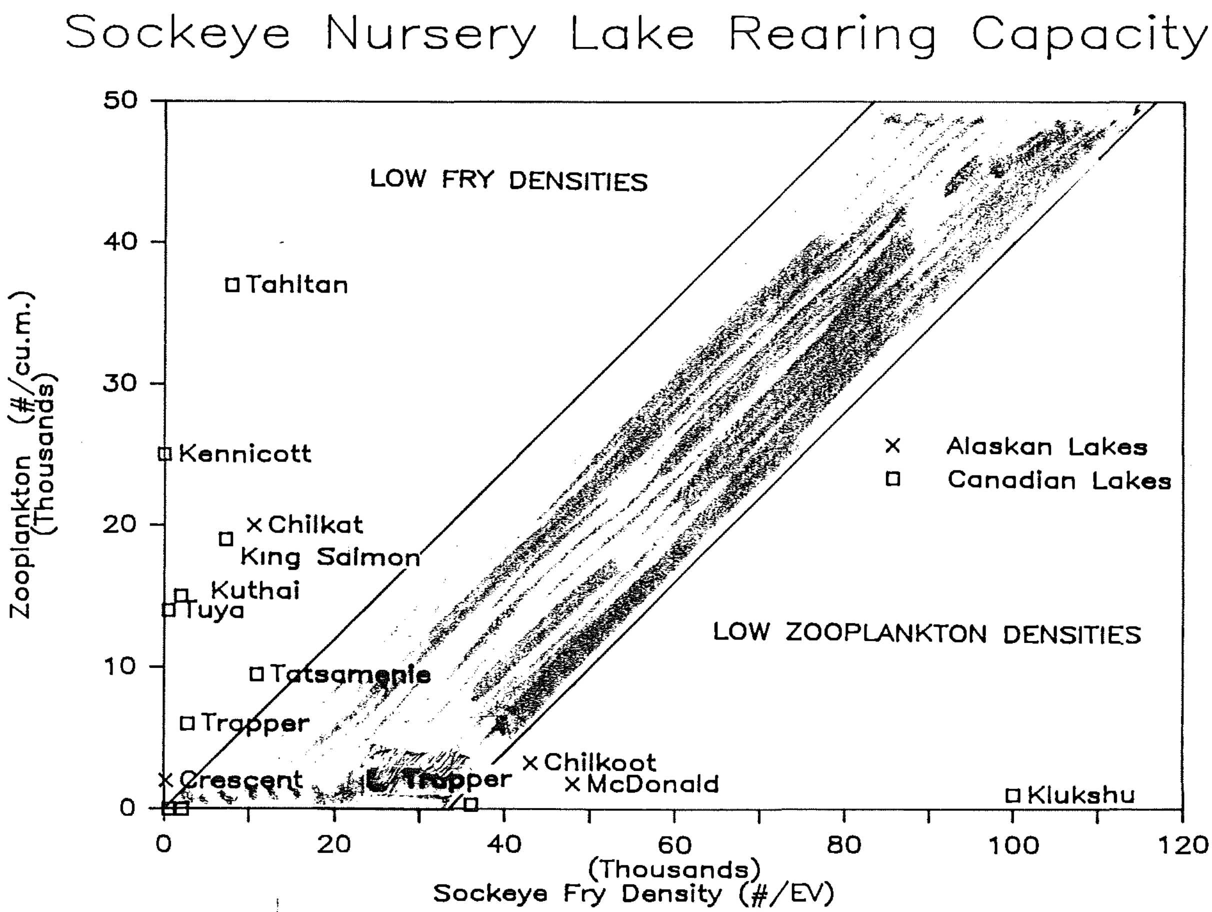

Figure 5. Sockeye nursery lake rearing capacities showing fall (August-September) fry and macrozooplankton (>500 um) densities for Canadian systems and fall (September) fry and seasonal macrozooplankton (>400 um) densities for Alaskan systems.

fry/EV; fry presumed to be kokanee) undoubtedly ranks highest in terms of its overall unused rearing habitat. Anadromous sockeye cannot use this lake at present due to a velocity barrier in the Tuya River. Although no anadromous sockeye juveniles were captured in the trawl surveys, sonar surveys suggest that kokanee (non-anadromous sockeye) occur in the lake at low densities. Tahltan Lake (1,600 fry/ha; 7,900 fry/EV) was enriched during the years 1985 to 1987 and this probably explains why the lake appears to be so underutilized by juvenile sockeye fry (Fig. 5), moreover, it is not clear whether fry recruitment from natural spawning would be adequate to fully utilize the lake's productivity even in the absence of artificial enrichment (Fig. 4). Tatsamenie Lake (1,400 fry/ha; 10,900 fry/EV) ranks highly as a candidate for increased fry recruitment based on the first model owing to its relatively large size (Fig. 4). However, its zooplankton density appears to be low in comparison to other lakes with similarly low fry densities (Fig. 5), so it may support fewer additional fry per hectare. Nevertheless, its relatively large size would make even modest increments in smolt production per hectare seem attractive.

Klukshu Lake was ranked among the least favorable candidates for enhancement through increased fry recruitment using the first model (Table 2). Indeed, fry densities in 1987 were found to be very high (7,500 fry/ha; 100,000 fry/EV) following a peak spawning escapement in 1986. Zooplankton density at the same time was very low (Fig. 5). However, the estimated volume of the euphotic zone in Klukshu Lake may be biased low since estimates of euphotic depth made in glacial and clearwater systems in the fall are usually more shallow than estimates based on seasonal means. Lake enrichment is recommended as an enhancement strategy if fry recruitment is to be maintained at the 1987 level. However, it seems unlikely that fry recruitment will be as high in 1988 following the relatively poor spawning escapement in 1987. Little Trapper Lake also appears to be a promising candidate for lake enrichment since zooplankton density was extremely low despite a desirable fry density (4,000 fry/ha; 36,000 fry/EV) (Fig. 5). Total phosphorus levels were lower in Little Trapper Lake than in any other lake studied (Table 1). The nitrogen content and the high flushing rate of the lake, neither of which have been measured, may also limit zooplankton production.

Finally, Kuthai Lake (330 fry/ha; 2,000 fry/EV), Trapper Lake (148 fry/ha; 2,800 fry/EV), and King Salmon Lake (1,300 fry/ha; 7,300 fry/EV) appear to be productive lakes that are currently underutilized by sockeye fry (Fig. 5). For their small size, all rank very highly in production potential; collectively their production could exceed that of Tahltan Lake. Kuthai Lake would be logistically easy and relatively inexpensive to enhance.

It should be recognized that specific enhancement strategies for individual lakes may change from year to year depending upon spawning escapement levels, zooplankton production and juvenile sockeye recruitment. For example, in a year following a particularly poor return to Tahltan Lake (e.g. 1987) fry outplants would be the best strategy, whereas the strategy may shift to lake enrichment in a year following a large spawning escapement.

OTHER CONSIDERATIONS

Costs

Detailed cost analyses have not been done. However, preliminary estimates of the cost of various enhancement activities for the various sites studied have been compiled (Table 4). Costs of specific projects will be influenced by ease of access to the systems and travel distance between systems and incubation facilities.

Annual operational costs for fry planting include egg-takes, egg transport from broodstock site to incubation facilities at Port Snettisham in Alaska, incubation, disease screening, and fry transport back to the enhancement site.

We caution that cost benefit analyses have not yet been done, but should be done before final decisions are made on enhancement activities.

Broodstock Availability

Broodstock availability is tabulated in appendix II of the Technical Committee's enhancement report issued in April, 1987. Recent (1983-1987) escapement data are used here to give a better idea of current levels of potential broodstocks (Table 5). Tahltan and Little Trapper Lakes both appear to be capable of routinely supporting significant egg takes (i.e. >3 million eggs) without seriously impacting wild spawning populations. A broodstock removal rate that exceeds about 30 percent of the total escapement is considered excessive.

Harvesting Enhanced Stocks

Harvest rates applied to enhanced stocks generally should be maintained at levels compatible with the natural productivity of unenhanced stocks exploited by the same fisheries. Thus, a large proportion of enhanced fish may have to be taken in terminal areas where quality and, hence, value may be reduced. However, each case must be evaluated individually as there may be situations where the benefits to be gained by harvesting enhanced stocks at a higher rate in mixed stock areas clearly outweigh the potential negative effects of over harvesting co-migrating wild stocks. In fact, in many mixed stock salmon fisheries, harvest rates are managed to maximize the catch from large, more productive stocks allowing the less productive ones to be exploited above optimal levels.

To minimize impacts on wild stocks and maximize benefits from enhancement, it is desirable to enhance stocks which can be harvested selectively owing to unique run timing or terminal fishing opportunities. In the Stikine system, Tahltan Lake is a favorable candidate from both production and run timing points of view. The Tahltan sockeye run is early and partially distinct from other Stikine

Table 4. Cost estimates for enhancement activities at full production on transboundary river system lakes.

Activity		Site	Approximate Cost (thousand U.S.$)
Fry Outplants million eggs	Potential Adult Production (thousands)		
24	764	Tuya Lake	300 - 600
3.6	126	Tahltan Lake	60 - 120
12	374	Tatsamenie Lake	150 - 300
2.4	95	Kuthai Lake	60 - 120
1.7	75	King Salmon Lake	60 - 120
2.1	93	Trapper Lake	60 - 120
Lake Enrichment		Klukshu Lake	15
		Little Trapper	25 - 35
Barrier Removal		Tuya Lake	4,000

Table 5. Sockeye spawning escapements in potential brood stock sources, the percent of escapement utilized for a five million egg-take level, and the number of adults and eggs available for brood stock given a 30 percent take from the adult spawning escapement for three potential enhancement systems.

System Destination/ Brood Stock Source	Escapement		Percent Escapement		Availability	
	Average (83-87)	Minimum (year)	Ave.	Min.	Adults (1000's)	Eggs (million)
Tuya/ Tahltan	30,000	7,000 (1987)	11%	49%	2-9	3.0-14
Trapper/ L. Trapper	12,000	8,000 (1983)	28%	43%	2-4	3.0- 6
Tatsamenie/ Tatsamenie	9,000	3,000 (1987)	38%	100%	1-3	1.5- 5

River stocks (Fig. 6) and, therefore, could be harvested at a relatively high rate in both U.S. and Canadian fishing areas during the first half of the season. Tuya Lake in the Stikine drainage, theoretically, has far more potential for enhancement than any other transboundary lake. If Tahltan stock were transplanted there as fry, the timing of the adult returns to Tuya probably would be the same as those returning to Tahltan Lake so they could be managed together. A negative factor associated with enhancement of Tahltan stock is the potential impact on chinook salmon which are currently protected in terminal areas to assist in stock rehabilitation. Increased harvesting of Tahltan sockeye salmon would increase incidental chinook catches and this would have to be weighed against the sockeye benefits. This could be offset by chinook enhancement. In addition, overall chinook production from the Stikine could be increased via transplants or natural colonization either in the Tuya River below the lake or in one of the tributaries off the Tuya River.

Unlike in the Stikine River there does not appear to be a major enhancement opportunity in the Taku system on a stock that is relatively isolated in run timing from other stocks (Fig. 7). Kuthai Lake sockeye salmon, which have relatively early timing, may have some potential in this regard although the production potential is somewhat less than that of Tahltan Lake. Production could be substantially higher if Kuthai and Little Trapper Lakes were both enhanced to increase the early and mid-season runs. In the Taku system Tatsamenie Lake appears to have the greatest potential for sockeye production, although the migratory timing of its sockeye stock coincides with that of other stocks, particularly the mainstem stock. This overlap of migrations would limit the harvesting options in the lower river, and, therefore, the feasibility of conducting terminal harvest should be fully explored.

The major sockeye producer in the Alsek system, Klukshu Lake, appears to be a favorable candidate for lake enrichment, although additional field studies are recommended to confirm this. Harvesting of enhanced Klukshu sockeye salmon in U.S. fisheries may be constrained by overlap in timing with other sockeye stocks. The present Canadian fishery is situated far enough upstream to avoid stock interactions.

RECOMMENDATIONS FOR FURTHER RESEARCH

Surveys

It is recommended that several of the preferred candidate lakes be resurveyed on a seasonal basis in 1988 to determine whether rearing conditions observed in 1987 are typical. Lake enrichment candidates, Klukshu and Little Trapper Lakes, should be resurveyed before any enhancement activity begins since changes in spawning escapement levels are expected to alter fry densities in 1988. Analysis of scale patterns in existing adult scale collections may provide an indication

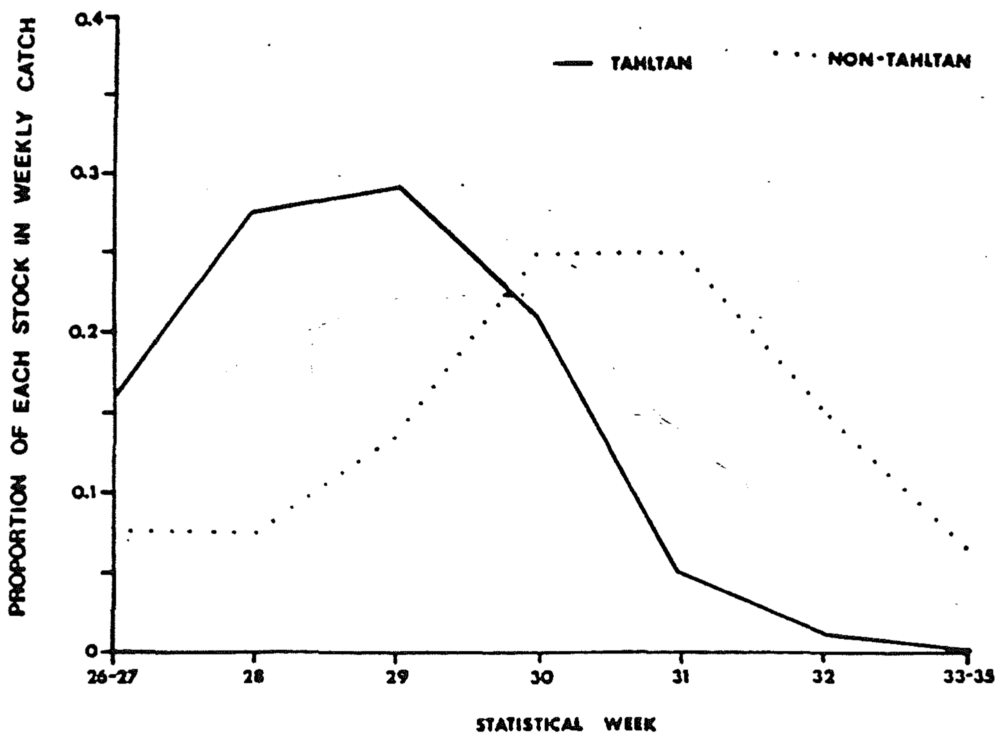

Figure 6. Migratory timing of the Tahltan and non-Tahltan sockeye salmon stock groups in Canada's Stikine River commercial fishery, 1986.

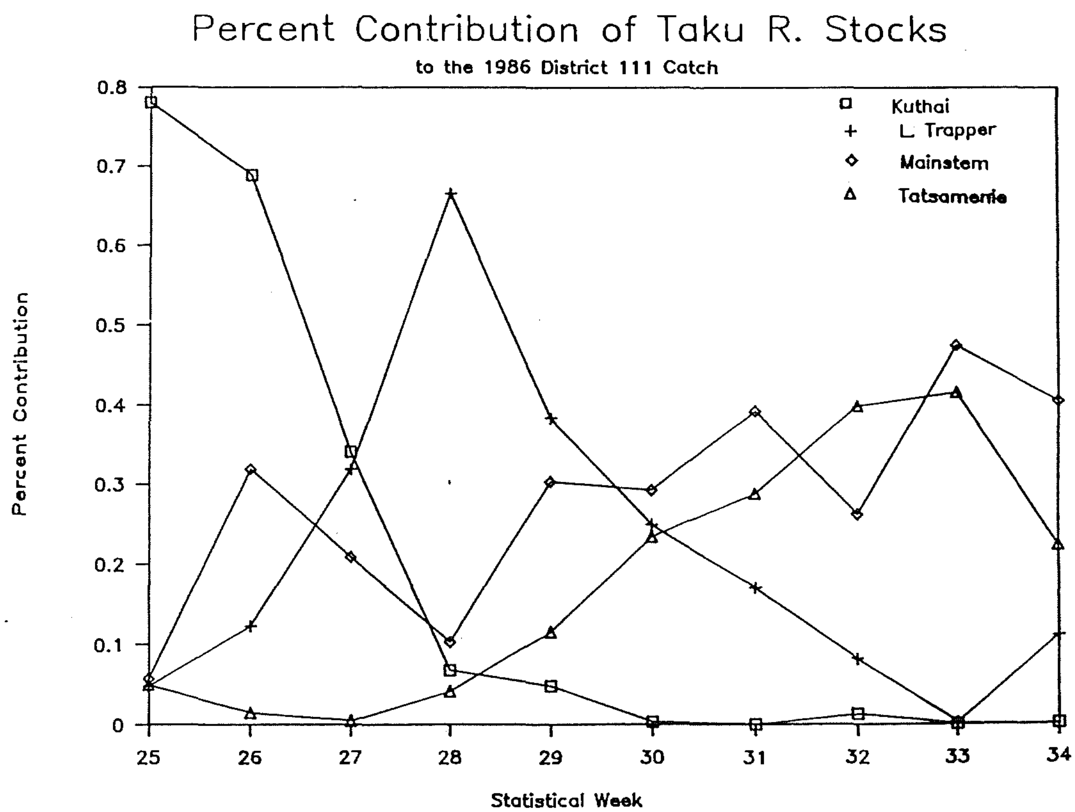

Figure 7. Migratory timing of major Taku River sockeye salmon stocks in Alaska's District 111 catch, 1986.

of expected variability in freshwater growth and rearing conditions. Lake enrichment of Tahltan Lake should be terminated and the lake resurveyed in 1988 to determine whether additional fry recruitment is required in the absence of artificial enrichment. Smolt samples should be collected in the spring of 1988 from each of the lakes surveyed to determine the ultimate growth rate of juvenile sockeye salmon rearing under the feeding conditions observed in 1987. The present analysis of enhancement potential is based on comparable data for coastal B.C. and Alaskan sockeye lakes. Smolt sampling was proposed originally as an essential part of the enhancement feasibility survey.

Enhancement projects designed to increase sockeye production from lakes could have detrimental effects on sockeye production from river rearing areas. This potential impact should be evaluated because river rearing habitats presently support a significant portion of the total sockeye production in both the Taku and Stikine Rivers. About 50 percent of spawning in both systems occurs in mainstem and side channel areas where fry have no access to lakes for rearing.

Stock Identification Methods

Stock identification procedures should be identified for enhanced runs which will require increased rates of exploitation by the fishery. Furthermore, it would be desirable to differentiate between natural and enhanced production from a single stock, both to evaluate the benefits from enhancement and to monitor sharing from enhanced runs. Baseline data already exist for most of the candidate stocks. However, enhancement can be expected to alter scale pattern characteristics, and present techniques may no longer be useful. It may be possible to genetically mark outplanted stocks by selecting broodstock so as to concentrate rare, marker genes that already occur in the natural stocks. The cost of such a program has not been estimated at this time. Additionally, other stock separation methods involving rare earth and tetracycline marks show promise, but are not technically feasible at this time.

Marketing Evaluation

Due to constraints on harvesting mixed stocks outlined previously, a portion (in some cases the majority) of the Canadian catch will need to be taken in terminal areas. The feasibility of capturing and subsequently marketing sockeye in non-traditional areas after they have separated from other stocks requires examination. As fish quality would be expected to decline in terminal areas, the effect of this on the value of the product must be taken into consideration in assessing overall costs and benefits of individual projects. It is recommended that these evaluations be undertaken on selected stocks in 1988.

Disease and Parasite Testing

Samples should be collected in 1988 to determine the disease and parasite profiles of sockeye stocks being considered for enhancement. It is important that this be done in order to identify stocks carrying diseases that could cause potential problems in fish culture facilities and to determine the incidence of parasites that could reduce fish quality.

Chinook and Coho

Although the focus of the Transboundary Technical Committee has been on sockeye salmon it is recognized that enhancement opportunities for chinook and coho salmon also exist but they have not been well defined. Some information regarding these two species exists in published and unpublished reports of the agencies involved in the transboundary rivers. This information needs to be compiled and reviewed in order to evaluate enhancement opportunities on these species.

SUMMARY AND CONCLUSIONS

Stikine River System

Stikine River sockeye salmon are harvested by Alaskan fisheries in Districts 106 and 108 and by in-river Canadian commercial and Indian food fisheries. The estimated total returns in recent years have ranged from about 40,000 to 200,000 and averaged 100,000 fish. The total exploitation rate since 1982 has averaged about 35 percent.

The Stikine River sockeye run consists of the early migrating Tahltan Lake stock and numerous later migrating stocks. Four lakes in this system were evaluated for enhancement potential. Tuya and Tahltan Lakes showed the highest potential for sockeye production. The potential exists for the combined enhancement of both systems using the Tahltan Lake sockeye stock. In addition, enhancement opportunities for chinook salmon exist.

<u>Tuya Lake.</u> This lake has the greatest production potential (764,000 adults) of the transboundary lakes studied because of the large size of the unused rearing habitat. There is presently no anadromous sockeye production in this lake due to a barrier to adult access. Preliminary studies indicated relatively high densities of large bodied zooplankters, but few, if any, rearing juvenile sockeye (assumed to be kokanee). Two enhancement scenarios could utilize the unused rearing area: 1) annual fry plants with harvest of the total return excluding that portion used for broodstock and 2) the one time

removal of the outlet barrier combined with fry plants for five years to establish a naturally spawning run with a sustainable harvest rate.

Considerations: 1) Potential broodstock from Tahltan Lake has appropriate migratory timing and run size. 2) Returning adult sockeye salmon can be targeted in Alaska's District 108 and in Canada's in-river fishery during a specific time span with little expected impact on wild sockeye stocks. 3) Fry plants in Tahltan Lake could replace, if needed, adults used for egg-takes for Tuya Lake and allow for the exploitation rate on the Tahltan stock to increase to the same level as that of the Tuya stock. 4) Increased harvest of Tahltan-Tuya sockeye salmon would increase incidental chinook catch; however, this could be offset by chinook enhancement, if needed. 5) The establishment of the Tuya run is contingent on barrier removal, adequate natural spawning area, and favorable rearing habitat.

Tahltan Lake. This system ranks third highest of the transboundary systems with an enhancement potential of 126,000 adult sockeye salmon in addition to the present average production of 50,000 fish. Fertilization should only be continued if accompanied by supplemental fry plants. The early run timing and ability to identify the stock enables stock specific management. Tahltan Lake appears capable of routinely supporting egg-takes without excessive removal of wild stocks.

Considerations: Increased harvest of Tahltan sockeye salmon would increase incidental chinook catches. The potential impact of this should be evaluated.

Chutine Lake. Enhancement potential is limited due to glacial turbidity and low zooplankton abundance. An additional production of 36,000 adult sockeye salmon over the current small run is projected. The run timing is similar to mainstem Stikine stocks, so there is little opportunity to target on this stock except in potential terminal harvest areas.

Christina Lake. Enhancement potential is limited due to glacial turbidity and low zooplankton abundance. An additional production of 34,000 adult sockeye over the current small run is projected. The run timing is similar to mainstem Stikine stocks, so there is little opportunity to target on this stock except in potential terminal harvest areas.

Taku River System

Taku River sockeye salmon stocks contribute to the U.S. District 111 drift gill net fishery and the Canadian in-river fishery. Recent total returns to the system have a range of 130,000 to 200,000 sockeye salmon and average about 170,000. The total exploitation rate by both fisheries since 1984 has averaged 45 percent.

Terminal harvesting opportunities should be evaluated. Most stocks in the system overlap in timing to the extent there is only limited potential to target enhanced fish in current fisheries without affecting unenhanced stocks.

Tatsamenie Lake. The present production of adult sockeye salmon is about 20,000 fish annually. The enhancement potential is high

(374,000 adults) and second only to Tuya Lake. Significant numbers of rearing juveniles are present, but the rearing environment appears to be underutilized as evidenced by the presence of moderate densities of large bodied zooplankters. Thus, the potential exists for supplemental fry plants.

Considerations: 1) Targeting opportunities in traditional fisheries are limited to current exploitation rates due to overlap in migration timing with other sockeye stocks (mainstem Taku River). Terminal harvest areas would be needed to fully utilize surplus returns, but the availability of suitable sites is questionable. 2) Increased harvest rates on enhanced Tatsamenie sockeye in traditional fishing areas would likely increase catches of early-run coho salmon. 3) Use of Tatsamenie broodstock will be limited in some years because of low escapements, adults spawning in inaccessible areas, and the possibility of having to hold adults in net pens to ripen. Other suitable broodstocks have not been identified.

Kuthai Lake. The enhancement potential is moderate (95,000 adults) in addition to the current adult production of approximately 5,000 sockeye. This clearwater system has high densities of large zooplankters. Scale patterns from adult sockeye salmon indicate very favorable growing conditions during freshwater residence. Increased adult production appears to be dependent on increasing fry recruitment (fry plants). Adult access during low water conditions is poor and the quantity of spawning habit is questionable.

Considerations: 1) Limited targeting on returns may be possible in existing fisheries because run timing of this stock is earlier than most other Taku sockeye stocks. 2) Run timing overlaps that of chinook stocks. 3). Logistics of enhancement work are easy and relatively inexpensive. 4) Broodstock is obtainable, but current escapement at this time cannot support a large egg-take. 5) No terminal harvest area exists. 6) Potential exists for mixing of enhanced Kuthai stock with wild mainstem Taku stocks owing to difficult access to Kuthai Lake.

King Salmon Lake. The enhancement potential is moderate (75,000 adults) in addition to the current adult production of approximately 5,000 fish. The high density of large bodied zooplankters indicates that unutilized rearing potential exists. Currently a beaver dam impedes the access to the lake for spawning adults. The lake is clearwater and small numbers of adults have been observed to enter the lake. Modification of the beaver dam may be appropriate.

Considerations: 1) Run timing of this stock is unknown so that potential impacts on other stocks associated with harvesting cannot be assessed. 2) Little opportunity exists for a terminal fishery although small catches could be taken in subsistence or sport fisheries at the mouth of the outlet stream. 3) Current escapements are too low for significant egg-takes.

Little Trapper Lake. Current production is approximately 25,000 adults and the enhancement potential through fry planting is about 52,000. The rearing habitat appears at present to be fully utilized. The lake is partially glacial, but the light penetration is acceptable (greater than 10 m). Zooplankton density is low and fish scale patterns indicate that juvenile growth of the sockeye salmon is slow. Thus, this system appears to be a likely candidate for lake enrichment.

Considerations: 1) The flushing rate of the lake may be high which may reduce the effectiveness of enrichment. 2) Run timing suggests some potential exists to selectively target this stock in existing U.S. and Canadian fisheries. 3) The potential for terminal harvest is unknown. 4) Broodstock is available from the lake and is plentiful.

Trapper Lake. No sockeye run exists to Trapper Lake because of a velocity chute at the lake outlet. The enhancement potential is moderate (93,000 adults) because the zooplankton density is limited by the presence of glacial silt. Although adults are unable to enter the lake, it is felt that smolts can successfully emigrate. Consequently, the production of adults would be dependent on annual fry plants unless adult access is provided.

Considerations: 1) Adults would be harvested together with those from Little Trapper Lake (enrichment candidate) in existing U.S. and Canadian fisheries and some potential exists for targeting on this stock. 2) Juvenile sockeye salmon (assumed to be kokanee) are present at low densities in the system. 3) Sufficient broodstock is available from Little Trapper Lake. 4) A fish pass would be required to permit a self-sustaining anadromous sockeye run.

Kennicott Lake. This is smallest of the lakes studied. Enhancement potential is estimated as low (39,000 adults). Although there is at present no sockeye run and zooplankton densities are high, it is thought to be too shallow for successful rearing of sockeye fry.

Alsek River System

Alsek River sockeye salmon are harvested in a lower river U.S. gill net fishery (average annual catch of 25,000 fish over past ten years) and smaller Canadian sport and Indian food fisheries (annual catch of 3,200 fish). The total escapement of sockeye salmon for the drainage system is unknown; however, escapement to Klukshu Lake, the major producer in the area, has averaged about 15,000 adults. This was the only lake surveyed in this system and it appears to offer enhancement opportunity through lake enrichment, although additional studies are needed.

Harvesting of enhanced sockeye salmon from this system in U.S. fisheries may be constrained by an overlap in run timing with other sockeye stocks. Existing Canadian fisheries are located far enough upstream to avoid the problems associated with mixed stock fishing.

Klukshu Lake. Current production is estimated to be about 30,000 adults and enhancement opportunities through fry plants are poor (21,000 adults) because the system appears to be rearing area limited. Sockeye fry densities are the highest of any system surveyed and zooplankton densities are low. Previous limnological surveys in 1977 suggest that this system is a suitable candidate for lake enrichment, but further work is necessary to confirm this recommendation.

Considerations: 1) Fry densities in 1988 may be lower than in 1987 due to a relatively poor spawning escapement in 1987. 2) This lake has moderate light penetration and high nutrient levels, i.e. nutrients may not limit system production. 3) Harvesting of enhanced sockeye salmon in U.S. fisheries may be constrained by an overlap in run timing with other sockeye stocks. Existing Canadian fisheries are located far enough upstream to avoid problems associated with mixed stock fishing. 4) Logistical costs would be the lowest of any of the study sites due to road access.

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