

**PACIFIC SALMON COMMISSION  
TRANSBOUNDARY TECHNICAL  
COMMITTEE REPORT**

**TRANSBOUNDARY RIVER SOCKEYE SALMON  
ENHANCEMENT ACTIVITIES.  
FINAL REPORT FOR FALL, 1990  
TO SPRING, 1992**

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TRANSBOUNDARY RIVER SOCKEYE SALMON ENHANCEMENT ACTIVITIES.  
FINAL REPORT FOR FALL, 1990 TO SPRING, 1992.

Prepared By

The Transboundary River Technical Committee

For

The Pacific Salmon Commission

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## EXECUTIVE SUMMARY

Joint Canada/U.S. enhancement of transboundary river sockeye stocks began in 1989, when eggs were taken at Tahltan Lake on the Stikine River, incubated at Snettisham Central Incubation Facility (CIF) near Juneau, Alaska, and the resulting fry backplanted to Tahltan Lake. In 1990, eggs were again taken at Tahltan Lake and enhancement of Taku River sockeye salmon stocks began, with egg-takes at Little Trapper and Little Tatsamenie lakes to produce fry for outplanting to Trapper and Tatsamenie lakes, respectively. Additional egg-takes were conducted at all three sites in 1991 and 1992. Under terms of the Treaty, brood-year (BY) 1991 and 1992 Tahltan fry were divided between Tahltan and Tuya lakes. Activities up to the summer of 1990 have been previously reported (PSC 1991); the present report begins with the egg-takes in the fall of 1990 and continues through to smolt migrations and outplants in the spring of 1992. Some important information obtained subsequent to this period is mentioned.

Methods are described, including egg-take and hatchery operations, otolith marking, outplanting, monitoring of outplants including hydroacoustic/limnological surveys and smolt sampling, and ancillary activities. Results of hatchery and otolith marking activities are presented and difficulties in monitoring growth and survival described. Results for the period from egg-take through smolt are then presented for each lake, followed by results of limnological observations and ancillary activities. The report concludes with a discussion, including a brief comment on the success of the outplants to each lake. Important results and conclusions are summarized below.

*Hatchery operations:* Modifications to the Snettisham temporary CIF in 1990 alleviated many of the problems encountered the first year. Further improvements in 1991 apparently helped prevent a reoccurrence of the whitespot disease experienced in brood-year (BY) 1990 Little Trapper stock. Little Trapper stock of both BY 1990 and BY 1991 experienced substantial losses to IHNV and did not achieve the 80% egg to fry biostandard used in planning the projects. BY 1990 and BY 1991 Tahltan stock exceeded the biostandard except for one group of BY 1991 fry destined for outplanting to Tuya Lake, which suffered high losses of undetermined cause while being held in tanks just prior to transport. The Tatsamenie stock exceeded the biostandard in both BY 1990 and BY 1991. A new improved permanent facility was completed at Snettisham in 1993 to replace the temporary CIF.

*Egg-take operations:* All Tahltan egg-takes to date (including 1992 and 1993) have come close to or exceeded target levels; tagging studies are being conducted to examine for evidence of genetic selection in broodstock collection. Eggs for the outplants to Trapper Lake are taken at Little Trapper Lake; all egg-takes to date at this location have come close to or exceeded the targets. Eggs to produce fry for outplanting to Tatsamenie Lake are collected at Little Tatsamenie Lake; egg-take problems here have included excessive adult mortalities during the initial year of the project and difficulties in capturing sufficient broodstock due to low escapements. Holding mortalities have been reduced to acceptable levels by development of new procedures for handling of broodstock but low escapements are likely to continue to be a problem unless the run size can be built up. Because of genetic concerns, studies are being conducted to examine the practicality of capturing broodstock at Tatsamenie Lake rather than at Little Tatsamenie Lake.

*Otolith marking:* A temporary laboratory has been established in Juneau to examine marking techniques and develop methods for mass processing of otoliths from returning adults. Marks have been recovered from Alaskan domestic sockeye stocks and transboundary sockeye juveniles and smolts arising from the outplants. There were problems with the clarity of some of the marks during the initial years of the program and the ability to identify these fish in mixed stock fisheries is uncertain. However, the technique has been judged to be successful and refinements to marking techniques and development of marking protocols to prevent recurrence of similar marks in mixed stock situations should correct the initial problems.

*Problems associated with growth and survival estimates:* Tahltan Lake is the only outplant lake where a smolt enumeration program is conducted and comparison of fall hydroacoustic estimates with subsequent smolt estimates suggest the fall juvenile population is often badly underestimated. Possible reasons for this are presented and a regression is developed which could be used for predicting smolt numbers from fall fry estimates in most years. Other lakes were examined for conditions similar to those observed at Tahltan which might bias hydroacoustic estimates. The 1991 Trapper Lake fall estimate was judged to be considerably more accurate than the Tahltan Lake estimate but the accuracy of the 1991 Tatsamenie fall estimate was judged to be similar to that of Tahltan Lake. Some difficulties are likely to be experienced at Tuya when fry densities increase. Accuracy at most lakes will likely vary between years. Depending on the conditions encountered and the accuracy desired, it may be desirable to conduct smolt enumeration programs at other sites, at least to examine the accuracy of hydroacoustic estimates. However, it is estimated the costs of enumeration programs would be 4 to 5 times those of hydroacoustic surveys.

*Evaluation of the outplants to Tahltan Lake:* Monitoring of the BY 1989 and 1990 outplants to Tahltan Lake showed the fry grew well, starting smaller than wild fish but eventually catching up to them in size. Survivals from outplanted fry to smolt have exceeded the 20% biostandard used in planning the projects. Based on smolt size and limnological observations there is very little indication that the productive capacity of Tahltan Lake has been taxed, despite the record smolt runs in 1991 and 1992 associated with the outplants.

*Evaluation of the outplants to Tuya Lake:* Outplanting to Tuya Lake did not begin until 1992 and monitoring of this outplant will be presented in a later report. Zooplankton studies in 1990 and 1991 continue to show this lake is capable of supporting large numbers of outplanted fry.

*Evaluation of the outplants to Trapper Lake:* The early outmigration of outplanted fry from Trapper Lake to Little Trapper Lake and the failure to capture smolts leaving Trapper Lake has important implications for the project, since the intent is for fry to utilize the food resource in Trapper Lake. Also, large numbers of outplanted fry rearing in Little Trapper could conceivably overtax its food supply, to the detriment of wild fish. It is not possible at this point to fully evaluate the success of the outplants to Trapper Lake. Fry and smolt sizes indicate outplanted fish are growing as well as wild fish but much further study is needed to answer questions relating to survival. It is very likely this may have to be judged by adult returns.

*Evaluation of the outplants to Tatsamenie Lake:* As in the outplants at other lakes, BY 1990 enhanced fry were initially smaller than wild fry but had reached a similar size by the fall. Survival to the fall may be lower than at Tahltan, but this cannot be stated with certainty. Overwinter survival of enhanced and wild fish is similar and it appears unlikely enhanced fry are migrating prematurely from Tatsamenie, as is occurring at Trapper Lake. Age 1 enhanced smolts were of a substantial size, very similar to that of wild smolts. As at Trapper Lake, estimates of survival to the smolt stage were not made. At this point, it can be said that the outplants to Tatsamenie appear to be relatively successful.

## 1.0 INTRODUCTION

Joint Canada/United States enhancement of transboundary river salmon stocks began in 1989, when 3.3 million sockeye salmon eggs were taken at Tahltan Lake on the Stikine River (Figure 1). These eggs were incubated at the Snettisham temporary Central Incubation Facility (CIF) near Juneau, Alaska, and the resulting fry backplanted to Tahltan Lake in the spring of 1990. Details of this project, including observations on the planted fry during their first summer and ancillary enhancement activities conducted during 1989 and early 1990, have been previously reported (PSC 1991). In 1990, eggs were again taken at Tahltan Lake and enhancement of Taku River sockeye salmon stocks began, with egg-takes at Little Trapper and Little Tatsamenie lakes to produce fry for outplanting to Trapper and Tatsamenie lakes, respectively (Figure 2). Further egg-takes were conducted at all three sites in both 1991 and 1992. This report briefly describes the methods used in the enhancement projects and presents details and results for all projects from the fall of 1990 through the spring of 1992. Information obtained subsequent to this period is briefly mentioned if considered important. This information will be presented in detail in future reports.

## 2.0 METHODS

### 2.1 Egg-takes

All egg-takes at Tahltan Lake were contracted to Triton Environmental Consultants Limited. All egg-takes at Little Tatsamenie and Little Trapper lakes were contracted to B. Mercer and Associates Aquatic Biology. Canadian egg-take protocols limit the number of fish taken for broodstock to 30% of the escapement. Approximately equal numbers of males and females were captured for broodstock and the milt of 2 males was used to fertilize the eggs of a single female, each male being used twice. Under this procedure, milt from a fresh male (*alpha* male) was applied to the eggs of a single female, followed immediately by application of milt from a previously used male (*beta* male). This male was then discarded and the *alpha* male used as the *beta* male for the next female, etc. This procedure was followed to protect against poor fertilizations should the milt of one male be defective. Attempts at shipping eggs and sperm separately and fertilizing at the hatchery produced poor results in the 1989 egg-takes (PSC 1991). As a result, the procedure in all subsequent egg-takes has been to fertilize at the spawning site prior to shipment. Under terms of Canadian Fish Health approvals all eggs were surface disinfected before being shipped to the hatchery and broodstock was sampled each year to test for incidence of infectious haematopoietic necrosis virus (IHNV) and bacterial kidney disease (BKD).

### 2.2 Hatchery Operations

All eggs were incubated at the Snettisham temporary CIF. Upon receipt the eggs were surface disinfected with an iodophor in accordance with Alaska Department of Fish and Game (ADF&G) standard operating protocol. In addition, all transport materials, coolers, muslin, and egg baskets were thoroughly disinfected prior to return to transboundary lakes. After disinfection, the number

of green-eggs were estimated. This was done by first weighing each basket of eggs and subtracting the known basket weight to obtain the total weight of the eggs in the basket. A sample of approximately 100 eggs was then withdrawn from the basket and weighed, the eggs counted, and the average individual egg weight calculated. The number of eggs in the basket was then calculated by dividing the total weight by the average individual egg weight. This procedure was deviated from only when eggs were not received on the same day as collected, usually due to poor weather. Because of the potential for physical shock to eggs which have undergone an extended period of incubation, the green-egg estimates for these lots were obtained by multiplying the historical average fecundity by the number of females represented. Once the numbers were estimated, the eggs were gently placed into Kitoi incubators set to flows of 6 gpm (U.S.) A chilled temperature regime was used to retard development to coincide with ice-out on the outplant lakes. When well eyed, the eggs were removed from the incubators, physically shocked (to turn unfertilized or dead eggs opaque) and sorted the following day. Live eggs were then seeded back into the incubators with a hatching substrate.

In late April, alevin samples were collected and shipped on ice to the ADF&G Pathology Laboratory in Juneau for pre-release disease screening. This fulfils the requirements of Canadian Fish Health approvals which state that all fry being returned to Canada must be tested for incidence of viral diseases; the return of fry undergoing an active outbreak of disease is not permitted. Incubator lots which tested positive for IHNV were chlorinated and burned. After pre-release screening the alevins were observed at intervals prior to ponding. Any incubators containing fish showing abnormal behaviour were tested in accordance with ADF&G protocol and destroyed if positive for IHNV. A further condition of the Canadian Fish Health approvals is that the hatchery be inspected and approved by a Canadian Local Fish Health Officer each year. An inspection was carried out in August, 1989; subsequent inspections have been waived in view of the satisfactory results of that visit.

To monitor the stage of development for determination of optimal ponding time, yolk sac ratios (weight of yolk remaining as a percentage of total body weight) were determined by removing small samples of alevins from each incubator. When yolk sac ratios reached 3-5%, fish were removed and placed in short-term rearing units. Each of these units has a capacity of approximately 500,000 fish, is individually plumbed for upwelling flows of 30 U.S. gpm, and is provided with supplementary oxygen. Each is also provided with a light to deter fish from sounding after gulping air to inflate the swim bladder. The ponded fry are held for short periods of time, the minimum being 24 hours, before transport to the outplant lakes.

### **2.3 Otolith Marking**

In 1989, the Transboundary Technical Committee agreed to mass mark all sockeye from transboundary river enhancement projects by manipulation of hatchery water temperatures during incubation to induce patterns of ring deposition on otoliths. A central laboratory for processing of otoliths is being developed by ADF&G in Juneau, Alaska. Responsibilities of this laboratory include refinement of techniques for marking and development of methods for mass processing of otoliths from returning adults.

## **2.4 Outplanting**

Fry transport flights were undertaken as soon as fry were ponded and weather and ice conditions on the outplant lakes permitted. In some cases, it was necessary to hold and feed fry for several days after emergence due to adverse conditions. An aluminum transport tank was loaded onto the floatplane, either a Dehavilland Otter or Twin-Beechcraft, at the Snettisham dock. This tank had a 180 gallon capacity ( U.S.) and was provided with an oxygen supplementation system, blower, recirculating pump, and agitator. All electronic equipment associated with the tank was powered by a 12 volt, 800 amp battery. Each short term rearing unit containing fish and water was picked up using a front end loader and moved to the head of a ramp leading to the dock. Fish were then gravity fed via a 4 inch pipe into the transport tank. Transport densities normally ranged between 0.75 and 0.80 lbs/gal (U.S.) with a maximum of 1.0 lbs/gal. Salt was added to the transport water (to 1 ppt) to reduce loss of blood electrolytes and reduce stress. " No Foam<sup>TM</sup> ", an anti-foaming agent, was also added.

During flight, oxygen levels were maintained as close as possible to 100 mg partial pressure oxygen (PO<sub>2</sub>) by manipulating oxygen flows. Total dissolved gas (TDG), carbon dioxide levels, temperature, PO<sub>2</sub>, and partial pressure nitrogen and argon(PN<sub>2</sub>Ar) were monitored closely, as was fish behaviour. Temperature was adjusted by the addition of ice if necessary. Maximum rate of climb and descent was 100 feet per minute to minimize tissue damage through gas bubble formation in the blood by allowing fish to adjust to changes in atmospheric pressure.

Upon arrival at the outplant lake the water temperature in the tank was acclimated to lake temperature at a rate of 1 ° C per 15 minutes, using a submersible DC operated pump. If the temperature differential was less than 4 ° C acclimation was not required. Once tank and lake temperatures were equal the fish were released directly into the lake through a short piece of 4 inch flexible pipe.

## **2.5 Monitoring of Outplants**

### **2.5.1 Hydroacoustic/Limnological Surveys**

Hydroacoustic and limnological surveys were conducted to evaluate the freshwater growth and survival of the outplanted fry. This work was contracted to Triton Environmental Consultants, Ltd. with subcontracting to B. Mercer and Associates Aquatic Biology. Surveys were conducted in early June (limnological only), mid-July (hydroacoustic/limnological), late August (limnological only), and late September to early October (hydroacoustic/limnological). All surveys included beach seining in the littoral (nearshore) zone to capture samples of wild and outplanted fry. Beachseining was done at ten fixed index sites at each lake; supplemental sets were sometimes made at non-index sites to increase sample size. Trawl sampling in the pelagic (offshore) zone was conducted in conjunction with the hydroacoustic surveys to obtain population estimates of wild and enhanced fish. Limnological observations included measurements of water clarity and temperature, levels of dissolved oxygen, total dissolved solids, total phosphorous, total nitrate and chlorophyll *a*, and collection of zooplankton and phytoplankton samples.

### **2.5.2 Smolt Sampling**

Smolt sampling was conducted at the outlet of each lake beginning the spring following the first outplant to the lake. At Tahltan Lake smolt migrations through a weir have been enumerated since 1984. From 1984-90, the entire smolt migration was trapped and smolt volume measured by water displacement; the number of smolts was estimated based on counted subsamples of specific volume. In 1991, a new procedure was introduced because of concerns about handling all smolts, and because smolt production was expected to increase following fry planting in 1990. Smolt migrations in 1991 and 1992 were therefore estimated by trapping all smolts, but measuring the volume of (i.e. handling) only approximately half the total catch. The remainder were estimated visually and the accuracy of this estimate checked periodically by making volumetric estimates as well. Smolt size and age composition was determined from daily subsamples, and weighted by daily smolt counts to obtain annual means. Since 1991, subsample size has been proportional to the daily smolt count to obtain a representative total sample of about 500 smolts which were also examined for presence of an otolith mark.

At Trapper and Tatsamenie lakes, samples were collected by fyke net a minimum of three times over the period of smolt migration to provide size, age and otolith mark information; smolt production for these lakes was based on the in-lake hydroacoustic estimates conducted the fall prior to migration.

### **2.6 Ancillary Enhancement Activities**

A number of sockeye enhancement related studies were conducted including fry transport studies, broodstock holding tests, and collection of more detailed limnological data from the outplant lakes or lakes scheduled for outplanting.

## **3.0 RESULTS**

### **3.1 Hatchery Operations**

A new module was added to the Snettisham temporary CIF during the summer of 1990. This provided the additional space needed to incubate sockeye eggs from the Taku enhancement projects, as well as the Stikine and U.S. Port Snettisham stocks. Modifications were made to expand and improve the chilling system. A vacuum degassing and oxygen injection system was installed to improve water quality. Plans to construct a new larger permanent CIF were cancelled because contractor bids exceeded the available funding. ADF&G therefore decided to remodel the existing main hatchery building into a permanent CIF. Under this plan, an incubation room formerly used for chum salmon would become the permanent CIF for all sockeye salmon stocks<sup>1</sup>. The temporary CIF would continue to be used for transboundary egg incubation in the interim.

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<sup>1</sup> Remodelling was completed in August, 1993.

A number of modifications were made to the water supply and the temporary CIF in 1991, following an occurrence of whitespot disease in two incubators containing 1990 brood- year (BY) Little Trapper Lake alevins<sup>2</sup>. These changes focused on eliminating or controlling the environmental and operational stressors felt to have contributed to the problem, including: unusually soft water; colder water in the Little Trapper Lake incubators; low dissolved oxygen; high levels of dissolved aluminum ions; overloading of the Little Trapper Lake incubators; and greater siltation in some incubators. Modifications included addition of a calcium chloride drip to increase water hardness, levelling of headboxes to reduce siltation, equalizing water temperatures, and installation of gate valves to permit back-flushing of incubators to remove flow-impeding entrapped air. These changes were apparently effective, as demonstrated by improved egg to fry survivals for the 1991 BY.

Experience has shown the green-egg estimates based on egg weight to be biased high for all stocks, as determined by comparison with actual counts obtained at the eyed stage. This is inherent in the technique used to obtain the estimates and in some cases has resulted in failure to achieve egg-take targets. As described earlier under Methods (2.1 Egg-takes) the eggs and basket are weighed as a unit and the variability and error of the estimates is attributable to varying amounts of water in the interstitial spaces between the eggs and the perforations in the aluminum baskets. Other methods of green-egg estimation have been considered and in 1993 the green egg estimates were made based on historical fecundities. This method is used by most sockeye salmon facilities in Alaska where good historical fecundity data is available.

### **3.2 Otolith Marking**

#### *Development of Laboratory and Marking Procedures*

For the 1989, 1990, and 1991 brood-years, temperature regimes were varied to apply unique marks to the fish destined for each lake within a river system for a given BY. Each mark consisted of a series of evenly spaced rings on the otolith. Marks were not unique between river systems for a given BY; i.e., the same marks were used in the Stikine and Taku river systems in the same BY, the rationale being that Taku and Stikine river stocks are not likely to be present in the same fisheries. This has been a subject of controversy and it was agreed that, if feasible, unique marks would be used for the outplants to each recipient lake in future years.<sup>3</sup> Unfortunately there was little baseline information available on producing quality thermal marks in sockeye salmon during the first several years of production at Snettisham hatchery. Consequently some of the early marking, in particular the Tatsamenie 1990 mark, are of poor

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<sup>2</sup> Details of this disease outbreak are presented in a later section of this report dealing specifically with the Trapper Lake project.

<sup>3</sup> This has been done. Starting with the 1992 BY distinct codes have been applied to each release group by varying the ring numbers and the spacing between rings.



quality and the ability to confidently recover these fish in mixed stock fisheries is uncertain.

Despite a shortage of Federal funding, ADF&G set up temporary lab facilities in 1992 and approximately \$60,000 of microscopes, grinding equipment, and imaging software was purchased. Approximately 16 months of staff time was funded and lab personnel began research to refine marking techniques and improve methods for processing otoliths and recognizing marks. Studies began using BY 1992 pink salmon and Tahltan Lake sockeye salmon to examine causes of "noise" in otolith marks and determine the minimum temperature changes and exposure times required to lay down marks. Otoliths were collected from 1,500 adult pink salmon returning from otolith marked fry released in 1991; lab personnel are using these otoliths to develop and refine methods for mass processing of adult otoliths.

New marking protocols have been developed by examining specimens from previous releases and from the 1992 BY studies mentioned above. Preliminary results of these studies indicate that using a 48 hour hot/48 hour cold temperature cycle to induce one thermal ring produces a more pronounced mark than those of shorter intervals. Repeating the cycle  $n$  times will produce  $n$  adjacent rings, which are separated by a constant distance. Adjacent rings define a band, and bands are separated by maintaining a period of constant temperature long enough to produce spacing on the otolith that is approximately three times the inter-ring distance. Accessory rings are separated from the primary marking area by a larger distance and may be used as an additional discriminator. Marking protocols are developed by varying the total number of thermal rings, grouping the rings into bands composed of different numbers of rings, varying the order of the bands, and including accessory rings.

Nine 1-ocean 'jack' sockeye were captured in 1992 as they returned to Sweetheart Lake near Port Snettisham. These fish resulted from outplants of otolith marked fry in 1990. The otoliths of seven of the nine fish were examined for thermal marks. In each of the seven fish the thermal rings were clearly evident. In 1993, four-year-old marked sockeye should be returning from outplants to Tahltan Lake and to several Snettisham area U.S. domestic stocks<sup>4</sup>. By 1996, 16 different groups of otolith marked sockeye salmon will be returning to the District 111 gillnet fishery and five groups returning to Districts 106 and 108.

For a summary of the thermal marks applied to transboundary river sockeye salmon refer to Appendix 1.

#### *Observations on Otolith Marks Recovered in Evaluation Surveys*

All processing of otoliths from fish in the samples collected in the evaluation surveys was done under contract by Eric Volk of the State of Washington Department of Fisheries. Mr. Volk did much of the initial research on thermal marking of otoliths and provided many of the comments

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<sup>4</sup> Returns of enhanced fish bearing thermal otolith marks from each of these stocks were documented in 1993 and will be summarized in a future report.

given here.

In general, there was no problem in distinguishing marked from unmarked fish in the fry and smolts recovered in the outplant evaluation studies. The processor was informed what marks to expect in each sample and all mark determinations were made based on comparisons with known voucher specimens provided by the hatchery. Where the number of rings deviated slightly from voucher specimens but their position and relative spacing on the otolith compared favourably with voucher specimens, the fish was considered marked. Where dense otolith rings reminiscent of thermally induced marks were present, but their numbers differed greatly from that expected, it was considered unmarked. In a few cases, specimens were encountered which had ring counts one lower than expected, although they were clearly applied marks based on the positioning of the other rings. These were classified as marked fish. In two instances, fry samples were processed which could not have contained marked fish, having been taken early in the year before outplants were made. This was done without the processors knowledge. In one case, 1990 BY Tatsamenie fry captured in early June, 1 out of 46 fry (2% of the sample) was classed as having the 3 ring 1990 BY mark. In the second case, 1991 BY Tatsamenie fry (4 ring mark) captured in June, 1992, none of the 45 fish examined were classed as marked. Thus, 'mimicking' of marks in wild fry did not appear to be a serious concern and it was felt to be far more likely that marked fish would be classified as unmarked rather than the reverse.

A more serious problem was distinguishing marks in samples containing marked fish from more than one brood-year. For example, there were several instances of errors in distinguishing the 3 ring 1990 BY Tahltan mark from the 4 ring 1991 BY mark. This was not surprising to the processor, since the otoliths from many of the Tahltan wild fish contained optically dense rings which could be mistaken for hatchery applied marks. Should one of these occur near the hatchery applied mark pattern it could result in brood-year misclassification. This points out the need to ensure mark patterns used must be very distinctly different when they will be present together in the samples collected. Separation by one ring definitely does not appear to be sufficient. Fortunately, in most cases where there were problems in distinguishing between brood-years, we were able to do so by scale ageing. In the few cases where scales were not available the final decision was based on fish size.

### **3.3 Problems Associated with Growth and Survival Estimates**

Several problems in monitoring the growth and survival of fry outplants have been encountered. Monitoring strategy was as follows: a) June surveys would be conducted at about the time of outplanting; these would not include hydroacoustics and trawl sampling to obtain population estimates but some information on the ages, sizes and relative abundance of wild and outplanted juveniles would be obtained from measurements and otolith readings of fry captured by beachseine; b) July surveys would provide age and size information and wild:outplanted juvenile ratio information based on trawl samples, which could then be applied to hydroacoustic estimates. Beachseining would hopefully indicate all juveniles had moved off-shore by this time, where they could be detected by the sounder; c) August surveys would be similar to the June surveys; they would not include hydroacoustics and trawling to obtain population estimates but beachseining

would be conducted to provide samples for analysis if juveniles were still present nearshore; d) fall surveys would provide the same information as the July survey, i.e., numbers of wild and outplanted fish as well as size and age information based on hydroacoustic estimates and trawl samples. Comparison of estimates of sizes and numbers obtained in the July and fall surveys would provide direct estimates of growth and survival for all types of juveniles. The fall values could also be used to estimate numbers of smolts of various types migrating the following spring. At Trapper and Tatsamenie lakes smolt size, age, and wild:outplant ratio information would be obtained by periodic sampling of the migration. Hydroacoustic surveys would be conducted at Tahltan Lake as well, however, the regular smolt enumeration (weir) program would provide final numerical estimates of both wild and outplanted smolts as well as age and size information.

Problems encountered include:

- 1) Fry remain onshore in considerable but undeterminable numbers in all lakes until July or August. This means the July hydroacoustic counts underestimate the total population by an unknown amount.
- 2) At Tahltan, there are indications that outplanted fry remain onshore longer than wild fry, thus biasing estimates of wild/outplant ratios obtained from beachseined samples.
- 3) It is often difficult to obtain adequate numbers of fish by trawling, especially at Tahltan where there appears to be a lot of net avoidance due to the very clear water. These samples are required to apportion the hydroacoustic estimates into wild and outplanted groups and age classes.
- 4) Although the sounder used (SIMRAD-EYM) is a rugged machine, climatic and working conditions are often extreme and there have been several equipment problems.
- 5) At Tahltan, hydroacoustic estimates in many years greatly underestimate the fall population, as evidenced by comparison with the smolt estimates at the weir the following spring.

Although trawl catches have improved considerably since modifications were made to the net, a large amount of effort is often still required and adequate samples are not always obtained. There are some obvious reasons for the inaccuracy of the hydroacoustic estimates at Tahltan Lake which do not apply to the other transboundary lakes surveyed and the accuracy of the estimates at these lakes is felt to be greater (see Discussion, 4.4.1 Hydroacoustic estimates). However, this can not be conclusively demonstrated since smolt enumeration weirs are not operated on these systems. The problems encountered in deriving estimates at the various lakes are described in the appropriate sections below.

### **3.4 Egg-takes, Incubation, Outplanting, Growth and Survival**

Levels of IHNV in the broodstock varied dramatically between brood-years for all lakes, for reasons not clearly understood. Levels of BKD varied much less, being relatively low in all cases. Details of broodstock disease testing for brood years 1990 and 1991 for all lakes are given in Appendix 2.

### **3.4.1 Tahltan Lake**

#### ***3.4.1 (a) Egg-take through outplant, Tahltan Lake***

Results for all BY's are summarized in Table 1. Project details for BY 1989 have been previously reported (PSC 1991), details for BY's 1990-1991 are given below. It should be noted that under terms of the existing Pacific Salmon Treaty, a portion of the fry resulting from Tahltan Lake egg-takes are to be planted to Tuya Lake if the BY escapement to Tahltan Lake exceeds 15,000; this occurred for the first time in 1991.

##### *1990 Brood-year*

The total number of fish utilized for broodstock was 1,615 females and 1,687 males, captured from an escapement of 14,927 fish. Eggs were shipped in ten lots during the period August 29 to September 18. All eggs were shipped the day they were taken except for two lots which had to be held overnight due to bad weather. The average fertilization rate was 82%, an improvement from the 69% experienced with the 1989 BY. This was likely a result of performing fertilizations on site and shipping only fertilized gametes in 1990. Although abnormally high lake temperatures apparently reduced fertilization rates early in the season, no major problems were encountered with the egg-takes and the target was nearly achieved.

The survival at the hatchery of 98% from fertilized egg to outplanted fry was a vast improvement from the 51% experienced with the 1989 brood. This probably resulted from correction of several environmental/mechanical problems, as was previously discussed. Green-egg to outplanted fry survival increased from 35% to 79% as a result of the increases in both fertilization rate and hatchery survival.

The otoliths of all 1990 BY Tahltan fry were marked with a 3 ring pattern (3 cycles of 48 h warm/ 48 h chilled) at the pre-hatch stage. Fry were planted during the period June 2-21, 1991.

##### *1991 Brood-year*

The total number of fish utilized for broodstock was 1,852 females and 1,852 males, captured from an escapement of 50,135 fish. Eggs were shipped in nine lots during the period September 2 to September 17. One shipment was delayed overnight and one lot of approximately 0.5 million eggs was planted in Tahltan Lake upon reaching a sensitive stage of development after weather conditions prevented flying. The fertilization rate of 95% was an improvement from the previous year and is probably attributable to lower lake temperatures in 1991. Broodstock was readily captured because of the high escapement; however, the egg-take target was not achieved because of initial underloading of the incubator boxes.

Since the Tahltan escapement exceeded 15,000 in 1991, the 1991 BY Tahltan eggs were divided into two groups and marked distinctively for planting to Tahltan and Tuya lakes. Survival at the hatchery was 95% from fertilized egg to outplanted fry for those fry planted in Tahltan.

The otoliths of all 1991 BY Tahltan stock planted in Tahltan Lake were marked with a 4 ring pattern (4 cycles of 48 h warm/ 48 h cold) at the pre-hatch stage. Fry were planted during the period June 9-10, 1992.

#### *Additional comments, egg-take through outplant*

Records of holding mortalities have not been kept for the Tahltan Lake operation, but mortalities are typically low because fish are not held for lengthy periods. A procedure of performing egg-takes and broodstock collection on alternate days has been developed. This technique works quite well as it allows adequate time for sufficient ripe fish for the next egg-take to move onto the spawning grounds where they can be readily captured, as well as allowing the penned fish to be held for a longer time period if weather problems are encountered. In order to efficiently load the incubators and for the disease prevention considerations discussed above, it is desirable that daily egg-takes be comprised of multiples of approximately 300,000 eggs, the capacity of one Kitoi box. This loading density is higher than that used for other stocks ( $\approx 250,000/\text{box}$ ) but is felt to be safe since Tahltan Lake sockeye eggs are considerably smaller than those of other sockeye stocks.

#### **3.4.1 (b) Growth and Survival, Tahltan Lake**

Survival of outplanted fry to various life stages is summarized in Table 2. Detailed observations of growth and survival for each brood-year follow.

##### *Juvenile observations*

Details of numbers of juveniles captured and samples taken by beach seine (onshore) and trawl (offshore) in evaluation surveys during the summer and fall of 1991 are presented in Table 3 and Figure 3. Juveniles were caught by beachseine on the first three trips but abundance decreased rapidly. This is indicated by the declining total catches for the index sites as fish apparently moved offshore. By the time of the fourth trip in mid-September none were captured by beachseine. No fish were captured by trawl on the second trip, the first of two trips on which trawling was done. However, a considerable number were captured by trawl on the fourth trip. For age 0+ juveniles (i.e., BY 90, planted in 1991), the proportion of enhanced fish in beachseine catches increased continually to over 50% as shown in Figure 3. This could be partly or entirely due to earlier movement offshore by the wild fry rather than differences in survival between enhanced and wild fry. In the final sample for the season, the September trawl catch, the proportion of enhanced fry was 48%. This sample was probably fairly representative of the whole population, since all fry had by now apparently moved offshore. Only 4 age 1+ juveniles (BY 89) were recovered, all of enhanced origin.

The mean lengths (preserved) for the 0+ juveniles are also shown on Figure 3. Differences between wild and enhanced juveniles are not great, with enhanced fish starting marginally smaller but equivalent in size to the wild fish by the time of the final trip in September.

Population estimates for the fall of 1990 and for the summer and fall of 1991 are presented below. The September, 1991 estimates were obtained using the total juvenile population estimate from hydroacoustics apportioned to enhanced or wild and age class based on the trawl catches. There were no trawl catches for the October, 1990 or the July, 1991 surveys to use in apportioning the total estimate. Estimates with 95% confidence limits were as follows:

	Oct. 1, 1990	July 11, 1991	Sept. 10, 1991
Category	272,330 <u>+/- 77,016</u>	848,656 <u>+/- 167,999</u>	995,918 <u>+/- 182,411</u>
age 0+, enhanced	n/a	n/a	479,286
age 0+, wild	n/a	n/a	510,408
age 1+, enhanced	n/a	n/a	6,224
age 1+, wild	n/a	n/a	0

The estimated survival for the 1990 BY enhanced fry from time of outplanting in June, 1991 to the Sept 10, 1991 survey would be  $479,286/3,585,000 = 13.4\%$  ( range 10.9% to 15.8%, using the lower and upper hydroacoustic estimates).

Comparison of these estimates with smolt counts from the Tahltan weir show the hydroacoustic estimates are unrealistically low. For BY 1989, the total fall 1990 hydroacoustic estimate of 272,330 juvenile sockeye (all ages, wild plus enhanced) represents only 18% of a total estimated smolt migration the following spring of 1,487 K. Results were better for the BY 90 fry, but the hydroacoustic estimates were still low; the fall 1991 total juvenile estimate of 995,918 represented only 64% of a total estimated 1992 smolt migration of 1,555 K. Considering age 0+ fish only (wild plus enhanced), the fall 1991 estimate of 989,694 fry represents 68% of the estimate of 1,454,092 age 1 smolts in 1992.

### *Smolt observations*

Survival from planted fry to age 1 and age 2 smolts is shown in Table 2. Note that these values represent smolt production rather than total survival to a given point since they do not include 'holdover juveniles' which remain in freshwater and migrate one or more years later if they survive to that point. Survival of enhanced fish from outplanted fry to age 1 smolt was very similar for the BY's 89 and 90, averaging 23.6%. Survival of wild fish for this period could not be calculated since the number of wild fry at the time of outplanting cannot be determined. Absolute survival from fall fry to smolt cannot be determined because of problems with the fall hydroacoustic estimates described above.

Detailed observations of the Tahltan smolt migrations in 1991 and 1992 are presented in Table 4. The first enhanced smolts (BY 89) migrated in 1991 and comprised 18.0% of the record total run. The 1992 migration was another record run, with enhanced age 1 (BY 90) and age 2 (BY 91) smolts comprising 50% and 2% of the total smolt migration, respectively.

Enhanced fry grew well (Table 4). Enhanced age 1 BY 1989 enhanced smolts were only slightly smaller in size than wild smolts, despite the fact they were considerably smaller as fry (PSC 1991). Age 1 BY 1990 smolts were almost identical in size to wild smolts, as were the fry of the two types in the fall of 1991.

Mean smolt size has not decreased significantly in recent years despite increased smolt migrations, indicating that food supply has not been an important limiting factor in Tahltan Lake (Table 5). Sockeye smolt size depends on growth rate during lake residence, which is influenced by the availability of food, and in turn, by lake fertility and by the density of planktivores in the lake (Goodlad et al. 1974; Koenings and Burkett 1987). Other limnetic, planktivorous fish are scarce in Tahltan Lake, so that sockeye fry density is the most important factor determining cropping pressure on large-bodied zooplankton. To determine whether sockeye growth is limited by competition among sockeye fry, we plotted mean smolt size against best estimates of total spring fry abundance in the lake (age 0+ and 1+ fry, both wild + planted) for brood years 1982-1990 using the data in Table 5. No significant density-dependence is evident at current fry recruitment levels (Figure 4). The record high recruitment of wild and planted fry in 1991 produced a record number of age 1+ smolts of about average size. This analysis confirms earlier conclusions that food supply has not limited wild smolt production.

#### *Mortality model for Tahltan Lake fry outplants*

Mortality rates for fry planted into Tahltan Lake were calculated using all available fry and smolt data for planted fry from brood years 1989 and 1990. Estimated survival rates are 30% and 69% for the first and second years of lake residence (from time of outplant), respectively, with a holdover rate of age 1 juveniles of 15%. Details of calculations are given in Appendix 3. The survival curves developed are shown in Figure 5.

### **3.4.2 Tuya Lake**

#### ***3.4.2 (a) Egg-take through outplant, Tuya Lake***

Results for all BY's are summarized in Table 6. Details are given below. The Pacific Salmon Treaty requires that a portion of the fry resulting from Tahltan Lake egg-takes be planted to Tuya Lake if the BY escapement to Tahltan Lake exceeds 15,000. This occurred for the first time in 1991.

#### *1991 Brood-year*

Since the Tahltan escapement exceeded 15,000 in 1991, the 1991 BY Tahltan eggs were divided into two groups and marked distinctively for planting to Tahltan and Tuya lakes. All details and survivals to the fertilized egg stage are the same as described for 1991 BY Tahltan (section 3.4.1 (a), above). One group of 880,000 fry destined for Tuya Lake began dying rapidly while being held temporarily in tanks just prior to shipment. After nine days total mortality was approximately 70%. IHNV was suspected and, in conformance with standard Alaskan sockeye culture protocol,

the remainder were destroyed. IHNV was not detected in subsequent pathology tests and the specific cause of mortality remains unknown. Water quality problems, high fry densities, the withholding of food (as a precautionary measure to reduce stress during transport), and the length of time fish were held in the tanks while waiting for the ice to clear from Tuya may have all contributed. To help prevent recurrence of such problems it was decided to use lower fry densities in the holding tanks in the future and, if possible, confirm that Tuya Lake is ice-free before ponding fry.

All fry planted in Tuya Lake were marked with a 6 ring pattern (6 cycles of 48 h warm / 48 h chilled) at the pre-hatch stage. Fry were planted during the period June 17-21, 1992.

### **3.4.3 Trapper Lake**

#### ***3.4.3 (a) Egg-take through outplant, Trapper Lake***

The first egg-take was conducted in 1990. Results are summarized in Table 7 and details are given below.

##### *1990 Brood-year*

Broodstock is captured in Little Trapper Lake which has a wild sockeye escapement averaging about 12,000. Little Trapper Lake is located downstream of Trapper Lake and is connected to the upper lake by a 3 km stream believed to be impassable to salmon; however, some wild sockeye, perhaps kokanee, are present in Trapper Lake. The total number of fish captured for broodstock in 1990 was 840 females and 826 males, captured from an escapement of 9,443 fish. Of these, 761 females and 761 males were spawned, while the remainder (79 females, 65 males) died during holding. Eggs were shipped in nine lots during the period August 29 to September 22. Two shipments were delayed overnight due to bad weather. Initially, broodstock was trapped at a diversion weir across the mouth of the inlet stream as fish moved from holding areas in Little Trapper to spawn in the stream. This was only marginally successful, since fish were reluctant to move through the trap and were observed spawning in sub-optimal areas below the weir. The diversion fence was subsequently abandoned, and the remaining 90% of the BY 1990 broodstock (and all broodstock in subsequent years) was captured using a beach seine off the mouth of the inlet stream. All fertilizations were done on site at Trapper Lake (this practice has been continued in subsequent years) and a fertilization rate of 87% was achieved.

Survival at the hatchery was only 47% from fertilized egg to outplanted fry. This was due to the destruction of approximately 1 M fry after high mortalities suggested an IHNV outbreak. Subsequent testing did not detect IHNV, and mortalities were attributed to whitespot, a non-infectious disease. As discussed previously, steps were taken the following year to correct the environmental conditions thought to have contributed to the outbreak and there was no recurrence of the disease in the 1991 fry. Green-egg to outplanted fry survival was only 41% as a result of the disease problem.



The otoliths of all BY 1990 Little Trapper stock were marked with a 5 ring pattern (5 cycles of 48 h warm/48 h chilled) at the pre-hatch stage. Fry were planted during the period June 5-22, 1991.

#### *1991 Brood-year*

The total number of fish taken for broodstock was 981 females and 968 males, captured from an escapement of 22,942 fish. Of these, 954 females and 954 males were spawned and 23 females and 10 males died during holding. The egg-take target was easily achieved because of the record high escapement. Eggs were shipped in nine lots during the period August 29 to September 17.

Survival at the hatchery from fertilized egg to outplanted fry was 73%. This was much improved from 1990, but still less than desirable as a result of the destruction of 589,000 fry after IHNV was detected during the pre-release screening. To reduce the possibility of future occurrences of IHNV it was agreed that attempts would be made to take eggs in multiples of 250,000, the capacity of a single Kitoi box. This would help reduce the chances of mixing IHNV positive eggs with groups negative for IHNV. Green-egg to outplanted survival was 61%.

The otoliths of all BY 1991 Little Trapper stock were marked with a 6 ring pattern (6 cycles of 48 h warm / 48 h chilled) at the pre-hatch stage. Fry were planted during the period June 4-11, 1992.

#### *Additional comments, egg-take through outplant*

Attempts are made to perform-egg takes on alternate days and to sort fish on the days between egg-takes. This approach has been taken so that an optimum number of ripe fish is available for each egg-take. The desirable loading density for Little Trapper eggs is 250,000 / Kitoi box; however, some have had to be loaded at slightly higher densities to achieve the desired egg-take levels. The desired egg shipments are multiples of 250,000 to facilitate efficient use of the boxes. Conducting egg-takes on alternate days allows the Kitoi boxes to be loaded and closed within 2 to 3 days.

### **3.4.3 (b) Survival and Growth, Trapper Lake**

#### *Juvenile observations*

Details of numbers of juveniles captured and samples taken by beachseine and trawl in evaluation surveys during the summer of 1991 are presented in Table 8 and Figure 6.

Juveniles were caught by beachseine on all trips. The total beachseine catch for the first trip was low compared to the second; however, only 45% of the fry had been outplanted at the time of the first trip. The catch declined rapidly after the second trip and only two were caught on the last trip, suggesting most fry had moved offshore. Only 17 fish were captured by trawl on the second trip, the first of two trips on which trawling was done. A total of 30 were captured by

trawl on the fourth trip. The proportion of enhanced fish (all BY 90 age 0+ fry since this was the first year of outplanting) was very high in all beachseine samples, approximately 97%. However, this was not true for the trawl catches, where the proportions of enhanced fish among the 0+ fry were 41% and 50% for the second and fourth trips, respectively. These results indicate the enhanced fry were slow to move offshore and mix with wild fry, which never appeared onshore in large numbers.

The mean lengths (preserved) for the beachseine caught 0+ fry suggest the enhanced fry were smaller than wild fry; however, the very small sample sizes for wild fry make it impossible to say this with any certainty (Table 8, Figure 6). The same appears true for trip 2 trawl caught age 0+ fry, however, fry of both types are nearly equal in size in the September trawls, indicating they were catching up in size. There were only two age 1+ juveniles in the samples, both wild fish caught in the September trawls (mean length 75.5 mm).

The July 16, 1991 hydroacoustic estimate for the total juvenile population was 377,111 +/- 163,553. This is probably an underestimate, due to problems with false bottom tracings obscuring targets on the chart in a few deep areas of the lake. Also, there were large numbers of fry onshore. Applying the trawl catch ratios indicates there were 155,281 enhanced 0+ fry and 221,830 wild 0+ fry. It should be noted that this is very tenuous, being based on a sample of only 17 fish.

In the September 16 hydroacoustics, there were two quite distinct types of targets on the charts, darker ones (indicating larger targets) at depths down to about 20 m, and much more numerous fainter ones (indicating much smaller targets) beginning at about 20 m but concentrated mainly at depths of 30 to 60 m (the maximum depth sounded). Unfortunately, the deepest trawl depth used was only 16 m, insufficient to provide a relatively pure sample from the areas of greatest concentrations of these faint targets. The total population estimates obtained including or omitting the faint targets were 496,477 +/- 104,843 and 139,023 +/- 85,650, respectively. It was initially suspected that these faint targets might have been some other type of organism detectable to the sounder, such as Mysids or Chaoborous (an insect larvae). However, extensive plankton sampling since 1987, trawling, and beachseining have never detected any organisms which might produce a signal on the sounder other than juvenile sockeye. In the opinion of hydroacoustic experts the sounder was functioning properly and the targets were typical of small fish at considerable depth. All targets were therefore included in the population estimates. Application of the ratios observed in the September trawl catches gave the following estimates:

Enhanced 0+ fry:	231,689
wild 0+ fry:	231,689
wild 1+ juveniles:	33,098

This implies an apparent survival rate of  $231,689 / 934,000 = 25\%$  for enhanced fry from time of outplanting to the fall survey.

Little Trapper Lake is located 3 km downstream of Trapper Lake and contains a wild sockeye

population. On July 10, 1991, a sample of fry was collected from the littoral zone in Little Trapper Lake and 100 of these fish examined for an otolith mark. Twelve bore the otolith mark applied to the fry planted in Trapper Lake approximately one month previous, indicating some amount of early outmigration.<sup>5</sup>

### *Smolt observations*

Despite quite extensive sampling (19 nights in the period May 18 to July 13, maximum interval missed was 7 days from June 7 -14) no smolts, enhanced or wild, were captured leaving Trapper Lake in the spring of 1992. However, a sample of 450 smolts was easily captured at the outlet of Little Trapper Lake. Details of this sampling are presented in Table 9. No attempt was made to estimate the actual numbers migrating and it was the consensus of the Transboundary Technical Committee that to do so using the fall hydroacoustic estimates from the upper (Trapper) lake and/or extrapolations involving assumed wild and enhanced survivals and 'holdover' rates, etc. would be too speculative to report here. As mentioned above, enhanced fry were found in Little Trapper in 1991. Examination of a subsample of 253 of the smolts captured leaving Little Trapper indicated 18 (7.1%) were of enhanced origin, a proportion similar to the 12% observed in the fry sample collected in Little Trapper Lake the previous summer. It is unlikely smolts leaving Trapper Lake in any significant numbers would have been missed entirely.<sup>6</sup> The fall 1991 hydroacoustic surveys discussed above indicate enhanced fish were still present in substantial numbers in Trapper Lake at that time and it is unlikely they would have suffered great mortality over the winter. A plausible explanation is that most of the enhanced smolts captured leaving Little Trapper derived from early outmigrating fry which had reared in Little Trapper and that fish which remained in Trapper may migrate at a later age.

Wild and enhanced age 1 smolts were of very similar size, about 2.9 g and 70 mm (Table 9). While very much smaller than Tahltan smolts, this size is not unusual for Little Trapper Lake, age 1 smolts sampled in 1988 measuring only 2.2g and 64.7 mm.

### **3.4.4 Tatsamenie Lake**

#### ***3.4.4 (a) Egg-take through outplant, Tatsamenie Lake***

The first egg-take was conducted in 1990. Results are summarized in Table 10 and details are given below.

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<sup>5</sup> This was observed to occur in 1992 as well, details will be presented in a later report.

<sup>6</sup> Even more extensive sampling was conducted in 1993; only one smolt was captured and this has not yet been examined for an otolith mark.

### *1990 Brood-year*

Broodstock for outplants to Tatsamenie Lake was captured in Little Tatsamenie Lake, located downstream of Tatsamenie Lake. The connecting stream is passable to fish and spawning occurs in both Tatsamenie Lake and the connecting stream. The proportion spawning in each location is uncertain. The total number of fish used for broodstock in 1990 from an escapement of 5,736 fish was 462 females and 345 males. Of these, 280 females and 280 males were spawned and 182 females and 65 males died during holding. Eggs were shipped in six lots during the period September 11 to September 30. Overall fertilization rate was 78%. All fertilizations were done on site at Tatsamenie Lake in this and all subsequent years.

The egg-take target was not achieved as a result of two serious problems, the latter being the primary reason: 1) the escapement to Little Tatsamenie was protracted and much lower than predicted, making it difficult to capture the required broodstock, and, 2) fish entering Little Tatsamenie Lake are quite green (i.e., not yet sexually mature) and must be held for several weeks to ripen. Holding sockeye salmon away from their spawning grounds often causes problems with ripening. Female mortalities were high during this holding period (34%) and methods for reducing them were considered; these methods included attempting to separate lake and stream spawners to look for holding mortality differences; trying various penning arrangements to see if mixing sexes, holding them separately, or having one sex upstream of the other would affect mortality; giving prophylactic injections of antibiotic at capture; and, injecting with gonadotrophin to accelerate maturation and reduce holding time. Some of these techniques were tested in subsequent years, as discussed below under ancillary activities.

Survival at the hatchery was good, 89% from fertilized egg to outplanted fry.

The otoliths of all 1991 brood Little Tatsamenie stock were marked with a 3 ring pattern (3 cycles of 48 h warm/ 48 h chilled) at the pre-hatch stage. Fry were all planted on June 22, 1991.

### *1991 Brood-year*

The total number of fish captured for broodstock was 415 females and 409 males, captured from an escapement of 8,381 to the Little Tatsamenie weir. Of these, 371 females and 371 males were spawned. A total of 44 females and 38 males died during holding. This was much improved over 1990, probably as result of various treatments tested, as discussed below under ancillary activities. The eggs were shipped in 7 lots during the period September 12 to October 4. One lot of eggs was held overnight at the lake because of poor weather and the eggs from another lot of 14 pairs were discarded as a result of communication problems during a weather-caused stopover while enroute to the hatchery. The egg-take target was achieved and average fertilization rate was high (93%).

Survival at the hatchery was excellent, 98% from fertilized egg to planted fry. This was a significant increase from 1990 brood results and was probably due to improved hatchery water quality.

The otoliths of all BY 91 Little Tatsamenie stock were marked with a 4 ring pattern (4 cycles of 48 h warm / 48 h chilled) at the pre-hatch stage. Fry were planted during the period June 22-26, 1992.

#### *Additional Comments, Egg-take through Outplant*

It may be desirable to use Tatsamenie Lake rather than Little Tatsamenie Lake as the source of broodstock for outplants to Tatsamenie Lake, for both logistical and genetic reasons (see Discussion section of this report). Relocation would require construction of a diversion weir for broodstock collection at the outlet of Tatsamenie Lake as well as broodstock holding facilities within the lake. A potential holding site has been located approximately 1.2 km from the lake outlet. Because of the distance involved, broodstock would have to be transported from the weir to the net pens, probably in oxygenated tanks.<sup>7</sup>

#### **3.4.4 (b) Survival and Growth, Tatsamenie Lake**

##### *Juvenile observations*

Details of numbers of juveniles captured and samples taken by beachseine and trawl in evaluation surveys during the summer of 1991 are presented in Table 11 and Figure 7.

Juveniles were caught by beachseine on the first three trips only. They were most abundant by far on the first trip, at which time only wild fish were present since outplanting had not yet begun. Only 3 fish were captured by trawl on the second trip, the first of two trips on which trawling was done; however 53 were captured by trawl on the fourth trip. All juveniles captured by trawl or beachseine were age 0+, the only possible age for enhanced fish since this was the first outplant. The proportion of enhanced fish in the beachseine samples ranged from 0 (first trip, before enhanced fry were present) to 15%. In the trawl catches, the proportions of enhanced were 0% and 5.7% for the second and fourth trips, respectively.

The mean length (preserved) for the beachseine caught age 0+ enhanced fry was initially less than that of wild fry but they rapidly caught up in size (Figure 7). The trawl caught age 0+ fry of both types from the fourth trip were very similar in size.

The July 14, 1991 hydroacoustic estimate for the total juvenile population was 1,429,846 +/- 536,617. There were still significant numbers of fry onshore at this time which would not be included in the estimate. Although the index site beachseining catches (Table 11) indicate the onshore fry were only about 1/8 as abundant as in June, catches increased again to about 1/3 the June value in August, indicating the July onshore abundance estimate may have been low for

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<sup>7</sup> A small scale trial egg-take operation was conducted at Tatsamenie Lake in 1993, details will be presented in later reports.

some reason.

As with the fall hydroacoustics at Trapper Lake, the September 14, 1991 Tatsamenie survey gave two quite distinct types of targets on the charts, dark and faint, with the fainter targets again being far more abundant at greater depths. Total juvenile population estimates including or excluding the faint targets were 3,560,954 +/- 701,907 and 821,688 +/- 289,562, respectively. It was similarly concluded that these faint targets represented smaller fish and should be included in the estimates. The larger number appears reasonable given good egg to fry survival of wild fish and a fairly large proportion of the total Tatsamenie system escapement spawning in Tatsamenie Lake ( $\approx 70\%$ ). Applying the trawl catch data, the population estimate was broken down as follows:

Enhanced 0+ fry:	201,563
wild 0+ fry:	3,359,390

This implies a survival rate of  $201,563 / 985,000 = 20.5\%$  for enhanced fry from time of outplanting to the fall survey.

### *Smolt observations*

A sample of 450 smolts was collected at the outlet of Tatsamenie Lake in the spring of 1992 and a subsample of 246 examined for otolith marks (Table 12). The otoliths indicated 14 (5.7% of the total, 8.7% of the age 1 fish) were of enhanced origin. Age 1 smolts of both types were of a substantial and equivalent size, approximately 81 mm and 4.9 g. No attempt was made to estimate the actual numbers of migrating smolts and it was the consensus of the Transboundary Technical Committee that to do so using the fall hydroacoustic estimates from Tatsamenie and assumed overwinter survival, 'holdover rates', etc. would be too speculative to report here.

## **3.5 Limnological Observations**

The results presented here summarize data collected as early as 1985 at Tahltan Lake and from regular monitoring of most other lakes beginning in 1987.

### **3.5.1 Zooplankton<sup>8</sup>**

#### ***3.5.1 (a) Tahltan Lake***

Because sockeye fry typically feed on large bosminid and daphnid cladocerans ( e.g. Goodlad et al. 1974), changes in zooplankton size and species composition in response to increased sockeye fry recruitment can be used to identify limits to potential sockeye smolt production in nursery

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<sup>8</sup> The analyses presented here are for zooplankton of all sizes, including rotifers and nauplii larvae.

lakes (Johannes et al., 1993) and can permit qualitative assessment of the impact of sockeye fry on the zooplankton forage base (Brooks and Dodson 1965; Galbraith 1967; O'Neill and Hyatt 1987). Early variations in Tahltan Lake zooplankton abundance, mean length and biomass were probably caused by lake enrichment from 1985-1987 (Figure 8). Zooplankton abundance and mean length has changed little despite a three-fold increase in sockeye fry density from 1989-1991, although zooplankton biomass has declined slightly. Moreover, high (30-90%) proportions of cladocerans persist in the zooplankton forage base despite the increased fry recruitment (Figure 9). The only indication of increased cropping pressure by sockeye fry is a seasonal decline in the proportion of daphnids in zooplankton samples from August to September in 1990 and 1991.

### **3.5.1 (b) Tuya Lake**

Tuya Lake (Figures 10 and 11) has a rich zooplankton community dominated by large predaceous zooplankton (e.g. diaptomid and calanoid copepods). This supports the theory that the lake is almost devoid of naturally occurring planktivorous fish and capable of supporting very large numbers of outplanted fry.

### **3.5.1 (c) Trapper and Little Trapper lakes**

Trapper Lake (Figures 12 and 13) is dominated by cyclopoids, nauplii and rotifers which make up the bulk of total zooplankton numbers. Zooplankton mean lengths and total biomass are strongly influenced by the large cyclopoid population. Biomass is low relative to most other lakes being studied. The zooplankton community in this lake appears heavily impacted by a combination of in-lake productivity limitations (e.g. glacial inputs) and moderate to high planktivory.

Little Trapper Lake (Figures 14 and 15) also has a low standing crop of zooplankton. Mean lengths and total abundance indicate that the zooplankton community is comprised of small zooplankton species with high abundance, principally bosminids and smaller cyclopoids. The zooplankton community appears primarily limited by in-lake productivity. Due to continual heavy predation, the community has assumed a highly predator resistant state, making it difficult to detect effects of unusually heavy predation, which may occur if substantial numbers of outplanted fry migrate prematurely from Trapper Lake.

### **3.5.1 (d) Tatsamenie Lake**

Tatsamenie Lake (Figures 16 and 17) has a high standing crop of zooplankton (200-500  $\mu\text{g/L}$ ), with large mean lengths (0.3-0.5mm) and moderate to high total abundance. The zooplankton community is comprised of a high biomass of cladocerans (daphnids and bosminids). This lake appears capable of supporting larger levels of sockeye planktivory.

## **3.5.2 Water Chemistry and Physical Properties**

The outplant recipient lakes can be categorized into two distinct types based on examination of

available physical, chemical, and biological data. Main features of each type are discussed in this section.

### **3.5.2 (a) Tahltan and Tuya lakes**

Tahltan and Tuya lakes, both located in the Stikine River drainage, are relatively warm, clear-water lakes, with sechii depths of up to 15.5 m (Tahltan) and 6.5 m (Tuya) and surface water temperatures reaching 15.5 (Tahltan) and 13.8 (Tuya) degrees centigrade in late summer. The most unusual features shared by the two lakes are an almost total depletion of nitrate-nitrogen from June through September and extremely high phosphorous levels (5-13 ug/L) for the levels of chlorophyll in the lakes (maximum 2-3 ug/L). Together, they suggest that nitrogen, rather than phosphorous, may be the limiting factor for plankton production in these lakes. Under-ice phytoplankton production before breakup, suggested by the low nitrate levels in spring, and the influence of relatively large and productive littoral zones in these clear, shallow lakes probably contribute to the high nitrogen demand and its rapid depletion.

One conclusion from the data is that phosphorous-based models of lake productivity, developed mainly for coastal lakes where phosphorous is usually the limiting factor, could not be reliably applied to estimating the forage base and productivity of sockeye stocks in these interior lakes.

### **3.5.2 (b) Trapper and Tatsamenie lakes**

Both of these Taku River drainage lakes exhibit the low phytoplankton productivity and many of the physicochemical characteristics typical of lakes receiving seasonal inflows of cold, glacially turbid water. Surface water temperatures were low, reaching maximums of only 11.0 (Trapper) and 13.0 (Tatsamenie) degrees centigrade in early fall. While Tatsamenie Lake does not have the extreme turbidity seen in Trapper Lake, Sechii depths in both lakes showed seasonal declines in water transparency reaching lows of 0.6 (Trapper) and 1.1 (Tatsamenie) meters coinciding with summer inflows of turbid glacial meltwaters. Total phosphorous levels also tracked the levels of suspended silt in the lake waters, reaching August highs of 10-20 ug/L. The majority of the total phosphorous is suspended mineral phosphorous extracted from the glacial silt during digestion of the samples but not generally available as nutrient to the phytoplankton. Thus, despite high levels of phosphorous in the lakes, chlorophyll levels are typically low, reaching highest levels of 1-2 ug/L in early fall. Phytoplankton productivity in cold, glacially-turbid lakes is often limited by the thermal stability and light penetration of their surface waters. Nutrients only become limiting when weather and water conditions allow formation of thermally stable surface layers and prolonged phytoplankton growth, generally in the fall when glacial runoff has declined.

## **3.6 Ancillary Activities**

### **3.6.1 Tahltan Lake**

In the fall of 1990, two small experimental upwelling incubation boxes were installed in Tahltan Lake at the outlet weir. On September 13, approximately 8,000 fertilized Tahltan Lake sockeye



eggs were placed in each box. On October 13 it was observed that build up of silt and gravel, probably a result of spawning activity in the area, was restricting flow to the boxes. All the eggs in one box had died. The eggs from the other box were shocked and picked, placed back in the box, and flow re-established. Approximately 3,600 fry were released from the box on May 25, 1991.

A tagging study was conducted in 1990 (unpublished data, DFO, Whitehorse) to begin to address the concerns over possible genetic selection of broodstock (see Discussion). In this study, adult sockeye were tagged with individually numbered tags at the Tahltan Lake weir to identify time of entry. Preliminary examination of tag recoveries in the broodstock used suggests the major temporal components of the broodstock corresponded reasonably well with those of fish as they entered the lake. A similar but more extensive tagging study was conducted in 1993 to examine the extent of representation of the different temporal and spatial segments of the run in the egg-take broodstock more closely. Tags were recovered from broodstock throughout the spawning period; results of this study will be included in a future report.

### **3.6.2 Tuya Lake**

In 1991, a contract was issued by the Canadian Salmon Enhancement Program to B. Mercer and Associates to investigate the possibility of exchange of water between the Pacific and Arctic watersheds in the headwaters of streams flowing into Tuya Lake and the Liard River, respectively. Such exchanges of water would have implications regarding introduction of sockeye salmon into Tuya Lake since there would be the potential for spreading disease and parasites to the Arctic watershed. The survey results indicated some limited opportunity for water exchange, however, the exchange would be from Arctic to Pacific (Mercer and Associates 1991). In the opinion of Canadian Department of Fisheries fish health officers, the risks associated with the outplants would be extremely low and did not warrant cancellation of the outplants.

A test was conducted at Tuya Lake in 1992 because of concerns about the possibility of gas bubble formation in the blood of the fry as a result of the high altitude attained during transport. The test involved holding 350 transported fry in a small net pen for 96 hours after arrival at the lake. Since only four fry died it appears this is not a concern provided proper transport techniques are used.

### **3.6.3 Tatsamenie Lake**

A number of tests were conducted on broodstock in 1991 and 1992 to determine if different holding strategies would result in a lower female pre-spawning holding mortality. Broodstock collection at Little Tatsamenie Lake has always involved transporting the selected fish from the weir to a number of holding pens located in the Tatsatua River approximately 100m upstream of the weir in a relatively deep section with a slow surface flow of approximately 5m/minute. In 1991, overall female mortality was reduced to 8.5%. In tests of antibiotics, the pre-spawn mortality for a test group injected with the antibiotic oxytetracycline was 1% whereas the pre-spawn mortality for a control group was 5%. The lower mortality rate was not statistically

attributable to the use of the antibiotic. Other factors which may have contributed to the decrease in holding mortality from 1990 to 1991 include: sedation with the anaesthetic Marinil (metomidate hydrochloride) to reduce stress during transport, reducing holding densities from 14.7 fish/sq. meter to 8 fish/sq. meter, lower water temperatures (a range of 8.5° C to 10° C in 1991 compared to 7° C to 13° C in 1990), improved holding facilities, and a greater number of fish available from which to select broodstock.

The experimental design for the 1992 trials involved a group of females sockeye injected with oxytetracycline and sedated with Marinil and a group (combined sexes) injected with oxytetracycline and sedated with MS-222 (Tricaine Methanesulfonate). Control groups of combined sexes were anaesthetized with either Marinil or MS 222 only, but not injected with the antibiotic. The female pre-spawn mortality rate for the group injected with oxytetracycline and sedated with Marinil was lowest (3.8%). Mortality rates for the other groups ranged from 7.5% to 9.8%. The results of the 1992 trials suggest the use of oxytetracycline and an anaesthetic reduced holding mortality. However, a lower percentage of the injected fish ripened, resulting in a net loss in egg production.

## **4.0 DISCUSSION**

### **4.1 Hatchery Operations**

The modifications to the temporary CIF in the summer of 1991 were judged effective in reducing the mortality of sockeye salmon eggs and fry from the green-egg to fry stage. These modifications were made to improve water quality during incubation, and included: 1) a vacuum degassing system to reduce supersaturation problems; 2) an oxygen injection system to raise oxygen levels; and, 3) the addition of a CaCl<sub>2</sub> drip to increase water hardness.

Hatchery assumptions for egg to fry survivals are 80%. This assumption was met for BY 1990 and 1991 Tahltan eggs destined for Tahltan Lake. The assumption was also met for BY 1990 and 1991 eggs from Little Tatsamenie. Poor hatchery survival for the 1991 brood Tahltan eggs destined for Tuya Lake were attributed to IHNV. Eggs from Little Trapper Lake continue to have poor egg to fry survivals due to IHNV. The problem of white spot disease in this stock seems to have been addressed with improvements in hatchery water quality.

Outbreaks of IHNV at the Snettisham Hatchery have thus far not been obviously related to the incidence of the virus in the parental broodstock, which has fluctuated dramatically at each of the three lakes. Outbreaks of IHNV occurred in alevins from Little Trapper Lake BY 1990 and 1991, but incidence of the virus in the broodstock varied from 96% for BY 1990 to 13% for BY 1991. No outbreaks occurred in Little Tatsamenie Lake alevins of either brood-year, however incidence of the virus in the broodstock varied from 64% (BY 1990) to 3% (BY 1991). The lack of a clear relationship between incidence of the disease in the parents and offspring suggests that, as long as the pathogen is present, outbreaks may be more closely related to incubation conditions at the hatchery or some other aspect of the fish culture process, than to parental incidence of the disease.

The temporary CIF was taken out of service in August, 1993. All BY 1993 Snettisham Hatchery related sockeye salmon eggs are being incubated in the new CIF. The new facility is equipped with an oxygen generation system which is capable of adding oxygen and reducing dissolved nitrogen levels to well below supersaturation. There is an improved system for heating and chilling incubation water, which will facilitate thermal marking, and a  $\text{CaCl}_2$  drip system is in place.

## **4.2 Egg-take Operations**

### **4.2.1 Tahltan/Tuya lakes**

All Tahltan egg-takes have come close to or exceeded target levels, largely due to ease of capture and holding of broodstock. Concern has been expressed over the possibility of loss of genetic diversity in the Tahltan Lake stock using the current broodstock collection procedures. Since eggs are taken in a relatively short time period, 21 and 16 days for the 1990 and 1991 egg-takes, respectively, broodstock may not represent all temporal components of the run. Almost all fish have entered the lake by the time of the egg-takes; the weir is normally pulled about 1 week after the egg-takes begin and very few fish enter during this last week. Once in the lake the fish aggregate and hold off the spawning grounds until ripe. Broodstock is taken from fish captured on the spawning grounds and if the time required for maturation and entry onto the spawning grounds is related to time of entry into the lake, not an unlikely scenario, then spawners from the tails of the distribution (very early and very late) may not be represented in the egg-takes in proportion to their abundance in the escapement. If this is occurring, the greatly increased egg to fry survival rates experienced in the hatchery compared to those in the wild could, over time, result in increasing the contribution of the central temporal portion of the spawning population relative to the tails.

Evidence against selection of minor temporal or spatial component of the run includes: 1) the vast majority of spawners enter Tahltan Lake within a very short time period (90% of the escapement passed through the weir in a 14 day period in 1990 and 1992); 2) it is likely some degree of mixing of fish from different temporal segments has occurred before their capture on the spawning grounds; and, 3) very limited spawning is known to occur in other areas of Tahltan Lake. Tagging studies have been conducted to address these genetic concerns as described in Section 3.6, Ancillary Activities.

### **4.2.2 Trapper Lake**

There have been no major problems associated with the Little Trapper Lake egg-takes. Broodstock is readily available at recent escapement levels and all egg-takes have come close to or have exceeded the targets.

#### **4.2.3 Tatsamenie Lake**

Egg-take problems encountered at Tatsamenie Lake have included both excessive mortalities associated with the requirement for prolonged holding of broodstock, and low escapements, making it difficult to capture sufficient fish. Development of new procedures for handling of broodstock appears to have significantly reduced holding mortalities, however, the problem of low escapements will probably be ongoing unless the run size can be built up through the current enhancement activities.

It has been suggested that it may be desirable to use Tatsamenie Lake rather than Little Tatsamenie Lake as the source of broodstock for outplants to Tatsamenie Lake. Sockeye captured at the Little Tatsamenie weir are bound for spawning areas located in both Tatsamenie Lake and in the inter-connecting creek between the lakes. This strategy presents several genetic and survival concerns. Firstly, selecting for sexually mature fish, the preferred broodstock to avoid prolonged holding and the associated mortality problems, could result in selection for spawners from the inter-connecting creek since these fish appear to pass through the weir in a more advanced state of maturation. The life history strategy of sockeye produced from the river spawning population is different from that of fish that spawn in the lake. Differences in age composition and scale patterns have been identified, suggesting they may be two distinct stocks. If enhanced fry from the creek spawning population are introduced to Tatsamenie Lake, they may have a genetic predisposition to leave the lake early, thus not taking advantage of the excess rearing capacity of the lake. Secondly, the continued removal of large numbers of fish from this population over a long period of time could jeopardize its long term survival.

Some of the problems associated with the present site would be reduced or eliminated by relocating the egg-take operation to Tatsamenie Lake; broodstock would include only fish bound for Tatsamenie Lake and water temperatures would probably be lower, which would be more favourable for holding fish. As mentioned previously, relocation would require construction of a diversion weir for broodstock collection at the outlet of Tatsamenie Lake as well as broodstock holding facilities within the lake.

#### **4.3 Otolith Marking**

Careful consideration of marking protocols is required when multiple releases are used. Potentially, large numbers of different groups can be distinguished using the protocols developed, provided that the hatchery can maintain strict control over the timing of temperature changes and that the addition of more thermal units does not accelerate the developmental rates of the salmon more than is desirable. Within the constraints, current recommendations include: 1) no patterns with a single band of less than four rings be used; 2) marking during the hatching period be avoided altogether; and, 3) where marks involving only single bands are expected to be present together in recovered samples, the number of rings in each band should differ by at least two.

The otolith marking technique was an extremely valuable tool for the evaluation surveys, although minor problems were encountered. However, the samples collected involved only limited

numbers of known marks and more serious problems could probably be expected in other situations, such as a mixed stock fishery containing many different stocks and multiple brood-years. One suggestion arising from processing of the evaluation survey samples is that it may be preferable not to attempt to mark brood years within a stock distinctively. Instead, each stock could be assigned a fixed mark and brood year determined using other ageing techniques, such as scales or the paired otolith. This would greatly reduce the number of distinct marks required, thereby reducing the need for complexity and simplifying their application and interpretation.

#### **4.4 Monitoring of Outplants and Limnological Observations**

##### **4.4.1 Hydroacoustic Estimates**

The fall juvenile population estimates obtained at Tahltan Lake in 1990 and 1991 appear unreasonably low when compared to smolt estimates at the weir the following spring. These results raise some serious concerns and warrant closer examination, since Tahltan Lake is the only location where hydroacoustic estimates can be compared to abundance estimates obtained by another means. Hydroacoustic estimates were made at Tahltan Lake during the fall in 1985, 1987, and 1988, as well as in 1990 and 1991. All juvenile sockeye population estimates calculated for Tahltan Lake (all ages, wild and enhanced) are presented in Table 13, including the July estimates made in 1990 and 1991. The Tahltan weir smolt estimate associated with each fall estimate is also given; this estimate represents all possible smolts derived from juveniles enumerated in the fall survey<sup>9</sup>. Fall estimates are plotted against smolt estimates in Figure 18. Underestimates were obtained in all years except 1985. The 1985 estimate appears reasonable, being 1.1 times the associated smolt estimate. These comparisons of fall juvenile estimates with smolt migrations do not make any allowance for overwinter mortalities of 'holdover' fish, i.e., fish which remain in the lake at the time of smolt migration to migrate in future years. Taking these into account, the mortality model presented earlier suggested the 1990 and 1991 fall estimates for enhanced age 0+ fry may have underestimated the true numbers by three or four times respectively, using the model giving high initial mortality (maximum  $u$ ). Examination of Figure 18 indicates the estimate for all juveniles (wild plus enhanced, all ages) in the fall of 1990 was under by an even greater amount while the 1991 estimate is improved considerably. These differences are due in part to the fact that the enhanced fry estimates involve partitioning of the total population estimate into wild and enhanced components, with associated variance.

In making these comparisons it is important to note that the accuracy of the hydroacoustic estimates is being judged by comparisons with smolt enumerations at the Tahltan weir. Enumerations at the weir are not absolute. They involve varying degrees of estimation, as described earlier in the Methods section. It seems reasonable to expect the accuracy of the smolt counts would be greater than that of the hydroacoustic estimates; however, this is an assumption and efforts should be made to determine the actual precision and accuracy of the smolt estimates

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<sup>9</sup> This includes age 1 and age 2 smolts the spring following the survey, age 2 smolts two springs following the survey, and age 3 smolts the third spring following the survey.

before attributing all discrepancies to inaccuracies in the hydroacoustic estimates.

The results obtained at Tahltan raise two questions: 1) Are there any obvious reasons for the quite consistent low bias of the Tahltan hydroacoustic estimates and are the estimates of any value; and, 2) if there are identifiable reasons for the underestimates, are they unique to Tahltan or can biases be expected in other lakes for similar reasons? These issues are discussed below:

1. The low estimates obtained in July can be at least partially explained by the substantial but undetermined numbers of fry remaining onshore, inaccessible to the hydroacoustic gear. However, by the time of the fall surveys all fry have apparently moved into the pelagic zone, as determined by beachseining, and this should not be a significant factor. Another possibility is that fish are inhabiting the near surface waters at the time of the surveys, the sounder being incapable of detecting targets within about the first 2 meters. This seems unlikely however, since fish were very seldom caught in surface trawls conducted specifically for the purpose of confirming the absence of fish. Also, densities on the chart recordings always declined sharply as the surface was approached; generally no fish are observed at depths of less than 3-4 meters.

There is one quite consistent factor which would contribute considerably to the low bias. This is the presence of significant numbers of fish at depths to within 0.5 meter of the lake bottom. Any fish closer to the bottom than this would be undetectable because of background noise from bottom echoes and it is therefore likely that significant numbers of fish are being missed. This was observed to some extent in all surveys, being least noticeable in the 1985 and 1987 surveys. Another factor which would have contributed to the particularly low estimate in 1990 was the behaviour of the fish, which tended to aggregate in small dense schools at depths from 5 to 20 meters, in response to the exceptionally bright conditions the night of the survey. Since target counts are made visually from chart recordings, individual targets become indistinguishable at high densities and the numbers in such schools tend to be underestimated. This was also observed to a much lesser extent in the 1988 survey, and is a particular problem at Tahltan Lake, where light penetration is high due to the exceptional water clarity. High densities likely contributed slightly to low estimates in 1987 and 1991 as well, when fish concentrated in narrow bands along the thermocline in some areas of the lake. Another condition which likely contributed to the underestimation in 1991 was the exceptionally high number of adults in the lake (escapement of 50,135) which undoubtedly obscured many smaller juvenile targets. This occurred in 1990 as well but to a much lesser degree (escapement of 14,927). Although the escapement of 67,326 in 1985 was higher than either of these, it did not present a problem, since the survey was not done until October 5, at which time adults were no longer present in substantial numbers.

While difficult to quantify, the factors described here could explain much of the apparent error in the fall estimates obtained at Tahltan Lake in 1987, 88, and 91. It is unlikely they could account as fully for errors of the magnitude seen in 1990, however there was a large amount of schooling in that year and the effect of this may be much greater than suspected. The greater accuracy of the 1985 estimate appears to have been related to low fish density; the associated smolt production was the lowest of any year. It may also have been related to the fact that this survey was conducted very late that year; substantial numbers of fry may still have remained

onshore in the fall in other years, despite the beachseining evidence this was not so.

If the extremely low fall hydroacoustic estimate in 1990 is omitted, there is a good correlation ( $r^2 = .94$ ,  $p = .03$ ) between fall juvenile hydroacoustic estimates and subsequent associated smolt estimates, as shown in Figure 19. If the 1990 fall estimate is included, the correlation becomes insignificant ( $r^2 = .22$ ,  $p = .43$ ). Thus, if the 1990 fall estimate is discounted as being exceptional or invalid for the reasons described above, the fall hydroacoustic estimates could be used as a fairly accurate predictor of smolt numbers. The fry model indicates associated smolts should represent from 44% to 67% of the fall juvenile estimates depending on which set of parameters are used. This is in agreement with the expected range of 50 to 90% used by Kyle 1988 for a number of Alaskan lakes. The regression in Figure 19 falls within Kyles' range at low numbers and is close to the model range (e.g. 76% for 200,000 smolts); however, hydroacoustic estimates begin to underestimate as smolt numbers increase. Since greater smolt numbers imply greater numbers of presmolt juveniles, the decline in accuracy of the hydroacoustic estimates is associated in some fashion with greater in-lake densities.

2. The conditions identified above which could explain much of the bias in the Tahltan fall estimates are, in order of perceived importance: 1) concentrations of fish very near the bottom; 2) schooling of fish under high ambient light conditions; 3) obscuring of juvenile targets by adult targets; and, 4) dense concentrations of fish along the thermocline. The physical features and hydroacoustic records for other lakes were examined for similar conditions, as well as any other factors which may have affected the accuracy of the estimates. Results were as follows:

*Trapper Lake:* In the 1987 fall survey, none of the above problems were encountered. In the 1991 fall survey fish densities were much greater and fish were present to much greater depths. There was no problem with localized concentrations of fish, however there was a slight problem with fish near the bottom on one transect. There was some masking of targets by false bottom on some deeper transects, which could have been avoided by switching to a deeper scale, as was used in 1987. There have been no problems with fish schooling; this is not surprising in view of the extreme glacial turbidity, which blocks light penetration. There have been no problems of obscuring of juvenile targets by adult targets. There was a very slight indication of fish remaining onshore in 1991 (no beachseining was done in 1987) and no indication of fish in surface layers in either year. The Trapper fall estimates for 1987 and 1991 are qualitatively judged to be considerably more accurate than the Tahltan estimates, although they probably still underestimate the true population. Unfortunately, considerable numbers of fish were captured onshore at the time of the fall survey in 1992 (still to be reported), suggesting results may vary from year to year.

*Tatsamenie Lake:* In the 1987 fall survey, none of the problems observed at Tahltan were encountered. There was a slight problem with false bottom, but fish were generally shallow and not obscured by this. In the 1991 fall survey, problems were numerous. Densities were much higher, and fish tended to aggregate near the very steep shores causing considerable target overlap. There was no indication of schooling at shallower depths. There were considerable concentrations of fish at the bottom on three of the seven transects. There was some masking of

targets by false bottom, which could have been avoided by switching to a deeper scale, as was done in 1987. There were no indications of fish at the surface and none were captured onshore (a very small number were captured in 1987). Although there are considerable numbers of adult sockeye in Tatsamenie Lake, their density is not such that they obscure juvenile targets. The Tatsamenie fall 1987 estimate was qualitatively judged to be fairly accurate; however, it is doubtful the accuracy of the 1991 estimate is much, if any better, than that of Tahltan.

*Tuya Lake:* No problems were encountered in preliminary surveys conducted in 1987 and 1988, prior to any outplanting. However, Tuya Lake is almost devoid of naturally occurring fish in the limnetic zone and there were very few targets. Preliminary examination of a fall, 1992 survey (after outplanting) indicates aggregations of fish near the bottom may be a concern because of the shallowness of the lake. Also, since Tuya is a clear lake, schooling can be expected on bright nights and surveys on such nights should be avoided.

From the preceding discussion, it is apparent that problems and their severity differ between lakes, and also between years. Under proper conditions, fall acoustic estimates can be quite accurate forecasters of smolt abundance. For example, Kyle (1988), comparing fall hydroacoustic estimates with associated smolts enumerated by a variety of methods, found that in 15 observations involving 6 Alaskan lakes, the two methods gave estimates outside the expected correlation range of 0.5 - 0.9 (i.e., smolts representing 50 to 90% of the fall fry) only 4 times. The cost of smolt enumeration programs could be in the range of 4 to 5 times that of hydroacoustic surveys, and it is therefore intended to continue using hydroacoustics and attempt to improve techniques. Methods of improving the accuracy of the fall estimates could include tape recording of signals to allow for electronic processing and echo integration of the digitized signal (especially when fish densities are high), postponing surveys if obvious schooling behaviour is observed or anticipated (e.g. full moon), and increasing the number of hydroacoustic transects to ensure concentrations of fish are not being missed. Beachseining effort and surface trawling effort should also probably be increased to confirm that only minimal numbers of fry, if any, are occupying areas not included in hydroacoustic estimates. It would be extremely difficult, and perhaps impossible, to enumerate these onshore fry. At all lakes, at least in the early season, the unknown numbers of fry remaining onshore also make it uncertain that any samples collected are truly representative of the total population. Depending on the problems encountered and the accuracy desired, it may at some point be desirable to consider conducting smolt enumeration programs at other lakes besides Tahltan, at least for a short period to check the accuracy of the hydroacoustic estimates at those locations.

#### **4.4.2 Tahltan Lake Synopsis**

The BY 1989 Age 1 smolts attained a size almost equal to that of the wild smolts (5.4g vs. 5.8g respectively, even though enhanced fry were considerably smaller in the summer of outplanting (PSC 1991). At Age 2, enhanced smolts were larger than wild smolts (12.0g vs. 10.2g). Relative survival of the two types cannot be commented on because of problems obtaining fry and juvenile population estimates, however, the survival rates of the enhanced fish to Age 1 and Age 2 smolt (25.6% and 28.6%, respectively) surpass the 20% biostandard used in planning the transboundary



sockeye outplant projects.

Monitoring of the BY 1990 fry outplant in 1991 indicated outplanted fry were initially smaller than wild fry but again they grew rapidly and by the time of the fall survey were equivalent in size to wild fry. The fall survey in 1991 showed 48% of the Age 0+ juveniles to be of enhanced origin. This is the same ratio observed in the Age 1 smolts in the spring of 1992, indicating equal overwinter survival. Survival to Age 1 smolt for the BY 1990 fry was 21.6%, again surpassing the biostandard, and enhanced smolt weight was essentially equivalent to that of wild smolts (4.8g and 4.6g, respectively).

In summary, the sockeye fry outplanted to Tahltan Lake in both 1990 and 1991 survived and grew well. Based on this information and zooplankton analyses, there is very little indication that the productive capacity of Tahltan Lake has been taxed, despite record smolt runs in 1991 and 1992.

#### **4.4.3 Tuya Lake Synopsis**

Outplanting of fry to Tuya Lake did not take place until the spring of 1992 and monitoring of this outplant will be presented in a later report. Zooplankton studies in both 1990 and 1991 continue to demonstrate that the zooplankton forage base can support substantial levels of planktivory. This may be substantially altered with the introduction of sockeye, through removal of large predaceous zooplankton species. Information collected in 1992, the first year of outplanting, will help determine predictions of sockeye carrying capacity, as will incremental increases in the numbers outplanted.

#### **4.4.4 Trapper Lake Synopsis**

Monitoring of fry and smolt survivals has been particularly difficult at Trapper Lake for a number of reasons. These include an apparent tendency for enhanced fry to remain onshore longer and in greater proportions than wild fry, difficulties in obtaining adequate trawl samples, early migration of outplanted fry to Little Trapper Lake, and the failure to capture smolts leaving Trapper Lake, even though enhanced smolts were caught leaving Little Trapper. The early outmigration of outplanted fry from Trapper Lake and their rearing in Little Trapper Lake has important implications for the success of the project, since the intent is for the outplanted fry to take advantage of the underutilized food supply in Trapper Lake. Furthermore, large numbers of enhanced juveniles rearing in Little Trapper could conceivably overtax its rearing capacity, which may be utilized to near the limit by wild fry. To this point there has been no evidence of this in the plankton community in Little Trapper Lake. However, such effects would be difficult to detect, as the community has assumed a highly predator resistant state due to continual heavy predation. Observations on smolts leaving Little Trapper Lake in 1992 also showed no indications of the lake being overtaxed; smolts, although small ( $\approx 2.9$ g for both enhanced and wild, Age 1), were larger than those observed in 1988 (2.2g for Age 1 smolts), the only other year of smolt observations for Little Trapper Lake.

Observations of fry from Trapper Lake in 1991 indicate enhanced fry were likely initially smaller than wild fry but were of very similar size by fall. As mentioned above the enhanced smolts leaving Little Trapper Lake in 1992 were equal in size to wild smolts, but it is not known for certain whether they reared in Trapper Lake or Little Trapper Lake. There are no estimates of survival of outplanted fry to the smolt stage, but the fall hydroacoustic surveys indicate a survival of about 25% from outplanted fry to fall fry for fry rearing in Trapper Lake. This compares to an estimate of 13.4% for the same period for Tahltan Lake fry, however, as discussed previously, the Tahltan estimate is biased low and was more likely around 40%. Assuming the Trapper Lake hydroacoustic estimates to be reasonably accurate, this would suggest a lower survival for Trapper Lake fry but this could also be attributable to early outmigration of fry to Little Trapper Lake rather than mortality.

Because of the problems encountered, it is impossible at this point to evaluate the success of the Trapper Lake outplants. Fry and smolt sampling indicates enhanced fish are growing as well as wild fish but further years of observations are required to answer questions relating to survival. It is possible some of these questions may never be answered and the ultimate success of the outplants may have to be judged by adult returns. In the meantime it is important to try to determine the extent of the early outmigration of outplanted fry and to consider and monitor the effects of this on the forage base in Little Trapper Lake and its wild sockeye population.

#### **4.4.5 Tatsamenie Lake Synopsis**

As in the outplants at all other lakes, BY 1990 enhanced fry were initially smaller than wild fry but had reached a similar size by the fall. The fall 1991 survey indicated 5.7% of the age 0+ fry were of enhanced origin at that time. The total number was estimated to be about 202,000, giving a survival of 20.5% from time of outplanting. As discussed above for Trapper Lake, comparison with Tahltan Lake results suggests survival at Tatsamenie Lake may be lower, but this cannot be stated with certainty. Smolt sampling at Tatsamenie Lake in 1992 indicated 8.7% of the Age 1 smolts were of enhanced origin, close to the fall survey estimate of 5.7% for the Age 0+ fry the previous fall. This suggests similar overwinter survival of wild and enhanced fish and also suggests it is unlikely enhanced fry are migrating prematurely from Tatsamenie, as is occurring at Trapper Lake. To confirm this, it is intended to examine samples of fry captured in Little Tatsamenie Lake (2 km downstream of Tatsamenie) during the summer following the next outplant.

Smolt sampling in 1992 showed enhanced and wild Age 1 smolts to be of a substantial and very similar size, about 4.9g, demonstrating outplanted fry grew as well as wild fry. Zooplankton observations indicate the lake is still capable of supporting much larger levels of fry. As at Trapper Lake, estimates of survival to the smolt stage were not made. At this point, it can only be said that the outplants to Tatsamenie appear to be relatively successful.

## ACKNOWLEDGMENTS

The Transboundary Technical Committee is grateful to Mark Johannes, Canadian Department of Fisheries and Oceans, Nanaimo, B.C., who was primarily responsible for the analyses and interpretation of zooplankton data, and to Erland MacIsaac, Canadian Department of Fisheries and Oceans, West Vancouver, B.C., who was primarily responsible for the analyses and interpretation of water sampling data.

## LITERATURE CITED

- Brooks, J.L. and S.I. Dodson. 1965. Predation, body size and the composition of plankton. *Science* 150:28-35.
- Galbraith, M.G. Jr. 1967. Size-selective predation on *Daphnia* by rainbow trout and yellow perch. *Trans. Amer. Fish. Soc.* 96:1-10.
- Goodlad, J.C., T.W. Gjernes, and E.L. Brannon. 1974. Factors affecting sockeye salmon (*Oncorhynchus nerka*) growth in four lakes of the Fraser River system. *J. Fish. Res. Board Can.* 31:871-892.
- Johannes, M.R.S., K.D. Hyatt, R.B. Morley, and C.C. Wood. 1993. Limitations to the freshwater production of sockeye salmon in the Stikine and Taku watersheds and methods for assessing stock enhancement potential: I. Zooplankton community structure as an index of carrying capacity. (MS for submission to *Can. J. Fish. Aquat. Sci.*)
- Koenings, J.P., and R.D. Burkett. 1987. Population characteristics of sockeye salmon (*Oncorhynchus nerka*) smolts relative to temperature regimes, euphotic volume, fry density, and forage base within Alaskan Lakes. p.216-234. In H.D. Smith, L. Margolis, and C.C. Wood [ed.] *Sockeye salmon (Oncorhynchus nerka) population biology and future management*. *Can. Spec. Publ. Fish. Aquat. Sci.* 96.
- Kyle, G. B., 1988. Comparisons of fall acoustic population estimates of juvenile sockeye salmon in Alaskan lakes with smolt estimates from trap catches. Paper presented at the North Pacific International Chapter American Fisheries Society 1988 Annual Meeting.
- Mercer, B., and Associates. 1991. Preliminary investigation of Arctic-Pacific watershed exchange at the headwaters of the Tuya River system. Prepared for Department of Fisheries and Oceans Canada.

### LITERATURE CITED (continued)

- O'Neill, S.M., and K.D. Hyatt. 1987. An experimental study of competition for food between sockeye salmon (*Oncorhynchus nerka*) and threespine sticklebacks (*Gasterosteus aculeatus*) in a British Columbia lake. p.143-160. In H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.
- Pacific Salmon Commission. 1991. Transboundary River sockeye salmon enhancement activities, 1989 brood year, July 1989 through October 1990. Pacific Salmon Commission Transboundary Technical Committee Report TCTR (91)-2: 16 p.

## FIGURES

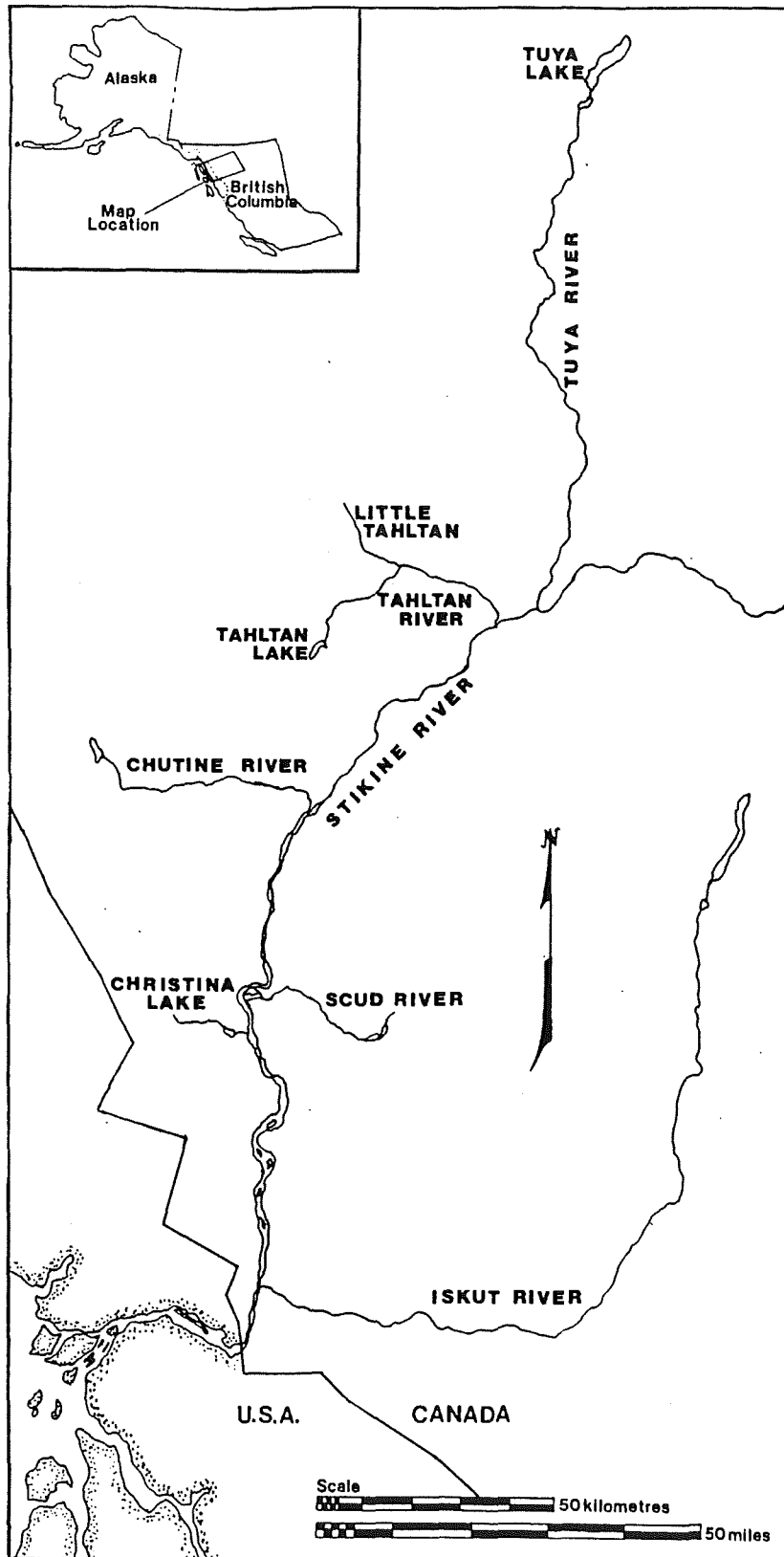


Figure 1. Stikine River drainages.

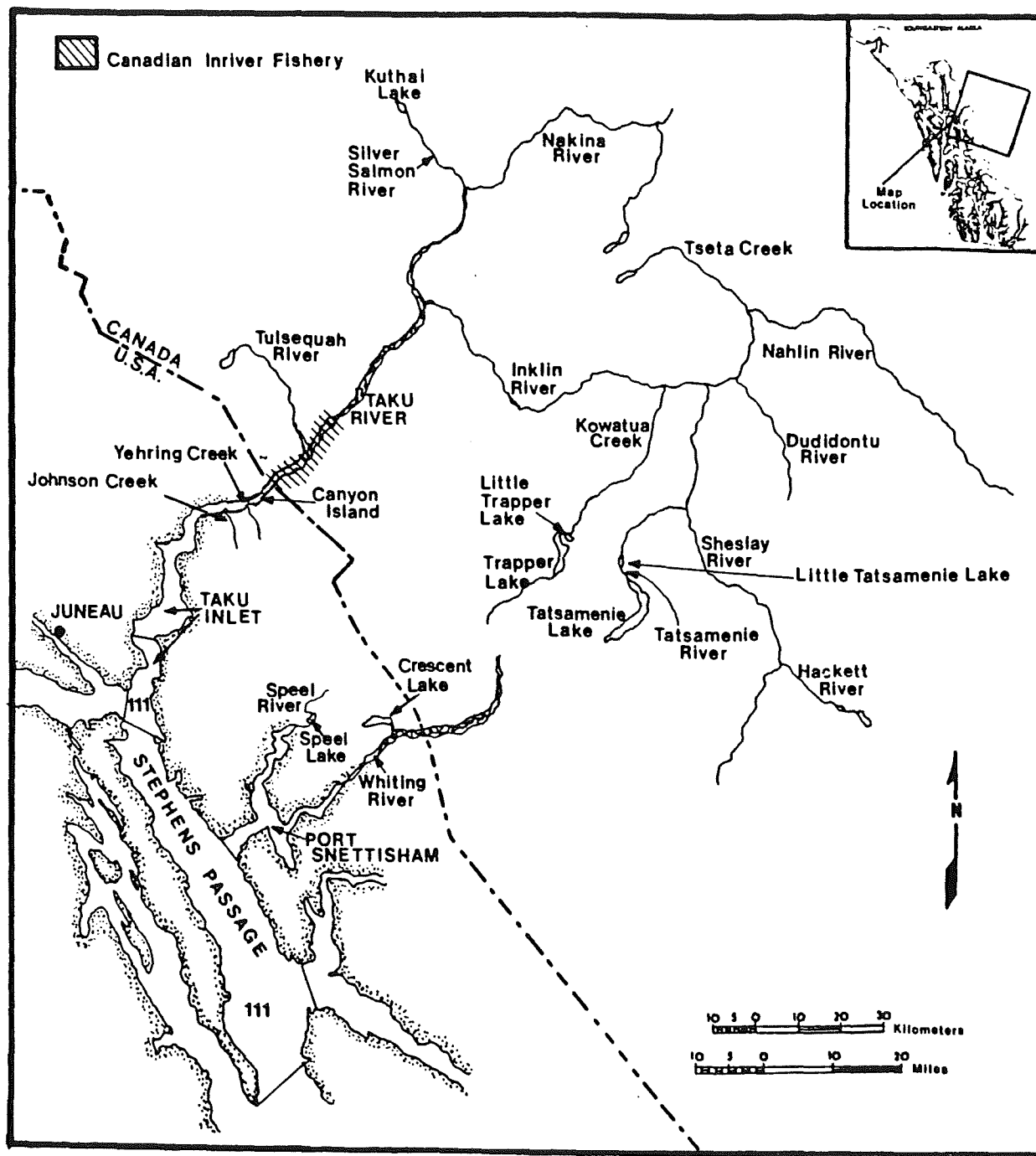


Figure 2. Taku River drainages.

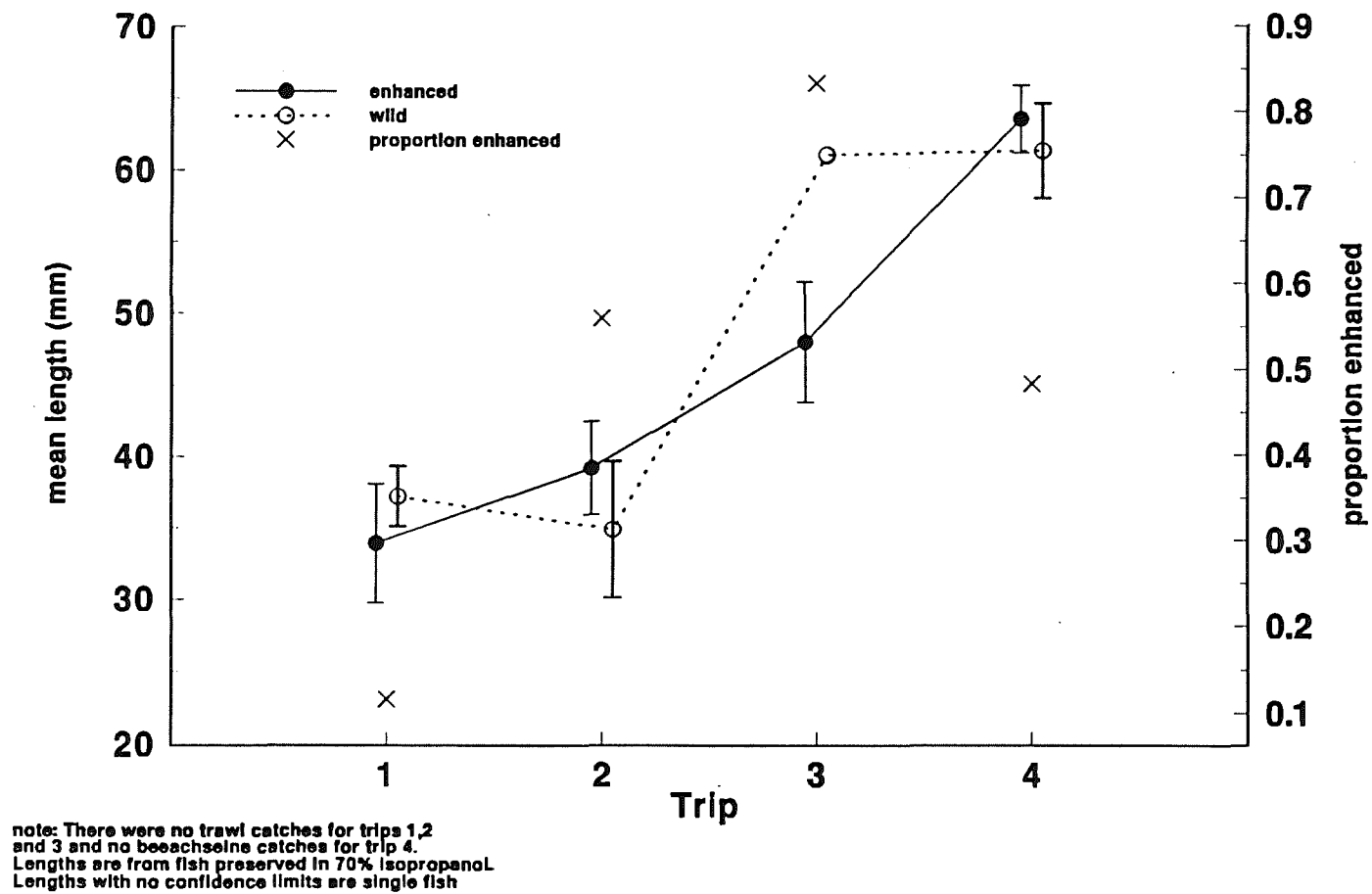


Figure 3. Tahltan Lake evaluation survey juveniles, 1991. Lengths and proportions of enhanced, Age 0+ only (BY 1990).



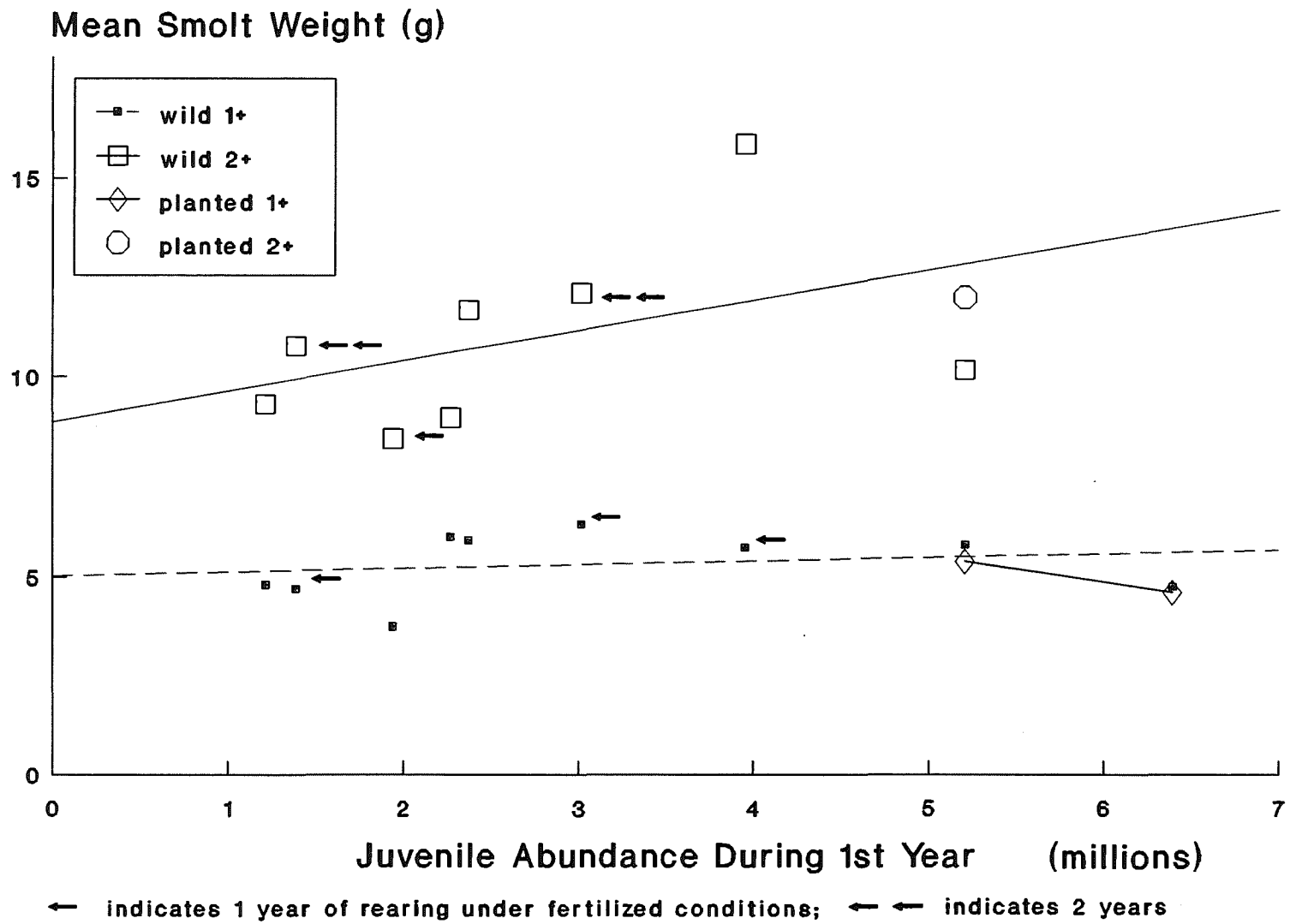


Figure 4. Tahltan Lake smolt size vs. juvenile abundance in 1st year of lake residency

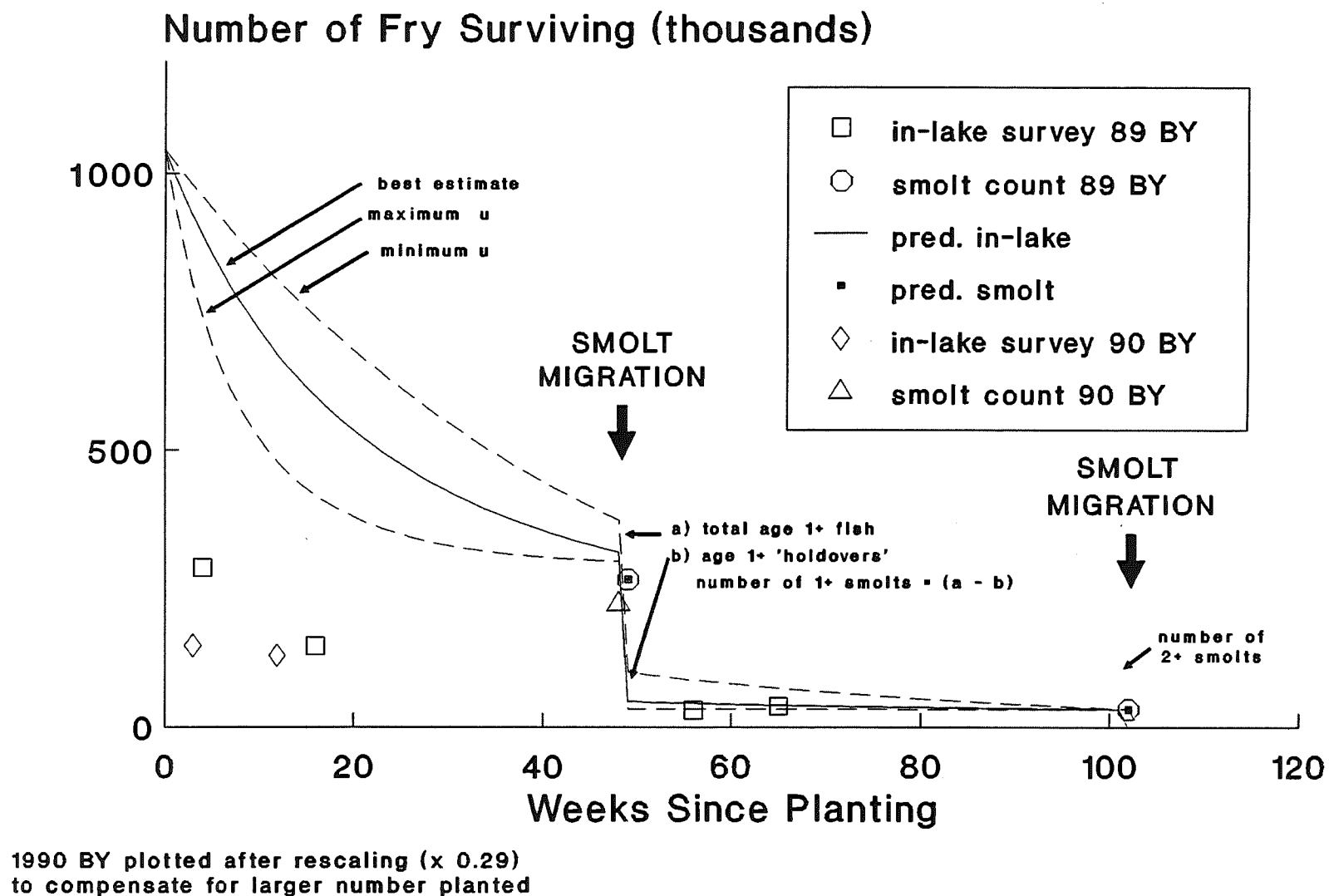


Figure 5. Estimated survival curve for sockeye fry planted in Tahltan Lake

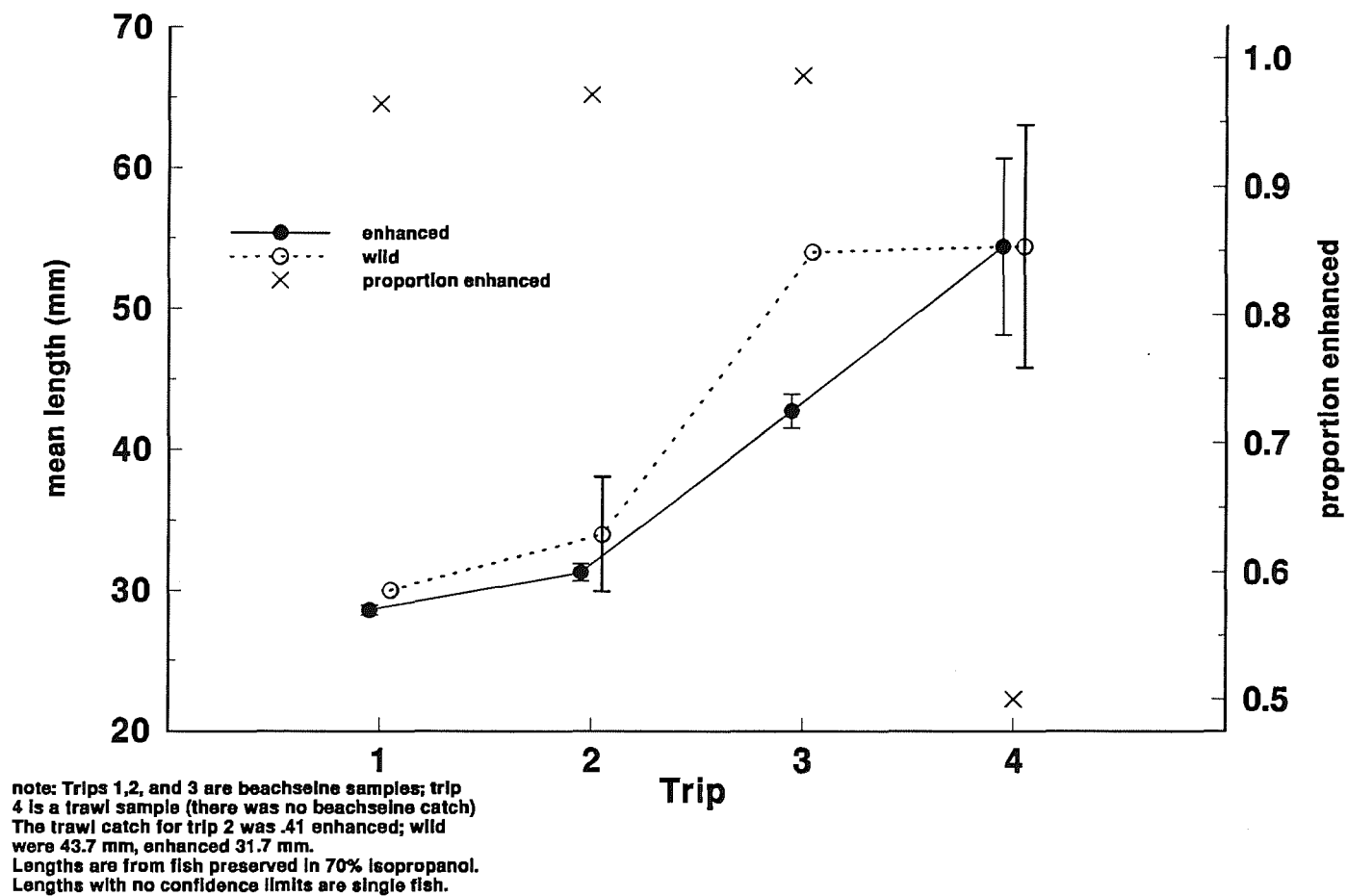


Figure 6. Trapper Lake evaluation survey juveniles, 1991. Lengths and proportions of enhanced, Age 0+ (BY 1990).

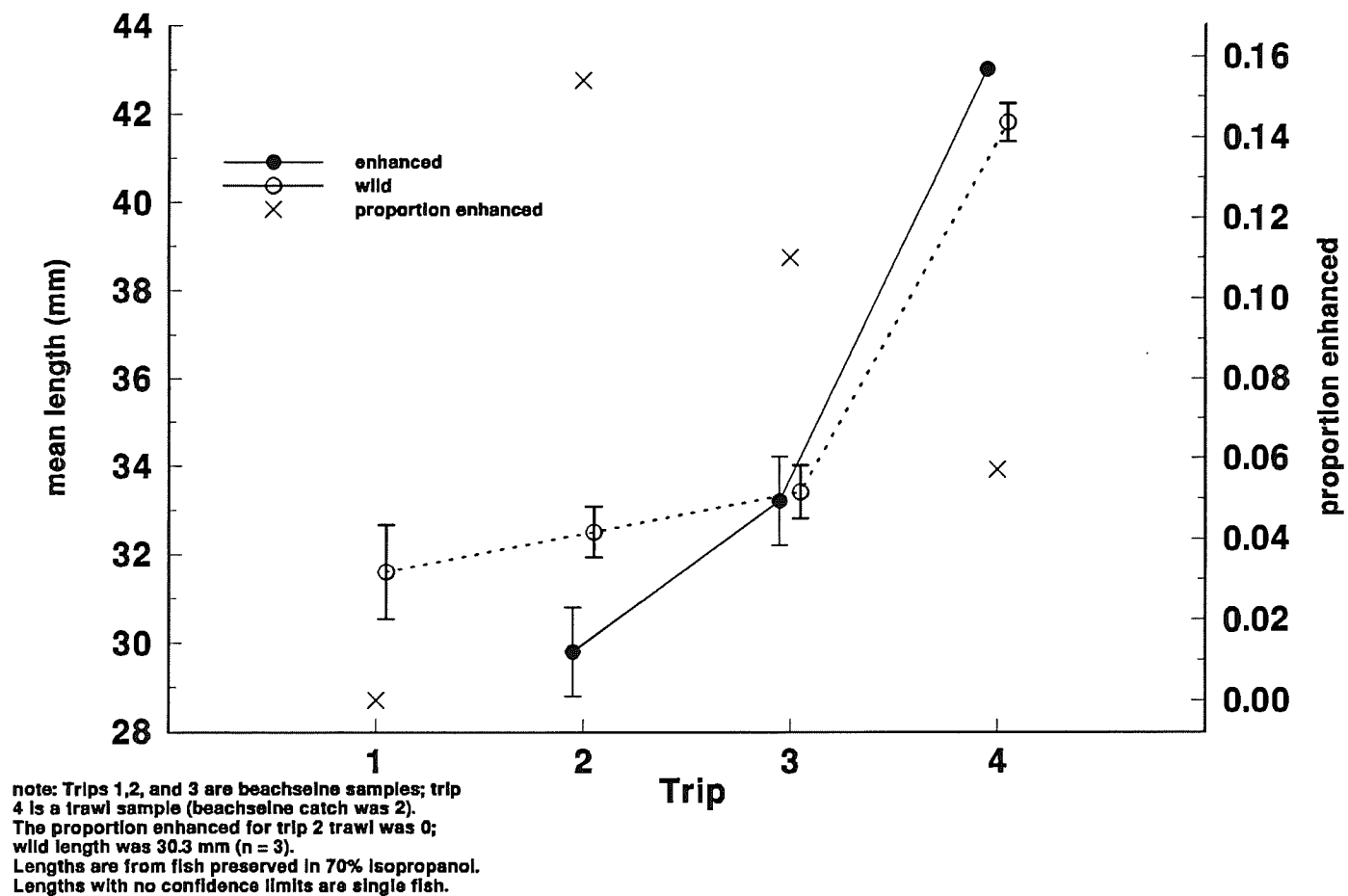


Figure 7. Tatsamenie Lake evaluation survey juveniles, 1991. Lengths and proportions of enhanced, Age 0+ (BY 1990).

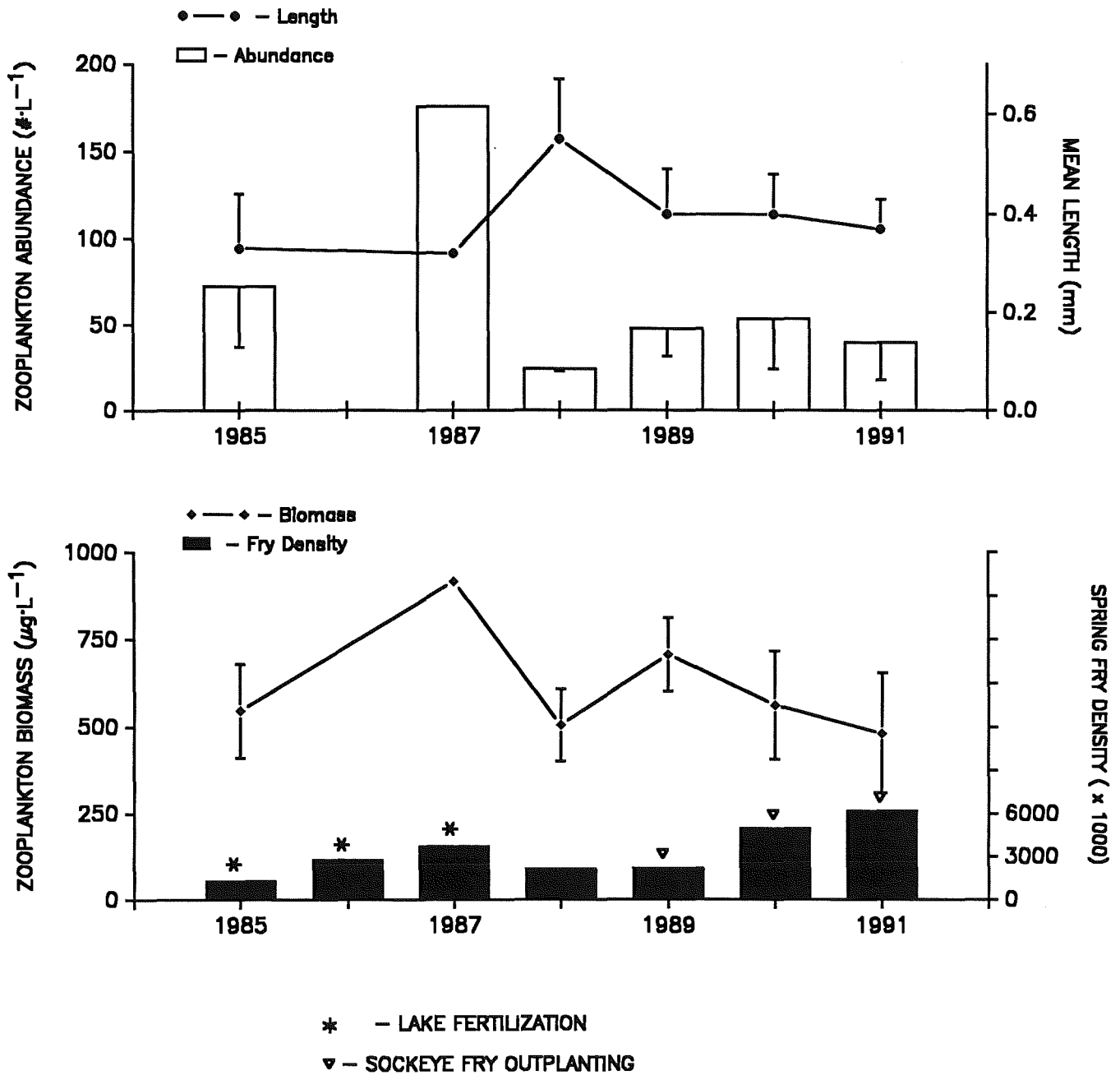


Figure 8. Tahltan Lake mean zooplankton abundance (density #/L), length (mm), and biomass ( $\mu\text{g/L}$ )(mean summer growing period) during 1985, 1987 to 1991 compared with total sockeye fry density (mid-June).

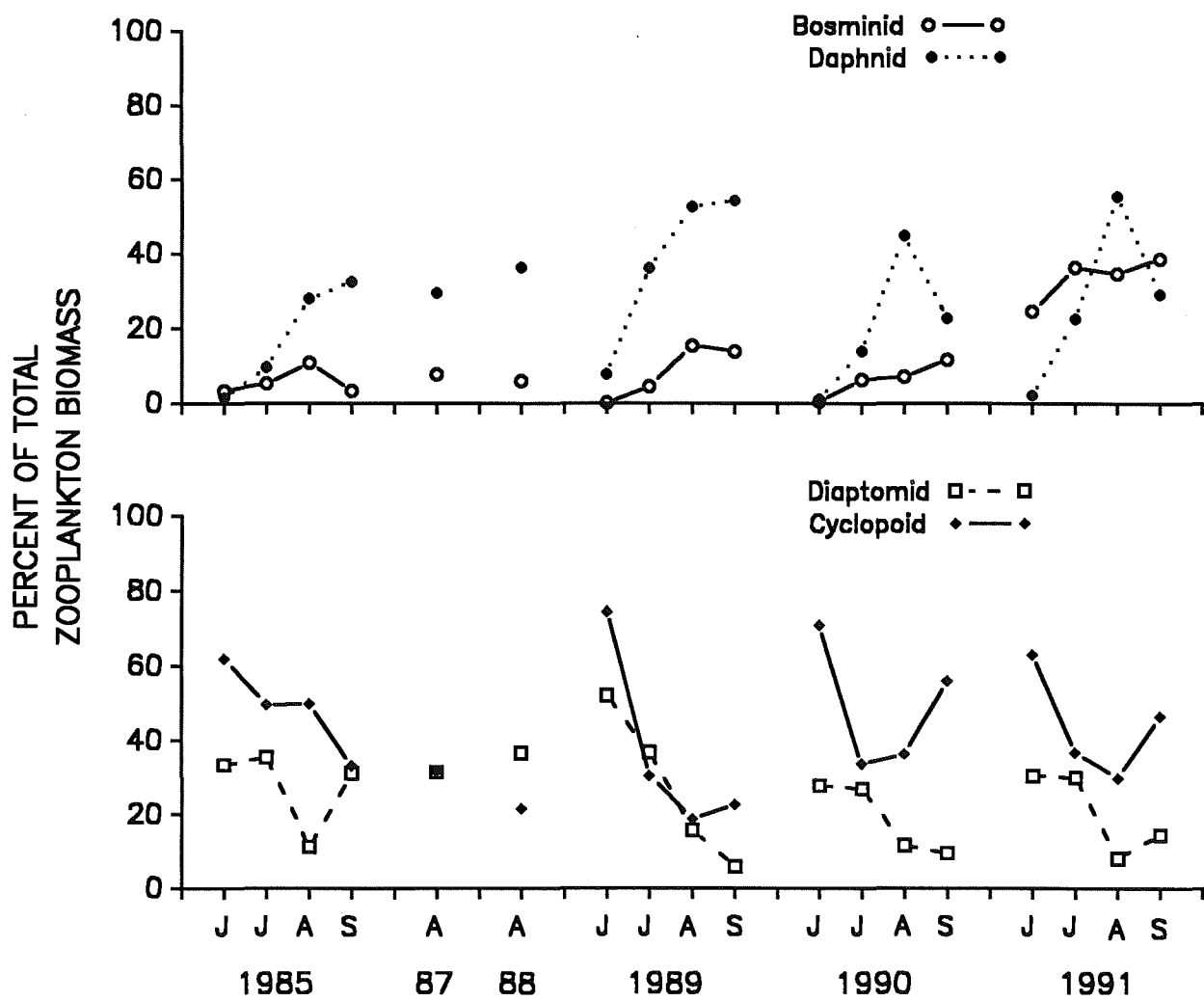
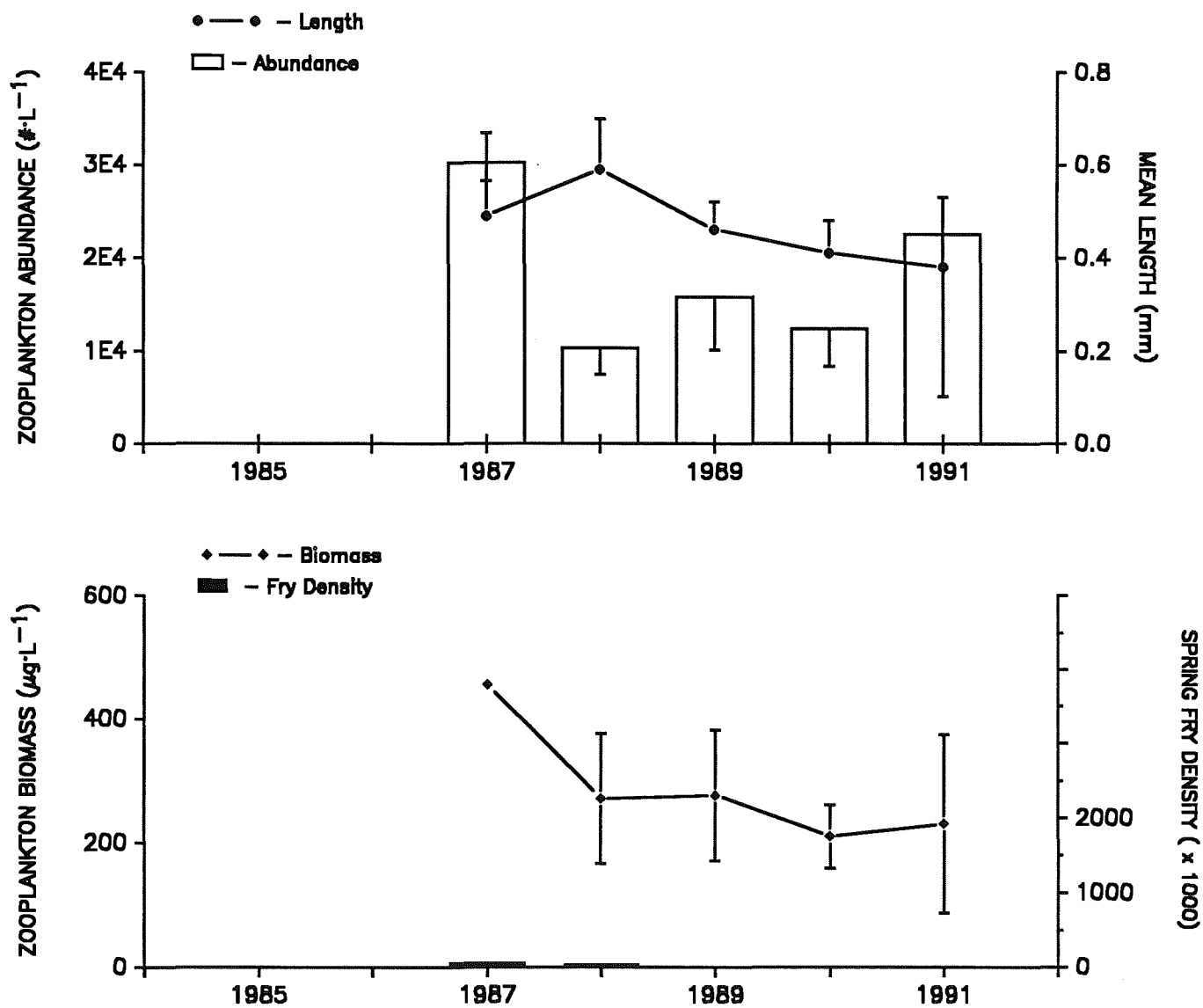


Figure 9. Proportional contribution of bosminids, daphnids, cyclopoids and diaptomids to the total zooplankton biomass in Tahltan Lake.



▼ — SOCKEYE FRY OUTPLANTING 1992

Figure 10. Tuya Lake mean zooplankton abundance (density #/L), length (mm), and biomass (μg/L) (mean summer growing period) during 1987 to 1991 compared with total sockeye fall fry densities observed in 1987 and 1988 (outplants began in 1992).

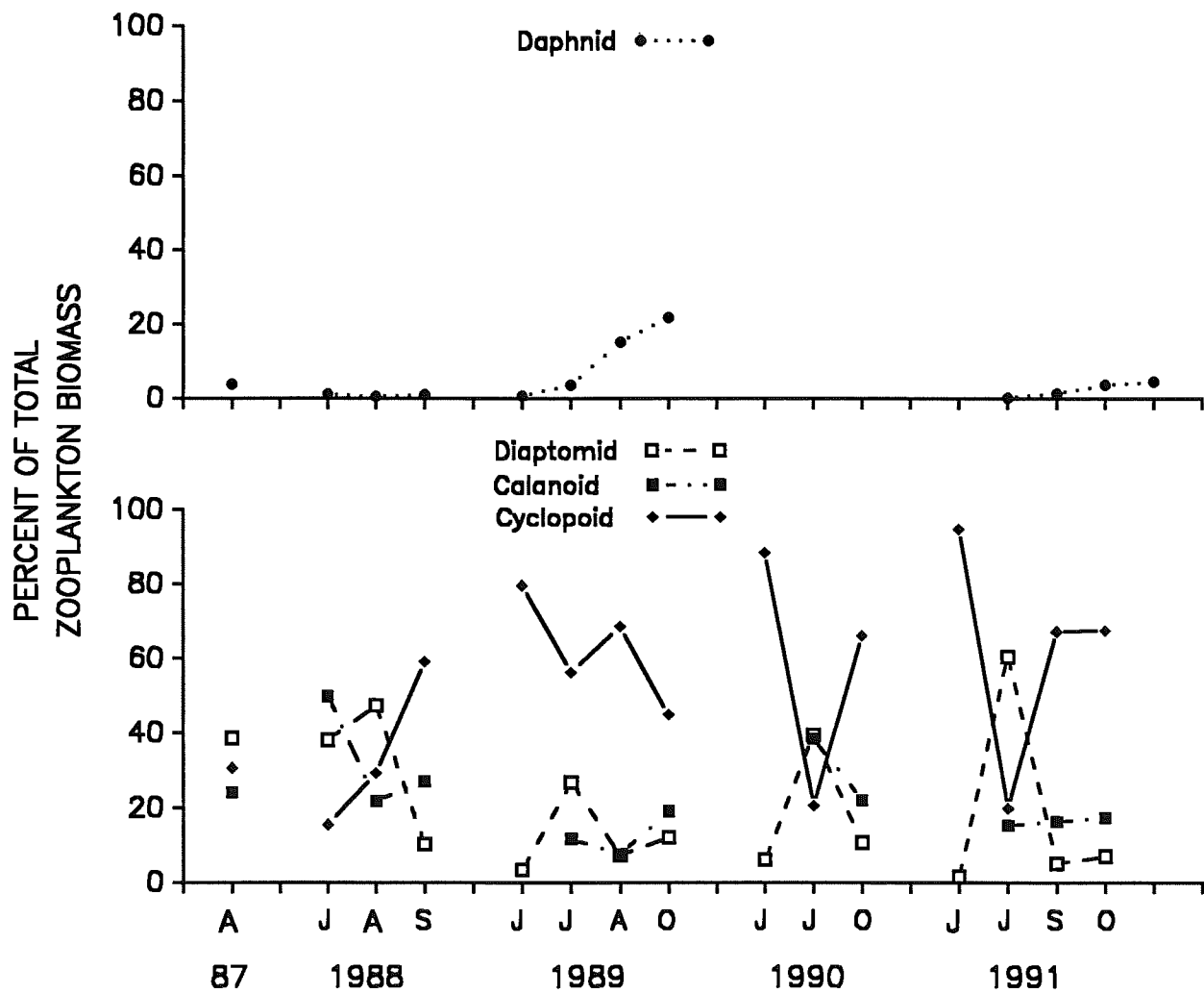


Figure 11. Proportional contribution of daphnids, cyclopoids, diaptomids and Heterocope calanoids (bosminids not observed) to the total zooplankton biomass in Tuyu Lake.



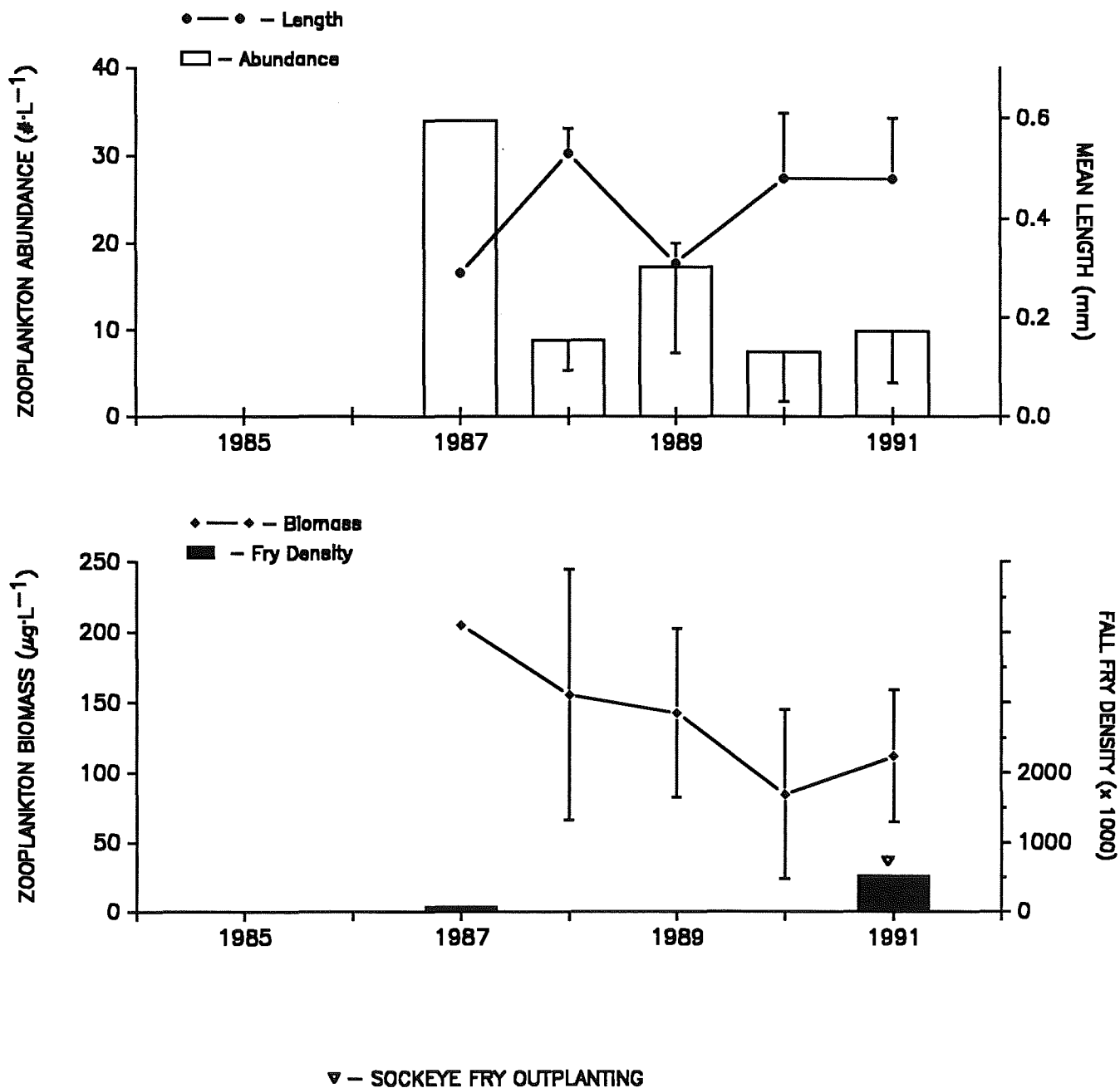


Figure 12. Trapper Lake mean zooplankton abundance (density #/L), length (mm), and biomass ( $\mu\text{g/L}$ )(mean summer growing period) during 1987 to 1991 compared with total sockeye fall fry density.

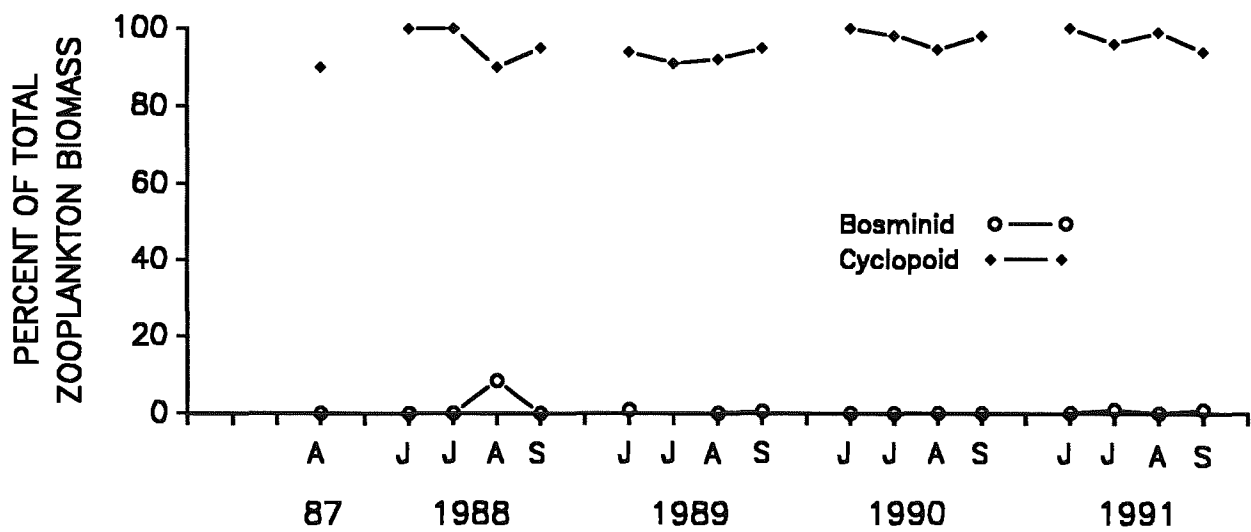


Figure 13. Proportional contribution of bosminids, daphnids, cyclopoids and diaptomids to the total zooplankton biomass in Trapper Lake.

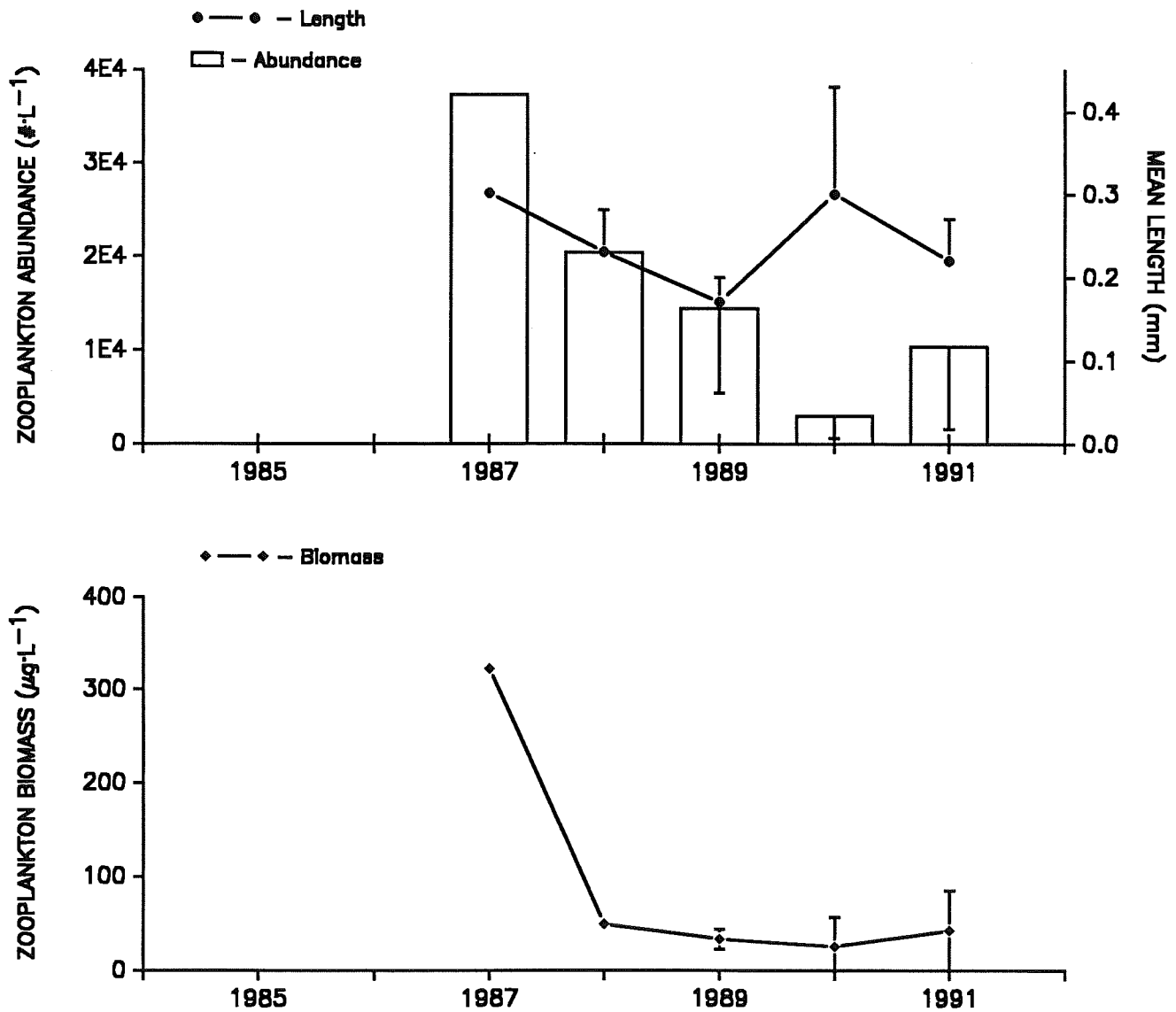


Figure 14. Little Trapper Lake mean zooplankton abundance (density #/L), length (mm), and biomass ( $\mu\text{g/L}$ )(mean summer growing period) during 1987 to 1991 compared with total sockeye fall fry density.

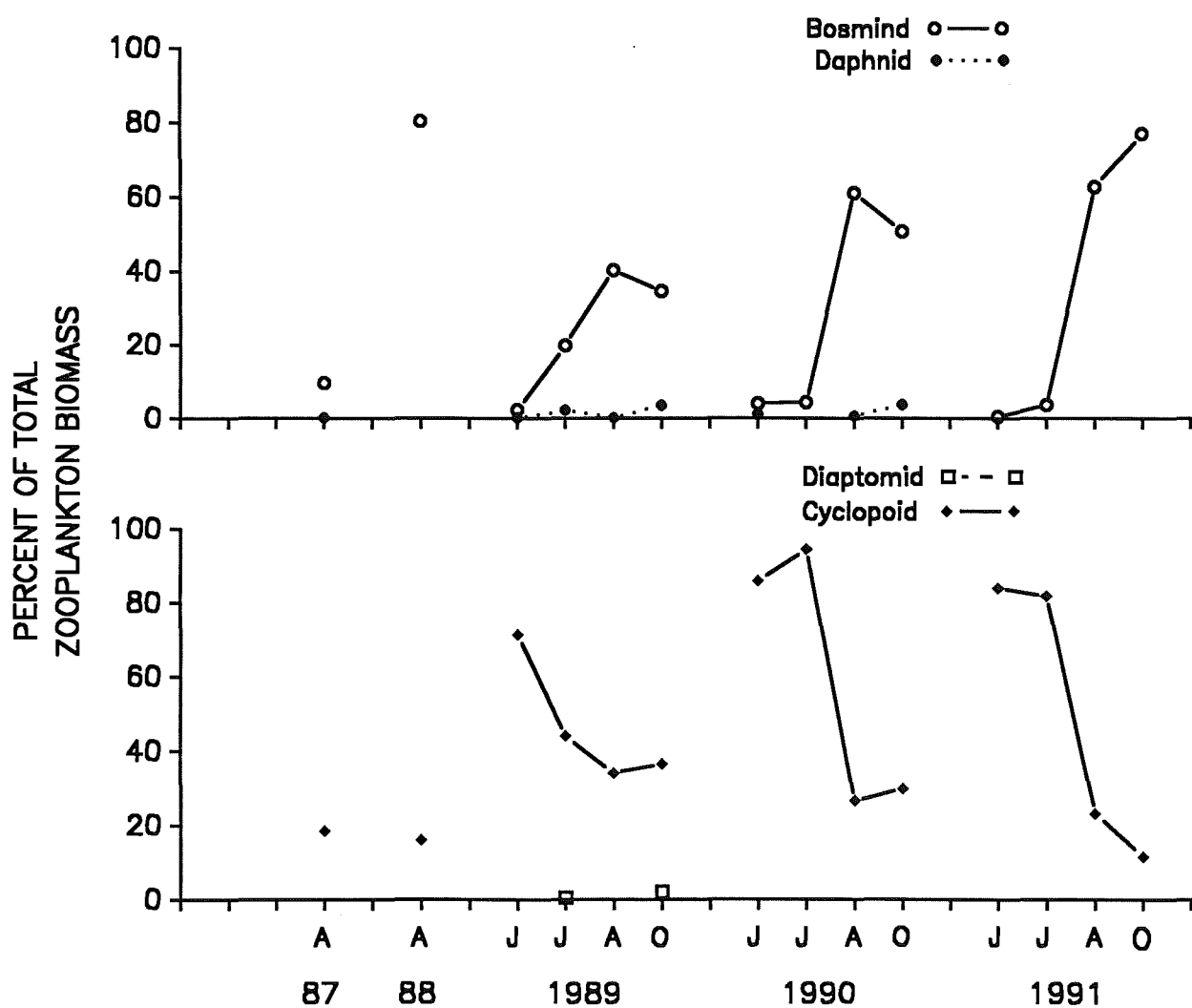


Figure 15. Proportional contribution of bosminids, daphnids, cyclopoids and diaptomids to the total zooplankton biomass in Little Trapper Lake.

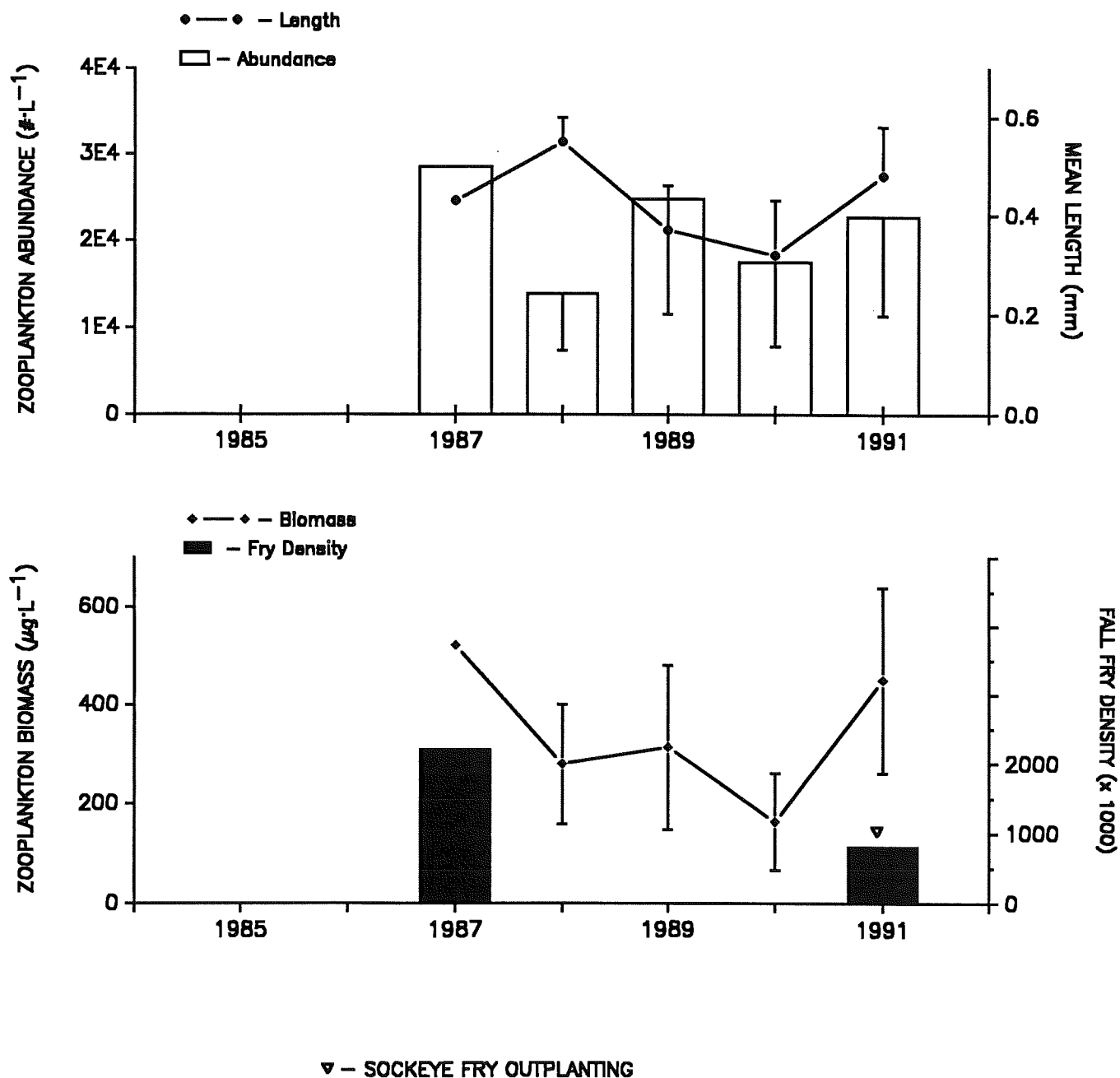


Figure 16. Tatsamenie Lake mean zooplankton abundance (density #/L), length (mm), and biomass ( $\mu\text{g/L}$ )(mean growing period) during 1987 to 1991 compared with total sockeye fall fry density (1987, 1991).

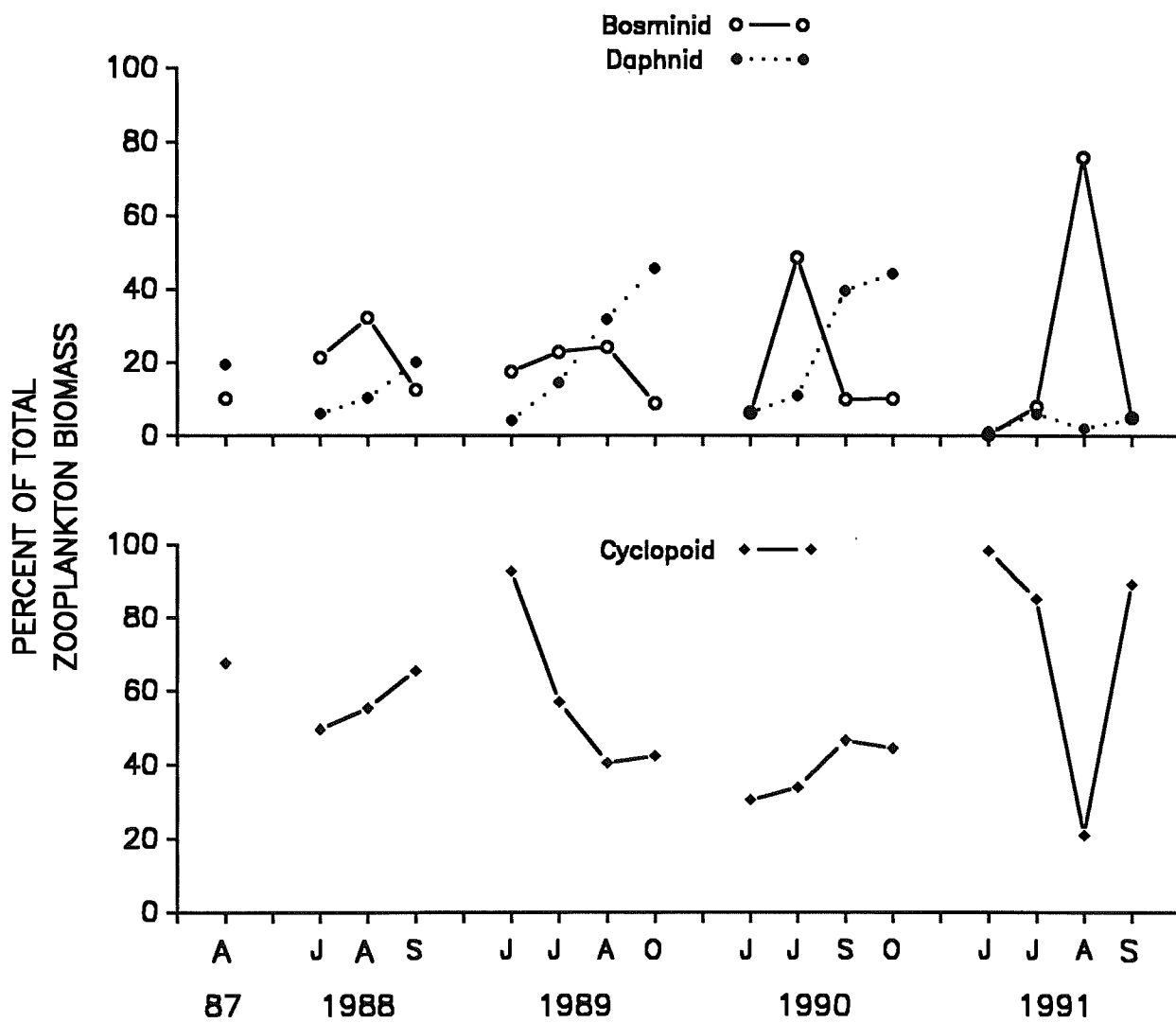


Figure 17. Proportional contribution of bosminids, daphnids and cyclopoids (diaptomids not observed) to the total zooplankton biomass in Tatsamenie Lake.

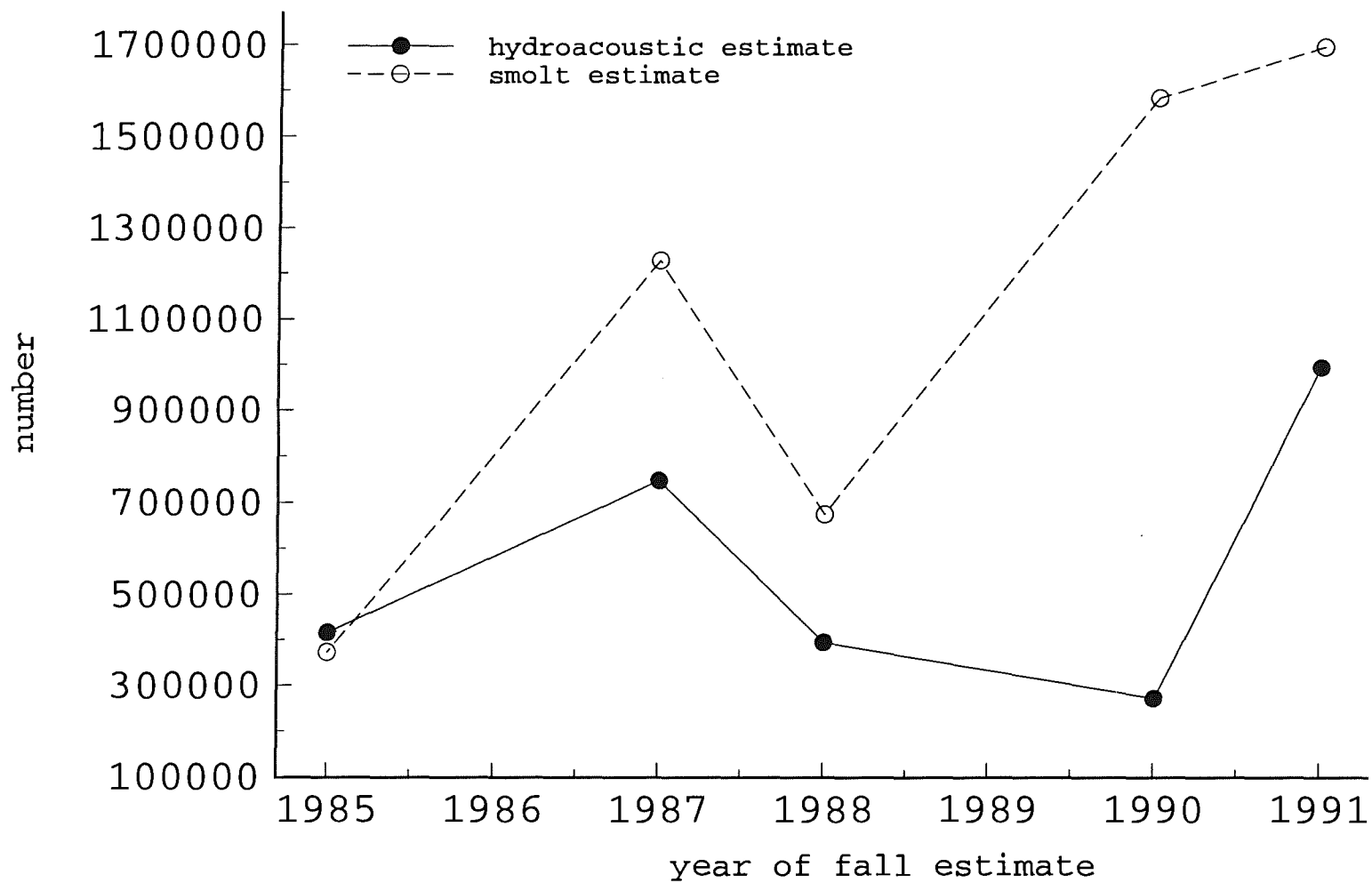
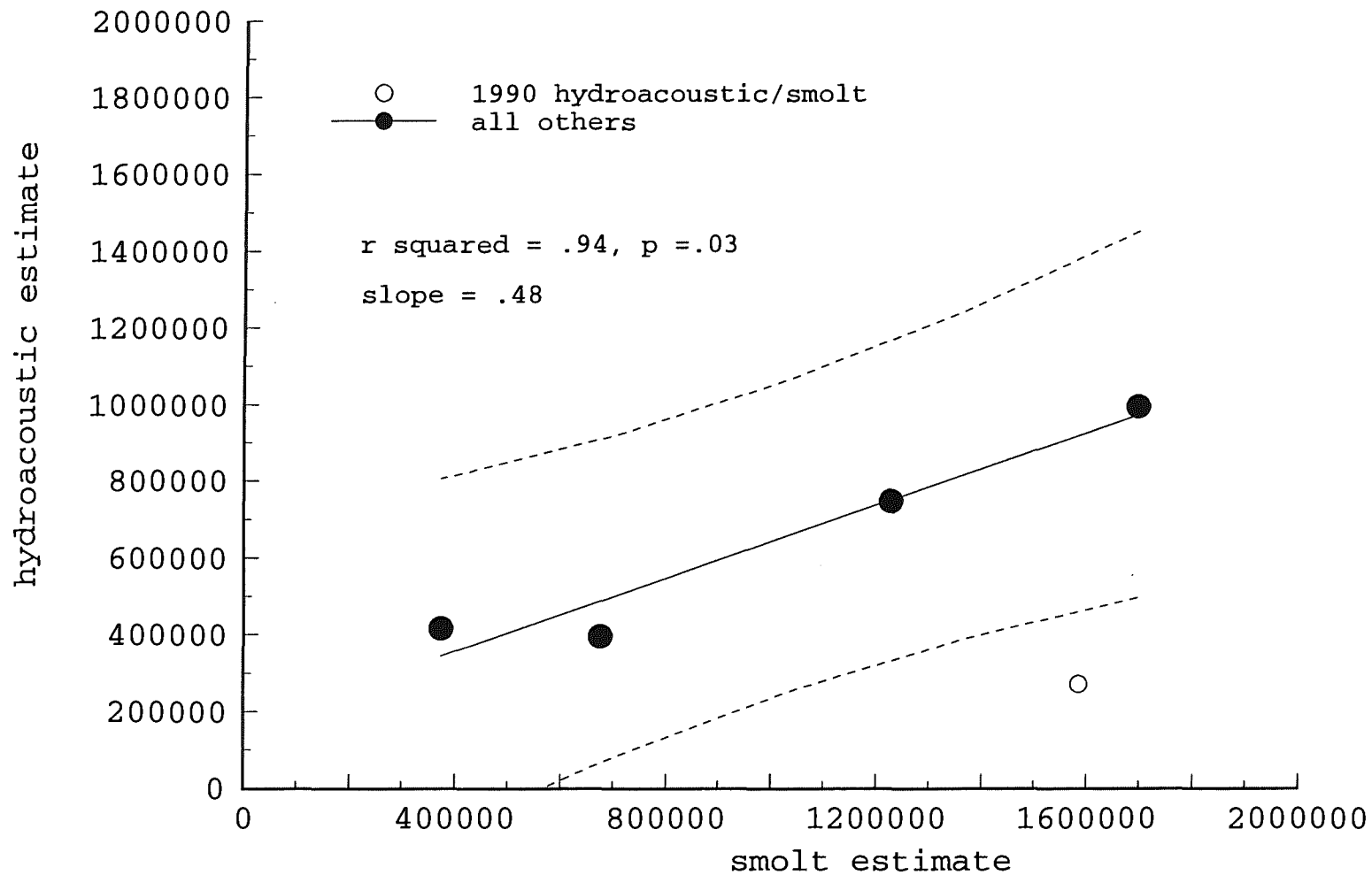


Figure 18. Comparison between fall hydroacoustic estimates (all ages) and associated smolt estimates (all ages) at Tahltan Lake.



Note: values include fish of all ages,  
both wild and enhanced.

Figure 19. Regression between Tahltan Lake fall hydroacoustic juvenile estimates and associated smolt estimates. The regression is based on the hydroacoustic estimates from 1985, 1987, 1988, and 1991; the 1990 estimate is excluded.



## **TABLES**

Table 1. Summary of results of Tahltan outplant projects, egg-take to outplanted fry stage.

Brood-year	# eggs <sup>a</sup> taken (K's)	# fry planted (K's)	percent fertil- ized	Survival	
				fertil- ized egg to planted fry	green-egg to planted fry
1989 <sup>b</sup>	2,955 (3M)	1,042	69 %	51 %	35 %
1990	4,511 (5M)	3,585	82 %	98 %	79 %
1991	4,245 <sup>c</sup> (5-6M)	1,414	95 %	76 %	72 %
1989-1991 average			82 %	82 %	69 %

<sup>a</sup> Egg-take targets are shown in parentheses

<sup>b</sup> The values given here for BY 1989 differ slightly from those reported previously (PSC 1991) as a result of minor corrections to the data.

<sup>c</sup> This value includes eggs taken for outplants to both Tahltan and Tuya lakes; eggs are divided at the eyed stage and percent fertilized is therefore the same for both groups.

Table 2. Summary of survival of fry outplanted to Tahltan Lake.

Fry planted (year)	Abundance				Survival from outplanted fry				
	Age 0+ Fall Juvenile (Year)	Age 1+ Fall Juvenile (Year)	Age 1 Smolts (Year)	Age 2 Smolts (Year)	to 0+ Fall Fry	to 1+ Fall Fry	to Age 1 Smolt	to Age 2 Smolt	Total Smolt (Age 1+2)
<u>Brood- year 1989</u>									
1042 K (1990)	no data (1990)	6,224 (1991)	266,868 (1991)	31,542 (1992)	no data	data invalid <sup>a</sup>	25.6%	3.03%	28.6%
<u>Brood-year 1990</u>									
3,585 K (1991)	479,286 (1991)	N/A (1992)	772,782 (1992)	N/A (1993)	13.4% <sup>a</sup>		21.6%		
<u>Average, Brood-years 1989 &amp; 90</u>									
							23.6%		

<sup>a</sup> see Discussion section for summary of problems associated with estimates of fall fry abundance.

Table 3. Numbers captured and lengths, weights, and proportions of enhanced fish in samples of sockeye salmon juveniles from surveys of Tahltan Lake during the summer and fall of 1991. <sup>a</sup>

Trawl				Beachseine		
	Enhanced	Wild	P <sub>enh</sub>	Enhanced	Wild	P <sub>enh</sub>
<u>Trip 1, June 23-24</u>						
Total Catch: No trawling done				Total Index Catch:	1,367	
				Total Sample:	51	
Age 0+ (BY 1990)						
Length				33.9	37.2	0.116
Weight				0.336	0.439	
n				6	45	
Age 1+ (BY 1989)						
Length						
Weight						
n				0	0	
<u>Trip 2, July 10-13</u>						
Total catch:				Total Index Catch:	134	
Total Sample:				Total Sample:	75	
Age 0+ (BY 1990)						
Length				39.2	34.9	0.560
Weight				0.523	0.354	
n	0	0		42	30	
Age 1+ (BY 1989)						
Length				43.7		1.000
Weight				0.747		
n	0	0		3	0	
<u>Trip 3, August 18-19</u>						
Total Catch: No trawling done				Total Index Catch:	2	
				Total Sample:	6 (includes 4 supplemental)	
Age 0+ (BY 1990)						
Length				48.0	61.0	0.833
Weight				0.800	1.560	
n				5	1	
Age 1+ (BY 1989)						
Length						
Weight						
n				0	0	
<u>Trip 4, September 9-13</u>						
Total Catch:				Total Index Catch:	0	
Total Sample:				Total Sample:	0	
Age 0+ (BY 1990)						
Length	63.5	61.3	0.484			
Weight	2.22	2.02				
n	77	82		0	0	
Age 1+ (BY 1989)						
Length	65.0					
Weight	2.79					
n	1	0		0	0	

<sup>a</sup> Beachseine catches for trip 1 were analyzed by stratifying into length categories and selecting subsamples proportional to relative abundance at 10 index sites. Other beachseine and trawl catches were treated as random samples. Total beachseine catches are for index sites only and do not include supplemental catches (see Methods). Measurements are from specimens preserved in 70% isopropyl alcohol and are not directly comparable to fresh measurements. Proportions of enhanced fish may not correspond to the sample sizes shown (n) due to weighting of subsamples and/or unmeasurable fish.

Table 4. Estimated numbers of migrants, lengths (mm), and weights (g) for smolts observed at Tahltan Lake weir in 1991 and 1992.

		1991		1992	
		BY 88	BY 89	BY 89	BY 90
		age 2	age 1	age 2	age 1
Wild	number	111,243	1,105,882	number	66,238
	length	112	90.6	length	110
	weight	11.80	5.82	weight	10.20
Enhanced	number	n/a	266,868	number	31,542
	length	--	88.6	length	115
	weight		5.40	weight	12.00

note: measurements are from fresh (unpreserved ) fish  
age 3 wild smolts not shown (3,272 in 1991; 3,154 in 1992)

Table 5. Summary of sockeye salmon smolt size in Tahltan Lake relative to juvenile abundance during the first year of rearing. Lake enrichment status is listed.

Brood Year (t)	Estimated Total Abundance (1000's) of Juveniles in Spring of Year t+1			Mean Weight (g) of Smolts Originating from BY t				Lake Enrichment Status	
	Age 0+ (BY t)	Age 1+ (BY t-1)	Total	Wild		Enhanced			
				Age 1+ (Year t+2)	Age 2+ (Year t+3)	Age 1+ (Year t+2)	Age 2+ (Year t+3)	(Year t+1)	(Year t+2)
1982	1195	19	1214	4.81	9.31			No	No
1983	1786	154	1940	3.75	8.45			No	No
1984	1350	35	1385	4.71	10.77			No	Yes
1985	2831	184	3015	6.34	12.11			Yes	Yes
1986	3791	165	3956	5.75	15.85			Yes	No
1987	2191	81	2272	6.02	8.97			No	No
1988	2243	133	2376	5.93	11.68			No	No
1989	5048	161	5209	5.82	10.17	5.40	12.0	No	No
1990	6256	142	6398	4.77	N/A	4.63	N/A	No	No

Table 6. Summary of results of Tuya outplant projects, egg-take to outplanted fry stage.

Brood-year	# eggs <sup>a</sup> taken (K's)	# fry planted (K's)	percent fertil- ized	Survival	
				fertil- ized egg to planted fry	green-egg to planted fry
1991	4,245 <sup>b</sup> (5-6M)	1,632	95 %	63 %	60 %

<sup>a</sup> Egg-take targets are shown in parentheses

<sup>b</sup> This value includes eggs taken for outplants to both Tahltan and Tuya lakes; eggs were divided at the eyed stage and percent fertilized is therefore the same for both groups.

Table 7. Summary of results of Trapper outplant projects, egg-take to outplanted fry stage.

Brood-year	# eggs <sup>a</sup> taken (K's)	# fry planted (K's)	percent fertil- ized	Survival	
				fertil- ized egg to planted fry	green- egg to planted fry
1990	2,315 (2.5M)	934	87 %	47 %	41 %
1991	2,953 (3M)	1,811	83 %	73 %	61 %
1990-1991 average	---	---	85 %	60 %	51 %

<sup>a</sup> Egg-take targets are shown in parentheses



Table 8. Numbers captured and lengths, weights, and proportions of enhanced fish in samples of sockeye salmon juveniles from surveys of Trapper Lake during the summer and fall of 1991. <sup>a</sup>

	Trawl			Beachseine		
	Enhanced	Wild	P <sub>enh</sub>	Enhanced	Wild	P <sub>enh</sub>
<u>Trip 1, June 19-20</u>						
Total Catch:	No trawling done			Total Index Catch:	104	
				Total Sample:	35	
Age 0+ (BY 1990)						
Length				28.6	30.0	0.964
Weight				0.101	0.090	
n				34	1	
Age 1+ (BY 1989)						
Length						
Weight						
n				0	0	
<u>Trip 2, July 16-19</u>						
Total Catch:		17		Total Index Catch:	827	
Total Sample:		17		Total Sample:	61	
Age 0+ (BY 1990)						
Length	31.7	43.7	0.412	31.3	34.0	0.971
Weight	0.264	0.674		0.245	0.396	
n	7	10		58	3	
Age 1+ (BY 1989)						
Length						
Weight						
n	0	0		0	0	
<u>Trip 3, August 14-15</u>						
Total Catch:	No trawling done			Total Index Catch:	478	
				Total Sample:	69	
Age 0+ (BY 1990)						
Length				42.7	54.0	0.986
Weight				0.643	1.500	
n				68	1	
Age 1+ (BY 1989)						
Length						
Weight						
n				0	0	
<u>Trip 4, September 16-19</u>						
Total Catch:		30		Total Index Catch:	2	
Total Sample:		30		Total Sample:	0	
Age 0+ (BY 1990)						
Length	54.4	52.1	0.500			
Weight	1.70	1.69				
n	14	14		0	0	
Age 1+ (BY 1989)						
Length		75.5	0.000			
Weight		4.48				
n	0	2		0	0	

<sup>a</sup> Beachseine catches were analyzed by stratifying into length categories and selecting subsamples proportional to relative abundance at 10 index sites. Other beachseine and trawl catches were treated as random samples. Total beachseine catches are for index sites only and do not include supplemental catches (see Methods). Measurements are from specimens preserved in 70% isopropyl alcohol and are not directly comparable to fresh measurements. Proportions of enhanced fish may not correspond to the sample sizes shown (n) due to weighting of subsamples and/or unmeasurable fish.

Table 9. Numbers, lengths (mm), and weights (g) of smolts in a sample of 253 smolts captured leaving Little Trapper Lake in 1992<sup>a</sup>.

		BY 1990 (age 1)	BY 1989 (age 2)
Wild	length	69.8	95.3
	weight	2.90	7.75
	n	179	56
Enhanced	length	69.9	n/a
	weight	2.93	n/a
	n	18	n/a
	Percent enhanced	9.1	n/a

<sup>a</sup> measurements are from fresh (unpreserved) fish  
sampling dates: May 23, June 1, June 3

Table 10. Summary of results of Tatsamenie Lake outplant projects, egg-take to outplanted fry stage.

Brood-year	# eggs <sup>a</sup> taken (K's)	# fry planted (K's)	percent fertil- ized	Survival	
				fertil- ized egg to planted fry	green-egg to planted fry
1990	985 (2.5M)	673	78 %	89 %	69 %
1991	1,360 (1.25- 1.5M)	1,232	93 %	98 %	91 %
1990-1991 average			86 %	94 %	80 %

<sup>a</sup> Egg-take targets are shown in parentheses

Table 11. Numbers captured and lengths, weights, and proportions of enhanced fish in samples of sockeye salmon juveniles from surveys of Tatsamenie Lake during the summer and fall of 1991. <sup>a</sup>

	Trawl			Beachseine		
	Enhanced	Wild	P <sub>enh</sub>	Enhanced	Wild	P <sub>enh</sub>
<u>Trip 1, June 21-22</u>						
	Total Catch: No trawling done			Total Index Catch:		802
				Total Sample:		46
Age 0+ (BY 1990)						
Length					31.6	0.000
Weight					0.180	
n				0	45	
Age 1+ (BY 1989)						
Length						
Weight						
n				0	0	
<u>Trip 2, July 13-16</u>						
	Total Catch:		3	Total Index Catch:		96
	Total Sample:		3	Total Sample:		96
Age 0+ (BY 1990)						
Length	30.3			29.8	32.5	0.154
Weight	0.13			0.122	0.210	
n	3	0		7	89	
Age 1+ (BY 1989)						
Length						
Weight						
n	0	0		0	0	
<u>Trip 3, August 16-17</u>						
	Total Catch: No trawling done			Total Index Catch:		259
				Total Sample:		82
Age 0+ (BY 1990)						
Length				33.2	33.4	0.110
Weight				0.297	0.271	
n				8	74	
Age 1+ (BY 1989)						
Length						
Weight						
n				0	0	
<u>Trip 4, September 13-16</u>						
	Total Catch:		53	Total Index Catch:		0
	Total Sample:		53	Total Sample:		0
Age 0+ (BY 1990)						
Length	43.0	41.8	0.057			
Weight	0.60	0.73				
n	2	47		0	0	
Age 1+ (BY 1989)						
Length						
Weight						
n	0	0		0	0	

<sup>a</sup> Beachseine catches were analyzed by stratifying into length categories and selecting subsamples proportional to relative abundance at 10 index sites. Other beachseine and trawl catches were treated as random samples. Total beachseine catches are for index sites only and do not include supplemental catches (see Methods). Measurements are from specimens preserved in 70% isopropyl alcohol and are not directly comparable to fresh measurements. Proportions of enhanced fish may not correspond to sample sizes (n) shown due to weighting of subsamples and/or unmeasurable fish.

Table 12. Numbers, lengths, (mm), and weights (g) of smolts in a sample of 246 smolts captured leaving Tatsamenie Lake in 1992<sup>a</sup>

		BY 90 (age 1)	BY 89 (age 2)	Unageable
Wild	length	81.0	117.5	85.7
	weight	4.87	14.10	5.96
	n	147	78	7
Enhanced	length	81.6	n/a	-----
	weight	4.99	n/a	-----
	n	14	n/a	0
	Percent enhanced	8.70%	n/a	0

<sup>a</sup> measurements are from fresh (unpreserved) fish  
sampling dates: May 20, May 21, May 26, May 29.

Table 13. Comparisons of Tahltan juvenile sockeye fall hydroacoustic estimates (all ages, wild and enhanced) with subsequent associated smolt weir estimates (all ages, wild and enhanced). July hydroacoustic estimates are also shown.<sup>a</sup>

Survey date	Hydroacoustic estimate and 95% confidence limits	Total associated smolt estimates	Ratio, hydroacoustic to smolt
Oct. 25, 1985	415,992 +/- 94,918	373,259	1.11
Aug. 25, 1987	747,997 +/- 314,188	1,227,501	.61
Aug. 28, 1988	395,020 +/- 182,095	674,705	.59
Jul. 14, 1990	534,377 +/- 146,472	na	na
Oct. 3, 1990	272,330 +/- 77,016	1,584,738	.17
Jul. 11, 1991	848,656 +/-167,999	na	na
Sep. 10, 1991	995,918 +/-182,411	1,695,009	.59

<sup>a</sup> Associated smolt estimates include Age 1 plus Age 2 smolts the following spring, Age 2 smolts two springs following, and Age 3 smolts three springs following. Age 2 smolts for 1993 and Age 3 smolts for 1993 are estimated using observed age structure averages.

## **APPENDICES**

Appendix 1. Summary of thermal marks applied at Snettisham Hatchery to transboundary river sockeye salmon, 1989 to 1991.

Stock	Release Site	Brood	Mark <sup>a</sup>
Tahltan	Tahltan	89	4
		90	3
		91	4
Tahltan	Tuya	91	6
Little Trapper	Trapper	90	5
		91	6
Little Tatsamenie	Tatsamenie	90	3
		91	4

<sup>a</sup> Each mark is comprised of a single band containing the listed number of rings.



## Appendix 2. Broodstock disease screening results for Tahltan, Little Trapper and Little Tatsamenie lakes.

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note: For IHN, a titer  $>10^4$  plaque forming units (pfu) is the point at which the likelihood of vertical (parent to offspring) transmission of IHN is felt to greatly increase.

### **Tahltan Lake**

#### 1990 Brood-year

Disease testing of broodstock showed 9/150 fish positive for BKD (6.0%). Five out of 150 (3.3%) tested positive for IHN; however, none of these had titers  $>10^4$  pfu. The incidences of both diseases were very comparable to those seen in 1989 (TTC 1991) and considerably lower than those seen in natural spawners in the preliminary survey year in 1988 (Transboundary Technical Committee, 1989). This was likely attributable to the 1990 samples having been captured sooner after entering the spawning grounds, thereby reducing stress and the likelihood of horizontal (fish to fish) transmission. Risk of vertical transmission was considered to be very low.

#### 1991 Brood-year

Disease testing of broodstock showed 11/148 fish positive for BKD (7.4%). Of 152 fish tested, 144 (94.7%) tested positive for IHN; 43 of these had titers  $>10^4$  pfu (28.3% of the total sample). The high incidence and high titers of IHN were comparable to those seen in 1988. It was felt the high incidence of IHN was due to the cyclical nature of the virus and/or a result of differences favouring horizontal transmission. The latter appears quite probable since the high escapement in 1991 resulted in large numbers of fish congregating near and competing for the limited spawning grounds, where broodstock is captured and held. It is unlikely the higher incidence was due to differences in methods for capture or holding of broodstock since these were very similar to those of previous years.

### **Little Trapper Lake**

#### 1990 Brood-year

Disease testing of broodstock showed 20/150 fish positive for BKD (13.3%). Incidence of IHN was very high, 146/152 (96.1%); 113 of these had titers  $>10^4$  pfu (74.3% of the total sample). BKD level was much higher than the 3.3% seen in the initial disease survey in 1988. Incidence of IHN was somewhat higher than the 1988 incidence of 86.7% IHN with 44.2% having  $>10^4$  pfu. It was felt the higher incidences were likely due to horizontal transmission resulting from holding large numbers of under stressful conditions for long periods. The possibility of vertical transmission of IHN was considered to be high.

### 1991 Brood-year

Disease testing of broodstock showed 9/150 fish positive for BKD (6.0%); 5 of these had titers  $>10^4$  pfu (3.3% of the total sample). Incidence of IHNV was much lower than in 1990, 20/150 (13.3%). The risk of vertical transmission of IHNV was considered to be minimal. The lower incidence of IHNV could have been attributable in part to the reduced need for sorting of fish due to the availability of more ripe fish from the larger escapement. However, capture and holding techniques employed in 1990 and 1991 were similar and it is also possible the lower incidence may have been attributable simply to an inherent annual variability in virus levels. If so, the similar reduced incidence of IHNV observed in the Little Tatsamenie broodstock in 1991 suggests annual fluctuations might be widespread rather than stock specific.

### **Little Tatsamenie Lake**

#### 1990 Brood-year

Disease testing of broodstock showed 12/150 fish positive for BKD (8.0%). Incidence of IHNV was 96/150 (64.0%), 50 of these having titers  $>10^4$  pfu (33.3% of the total sample). The incidence of both diseases was higher than those seen in the 1988 preliminary survey (0% BKD; 38.5% IHNV with 16% tier  $>10^4$ ). Tatsamenie broodstock is quite green when captured and the higher incidences may have been attributable to the requirement to hold broodstock fish for several weeks to ripen.

#### 1991 Brood-year

Disease testing of broodstock showed 9/150 fish positive for BKD (6.0%). Incidence of IHNV was only 5/150 (3.3%), with none of these having titers  $>10^4$  pfu. Incidence of IHNV was considerably lower than in 1990, possibly a result of lower holding densities and reduced stress. Likelihood of vertical transmission was felt to be very low.

### Appendix 3. Estimates of mortality in Tahltan Lake.

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Mortality rates for fry planted into Tahltan Lake were calculated as follows:

The instantaneous rate of mortality ( $Z$ ) was assumed to decrease monotonically with time ( $t$ ) during lake residence according to the following equation:

$$dN/dt = -Z(t)N$$

where  $Z(t) = Z_0 e^{-ut}$  and  $Z_0$  and  $u$  are parameters to be estimated. Solving this differential equation with the initial condition  $N = N_0$  at  $t = 0$  yields:

$$N_t = N_0 \exp\{-Z_0(1-e^{-ut})/u\} \quad [1]$$

The following expressions were defined:

$N_0$  = number of spring fry planted

$t'$  = time at which half the age 1+ smolts had emigrated

$t''$  = time at which half the age 2+ smolts had emigrated

$a$  = proportion surviving from  $t=0$  to  $t'$

$b$  = proportion surviving from  $t'$  to  $t''$

$p$  = proportion of juveniles not emigrating at  $t'$

(i.e., "holdovers" that smolt at age 2+)

$S_{1+}$  = number of age 1+ smolts at  $t'$

$S_{2+}$  = number of age 2+ smolts at  $t''$

Then, for a single brood year

$$N_t = S_{1+} + S_{2+}/b$$

$$\text{and} \quad N_0 = (S_{1+} + S_{2+}/b)/a$$

Since  $N_0$ ,  $S_{1+}$ , and  $S_{2+}$  are known, and hydroacoustic surveys at time  $t$  provide a direct estimate of  $N_t$  (using age data from trawl samples to separate brood years), it should be possible to estimate the parameters  $Z_0$  and  $u$ , and thus,  $a$  and  $b$ . Unfortunately, hydroacoustic surveys in 1989 and 1990 greatly underestimated fry abundance in Tahltan Lake and were of little use in estimating the mortality parameters. Moreover, since there were complete observations for only one brood year (1989), it was impossible to obtain a unique solution to equation [1]. Nevertheless, the maximum, minimum and "best" estimates for  $u$  (and corresponding values for  $Z_0$ ) consistent with all available fry and smolt data for planted fry from brood years 1989 and 1990 were determined, yielding parameters  $Z_0 = .0420$  and  $u = 0.0244$  as the best estimates (Fig. 5). Since it proved impossible to precisely fit this model, or any other plausible model, to the hydroacoustic estimates of abundance, the best estimate reflects a tradeoff in fitting the curve to hydroacoustic estimates of age 0+ fry abundance (which were clearly underestimated) and age 1+ fry abundance (which appear to be overestimated). The parameters for the model with highest initial mortality are  $u = .0785$  and  $Z_0 = 0.10$ ; those for the model with more constant mortality are  $u = 0.000001$  and  $z_0 = 0.02132$