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**Research Document 2002/124**

**Document de recherche 2002/124**

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# Meziadin Lake biological escapement goal and considerations for increasing yield of sockeye salmon (*Oncorhynchus nerka*)

# Objectif biologique d'échappée et étude de la possibilité d'augmenter la production du stock de saumon rouge (*Oncorhynchus nerka*) dans le lac Meziadin

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ISSN 1480-4883



Canada

## ABSTRACT

Meziadin Lake has historically produced sockeye salmon (*Oncorhynchus nerka*) returns ranging from 145,500 to 1.7 million, and averaged 523,000 total returns with an average escapement of 174,600. Two lake euphotic zone capability models (EV and PR), a Ricker stock-recruit function and fry recruitment analysis indicate that escapements between 155,000 and 185,000 are within the optimal range for the system. Above 200,000 spawners, the probability of returns being less than replacement increases, while at escapements below 150,000, and as low as 50,000, there have been good levels of recruitment. Nass sockeye are currently managed to a total aggregate escapement goal of 200,000. Historically, Meziadin sockeye have comprised between 45% and 95% of this aggregate. Accordingly, this management approach will tend to result in net escapements to Meziadin of between 90,000 and 190,000 sockeye. These escapement levels are within the "safe" limits for ensuring adequate recruitment of Meziadin sockeye. There is some evidence that the yield of sockeye from Meziadin Lake could be increased by increasing fry size and hence, survivals from smolt to adult through a lake fertilization program. However, we recommend that experimental manipulations of lake productivity not be considered further until assessment and management procedures to safe-guard the weaker stocks are developed or the capability to harvest Meziadin sockeye surplus to escapement at terminal locations is developed. Without improved information on the productivity of weaker Nass sockeye stocks, there can be little justification for changing the overall Nass escapement goal of 200,000.



## RÉSUMÉ

La remonte de saumon rouge (*Oncorhynchus nerka*) vers le lac Meziadin a varié au fil des ans entre 145 500 et 1,7 million, et la moyenne annuelle se chiffre à 523 000 saumons, pour une échappée moyenne de 174 600. Deux modèles de capacité de la zone euphotique du lac, une courbe de Ricker du nombre de recrues en fonction de la taille du stock et une analyse du recrutement des alevins montrent qu'une échappée variant entre 155 000 et 185 000 correspond au niveau optimal du système. Si l'échappée dépasse 200 000, la probabilité que la remonte soit inférieure au remplacement augmente, tandis que si elle est inférieure à 150 000, ou aussi basse que 50 000, le taux de recrutement est bon. L'objectif global d'échappée du saumon rouge de la Nass est actuellement fixé à 200 000. Historiquement, le saumon rouge du lac Meziadin a compté pour 45 % à 95 % de ce total. En conséquence, cette méthode de gestion entraînerait des échappées nettes vers le lac Meziadin variant entre 90 000 et 190 000 saumons rouges. Ces valeurs demeurent à l'intérieur des limites visant à assurer un bon recrutement de saumon rouge. Certaines indications laissent croire que la production de saumon rouge pourrait être améliorée en augmentant la taille des alevins et, ainsi, le taux de survie du saumoneau à l'adulte au moyen d'un programme de fertilisation du lac. Nous recommandons cependant que les expériences sur la productivité du lac ne soient pas envisagées avant que des procédures d'évaluation et de gestion pour protéger les stocks les plus faibles soient élaborées ou que la capacité de récolter le saumon rouge en surplus de l'échappée dans les sites terminaux soit développée. Sans de meilleures données sur la productivité des stocks plus faibles de saumons rouge de la Nass, il existe peu de raisons permettant de justifier une modification de l'objectif global d'échappée dans la rivière Nass.

## TABLE OF CONTENTS

ABSTRACT........ 2
LIST OF TABLES........ 4
LIST OF FIGURES........ 4
ACKNOWLEDGEMENTS........ 6
INTRODUCTION........ 7
    Description of Meziadin Lake........ 9
METHODS........ 10
    Lake Limnology........ 10
    Lake Capacity........ 11
    Adult Recruitment........ 11
    Juvenile Recruitment........ 12
        Potential Egg Deposition........ 12
        Juvenile Abundance........ 13
        Fall Fry Biomass........ 14
RESULTS........ 15
    Lake Limnology........ 15
        Water Clarity........ 15
        Temperature........ 15
        Nutrients........ 15
        Phytoplankton........ 16
        Zooplankton........ 16
    Lake Capacity........ 16
    Adult Recruitment........ 16
        Adult Returns per Spawner........ 17
    Juvenile Recruitment........ 17
        Egg Deposition........ 17
        Juvenile Abundance........ 17
        Fresh-water Survival........ 18
        Fry and Smolt Size........ 18
DISCUSSION........ 19
    Biological Escapement Goal........ 19
        Lake Capacity........ 19
        Adult Recruitment........ 20
        Juvenile Recruitment........ 20
    Options for Increasing Yield........ 21
    Fishery Management Concerns........ 22
SUMMARY OF RECOMMENDATIONS........ 23
REFERENCES........ 24
TABLES
FIGURES

## LIST OF TABLES


Table 1. Catch of Nass River sockeye in Canadian and Alaskan fisheries, 1967-2000.

Table 2. Water temperature and nutrients measured in Meziadin Lake, 1990-1998 brood years.

Table 3. Meziadin zooplankton abundance and biomass estimates for growing season (May-Sept), 1990-1998 brood years.

Table 4. Summary of two sockeye rearing capacity models for Meziadin Lake.

Table 5. Sockeye salmon escapements and harvests for the Nass River aggregate and Meziadin stocks, 1967-2000.

Table 6. Sockeye salmon age compositions for Meziadin stock, 1967-2002.

Table 7. Sockeye salmon escapement, recruitment of adults and returns per spawner for Meziadin stock, brood years 1967-1994.

Table 8. Meziadin Lake sockeye abundance estimates, from spawner to fall fry, 1990-1998 brood years.

Table 9. Juvenile sockeye salmon size and age compositions for Meziadin Lake, 1990-1998 brood years.

Table 10 Comparison of trawl net and inclined plane trap caught sockeye smolts in Meziadin River, 1998 and 1999.


## LIST OF FIGURES


Figure 1. Map of Nass River watershed showing Nisga=a communities and known sockeye salmon spawning areas.

Figure 2. Map of Meziadin Lake and river, showing acoustic transects, limnology sample sites and smolt sampling site.

Figure 3. Seasonal changes in macro-zooplankton composition in Meziadin Lake, 1995-1999 survey years.

Figure 4. Annual sockeye salmon escapements to Meziadin Lake, 1967-2000.

Figure 5. Relationship between estimated total Nass River sockeye escapement and Meziadin Lake sockeye escapement, 1967-2000.

Figure 6. Annual variation in returns per spawner of Meziadin sockeye, 1967-1994 brood years.

Figure 7. Stock-recruitment relationship for Meziadin Lake sockeye salmon, 1967-1994 brood years.

Figure 8. Regression between spawner numbers and returns per spawner for Meziadin Lake sockeye, 1967-1994 brood years.

Figure 9. Vertical distribution of fish densities in Meziadin Lake, September acoustic survey (1994-1998 survey years).

Figure 10. Sockeye salmon escapement of eggs versus fall fry abundance, 1990-1998 brood years.

Figure 11. Egg-to-fall fry (age-0) survival versus spawner abundance, 1990-1998 brood years.

Figure 12. Relationship between September water temperature in Meziadin Lake and egg-to-fall fry survival, 1991-1998 brood years.

Figure 13. Total fall fry abundance and fall fry biomass, 1993-1998 brood years.

Figure 14. Sockeye age-0 fall fry weight and age-1 smolt weight, 1990-1998 brood years.

Figure 15. Relationship between Age-0 fall fry weight and mean seasonal (May-Sept) zooplankton biomass, 1991-1998 brood years.

**ACKNOWLEDGEMENTS**

The authors would like to acknowledge the contributions of many people who have contributed data or assisted in the collection of data used in this analysis.  For the period 1991-1993, we gratefully acknowledge the contributions of Karen Cooper, Kevin McCreight, Al Hirst, Scott Murdoch, Mark Johannes, Paul Rankin and Kim Hyatt.  For the period 1994-2000, we appreciate the contributions of Vincent Johnson, Leonard Squires, Lawrence Stephens, Cheryl Stephens, Reggie Robinson, Tim Angus, Jerry Clayton, Cecelia Azak, Ben Gonu, Ritchie Gosnell, Alex Watts, Glenn Barner, and Dean Miller.  Brock Stables conducted all acoustical surveys from 1994-1999.  Thanks also to Kim Hyatt and Dennis Rutherford for their review of the manuscript and to Karl English and Bill Gazey for reconstructing the abundance of Nass sockeye.  Special thanks also to Dave Peacock, Harry Nyce and the Nisga'a Lisims Government for their unwavering support of this initiative.  The Government of Canada funded this research as part of the Nisga'a-Canada Aboriginal Fisheries Strategy Agreement.

## INTRODUCTION

The Nass River drainage produces one of the more important sockeye salmon (*Oncorhynchus nerka*) stocks in British Columbia and follows the Fraser, Skeena, and Barkley Sound systems in total production. Meziadin Lake produces the most abundant sockeye salmon stock in the Nass River drainage and the escapement comprises an average of 75% of the total sockeye salmon escapement to the Nass River. Since 1990, the annual catch of Meziadin sockeye has averaged 572,878 fish with a landed value of nearly 10 million dollars. The largest of these catches occurred in the early 1990s.

Returning Nass River sockeye salmon migrate through Southeast Alaska where they are captured in several directed seine and gillnet fisheries. The largest Alaskan harvests of Nass River sockeye occur in net fisheries at Noyes Island and Cape Fox (English et al. 2003). Since 1970, Alaskan fisheries have captured 43.1%, on average, of the total harvest of Nass River sockeye salmon (Table 1). In Canada, commercial seine and gillnet fisheries in Statistical Areas 1, 3, 4 and 5 have captured 49.8%, on average, of the total harvest of Nass River sockeye salmon. Over the same period, British Columbia First Nations (Nisga=a and Gitanyow) harvested 7.1%, on average, of the sockeye salmon in setnet and driftnet fisheries in the ocean and in the Nass River. In 2000, with the implementation of the Nisga=a Final Agreement, the First Nation share of the harvest increased to 22.7%.

With the exception of the terminal commercial fishing area (Area 3-12), much of the commercial fishing effort that harvests Nass River sockeye salmon is managed coincidentally with effort directed at the more abundant Skeena River sockeye salmon. As a result, it has often been difficult for managers to fine-tune Nass River sockeye salmon harvests. Sockeye salmon first enter the Nass River in late May and continue until mid-September. The first Canadian fisheries that harvest Nass River sockeye salmon are usually initiated in the 3rd or 4th weeks of June. Peak weekly catches in the commercial fishery vary from the first to the last week of July, depending in part on the run timing and in part on the pattern of fishing in Alaskan waters.

In addition to Meziadin Lake, there are three other sockeye producing lakes in the Nass River drainage; Damdochax, Fred Wright (Kwinageese), and Bowser. Combined, these three lakes account for most of the remaining sockeye returning to the Nass River. A number of small stream-type populations comprise approximately 1% of the total aggregate stock. The total aggregate stock is managed to an overall escapement goal of 200,000. Protection of the weaker stocks while optimizing harvests of the dominant Meziadin stock is a challenging fishery management issue. Escapements lower than the optimum may result in reduced adult returns while escapements higher than the optimum will result in foregone catch and may result in decreased abundance in future years.

The biological limits to production of Meziadin sockeye have been a subject of discussion among fishery managers for many years. Todd and Dickson (1970) used long-term average harvests for Nass River sockeye salmon to estimate that an escapement of 200,000 fish would be required to produce an average annual harvest of 250,000 fish in the terminal fishing areas. They also estimated that an appropriate spawning level for Meziadin Lake would be 125,000 fish based on the spawning area in relation to lake nursery area for four Nass River sockeye salmon stocks.

A complete limnology assessment of Meziadin Lake was first conducted in 1975 (Graham et al. 1979). The authors of this study concluded that inorganic nitrogen and a low diversity and abundance of zooplankton might limit sockeye salmon production in Meziadin Lake, but they did not examine fisheries data and did not recommend an escapement target. In 1977 and 1978, Meziadin Lake was surveyed as part of a program to evaluate lakes in northern British Columbia as candidates for nutrient enrichment (Stockner and Shortreed 1979; Rankin and Ashton 1980; Simpson et al. 1981). This group of researchers found that Meziadin Lake was a marginal candidate for nutrient treatment because at the time, juvenile growth appeared healthy but there was an infestation by *E. salvelini*. In addition, as Nass River sockeye salmon are intercepted by the Alaskan fishery there was concern that a large proportion of an increase return from enhancement would not benefit the Canadian fishery.

Henderson et al. (1991) examined stock-recruit data for Nass River sockeye salmon using Ricker analysis (Ricker 1958) and concluded that an optimum escapement to Meziadin Lake was 107,000 (range: 97,000 to 114,000). The target escapement for non-Meziadin Lake sockeye salmon was determined to be 65,000 fish. However, this is at the low end of the range of escapements that would be expected when Meziadin comprises only 50% of the total Nass aggregate, given a system-wide target of 200,000 fish.

In 1991, an intensive survey of Nass River drainage sockeye salmon nursery lakes was initiated as part of pre-treaty fisheries research in the Nisga=a Nation traditional territory (Cooper et al.1994ab; Johannes and Hyatt 1994; Johannes et al. 1994 and 1995). Johannes and Hyatt (1994) assessed the carrying capacity of Meziadin Lake based primarily on juvenile sockeye salmon production parameters (i.e., abundance, size, survival) from escapements, and secondly, on limited limnology data. In contrast to Graham et al. (1979), Johannes and Hyatt (1994) suggested that sockeye salmon production was limited by fry recruitment to the lake rather than freshwater production itself. In addition, Johannes and Hyatt (1994) recommended that the point escapement target should be 160,000 adult sockeye salmon (range: 121,000 to 200,000) and that there was little, if any, justification to manage the escapement level in excess of 200,000 fish to Meziadin Lake. However, recognizing the limitations of their data, Johannes and Hyatt (1994) recommended that annual monitoring continue at Meziadin Lake to obtain estimates of fall fry abundance and average smolt size. In 1994, the Nisga=a Tribal Council assumed responsibility for the annual monitoring at Meziadin Lake related to sockeye salmon production.

Since 1995, assessments of Meziadin Lake sockeye have included: escapement counts, fall fry abundance estimates, fall fry size estimates, monthly lake nutrient collections, monthly zooplankton collections and annual smolt size estimates. This paper is a synthesis of all data collected for brood years 1990 to 1998. The primary objectives of the paper are to:

1. Identify the biological escapement goal for Meziadin sockeye;

2. Identify factors limiting production of juvenile sockeye from the lake; and

3. Evaluate the potential for increasing sockeye salmon production at Meziadin Lake.

**Description of Meziadin Lake**

Meziadin Lake (56° 02, N, 129° 15,W) is located 160 km northwest of Prince Rupert, British Columbia (Figure 1). The lake is located at an elevation of 246 m, drains an area of 642 $km^2$, and lies in the Interior Cedar-Hemlock and Englemann Spruce-Subalpine Fir biogeoclimatic zones. The lake has a surface area of 3,606 ha, a mean depth of 57.1 m, a maximum depth of 133.8 m, and a volume of 2,060 $km^3$ (Murdoch et al. 1993). Graham et al. (1979) estimated the water residence time of Meziadin Lake at 2.23 years using a poorly defined extrapolation from the annual Nass River discharge. The outlet of Meziadin Lake is 155 km from tidewater at the mouth of the Nass River.

Historically, access to Meziadin Lake by anadromous fish was severely hindered by Victoria Falls on the Meziadin River (Figure 1). The falls were first suspected to be a hindrance to sockeye salmon when large numbers of un-spawned fish were found dead on the shores of the lower Nass River (McCullagh 1905). High water appears to have made it considerably easier for fish to ascend the falls based on 5 years of observations beginning in 1907 (Hickman 1912). The hindrance of passage due to Victoria Falls likely influenced the run timing and maturation rate of Meziadin Lake sockeye salmon.

A small fishway was constructed at Victoria Falls in 1913 to improve the access to the lake for sockeye salmon (Babcock 1914). In the late 1950s, results from a 3-year tagging project suggested that as much as 38% of the sockeye salmon arriving at Victoria Falls were unsuccessful at ascending the falls and the fishway (Department of Fisheries 1957; 1958; 1959). In 1965, a vertical-slot fishway was constructed to bypass the entire series of falls; the fishway was completed in time for the 1966 return. Along with the fishway, a concrete sill was installed in the river at the lower falls and was designed to create an impassable falls to direct all returning sockeye salmon through the fishway. Beginning in 1966, all fish using the fishway have been enumerated as they pass through counting chutes (Haugan et al. 1989). Sockeye salmon first arrive at the Meziadin River fishway in early July (and continue until the end of September) in very good physiological condition, and spawn in tributaries and shoreline areas from September through November. Sockeye salmon spawn in all major tributaries to Meziadin Lake (Hanna, Tintina and Surprise creeks), in the Meziadin River, and along the lakeshore.

Protein electrophoresis indicated that there is a degree of genetic separation among fish using different spawning areas within Meziadin Lake. Rutherford et al. (1994) found a significant difference in allele frequencies for a single protein (*LDH-B2*; $p < 0.001$) between lakeshore and creek spawners in Meziadin Lake. This is consistent with the observation that fish spawning in the lake are separated in space and time from tributary spawners. In addition, water temperature profiles during winter incubation period are substantially different between the creek and lakeshore (M. Link, unpublished data); a possible reason for divergent adaptation.

Meziadin sockeye have multiple age classes. The dominant age class is 2.2 indicating 1 full year of lake residency followed by 3 years of ocean residency. The next dominant age class is 1.2.

In addition to sockeye salmon, Meziadin Lake supports coho salmon (*O. kisutch*), chinook salmon (*O. tshawytcha*), steelhead (*O. mykiss*), cutthroat (*O. clarki*), and Dolly Varden (*Salvelinus malma*). Occasionally a few hundred pink salmon (*O. gorbuscha*) are counted at the fishway, but the infrequent nature of these observations suggests that pink salmon have not colonized in the Meziadin River system. Other fish species present in the watershed include mountain whitefish (*Prosopium williamsoni*), white sucker (*Catostomus commersoni*), peamouth chub (*Mylocheilus caurinus*), longnose dace (*Rhinichthys cataractae*), redside shiner (*Richardsoni balteatus*), sticklebacks (family Gasterosteidae), and sculpins (family Cottidae).

## METHODS

### Lake Limnology

The Pacific Biological Station conducted limnological sampling from 1991-1993. In 1991, one lake station was sampled at the end of August (Table 2). In 1992, two stations were sampled four times from May to September. In 1993, five stations were sampled from June to September. Methodologies used from 1991 to 1993 are described in Cooper et al. (1994a). During these years, nutrient sampling was limited to total phosphorous and chlorophyll. There was no nutrient sampling conducted in 1994. Limnological sampling from 1995 onwards was conducted at three sites, roughly equidistance throughout the lake (Figure 2). Secchi depths and 10 m temperature profiles were recorded at varying time intervals for each year. Not until 1995, were these data collected consistently for the summer months (June - September). Nutrient data were collected for only a few years. Complete data were only available for 1995, 1998, and 1999 sample years. For these years, nutrients analyzed included: total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorous (SRP), ammonia-N (NH3) and nitrate-N (NO3). Additional water samples were collected in some years for chlorophyll-*a* analysis. All nutrient sampling followed procedures requested by the Department of Fisheries and Oceans West Vancouver and Cultus Lake Salmon Research Laboratories.

From 1991-1993 zooplankton data were collected with a 100 *m* mesh, 0.25 $m^2$ vertical-haul plankton net from a depth of at least 25 m to the surface at between one and five mid lake stations. Complete methods are described in Cooper et al. (1994b) and zooplankton densities and length measures are presented in Rankin and Hyatt (2002). Data from 1991 were not included in the analysis because samples were only collected in August.

No zooplankton samples were collected in 1994. From 1995-1999, zooplankton data were collected with a 100 *m* mesh net that had a diameter of 0.15 m, hauled vertically from a depth of 15-20 m. All zooplankton samples were transferred to 500 ml bottles containing a buffered formalin solution that was topped up with lake water to achieve a 10% formalin solution. Zooplankton were later counted, identified to genus, and measured for body length according to Koenings et al. (1987) and Stallard (1998; 1999). Zooplankton biomass was calculated for all years using regression equations derived from empirical sampling of Alaskan lakes (Koenings et al. 1987 and revised by J. Edmundson, Alaska Dept. of Fish and Game, Soldotna, AK, pers. comm.). The standing crop of macro-zooplankton available for forage by juvenile sockeye was determined by averaging biomass measures for the growing season (May - September).

## Lake Capacity

Shortreed et al. (1999) used a simple sockeye salmon rearing capacity model, the photosynthetic rate (PR) model to estimate rearing capacity for Meziadin Lake. The model is based on a correlation between photosynthetic rate expressed in metric tons of carbon per year and sockeye salmon smolt biomass. For comparison, we applied the empirical relationship between euphotic volume (EV) and sockeye salmon production of Koenings and Burkett (1987) for Alaskan sockeye lakes.

## Adult Recruitment

Total adult returns to Meziadin were reconstructed using catch data from all fisheries and escapement data. Meziadin total returns were determined by the proportion of Meziadin escapement to total Nass escapement, applied to the total return of Nass sockeye.

Catch data for Nass sockeye taken in Canadian and Alaskan commercial fisheries came from sales slip data, separated into Alaskan and Canadian stock origins using scale pattern analyses. For the period of 1982-2000, these data are referenced in English et al. (2003). For the earlier years, the data are from the Department of Fisheries and Oceans stock assessment database (source: Les Jantz, Prince Rupert). Catch data for First Nation fisheries in Canada are from DFO Fishery Officer estimates that were reconstructed for the period 1983-1991 (Bocking et al. 1993). From 1992 to the present, estimates of Nisga'a sockeye harvests have been derived using a comprehensive monitoring program operated by the Nisga'a Tribal Council (now Nisga'a Lisims Government).

Total Nass escapement data for the period 1982-2001 are from English et al. (2003). Escapement data for all other years are from the Department of Fisheries and Oceans stock assessment database (source: Les Jantz, Prince Rupert). Meziadin escapements of sockeye have been consistently determined from direct counts at the Meziadin fishway (Haugan et al. 1989, Southgate 1991). Prior to 1994, total Nass escapements of sockeye were determined by expanding the Meziadin fishway final count by the relative stock proportion of all Nass sockeye using scale pattern analyses from commercial and test fishery catch samples. From 1994-present, total Nass River sockeye escapements were determined using mark-recapture estimates. Sockeye were marked at fishwheels operating in the lower river and recovered at the Meziadin fishway (e.g. Link and English 1996). Escapement estimates of non-Meziadin stocks were derived using a variety of methods including scale pattern analysis, visual counts from helicopters, and stream walks.

Age composition data were collected from adult sockeye passing the Meziadin fishway from 1978 to 2002 (DFO, Prince Rupert). For 1967-1977, we used age composition data from the Canadian commercial fishery.

A Ricker stock-recruit function was used to evaluate total adult returns per spawner from Meziadin Lake for the brood years 1967-1994:

$$R = Se^{a(1-S/b)} \tag{1}$$

where R is the number of recruits (summed across several ages and return years), S is the number of spawners, $a$ is the productivity parameter, and $b$ is the equilibrium stock size in the absence of harvest. The parameters were estimated by least squares regression of the natural logarithm of R/S on S. We estimated an optimum escapement using an iterative search to find where the slope of the stock-recruit function was equal to one. The linear model ($\ln(R/S) = a-bS$) of the Ricker stock-recruit function was used to assess if the regression was significant and whether depensation (positive slope) or compensation (negative slope) is occurring.

## Juvenile Recruitment

### Potential Egg Deposition

When examining the relationship between fall fry abundance and spawners, potential egg deposition may be a more appropriate parameter to use on the recruitment relationship. We determined the total number of eggs available to be deposited in the gravel (i.e. the number of eggs escaping to the lake) from each spawning cohort using Meziadin female lengths and the pooled relationship for Fulton River sockeye (West and Mason 1987):

$$\text{Eggs/Female} = 11.52\text{Length} - 2152 \tag{2}$$

We used both the mean female proportion and the annual observed sex ratios at the Meziadin fishway to determine the total number of eggs available to be deposited each year.

Juvenile Abundance

Juvenile sockeye numbers and size have been determined with hydroacoustic and trawl surveys since 1990 (Johannes et al. 1994 and 1995; Nass et al. 1999; Baxter and Nass 1999; Baxter 2000). All sampling was done during hours of darkness when juvenile sockeye are dispersed within the working range of the acoustic system. Six transects were established in the lake at roughly equidistance and were sampled every year (Figure 2). From 1990 to 1997, the total abundance of fry was determined according to a stratified random sampling design model with vertical stratification (nine depth intervals) and no horizontal stratification. To improve precision of the estimates, a stratified sample design that included horizontal stratification was implemented (Baxter and Nass 1999; Stables and Thorne 1998). The lake was horizontally stratified based on observed abundances of sockeye fry for the period 1990-1997. Three strata (two transects in each) were established. Each transect was sampled three to four times per survey. Except for 1991 and 1992 (brood years 1990 and 1991), all surveys were conducted in late September or early October. In 1991 and 1992, surveys were conducted in late August and early September. Since early studies indicated that recruitment of fry to the lake may continue into late September, data from these two early years may underestimate fry recruitment.

From 1991 to 1993 acoustic surveys were conducted using a 70 kHz Simrad EYM sounder with 75 watts of output power and a constant pulse width of 0.6 ms (Johaness et al. 1995). From 1994 to 1996 acoustics surveys were conducted using a Biosonics 420 kHz dual beam echo sounder. From 1997 to 1999 acoustics surveys were conducted using a Biosonics 420 kHz split beam echo sounder. In all years, echo counting was the signal processing procedure used.

Trawl net sampling was conducted to determine the size and age of juvenile sockeye salmon in Meziadin Lake. A 2 m x 2 m x 7 m variable mesh trawl net was towed behind an outboard powered boat for periods of 15 and 30 min. The trawl net was fished at depths ranging from 10-20 m coinciding with hydro acoustic information of maximum fish densities. Trawl data were used to determine the species, size and age composition of the limnetic fish community. The trawl gear used is clearly size-selective based on the freshwater age composition of returning adult sockeye and downstream migrating smolts (see below). Others have documented trawl-size selectivity (K. Hyatt, DFO, pers. comm.). Juvenile sockeye in Kennedy Lake, BC showed decreasing catchability with increasing size. Because of this bias, we corrected lake acoustic estimates for age-0 fall fry using age composition at the time of smolting.

All sockeye fry captured in the trawl were preserved in 95% ethanol or 3.7% buffered formaldehyde solution and later measured for fork-length and weight. Scale smears were taken for later ageing. Scale samples were interpreted by Birkenhead Scale Analysis (Lone Butte, BC) and are reported in European notation where freshwater age-1 sockeye have a single freshwater annulus. Mean length and weights were determined according to procedures described in Baxter and Nass (1999). Because of the size-selective nature of the lake trawl gear (i.e. larger fry are less susceptible to capture, mean lengths and weights for age-0 fall fry may underestimate the true size. However, this bias should be consistent from year to year because the data was collected in late September of each year. The notable exception to this is the 1991 sample year when samples were collected in late August. However, in 1992, when samples were collected on 7 August and 7 September, there was only a 5 mm increase (from 45 mm to 50 mm) in mean length over this 30-day period. Growth rates of juvenile sockeye in late summer and early fall likely slow considerably. Consistent sampling time for acoustic and trawl surveys in Meziadin Lake (i.e. late September or early October) are critical to allow for continued interannual comparisons.

From 1994-1997, sockeye smolts were captured during their downstream migration using a 2 m x 2 m x 7 m variable mesh trawl, located approximately 1 km upstream of the river mouth. Sampling effort consisted of several one or two-day trapping sessions, scheduled to cover the majority of the smolt migration period (May-June).

Sockeye smolts were anaesthetized in a tricaine methanosulfanate (MS-222) solution and measured for fork length and weight. Age composition was determined following the stratified method of Ketchen (Ricker 1958). Scale samples were interpreted by Birkenhead Scale Analysis (Lone Butte, BC).

Nass et al. (1999) raised concerns of juvenile size and age selectivity in the trawl sampling gear as the age composition of sampled age-1 smolts was > 90% compared to < 80% age-1 smolts based on adult return age data. In 1998, (brood year 1996) an inclined plane trap (IPT) was used to capture sockeye salmon smolts in addition to the traditional trawl net. Baxter and Nass (1999) showed that smolts captured in the IPT were significantly larger ($p < 0.05$) than those captured in the trawl net. The IPT provides a more representative age sample of the population, and previous year's estimates of smolt size are likely biased low and age compositions derived from the trawl sample are biased toward underestimating the proportion of age-2 smolts (Baxter 2000).

We used brood year adult return age data collected at the Meziadin fishway to estimate the age composition of fall fry for brood years 1990 to 1996. Because adult return age composition data were not available for all age classes arising from brood years 1997 and 1998 (some fish will return in 2003 and 2004), we used the age composition from smolt sampling of these brood year fish to estimate the fall fry abundance for those two brood years.

<u>Fall Fry Biomass</u>

Fall fry biomass was estimated by summing the biomass for Age-0 fry and Age-1 fry. Because size information was unavailable for Age-1 fall fry, we estimated the weight of Age-1 fry using the year-specific growth rate for Age-0 fall fry to Age-1 smolts and back-calculating Age-1 fall fry weight from Age-2 smolt weight (data available for brood years 1993-1998 only). This method assumes that Age-0 fall fry and Age-1 fall fry have similar growth rates to smolting.

## RESULTS

### Lake Limnology

Water Clarity

Based on a seasonal mean secchi depth of 3.8 m, Meziadin Lake is considered a clear-water system with a glacial influence. Most of the glacial silt enters from the north end of the lake from Strohn and Surprise creeks, and none from Hanna and Tintina creeks located mid-lake.

Secchi depth (SD) varied both seasonally and by sample site in 1998 (Baxter and Nass 1999). For example, site 2 had the shallowest and deepest SD (0.8 m in June; 6.8 m in November), but over the season, SD at site 3 was slightly shallower. In addition, the SD was somewhat deeper in the spring and fall, while during the summer (June-August) was relatively shallow. Overall, the SD ranged from 0.8 m to 6.8 m, and averaged 3.5 m. Converting SD to euphotic zone depth (EZD) is possible using the relationship of Koenings and Edmundson (1991). The mean EZD in 1998 was 11.4 m, which equates to an euphotic volume (EV) of 411 x $10^6$ $m^3$ or 411 EV units. The EV volume represents 19% of the total lake volume.

Temperature

Lake temperatures ranged from 5.5 $^{o}$C at 10 m in the spring to 15.9 $^{o}$C at the surface in August of 1998 (Baxter and Nass 1999), which is considered optimal for growth and food conversion efficiency for juvenile sockeye salmon (Brett et al. 1969). Mean September temperatures at 10 m depth ranged from 7.7 $^{o}$C to 11.3 $^{o}$C for 1990 - 1998 brood years (Table 2).

Nutrients

Mean total phosphorus (TP) for the five years of seasonal measurements ranged from 4.8 to 10.2 mg $L^{-1}$ (Table 2), and averaged 7.5 mg $L^{-1}$. Soluble reactive phosphorus (SRP) ranged from 0.9 to 1.9 mg $L^{-1}$ and averaged 1.3 mg $L^{-1}$, while total dissolved phosphorus (TDP) ranged from 2.6 to 5.8 mg $L^{-1}$ and averaged 4.2 mg $L^{-1}$ for three years of seasonal measurements (1995, 1998 and 1999). During the same three years, nitrate ($NO_3$) concentrations ranged from 98.1 to 121.0 mg $L^{-1}$ and averaged 109.6 mg $L^{-1}$, while ammonia ($NH_3$) ranged from 3.9 to 7.8 mg $L^{-1}$ and averaged 6.5 mg $L^{-1}$. The average TP concentration in Meziadin Lake was slightly higher (7.5 mg $L^{-1}$) than the mean of 6 mg $L^{-1}$ found for sockeye salmon nursery lakes in Alaska (Edmundson and Carlson 1998). Similarly, the mean inorganic nitrogen ($NO_3$ + $NH_3$) concentration in Meziadin Lake of 116 mg $L^{-1}$ was slightly higher than the mean of 100 mg $L^{-1}$ for Alaskan lakes (Edmundson and Carlson 1998).

Meziadin Lake is classified as slightly mesotrophic based on mean total phosphorus (TP) concentration, and ultra-oligotrophic based on inorganic nitrogen (IN) (Vollenweider 1971). Graham et al. (1979) reported a mean TP for 1972 and 1975 of 13 mg $L^{-1}$ (compared to a mean of

7.5 *m*g L$^{-1}$ for 1992, 1993, 1995, 1998 and 1999), and an inorganic nitrogen mean of 70 *m*g L$^{-1}$ (compared to a mean of 116 *m*g L$^{-1}$ for 1992, 1993, 1995, 1998 and 1999). Thus, compared to earlier years TP has decreased but inorganic nitrogen has increased. However, the productivity classification is the same in that overall, the lake is oligotrophic, and TP is somewhat in short supply while inorganic nitrogen is considered limiting (algal) production.

<u>Phytoplankton</u>

Seasonal mean algal biomass, as measured by chlorophyll *a* (chl *a*), ranged from 0.5 to 2.4 *m*g L$^{-1}$ and averaged 1.7 *m*g L$^{-1}$ for the five years of measurements. In general, chl *a* concentrations were highest in September (fall turnover). The mean chl *a* in Meziadin Lake was 38% higher than the mean of 1.3 *m*g L$^{-1}$ for sockeye salmon nursery lakes in Alaska (Edmundson and Carlson 1998).

<u>Zooplankton</u>

The macro zooplankton (cladocera and copepoda) community in Meziadin Lake consists mainly of *Daphnia*, *Bosmina*, *Cyclops*, and *Diaptomus* (Rankin and Hyatt 2002; Nass et al. 1999; Baxter and Nass 2000). From brood years 1991 to 1995, *Daphnia* sp. and *Cyclops scutifer* dominated the macro zooplankton community (Table 3; Figure 3). From brood years 1996 to 1998, *Bosmina*, *Cyclops bicuspidatus thomasi* and unidentified (immature) Cyclopoida dominated the composition. Macro zooplankton abundance was typically highest in July and August and declined into September.

**Lake Capacity**

According to the EV model of Koenings and Burkett (1987), Meziadin Lake is capable of producing a maximum of 33,251 kg of smolts, or 9.4 million smolts at an average size of 3.5g (Table 4). This compares to 10.0 million smolts at a size of 4.5 g using the PR model of Shortreed et al. (1999). Assuming a fall fry-to-smolt survival of 70-90%, this suggests that Meziadin Lake is capable of supporting between 10.0 and 14.0 million 3.5 – 4.5 g fall fry.

The PR model of Shortreed et al. (1999) suggests that Meziadin Lake can support an optimum escapement of 185,317 sockeye. Applying the same egg deposition-to-smolt survival of 3.0% to the EV model results, we derived an optimum escapement of 173,974.

**Adult Recruitment**

Sockeye salmon escapement to the Nass River has averaged 236,788 since 1967, while escapement to Meziadin Lake has averaged 174,611 (Table 5). Total sockeye salmon returns (catch plus escapement) for Meziadin Lake have ranged from 145,500 to 1.79 million fish (1967-2000). Escapements have been highly variable over the same period (Figure 4). Age 2.2 sockeye salmon have dominated (mean of 48%) the escapement, followed by age 1.2 fish (mean of 26%; Table 6).

A regression analysis of Meziadin sockeye escapement and total Nass escapement revealed a significant relationship ($R^2 = 0.92$, $p < 0.0001$; Figure 5). This is not surprising given that the total Nass escapement prior to 1994 was determined by expanding the Meziadin fishway count by the relative proportion of all Nass stocks using scale pattern analysis. The data suggests that Meziadin sockeye comprised, on average, 75% of the total Nass stock for the period 1967 - 2000.

Adult Returns per Spawner

For brood years 1967-1994, the returns-per-spawner (R/S) averaged 4.5 and ranged from a low of 0.8 to a high of 18.0 (Table 7). The highest returns-per-spawner were from the 1988 and 1989 brood years. Figure 6 shows the annual variability in returns-per-spawner for Meziadin sockeye. Since 1967, there have been periods of good and poor returns-per-spawner. The most recent period of high yield occurred in the late 1980s and early 1990s, corresponding to a period of relatively favorable marine conditions as evidenced by high marine survival of Skeena sockeye (Wood et al. 1999).

The estimated optimum escapement to Meziadin Lake, based on stock-recruit analysis is 155,825 spawners (Figure 7). The regression of ln(R/S) on S was significant ($R^2 = 0.47$, $p < 0.001$; Figure 8). When the abundance of spawners exceeds 150,000, the probability of below optimal recruitment increases.

## Juvenile Recruitment

Egg Deposition

The proportion of females in the Meziadin escapement was determined for each year from observations at the Meziadin fishway. These proportions ranged from 53% to 67% female. Using equation (2), the estimated number of eggs available to be deposited in the gravel ranged from 278 million to 1,091 million for the period 1990 to 1998 (Table 8). The estimated number of eggs per female ranged from 3,378 to 4,103 over this period.

Juvenile Abundance

Juvenile sockeye in the fall occupy depths from the surface to 25 m, with the majority of acoustic targets found between 10 and 20 m during nighttime surveys (Figure 9). Fall fry sockeye abundance estimates are presented in Table 8. From 1990 to 1998, total fall fry estimates ranged from 2.4 to 10.1 million. Confidence limits ranged from 5% to 55% of the point estimate. This estimate includes both age-0 and age-1 fry. The precision of the acoustic estimates was poorest for the 1990-92 broods because of low replication. In subsequent years, we were able to increase precision by increasing the number of replicate transects (Stables and Thorne 1998).

Age-0 fry dominated (94-100%) the trawl catches of fry in Meziadin Lake during the fall surveys (Table 9). Average fry length and weight ranged from 44 to 58 mm and 0.7 to 2.2 g (Table 9). Based on observed age classes in returning adults, the age composition of the trawl catch is known to be biased toward age-0 fish. For brood years 1990-96, we estimated the proportion of age-0 fry in the lake using freshwater annuli from scales collected from returning adult sockeye at the fishway, by brood year. For 1997-98 brood years, the proportion of age-0 fry was estimated from scale analysis of smolts. Sample sizes for the smolt ageing were 598 and 823 for 1997 and 1998 brood years respectively.

We examined sizes of age-1 and age-2 smolts for both trawl net catches and inclined-plane trap (IPT) catches in 1998 and 1999 (Table 10). Age-2 smolts were significantly larger than age-1 smolts. The trawl net underestimated the percentage of age-2 smolts in the population in both years.

Using the freshwater age composition estimates, we calculated the acoustic estimate of age-0 fall fry (Table 8). The smallest proportion of Age-0 fry was found for the 1997 fall acoustic surveys, when only 62% of the total fall fry population was estimated to be age-1 (recruited from age-0 fry in the previous year). The highest proportion (83%) of Age-0 fry was found from the 1999 fall acoustic surveys.

### Fresh-water Survival

Estimates of egg-to-fall fry survival ranged from 0.22% to 2.1% for brood years 1990 to 1998 (Table 8). We found no relationship between the number of eggs available for deposition and resulting fall fry abundance (Figure 10). However, there was a significant relation between egg-to-fall fry survival and brood year spawner abundance (Figure 11). Egg-to-fry survival decreased exponentially with increasing spawner abundance ($R^2$ = 0.72, p=0.004).

Egg-to-fall fry survival was also highly correlated with September epilimnetic water temperature (10 m depth; Figure 12). This linear regression relationship between these two variables was significant ($R^2$ = 0.60, p=0.02). Employing a polynomial fit to the data improved the relationship to an $R^2$ of 0.80. The relationship between temperature and egg-to-fry survival may be more realistically approximated by the polynomial equation. This relation is consistent with observations elsewhere that growth conversion efficiency for juvenile sockeye peaks at about 11.5 °C (Brett 1971). When combined, spawner abundance and epilimnetic temperature explained over 90% of the variation in egg-to-fall fry survival (adjusted $R^2$ = 0.91, p=0.0003).

### Fry and Smolt Size

Total fall fry biomass was significantly correlated with total fall fry abundance ($R^2$ = 0.74) (Figure 13) and suggests an optimum fall fry abundance of approximately 7 million. This suggests that there may be depensatory factors influencing fry growth with optimum growth occurring at a fall fry population of about 7 million. Above 8.0 million fry, fall fry biomass reduced dramatically.

Age-0 fall fry weight was a good predictor of smolt size ($R^2 = 0.78$, $p = 0.004$; Figure 14). Total fall fry biomass of sockeye may be a better indicator of the magnitude of intra-specific competition (hence reduced weight with abundance) because age-0 and age-1 juveniles will share the same food resource but each age 1 juvenile is the equivalent of multiple age-0 fry in terms of demands they place on the zooplankton forage base (K. Hyatt, DFO, pers. comm.). However, we were unable to test for an association between total fry biomass and age-0 fall fry weight because of the absence of size data for age-1 fall fry.

A linear relation between zooplankton biomass and fall fry weight explained 82% of the variation in fry weight ($R^2 = 0.82$, $p < 0.007$; Figure 15). When a power function was fit to the same variables, 86% of the variation in fry weight was explained by mean seasonal zooplankton biomass and the relation was significant ($R^2 = 0.86$, $p < 0.05$) (Figure 15). It would appear that macro zooplankton abundance is a determinant of fry size in the fall.

## DISCUSSION

### Biological Escapement Goal

#### Lake Capacity

The two lake capacity models we examined suggest that Meziadin Lake is capable of supporting a fall fry population of approximately 10-14 million. This exceeds the abundance of fall fry that has been observed in the lake since 1990 (maximum of 10 million in fall of 1996). The optimum escapement estimates of 174,000 to 185,000 to produce the fall fry population abundances that were derived from the models, are likely biased high. For one, the models assume a single age composition. Since age-1 fry occupy only a portion of the euphotic zone, the models likely overestimate the rearing capacity for age-0 fry. If we assume that only 75% of the euphotic zone is available for age-0 fry (based on the age composition of fry in the fall), then the predicted escapements to fill the lake rearing capacity would be between 125,000 and 135,000. In all likelihood, the appropriate estimate of rearing capacity is somewhere between the two estimates.

Secondly, the egg-to-smolt survival rate of 3% assumed for the EV and PR models is more than double what has been observed, on average, since 1990 (1.25%). For the nine years of data examined, the highest egg deposition-to-fall fry survival measured was 2.1% (Table 8).

Adult Recruitment

The ln(R/S) versus spawners relationship for Meziadin Lake was significant, but the relationship, like many stock-recruitment relationships, is not strong ($R^2 < 0.50$); data points are widely scattered and there are a few influential points (Figure 7). The mean R/S for escapements < 160,000 was two-fold higher than for escapements greater than 160,000 (average of 5.3 compared to 2.3). The highest R/S of 16.6 and 18.0 for brood years 1988 and 1989 (Table 7) resulted from escapements of 116,984 and 50,000 respectively, which are considerably lower than the current goal of 160,000. These findings suggest the historical average escapement of 174,600 (1967-2000), and especially the more recent escapements (mean of 231,700 during the 1990-2000 period) exceeded the optimum level, and that the preferred escapement may be closer to 150,000. The MSY for Meziadin Lake was determined from the Ricker stock-recruit relation to be 155,825 spawners and is slightly lower than that predicted by the two lake euphotic volume models.

Juvenile Recruitment

The population estimates of fall fry (all ages) in many years were similar (6-9 million) for escapements ranging from 100,000 to 200,000 (Table 8; Figure 7). The two lowest fry abundances resulted from brood year escapements of 250,000 and 400,000. The extremely low fall fry abundance off the 1993 brood year suggests that either; 1) the rearing capacity of the lake was exceeded in 1994, or 2) there was poor recruitment of fry to the lake (low egg-to-fry survival). The high abundance of age-1 fry from the 1992 brood and/or a large recruitment of age-0 fry from the 1993 brood may have contributed to reduced survivals of the 1993 brood.

Of the variables examined, spawner abundance and water temperature in September appear to have a significant effect on egg-to-fry survival and it is evident that escapements greater than 200,000 will not necessarily produce larger returns. The relatively low temperatures observed in Meziadin Lake (below optimum forage temperatures) also appear to limit fry production. In four of eight years, lake temperatures were significantly lower than the optimum of 10.5 °C. For the 1993 brood year, low lake temperatures may have also been a contributing factor to the low fry recruitment.

Our data show that total fry biomass declined dramatically when the total fall fry abundance exceeded 8 million (Figure 13). Thus, approximately 7-8 million fall fry (or 6 million age-0 fry based on the average age composition) may be the upper limit before causing a reduction in weight and reduced survival.

Finally, although it was not a significant factor in determining fall fry abundance, macro zooplankton biomass ($mg/m^3$) appears to be a determinant of subsequent fall fry size (Figure 15). Thus, it may be feasible to improve egg-to-fry survival and subsequent smolt size by increasing the biomass of macro zooplankton in the lake through nutrient enrichment.

**Options for Increasing Yield**

We do not know for sure whether limitations on the recruitment to fall fry occur at the spawning stage, egg incubation stage, recruitment to the lake stage, or during lake rearing. However, the data suggest, given current rearing conditions in the lake, that available spawning habitat is not limiting sockeye production beyond the limitations imposed by the lake rearing capacity. The lake capacity models (EV and PR) suggest that the juvenile abundance produced from escapements in the order of 170,000 to 190,000 spawners (less an amount to account for the multiple age structure) are all Meziadin Lake can support. The current available spawning habitat in Hanna and Tintina creeks is approximately 145,000 $m^2$. Assuming a spawning density of 1.5 females per $m^2$, there is sufficient habitat to support approximately 217,500 spawners. This does not include the production capability of lake spawners. Increasing available spawning habitat would not result in higher yields given the rearing limitations of the lake. To increase the production of Meziadin sockeye would therefore likely require increasing the rearing capacity of the lake.

In Alaska and Canada, seasonal nutrient enrichment has produced a sustained increase in primary and secondary production throughout the summer growing season without changing the oligotrophic nature of lakes (Stockner and Shortreed 1985; Stockner 1987; Kyle 1994; Kyle et al. 1997). Increases in the standing stock of macro zooplankton have increased the growth and survival of juvenile sockeye salmon, which results in larger adult returns (Hyatt and Stockner 1985; Kyle 1994; Kyle et al. 1997). Estimating the benefit of nutrient enrichment projects is difficult because the efficacy of nutrient enrichment appears to be lake specific and dependent upon a number of biological (e.g., food web processes, fish densities and behavior, predators, competitors, and plankton structure) and physical (lake morphometry) factors. However, in other oligotrophic sockeye salmon nursery lakes adult production has substantially increased through nutrient enrichment (LeBrasseur et al. 1978; Hyatt and Stockner 1985; Kyle et al. 1997).

The Meziadin Lake data provides evidence of density-dependent responses of fry survival to spawner abundance as well as temperature and macro zooplankton limitations in Meziadin Lake. Thus, at times the lake is not capable of supporting the existing number of juveniles that are offspring from average spawner abundance. Consequently, a nutrient enrichment program would likely be needed to increase the survival of smolts to the adult stage by producing larger size juveniles and smolts. This would not necessarily produce more fall fry. If smolt size could be increased by 10 mm in length, smolt survival would be estimated to increase by 5% (Koenings and Burkett 1987), resulting in greater production.

To test the feasibility of increasing sockeye production through lake enrichment would require experimental fertilization of the lake and assessment of the macro zooplankton and juvenile sockeye response to the nutrient enrichment. It is also recommended that the capacity of the spawning grounds be properly assessed in the field to confirm whether or not spawning ground quantity and/or quality is potentially limiting fry recruitment to the lake.

## Fishery Management Concerns

The feasibility of experimental enrichment of Meziadin Lake to increase smolt productivity cannot be explored without considering the impacts to the Nass River and other stocks in this mixed-stock fishery. There are negative implications to non-Meziadin Lake sockeye salmon stocks (within the Nass watershed) by attempting to achieve a specific target escapement for Meziadin Lake. For example, to achieve an escapement of 125,000 sockeye salmon for Meziadin Lake would have required a harvest rate as high as 94% in 1992 and 1993, and harvest rates > 80% in 7 of the last 32 years. It is improbable that smaller stocks in the Nass River drainage (e.g., Fred Wright Lake, Damdochax Lake) would be able to sustain such high harvest rates.

An important point is that the Nass River fisheries are conducted to meet a Nass River aggregate escapement of 200,000 sockeye salmon (160,000 Meziadin and 40,000 to other stocks). Historically, sockeye salmon returns to the Nass River have comprised 45-95% Meziadin Lake stock. Assuming this range of composition for the Meziadin Lake stock continues, and if management continues to target 200,000 sockeye salmon escapement for the Nass River, we would expect Meziadin Lake escapements to range between 90,000-190,000 sockeye salmon. This range of escapements seems to produce reasonable recruitment of adults.

In years, when the total aggregate escapement target of 200,0000 is exceeded and the proportion of Meziadin sockeye is high (80-90%), resulting escapements to Meziadin may be too high resulting in lower recruitment. Until such time when we can estimate the proportion of the Nass River return comprising Meziadin Lake stock during the early part of the migration (June to early July), we recommend leaving the total Nass River escapement goal at 200,000 fish. Furthermore, biological escapement goals and management goals for non-Meziadin stocks need to be determined before any changes to this aggregate escapement target should be considered. Improving estimates of non-Meziadin stocks remains a high priority to facilitate protection of these weaker stocks while providing maximum harvest opportunities of Meziadin sockeye. Once these tools are developed, fishery managers can make inseason adjustments to harvest levels to ensure that escapements to the weaker stocks are met. Fred Wright Lake in the Kwinageese River system is the best candidate at this time for research. Fred Wright Lake and the lower Kwinageese River now have good road access, which will greatly reduce the costs from previous years.

Finally, it is unlikely that the Nass River fisheries would ever be able to selectively target a more abundant Meziadin stock unless a terminal harvest arrangement is established for the Meziadin River. This would be required to meet the biological escapement goal for Meziadin Lake while maintaining healthy non-Meziadin Lake stocks. The quality of fish is still reasonably good for cannery grade and the fishway provides an effective facility to harvest fish.

## SUMMARY OF RECOMMENDATIONS

1. The current escapement goal of 200,000 sockeye for the total Nass stock should be maintained until further evidence is obtained to refute this goal.
2. The biological escapement goal (MSY) for Meziadin sockeye, as defined on the basis of the Ricker stock recruit function of 155,825 sockeye, is sufficiently close to the current goal of 160,000 to warrant no change at this time; recognizing that the goal could change as additional years of information are obtained or if extreme changes in freshwater productivity occur.
3. Inseason stock discrimination methods should continue to be refined so that the percent Meziadin can be better defined, inseason.
4. Biological escapement goals should be established for non-Meziadin sockeye stocks, commencing with Fred Wright Lake in the Kwinageese system.
5. In brood years of low spawner abundance (<100,000) and high spawner abundance (>300,000), acoustic estimates of fall fry abundance and age composition (from smolt collections) should be obtained to further refine the relationship between spawner abundance and fall fry survival and adult returns.
6. For these same brood year abundance extremes, lake limnology should be measured throughout the growing season to further explain factors affecting fry survival and growth; in particular lake temperature and macro zooplankton biomass.

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# TABLES

Table 1. Catch of Nass River sockeye in Canadian and Alaskan fisheries, 1967-2000.

| | Canadian Native | | Canadian Commercial | | Alaskan Commercial | | Total |
|---|---|---|---|---|---|---|---|
| Year[1,2] | Catch | % of Total | Catch | % of Total | Catch | % of Total | Catch |
| 1967 | | | | | | | 316818 |
| 1968 | | | | | | | 196255 |
| 1969 | | | | | | | 197304 |
| 1970 | 7632 | 5.1% | 90174 | 59.8% | 52982 | 35.1% | 150788 |
| 1971 | 6953 | 3.9% | 84377 | 47.0% | 88200 | 49.1% | 179530 |
| 1972 | 5264 | 2.1% | 115155 | 46.0% | 129737 | 51.9% | 250156 |
| 1973 | 9960 | 1.7% | 431206 | 72.4% | 154201 | 25.9% | 595367 |
| 1974 | 10050 | 2.6% | 268512 | 69.2% | 109367 | 28.2% | 387929 |
| 1975 | 17179 | 14.3% | 72162 | 60.2% | 30435 | 25.4% | 119776 |
| 1976 | 25542 | 9.5% | 133851 | 49.8% | 109423 | 40.7% | 268816 |
| 1977 | 29000 | 5.0% | 355597 | 60.8% | 200270 | 34.2% | 584867 |
| 1978 | 13175 | 3.8% | 173705 | 49.8% | 162231 | 46.5% | 349111 |
| 1979 | 13046 | 5.0% | 92942 | 35.5% | 155734 | 59.5% | 261722 |
| 1980 | 11059 | 4.2% | 62181 | 23.7% | 189076 | 72.1% | 262316 |
| 1981 | 13153 | 3.4% | 202633 | 52.7% | 168719 | 43.9% | 384505 |
| 1982 | 22872 | 4.0% | 389869 | 68.4% | 157232 | 27.6% | 569973 |
| 1983 | 25439 | 6.3% | 212810 | 52.4% | 168012 | 41.4% | 406261 |
| 1984 | 41081 | 12.0% | 157330 | 46.1% | 142598 | 41.8% | 341009 |
| 1985 | 41374 | 9.5% | 211193 | 48.6% | 182201 | 41.9% | 434768 |
| 1986 | 45604 | 10.2% | 118889 | 26.6% | 282035 | 63.2% | 446528 |
| 1987 | 40653 | 11.5% | 161694 | 45.9% | 150267 | 42.6% | 352614 |
| 1988 | 34229 | 14.0% | 68950 | 28.1% | 141793 | 57.9% | 244972 |
| 1989 | 31502 | 6.8% | 203890 | 44.0% | 228167 | 49.2% | 463559 |
| 1990 | 27857 | 9.9% | 80866 | 28.7% | 173465 | 61.5% | 282188 |
| 1991 | 72872 | 11.2% | 345037 | 53.0% | 232807 | 35.8% | 650716 |
| 1992 | 58696 | 4.6% | 840660 | 65.3% | 387905 | 30.1% | 1287261 |
| 1993 | 35434 | 2.2% | 1011969 | 62.7% | 567447 | 35.1% | 1614850 |
| 1994 | 34325 | 6.5% | 245426 | 46.5% | 247670 | 47.0% | 527421 |
| 1995 | 39054 | 4.3% | 550923 | 60.9% | 314933 | 34.8% | 904910 |
| 1996 | 34220 | 4.1% | 441835 | 52.8% | 360863 | 43.1% | 836918 |
| 1997 | 36786 | 4.9% | 286744 | 38.3% | 425219 | 56.8% | 748749 |
| 1998 | 38430 | 8.5% | 141400 | 31.3% | 272096 | 60.2% | 451926 |
| 1999 | 45065 | 7.1% | 389320 | 61.4% | 199451 | 31.5% | 633836 |
| 2000 | 96061 | 22.7% | 239022 | 56.6% | 87556 | 20.7% | 422639 |
| | | | | | | | |
| 1970-79 | 13780 | 5.3% | 181768 | 55.1% | 119258 | 39.7% | 314806 |
| 1980-89 | 30697 | 8.2% | 178944 | 43.7% | 181010 | 48.2% | 390651 |
| 1990-00 | 47164 | 7.8% | 415746 | 50.7% | 297219 | 41.5% | 760129 |
| 1970-00 | 31083 | 7.1% | 263881 | 49.8% | 202326 | 43.1% | 474305 |

[1] Data for 1967 - 1981 from Department of Fisheries and Oceans stock status database, Prince Rupert, BC.

[2] Data for 1982-1995 from English et al. (2003).

Table 2. Water temperature and nutrients measured in Meziadin Lake, 1990-1998 brood years.

| Brood year | Sample year | # of months | # of stations | Depth replicates | Secchi Depth (m) | Nutrient sample depth (m) | September temperature at 1 m (°C) | September temperature at 10 m (°C) | $NO_3$ ($\mu$g L$^{-1}$) | $NH_3$ ($\mu$g L$^{-1}$) | SRP ($\mu$g L$^{-1}$) | TP ($\mu$g L$^{-1}$) | TDP ($\mu$g L$^{-1}$) | IN:TP atomic ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1991 | 1 | 1 | 2 | 3.0 | 1.3 | 10.0 | 7.7 | - | - | - | - | - | - |
| 1991 | 1992 | 4 | 2 | 2 | 3.6 | 10 | 11.0 | 8.2 | - | - | - | 4.8 | - | - |
| 1992 | 1993 | 4 | 5 | 2 | 3.7 | 10 | 12.0 | 8.7 | - | - | - | 10.2 | - | - |
| 1993 | 1994 | | No sampling | | | - | 10.5 | 8.0 | - | - | - | - | - | - |
| 1994 | 1995 | 4 | 3 | 1 | 4.8 | 0 | 13.1 | 11.3 | 98.1 | 7.7 | 0.9 | 8.4 | 2.6 | 27.9 |
| 1995 | 1996 | 6 | 3 | 1 | 4.4 | - | 9.8 | 8.7 | - | - | - | - | - | - |
| 1996 | 1997 | 5 | 3 | 1 | 3.6 | - | 13.1 | 9.8 | - | - | - | - | - | - |
| 1997 | 1998 | 6 | 3 | 1 | 3.6 | 0 | 11.9 | 10.9 | 109.7 | 7.8 | 1.9 | 6.2 | 4.2 | 44.5 |
| 1998 | 1999 | 6 | 3 | 1 | 4.0 | 0 | 13.3 | 9.4 | 121.0 | 3.9 | 1.0 | 7.7 | 5.8 | 36.0 |
| Mean | | | | | | | 11.6 | 9.2 | 109.6 | 6.5 | 1.3 | 7.5 | 4.2 | 36.1 |

Sources: 1991-1993 from Cooper et al. (1994a); 1995-1999 from annual Nisga'a Fisheries Program reports (see reference list).

Table 3. Meziadin zooplankton abundance and biomass estimates for growing season (May-Sept), 1990-1998 brood years.

| Brood | Sample | Macrozooplankton (No./$m^3$) | | | | | Macrozooplankton (mg./$m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| year | year | Daphnia | Bosmina | Calanoida | Cyclopoida | Total | Daphnia | Bosmina | Calanoida | Cyclopoida | Total |
| 1990 | 1991 | - | - | - | - | - | - | - | - | - | - |
| 1991 | 1992 | 1454 | 78 | 24 | 4958 | 6514 | 3.62 | 0.68 | 0.18 | 7.62 | 12.10 |
| 1992 | 1993 | 25 | 235 | 10 | 11097 | 11367 | 0.06 | 1.68 | 0.08 | 11.33 | 13.15 |
| 1993 | 1994 | - | - | - | - | - | - | - | - | - | - |
| 1994 | 1995 | 6274 | 97 | 264 | 8234 | 14869 | 13.63 | 0.13 | 0.93 | 41.73 | 56.43 |
| 1995 | 1996 | 1295 | 63 | 96 | 7264 | 8717 | 4.08 | 0.19 | 0.67 | 14.90 | 19.84 |
| 1996 | 1997 | 31 | 124 | 2 | 2007 | 2164 | 0.17 | 0.74 | 0.00 | 0.47 | 1.38 |
| 1997 | 1998 | 125 | 6952 | 2 | 3439 | 10518 | 0.95 | 8.57 | 0.01 | 4.09 | 13.62 |
| 1998 | 1999 | 1010 | 3397 | 6 | 3762 | 8175 | 2.61 | 4.42 | 0.03 | 5.91 | 12.97 |

Sources: Sample year 1992-93 from Rankin and Hyatt (2002); 1994-98 from annual Nisga'a Fisheries Program reports (see reference list).

Table 4. Summary of two sockeye rearing capacity models for Meziadin Lake.

| EV Model (Koenings and Burkett 1987) | | | PR Model (Shortreed et al. 1999) | | |
|---|---|---|---|---|---|
| EV units | 411 | | $PR_{total}$ | 991 | |
| Maximum Smolts (1,000s) | 9,415 | | Maximum Smolts (1,000s) | 10,029 | |
| Maximum Smolt Biomass (kg) | 33,251 | | Maximum Smolt Biomass (kg) | 45,091 | |
| Smolt Weight (g)[1] | 3.5 | | Smolt Weight (g)[1] | 4.5 | |
| Maximum Egg to Fry Survival | 10% | | Maximum Egg to Fry Survival | 10% | |
| Fall Fry to Smolt Survival[2] | 70% | 90% | Fall Fry to Smolt Survival[2] | 70% | 90% |
| Maximum Fall Fry (1,000s)[3] | 13,450 | 10,461 | Maximum Fall Fry (1,000s)[3] | 14,327 | 11,143 |
| Egg Deposition to Smolt[4] | 3.0% | | Egg Deposition to Smolt[4] | 3.0% | |
| Optimum Escapement[5] | 173,974 | | Optimum Escapement[5] | 185,317 | |

[1] Smolt weight is calculated by dividing maximum smolts by maximum biomass.

[2] Fall fry to smolt survival of 70% is for a typical Alaskan nursery lake at rearing limitation (Koenings and Kyle 1997).

[3] Maximum fall fry abundance is calculated assuming a fall fry-to-smolt survival of 70% and 90%.

[4] Egg deposition-to-smolt survival for PR model is calculated from predicted optimum escapement value; egg deposition-to-smolt survival for EV model is assumed to be the same as for PR model.

[5] Optimum escapement for PR model is predicted ($187PR_{total}$); optimum escapement for EV model is calculated using egg deposition-to-smolt survival.

Table 5. Sockeye salmon escapements and harvests for the Nass River aggregate and Meziadin stocks, 1967-2000.

| Year | Total Nass Escapement[1] | Total Nass Catch[2] | Total Nass Return | Meziadin Escapement[3] | Total Meziadin Catch[4] | Total Meziadin Brood Year Return[5] | Meziadin Harvest Rate (%) |
|---|---|---|---|---|---|---|---|
| 1967 | 79,278 | 316,818 | 396,096 | 41,278 | 164,959 | 206,237 | 80.0 |
| 1968 | 94,805 | 196,255 | 291,060 | 71,730 | 148,488 | 220,218 | 67.4 |
| 1969 | 179,228 | 197,304 | 376,532 | 135,328 | 148,976 | 284,304 | 52.4 |
| 1970 | 113,953 | 150,788 | 264,741 | 77,078 | 101,993 | 179,071 | 57.0 |
| 1971 | 246,774 | 179,530 | 426,304 | 191,674 | 139,444 | 331,118 | 42.1 |
| 1972 | 177,216 | 250,156 | 427,372 | 129,525 | 182,836 | 312,361 | 58.5 |
| 1973 | 284,082 | 595,367 | 879,449 | 234,627 | 491,721 | 726,348 | 67.7 |
| 1974 | 193,203 | 387,929 | 581,132 | 165,259 | 331,821 | 497,080 | 66.8 |
| 1975 | 70,874 | 119,776 | 190,650 | 54,095 | 91,420 | 145,515 | 62.8 |
| 1976 | 142,805 | 268,816 | 411,621 | 102,430 | 192,814 | 295,244 | 65.3 |
| 1977 | 399,821 | 584,867 | 984,688 | 242,351 | 354,516 | 596,867 | 59.4 |
| 1978 | 147,218 | 349,111 | 496,329 | 111,018 | 263,267 | 374,285 | 70.3 |
| 1979 | 212,890 | 261,722 | 474,612 | 200,000 | 245,875 | 445,875 | 55.1 |
| 1980 | 155,265 | 262,316 | 417,581 | 142,000 | 239,905 | 381,905 | 62.8 |
| 1981 | 255,643 | 384,505 | 640,148 | 214,193 | 322,161 | 536,354 | 60.1 |
| 1982 | 350,008 | 569,973 | 919,981 | 250,000 | 407,114 | 657,114 | 62.0 |
| 1983 | 209,432 | 406,261 | 615,693 | 170,000 | 329,770 | 499,770 | 66.0 |
| 1984 | 201,970 | 341,009 | 542,979 | 140,000 | 236,378 | 376,378 | 62.8 |
| 1985 | 407,042 | 434,768 | 841,810 | 288,663 | 308,326 | 596,989 | 51.6 |
| 1986 | 213,695 | 446,528 | 660,223 | 115,543 | 241,434 | 356,977 | 67.6 |
| 1987 | 210,166 | 352,614 | 562,780 | 143,989 | 241,583 | 385,572 | 62.7 |
| 1988 | 155,793 | 244,972 | 400,765 | 116,984 | 183,948 | 300,932 | 61.1 |
| 1989 | 127,418 | 463,559 | 590,977 | 50,000 | 181,905 | 231,905 | 78.4 |
| 1990 | 177,461 | 282,188 | 459,649 | 120,954 | 192,334 | 313,288 | 61.4 |
| 1991 | 308,716 | 650,716 | 959,432 | 250,000 | 526,954 | 776,954 | 67.8 |
| 1992 | 672,844 | 1,287,261 | 1,960,105 | 592,118 | 1,132,819 | 1,724,937 | 65.7 |
| 1993 | 538,263 | 1,614,850 | 2,153,113 | 400,000 | 1,200,045 | 1,600,045 | 75.0 |
| 1994 | 310,044 | 527,421 | 837,465 | 158,010 | 268,793 | 426,803 | 63.0 |
| 1995 | 264,689 | 904,910 | 1,169,599 | 205,853 | 703,763 | 909,616 | 77.4 |
| 1996 | 217,909 | 836,918 | 1,054,827 | 182,082 | 699,318 | 881,400 | 79.3 |
| 1997 | 250,460 | 748,749 | 999,209 | 158,687 | 474,394 | 633,081 | 74.9 |
| 1998 | 266,463 | 451,926 | 718,389 | 163,925 | 278,020 | 441,945 | 62.9 |
| 1999 | 210,959 | 633,836 | 844,795 | 180,350 | 541,870 | 722,220 | 75.0 |
| 2000 | 204,408 | 422,639 | 627,047 | 137,042 | 283,351 | 420,393 | 67.4 |
| Mean (67-79) | 180,165 | 296,803 | 476,968 | 135,107 | 219,856 | 354,963 | 61.8 |
| Mean (80-89) | 228,643 | 390,651 | 619,294 | 163,137 | 269,252 | 432,390 | 63.5 |
| Mean (90-00) | 311,111 | 760,129 | 1,071,239 | 231,729 | 572,878 | 804,608 | 70.0 |
| Mean (67-00) | 236,788 | 474,305 | 711,093 | 174,611 | 348,598 | 523,209 | 65.0 |

[1] Nass escapement numbers for 1982-1995 are from English et al. (2003); data for other years from DFO stock status database, Prince Rupert, BC.

[2] Nass catch numbers for 1982-95 are from English et al. (2003); data for other years from DFO stock status database, Prince Rupert, BC. Native catch for 1993-95 includes ESSR catches not previously reported in English et al. (2003).

[3] Meziadin escapement numbers are from DFO stock status database, Prince Rupert, BC.

[4] Meziadin catch is total Meziadin return minus escapement.

[5] Meziadin total return is calculated as the ratio of Meziadin escapement to total Nass escapement times the total Nass return.

Table 6. Sockeye salmon age compositions for Meziadin stock, 1967-2002.

| | Brood Year Age Class (%)[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0.2 (31) | 1.1 (32) | 0.3 (41) | 1.2 (42) | 2.1 (43) | 1.3 (52) | 2.2 (53) | 1.4 (62) | 2.3 (63) | Other |
| 1967 | 0.0 | 0.0 | 0.0 | 59.4 | 0.0 | 10.2 | 23.3 | 0.0 | 5.5 | 1.6 |
| 1968 | 0.0 | 0.0 | 0.0 | 11.9 | 0.0 | 17.2 | 55.5 | 0.0 | 2.2 | 13.2 |
| 1969 | 0.0 | 0.0 | 0.0 | 46.4 | 0.0 | 9.6 | 36.6 | 0.0 | 5.5 | 1.9 |
| 1970 | 0.0 | 0.0 | 0.0 | 23.7 | 0.0 | 12.2 | 58.0 | 0.0 | 4.8 | 1.3 |
| 1971 | 0.0 | 0.0 | 0.0 | 30.1 | 0.0 | 10.5 | 55.1 | 0.0 | 2.8 | 1.5 |
| 1972 | 0.0 | 0.0 | 0.0 | 18.3 | 0.0 | 15.8 | 46.3 | 0.0 | 15.4 | 4.2 |
| 1973 | 0.0 | 0.0 | 0.0 | 42.7 | 0.0 | 6.6 | 46.1 | 0.0 | 2.6 | 2.0 |
| 1974 | 0.0 | 0.0 | 0.0 | 7.3 | 0.0 | 31.7 | 48.4 | 0.0 | 12.5 | 0.1 |
| 1975 | 0.0 | 0.0 | 0.0 | 22.2 | 0.0 | 7.7 | 63.1 | 0.0 | 4.6 | 2.4 |
| 1976 | 0.0 | 0.0 | 0.0 | 25.1 | 0.0 | 9.0 | 59.2 | 0.0 | 3.7 | 3.0 |
| 1977 | 0.0 | 0.0 | 0.0 | 28.6 | 0.0 | 19.4 | 44.8 | 0.0 | 4.6 | 2.6 |
| 1978 | 0.0 | 0.0 | 0.0 | 7.1 | 0.3 | 11.6 | 61.9 | 0.0 | 19.1 | 0.0 |
| 1979 | 0.0 | 0.2 | 0.0 | 10.9 | 1.7 | 3.5 | 79.8 | 0.0 | 4.0 | 0.0 |
| 1980 | 0.0 | 0.0 | 0.0 | 16.9 | 0.1 | 5.0 | 71.6 | 0.0 | 6.4 | 0.0 |
| 1981 | 0.0 | 0.0 | 0.0 | 37.2 | 0.0 | 1.0 | 59.4 | 0.0 | 2.4 | 0.0 |
| 1982 | 0.0 | 0.0 | 0.0 | 8.3 | 0.1 | 32.0 | 52.6 | 0.0 | 7.0 | 0.0 |
| 1983 | 0.0 | 0.2 | 0.0 | 27.8 | 0.3 | 9.4 | 51.2 | 0.0 | 11.0 | 0.0 |
| 1984 | 0.0 | 0.0 | 0.0 | 10.5 | 0.2 | 20.6 | 52.2 | 0.0 | 16.5 | 0.0 |
| 1985 | 0.0 | 0.0 | 0.0 | 36.4 | 0.0 | 9.4 | 39.7 | 0.0 | 14.4 | 0.0 |
| 1986 | 0.0 | 0.0 | 0.0 | 13.3 | 0.0 | 29.4 | 35.0 | 0.1 | 22.3 | 0.0 |
| 1987 | 0.0 | 0.0 | 0.0 | 13.0 | 0.0 | 19.5 | 57.8 | 0.0 | 9.7 | 0.0 |
| 1988 | 0.0 | 0.0 | 0.0 | 12.9 | 0.7 | 12.4 | 66.0 | 0.2 | 7.8 | 0.0 |
| 1989 | 0.0 | 0.0 | 0.0 | 19.7 | 0.0 | 29.2 | 18.2 | 0.0 | 32.9 | 0.0 |
| 1990 | 0.1 | 0.0 | 0.0 | 19.5 | 0.0 | 10.8 | 56.3 | 0.1 | 13.2 | 0.0 |
| 1991 | 0.0 | 0.0 | 0.0 | 49.2 | 0.1 | 11.5 | 33.9 | 0.0 | 5.3 | 0.0 |
| 1992 | 0.0 | 0.0 | 0.0 | 53.4 | 0.0 | 9.9 | 32.3 | 0.0 | 4.3 | 0.0 |
| 1993 | 0.0 | 0.0 | 0.1 | 31.9 | 0.0 | 16.3 | 44.2 | 0.0 | 7.6 | 0.0 |
| 1994 | 0.0 | 0.1 | 0.0 | 11.4 | 0.5 | 36.0 | 39.7 | 0.1 | 12.2 | 0.0 |
| 1995 | 0.0 | 0.0 | 0.0 | 51.3 | 0.0 | 5.9 | 35.6 | 0.0 | 7.2 | 0.0 |
| 1996 | 0.0 | 0.0 | 0.0 | 7.2 | 0.0 | 28.5 | 58.4 | 0.0 | 6.0 | 0.0 |
| 1997 | 0.0 | 0.0 | 0.1 | 29.9 | 0.1 | 10.8 | 42.7 | 0.1 | 15.9 | 0.0 |
| 1998 | 0.0 | 0.0 | 0.0 | 21.8 | 0.6 | 15.7 | 52.4 | 0.0 | 9.4 | 0.0 |
| 1999 | 0.0 | 0.0 | 0.0 | 30.6 | 0.2 | 12.1 | 51.2 | 0.0 | 5.9 | 0.0 |
| 2000 | 0.0 | 0.0 | 0.0 | 23.0 | 0.0 | 13.8 | 36.2 | 0.0 | 26.9 | 0.0 |
| 2001 | 0.0 | 0.1 | 0.1 | 27.8 | 0.3 | 19.7 | 20.2 | 0.0 | 31.7 | 0.0 |
| 2002 | 0.0 | 0.1 | 0.0 | 45.9 | 0.0 | 7.1 | 43.8 | 0.0 | 3.1 | 0.0 |
| Mean (67-79) | 0.00 | 0.01 | 0.00 | 25.67 | 0.15 | 12.69 | 52.16 | 0.00 | 6.72 | 2.60 |
| Mean (80-89) | 0.00 | 0.03 | 0.00 | 19.60 | 0.13 | 16.80 | 50.39 | 0.03 | 13.02 | 0.00 |
| Mean (90-02) | 0.01 | 0.02 | 0.02 | 31.01 | 0.13 | 15.24 | 42.07 | 0.02 | 11.44 | 0.00 |
| Mean (67-02) | 0.00 | 0.02 | 0.01 | 25.91 | 0.14 | 14.75 | 48.03 | 0.01 | 10.18 | 0.94 |

[1] Age composition is from scale ageing of samples taken at fishway except for 1967-1977 when ageing data came from commercial fishery.

Table 7. Sockeye salmon escapement, recruitment of adults and returns per spawner for Meziadin stock, brood years 1967-1994.

| Brood Year | Meziadin Escapement (S) | Recruits from brood year (R)[1] | Spawners from brood year | Yield from brood year | Recruits per Spawner (R/S) |
|---|---|---|---|---|---|
| 1967 | 41,278 | 322,935 | 148,759 | 174,177 | 7.8 |
| 1968 | 71,730 | 512,463 | 171,592 | 340,871 | 7.1 |
| 1969 | 135,328 | 721,898 | 237,285 | 484,613 | 5.3 |
| 1970 | 77,078 | 153,143 | 55,224 | 97,919 | 2.0 |
| 1971 | 191,674 | 268,871 | 95,768 | 173,104 | 1.4 |
| 1972 | 129,525 | 541,454 | 207,497 | 333,957 | 4.2 |
| 1973 | 234,627 | 468,170 | 160,764 | 307,406 | 2.0 |
| 1974 | 165,259 | 423,230 | 183,775 | 239,454 | 2.6 |
| 1975 | 54,095 | 361,270 | 138,973 | 222,296 | 6.7 |
| 1976 | 102,430 | 435,701 | 171,375 | 264,326 | 4.3 |
| 1977 | 242,351 | 810,622 | 309,964 | 500,658 | 3.3 |
| 1978 | 111,018 | 420,402 | 147,201 | 273,201 | 3.8 |
| 1979 | 200,000 | 500,723 | 191,365 | 309,358 | 2.5 |
| 1980 | 142,000 | 414,342 | 182,977 | 231,366 | 2.9 |
| 1981 | 214,193 | 484,788 | 193,551 | 291,237 | 2.3 |
| 1982 | 250,000 | 369,662 | 136,059 | 233,603 | 1.5 |
| 1983 | 170,000 | 362,148 | 126,822 | 235,326 | 2.1 |
| 1984 | 140,000 | 192,456 | 55,661 | 136,795 | 1.4 |
| 1985 | 288,663 | 297,023 | 104,252 | 192,770 | 1.0 |
| 1986 | 115,543 | 488,746 | 162,795 | 325,950 | 4.2 |
| 1987 | 143,989 | 1,233,012 | 403,732 | 829,280 | 8.6 |
| 1988 | 116,984 | 1,940,493 | 577,307 | 1,363,186 | 16.6 |
| 1989 | 50,000 | 898,535 | 262,438 | 636,097 | 18.0 |
| 1990 | 120,954 | 469,557 | 115,148 | 354,409 | 3.9 |
| 1991 | 250,000 | 1,318,375 | 289,162 | 1,029,213 | 5.3 |
| 1992 | 592,118 | 466,682 | 113,316 | 353,366 | 0.8 |
| 1993 | 400,000 | 612,572 | 170,192 | 442,380 | 1.5 |
| 1994 | 158,010 | 682,601 | 187,808 | 494,793 | 4.3 |
| Mean (67-79) | 135,107 | 456,991 | 170,734 | 286,257 | 4.1 |
| Mean (80-89) | 163,137 | 668,120 | 220,559 | 447,561 | 5.9 |
| Mean (90-94) | 304,216 | 709,957 | 175,125 | 534,832 | 3.2 |
| Mean (67-94) | 175,316 | 577,567 | 189,313 | 388,254 | 4.5 |

[1] Reconstructed using age composition and total return to Meziadin.

Table 8. Meziadin Lake sockeye abundance estimates, from spawner to fall fry, 1990-1998 brood years.

| Brood year | Acoustic Survey Date | Spawners (thousands) | Female Proportion[1] | Female Spawners (thousands) | Female PH length (cm)[2] | Number of eggs per female[3] | Total eggs available (millions) | Total fall fry abundance: Hydroacoustic estimate (millions)[4] | Total fall fry abundance: 95% CI (millions) | Age-0 fry abundance: Percent age-0[5] | Age-0 fry abundance: Hydroacoustic estimate (millions) | Survival[6] (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 30-Aug-91 | 121 | 67% | 81 | 485 | 3435 | 278 | 6.4 | 2.5 | 78% | 5.0 | 1.79 |
| 1991 | 7-Sep-92 | 250 | 60% | 150 | 480 | 3378 | 507 | 5.0 | 2.8 | 74% | 3.7 | 0.73 |
| 1992 | 22-Sep-93 | 592 | 54% | 320 | 483 | 3412 | 1091 | 8.9 | 3.2 | 75% | 6.7 | 0.61 |
| 1993 | 26-Sep-94 | 400 | 58% | 232 | 502 | 3636 | 844 | 2.4 | 0.3 | 79% | 1.9 | 0.22 |
| 1994 | 30-Sep-95 | 158 | 59% | 93 | 502 | 3636 | 339 | 7.7 | 0.5 | 70% | 5.4 | 1.58 |
| 1995 | 2-Oct-96 | 206 | 64% | 132 | 501 | 3620 | 477 | 7.2 | 0.7 | 67% | 4.8 | 1.01 |
| 1996 | 22-Sep-97 | 182 | 59% | 107 | 531 | 3965 | 426 | 10.1 | 2.3 | 62% | 6.3 | 1.47 |
| 1997 | 29-Sep-98 | 159 | 64% | 102 | 494 | 3539 | 359 | 9.2 | 0.9 | 75% | 6.9 | 1.92 |
| 1998 | 28-Sep-99 | 164 | 53% | 87 | 543 | 4103 | 357 | 9.0 | 0.4 | 83% | 7.5 | 2.10 |

[1] Sampled from Meziadin fishway.

[2] Sampled from Meziadin fishway.

[3] Female fecundity relation from West and Mason (1987) for Fulton River spawning channel, Babine Lake;
y = 11.52x - 2152 (equation 2)

[4] Acoustic data for 1991-93 are from Johaness et al. (1995); for 1994-99 data are from annual Nisga'a Fisheries reports (see reference list)

[5] 1990-1996 data from adult scale ages, by brood year return; 1997-1998 data from inclined plane trapping of smolts.

[6] Survival was calculated as age-0 fry abundance divided by number of eggs available to be deposited.

Table 9. Juvenile sockeye salmon size and age compositions for Meziadin Lake, 1990-1998 brood years.

| Brood year | Fall fry sample date | Average Age-0 fall fry length [1] (mm) | 0.95 CI [2] | Average Age-0 fall fry weight (g) | 95% CI [2] | Percent Age-0 (%) | Average Age-1 smolt length [3] (mm) | 0.95 CI [2] | Average Age-1 smolt weight (g) | 0.95 CI [2] | Percent Age-1 smolt (trawl) (%) | Percent Age-1 smolt (IPT) (%) | Percent Age-1 smolt (Adult Return) (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 31-Aug | 53.0 | 1.59 | 2.0 | 0.12 | 100 | 79.0 | 0.78 | 4.5 | 0.16 | 93 | | 78 |
| 1991 | 7-Sep | 50.0 | 0.87 | 1.5 | 0.03 | 100 | 77.0 | 0.80 | 4.3 | 0.16 | 93 | | 74 |
| 1992 | 20-23-Sep [b] | 44.0 | 1.10 | 1.0 | 0.12 | 100 | 68.9 | 0.86 | 3.4 | 0.13 | 99 | | 75 |
| 1993 | 27-Sep | 54.7 | 1.06 | 1.9 | 0.11 | 100 | 78.2 | 2.24 | 4.3 | 0.37 | 94 | | 79 |
| 1994 | 30-Sep | 58.3 | 1.05 | 2.2 | 0.11 | 100 | 79.3 | 0.45 | 4.8 | 0.10 | 95 | | 70 |
| 1995 | 2-Oct | 49.7 | 1.24 | 1.5 | 0.16 | 98 | 71.3 | 0.38 | 3.6 | 0.07 | 93 | | 67 |
| 1996 | 23-Sep | 47.7 | 1.10 | 0.7 | 0.09 | 94 | 72.1 | 1.32 | 3.6 | 0.18 | 80 | 49 | 62 |
| 1997 | 30-Sep | 50.6 | 0.90 | 1.2 | 0.08 | 99 | 76.5 | 0.69 | 3.7 | 0.09 | 98 | 75 | |
| 1998 | 30-Sep | 53.1 | 1.27 | 1.4 | 0.11 | 100 | 78.7 | 0.70 | 3.8 | 0.09 | 98 | 83 | |
| Mean | | 51.2 | | 1.5 | | 99 | 75.7 | | 4.0 | | 94 | 69 | 72 |

[1] Fall fry samples collected using mid-water trawl.

[2] 95%CI = t*sqrt(VAR/n)

[3] Smolt samples used on length and weight calculations are from trawl net and include only age-1 fish.

Table 10. Comparison of trawl net and inclined plane caught sockeye smolts in Meziadin River, 1999-1999.

| Sample year | Gear type | Catch (n) | Age-1 smolts length | Age-1 smolts 95% CI | Age-1 smolts weight | Age-1 smolts 95% CI | Age-2 smolts length | Age-2 smolts 95% CI | Age-2 smolts weight | Age-2 smolts 95% CI | Percent Age-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | trawl net | 268 | 72.1 | 1.32 | 3.6 | 0.18 | 90.8 | 1.32 | 6.3 | 0.18 | 79.7 |
| | IPT | 289 | 75.8 | 1.27 | 3.9 | 0.20 | 93.4 | 1.27 | 6.7 | 0.20 | 48.8 |
| 1999 | trawl net | 292 | 76.5 | 0.69 | 3.7 | 0.09 | 85.8 | 0.69 | 4.9 | 0.09 | 97.8 |
| | IPT | 826 | 83.9 | 0.91 | 4.6 | 0.20 | 106.5 | 0.91 | 9.2 | 0.20 | 74.5 |

**FIGURES**

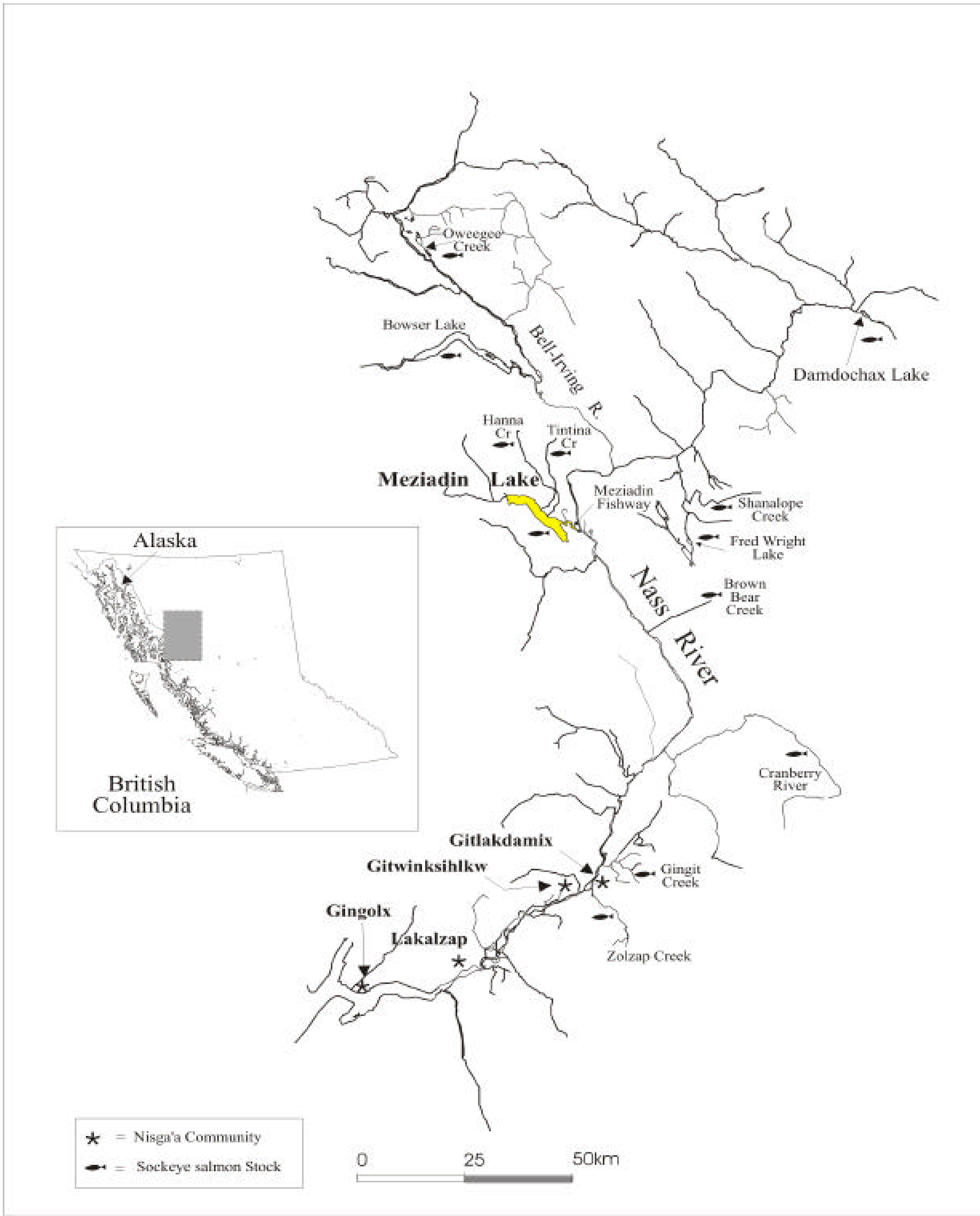


Figure 1. Map of Nass River watershed showing Nisga'a communities and known sockeye salmon spawning areas.

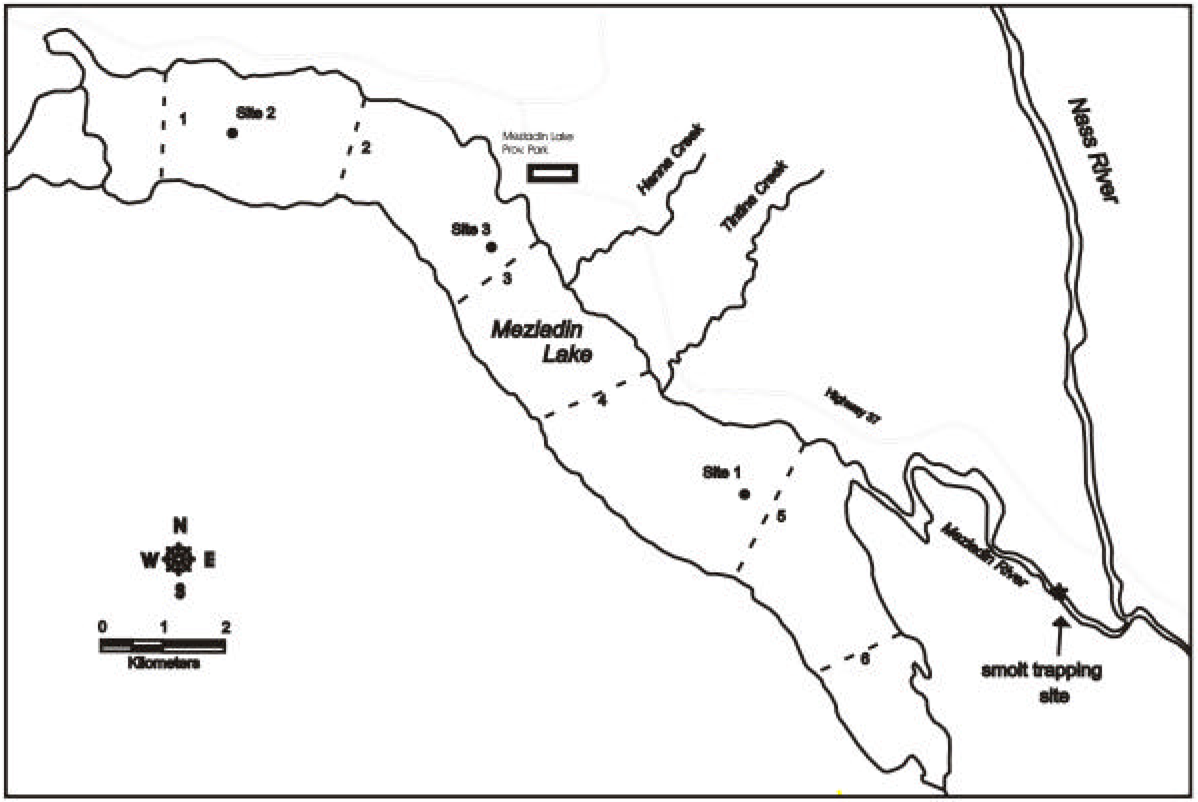


Figure 2. Map of Meziadin Lake and river, showing acoustic transects, limnology sample sites and smolt sampling site.

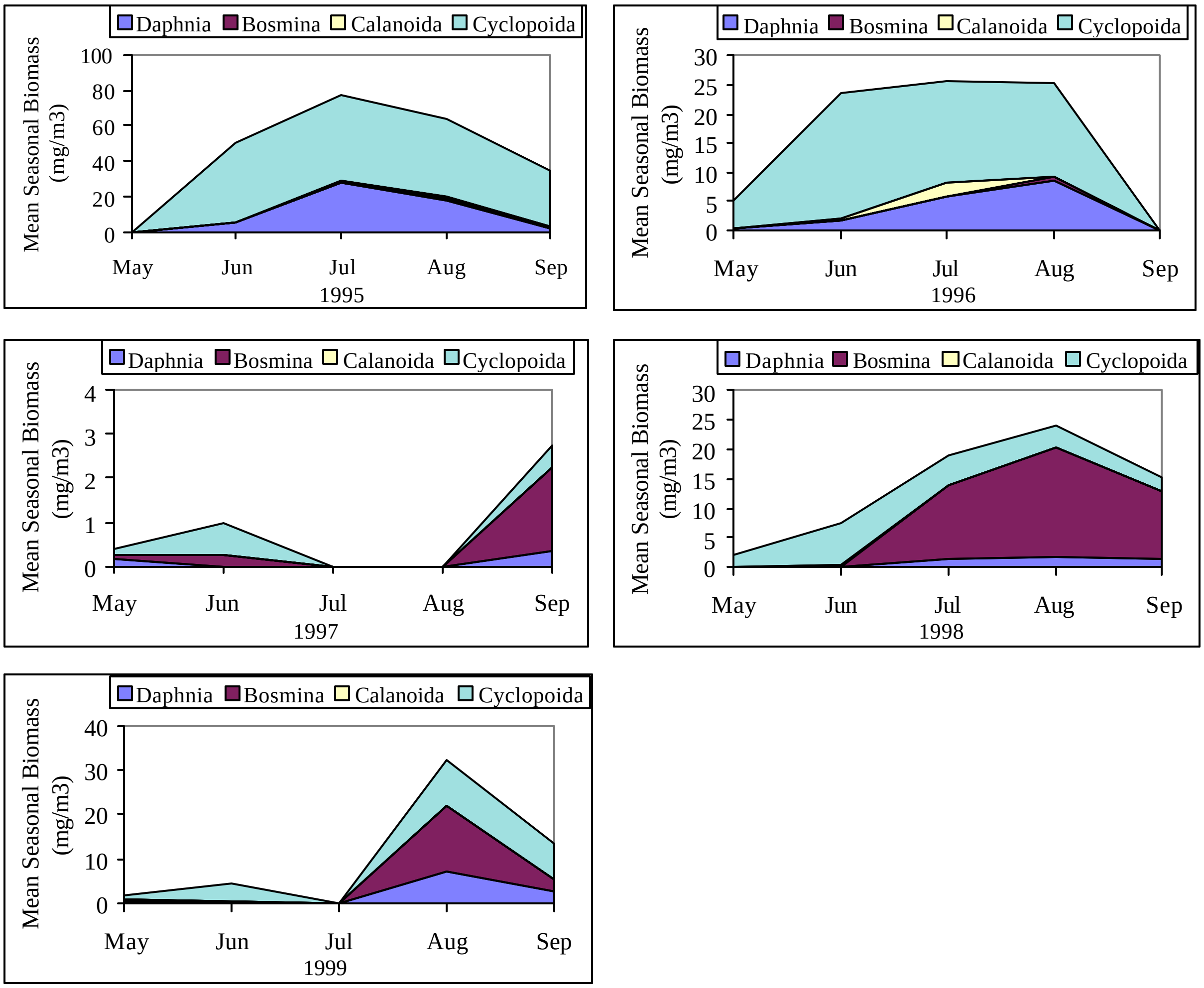


Figure 3. Seasonal changes in macro-zooplankton composition in Meziadin Lake, 1995 - 1999 survey years.

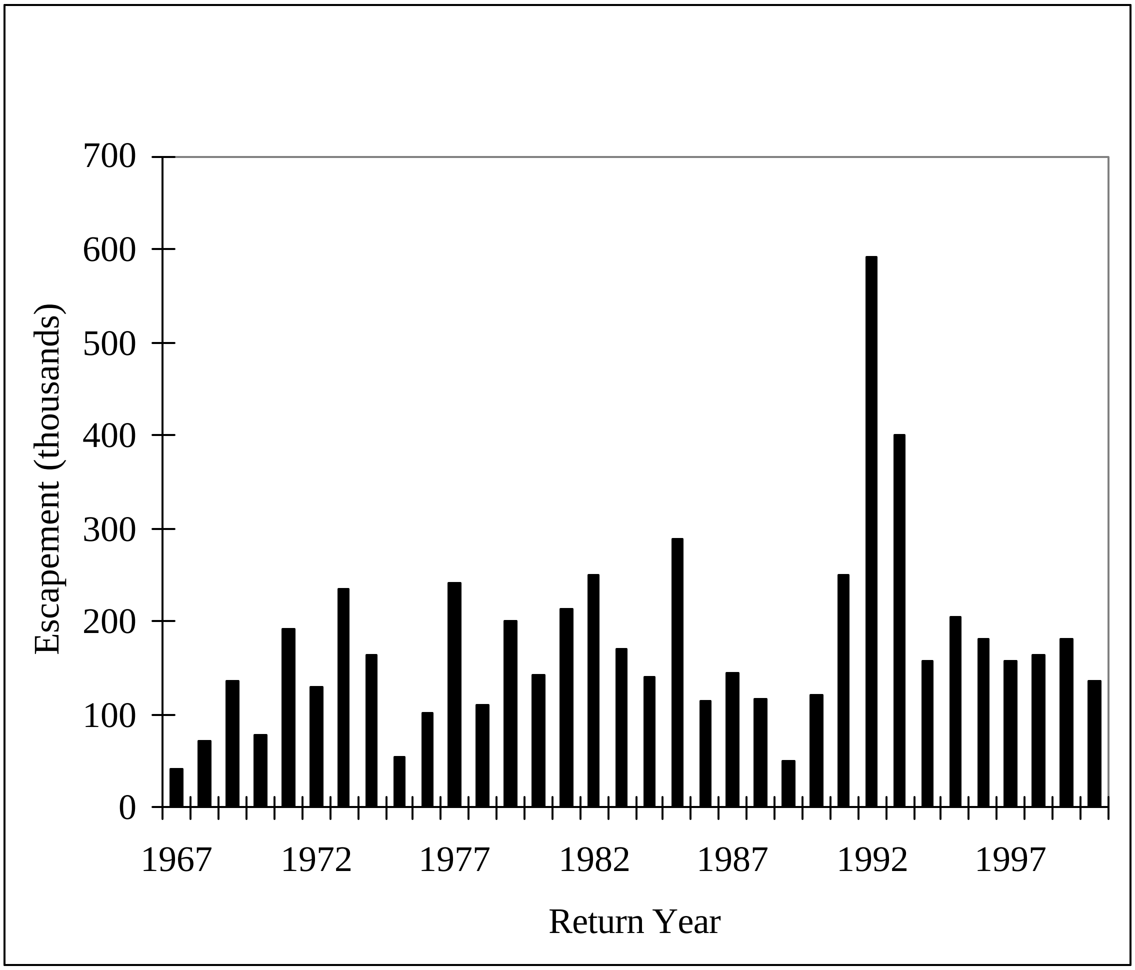


Figure 4. Annual sockeye salmon escapements to Meziadin Lake, 1967-2000.

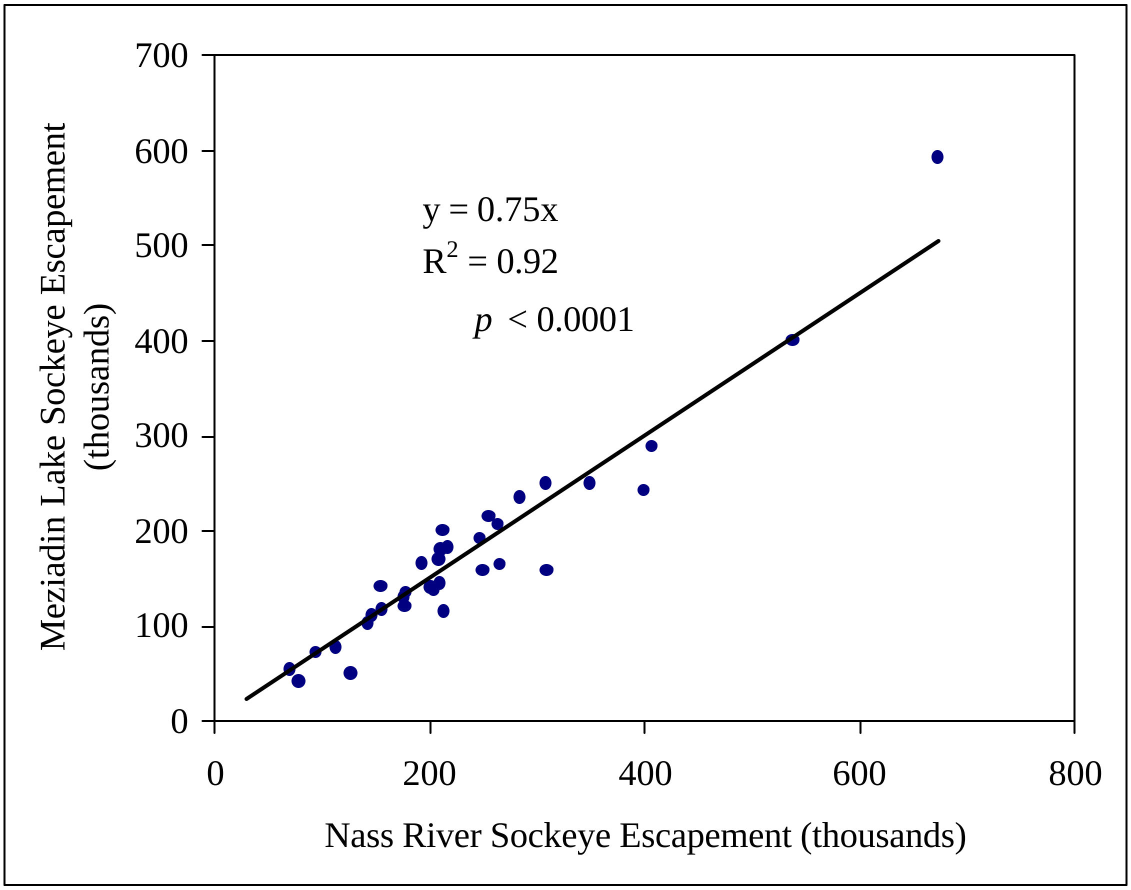


Figure 5. Relationship between estimated total Nass River sockeye escapement and Meziadin Lake sockeye escapement, 1967-2000.

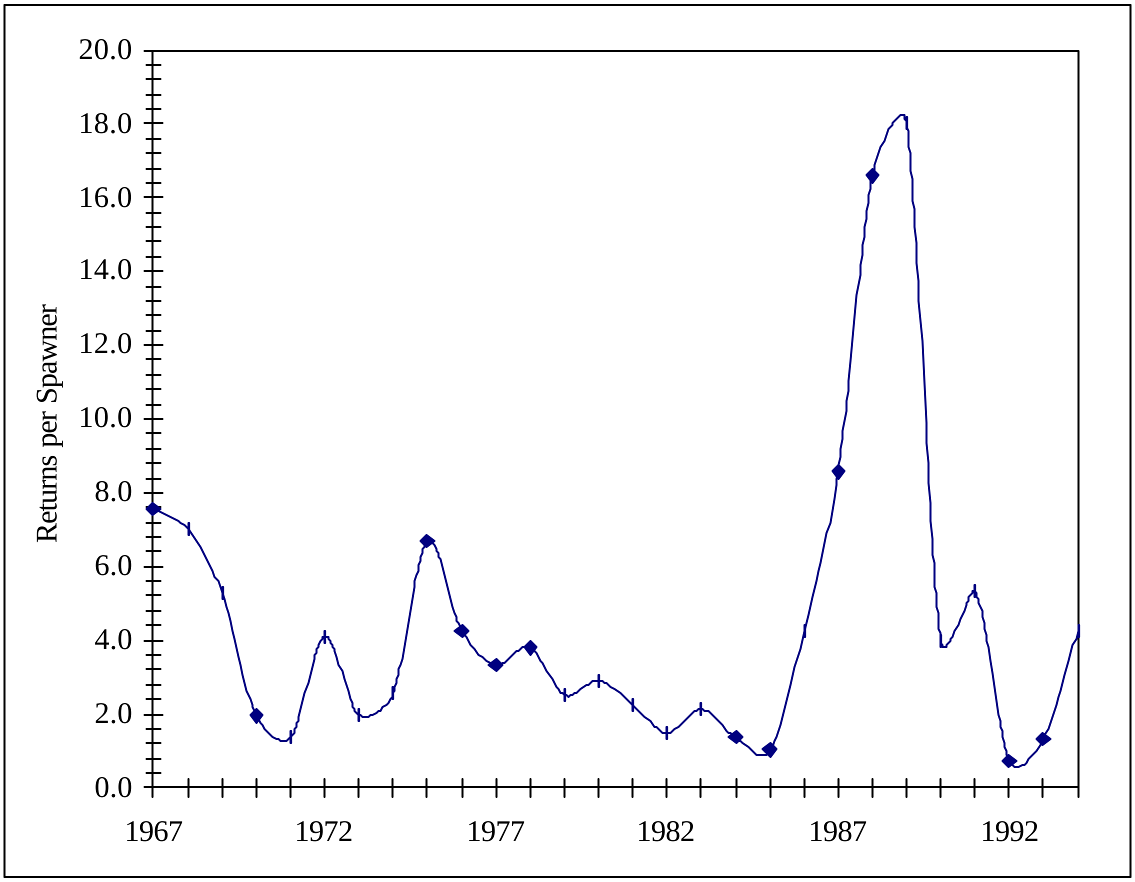


Figure 6. Annual variation in returns per spawner of Meziadin sockeye, 1967 - 1994 brood years.

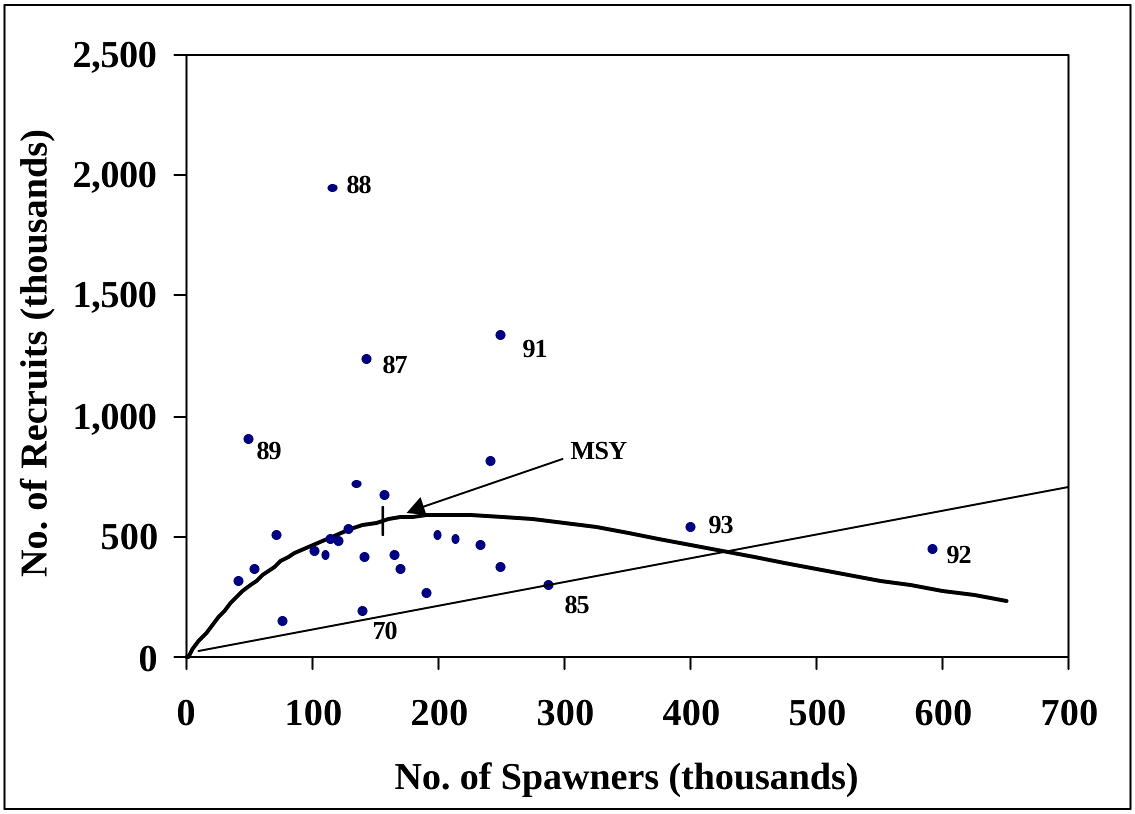


Figure 7. Stock-recruitment relationship for Meziadin Lake sockeye salmon, 1967-1994 brood years.

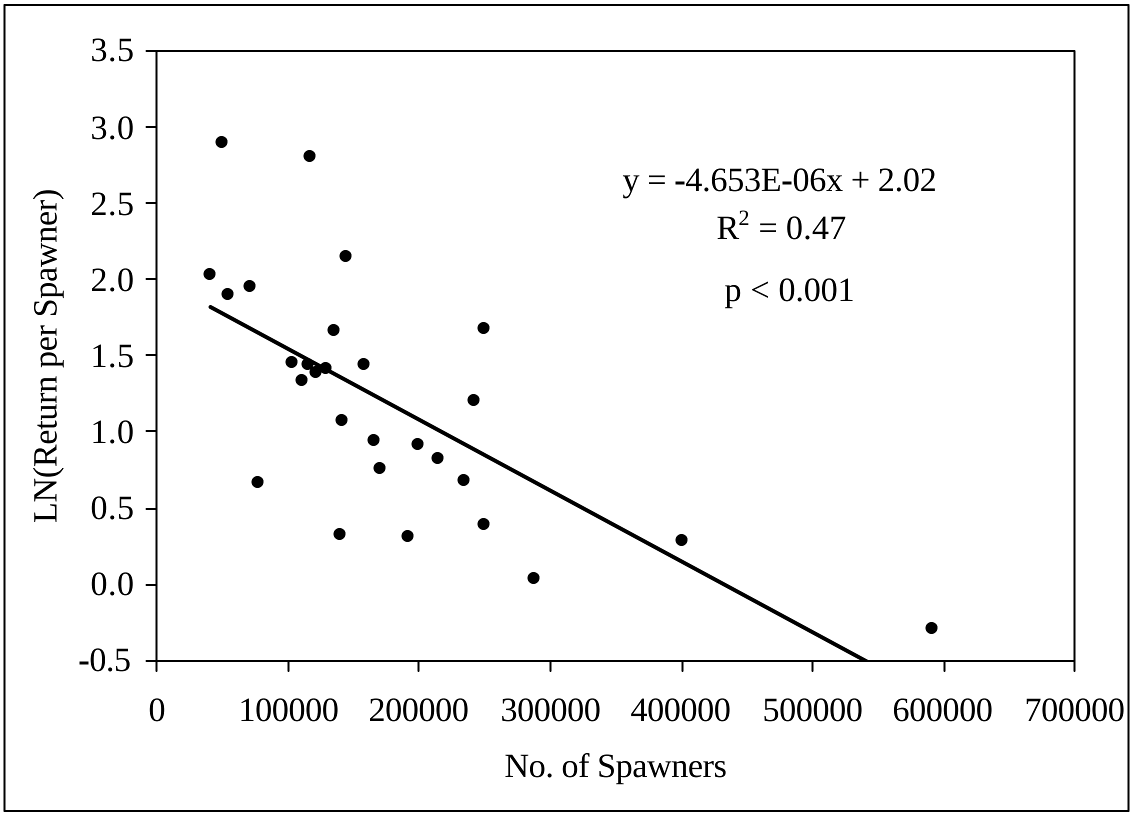


Figure 8. Regression between spawner numbers and returns per spawner for Meziadin Lake sockeye, 1967-1994 brood years.

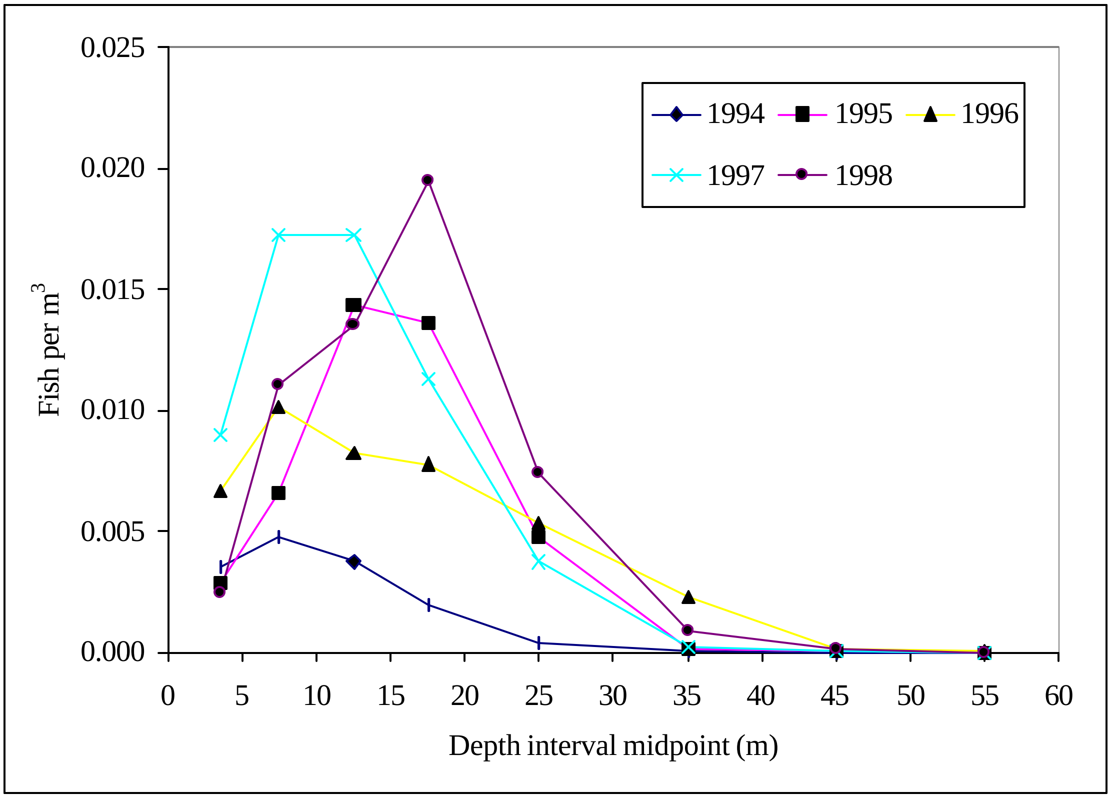


Figure 9. Vertical distribution of fish densities in Meziadin Lake, September acoustic survey (1994 - 1998 survey years).

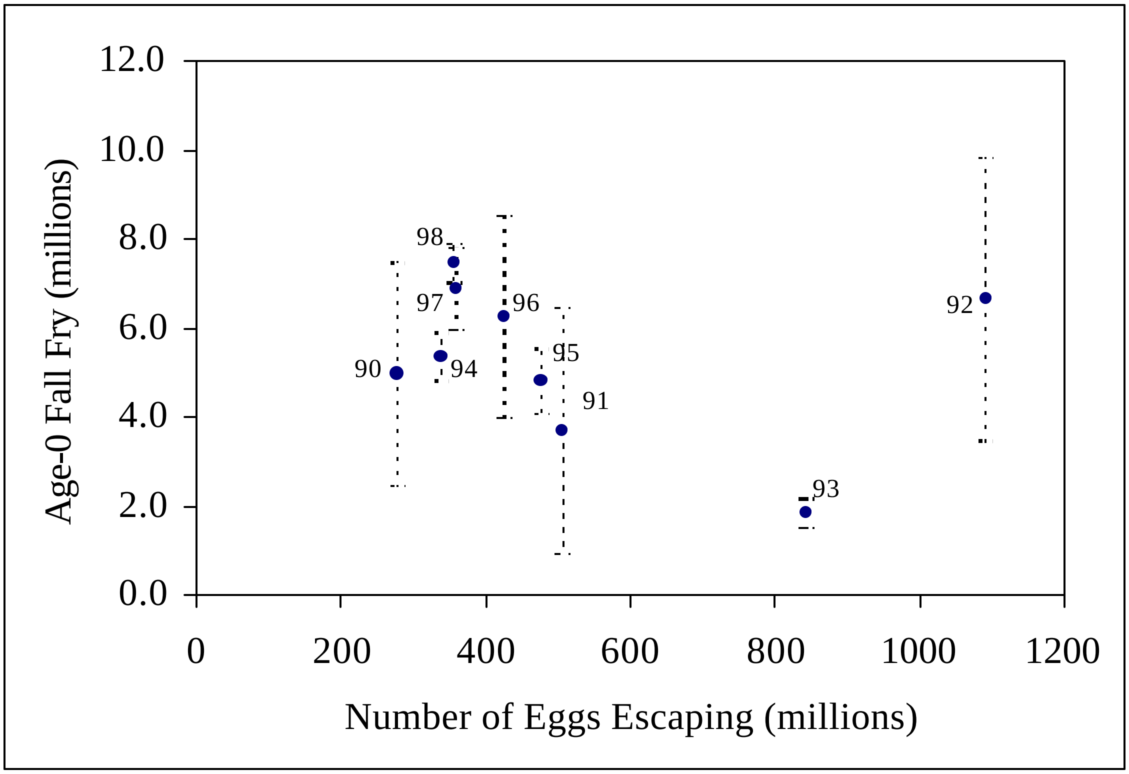


Figure 10. Sockeye salmon escapement of eggs versus fall fry abundance, 1990-1998 brood years.

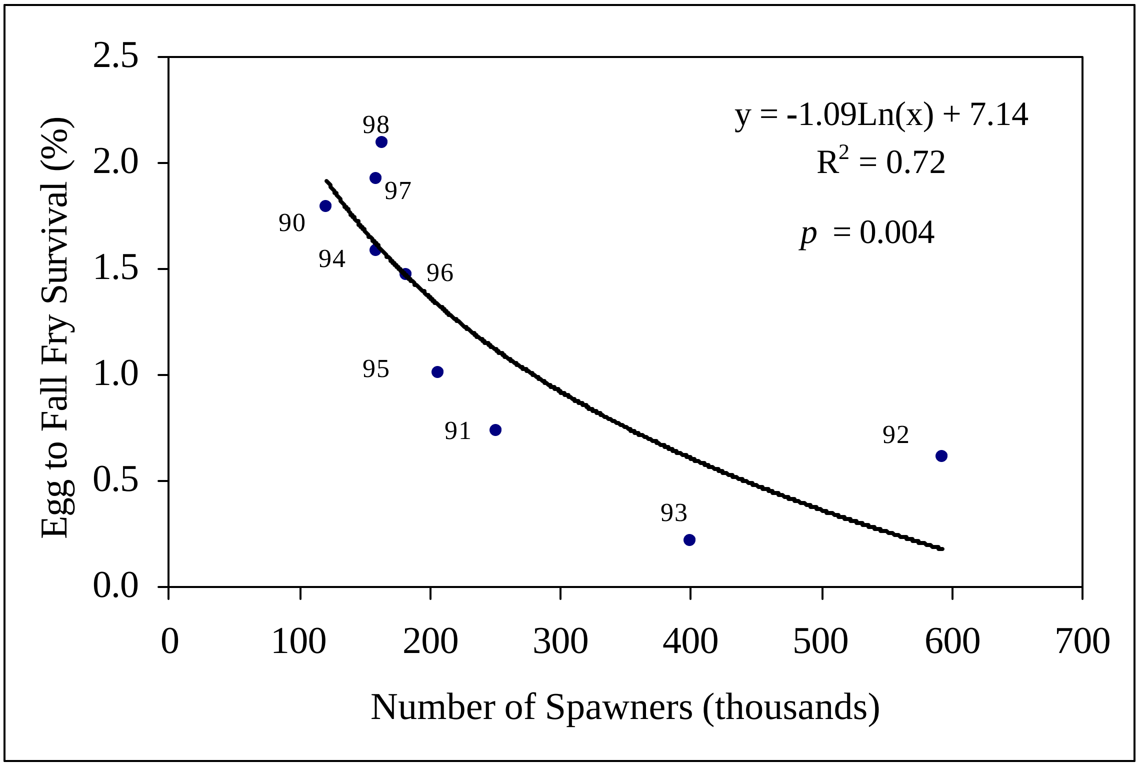


Figure 11. Egg-to-fall fry (age-0) survival versus spawner abundance, 1990-1998 brood years.

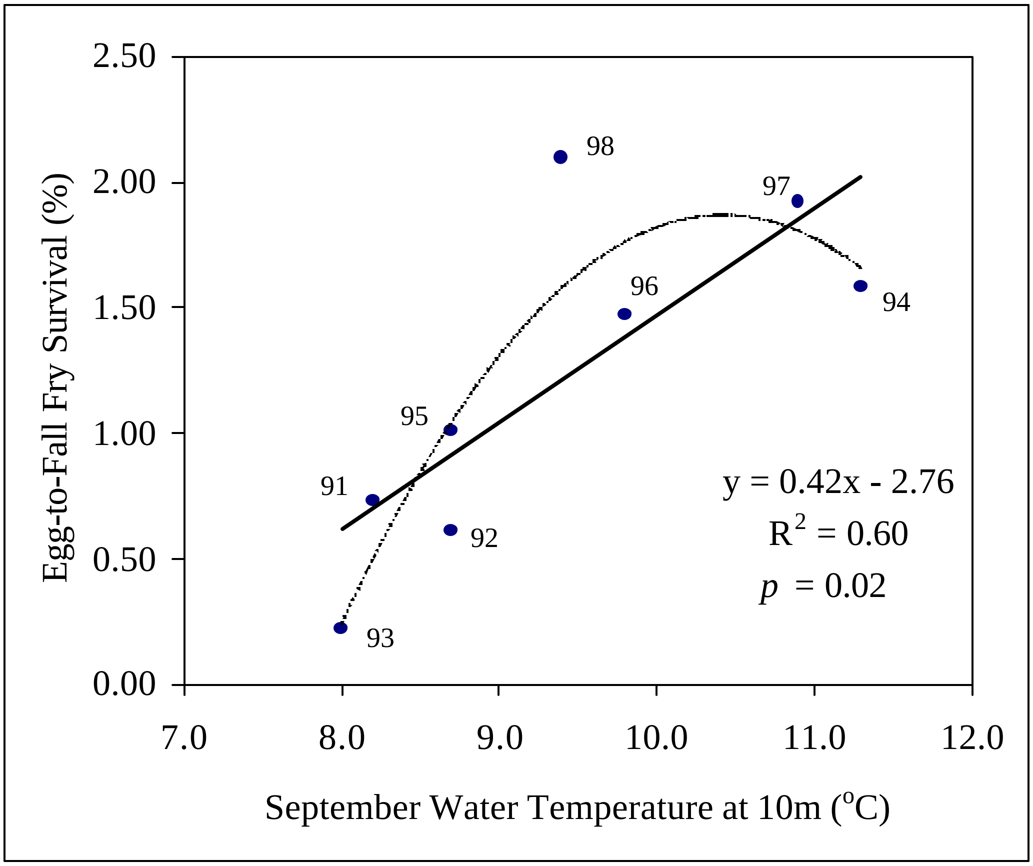


Figure 12. Relationship between September water temperature in Meziadin Lake and egg-to-fall fry survival, 1991-1998 brood years. Dashed line is polynomial fit to data with $R^2$ of 0.8; $y = -0.29x^2 + 5.77x - 28.2$.

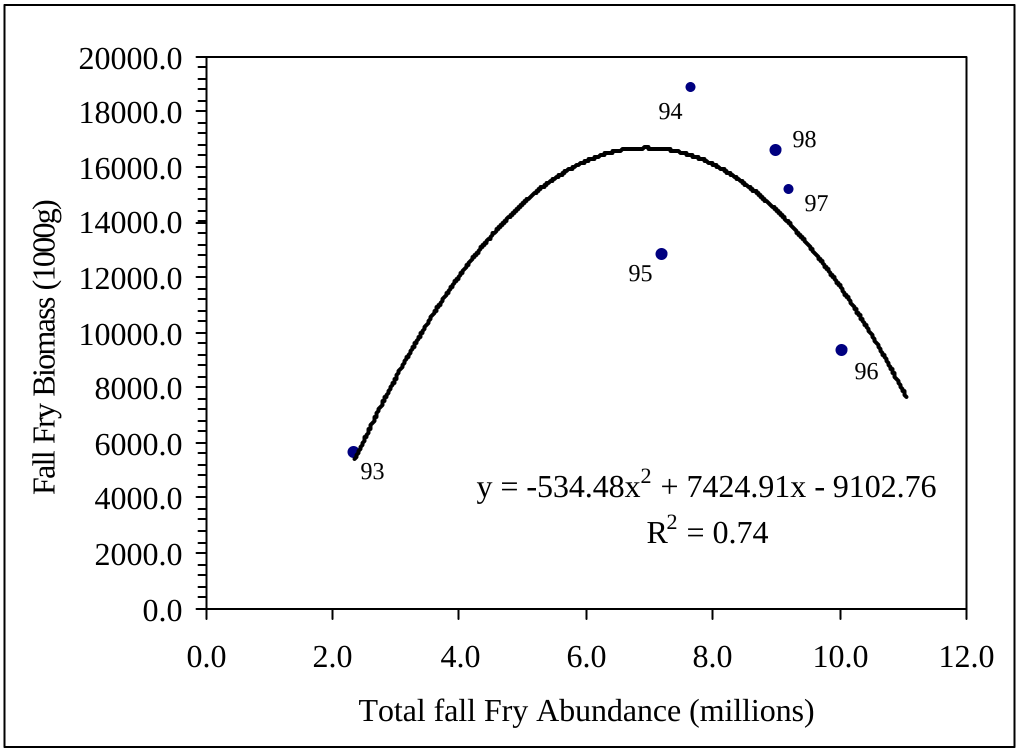


Figure 13. Total fall fry abundance and fall fry biomass, 1993-1998 brood years. Fall biomass is the sum of the biomass of Age-0 fall fry and Age-1 fall fry.

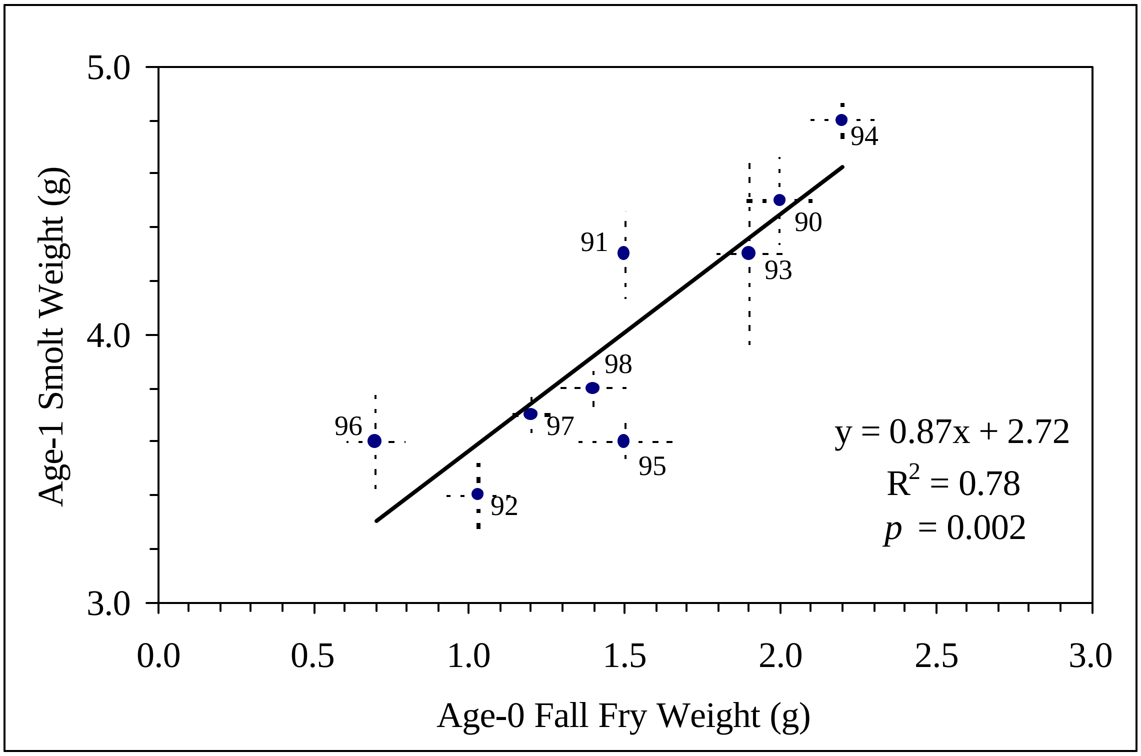


Figure 14. Sockeye age-0 fall fry weight and age-1 smolt weight, 1990-1998 brood years.

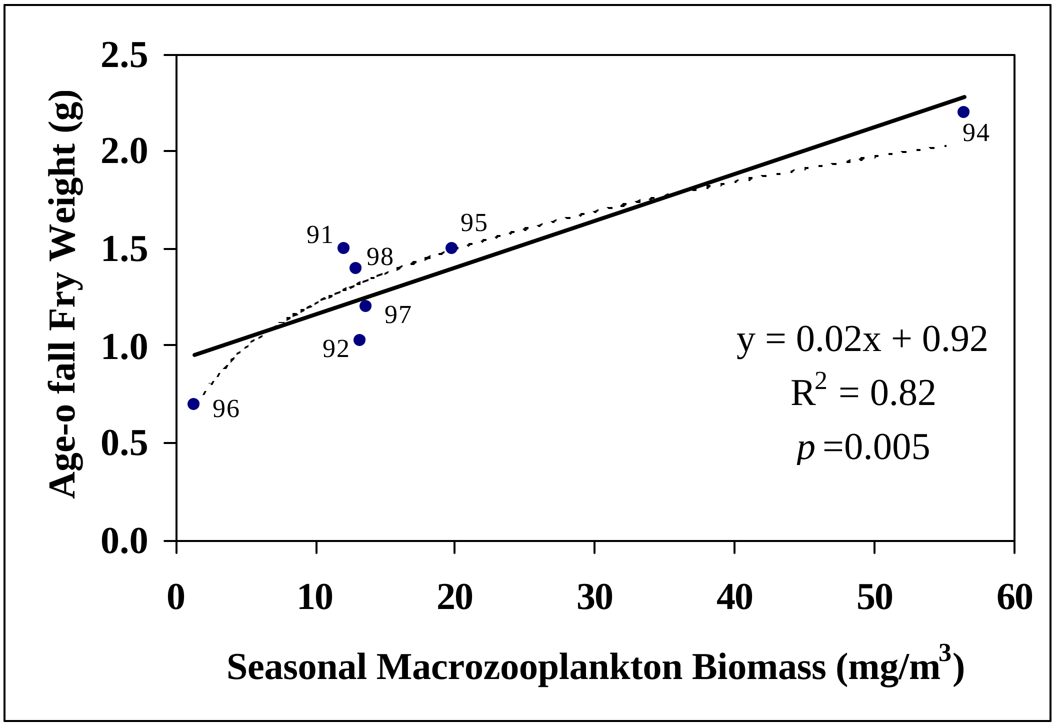


Figure 15. Relationship between Age-0 fall fry weight and mean seasonal (May-Sept) zooplankton biomass, 1991-1998 brood years (no data for 1993 brood year). Dashed line is power function with $R^2$ of 0.86; $y = 0.61x^{0.3}$.