PACIFIC SALMON COMMISSION JOINT TRANSBOUNDARY TECHNICAL COMMITTEE

REVIEW OF ENHANCEMENT ACTIVITIES AT TATSAMENIE LAKE 1990 - 2005

REPORT TCTR (06)-1

By
The Enhancement Subcommittee
of the
Joint Transboundary Technical Committee

May 19, 2006

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APPENDICIES

ACRONYMS

ADF&G	Alaska Department of Fish and Game
DFO	Department of Fisheries and Oceans (Canada)
DIPAC	Douglas Island Pink and Chum (Private Hatchery)
IHN	Infectious Hematopoietic Necrosis (a virus which infects sockeye salmon)
PSC	Pacific Salmon Commission
PST	Pacific Salmon Treaty
SPA	Scale Pattern Analysis
TBR	Transboundary River
TRTFN	Taku River Tlingit First Nation
TTC	Transboundary Technical Committee

INTRODUCTION

On November 21 and 22, 2005 at the Pacific Biological Station in Nanaimo British Columbia, members of the Transboundary Enhancement Subcommittee met with scientists and specialists in sockeye salmon enhancement to undertake a review of the Tatsamenie Lake Enhancement Project. In this paper we summarize the presentations, findings and directions that resulted from this review.

The review was in response to direction from the Transboundary River Panel as presented in a Bilateral Statement (Appendix 1). Funding for the review was secured from the Northern Fund in March of 2005. The Enhancement Subcommittee was responsible for the conduct of the review. The objectives were developed in response to the direction of the panel and the technical capabilities and expertise of the committee. We asked members of the committee to present data on areas that we felt were relevant to the review.

The reviewers were selected with a goal of having a range of expertise related to sockeye salmon from both countries. We sought out scientists that were not involved with the Transboundary River projects with the hopes of getting some new perspectives. Members of the TTC were also involved. Table 1 lists the review participants.

Table 1. List of reviewers and their affiliation.

Name	Affiliation
Andy McGregor	ADF&G – Former Panel Chair
Brian Mercer	Canada – Enhancement Committee
Brian Riddle	Canada – DFO Scientist
Don McQueen	Canada – Scientist
Doug Eggers	ADF&G - Scientist
Eric Prestegard	DIPAC Snettisham Hatchery – Enhancement Committee
Flip Pryor	ADF&G – Enhancement Committee
Ian Boyce	Canada – Enhancement Committee
Jeremy Hume	Canada – DFO Scientist
John Burke	SSRAA – Alaska Scientist
John Joyce	NOAA – Technical Committee
Kathleen Jensen	ADF&G - Technical Committee
Kim Hyatt	Canada – Enhancement Committee
Paul Rankin	Canada – Enhancement Committee
Richard Erhardt	Canada - TRTFN – Technical Committee
Ron Josephson	ADF&G – Enhancement Committee
Steve Honnold	ADF&G - Scientist
Steve Reifenstuhl	NSRAA – Enhancement Committee

Objectives

The objectives of the review were:

- Identify factors limiting hatchery & wild sockeye production
- Evaluate biological risks of the Tatsamenie enhancement program
- Identify studies for better understanding mechanisms limiting production
- Develop strategies/plans for mitigating limiting factors

Presentations

All of the reviewers had some knowledge of the Tatsamenie project, but we felt it was important to renew our understanding of the mechanisms that initiated the joint enhancement efforts on the Transboundary Rivers. Andy McGregor, a former Cochairman of both the Transboundary Panel and Transboundary Technical Committee, provided a presentation which gave a brief historical context for the initiation of the project. This was followed by a series of reviews of studies at Tatsamenie Lake by members of the Enhancement Subcommittee.

1. Background of the Enhancement Projects and Panel Direction (McGregor)
2. Limnology, water chemistry and acoustics (Rankin)
3. Egg collection, incubation and release strategies (Prestegard)
4. Fry behavior, growth and survival (Mercer)
5. Predators (Mercer)
6. Smolt estimates and survival (Josephson)
7. Smolt to adult survivals (Boyce)

TBR SOCKEYE ENHANCEMENT: HISTORY OF U.S./CANADA BILATERAL AGREEMENTS

By Andy McGregor, ADF&G

Establishing bilateral sockeye salmon enhancement programs on the Taku and Stikine rivers played an important role in development of Pacific Salmon Treaty agreements on the management and sharing of transboundary river (TBR) salmon stocks. A review of the history and progression of TBR agreements was provided, with particular emphasis on the enhancement programs.

Following expiration of the original TBR provisions (Annex IV: Chapter 1) that covered the 1985 and 1986 fishing seasons, the U.S. and Canada were unable to come to a new agreement prior to the 1987 fishing season. The primary disagreement was over harvest shares. In 1988 a new TBR agreement was reached, which included revised harvest shares and an understanding on development of bilateral enhancement programs to annually produce 100,000 sockeye salmon returning to each river. The enhancement program was an integral part of this agreement, representing an avenue for fishermen from both countries to experience benefits rather than a simple reallocation of existing harvest shares from one country to the other. A penalty clause was included in the agreement, specifying changes in harvest sharing percentages if either country unilaterally withdrew from the bilateral enhancement programs. The parties developed a second Understanding covering further details of the Stikine River program in 1989 and egg takes began at Tahltan Lake that year. The following year an additional Understanding was reached for the Taku program, and egg takes began at Little Trapper and Little Tatsamenie lakes in 1990.

Provisions of the 1999 PST agreement, covering the years 1999 through 2008, included continuation of the goal of producing 100,000 sockeye salmon annually to the Taku and Stikine rivers through bilateral enhancement programs. The three prior Understandings were consolidated and modified into a single Understanding on the Joint Enhancement of Transboundary River Sockeye Stocks that was included as an Appendix to the new TBR chapter.

A number of important milestones have been reached during the bilateral enhancement programs. These include the development of successful remote egg take collection methods, egg and fry transportation procedures, and successful hatchery protocols to limit and contain IHN. In addition the transboundary river sockeye enhancement projects have been a model for the large-scale application of thermal mark and recovery programs that aid in project assessment and monitoring of harvest sharing agreements, and have resulted in substantial production of adult returns to the Stikine River.

Returns of enhanced fish to the Taku River have been well below the program's goals. The Taku River enhancement program has evolved since 1990. The Trapper Lake program was terminated after planting fry from the 1994 egg take. The location of the Tatsamenie egg take was moved from Little Tatsamenie Lake to Tatsamenie Lake in 1994 to ensure that brood stock came from a single source. A variety of modifications have been made to the Tatsamenie program to attempt to improve performance in producing adult returns, and annual assessments have been conducted to better understand in-lake survival.

In February 2004, the Transboundary Panel produced a Bilateral Statement of the Transboundary Panel on Transboundary Sockeye Enhancement (see Appendix 1). The statement included an agreement to conduct a review of the Tatsamenie Lake enhancement program. Results of the review were to be presented to the TBR Panel in January 2005. The review and Panel discussion were delayed to coincide with the 2006 PSC schedule due to constraints on staff time and the extensive negotiations on Taku and Stikine River chinook salmon fisheries that took place during TBR Panel meetings in 2005

LIMNOLOGY

By Paul Rankin, DFO

It may not be possible to say much about the zooplankton of Tatsamenie Lake during the years in which juvenile sockeye were out-planted to the lake. Sampling frequency was low, only 2 stations were sampled and none of the vertical hauls were metered to quantify seasonal fluctuations in net efficiency. However we can look at the ratio of Cladocerans to Copepods across the years in which zooplankton samples were collected. Since the beginning of the project, Cladoceran to Copepod ratios have declined at Tatsamenie Lake. The shift appears to be from a community dominated by Bosminids and Daphnids to one dominated by Cyclopoids.

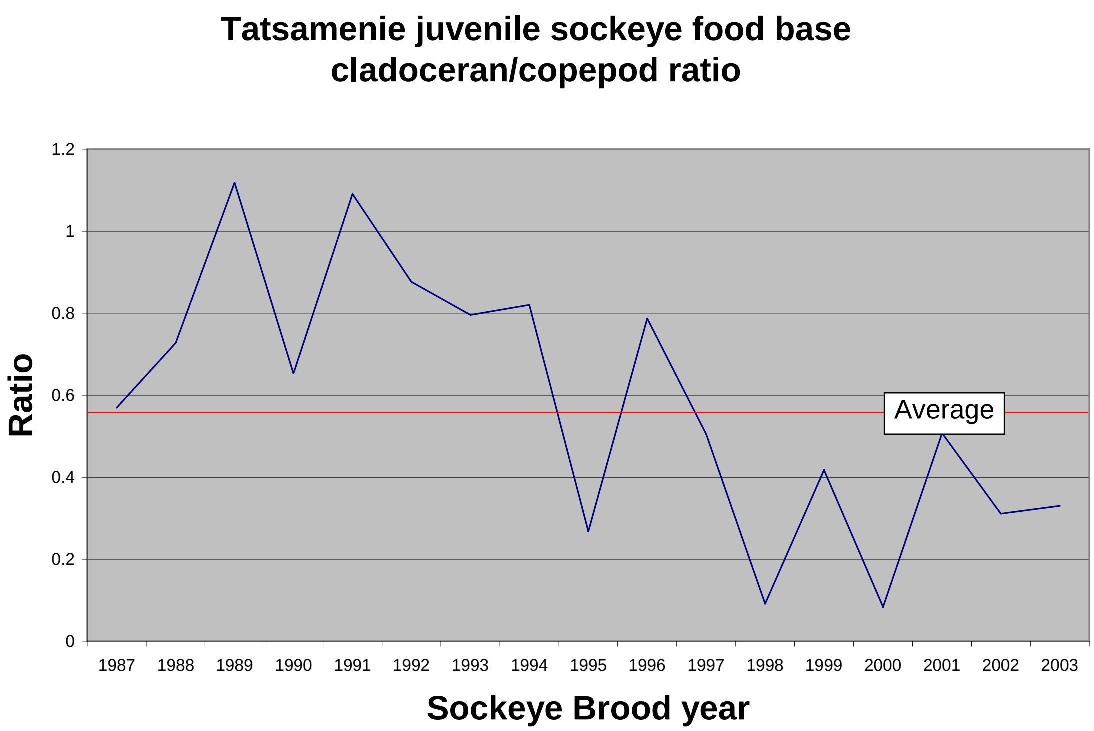

Figure 1. Ratio of cladoceran to copepod at Tatsamenie Lake.

Recent work at Woss and Vernon Lakes on Vancouver Island indicates that juvenile sockeye will consume Cladocerans (Bosminids and Daphnids) where possible, as well as adult Calanoid Copepods (Epischura and Diaptomids). Immature Calanoids and all stages of Cyclopoids tended not to be consumed if the other food species were available (Hyatt et al., 2004). Hyatt et al. (2005) was unable to demonstrate any significant relationship between egg to fall fry survival and mid summer zooplankton biomass between 1988 and 1999.

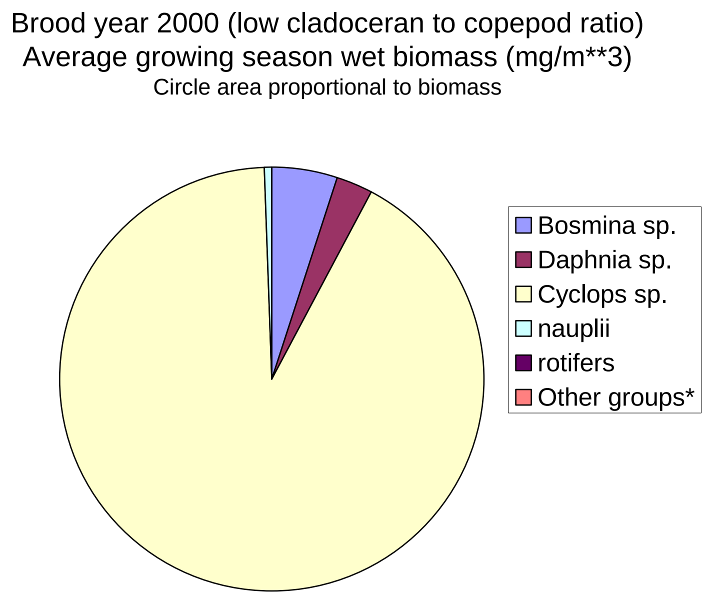

Figure 2. Representation of plankton biomass at Tatsamenie Lake in 2000.

EGG COLLECTION, INCUBATION AND RELEASE STRATEGIES

By Eric Prestegard, Snettisham Hatchery – DIPAC

Egg Collection

Eggs have been collected at Tatsamenie Lake for the last 16 years, with the first 4 years coming from Little Tatsamenie Lake and the remaining 12 years from the main lake. Adults are collected during the fall weir operations and held in cages for ripening. The egg takes are conducted during October and use the procedures developed in the Alaska Sockeye Salmon Culture Manual (ADF&G, 1994). The fertilized eggs are flown to Snettisham Hatchery at the end of each egg take day and placed into individual incubators. See Table 2 for a summary of the egg takes and Figure 3 for a comparison of number of eggs collected and adult escapement. DFO guidelines allow for a maximum of 30% of the escapement to be used for egg collection broodstock.

Table 2. Summary of eggs collected and weir counts by brood year at Tatsamenie Lake.

Brood-year	No. eggs taken	Weir Count
1990	985,000	5,706
1991	1,360,000	8,231
1992	1,486,000	6,536
1993	1,144,000	4,040
1994	1,229,000	3,559
1995	2,407,000	5,780
1996	4,934,000	9,381
1997	4,651,000	8,097
1998	2,414,000	5,997
1999	461,000	2,104
2000	2,816,000	7,575
2001	4,364,000	21,822
2002	2,498,000	5,495
2003	2,642,000	4,515
2004	750,000	1,954
2005	1,810,000	3,372

Brood Year 2000; 244,000 eggs placed in in-lake incubator and 2,572,000 delivered to Snettisham Hatchery.
Brood Year 2001; 865,000 eggs place in in-lake incubators and 3,499,000 delivered to Snettisham Hatchery.
Brood Year 2002; 196,000 eggs place in in-lake incubators and 2,302,000 delivered to Snettisham Hatchery.
Brood Year 2003; 190,000 eggs place in in-lake incubators and 2,452,000 delivered to Snettisham Hatchery.

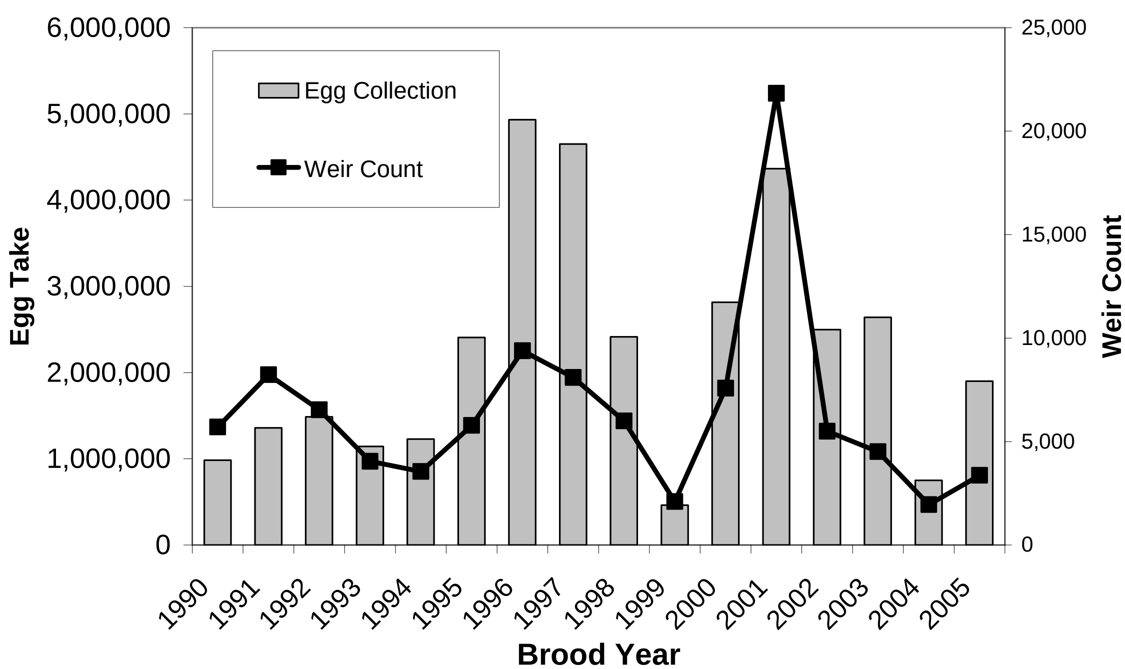

Figure 3. The number of eggs collected and weir counts of sockeye salmon adults at Tatsamenie Lake.

Incubation

The eggs are incubated at Snettisham Hatchery from October to May. During that time they are picked at the "eyed" stage and only the live eggs are reseeded back into the incubators. An otolith mark is applied to all eggs either just before or after the hatching event. The swim-up fry are volitionally released out of the incubators and enumerated at that time for final numbers and survival percentages.

Fry Transport

The fry are transported back to the lake via fixed-wing aircraft on floats. The fry are loaded into a 200 gal. plastic container that has been modified for transporting sockeye fry. Water quality is monitored during the 45-minute flight, with dissolved oxygen and supersaturated gases being of most concern. The fry are acclimated upon arrival at the lake for 20 to 30 minutes before being released into the lake.

Water Quality

In the late 1990s the Enhancement Subcommittee was concerned that there might be significant differences in water quality between Snettisham Hatchery and the Canadian Lakes in the enhancement project. A comparative water quality study was undertaken in 2001. Water samples were collected from Snettisham Hatchery, and Tahltan, Tuya, Tatsamenie, and Chilkat Lakes. (Chilkat Lake is not a TBR lake but was compared for US interests). The analysis compared various parameters with established criteria used in salmon aquaculture. No significant differences were found between Snettisham and TBR lakes for those parameters tested (Appendix 2).

TATSAMENIE LAKE SOCKEYE FRY GROWTH, SURVIVAL, AND BEHAVIOUR

By Brian Mercer

Investigations of Tatsamenie Lake sockeye fry population dynamics, growth and survival has been ongoing since the inception of the project in 1990. Initially the research was focused on determining the survival and growth of enhanced fry. In 1998 and 1999, the sampling program was expanded to examine the enhanced fry survival throughout the ice free period after stocking. In 2001 and 2002, an intensive research project was added to closely examine the behaviour of both the wild and enhanced fry. The increased research effort was directed at determining the cause(s) of the lower than expected enhanced fry survival.

Typically the fry assessment program at Tatsamenie Lake consisted of 3-4 beachseine surveys during the ice free season approximately 30 days apart, with 10 sets at specific sites around the lake performed during each survey. In addition, mid-lake trawling was performed in September and/or October in order to sample the juvenile sockeye population in the limnetic zone. Hydro-acoustic surveys were also conducted in the fall to estimate the late fall fry population within the lake. In the years the assessment program was expanded, the sampling regime was increased. The sampling schedule and results of the fry research program from 1992 through 2002 are presented in Table 3.

A great deal of effort by many researchers has been directed at understanding the dynamics of sockeye fry behaviour, growth, and survival (Burgner 1991). Factors affecting these dynamics in lacustrine environments can be highly complex and are often system and/or stock specific.

Table 3. Results of fry sampling at Tatasamenie Lake.

		Wild fry						*Enhanced fry*					
Sampling date	**Capture method**	**Mean length (mm)**	**95% CI**	**Mean weight (g)[a]**	**95% CI**	**n**	**%**	**Mean length (mm)**	**95% CI**	**Mean weight (g)[a]**	**95% CI**	**n**	**%**
21-Jun-92	beach seine	33.4	0.4	0.28	0.02	100	100	.	.	.	.	0	0
24-Jun-92	stocking	.	.	.	.	.		.	.	0.15	.	.	
1-Aug-92	beach seine	36.0	0.7	0.29	0.02	116	93	33.4	1.9	0.20	0.04	9	7
1-Aug-92	trawl age 0+	36.0	32.3	0.54	1.78	3	100	.	.	.	.	0	0
21-Aug-92	beach seine	50.2	2.0	1.33	0.19	89	98	48.5	57.2	1.14	5.14	2	2
28-Sep-92	beach seine	35.3	2.7	0.36	0.11	32	97	30.0	.	0.19	.	1	3
28-Sep-92	trawl age 0+	50.9	.	1.03	.	49	92	48.3	.	0.77	.	4	8
10-Jul-93	stocking	.	.	.	.	.		.	.	0.13	.	.	
1-Aug-93	beach seine	37.4	1.2	0.47	0.05	95	96	34.3	11.1	0.36	0.39	4	4
14-Sep-93	beach seine	33.5	2.8	0.28	0.09	10	91	41.0	.	0.49	.	1	9
14-Sep-93	trawl age 0+	47.9	1.2	1.10	0.08	102	86	43.8	4.1	0.89	0.45	16	14
14-Jul-94	stocking	.	.	.	.	.		.	.	0.15	.	.	
26-Jul-94	beach seine	44.3	1.5	0.89	0.09	119	98	31.5	6.4	0.21	0.30	2	2
15-Sep-94	beach seine	38.4	4.8	0.55	0.22	16	94	55.0	.	1.46	.	1	6
15-Sep-94	trawl age 0+	60.0	2.6	2.43	0.32	50	98	55.0	.	1.93	.	1	2
20-Jul-95	stocking	.	.	.	.	.		.	.	0.15	.	.	
28-Jul-95	beach seine	36.7	1.4	0.46	0.06	37	48	29.1	0.7	0.17	0.01	40	52
19-Sep-95	trawl age 0+	48.4	2.5	1.16	0.19	39	91	46.5	10.3	1.00	0.67	4	9
20-Jun-96	stocking	.	.	.	.	.		.	.	0.11	.	.	
23-Jul-96	beach seine	31.4	0.5	0.21	0.02	186	93	31.4	1.4	0.23	0.05	13	7
19-Sep-96	beach seine	38.9	1.8	0.54	0.14	52	93	47.5	16.8	0.98	1.08	4	7
19-Sep-96	trawl age 0+	45.2	1.4	0.86	0.11	51	94	50.3	16.9	1.21	0.99	3	6
22-Jun-97	stocking	.	.	.	.	.		.	.	0.17	.	.	
26-Jun-97	beach seine	33.1	0.6	0.27	0.02	126	62	29.8	0.3	0.16	0.01	78	38
25-Jul-97	beach seine	36.0	0.6	0.41	0.03	228	65	35.8	0.5	0.39	0.02	125	35
4-Sep-97	beach seine	45.5	1.4	0.96	0.13	124	93	48.6	7.6	1.23	0.83	9	7
4-Sep-97	trawl	44.9	1.8	1.00	0.17	85	89	49.5	6.0	1.32	0.59	10	11
1-Oct-97	beach seine	38.0	2.3	0.55	0.20	42	100	.	.	.	.	0	0
1-Oct-97a	trawl	68.9	2.2	4.20	0.42	88	90	76.2	4.1	5.64	1.00	10	10
22-Jun-98	stocking	.	.	.	.	.		.	.	0.14	.	.	
30-Jun-98	beach seine	33.9	1.4	0.29	0.05	93	52	30.2	0.6	0.17	0.02	87	48
19-Jul-98	beach seine	36.7	1.4	0.45	0.08	82	65	36.2	0.9	0.39	0.04	45	35
5-Aug-98	beach seine	38.8	4.4	0.58	0.28	23	61	46.1	3.5	0.88	0.17	15	39
23-Aug-98	beach seine	31.3	1.0	0.22	0.03	52	95	45.0	7.5	0.74	0.58	3	5
13-Sep-98	beach seine	48.3	1.8	0.98	0.12	47	85	51.4	2.9	1.20	0.20	8	15
23-Sep-98	trawl	43.8	1.0	0.80	0.07	134	92	44.2	4.5	0.81	0.23	11	8
3-Oct-98	beach seine	45.0	4.7	1.23	0.44	48	84	54.2	8.8	1.51	0.66	9	16
15-Oct-98	trawl age 0+	54.1	2.2	1.54	0.27	79	89	59.2	5.2	2.20	0.77	10	11
4-Jun-99	stocking	.	.	.	.	.		.	.	0.15	.	.	
14-Jun-99	beach seine	31.6	0.4	0.17	0.01	57	70	29.9	0.5	0.13	0.01	24	30
2-Jul-99	beach seine	34.2	0.8	0.27	0.03	74	62	35.3	0.8	0.27	0.04	45	38
22-Jul-99	beach seine	34.7	1.1	0.35	0.05	65	79	42.2	1.1	0.66	0.06	17	21
10-Aug-99	beach seine	37.9	1.6	0.43	0.07	91	91	44.0	1.7	0.66	0.10	9	9
31-Aug-99	beach seine	42.6	5.4	0.77	0.35	16	100	.	.	.	.	0	0
17-Sep-99	beach seine	37.8	1.5	0.41	0.06	72	99	50.0	.	0.88	.	1	1

(Continued)

Table 3 (continued). Results of fry sampling at Tatasamenie Lake.

		Wild fry						Enhanced fry					
Sampling date	Capture method	Mean length (mm)	95% CI	Mean weight (g)[a]	95% CI	n	%	Mean length (mm)	95% CI	Mean weight (g)[a]	95% CI	n	%
14-Jun-01													
18-Jun-01	Beachseine	31.0	0.2	0.11	0.005	167	47	32.4	0.27	0.15	0.01	189	53
24-Jun-01	Beachseine	31.2	0.2	0.13	0.005	229	58	33.7	0.3	0.18	0.01	164	42
29-Jun-01	Beachseine	32.2	0.3	0.15	0.01	211	50	33.3	0.3	0.17	0.01	209	50
3-Jul-01	Beachseine	31.8	0.3	0.23	0.15	245	61	33.9	0.4	0.19	0.01	159	39
8-Jul-01	Beachseine	32.3	0.3	0.16	0.01	309	74	35.3	0.5	0.23	0.01	111	26
15-Jul-01	Beachseine	30.5	1.2	0.18	0.01	270	67	37.2	0.7	0.29	0.01	130	33
24-Jul-01	Beachseine	34.5	0.6	0.23	0.02	240	58	39.3	0.6	0.37	0.02	42	42
4-Aug-01	Beachseine	34.8	0.6	0.25	0.02	302	72	42.6	0.7	0.51	0.03	119	28
12-Aug-01	Trawl	39.1	1.1	0.44	0.05	237	60	49.0	0.7	0.81	0.04	160	40
13-Aug-01	Beachseine	35.9	0.9	0.31	0.04	299	75	44.9	1.0	0.61	0.06	99	25
6-Sep-01	Trawl	39.2	1.9	0.39	0.08	46	75	59.2	2.8	1.51	0.25	15	25
10-Sep-01	Trawl	39.9	1.1	0.40	0.05	132	97	59.8	7.2	1.70	0.87	4	3
19-Sep-01	Beachseine	48.3	1.5	0.84	0.08	178	95	61.8	5.2	1.92	0.46	9	5
20-Sep-01	Trawl	44.0	1.2	0.58	0.08	170	96	65.6	4.7	2.29	0.67	7	4
[b]22-Oct-01	Trawl	56.0	4.2	1.49	0.41	22	58	61.2	3.2	1.86	0.33	16	42
8-Oct-01	Beachseine	48.4	1.8	0.89	0.13	120	82	62.4	2.6	1.90	0.22	27	18
8,9-Oct-01	Trawl	46.4	1.5	0.65	0.07	55	97	65.0	9.8	2.36	1.48	2	3
20,23-Oct-01	Trawl	46.4	2.1	0.64	0.08	27	97	67.0	n/a	2.05	n/a	1	3
June 7-02	Beachseine	32.0	0.60	0.16	0.03	150	66	31.2	0.29	0.14	0.01	76	34
19-Jun-02	Beachseine	32.6	0.25	0.17	0.01	235	57	32.8	0.25	0.18	0.007	179	43
30-Jun-02	Beachseine	34.3	0.39	0.22	0.01	281	71	34.7	0.5	0.25	0.01	117	29
11-Jul-02	Beachseine	34.7	0.43	0.26	0.02	368	85	38.9	0.8	0.39	0.03	63	15
20-Jul-02	Beachseine	34.7	0.47	0.26	0.02	336	86	41.5	1.2	0.50	0.05	56	14
31-Jul-02	Beachseine	41.0	1.0	0.54	0.05	316	82	47.1	1.2	0.76	0.07	70	18
10-Aug.-02	Beachseine	39.2	0.9	0.56	0.03	353	96	51.4	1.4	1.07	0.10	15	4
24-25 Aug - 02	Beachseine	42.0	0.7	0.57	0.04	138	95	53.0	0.9	1.53	0.08	7	5
28-Aug-02	Beachseine	40.2	4.3	0.56	0.07	77	97	45.0	4.0	0.68	0.06	2	3
11-Sep-02	Beachseine	31.2	2.7	0.16	0.08	16	100	-		-		0	
30-Sep-02	Beachseine	32.9	4.4	0.23	0.06	33	100	-		-		0	
17-Jul-02	Trawl	33.6	3.7	0.21	0.09	10	83	40.0	5.0	0.47	0.21	2	17
21-Jul-02	Trawl	33.4	5.5	0.26	0.33	171	98	37.8	4.5	0.39	0.20	4	2
22-23 - Jul -02	Trawl	32.7	0.9	0.23	0.03	53	96	31.7	1.9	0.51	0.19	2	4
6,8 - Aug - 02	Trawl	36.8	0.5	0.32	0.03	382	98	45.0	2.0	0.75	0.17	9	2
20,22 Aug - 02	Trawl	38.1	6.5	0.45	0.36	352	94	50.9	3.4	1.22	0.17	23	6
1-Sep-02	Trawl	40.2	2.4	0.54	0.05	379	98	45.0	2.5	0.75	0.16	9	2
10-Sep-02	Trawl	42.4	4.2	0.63	0.44	476	100	47.0	2.0	0.90	n/a	2	0
3-Oct-02	Trawl	46.1	2.2	0.83	0.38	42	100	-		-			
10-Oct-02	Trawl	49.5	3.4	1.43	0.31	177	99	67.0	6.7	2.23	n/a	1	1

Fry Behaviour

Wild sockeye fry emergence at Tatsamenie Lake occurs from late May through to mid August with peak emergence in early-mid July (Riffe and Mercer 2005). This long emergence timing is likely a function of the protracted spawning period which extends from late August into November. The relative size, ratios of wild to enhanced fry, and total beachseine catches over the course of the season illustrate the emergence timing of the wild fry (Figures 4, 5, and 6). Figures 7 and 8 depict the skewed weight frequency distribution of the wild fry relative to the symmetric size distribution of the outplanted fry; a result of the recruitment of newly emerged wild fry into the population[1]. Typically both wild and enhanced fry remain in the littoral areas for at least 1 – 2 months before transition to the limnetic zone where it is believed they remain until smolting. Declining beach seine catches over the season are indicative of the migration of fry from the littoral to limnetic zones (Figure 6). This may also reflect size selectivity of the gear, i.e. bigger fish may be there but less vulnerable. There was evidence during studies in 2001 and 2002 (Riffe and Mercer 2005), to suggest the transition of fry from the littoral

[1] In 2001 the enhanced fry were outplanted on June 15 and 25, before peak emergence of wild fry.

to limnetic areas was not abrupt. The highest rate of predation by the dominant piscivorous fish species (lake trout) occurred in the sub-littoral zone. Therefore the timing and length of the transition period between littoral and limnetic zones may be an important factor in brood year fry survival.

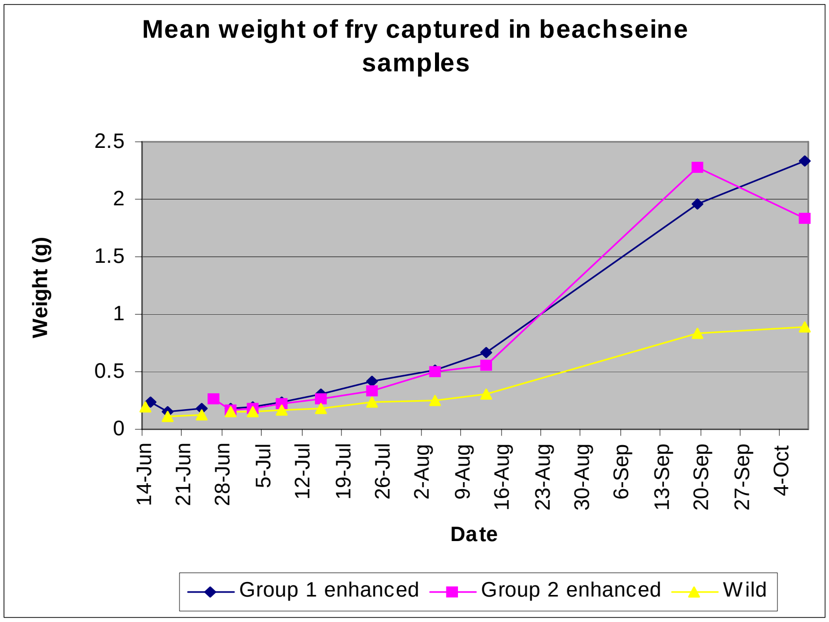

Figure 4. Mean weight of Tatsamenie Lake fry captured in beachseine samples in 2001.

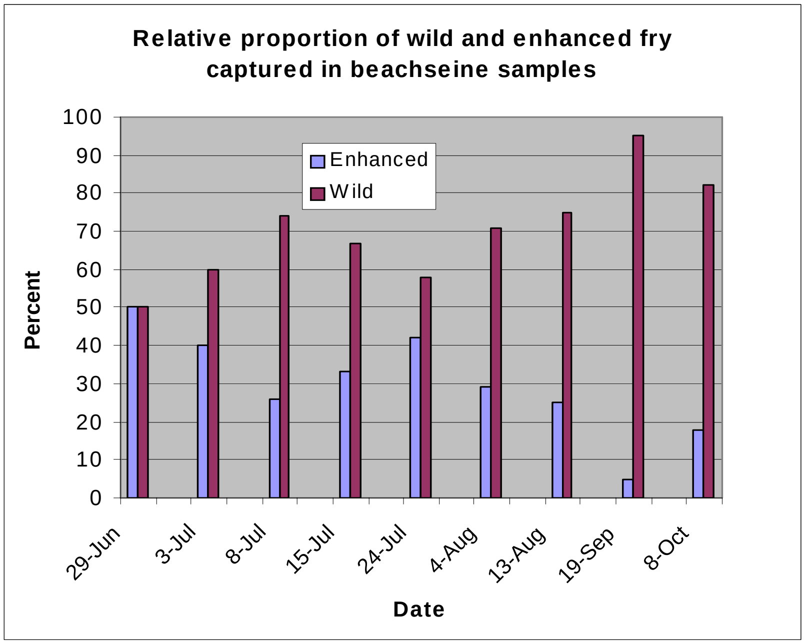

Figure 5. Relative proportions of wild and enhanced Tatsamenie Lake fry in beachseine samples in 2001.

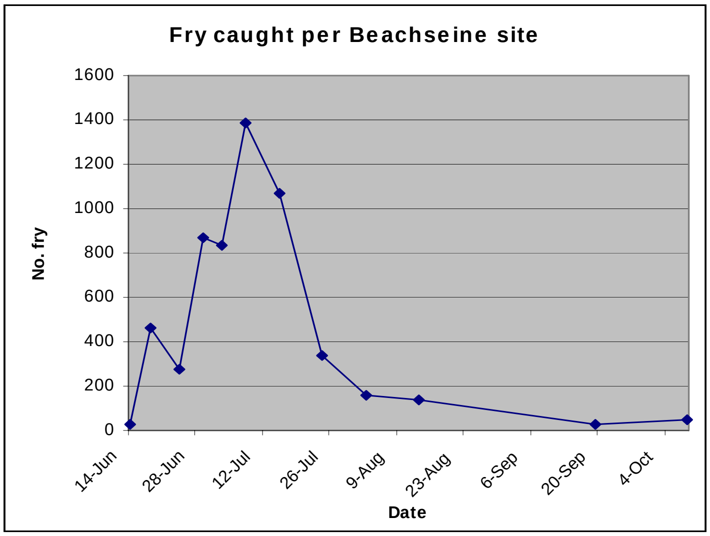

Figure 6. Total number of fry caught in each Tatsamenie Lake beachseiene survey, 2001.

Littoral zone sampled fry contained predominantly (70%) dipteran insect larvae and Thysanoptera adults, as well as representative zooplankton taxa (30%) (Mathias 2000) . To date temporal and spatially representative sockeye fry diet analysis at Tatsamenie Lake is lacking. It is probable that the diet of onshore fry is predominantly insects of all life stages.

The mean size of fry in the littoral zone is smaller than fry found in mid-lake however there is significant overlap of fry size and weight within the two habitats. Moreover, there does not appear to be a set threshold size when the fry migrate offshore. Figures 9 – 10 illustrate the weight frequency range of both wild and enhanced fry in the littoral and limnetic zones in early August.

The results of beachseine sampling in 2001 and 2002 suggest that enhanced fry do not randomly disperse throughout littoral areas after outplanting. Typically the outplanted fry remain within 1-2 km of the outplant site before migrating to the limnetic zone. This may have implications regarding fry outplant methods as it could result in local depletion of the forage base. This could influence fry behaviour and and resultant predation rates.

Fry Growth

The growth rate of Tatsamenie Lake fry appears to follow a typical pattern from emergence through to the late fall (Figure 4). The size of emergent wild fry is thought to be the same as the unfed outplanted fry, which averages 0.15 gm (Hyatt et al. 2005). Beachseine samples analyzed at Tatsamenie Lake during the 1998 and 1999 seasons indicated that the growth rates of the wild and enhanced sockeye were equal and the diets of both groups, at least within the littoral zone, consisted of the same food items, (Mathias 2000).

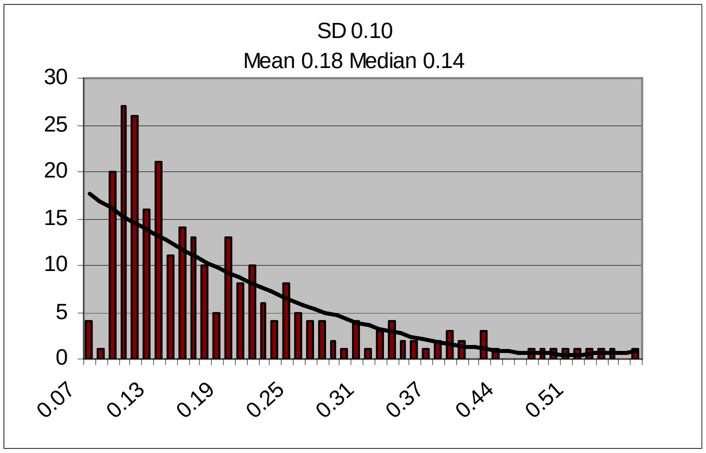

Figure 7. Weight (gm) frequency distribution of wild fry captured in beachseine surveys July 15, 2001.

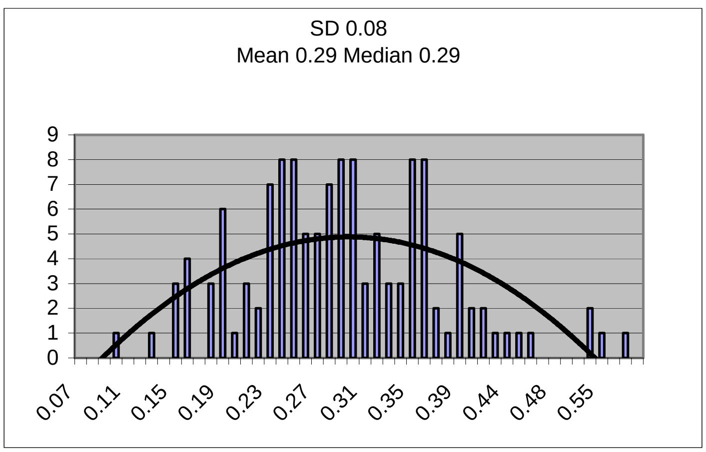

Figure 8._Weight (gms) frequency distribution of enhanced sockeye fry captured in beachseine surveys July 15, 2001.

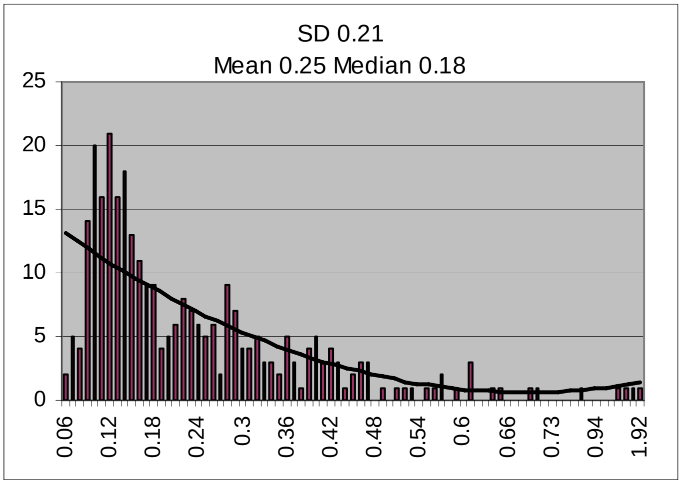

Figure 9. Weight frequency distribution of Tatsamenie Lake wild sockeye fry captured in beachseine survey August 4, 2001.

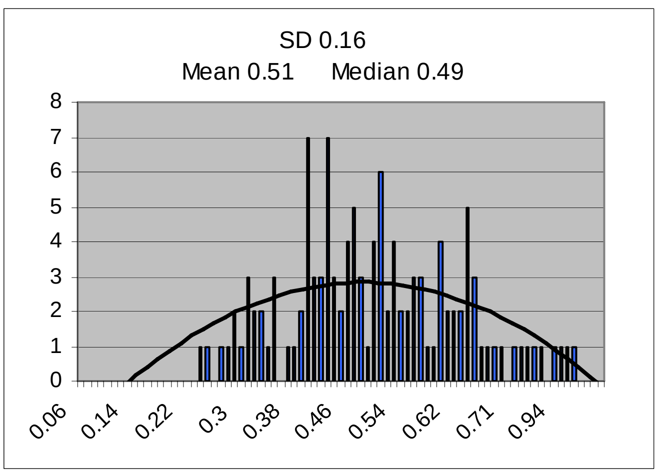

Figure 10. Weight frequency distribution of Tatsamenie Lake enhanced sockeye fry captured in beachseine survey August 4, 2001

The mean weights of both wild and enhanced late fall fry at Tatsamenie Lake have not been determined. Mid-lake trawl sampling is size selective for smaller fish and the late fall beachseine catches are also likely reflective of the smaller size classes. Therefore the fall fry weights depicted in Figures 11 and 12 are not representative of the total fry population, but do represent a minimal estimate. However, it is probable that significant fry growth occurs over the winter and prior to smoltification in the spring. The mean size of wild and enhanced fry captured in late fall 2001 beach seine sampling was approximately 1.0 g and 2.0 g respectively, whereas the mean size of age 1+ smolts sampled in 2002 was 4.4 g and 4.5 g (Riffe and Mercer 2005, TTC 2001).

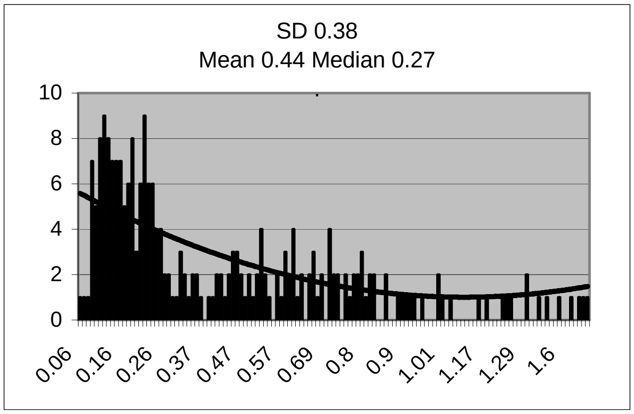

Figure 11. Weight frequency distribution of Tatsamenie Lake wild sockeye fry captured in limnetic zone trawl surveys August 10, 2001.

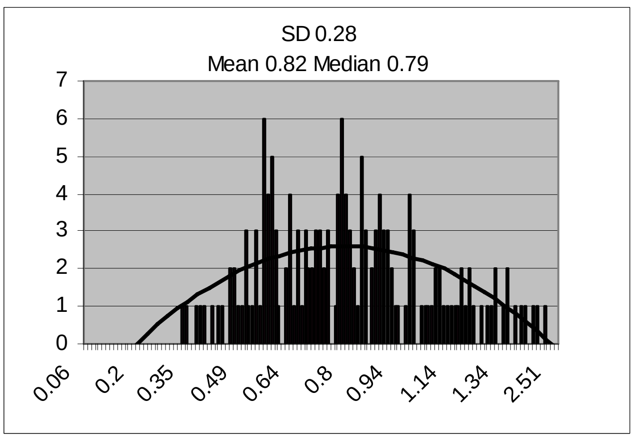

Figure 12 Weight frequency distribution of Tatsamenie Lake enhanced sockeye fry captured in limnetic zone trawl surveys August 10, 2001.

Fry Survival

There does not appear to be a significant relationship between release dates and fry survival from BY 1990 through BY 2000, however this may be due to other non-standardized variables such as outplant techniques. There is a weak non-significant relationship between release dates and relative enhanced fry survival for BY 1996 through 2003 (Figure 13). However, there is a significant relationship between early summer fry weight and egg to smolt survival (Figure 14).

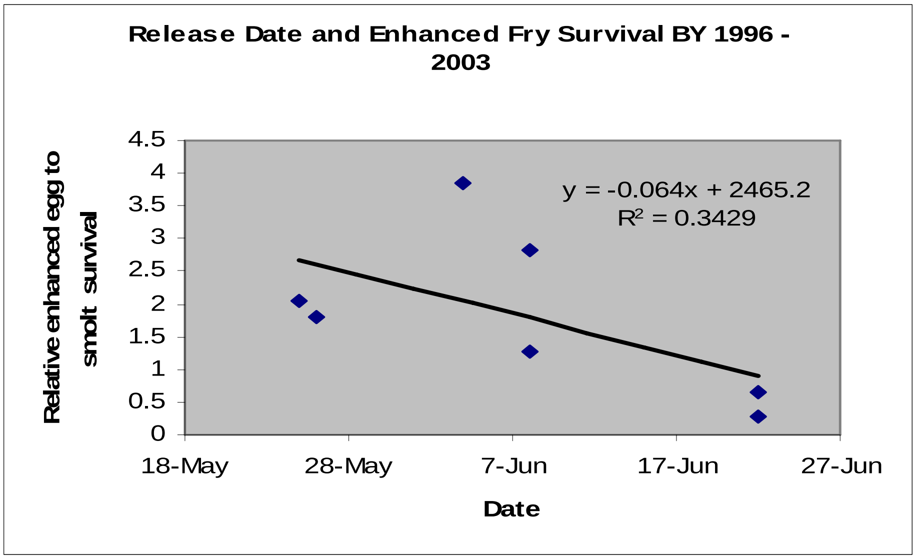

Figure 13. Release dates and enhanced fry egg to smolt survival 1996 – 2003.

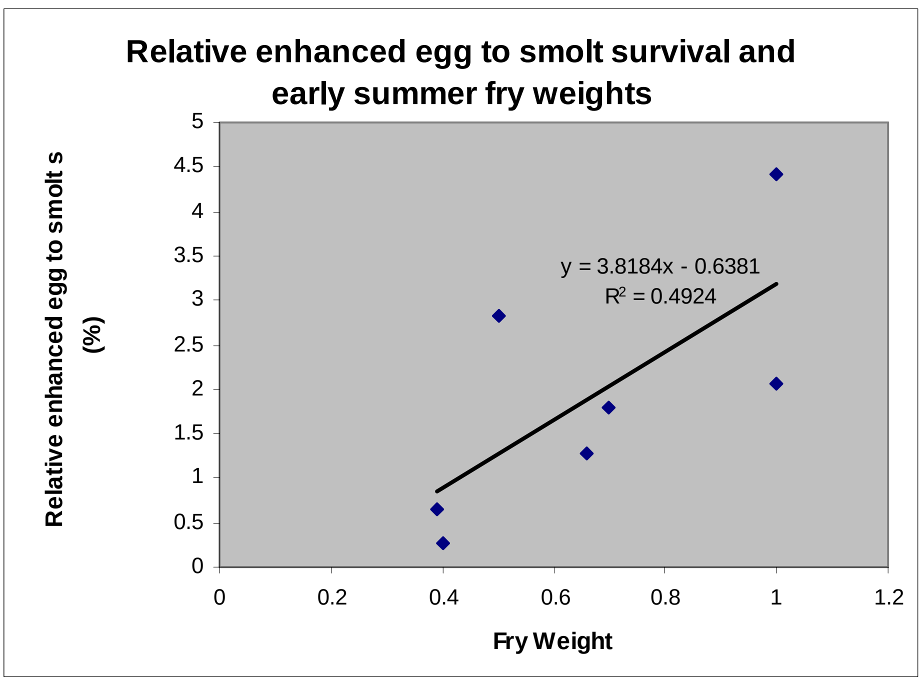

Figure 14. Enhanced egg to smolt survival and early summer fry weights.

Although smolt population estimates were not obtained prior to BY 1994 it appears that based on smolt sampling and mid-lake trawl sampling, the 1991 –1995 mid-lake un-fed fry outplanting technique resulted in very low survivals (See Figure 22 in the Smolt

Survival Section).[2] On-shore un-fed fry survivals were somewhat better than those observed in the early 90's, but not as high as those with very early outplant dates. The outplant strategy that has produced the highest enhanced egg to smolt survival (relative to wild survival) involves early (immediately after ice out) stocking dates using un-fed fry (Table 4).

Table 4. Egg to smolt survival and outplant strategy 1994 through 2003.

Brood year	% Survival egg to age 1+ smolt		Outplant strategy
	Wild	Enhanced*	
1994	10.0	1.2	Released in mid-lake July 18-21
1996	11.1	7.2	Unfed onshore/offshore June 16 -27
1997	6.0	1.6 (5.5)	Unfed onshore June 15 -29; fed July 9 (0.36g)
1998	1.1	1.4(1.7)	Un-fed onshore Jun 1 - 9/Fed onshore Jun 20-30 (0.4g)
1999	0.9	1.8	All fed; released mid-lake Jul 4 (.46 g)
2000	0.8	3.1	All fed; (early (jun-15) Released =4.6%, later (Jun-25) release =1.8%)
2001	1.1	2.6 (1.9)	Late(Jun 20&25) release fed(1.9); unfed early (May 30)release (3.3)
2002	1.7	7.5	Early (May 21&27)release unfed = 7.5%. IHNV mortality to fed group.
2003	5.1	10.0	Unfed early(May23 north, May 27 south) release

* Parentheses denote fed fry survival.

Many researchers have documented the positive relationship between fry growth rates, size and overall fry to smolt survival (Burgner 1991). The conclusions were that the smaller size classes in the population are more vulnerable to predation. It was postulated that the lower than expected enhanced fry survival was due to differential survival of the smaller enhanced fry (Mathias 2000). The evidence obtained during the 2001 and 2002 studies does not support this supposition (Riffe and Mercer 2005). Within the closed population of enhanced fry there did not appear to be selective predation on the smaller size classes within the population (Figures 8, 10, and 12. Therefore although early outplanting and the resultant larger enhanced fry appears to confer a survival advantage it is not certain the causal relationship is due to fry size. Early onshore outplanting means there is less intraspecific competition for preferred habitats and food resources for the enhanced fry. It is possible the reduced competition confers a survival advantage by allowing the enhanced fry to occupy those littoral micro-habitats where efficient foraging opportunities exist while providing less vulnerability to predation.

The mortality of both the enhanced and wild post-emergent sockeye fry in Tatsamenie Lake is very likely caused by predation. Many researchers have identified predation as the primary cause of juvenile sockeye mortality (Burgner 1991). Long term fry holding experiments at Tatsamenie Lake have indicated there are no post-transport or post-emergent mortality events that could be attributed to fry transport methods or pathological agents (PSC 1998). Many studies have demonstrated that sockeye fry can withstand prolonged periods of fasting therefore limited food resources are unlikely to be a direct causal mechanism of mortality (Burgner 1991).

[2] The BY 1999 mid-lake outplants were an exception, demonstrating significantly higher survival than the wild fry. However these fish were fed prior to release and the release number was relatively low, in addition the wild fry survival was estimated to be very low that year.

Presumably because of energetic efficiency, sockeye fry do show a preference for large prey items. Juvenile sockeye are insectivorous and planktivorous and need to visually seek and pursue prey items. Thus they are also vulnerable to sight feeding piscivores and the act of feeding exposes them to risk of predation. Research at Tatsamenie Lake and at other locations indicates that sockeye behaviour and survival can be extremely complex and dynamic. Due to predation there is extreme selection pressure for fry to be efficient foragers while minimizing the risk of predation. Because of the long term littoral zone residency the fry survival and resultant overall Tatsamenie sockeye smolt production may be significantly influenced by the dynamic interplay of littoral zone insect production, habitat partitioning, and predation. Both enhanced and wild sockeye egg to smolt survival has been shown to be independent of fry densities or the status of the limnetic zooplankton population. This indicates other factors, perhaps littoral zone food availability and predation pressure on fry when they are in transition from the littoral to limnetic zones, are important determinants of juvenile survival.

PREDATOR STUDY

By Brian Mercer

A limited semi-quantitative examination of the potential predators of Tatsamenie Lake sockeye fry was conducted concurrently with the fry research performed in 2001 and 2002 (Riffe and Mercer 2005). A qualitative analysis of the stomach contents of 936 potential predator fish was performed. The results of the study must be examined with care because of the variables introduced from non-standardized capture methods, the small sample size of some species, and skewed effect that a few single samples had on the overall results. Unsurprisingly, Dolly Varden, juvenile coho salmon, and lake trout were the 3 identified predators on sockeye fry (Table 5).

Several suppositions can be inferred from the predator study:

1. It appears that lake trout were numerically the most abundant predator species in the lake followed by juvenile coho and Dolly Varden.
2. Over the course of the study period, June through August 2001, sockeye salmon fry comprised a relatively small proportion (by volume) of the dietary intake of the potential predators examined. Invertebrates (various insect life stages and mollusks) made up over 70% of the dietary items. Dolly Varden had the highest incidence of sockeye fry in their stomach contents (39%), although numerically they were the least abundant. Approximately 8% of Juvenile coho and lake trout had sockeye fry in their stomach contents.
3. Differential capture methods indicated that Dolly Varden and juvenile coho were the predominant predators in very shallow littoral habitats. Lake trout predation generally occurred in deeper waters and in the sub-littoral zone.
4. Lake trout likely account for the largest sockeye fry predatory losses. The highest rates of predation by lake trout occurred later in the season (mid July through August). It is inferred these higher predation rates occurred when the sockeye fry were in transition from the littoral to limnetic zones.

Table 5. Fish captured for analysis of stomach contents, by species and method of capture, in Tatsamenie Lake predator study, 2001.

Method of Capture	Kokanee	Rainbow Trout	Mountain Whitefish	Sculpin	Dolly Varden	Coho Juveniles	Lake Trout
Angling							
No. Examined	1	1			3		579
No. with salmon fry	0	0			0		36
Beach Seine							
No. Examined					8	5	2
No. with salmon fry					2	0	1
Gillnet							
No. Examined	1	7	19		3		52
No. with salmon fry	0	0	0		1		7
Trap Net							
No. Examined		7		15	42	123	7
No. with salmon fry		0		1	18	14	1
Gee Trap							
No. Examined		2		18		39	
No. with salmon fry		0		0		0	
Total							
No. Examined	2	17	19	33	56	167	641
No. with salmon fry	0	0	0	1	21	14	45

SMOLT ESTIMATES AND SURVIVAL

By Ron Josephson, ADF&G

Sockeye salmon smolt sampling has been conducted at Tatsamenie Lake since 1992 (which corresponded with the outmigration of the first outplants from brood year 1990). Initially, samples were collected from a fyke net set in the outlet at regular intervals over the course of the expected emigration. Beginning in 1996 and continuing thru 2005, with the exception of 1997, an estimate of total smolt emigrants has been undertaken by means of mark-recapture methodology. Typically a weighted sub-sample of 500 smolts is used to estimate average size, age class, and thermal mark status of the emigration. Fall hydroacoustic estimates of juvenile sockeye in the lake have been conducted at least once a year since 1991.

The enhancement subcommittee has used the estimated survival from egg to smolt as a gauge for comparing survival rates of wild and enhanced fish. This approach provides a common denominator for comparison. The number of eggs collected for the enhancement programs is a relatively easy number to accurately obtain. The potential wild egg deposition is based on the estimated number of females in the escapement multiplied by the fecundity observed in the enhancement egg take.

When the Tatsamenie project was initiated, the normal enhancement approach with a lake stocking program was to stock fry in the pelagic area at a time intended to coincide with the Spring plankton bloom; this approach was followed at Tatsamenie Lake from 1990 thru 1995. When very low proportions of the outmigrant smolts were observed to be enhanced fish, the subcommittee examined release strategies with the goal to improve survival rates. Starting in 1996, fry were released along the shore to emulate natural conditions. For the period from 1996 through 2004 one or two different approaches were used every year as the committee searched for a strategy that would improve survival rates. Table 6 summarizes the treatments applied by brood year; for the most part the primary treatment resulted in the best survival. For those years with total smolt emigration estimates, we have calculated survival from egg to smolt for hatchery fish and wild sockeye fry at Tatsamenie Lake (Figure 15). The survival rates for all treatments

Table 6. Summary of methods used for sockeye fry plants in Tatsamenie Lake by brood year.

Brood Year	Primary Treatment	Secondary Treatment
1990-94	Released In Lake Center	
1995	On Shore	
1996	On Shore	
1997	Fed	On Shore
1998	Fed	Unfed
1999	Fed	
2000	Early Fed	Late Fed
2001	Early Unfed	Late Fed
2002	Early Unfed	Fed (IHN Loss)
2003	Early Unfed North	Early Unfed South
2004	Early Unfed North	Early Unfed South

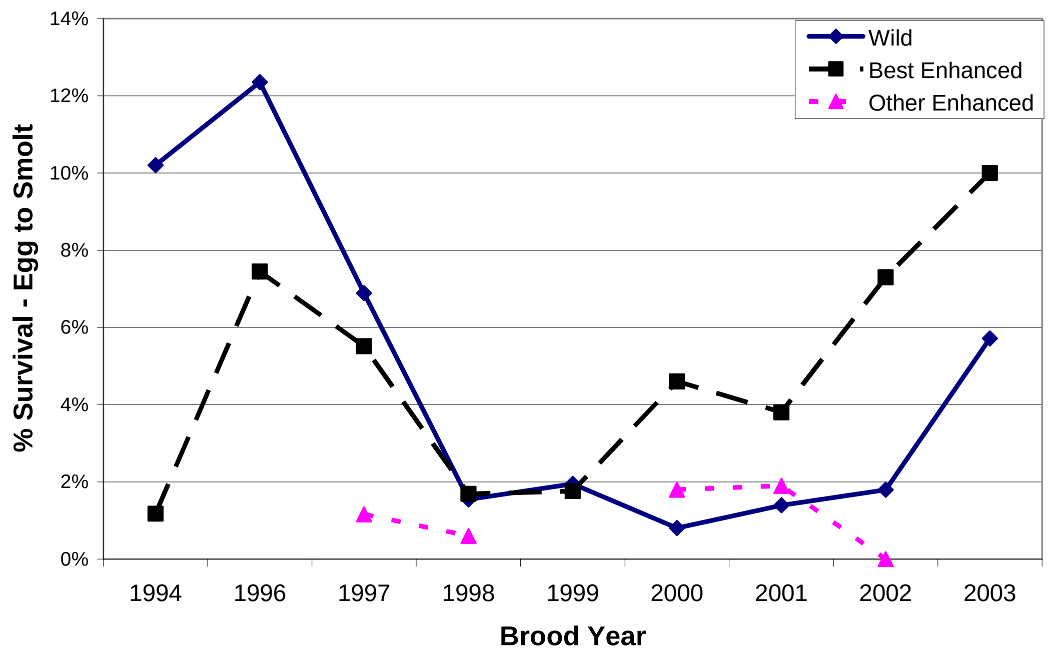

Figure 15. The estimated survival from egg to smolt for hatchery and wild sockeye at Tatsamenie Lake by brood year.

improved in recent years and the hatchery fish have consistently done better than wild fish. .Even though there are many variables between years that can effect survival, there can be agreement within some treatments that suggests a correlation. For example the approach of releasing fry earlier was based on a relationship between day of release and survival at Tahltan Lake. In 1999 the enhancement subcommittee had noted that survival rates from egg to smolt at Tahltan had declined and that the better survivals seemed to coincide with releases on earlier dates (Figure 16). Therefore, starting in 1999 the committee initiated early releases at Tatsamenie Lake (PSC 2001). As part of the ongoing assessment of the Tatsamenie enhancement project we looked at the relationships between a series of variables to determine how fish culture, transport, or outplant techniques influenced fry to smolt survival. The Figures 16-19 present some of these analyses.

The average size of hatchery and wild smolts has been estimated for all years of the project (Figures 20 and 21). Smolt size is a general indicator of rearing conditions and density dependence; average sizes have been quite consistent with a slight increase in 2004 and 2005.

The TBR panel has directed us to keep the proportion of hatchery smolts below 50%. Figure 22 shows the estimated percent of the Tatsamenie Lake smolts that are enhanced; the highest percentage observed in any given year to date has been 38%.

Recent increases in size of wild and hatchery fish as well as survival rates to smolt suggest that there are not negative impacts from the enhancement program.

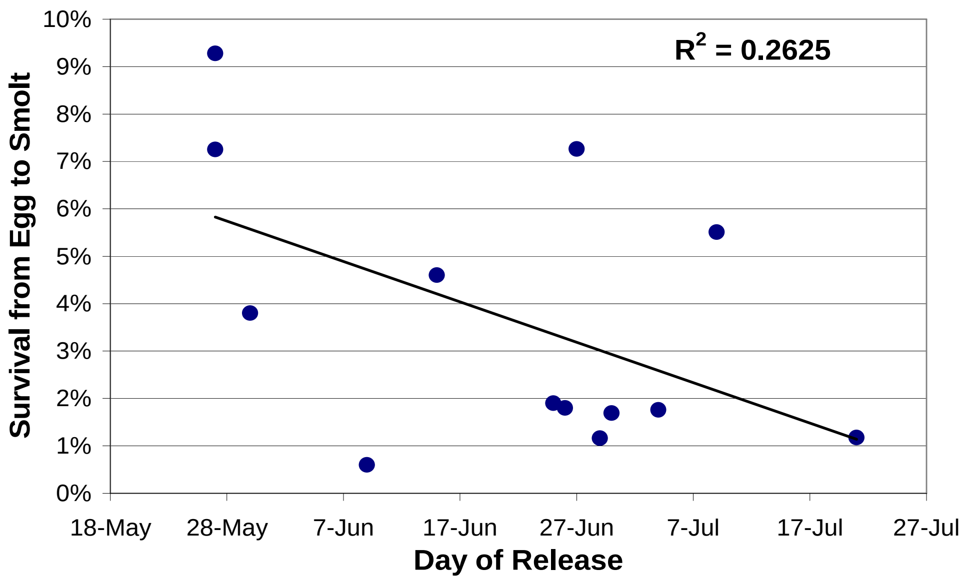

Figure 16. Relationship between day of release and survival from eggs collected to smolt for Tatsamenie sockeye salmon brood years 1994, and 1996 through 2003.

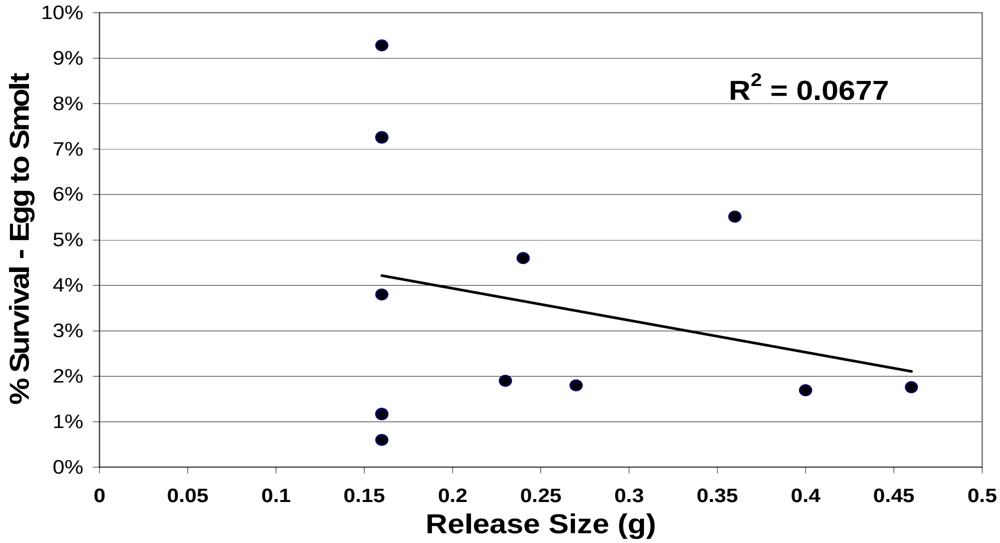

Figure 17. Relationship between size of hatchery fry at release and survival from eggs collected to smolt for Tatsamenie sockeye salmon brood years 1994, and 1996 through 2003.

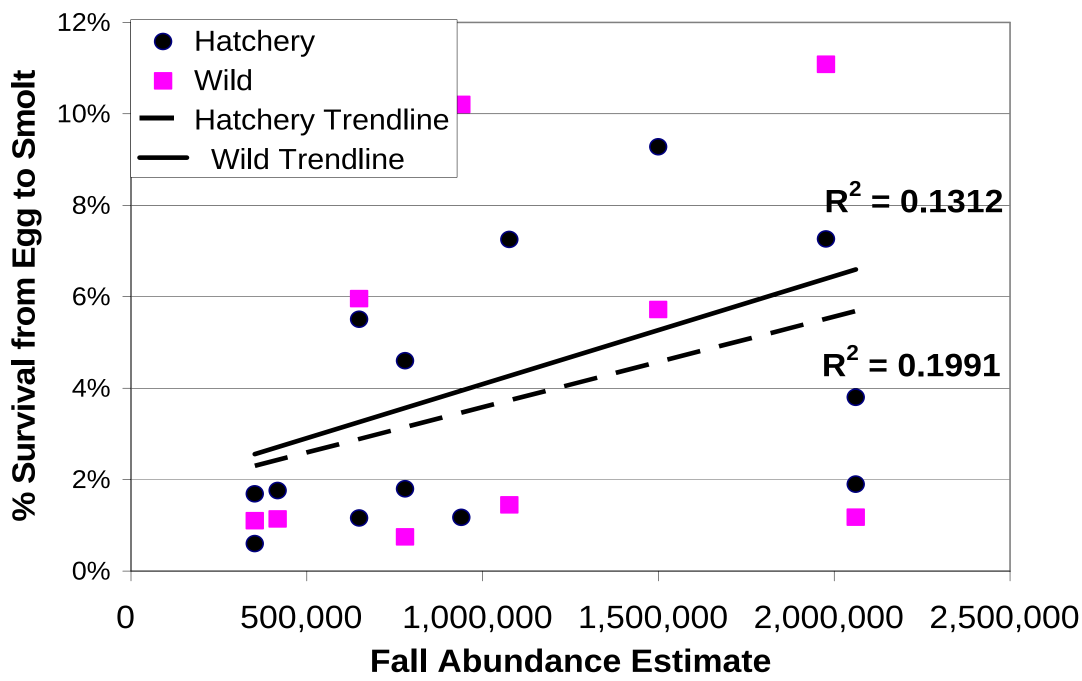

Figure 18. Relationship between the fall fry estimate and survival from eggs collected to smolt for Tatsamenie wild and hatchery sockeye salmon brood years 1994, and 1996 through 2003.

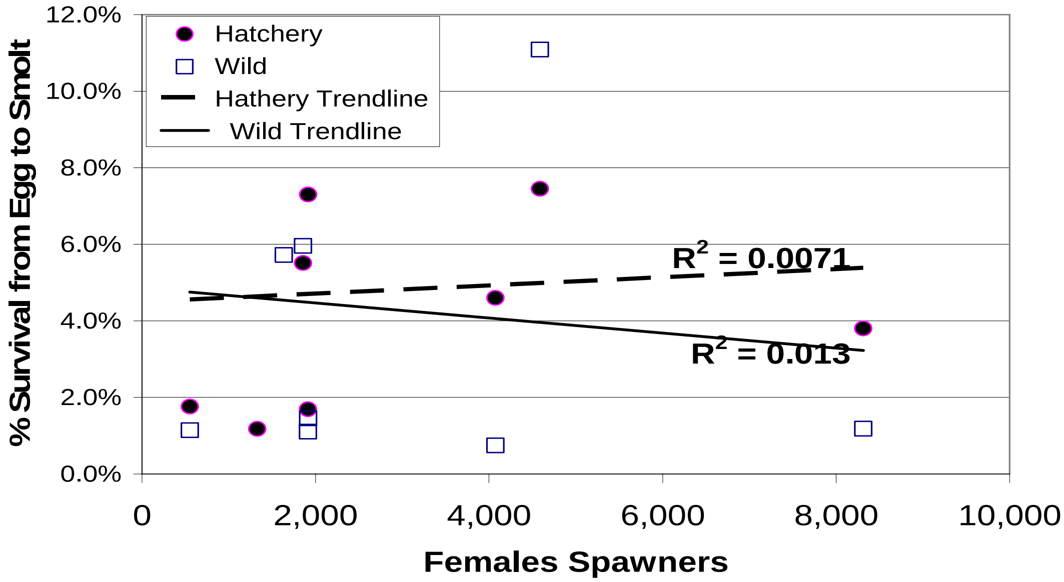

Figure 19. Relationship between estimated female spawners and survival from eggs collected to smolt for Tatsamenie wild and hatchery sockeye salmon brood years 1994, and 1996 through 2003.

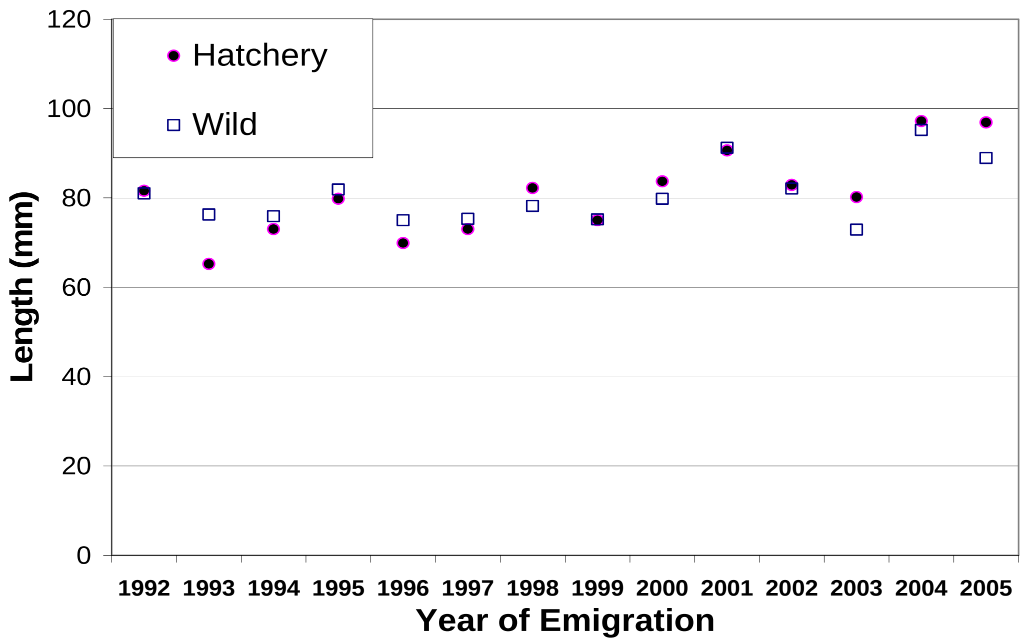

Figure 20. Average length in mm of age 1.0 Tatsamenie Lake wild and hatchery sockeye smolt, 1992 through 2005.

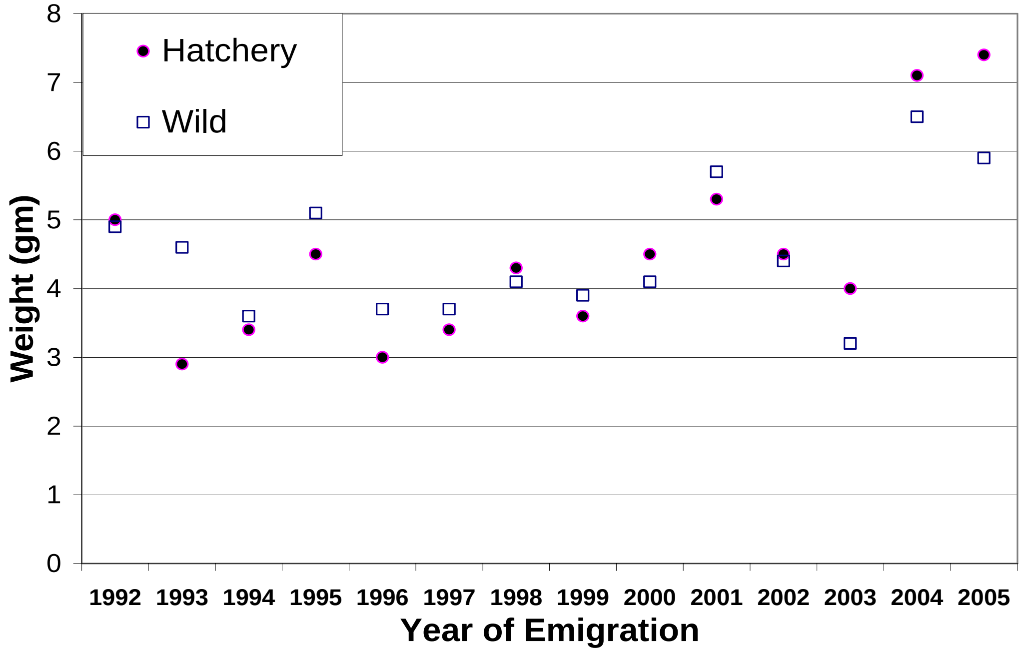

Figure 21. Average weight in grams of age 1.0 Tatsamenie Lake wild and hatchery sockeye smolt, 1992 through 2005.

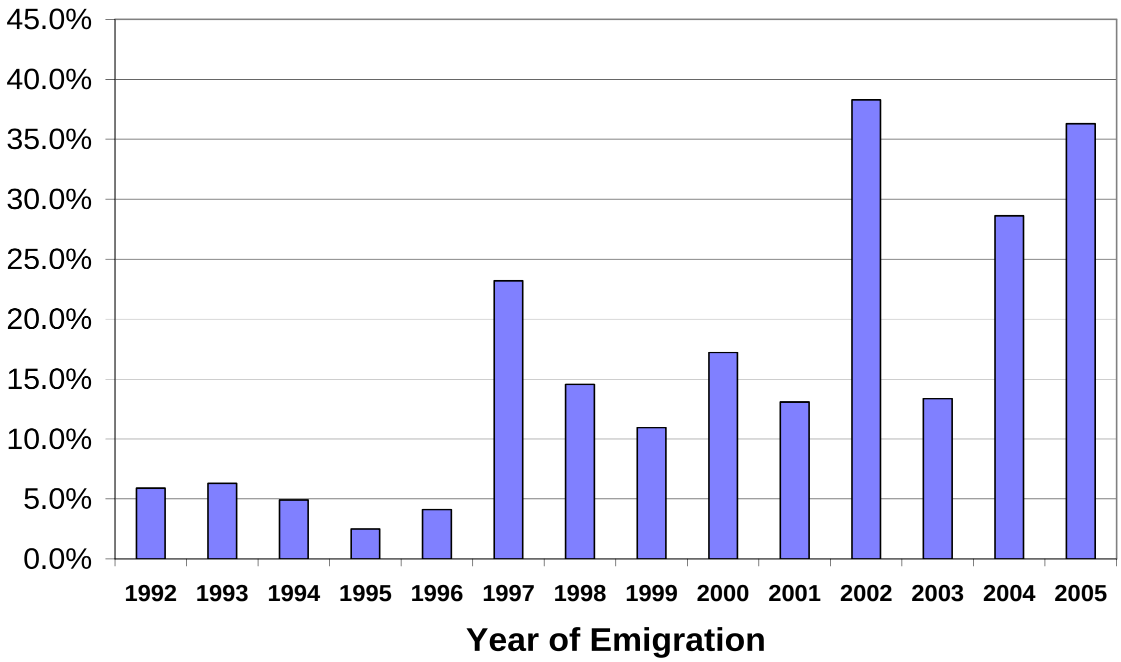

Figure 22. Percentage of smolts at Tatsamenie Lake that are of hatchery origin.

SMOLT-TO-ADULT SURVIVAL

By Ian Boyce, DFO

A brood table for enhanced fish was constructed using estimates of smolt outmigration, catches and escapement (Table 7).

Table 7. Estimated numbers of smolts and adult returns of Tatsamenie Lake enhanced sockeye smolts.

Brood Year	Smolts 1+	Smolts 2+	Smolts Total	1.2	1.3	1.4	1.5	Total
1991	-					246	0	246
1992	-				896	54	0	950
1993	-			5	219	27	0	251
1994	14,442	0	14,442	34	509	247	0	791
1995				0	488	291	126	905
1996	364,093	3,456	367,549	1,915	14,081	463	0	16,460
1997	81,544	2,781	84,325	272	593	65	11	941
1998	30,049	555	30,604	183	2,356	11	19	2,569
1999	8,728	590	9,318	193	560	0		754
2000	88,473	0	88,473	1,152	997			2,149
2001	72,098	0	72,098	372				372

(Adults were assumed to be age 1.x fish.)

Thermal marks were used for all estimates of enhanced contribution and associated age composition. In assigning adult returns to respective brood years it was assumed that all fish outmigrated after one winter in freshwater. Based on smolt sampling, typically more than 95% of enhanced fish outmigrate after only one winter in freshwater.

Smolt outmigration was estimated using mark-recapture methodology. This program was initiated in 1996 and conducted annually, with the exception of 1997. The enhanced contribution and its age composition were based on representative samples of 400-600 fish per annum.

Estimates of the number of enhanced fish caught in the US fishery was based on weekly samples of 300-700 fish taken throughout the various District 111 sub-districts with the greatest emphasis on Taku Inlet (District 111-32). The sampling target for the Canadian commercial fishery ranged from 60 to 96 fish per week. Recreational, personal use and aboriginal catches were not sampled; this is considered to be inconsequential as those catches are relatively minor in relation to commercial catches.

Estimates of enhanced escapement were based on samples taken from Tatsamenie Lake broodstock. This data source was used rather than sacrifice fish which otherwise would have contributed to egg deposition. Broodstock collection is not completely random as earlier migrants are selected preferentially. This would only be an issue if there are significant differences in terminal migration timing for enhanced and wild fish. This has not been demonstrated.

Using the above data/ time series Tatsamenie sockeye smolt-to-adult survivals for 1994 and 1996 through 2000 brood years were calculated (Table 8 and Figure 23). The estimate of survival for the 1994 brood year should be considered a minimal estimate as enhanced escapement figures were not available for 1.2 and 1.3 fish. The same applies to the 2000 brood year as age 1.4 fish will not return until 2006 (age 1.4 fish have comprised 0-33% of the enhanced return). Survival for this time series averaged 5.1%.

Table 8. Estimated smolt-to-adult survivals of Tatsamenie Lake and Tahltan Lake sockeye**.**

Brood Year	**Tahltan Wild**	**Tahltan Enhanced**	**Tatsamenie Wild**	**Tatsamenie Enhanced**
1990	11%	6%		
1991	8.1%	6.9%		
1992	9.6%	6.8%		
1993	4.0%	4.2%		
1994	4.1%	1.6%	2.9%	5.5%
1995	5.4%	2.9%		
1996	5.1%	3.6%	3.1%	4.5%
1997	3.2%	0.9%	5.4%	1.2%
1998	14.3%	12.1%	10.9%	8.5%
1999				8.6%
2000				2.4%
Averages				
94, 96-00				5.1%
94,96-98	6.7%	4.6%	5.6%	4.9%
90-98	7.2%	5.0%		

Comparisons were made with available data from Tahltan Lake, both enhanced and wild. Over similar time periods (1994 and 1996-1998), enhanced survivals both averaged 4.6% and 4.9% for Tahltan and Tatsamenie smolts respectively.

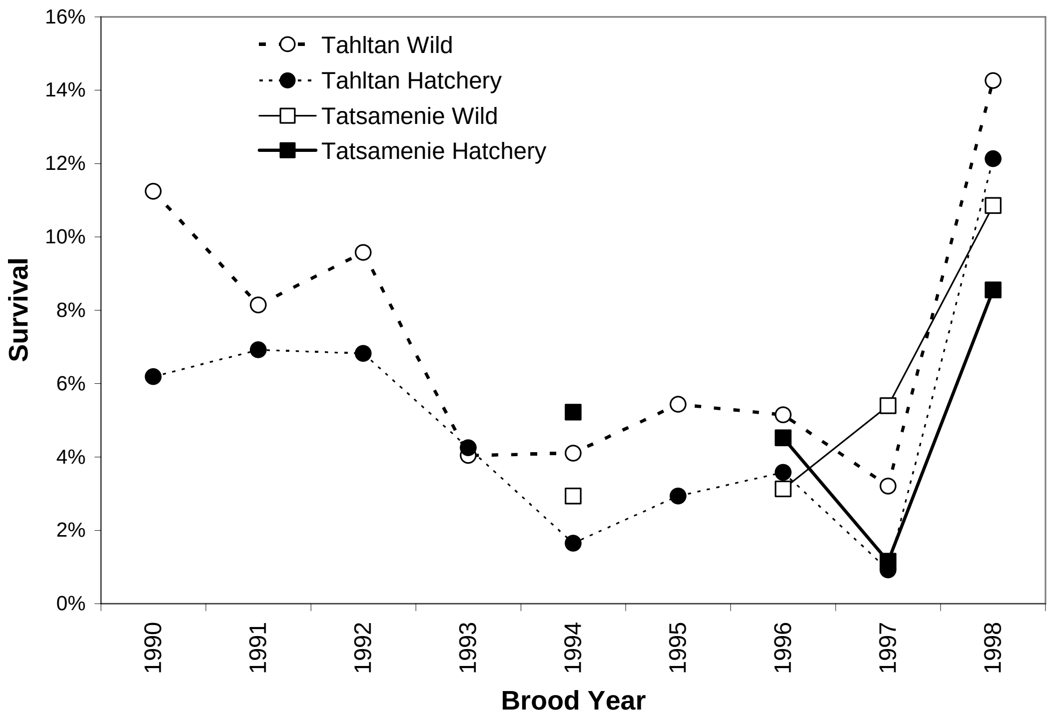

Figure 23. Estimated smolt-to-adult survivals of Tatsamenie Lake and Tahltan Lake sockeye.

Estimated smolt weights are presented in Table 9. A weak relationship was observed between smolt weight and survival for enhanced Tatsamenie fish (r2 =0.44, df=4). Similar results were observed with Tahltan enhanced fish (r2 =0.44, df=8). Strong relationships were observed between smolt weight and smolt length (r2 =0.91, df=10 for Tatsamenie fish and r2 =0.96, df=10 for Tahltan fish).

Table 9. Mean weight (g) of age-1 sockeye salmon smolt from Tatsamenie and Tahltan Lake.

Brood Year	Tahltan Wild	Tahltan Enhanced	Tatsamenie Wild	Tatsamenie Enhanced
1990	4.8	4.6	4.9	5.0
1991	4.1	3.9	4.6	2.9
1992	5.0	4.7	3.6	3.4
1993	4.7	4.4	5.1	4.5
1994	4.0	3.2	3.7	3.0
1995	3.4	3.2	3.7	3.4
1996	4.5	4.8	4.1	4.3
1997	4.7	4.6	3.9	3.6
1998	5.5	5.9	4.1	4.5
1999	5.6	6.3	5.7	5.3
2000	5.9	6.9	4.4	4.5
Mean	4.7	4.8	4.3	4.0

Comparisons between enhanced and wild survival for Tatsamenie smolts should be made cautiously due to difficulties associated with identifying wild Tatsamenie fish in the mixed stock fisheries in Canada and the US. Scale pattern analysis (SPA) is used for this purpose, but results have large confidence intervals, and are believed to be biased high since the SPA model allocates harvest between only four stocks, when in fact there are several others.[3] For available years (1994 and 1996-1998) survival averaged 5.6% and 4.9% for wild and enhanced fish respectively. Assuming that estimates of wild smolt survival are inflated, it appears that the survival of enhanced fish is at least as high as that of wild fish. The converse appears to be true for Tahltan Lake fish, with wild and enhanced survivals averaging 7.2% and 5.0% respectively. Stock identification for Tahltan Lake fish is generally considered to be more accurate in Canadian fisheries where it is based on an easily observable morphological characteristic (egg diameter); however SPA is used for US fisheries.

To meet the Pacific Salmon Treaty goal of producing 100,000 adult returns annually, the minimum number of enhanced smolts required would be 1.2 million based on the maximum survival observed to date (8.6%). The largest outmigration of enhanced Tatsamenie Lake sockeye smolts recorded so far is 367,500 fish; this produced a return of 16,460 adults (Table 1).

PRODUCTS OF THE REVIEW

After the presentations were concluded a general discussion ensued. There were a lot of questions directed toward the presentations on behavior of fry in the lake and the general change in survival rates that have been observed in recent years. The group recommended that we summarize these discussions into three categories: observations, unresolved issues/questions, and recommended approaches.

Observations

The reviewers all agreed that it was improbable that we could ever produce 100,000 adults at Tatsamenie following our fry stocking program. Two aquaculturists commented that their organizations do not use fry stocking anymore. Canadian reviewers also commented that they only know of two lakes [other than TBR] in BC where fry stocking is done. One reviewer commented that fry stocking has been successful at Tahltan and Tuya. There was also a comment that we do not yet know what we can produce as we don't know if we have identified the best strategy. Another reviewer offered the observation that the escapement to Tatsamenie is averaging 4,000 adults and that is quite a bit short of the number that would be needed to collect enough eggs to produce 100,000 adults even if the survival rates were at our original assumptions. The reviewers all felt a more detailed analysis of expected adult returns from the Tatsamenie project should be developed based on observed survival rates. Table 10 presents the range in potential

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3 . Tatsamenie exploitation rates based on SPA appear inflated; they average 79% from 1995-2003 compared to 58% for the Taku composite stock.

adult production using the average survival rates from egg to smolt and smolt to adult as well as a best case scenario using the best rates for each; Tahltan Lake estimates are shown for comparison.

Table 10. Potential adult production based on average survival rates for egg to smolt and smolt to adult and best survival rates for Tatsamenie and Tahltan Lakes.

	Egg Collection	Egg to Smolt Survival (%)	Smolt to Adult Survival (%)	Projected Adult Production
Tatsamenie Lake				
Average	5,000,000	4.8%	4.9%	11,783
Best	5,000,000	10.0%	8.5%	42,493
Tahltan Lake				
Average	5,000,000	16.4%	5.5%	45,146
Best	5,000,000	47.0%	12.1%	284,194

It was observed that Tatsamenie Lake doesn't appear to be density dependent at the stocking levels we have tried. This comment was primarily in response to seeing that the largest smolt size to date were observed in 2005 when we had the greatest numbers of smolt since 1999. The premise was also supported by the weak but positive relationships between juvenile survival and fall acoustic counts and also between acoustic counts and size of smolt. In 2005, both wild and hatchery smolts were the largest we have seen in the 14 years of the project. However, one reviewer commented that he was concerned regarding competition in littoral zone and another reviewer cautioned that we need to maintain observations in regard to density dependent effects as there is potential for competition with wild fry. It was noted that there remains no easy way to assess this, nor any indication that it is occurring. This is considered an uncontrollable risk, meaning it would have happened by the time we see a negative affect. However in such a situation, if stocking is discontinued the lake would eventually revert to its former dynamic equilibrium. The final point was made that we know the variation in survival so if the survival drops below the low end of the historical range then there is likely a negative affect.

There was some discussion about following an alternative approach where fry are held in net pens and reared to about 6 grams and released in late fall. This approach has worked well for an aquaculture group in Alaska. Some reviewers felt this approach could be followed at Tatsamenie without negative impacts and others felt there would be problems with managing returning adults. This approach would also address concerns about negative impacts of enhanced fry during the critical transition from littoral to limnetic feeding, since enhanced fry would be contained and fed in net pens, would require technician support and present some logistical concerns. It was pointed out that long term holding could result in increased disease losses. In addition, the premise of the enhancement program is the utilization of un-used rearing potential in the outplant lakes. Net pen rearing would not take advantage of this supposition. The review did not pursue any more discussion of this approach.

There was some criticism that the committee had undertaken too many strategies for stocking and that we need to stick with one strategy to see if the results were true or just an artifact. Consensus was reached that the committee should stick with early stocking approach. It was similarly observed that the data set for Tatsamenie Lake isn't sufficient to definitively conclude about a difference in survival between on-shore and off-shore releases. While there was not much discussion on this topic, this seems to fit as one of the unresolved questions which could be addressed at a later date.[4]

Unresolved Issues/Questions

The review committee asked that we expand Figures 6 and 12 from the Hyatt et al. (2005) report to include more recent year's data. These figures were felt to be particularly demonstrative of the changes that had taken place in the lake since brood year 1999 which was the last year compared in Hyatt et al. (2005). Those two figures are presented below (Figures 24 and 25).

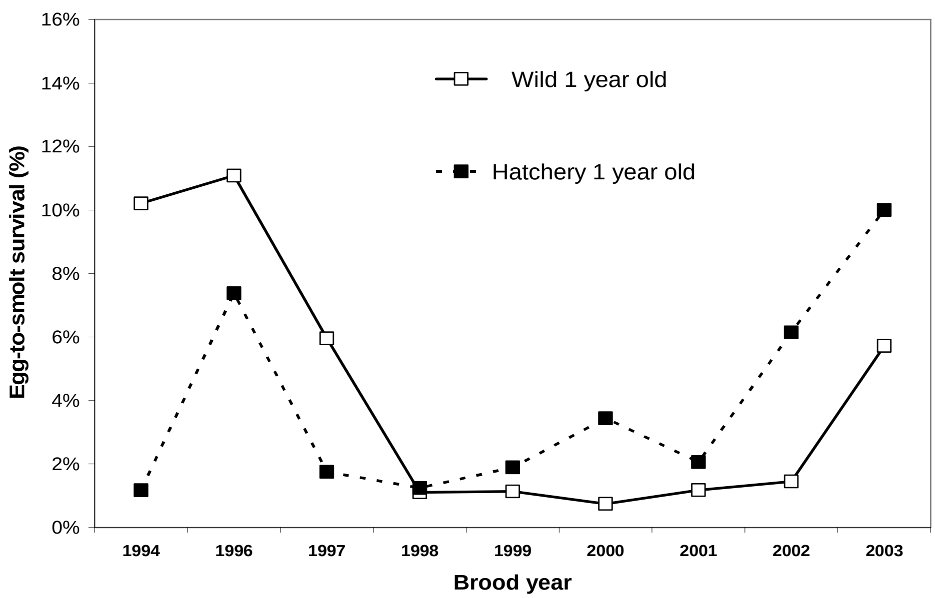

Figure 24. Sockeye salmon egg-to-smolt survival (age-1 smolt number expressed as a percentage of egg number) based on Tatsamenie Lake weir mark-recapture data of hatchery and wild smolts. (updated Figure 6 in Hyatt et al. (2005)).

[4] The question of survival differences between onshore and offshore is discussed in the Fry Survival section of this paper and the technical committee believes there is strong evidence that onshore releases do have higher survival rates.

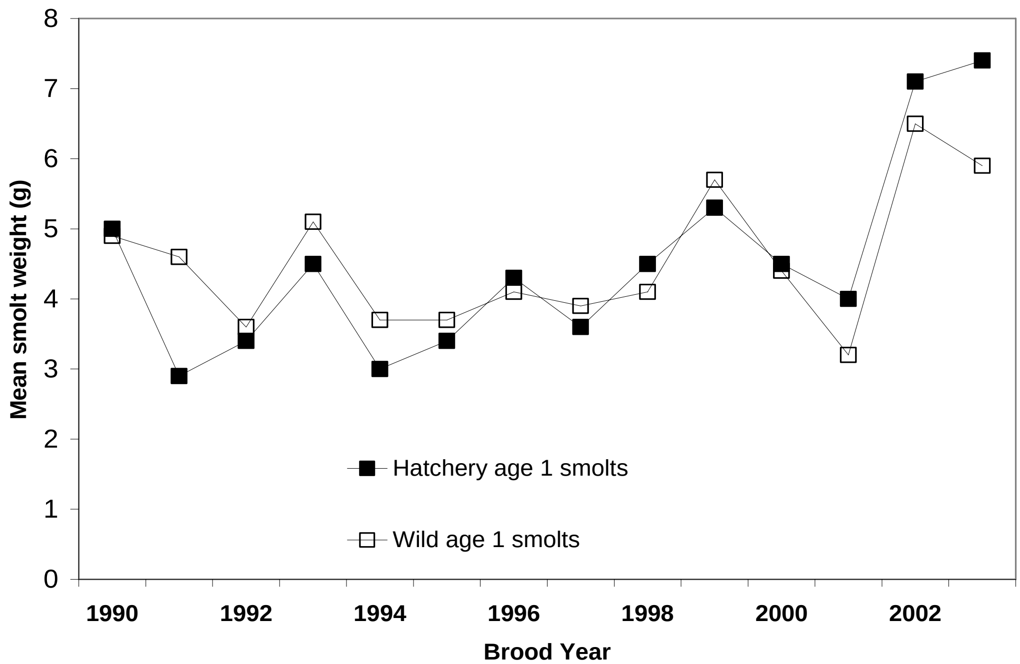

Figure 25. Mean weights (G) of hatchery and wild age-1 sockeye salmon smolts from Tatsamenie Lake. (updated Figure 12 in Hyatt et al. (2005))

The relation ship between escapement, fall acoustic estimate of fry, and emigrant smolts shown in Figure 26 resulted in some discussion about the accuracy about the estimate of annual smolt emigration. The reviewers thought there was a pretty good relationship with the escapement and the resulting fall fry estimate, but less so to the smolt estimate. How evermore, in most years there appears to be a good relationship between smolt population estimates and escapements in the dominant return year (5+). They asked the committee to analyze this data more closely.

We examined the relationships between female escapements, the following year's fall acoustic counts and the next year's spring count of age-1 smolts to determine if predictions were possible (Figure 26). The only relationship that was statistically significant was predicting fall acoustic counts using the prior year escapements (F= 0.024: R^2= .35). Escapement was not a good predictor of the count of age-1 smolts or overall smolt production in Tatsamenie Lake, nor was fall acoustic a good predictor of spring smolt counts. The enhancement sub-committee has a lot of confidence in the mark recapture methods used for the smolt estimates. We note that the estimated marine survival rate from smolt to adult for Tatsamenie and Tahltan Lakes have good agreement for the same brood years. If smolt estimates were not accurate, this relationship would be poor. The committee would like to undertake more detailed analysis of escapements, acoustic counts, smolt counts, and size information as they relate to marine survival. In addition, commercial catches, and exploitation rates, will be examined in more detail as additional adult data become available.

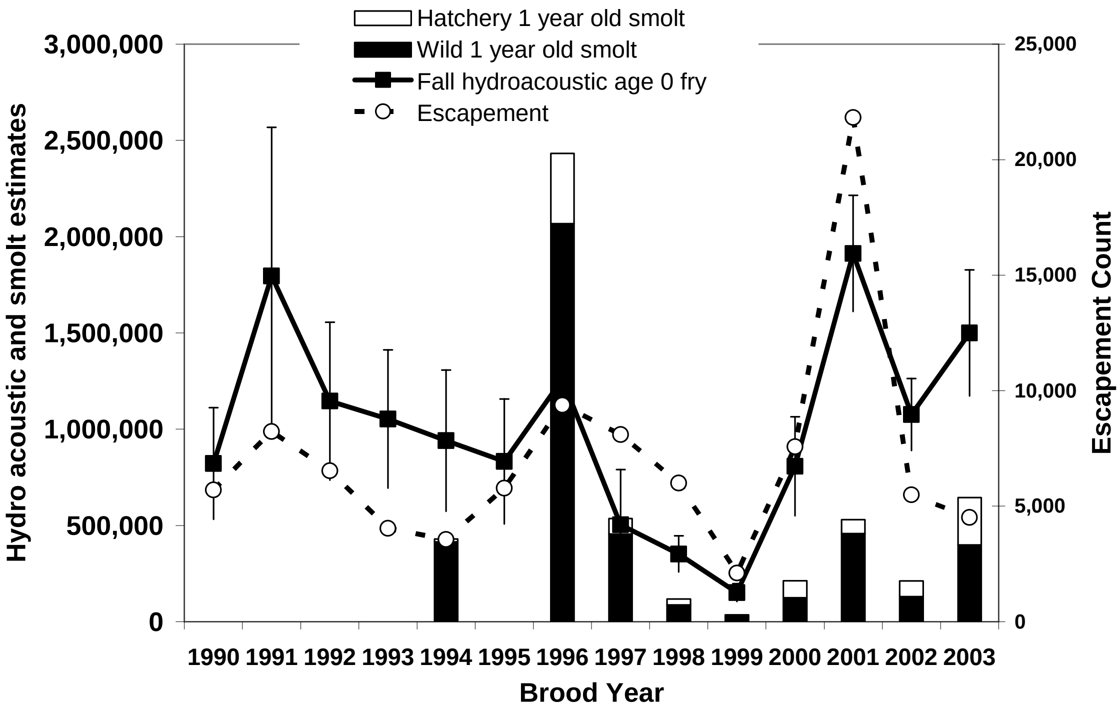

Figure 26. Comparison of the adult escapement, the fall hydroacoustic fry estimate that took place the following year, and the 1 year old smolt estimate the next year.

Recommended Approaches

The following list is a product of recommendations offered during the discussion phase of the review.

1. The reviewers recommended that the committee do more work on the analysis of survivals from smolt to adult. In particular it was suggested that the committee look at any differences between hatchery and wild smolt survival rates. Brian Mercer commented that, based on his observations, the ratio of wild to enhanced was similar at emigration and as adults. More detailed analysis of the catch, exploitation rate, timing, and escapement of wild and enhanced fish would aid in clarifying the evaluation of brood year success.
2. The egg take goal should remain at treaty goal of 5 million eggs or 30% maximum numbers of escapement through the remainder of the annex period.
3. Continue stratagy of early entry, shore based releases with no other changes. This would build on the past two years of work and show if this approach really does result in a consistent pattern of success.
4. Smolt biosampling should be expanded.
5. Continue plankton sampling two to three times per year; however it was noted that the literature recommends sampling a minimum of 5 times per year.
6. Project should use a top of the line current meter for plankton tows.

7. It was suggested that DFO should seek a hydroacoustic machine through the Northern Fund.
8. Consider beach seining earlier in the rearing season to define prey presence/preference in the littoral zone. In addition perform additional stomach content analysis to see if there is a difference in prey between hatchery and wild fry. Consider possible methods to evaluate dipteran production, which has been identified as a possible factor in the successful transitioning from littoral to limnetic feeding
9. The enhancement subcommittee should get a new person on the committee that has greater expertise for evaluation of program. Outside review should be pursued.
10. If the early stocking proves successful, a single larger than average release should be considered. This would be like a pulse of hatchery fry that might show something that is not revealed in normal program.

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APPENDICES

Appendix 1. Bilateral Transboundary River Panel Statement from 12 February 2004.

BILATERAL STATEMENT OF THE TRANSBOUNDARY PANEL ON TRANSBOUNDARY SOCKEYE ENHANCEMENT

Stikine sockeye enhancement

Although joint enhancement of Stikine River sockeye salmon has resulted in increased catches in existing fisheries, a number of concerns have arisen in Canada as a result of this program including:

- relatively poor success in harvesting terminal surpluses in the Tuya River,
- straying of Tuya sockeye into other spawning areas; and
- potential kokanee production in Tuya Lake:

The parties wish to maintain their obligations to enhance Stikine River sockeye salmon. However, in light of these concerns and to acknowledge a need for a cautious approach to enhancement on the river, the Parties agree to undertake the following:

a). immediately pursue funding (Northern Fund or other sources) and develop a suitable (effective, economical and safe) and improved terminal harvest capability in the Tuya River so that at least 80% of the terminal sockeye are harvested (or another appropriate level as determined through point (c) below);

b). determine the degree of straying of sockeye originating from the Tuya Lake fry outplants through examination of sockeye populations in other major spawning areas;

c). conduct a risk analysis by the Transboundary Technical Committee with respect to potential long-term impacts of the enhancement program on wild stocks;

d). develop a process for conducting periodic review as identified in Appendix to Annex IV, Chapter 1, paragraph 1(b);

e). plant fewer fish into Tuya Lake in 2004 than what is permitted under the Appendix to Annex IV, Chapter 1, paragraph 3(b)b. The number of fry to be outplanted into Tuya Lake in 2004 will not exceed 2.5 million; and

f). continue outplants into Tahltan Lake with the goal of not exceeding a ratio of 1:1 enhanced - to - wild out-migrating smolts.

The Parties agree that future decisions about fry outplants into Tahltan and Tuya lakes will be the charge of the Enhancement Sub-committee of the Transboundary Technical Committee. In the absence of agreement, the resolution of the impasse will first be addressed by the Transboundary Technical Committee, then by the Transboundary Panel.

Taku River sockeye enhancement

Although extensive efforts have been made by the Parties to improve the success of the Tatsamenie Lake sockeye enhancement project, the Parties are disappointed with the results to date. The project has thus far failed to produce the expected benefits and the costs have been excessive relative to benefits from resulting enhanced fish production.

Consistent with Appendix to Annex IV, Chapter 1, paragraphs 1(b) and 2(b)(iv), the Parties agree that the Transboundary Technical Committee develop a review process for Transboundary enhancement projects and to further conduct a review of the Tatsamenie project to address, amongst other things:

a). the lack of success of the project;
b). the costs associated with the project;
c). procedures for evaluation;
d). biological risks of the project (Appendix to Annex IV, Chapter 1, paragraph 4(a));
e). and recommend appropriate actions.

The target date for completion of the review of the Tatsamenie project is the 2005 January meeting of the PSC.

The Parties also agree to develop proposals to the Northern Fund to begin feasibility projects in 2004 on other joint enhancement options identified by the Parties pursuant to Annex IV, Chapter 1, paragraph 7.

TBR Lake Water Quality Study - 2001 Spring WATER QUALITY CRITERIA AND MEASUREMENTS											
		Recommended Criteria:									
Parameter	Units	WDF (a)	Piper et. Al (b)	ADF&G ©	DFO (d)	Snett. Treated	Snett. Untreated	Tuya Lake	Tahltan Lake	Tatsamenie lake	Chilkat lake
Alkalinity (as CaCO3)	Mg/L		10 – 400		>15	3.9	3.9	30.0	93.0	65.0	56.0
Aluminum	Mg/L	<0.01	<0.01	<0.01	0.1	0.089	0.190	0.028	0.007	0.034	0.044
Ammonia (as NH3)	Mg/L	<0.0125	<0.0125	<0.0125	<0.05	ND	ND	ND	ND	ND	ND
Arsenic	Mg/L	<0.05	<0.05	<0.05							
Barium	Mg/L	<5	<5	<5							
Cadmium (d)	Mg/L	<0.0002	<0.0004	<0.0005	0.0003	ND	ND	ND	ND	ND	ND
Calcium Carbonate	Mg/L	<10	4-160								
Carbon Dioxide	Mg/L	<1	0-10	<1	<10						
Chloride	Mg/L		<0.03	<4							
Chlorine	Mg/L			<0.003							
Chromium	Mg/L	<0.01	<0.03	<0.03	<0.04	ND	ND	ND	ND	ND	ND
Copper (e)	Mg/L	<0.05	<0.006	<0.006	<0.002	0.00033	0.00024	0.00023	0.00037	0.00086	0.00091
Dissolved Oxygen (inflow)	% saturation		95 – 100	90	>95						
Dissolved Oxygen (outflow)	Mg/L			7							
Fluoride	Mg/L	<O.5	<0.5	<0.5							
Hardness (as CaCO3)	Mg/L	<200	10-400		>20	50	n/a	28	110	83	76
Hydrogen cyanide	Mg/L	<0.005	<0.01								
Hydrogen sulfide	Mg/L	<0.003	<0.0001	<0.003	<0.002						
Iron	Mg/L	<0.1	<0.15	<0.1	0.3	0.087	0.19	0.068	ND	ND	0.058
Lead	Mg/L	<0.02	<0.03	<0.02	0.004	ND	ND	ND	ND	ND	0.00049
Magnesium	Mg/L	<15	Needed	<15							
Manganese	Mg/L	<0.01	<0.01	<0.01	0.1	0.0064	0.0090	0.0041	0.0031	0.0019	0.0039
Mercury	Mg/L	<0.0002	<0.0002	<0.0002	0.0002	ND	ND	ND	ND	ND	ND
Nickel	Mg/L	<0.01	<0.01	<0.01	0.045	ND	ND	ND	0.00064	0.00087	0.00092
Nitrate (as N03)	Mg/L	<1	0-3	<1							
Nitrite (as N02)	Mg/L	<0.1	<0.1	<0.01	<0.015	ND	ND	ND	ND	ND	ND
Nitrogen	% saturation	<110	<100	<103							
Ozone	Mg/L		<0.005								
PCBs	Mg/L		<0.002								
pH	pH units	6.5-8.0	6.5-8.0	6.5-8.0	7.2 - 8.5	6.9	7.3	7.7	8.2	8.1	8.2
Potassium	Mg/L	<5	<5	<5							
Salinity	ppt		<5	<5							
Selenium	Mg/L	<0.002	<0.01	<0.01	0.05		ND	ND	ND	ND	ND
Settleable solids	Mg/L		<80	<80							
Silver	Mg/L	<0.003	<0.003	<0.003	0.0001	ND	ND	ND	ND	ND	ND
Sodium	Mg/L	<75	<75	<75							
Strontium	Mg/L					0.025	0.015	0.027	0.066	0.097	0.060
Sulfate	Mg/L	<50	<50	<50							
Sulfur	Mg/L		<1								
Total dissolved solids	Mg/L		10-1000	<400							
Total suspended solids	Mg/L		<80		<3	ND	6.2	ND	ND	ND	ND
Uranium	Mg/L		<0.1								
Vanadium	Mg/L		<0.1								
Zinc	Mg/L	<0.005	<0.03	<0.005	0.015	0.0045	0.0036	0.0034	0.0029	0.0036	0.0059
Zirconium	Mg/L		<0.03								

(a) WDF, July 11, 1989, Letter from Steve Schroeder, Washington Department of Fisheries, to Cave Parkinson, Seattle Water Department.

(b) Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler and J.R. Leonard. 1982. Fish Hatchery Management.

(c) FRED Staff, Alaska Department of Fish and Game. 1983. Fish Culture Manual.

(d) DFO, Summary of Water Quality Criteria for Salmonid Hatcheries, October

(e) Criterion is for waters with alkalinity <100 mg/L.

Appendix 2. Water quality results for Snettisham Hatchery and Transboundary Lakes.

Appendix 3 Summary of Tatsamenie egg collection, survival, fry transports, thermal marks, numbers released, and release dates.

Brood-year	No. eggs taken	Egg Take Target ($x10^6$)	No. fry transported	Survival: Percent Fertilized	Survival: Fertilized egg to planted fry	Survival: Green egg to planted fry	Thermal mark pattern	Treatment	Number of Fry Released	Last Date Released
1990	985,000	2.5	673,000	77%	88%	68%	1:1.3		673,000	6/22/1991
1991	1,360,000	1.5	1,232,000	93%	98%	91%	2:1.4		1,232,000	6/26/1992
1992	1,486,000	1.75	909,000	86%	71%	61%	1:1.5		909,000	7/14/1993
1993	1,144,000	2.5	521,000	62%	74%	46%	2:1.5		521,000	7/21/1994
1994	1,229,000	2.5	898,000	80%	91%	73%	1:1.5		898,000	7/21/1995
1995	2,407,000	2.5	1,724,000	84%	85%	72%	2:1.5		1,724,000	6/25/1996
1996	4,934,000	5.0	3,945,000	85%	94%	80%	1:1.5	onshore	3,945,000	6/27/1997
							1:1.5+2.3	onshore		6/27/1997
1997	4,651,000	5.0	3,597,000	91%	85%	77%	2:1.5	onshore	3,202,327	6/29/1998
							2:1.5,2.3	fed at lake	394,266	7/9/1998
1998	2,414,000	2.5	1,769,000	90%	82%	73%	1:1.4+2.5	unfed	750,943	6/9/1999
							1:1.4+2.3	fed at lake	1,017,989	6/30/1999
1999	461,000	2.5	350,000	92%	80%	74%	2:1.5	fed at lake	350,139	7/4/2000
2000	2,816,000	3.0	2,320,000	94%	96%	90%	1.1.5+2.3	fed early	1,265,496	6/15/2001
							1.1.5	fed late	1,054,092	6/26/2001
2001	4,364,000	4.8	2,233,000	90%	71%	64%	2:1.5	unfed	1,432,267	5/30/2002
							2:1.5,2.3	fed	727,425	6/25/2002
2002	2,498,000	3.0	911,000	82%	71%	59%	1:1.4	direct release early	911,378	5/27/2003
			442,000				1:1.4+2.3	fed - IHN loss	-	none
2003	2,642,000	5.0	1,004,962	92%	95%	87%	1.1.5+2.3	unfed early south	1,004,962	5/27/2004
			1,135,995				1.1.5	unfed early north	1,135,995	5/24/2004
2004	750,000	5.0	366,778	93%	95%	84%	1:1.4+2.5N	unfed early south	366,778	5/20/2005
			261,279				1:1.4+2.3,3.3	unfed early north	261,279	5/20/2005
2005	1,810,657	5.0								
Average	2,246,979	2.9	1,619,534	86%	85%	73%			1,585,156	

Brood Year 2000; 244,000 eggs placed in in-lake incubator and 2,572,000 delivered to Snettisham Hatchery.
Brood Year 2001; 865,000 eggs place in in-lake incubators and 3,499,000 delivered to Snettisham Hatchery.
Brood Year 2002; 196,000 eggs place in in-lake incubators and 2,302,000 delivered to Snettisham Hatchery.
Brood Year 2003; 190,000 eggs place in in-lake incubators and 2,452,000 delivered to Snettisham Hatchery.

Appendix 4. Estimation of total emigration and percent by age class of wild and enhanced Tatsamenie Lake smolts.

Sample Year	Total Smolts	n	Wild Percent 1+	Wild Percent 2+	Wild Estimate 1+	Wild Estimate 2+	Enhanced % 1+	Enhanced % 2+	Enhanced Estimate 1+	Enhanced Estimate 2+	Percent Enhanced
1992		n/a	65.3%	34.7%			100.0%	0.0%			5.9%
1993		n/a	89.9%	10.1%			100.0%	0.0%			6.3%
1994		n/a	88.4%	11.6%			62.5%	37.5%			4.9%
1995		n/a	87.0%	13.0%			79.9%	20.1%			2.5%
1996	513,022	n/a	83.9%	16.1%	415,133	79,439	68.3%	31.7%	14,442	6,705	4.1%
1997		490	88.0%	12.0%			95.7%	4.3%			23.2%
1998	2,502,154	475	96.7%	3.3%	2,068,001	70,060	100.0%	0.0%	364,093	0	14.6%
1999	776,641	498	65.8%	34.2%	455,240	236,401	95.9%	4.1%	81,544	3,456	10.9%
2000	190,720	503	55.1%	44.9%	87,008	70,882	91.5%	8.5%	30,049	2,781	17.2%
2001	70,906	378	43.5%	56.5%	26,797	34,826	94.0%	6.0%	8,728	555	13.1%
2002	232,715	283	86.7%	13.3%	124,574	19,078	99.3%	0.7%	88,473	590	38.3%
2003	539,491	323	97.9%	2.1%	457,563	9,830	100.0%	0.0%	72,098	0	13.4%
2004	238,279	470	61.1%	38.9%	130,000	82,860	96.5%	3.5%	82,290	3,000	28.6%
2005	675,406		92.8%	7.2%	399,000	31,000	100.0%	0.0%	245,000	0	36.3%
Average			78.9%	21.1%	462,591	70,486	90.3%	9.7%	109,635	1,899	17.3%

Appendix 5. Tatsamenie Lake fall fry abundance and mean smolt length and weight by age class.

Brood-year BY=t	Brood-year spawning escapement[a]	Sockeye fall fry abundance in t+1[b]	Emigrating smolt population estimate in t+2[c]	Mean weight (g) of wild smolts in t+2 (age 1+)	Mean weight (g) of wild smolts in t+3 (age 2+)	Mean weight (g) of enhanced smolts in t+2 (age 1+)	Mean weight (g) of enhanced smolts in t+3 (age 2+)
1990	3,725	822,000		4.9	9.5	5.0	
1991	6,383	1,796,000		4.6	13.3	2.9	11.5
1992	4,541	1,146,000		3.6	16.1	3.4	15.2
1993	2,700	1,053,000		5.1	16.3	4.5	16.9
1994	1,740	940,000	513,022	3.7	9.6	3.0	9.5
1995	4,380	832,000		3.7	10.2	3.4	
1996	6,447	1,977,000	2,502,154	4.1	12.8	4.3	16.2
1997	5,338	504,000	776,641	3.9	10.3	3.6	9.8
1998	4,070	352,000	190,720	4.1	10.9	4.5	10.9
1999	1,890	417,000	70,906	5.7	8.5	5.3	9.4
2000	6,094	780,000	233,000	4.4	6.8	4.5	
2001	21,400	2,061,500	539,491	3.2	8.0	4.0	
2002	4,800	1,076,000	298,150	6.5		7.1	
2003	5,300	1,500,000	675,406	5.9		7.4	
2004	1,954						
2005							
Average	5,384	1,089,750	644,388	4.5	11.0	4.5	12.4

[a] Tatsamenie Lake escapement estimates are derived from the Tatsamenie Lake wier counts, minus sockeye used for broodstock, and the little Tatsamenie (1991 to 1993) wier counts less broodstock and the estimated connecting stream stock.

[b] Derived from fall fry population acoustic estimates.

[c]Obtained from smolt mark -recapture program.

Appendix 6. Egg to smolt survival by brood year for Tatsamenie Lake wild and hatchery sockeye salmon

Brood Year	Weir Count	Female Egg Take	Female Other	Female Spawners	Fecundity	Eggs Deposited	Wild Smolt Production 1.0	Wild Smolt Production 2.0	Total Smolts	% egg to smolt age 1+	% egg to smolt age 2+	% egg to smolt comb.
1993	4040	286	53	1,100	3,671	4,038,100		79,439	79,439	0.0%	2.0%	2.0%
1994	3559	381	29	1,331	3,056	4,067,536	415,133		415,133	10.2%	0.0%	10.2%
1995	5780	726	32	3,802	3,796	14,432,392		70,060	70,060	0.0%	0.5%	0.5%
1996	9381	1,244	30	4,586	4,068	18,655,848	2,068,001	236,401	2,304,402	11.1%	1.3%	12.4%
1997	8097	1,212	142	1,857	4,113	7,637,841	455,240	70,882	526,122	6.0%	0.9%	6.9%
1998	5997	648	25	1,913	4,124	7,889,212	87,008	34,826	121,834	1.1%	0.4%	1.5%
1999	2104	116	0	554	4,247	2,352,838	26,797	19,078	45,875	1.1%	0.8%	1.9%
2000	7575	765	18	4,073	4,094	16,674,862	124,574	9,830	134,404	0.7%	0.1%	0.8%
2001	21822	1,045	221	8,314	4,663	38,768,182	457,563	82,868	540,431	1.2%	0.2%	1.4%
2002	5495	542	74	1915	4679	8,960,285	130,000	31,000	161,000	1.5%	0.3%	1.8%
2003	4515	668	48	1,636	4,267	6,979,105	399,000		399,000	5.7%	0.0%	5.7%
2004	1954	210	15	752	4,282	3,220,064						
2005	3372	499	13	1,715	3,850	6,602,750						
Average	6,438	642	54	2,581	4,070	10,790,693	462,591	70,487	436,155	3.5%	0.6%	4.1%

Brood year	Release year	Eggs to hatchery	Smolt production 1.0	Smolt production 2.0	Total	% egg to smolt age 1+	% egg to smolt age 2+	% egg to smolt comb.	Unfed fry 1+	Fed fry1+
1993	1994	1,144,000		6,705	6,705	0.0%	0.6%	0.6%		
1994	1995	1,229,000	14,442		14,442	1.2%	0.0%	1.2%		
1995	1996	2,407,000			0	0.0%	0.0%	0.0%		
1996	1997	4,934,000	364,093	3,456	367,549	7.4%	0.1%	7.4%		
1997	1998	4,651,000	81,544	2,781	84,325	1.8%	0.1%	1.8%	1.2%	5.5%
1998	1999	2,414,000	30,049	555	30,604	1.2%	0.0%	1.3%	0.6%	1.7%
1999	2000	461,000	8,728	590	9,318	1.9%	0.1%	2.0%		2.0%
2000	2001	2,572,000	88,473	0	88,473	3.4%	0.0%	3.4%	1.8%	4.6%
2001	2002	3,499,000	72,098	3,000	75,098	2.1%	0.1%	2.1%	3.8%	1.9%
2002	2003	2,302,000	82,290	0	82,290	3.6%	0.0%	3.6%	7.3%	
2003	2004	2,452,000	245,000		245,000	10.0%	0.0%	10.0%	10.0%	
2004	2005	897,000								
2005	2006	1,877,000								
Average		2,590,111	109,635	2,136	75,880	4.2%	0.1%	2.9%	1.84%	3.14%

Appendix 7. Tatsamenie Lake mean annual zooplankton biomass and densities

Mean Annual Zooplankton Wet Biomass (mg/m3) - Tatsamenie Lake.

Year	Total (minus LGB)	*Bosmina* sp.	*Daphnia* sp.	*Cyclops* sp.	nauplii	rotifers	Other groups*	N
1988	285.99	65.36	36.93	179.62	2.20	1.88	1.23	3
1989	314.34	57.59	70.97	176.73	2.81	6.17	0.07	4
1990	175.13	36.96	52.22	79.75	2.24	3.94	0.00	4
1991	449.88	139.84	15.67	238.16	1.23	3.07	51.90	4
1992	309.62	86.63	72.54	145.91	2.85	1.70	0.00	4
1993	286.69	73.34	56.70	148.35	2.34	5.97	0.00	3
1994	329.24	114.99	25.91	177.04	4.85	6.88	0.00	3
1995	278.05	54.77	59.60	139.40	1.98	3.31	0.00	2
1996	324.81	37.41	30.10	251.88	2.79	2.00	0.64	2
1997	346.65	30.00	122.03	193.09	2.15	0.49	0.00	3
1998	297.81	20.85	76.79	193.54	3.38	3.60	0.00	7
1999	376.30	12.96	17.81	335.80	5.29	4.44	0.00	12
2000	489.17	117.33	24.67	339.83	7.33	0.00	0.00	6
2001	842.17	41.33	23.00	772.00	3.67	0.50	0.00	6
2002	436.50	11.88	132.13	283.63	7.13	2.13	0.25	8
2003	463.00	12.43	94.75	344.00	11.00	1.75	0.00	8
2004	270.17	4.17	61.33	198.50	5.33	0.00	0.00	6
Mean:	369.15	53.99	57.24	246.90	4.03	2.81	3.18	

* Other groups include calanoid copepods, *Skistodiaptomus* sp. and *Holopedium* sp.

Mean Annual Zooplankton Density (no./m3) - Tatsamenie Lake.

Year	Total (minus LGB)	*Bosmina* sp.	*Daphnia* sp.	*Cyclops* sp.	nauplii	rotifers	*Other groups	N
1988	13689.47	1875.56	1088.00	6712.88	1699.45	2291.56	10.77	3
1989	23253.98	1721.33	1686.99	6484.78	7349.30	7528.47	0.16	4
1990	16916.79	1241.60	1397.85	3542.40	5933.56	4801.02	0.00	4
1991	22665.42	4693.35	455.04	7390.48	5569.53	3745.52	804.57	4
1992	17937.97	2847.54	2035.85	4730.82	6255.00	2067.89	0.00	4
1993	24667.36	2993.78	1915.73	6904.87	5572.27	7280.26	0.00	3
1994	23690.13	3121.78	585.89	4163.98	6858.59	7861.28	0.00	3
1995	14464.13	1360.00	1520.00	3520.00	4032.00	4031.95	0.00	2
1996	12117.10	985.60	394.40	6117.27	2204.80	2434.14	4.64	2
1997	12160.71	824.89	2350.22	5045.33	3313.78	597.33	0.00	3
1998	17001.64	493.43	1540.50	4531.81	6049.48	4391.83	0.00	7
1999	17503.98	457.50	566.86	8671.42	8783.67	5418.67	0.00	12
2000	21545.58	3171.97	557.68	9727.12	8182.90	28.43	0.00	6
2001	36946.72	241.50	453.60	16664.00	3928.90	5645.68	0.00	6
2002	37741.75	296.63	2725.50	9004.50	7274.38	18440.38	0.00	8
2003	37836.63	249.88	1809.50	10183.38	12328.50	13264.88	0.10	8
2004	16099.30	116.70	1339.88	5994.67	7210.67	1403.30	0.00	6
Mean:	21543.45	1570.18	1319.03	7022.92	6032.16	5366.62	48.25	

* Other groups include calanoid copepods, *Skistodiaptomus* sp. and *Holopedium* sp.

Mean Annual Large Beast (LGB) Biomass (mg/m3) - Tatsamenie Lake.

Year	Chironomid larva	Acarina
1988	84.88	0.00
1989	50.88	0.00
1990	1.34	0.00
1991	23.90	0.00
1992	272.89	0.00
1993	69.32	0.00
1994	3.98	0.00
1995	572.30	0.00
1996	539.68	0.00
1997	546.32	0.00
1998	129.23	0.09
1999	2.73	0.00
2000	0.00	0.00
2001	0.00	0.00
2002	0.25	0.00
2003	0.00	0.00
2004	0.67	0.00
Mean:	135.20	0.01

Appendix 8. Acoustic Estimates of Limnetic Fry Populations in Tatsamenie Lake.

Survey Year	Survey Date	Hydroacoustic Estimate	95% CI	Wild	Enhanced
1990	no survey	n/a	n/a	n/a	n/a
1991	13-Sep	822,000	289,562	767,347	32,653
1992	1-Aug	1,796,000	772,015	n/a	n/a
1993	14-Sep	1,146,000	409,859	1,000,409	145,691
1994	15-Sep	1,053,000	358,658	1,034,393	18,807
1995	19-Sep	940,000	366,896	852,649	87,451
1996	19-Sep	832,000	324,400	772,479	59,421
1997	4-Sep	2,695,000	869,666	1,132,906	127,293
	1-Oct	1,260,000	488,833	2,411,398	283,694
	Average	1,977,000	679,250	1,772,152	205,493
1998	2-Sep	689,000	263,792	n/a	n/a
	22-Sep	755,000	281,627	697,653	57,270
	12-Oct	504,000	286,169	425,585	78,812
	Average	649,000	277,196	561,619	68,041
1999	16-Oct	352,000	94,000	321,376	30,624
2000	24-Aug	683,000	298,000	635,190	47,810
	11-Oct	151,000	46,000	141,940	9,060
	Average	417,000	172,000	388,565	28,435
2001	18-Aug	558,000	165,000	334,800	223,200
	19-Sep	975,000	449,000	936,000	39,000
	8-Oct	807,000	158,000	790,860	16,140
	Average	780,000	257,333	687,220	92,780
2002	19-Jul	2,210,000	523,000	1,834,717	375,283
	3-Oct	1,913,000	302,000	1,904,265	8,735
	Average	2,061,500	412,500	1,869,491	192,009
2003	4-Oct	1,076,000	187,000		
2004	3-Oct	1,500,000	328,000	1,455,000	45,000
2005	Oct				