2011 to 2013 Morrison Lake

Hydroacoustic Surveys

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Summary
The Skeena Fisheries Commission conducted hydroacoustic surveys at Morrison Lake in 2011, 2012 and 2013 in order to determine the density and abundance of juvenile sockeye. The densities of juvenile sockeye ranged from 95 fish/hectare in 2011 to 1,250 fish/hectare in 2012. The juvenile sockeye population estimates varied considerably between the three years sampled and ranged from just over 126,000 in 2011 to nearly 1.7 million in 2012. The highest densities of juvenile sockeye were observed in years following large adult sockeye escapements to Tahlo Creek. The large population size and high densities of juvenile sockeye produced at Morrison Lake make it one of the most important sockeye producing lakes in the Skeena watershed.

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Introduction

The Skeena Fisheries Commission (SFC) conducted hydroacoustic surveys at Morrison Lake during the fall of 2011, 2012, and 2013 in order to determine the density and abundance of juvenile sockeye in this system. Morrison Lake, located in the Babine drainage, is the second largest sockeye producing lake in the Skeena Watershed. Morrison-Tahlo is the second largest sockeye conservation unit in the Skeena (Gottesfeld and Latremouille, 2012) after the Babine-Nilkitkwa conservation unit.

The Morrison-Tahlo conservation unit is comprised of sockeye which spawn in Morrison Creek, Morrison Lake, and Upper and Lower Tahlo creeks. There are an unknown number of lake spawners in Morrison Lake itself, some of which were observed directly during the 2011 and 2012 hydroacoustic surveys at Morrison Lake. Morrison Creek sockeye spawners produce juveniles that rear in Morrison Arm of Babine Lake, spawners in Morrison Lake and Lower Tahlo Creek produce juveniles that rear in Morrison Lake, and spawners in Upper Tahlo Creek produce juveniles which rear in Tahlo Lake (Gottesfeld, Latremouille, and Carr-Harris 2011).

The combined sockeye escapement to Morrison and Upper/Lower Tahlo creeks in 2010, the brood year for our 2011 hydroacoustic survey, was approximately 6,800 spawners, much lower than the previous decadal average of over 30,000 (Fisheries and Oceans Canada, 2013). The combined sockeye escapements to Morrison and Tahlo Creeks were significantly higher in 2011 and 2012, estimated at over 30,000 and over 50,000 spawners respectively (Fisheries and Oceans Canada, 2013). The large escapements of 2012 and 2013 suggest that the Morrison-Tahlo catchment remains a significant producer of Skeena River sockeye while the variability in escapements across years indicates that these populations are also a conservation concern.

Methods

Study area

Morrison Lake is located upstream from Morrison Creek, which flows into the Morrison Arm on the north-east side of Babine Lake, approximately 74 km north-east of the community of Smithers, BC, in the eastern section of the Skeena Watershed (Figure 1). Morrison Lake is a clear and relatively deep lake, with an average depth of 28 meters, maximum depth of 62 meters, and total surface area of about 1,327 hectares. Morrison Lake consists of two main basins that are separated by a shallow, narrow channel approximately two thirds down the long axis of the lake (Figure 2).

Limnology and fish sampling

Temperature profiles were collected on Morrison Lake in 2011, 2012, and 2013 using a hand held YSI meter (model 85) with a maximum cable length of 30 m. The YSI meter was calibrated to the nearest 100’ elevation and allowed to stabilize for at least 15 minutes before data were recorded.

Pelagic fish were sampled using a 2 x 2 m midwater trawl, which was deployed to a maximum depth of 35 m. The net was towed behind the boat at a constant speed of approximately 1m/s, and retrieved with a portable winch. The depth of each tow varied according to the length of the line that was deployed, which was calibrated and marked prior to sampling. In 2013, trawl depths were also recorded using a depth logger (Sensus Ultra by Reefnet). Gillnets were also used to capture fish from the 0-2m depth layer in the littoral zones at Morrison Lake in 2011. These gillnets consisted of 4 variable mesh sizes between ½" and 1". Gillnets were set at dusk and allowed to soak for 10-21 hours.

Large fish were counted and released. Small fish were sorted by species and stored in 10% formaldehyde and weighed and measured after at least 30 days of preservation. Scales were removed and inspected under a compound microscope to determine the age of juvenile salmonids.

Acoustic survey

Hydroacoustic surveys were conducted using the same methods and technology as the SFC and the Gitksan Watershed Authorities have used since 2005 (Hall & Carr-Harris 2008) and described in MacLellan and Hume (2010) and Parker-Stetter et al. (2009). The transect layout (Figure 2) was established prior to our 2011 surveys.

Transects were sampled using a Biosonics DT-X echosounder with a 200 kHz split-beam transducer producing a 6 degree beam. The single downward-pointing transducer was pole-mounted to our inflatable vessel, a Bombard Commando C-5. Hydroacoustic data were collected to an acoustic threshold of -100 dB using Biosonics Visual Acquisition software as the vessel proceeded along transects at a constant speed of about 0.7 m/sec.

The hydroacoustic system was calibrated prior to each survey by suspending a standard tungsten carbide sphere (36 mm diameter) in the acoustic beam. The observed target strength was compared to the predicted target strength at that temperature for the standard target. The difference between the observed and predicted target strength produced a calibration offset, which was applied during post-processing of the data.

Post-processing of hydroacoustic data was performed using Echoview software (v. 5.00). Data analysis was conducted using the same methodology as the SFC and the Gitksan Watershed Authorities have used since 2005 (Hall & Carr-Harris 2008). Fish densities were calculated using two different methods for down-looking acoustic data. The integration method divides the average acoustic energy by the average target strength for each transect depth layers sampled, which results in a volumetric fish density (n/m^3) for each transect depth layer. The tracked target estimate is produced by grouping single targets into individual fish tracks using the standard algorithms in Echoview. The tracked targets are visually examined and edited where necessary to correct tracking errors using the editing tools in Echoview. The total number of tracked targets, or fish tracks, is then divided by the sampled wedge volume, which results in a volumetric fish density (n/m^3) for each sampled transect depth layer. During the 2011 survey, bathymetric data was collected on Morrison Lake to calculate the depth layer volumes on which the hydroacoustic estimates were based. A bathymetric map produced from those data is shown in Figure 2.

Primary analysis outputs from Echoview were processed in Microsoft Excel to calculate estimates of total age-0 *O.nerka* population for Morrison Lake. Population estimation procedures were consistent with a stratified random transects sampling technique described by Simmonds and MacLennan (2005), and used by MacLennan and Hume (2010), and by the SFC (Carr-Harris 2011). The data from each transects was analyzed in 4m depth layers. The volumetric fish densities calculated for each transect depth layer were multiplied by the respective depth layer volume of the lake area represented by that transect to produce a transect depth layer fish population estimate. Total transect estimates are produced from the sum of layer population estimates. Transect densities are averaged and multiplied by the whole surface area of the section or lake to produce the total fish estimate for the entire section or lake.

Fish estimates were divided into “small” and “large” fish based on the distribution of target strengths from each transect layers. "Small" fish were classified as fish with target strengths between –64 and –46 decibels. This target strength is approximately equivalent to salmoniform fish <135 mm, based on Love’s (1977) 45^{o} aspect formula. Small fish were apportioned into juvenile sockeye and “other small fish” based on the relative proportion of species in the trawl catch. In this report, juvenile sockeye may be referred to as O. nerka, which also includes kokanee, the non-anadromous form of *Oncorhynchus nerka*. Juvenile sockeye and kokanee are indistinguishable except by genetic or isotopic analysis, which were not carried out for this project, but since there have been no observations of adult kokanee at Morrison Lake, it is reasonable to assume that all of the O. nerka juveniles that were captured during the 2011-2013 hydroacoustic surveys were juvenile sockeye.

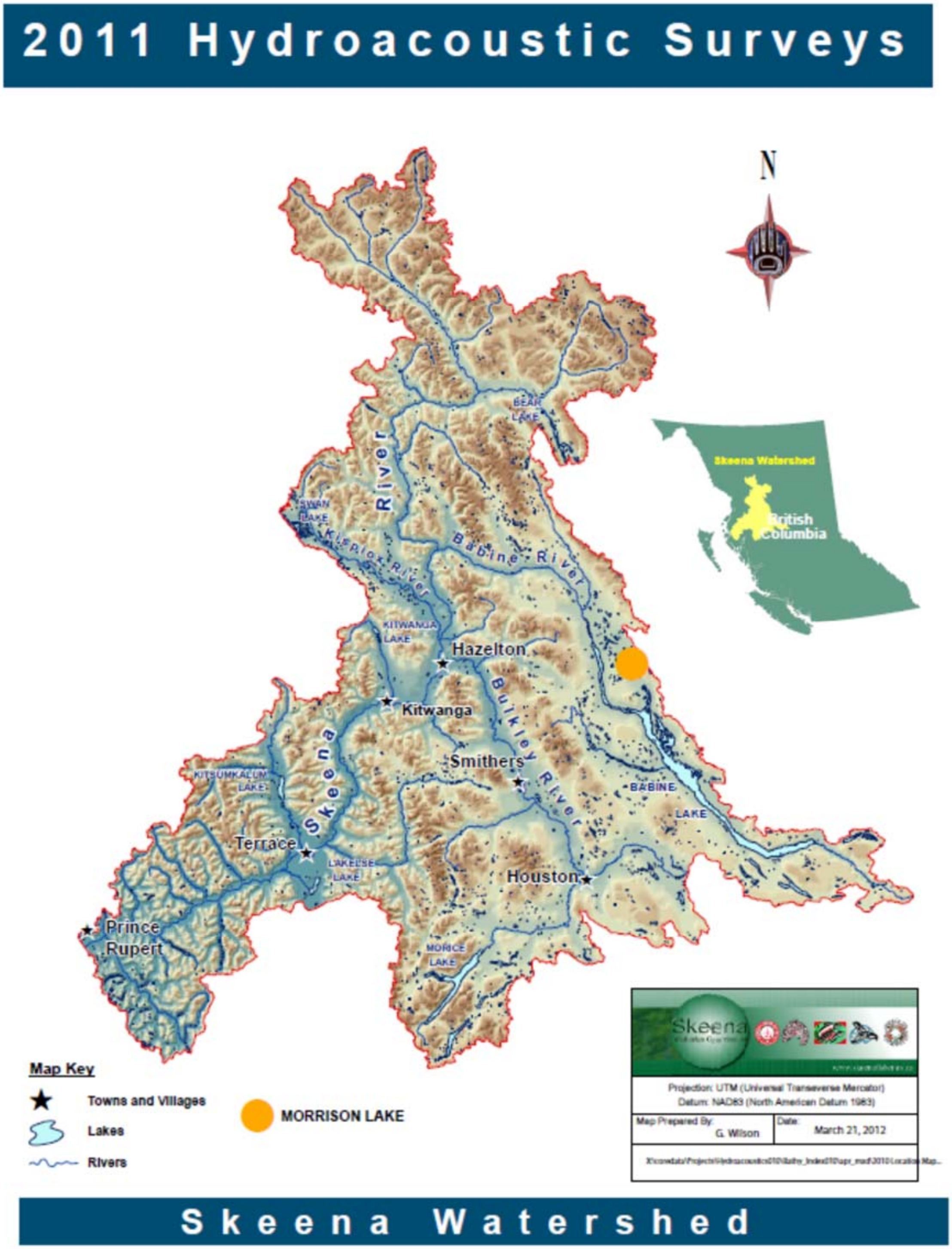

Figure 1. Map of the Skeena Watershed showing the location of Morrison Lake

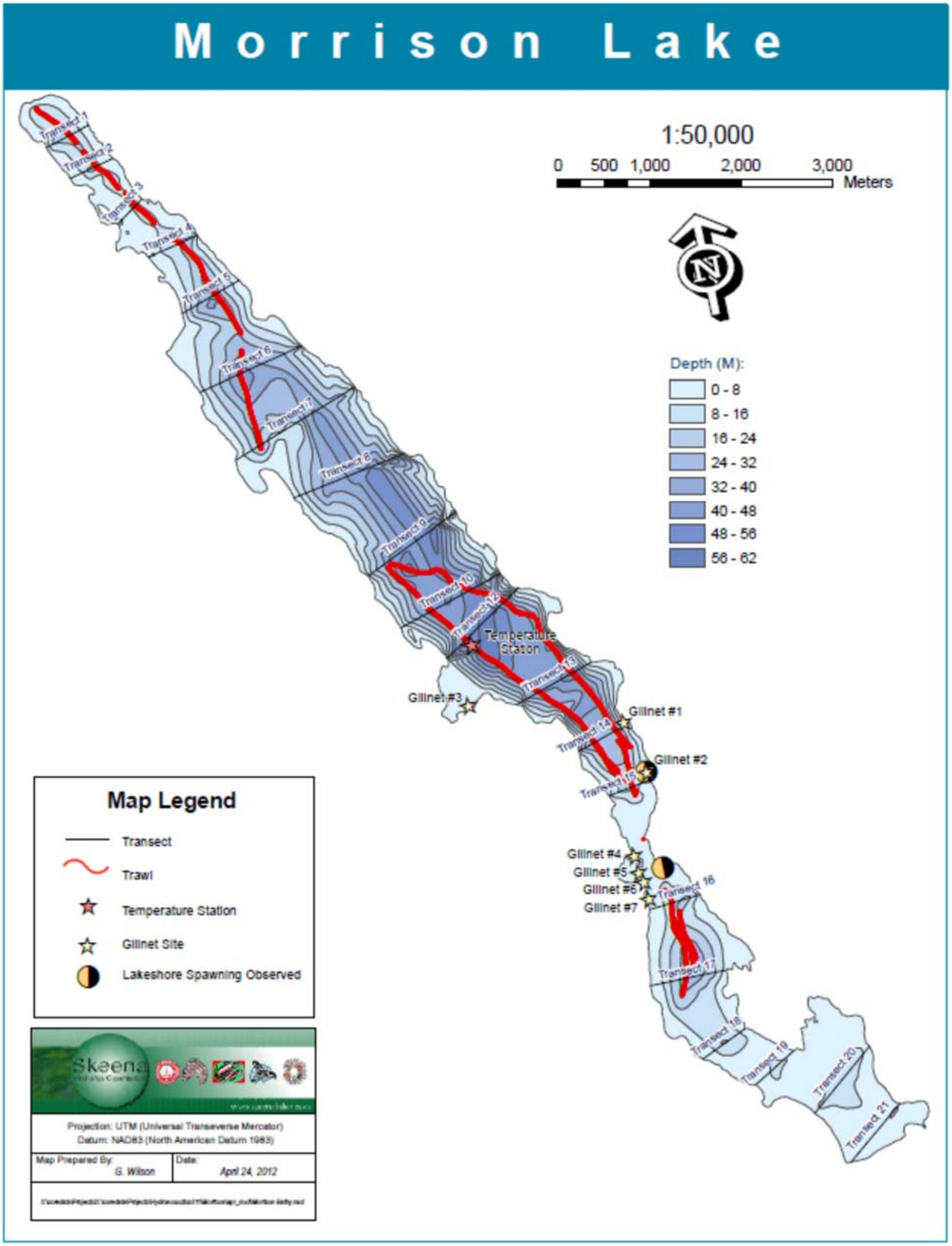

Figure 2. Bathymetric map of Morrison Lake showing 2011 transects, trawls, temperature profile station, gillnets, and sites where lakeshore sockeye spawning was observed

Results and Discussion

Morrison Lake was surveyed on the nights of September 23 to 25, 2011, September 19-20, 2012, and September 5-6, 2013.

Temperature, dissolved oxygen, and vertical distribution of acoustic targets

The coolest surface temperature was observed in 2011 (11.2°C). Surface temperatures were warmer in 2012 (15.1°C) and 2013 (19.6°C). In all years, there was a thermocline between about 7 and 15 meters depth with a hypolimnion of approximately 5°C below 20 meters (Figure 3a). In all years, the water column was well oxygenated to the lowest depth measured (30m). In 2011, dissolved oxygen levels declined from 8.2 mg/L at the surface to 7.5 mg/L at 30 m depth. In 2012 and 2013, there were steeper declines in dissolved oxygen levels between 7 and 9 m depth (Figure 3b). Fish targets were observed at all depths of the water column in Morrison Lake in all years, but were mostly concentrated between 5 and 20 m depth with peak densities observed at a depth of 10 m (Figure 3c). Our observations are consistent with the typical behavior of juvenile sockeye feeding on zooplankton at depths where water temperatures are within their temperature preference range of 6 to 13°C (Brett 1952).

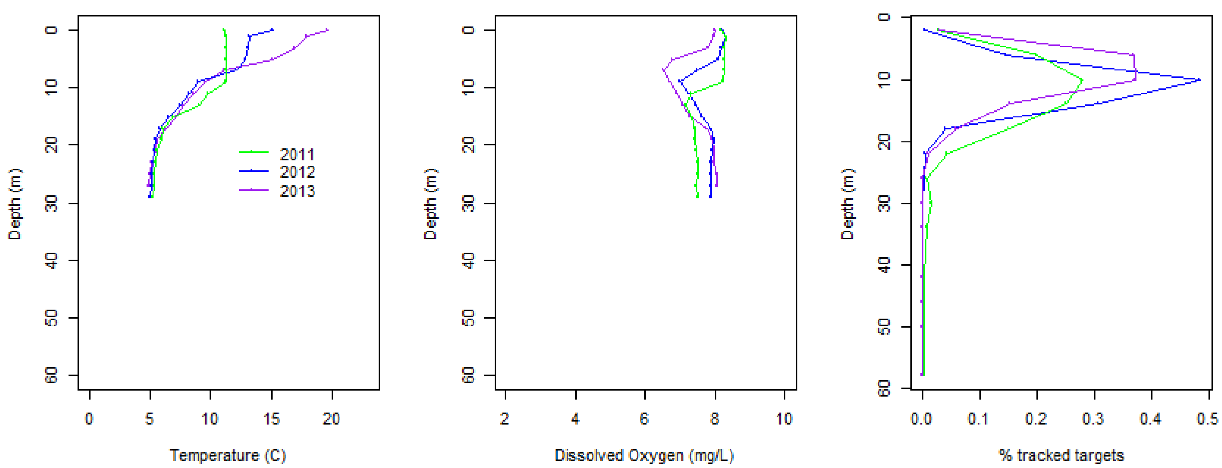

Figure 3. Temperature and dissolved oxygen profiles, and proportion of tracked targets by depth for 2011, 2012, and 2013 Morrison Lake hydroacoustic surveys.

Fish sampling

We encountered low densities of juvenile sockeye throughout Morrison Lake in 2011. In that year, we captured only 10 juvenile sockeye during thirteen trawls with a combined duration of over 4.3 hours (Appendix 1). Pygmy whitefish (*Prosopium coulterii*) were the most numerous (n=17) fish species observed in the 2011 trawl collection, which included several other fish species including lake whitefish (*Coregonus clupeaformis*), lake trout (*Salvelinus namaycush*), burbot (*Lota lota*), and a large pikeminnow (*Ptychocheilus oregonensis*) (Appendix 1). Juvenile sockeye, which were the only species captured by trawl in 2012 and 2013 were far more abundant in these years. We captured 67 sockeye in 3 trawls with a combined duration of under one hour in 2012, and 154 sockeye in 3 trawls with a combined duration of 68 minutes in 2013 (Appendix 1). All of the juvenile sockeye that we caught and examined were age-0, or young of the year. An example of the trawl catch is shown in Figure 4. Summary statistics for lengths and weights of trawl-captured sockeye are given in Table 1.

Figure 4. Juvenile sockeye captured in a single set (Trawl 4) during a Morrison Lake hydroacoustic survey, September 9 2013.

		Length (mm)		Weight	
Year	n	mean	sd	mean	sd
2011	10	61	5.7	2.6	0.8
2012	67	65	8.1	3.0	1.1
2013	100	58	6.8	2.2	0.8

Table 1. Lengths and weights of trawl-captured sockeye

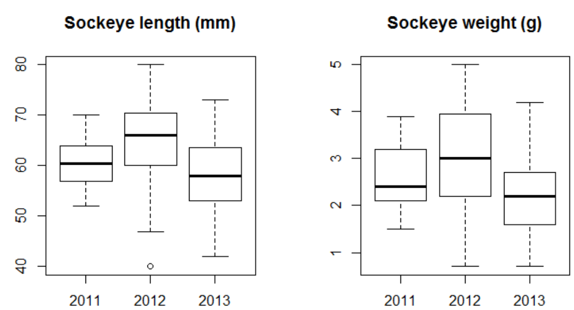

Figure 5. Boxplots showing distribution of length and weight of juvenile sockeye captured by trawl at Morrison Lake, 2011 to2013.

We set seven gillnets in littoral zones around Morrison Lake in 2011. The combined soak time was 141 hours, and the total catch included 56 redside shiners (*Richardsonius balteatus*), 5 large (>15 cm) rainbow trout (*Onchorhynchus mykiss*), and 3 adult sockeye, including one mature jack, one spawned out adult male, and one mature adult female (Appendix 2). We observed sockeye spawning activity in two nearshore locations during daylight hours, indicated on Figure 2.

Acoustic survey

Acoustic data were collected from 19 transects across the long axis of the lake (Figure 2) in 2011 and 2013, and 18 transects in 2012. In 2011 and 2012, acoustic data were also collected from longitudinal transects along the long axis of the lake. The data from the longitudinal transects were not included in the hydroacoustic estimates, but were used for producing contour maps of fish target density. In all years, the observed target strength from the calibration sphere exceeded the expected target strength by 4 decibels, and this offset was applied in post-processing of hydroacoustic data.

There was considerable interannual variation in the density and abundance of small fish between the three years surveyed. Hydroacoustic estimates for fish densities were lowest in 2011 and highest in 2012. Small fish densities ranged from 210 “small” fish/hectare (Integration estimate) in 2011 to 1,250 “small” fish/hectare (Integration estimate) in 2012 (Table 2). Based on the relative proportion of juvenile sockeye observed in the trawl samples in each year (46% in 2011 and 100% in 2012 and 2013), the total juvenile sockeye population estimate ranged from just over 126,000 in 2011 to nearly 1.7 million in 2012 (Table 2). A comparison of echograms from a single transect (Transect 5) is shown in Figure 6. The large fish population was relatively stable in all years surveyed.

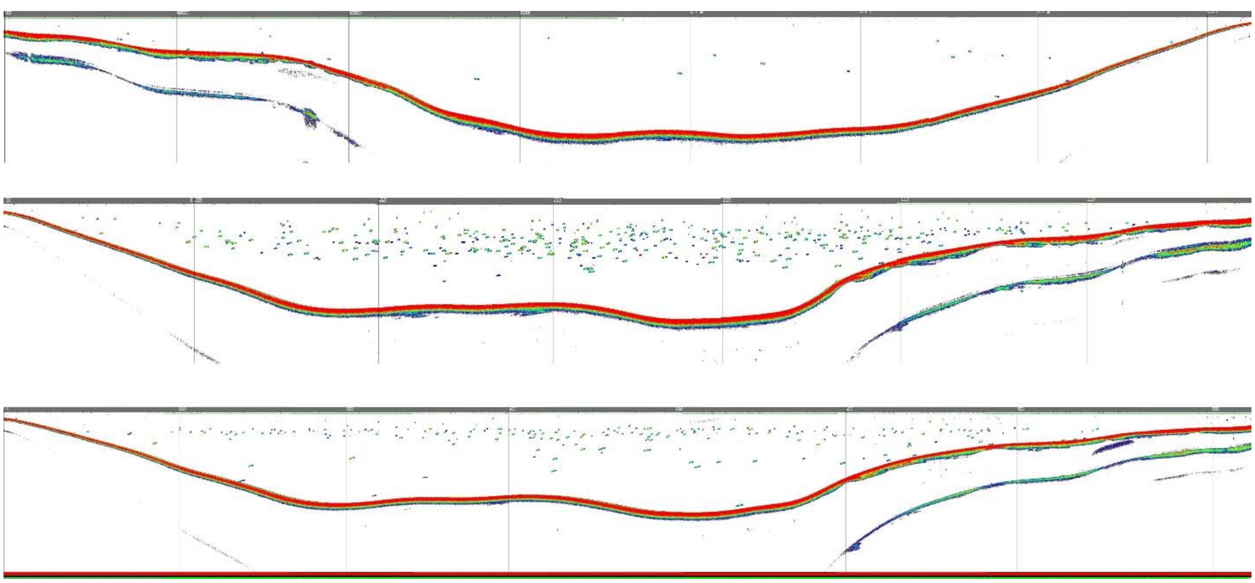

Figure 6. Echograms from Morrison Lake Transect 5 in 2011 (top), 2012 (middle) and 2013 (bottom).

Table 2. Hydroacoustic density and abundance estimates for Morrison Lake, 2011-2013

Year	Method	Class	Density (n/ha)	Population estimate	95% CI
2011	Tracked target	Small fish	176	233,843	35.7%
		Age-0 *O. nerka*	80	106,292	
		Large fish	43	57,471	52.3%
	Integration	Small fish	210	278,346	43.1%
		Age-0 *O. nerka*	95	126,521	
		Large fish	44	59,014	49.5%
2012	Tracked target	Small fish	1,527	2,026,156	38.0%
		Age-0 *O. nerka*	1,527	2,026,156	
		Large fish	85	113,200	36.1%
	Integration	Small fish	1,250	1,658,645	33.7%
		Age-0 *O. nerka*	1,250	1,658,645	
		Large fish	64	85,363	36.8%
2013	Tracked target	Small fish	1,366	1,812,184	21.2%
		Age-0 *O. nerka*	1,366	1,812,184	
		Large fish	69	91,156	37.7%
	Integration	Small fish	1,031	1,368,836	21.7%
		Age-0 *O. nerka*	1,031	1,368,836	
		Large fish	50	66,902	38.8%

The horizontal distribution of fish targets varied somewhat between years, with relatively high densities observed in the north and south section of the lake in all years, and higher densities in the north part of the main basin in 2012 and 2013 (Figure 7). In 2012, the highest abundances were observed in the section between the south part of the main basin and the south basin (Figure 7).

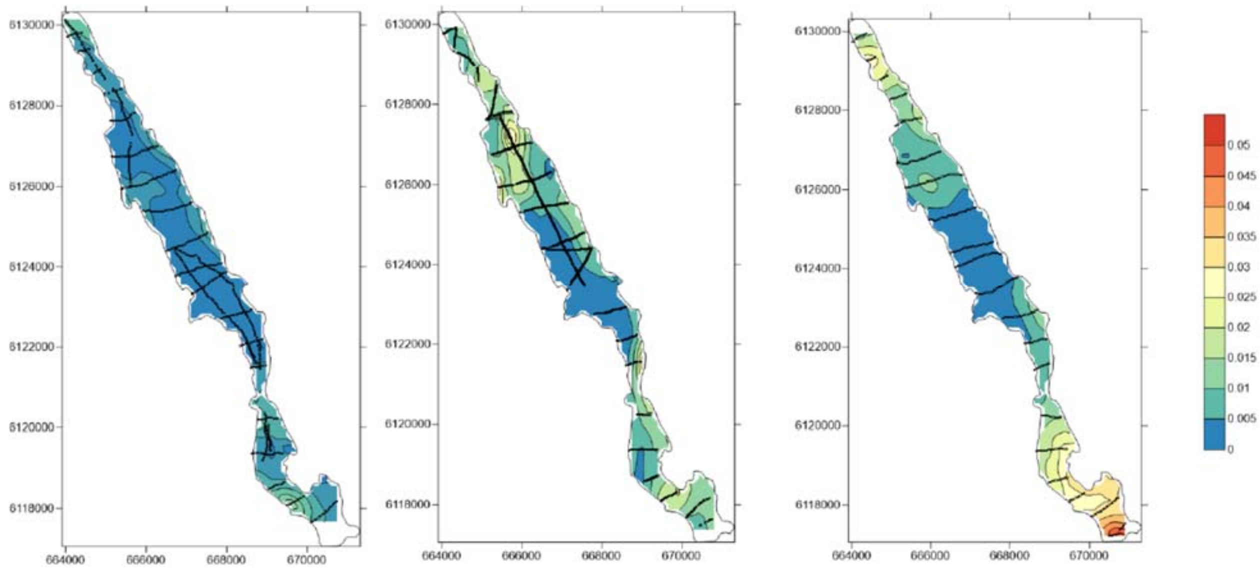

Figure 7. Contour maps showing horizontal distribution of tracked target density at Morrison Lake during hydroacoustic surveys in 2011 (left), 2012 (middle) and 2013 (right). Acoustic data transects are indicated.

PR model and carrying capacity

Shortreed et al. (1998) conducted a hydroacoustic survey at Morrison Lake in 1995, and juvenile sockeye population estimate for that year was 497,000. Shortreed *et al*.(1998), Cox-Rogers and Shortreed 2004 also estimates the rearing capacity, based on the photosynthetic rate (PR) at Morrison Lake in 1995, which describes the optimal fry biomass (R_{max}) and number of adult female spawners (S_{max}) required to produce that biomass based on the carbon production of a given lake. For Morrison Lake, S_{max} is approximately 48,000 (Shortreed 1998). The estimated returns to Tahlo Creek in 2010, 2011, and 2012 (the brood years for the cohorts of fall fry enumerated in the 2011, 2012, and 2013) were 2,780, 7,637, and 16,514 respectively. The total number of lakeshore spawners in these years is not known.

Even though the 2012 and 2013 juvenile sockeye population estimates were more than an order of magnitude larger than the 2011 estimate, the fall fry estimates for 2011, 2012 and 2013 are all well below the estimated rearing capacity for Morrison Lake (Table 3). Of the three years that we surveyed, the largest juvenile sockeye were observed in 2012 (Table 1) which was also the year of highest densities (Table 2), suggesting that sockeye growth was not limited by excessive density in that year.

Table 3. Comparison of hydroacoustic estimate with Rmax estimated from PR capacity model

Survey date	Population Estimate (n)	Average weight (g)	Observed biomass (t)	Rmax (t)	% Rmax
2005-09-29	**497,473**	4.9	2.44	10.9	22%
2011-09-26	**126,521**	2.6	0.33	10.9	3%
2012-09-19	**1,658,645**	3.0	4.98	10.9	46%
2013-09-09	**1,368,836**	2.2	3.01	10.9	28%

Conclusion

Morrison Lake is a significant sockeye rearing habitat that supports a large juvenile sockeye population. The difference in fall fry populations that were observed between 2011 and 2013 underscores the importance of conducting multiple surveys in different years in order to determine trends in abundance in a given system. The 2011 survey, conducted in the year following a poor escapement to Tahlo Creek yielded considerably different results than the 2012 and 2013 surveys that were conducted in the years following higher escapements. Even so, the three hydroacoustic surveys provide only a snapshot of fall fry abundance. More information is also required about the distribution and abundance of the lakeshore spawners in this system. Morrison Lake also contains a high diversity of freshwater species, including large long-lived predators such as lake trout and burbot, both of which we captured during sampling in 2011. A more extensive fish sampling project would help us gain an understanding of the intraspecific population dynamics at Morrison Lake.

Understanding the causes of the interannual variability in sockeye production that were observed in the low escapements to the Morrison-Tahlo catchment in 2011 compared with the high escapements in 2012 and 2013 is important for assessing the productivity potential at Morrison Lake. While survival variability during the marine stages of the life history of sockeye salmon exceeds the variability during the freshwater phases (McDonald et al. 1987), the potential cumulative effects of stressors in freshwater and marine environments both contribute to reduced productivity. Morrison Lake itself contains only a portion of the juvenile sockeye fry produced in the Morrison-Tahlo conservation unit, which includes the progeny of spawners in Upper and Lower Tahlo Creek and Morrison Lake, which rear in Morrison Lake, and spawners in Morrison Creek, which rear downstream in Morrison Arm of Babine Lake. Past hydroacoustic surveys (Shortreed and Morgan 2000), in addition to a Skeena Fisheries Commission habitat assessment project conducted in 2011, suggest that Morrison Arm is also important sockeye rearing habitat for this conservation unit (Doire and Gottesfeld 2013). We anticipate that the results from a hydroacoustic survey carried out at Babine Lake in 2013 will provide additional information about the stock status of juvenile sockeye in Morrison Arm. That report will be available later this year.

Acknowledgements

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Appendix 1. Trawl sample summary for 2011, 2012, and 2013 hydroacoustic surveys

Year	Trawl	Date	Start	End	Depth	ON	WF	LT	Bu	PM
2011	1	24-Sep	21:56	22:14	10	1	3			
	2	24-Sep	22:18	22:28	18					
	3	24-Sep	23:18	23:31	25	1				
	4	25-Sep	20:13	20:23	15		3	1		
	5	25-Sep	20:31	20:42	30		2			
	6	25-Sep	20:50	21:00	5		1		1	
	7	25-Sep	21:07	21:31	15					
	8	25-Sep	21:40	22:00	12	3				1
	9	25-Sep	22:51	23:20	12	1				
	10	25-Sep	23:25	0:04	11	1				
	11	26-Sep	0:09	0:40	10	3				
	12	26-Sep	0:47	1:19	10					
	13	26-Sep	1:34	2:00	8		9	1		
2012	1	19-Sep	22:47	23:07	13	24				
	2	19-Sep	23:19	23:39	10	30				
	3	19-Sep	2350	0:05	11	13				
2013	1	05-Sep	1:11	1:28	10	19				
	2	05-Sep	2:17	2:39	10	17				
	3*	05-Sep	4:15	4:36	9					
	4	06-Sep	21:32	21:55	7	118				

ON: juvenile sockeye, WF: whitefish (all species), LT: Lake trout, Bu, Burbot, PM: Pikeminnow
* - The trawl net was not fully deployed in the third trawl set of 2013. It was most likely tangled from the start of the trawl set, and did not fish. Hence, the third trawl in 2013 is mentioned here, but not in the analysis.

Appendix 2. Gillnet summary for 2011

Lake	GN#	Easting	Northing	Date set	Soak time (hours)	PM	SK	RSS	RT
Morrison	1	668872	6122241	24-Sep-11	21			3	1
Morrison	2	669000	6121657	24-Sep-11	21	1	1	3	
Morrison	3	667244	6122769	24-Sep-11	21			9	1
Morrison	4	668684	6120786	24-Sep-11	21			10	1
Morrison	5	668690	6120591	25-Sep-11	19	2	1	3	
Morrison	6	668725	6120493	25-Sep-11	19		1	9	
Morrison	7	668738	6120292	25-Sep-11	19			19	2

PM: pikeminnow, SK: sockeye (adult), RSS: redside shiner, RT: Rainbow trout