Kitwanga Sockeye Enhancement Program, 2007/08 – Year 2

Prepared by: Mark C. Cleveland, B.Sc., R.P.Bio.
Gitanyow Fisheries Authority
P.O. Box 148, Kitwanga, BC V0J 2A0

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Abstract

Kitwanga sockeye salmon culture was piloted for the second consecutive year in 2007-08 to supplement natural production from Gitanyow Lake. Unlike the previous year only one brood stocking collection technique was used which consisted of holding green adults at the Kispiox Hatchery until ripe. Overall, Kitwanga sockeye adult escapement was low in 2007, therefore only 12 sockeye were used for hatchery production purposes. Holding experiments were successful and average female fecundities were almost 3,400 eggs per female. Eggs were small again in 2007-08 averaging only 0.083g per egg and survivals from the egg to eyed stage were high exceeding 91%. Fry survival rates exceeded 99% and fry increased their average body weight by 1.74% pr / day. In total over 12,000 fry were successfully raised and released in the 2007-08 and released as >1g marked fry. Disease screening showed that hatchery brood stock was IHN and BKD free in 2007-08. The operation of a modified IPT in the Kitwanga River downstream of Gitanyow Lake showed that none of the 2007-08 hatchery fry left the lake.

Acknowledgements

The Gitanyow Fisheries Authority (GFA) would like to thank the Pacific Salmon Commission for funding this worthwhile project again in 2007/08; the works described in this report could not have taken place without their financial support. As in the previous year Al Stobbart and Doug Lofthouse from DFO provided technical support for the project and deserve special thanks. We would also like to thank the many Gitxsan Watershed Authorities and the GFA technicians that worked on the project.

Table of Contents

List of Tables

List of Figures

List of Photographs

Project Backgrounder

The Kitwanga River is biologically rich, supporting populations of all six species of salmon found in northern BC, as well as various species of resident salmonids and coarse fish. A species of significant importance in the Kitwanga River is sockeye salmon. Historically, Kitwanga sockeye numbered in the tens of thousands, and were actively fished for sustenance purposes by the Gitanyow and the Gitwangak who inhabited the watershed (Cleveland et al., 2006). However, drastic declines in stock abundance were first observed in the 1960's and today the stock is no longer fished for Food, Social or Ceremonial purposes because of conservation concerns.

Kitwanga sockeye are an evolutionary significant unit as defined by Waples (1995) and therefore an important fisheries management unit. This suggests that Kitwanga sockeye have developed specific life history adaptations and timing regimes that are genetically determined. Consequently, there is little possibility that neighbouring sockeye populations could replace Kitwanga sockeye naturally, given the extremely limited gene flow and the degree of local adaptation. The Kitwanga sockeye stock is currently at a depressed level and a stock of special concern. The reasons for the decline are not completely understood, however it is believed that over-exploitation in the commercial fishery and habitat deterioration in Gitanyow Lake are the main contributors. Fishery re-constructions for the last 40 years show average exploitation rates on Kitwanga sockeye of over 50%, reaching highs of over 65% in some years (Cleveland et al., 2006). Furthermore, the Kitwanga Watershed was heavily logged beginning in the 1960's and it is believed that both spawning and rearing areas have been negatively impacted by road building and harvesting activities (Cleveland et al., 2006).

In response to the conservation concern for Kitwanga sockeye, the Gitanyow Fisheries Authority (GFA) in co-operation with Fisheries and Oceans Canada (DFO) and the Skeena Fisheries Commission (SFC) have initiated a rebuilding plan to restore Kitwanga sockeye while retaining the genetic structure of the stock (Cleveland et al., 2006). The plan discusses in detail the biology of Kitwanga sockeye, identifies potential limiting factors to production and outlines recovery actions based on recommendations from the Kitwanga sockeye expert panel-working group. The *Kitwanga River Sockeye Salmon Recovery Plan* (KSRP), which was developed in 2005/06, rated the out planting of sockeye fry into Gitanyow Lake as one of the highest priority projects in the short term to rescue the stock. The consensus of the working group was that the stock should be artificially enhanced as soon as possible to ensure that no more genetic diversity is lost in the event that the population continued to decrease in size.

In 2006/07, GFA was successful in securing funds from the PSC to culture Kitwanga sockeye from egg to fry to supplement natural sockeye production from Gitanyow Lake. To perform this task, GFA partnered with the Gitxsan Watershed Authorities and the Kispiox Hatchery was used to produce Kitwanga sockeye fry. Initial production goals for this pilot year were set at a modest 100,000 fry. Overall, the 2006/07 enhancement program proceeded as planned, hatchery operations were successful and a total of 81,000 fry were raised from egg to >1g fry and released with an adipose fin clip into Gitanyow Lake during the spring and summer of 2007. Survival rates of eggs from fertilization to the eyed stage were high and exceeded 85%, while fry survivals from ponding to release were even higher at 92%. The program did see one setback

that may affect the final adult production outcome from the 2006/07 enhancement program. It consisted of observations that found a portion of the early released clipped hatchery fry leaving the lake almost immediately after release, instead of staying for a year to nurse as is customary in the wild stock. However, several release strategies were employed in 2006/07 and again in 2007/08 and the results look more promising. This topic will be discussed in more detail in the results section of this report.

In 2007/08 the GFA were successful in securing funds from the PSC to implement year 2 of the Kitwanga Sockeye Enhancement Program. Production goals for 2007/08 were set at 200,000 fry, double of what was proposed for the previous year. This report will summarize the works completed under this project.

Introduction

The objective of the Kitwanga Sockeye Enhancement Program in 2007/08 was to raise 200,000 Kitwanga sockeye fry to supplement the natural wild production in Gitanyow Lake. This initiative was undertaken by the GFA in partnership with the Gitxsan Watershed Authorities (GWA) and consisted of brood stock capture and transport, adult sockeye holding experiments, egg and milt takes, manual spawning, egg incubation, fry rearing, fry release, and follow-up studies.

Kitwanga sockeye enhancement works were initially piloted in 2006/07, and overall the project was deemed a success. The 2007/08 enhancement efforts will mark year 2 of the program and the works completed during this round will build on the lessons learned in 2006/07. This second year of culture should be once again considered a pilot program; nevertheless production goals were double to 200,000 fry for this round. Once again a focal point of the 2007/08 enhancement program will be to ensure that GFA and GWA staff focused on ensuring that disinfection, compartmentalization, and virus screening protocols are strictly followed.

Through works completed in 2006/07, GFA and GWA were able to recommend the following protocol to improve the outcomes of subsequent Kitwanga sockeye enhancement initiatives:

- In years of relatively high adult sockeye escapement brood stock should be collected off of lakeshore spawning grounds. This method is the simplest and most cost effective means of acquiring brood stock. If escapements are low adults should be held in the hatchery rather than in lake net-pens. Hatchery held sockeye are more secure, easier to work with and can be treated regularly with Parasite S to prevent infections and abnormalities.

- Automated feeders should be introduced to provide an optimal feeding regime for ponded fry.

- Attempts should be made to slow down egg to fry development in order to synchronized release schedules with what is seen naturally in Gitanyow Lake. Studies should be undertaken to refine natural emergence timing for Kitwanga sockeye in Gitanyow Lake. One avenue for hatchery manipulation of eggs and fry development could come from the installation of chillers to slow down egg development.

- In the spring of 2007, early released grouped hatchery fry unexplainably left the lake shortly after release rather than staying for one year like most of the wild stock (Cleveland, 2008). Several release strategies were tested in 2007 and later timed released hatchery fry (post spring freshet) were observed to stay in the lake unlike the early release groups. Attempts should be made in 2008 to release hatchery fry later in the season (early summer) to maximize the likelihood that the release groups will stay in the lake for one year like the wild component of the stock.

- There should be some means (smolt trap or fence) in place to assess whether fry leave the lake soon after release and to monitor fry to smolt success from the hatchery program.

- Pursue a fry marking system that could differentiate hatchery produced sockeye from different year classes.

The culture of 2007/08 Kitwanga sockeye was performed according to the *Alaskan Sockeye Salmon Culture Manual – Special Publication #6, August 1994* protocol and the *Fish Culture Manual – produced by the FRED Division of the Alaska Department of fish and Game, 1983*. The Alaskan protocol was implemented to minimize the chance of disease outbreaks, which could have put the project in jeopardy. All adults used for culture purposes were matrix spawned to preserve their genetic variability in the enhanced population. All enhanced fry were adipose fin clipped to make them recognizable from wild sockeye. By making hatchery fry recognizable, it is possible to assess future survival rates for the cohort utilizing the Kitwanga River smolt enumeration fence (KsF), as smolts leave the lake and again through adult enumeration at the Kitwanga River Salmon Enumeration Facility (KSEF). As a precautionary measure, no adult sockeye would be collected until at least 100 female and 100 male sockeye had escaped into the Kitwanga River (confirmed through enumeration at the KSEF). This would ensure that no more than 50% of the 2007 stock is used for the proposed hatchery culture. A target of 130 adult Kitwanga sockeye (1:1 sex ratio) was set as a brood stock collection goal for 2007. Based on the previous years female fecundity levels of approximately 3,100 eggs per female, we predicted that we would require approximately 65 females to satisfy our production needs.

Study Area

a) Kitwanga River and Gitanyow Lake

The Kitwanga River is a fifth order stream that drains into the Skeena River approximately 250 kilometres east (upstream) of Prince Rupert, B.C. It supports six species of Pacific salmon including pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*) and steelhead trout (*O. mykiss*). The Kitwanga River is also known to support populations of resident rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki*), Dolly Varden char (*Salvelinus malma),* bull trout char *(S. confluentus*), mountain whitefish (*Prosopium williamsoni*) and various other species of coarse fish (Cleveland 2000). It is coded 40-2200 by the B.C. Watershed Classification System. The UTM coordinates at its confluence are 090055840 N, 6106300 E. The drainage encompasses an area of approximately 83,000 hectares and has a total main stem length of 59 kilometres (Cleveland 2000). The river can be divided into two sections, the Upper and the Lower Kitwanga River. The Upper Kitwanga is located directly north of Gitanyow Lake and has a main stem length of approximately 23 km. The Lower Kitwanga River flows south for approximately 36 km between Gitanyow Lake and the Skeena River. The Lower Kitwanga River has four major tributaries Tea Creek (40-2200-010), Deuce Creek (40-2200-020), Kitwancool Creek (40-2200-030) and Moonlit Creek (40-2200-040). The Upper Kitwanga River has no major tributaries and exhibits a multi-channel meandering configuration, with numerous beaver dams along its lower reaches (Figure #1).

Gitanyow Lake is the only lake found within the Kitwanga Watershed. The lake is mesotrophic with a mean depth of approximately 5 meters and a maximum depth of 15m (Shortreed *et al.*, 1998). It is relatively clear and the euphotic zone encompasses the entire water column in most areas of the lake. The lake can be broken into two sub-basins separated by narrows. The sub-basins for the purpose of this report will be referred to as North Gitanyow Lake and South Gitanyow Lake. Gitanyow Lake is considered one of the most productive sockeye nursery lakes in British Columbia mainly due to its extremely high macrozooplankton biomass, which is composed mostly of *Daphnia sp.*, the main food source of juvenile sockeye salmon (Shorteed *et al*., 1998). Through lake and stream reconnaissance surveys completed by the GFA, it has been determined that Kitwanga sockeye utilize Gitanyow Lake for spawning and rearing purposes (Cleveland, 2000). Four key lakeshore spawning sites encompassing an area of approximately 17,000 m² make-up most of the known sockeye spawning areas in Gitanyow Lake (Figure #2) (Cleveland et al., 2003). One other small isolated spawning site at a depth of >6m in the narrows between the upper and lower portion of the lake may also support sockeye but this is yet to be confirmed. Juvenile Kitwanga sockeye use the lake as a nursery area for 1 or 2 years before migrating to the ocean as smolts (Shortreed et al., 1998). Therefore, Gitanyow Lake plays a vital role in the life cycle of Kitwanga sockeye for spawning and juvenile rearing purposes.

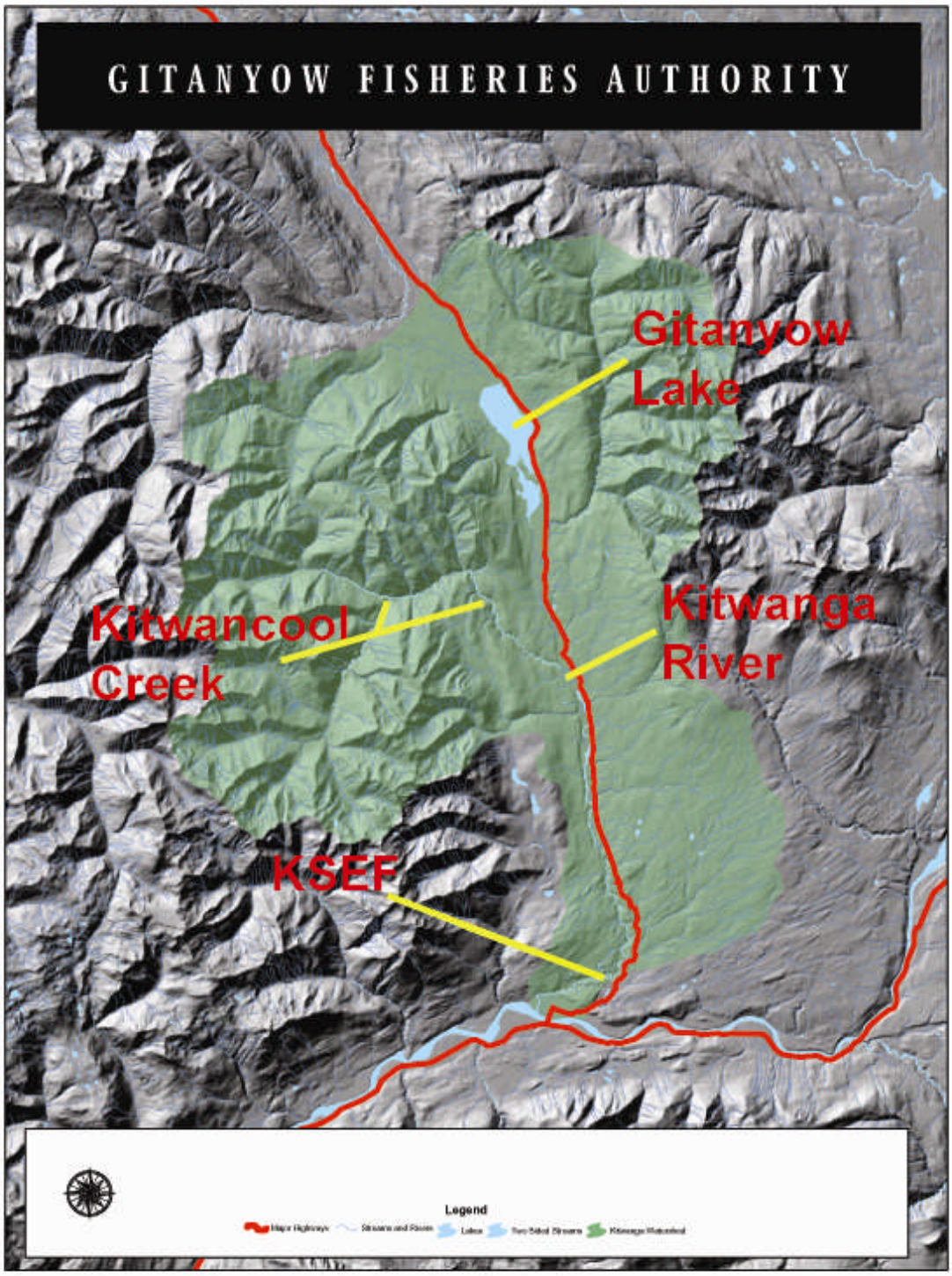


Figure # 1. Illustration of the Kitwanga Watershed, making specific reference to the location of the Kitwanga River Salmon Enumeration Facility (KSEF), Kitwancool Creek, Kitwanga River and Gitanyow Lake.

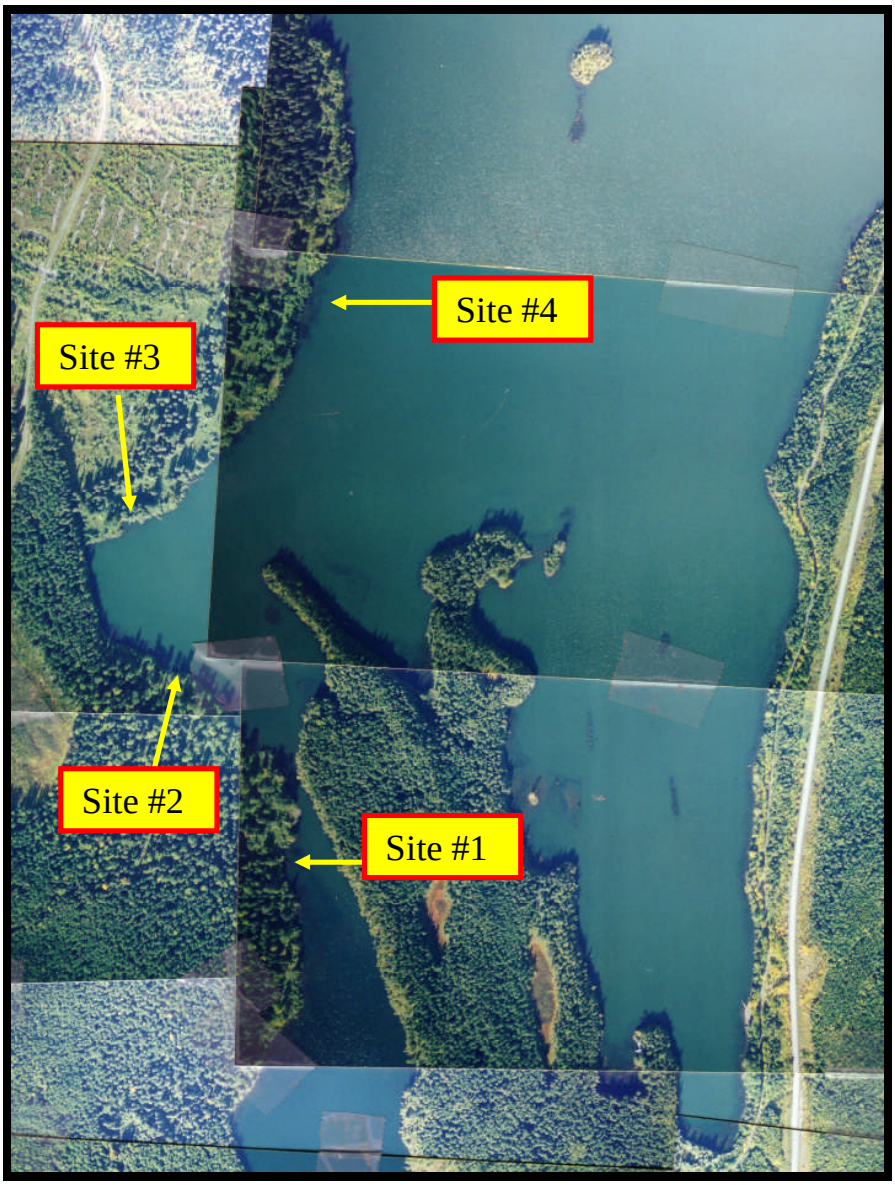


Figure #2: Kitwanga sockeye lakeshore spawning Sites #1 to 4.

b) Kispiox Hatchery

The Gitanyow Fisheries Authority contracted the services of the Gitxsan Watershed Authorities (GWA) in 2007/08 to raise Kitwanga sockeye from egg to fry as part of this enhancement initiative. The GWA operate the Kispiox Hatchery, which is the closest hatchery to the Kitwanga River. It is located in Kispiox Village only a few hundred meters from the confluence of the Skeena and Kispiox Rivers. The hatchery has been in operation since 1983 and has a good record of effectively producing healthy salmonids. In 2006/07 the GWA successfully raised Kitwanga sockeye and egg to fry release success rates were above 80%. Again in 2007/08 the GFA awarded a contract to the GWA to raise Kitwanga sockeye to >1g fry.

The Kispiox Hatchery is very conducive to sockeye culture because of its high quality, virus-free water source. The water source is ground fed by three separate wells, and transported by one 10" pipe and two 8" pipes. Three water pumps supply water to the hatchery: one 40 hp pump that supplies 400 gallons / minute and two 15 hp pumps each supplying 125 gallons / minute. The water supplied by the wells is usually a constant temperature of approximately 6-7ºC, which approximates water temperatures found in the gravels along Gitanyow Lake while the eggs are in the gravel. This should ensure that artificially raised fry maturing at the Kispiox hatchery develop over similar time frames as non-enhanced sockeye in Gitanyow Lake. Power to the hatchery is supplied by the local electrical grid and is backed-up by one diesel generator (for the submersible pumps) and another diesel engine for the rotor positive displacement pump. There is an emergency back-up water supply, which consists of gravity fed (no power required) surface water from Dale Creek. Currently, the Kispiox Hatchery has the capacity to incubate in excess of 500,000 sockeye eggs and 300,000 sockeye fry on an annual basis. Incubation is conducted in 128 heath trays, which are stacked in multiples of eight. Rearing is conducted in 12 Capilano troughs, where densities are kept at less than 25 kg per trough (< 25,000 1.0g fry).

Photograph #1: Kispiox Hatchery, Kispiox Village, BC.

Methods

In 2007 the overall sockeye return to the Kitwanga River was extremely poor with a return of only 240 fish. The returns were so low at the end of August that there were doubts as to whether the minimum adult return threshold of 200 adults (100 of each sex) would be met to allow the for the enhancement program to proceed. However, by the second week of September we had escaped the minimum of 200 adults to the river to allow us to collect some adults for brood stocking purposes.

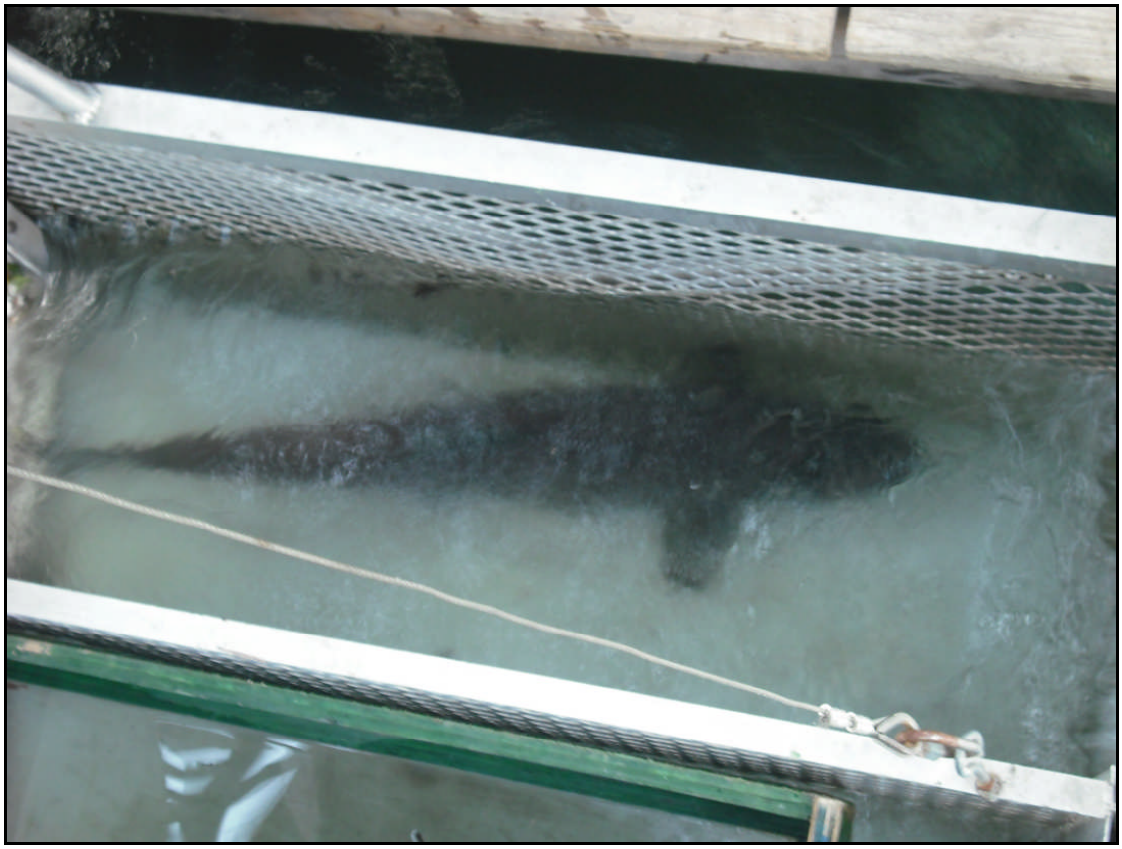
Kitwanga sockeye salmon were captured as green (not sexually mature) adults for brood stocking purposes. Green sockeye were captured on the Kitwanga River at the KSEF as they migrated through the fence and taken to the Kispiox Hatchery. At the hatchery they were held until sexually mature. Eggs and milt were stripped from female and male sockeye at the hatchery, and then immediately manual spawned. Fertilized eggs were incubated in Heath trays from mid November 2007 until the middle of July 2008 and fry were reared indoors in Capilano troughs until they reached a suitable size to be marked and released into the wild. Fry were marked with an adipose fin clip to render hatchery-produced sockeye recognizable from fry produced in the wild. All hatchery-produced fry were released into Gitanyow Lake in the summer of 2008. A more detailed account of the procedures used to enhance Kitwanga sockeye is presented below by task. It should be noted that a licence to import / transfer live fish within the province of British Columbia was acquired from Fisheries and Oceans Canada and the Province of BC. Licence # 11314 was issued under Section 22(1) of the Federal Fishery Regulations and pursuant to BC regulation 261/83 made under the Wildlife Act (Section 108 (2)(h) and (3)(a).

1) Brood Stock Collection

Green adult Kitwanga sockeye were captured at the KSEF for brood stocking purposes (Photograph #2). Desired specimens were trapped as they swam through sampling boxes (Photograph #3). Once the sockeye were captured they were inspected visually to ensure that they were in good shape and free of body wounds or abnormalities that may effect their survival during the long-term holding experiments. If the sockeye looked healthy, they were sexed and placed in an aluminium holding bin located in the river on river left (Photograph #4 & 5). The sides of the holding bin were made of solid aluminium sheeting, while the upstream and downstream walls were constructed of 5/8" perforated sheeting which allowed for adequate water exchange to sustain holding fish for long periods of time.

Adult sockeye were usually captured during a night shift (14:30-22:00) by KSEF salmon counting technicians and retained in the holding bin over night. The following morning they were transferred to the Kispiox Hatchery where they were held until ripe.

Photograph #2: Upstream view of the KSEF, September 13, 2007.



Photograph #3: Kitwanga sockeye captured in KSEF trap, 2007.

Photograph #4: GFA crews preparing to move adult sockeye from the over night holding bin to the transport tank.

Photograph #5: Kitwanga sockeye held in over night holding bin, taken just prior to transport.

Sockeye were transported at a maximum of twelve fish per load. The transport bin consisted of a fish tote with a water capacity of 700 L, which was secured into the back of a pick-up truck. The tote was filled with river water and initial temperature and oxygen readings were taken from the bin (Photograph #6). Water conditioner was added to the tote to help transported fish retain scales and mucus during handling and transportation. The conditioner used was Vitalife, which is marketed by Syndel International Inc. Approximately 50 ml of Vitalife was added to the water in the transportation tank. Vitalife binds with heavy metals and harmful chemicals in the water to reduce water toxicity. Approximately 0.5g of Aquacalm or metomidate hydrochloride was also added to the water in the tote to sedate sockeye during the transport. This medically regulated drug reduces the harmful effects of stresses induced by capture and transport. GFA was required to obtain veterinarian approval to procure and use Aquacalm for this project. Veterinarian approval was granted by Christine MacWilliams, DVM of the Pacific Biological Station, Nanaimo, BC. MacWilliams acted as the technical advisor on the project and helped GFA fulfill Veterinary Drug Directorate of Health Canada regulations relating to the use of the drug. Finally, tote water was given a constant supply of oxygen, delivered through an air canister and a bubbler. Oxygen levels were monitored before and during transport using an Oxyguard to ensure they remained at the adequate levels to support adult sockeye during transport. Fish were dip netted out of the river holding bin, placed directly into a transportation tote, where they were immediately moved to the Kispiox Hatchery. The total transportation time to move fish from the KSEF to the hatchery was approximately 60 minutes.

Photograph # 6: GFA staff checking temperature and dissolved oxygen in transport tank.

Adult green Kitwanga sockeye were held in a raceway at the hatchery. Once at the hatchery, fish were given a 0.1ml prophylactic injection (0.033ml / kg of fish) of Oxyvet LA200, also referred to as Liquamycin or oxytetracycline. The Oxyvet was administered to the fish between the dorsal muscles directly behind the dorsal fin using a 1ml 26g sterile syringe equipped with a 3/8" needle (Photograph #7). Oxyvet was used as a general antibiotic to help prevent fish from developing infections. Oxyvet, like Aquacalm is a Health Canada controlled substance and hence required veterinarian approval for its use. As with Aquacalm, Dr. MacWilliams provided veterinarian services to allow GFA staff to utilize Oxyvet for holding experiments related to the project.

Photograph #7: Sockeye being injected with OxyVet.

The holding experiment involved holding green Kitwanga sockeye in a cement raceway at the Kispiox Hatchery (Photograph #8). The raceway was originally designed for the rearing of salmon smolts but given its size and capacity, it was determined that it would be a good fit to hold adult sockeye until they became ripe at which time eggs and milt could be extracted. The raceway was 12.2m long, 1.83m wide and 1.22m deep. The water depth in the raceway was kept at approximately 0.90m (Photograph #9). Therefore, the raceway contained approximately 20,000 litres of water or 20 m^3 of holding space for captive adults. A fresh supply of aerated ground water (IHN virus free) was constantly fed to the raceway while fish were being held. Approximately 100 litres per minute of water was circulated through the raceway at all times providing adequate water exchange and suitable oxygen levels to sustain the captive salmon.

Photograph #8: Kitwanga Sockeye being held at the Kispiox Hatchery.

Photograph #9: View of the raceway where green adult sockeye were held until sexually mature.

As an extra precaution in preventing fungus outbreaks in the raceway, a drip bath treatment of Parasite S (formalin) was delivered twice a week. The exposure time consisted of 60 minutes per treatment at a concentration of 100 ppm.

The raceway was kept covered at all times with black poly lids, to prevent fish from jumping out of the raceway. Temperature and dissolved oxygen in the raceway were monitored daily to ensure the levels remained optimal for fish health. Holding sockeye were disturbed as little as possible, but as they approached sexual maturity they were each checked weekly for sexual ripeness. When at least one male and one female were determined ready to spawn they were taken out of the raceway, culled and manually spawned directly on site.

2) Manual Spawning

Eggs and milt were collected from sexually mature Kitwanga sockeye according to the protocol outlined in the *Alaskan Sockeye Salmon Culture Manual – Special Publication #6, August 1994* protocol and the *Fish Culture Manual – produced by the FRED Division of the Alaska Department of fish and Game, 1983* guidelines. All brood stock extraction and spawning was conducted at the Kispiox Hatchery. The Alaskan protocol / guidelines were strictly followed to minimize cross contamination of individual egg lots. This was conducted in order to minimize the chances of *infectious hematopoietic necrosis* virus (IHN) and *Renibacterium salmoninarum* (BKD) infestations, which could surface at anytime during the hatchery operations. Egg take crews were trained in proper disinfection procedures and on the importance of egg lot segregation and compartmentalization. All containers, tools and articles used for brood stock collection were disinfected with an Ovadine solution mixed at a concentration of 25ml per litre of water (250 ppm) and given an exposure time of at least 3 minutes. Hands and rain gear of all persons involved in egg takes were thoroughly disinfected, before, during and after egg take exercises. Each fish was treated as an infected individual.

Fish were killed by striking them with a hard object between and slightly behind the eyes, being careful not to strike them too hard as to cause their eyes to bulge out of their sockets. Dead sockeye were then individually disinfected by dipping their bodies into an Ovadine solution mixed at a concentration of 10ml per litre of water (100ppm) (Photograph #10). The vent area was then wiped dry with clean paper towel prior to spawning.

Males were milked manually by massaging both sides of the lower ventral area Photograph #11). Sperm was collected in a 13 ml whirl-pack and labelled with a unique mark to ensure that each fish was identified as an individual for matrix spawning purposes.

Photograph #10: Sockeye being disinfected in Ovadine just prior to manual spawning.

Photograph #11: Male sockeye being milked.

After killing and disinfecting, females were hung from their tail with a small rope. The gills were cut, stuffed with clean paper towel and allowed to bleed out for approximately 10-15 minutes (Photograph #12). Each female was processed individually by a crew of two. The first crew member would hold the fish in an upright position (head up) while the other proceeded to make an abdominal incision with a Zak knife from the genital pore to the transverse septum, making sure to cut around the pelvic fins. Using rubber gloves, the cutter then gently scooped the eggs from the abdominal cavity into a disinfected bowl, making sure not to allow the eggs to fall more than 30cm. Skeins were gently ripped from the body cavity and all loose eggs were then massaged free prior to discarding (Photograph #13).

Photograph #12: Female sockeye being hung just prior to having their eggs extracted.

Photograph #13: Eggs being gently massaged from the female skein.

After the eggs are deposited into the bowl, a sample of ovarian fluid was extracted from around the eggs with a 7ml polyethylene disposable pipette. At least 2ml (preferably more) of ovarian fluid was collected from each female and placed in a sterile centrifuge tube (Photograph #14). Tubes were sealed and labelled accordingly, making specific reference to the female sockeye from which it originated. Each female was then dissected to acquire a small sample of its kidney for BKD analysis purposes. Kidney samples at least ¼ inch thick by 1 ¼ inches long were cut from the anterior part of the kidney and placed in a small whirl-pack. The whirl-pack was sealed and labelled accordingly, once again being sure to reference the specific female from which it originated. Kidney samples were extracted using a sterile scalpel; scalpel blades were sterilized using ethanol and a pocket torch prior to any cutting. Both the ovarian and kidney samples were stored in a cooler and packed with ice (gel packs) then shipped by air cargo to the Pacific Biological Station where they were analysed for the prevalence of the IHN and / or the BKD virus. If IHN was found present in any of the female ovarian samples, her eggs lots would be immediately destroyed to eliminate the potential for cross contamination. BKD testing can return results of low and high positive for the presence of titres by ELISA (testing procedure). Any samples returned as high positive for BKD would be immediately destroyed, while low positives would be kept segregated in their own Capilano trough and released as an early-unmarked sub-group to reduce the levels of BKD in the hatchery.

Photograph #14: Ovarian fluid being collected and placed in sterile centrifuge tube.

In order to utilize as much genetic diversity as possible, and equalize each male's genetic contribution to the captive brood stock pool, matrix spawning was employed. A simple two males per female design was employed, where female #1 was spawned with male #1 and male #2, and female #2 was spawned with male #2 and male #3, and so on. When the last female was spawned she would get sperm from the last male plus male #1. The eggs from each female were divided equally into two containers and sperm from two males were added to one or the other container to fertilize the eggs. This was conducted to prevent the dominant male from fertilizing all the eggs in the cases where the sperm of one male was significantly stronger than the others.

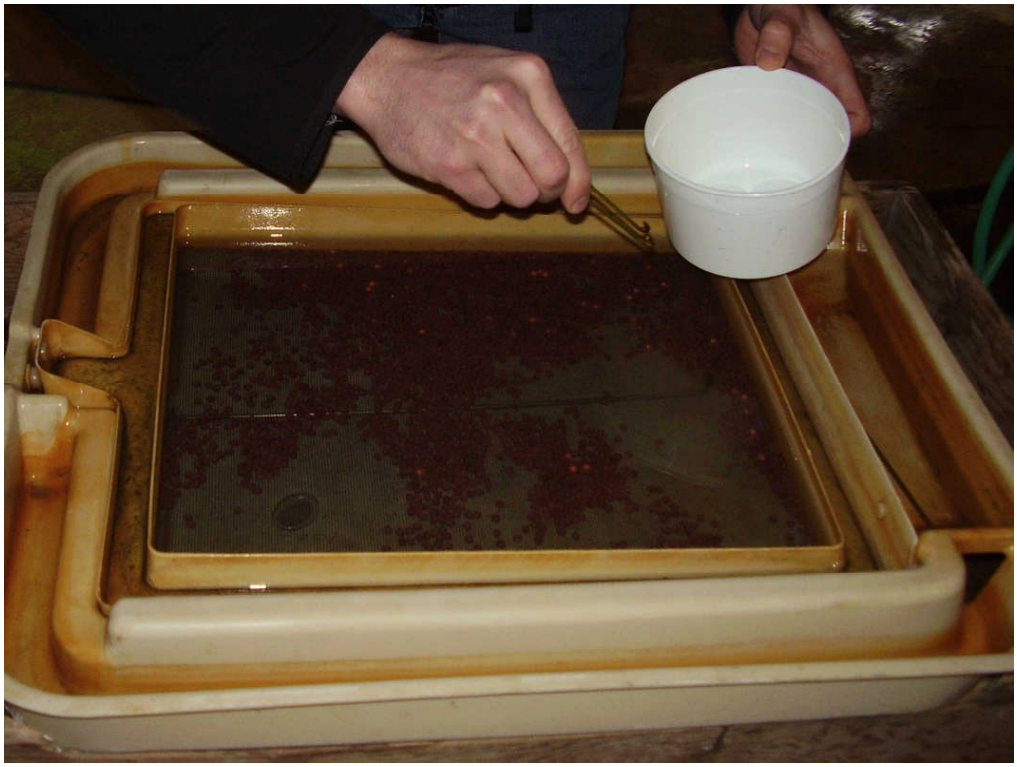
Disposable 7ml polyethylene pipettes were used to transfer sperm from whirl-paks to individual egg batches. The sperm was squirted into the centre of the eggs and enough water (ground fed hatchery water) was added to the bowl to cover the eggs. The water, egg and sperm mixture was gently swirled for approximately 60 seconds. Eggs were then thoroughly rinsed with clean hatchery water for approximately 2 minutes, until all the water and milky colour was eliminated from the eggs. Next the eggs were covered with 100 ppm Ovadine and water solution and allowed to sit for 10-15 minutes. After the initial 10-15 minute sterilization period, the Ovadine solution was gently poured off and new Ovadine solution was added to the eggs. After a total soaking time of 60 minutes, the Ovadine solution was poured off and both containers were placed together in a Heath tray where they remained for the entire incubation period. Each female had its own Heath tray and subsequently the tray was labelled accordingly to identify it as Female # x. The fertilization process was repeated for each female.

3) Egg Incubation

Each female egg batch was incubated in one of the available 128 Heath trays at the Kispiox Hatchery. For the most part the incubation room was kept dark while eggs were being incubated, however a dim light was required while hatchery personnel were working in the room. To minimize any potential negative effects of the dim light, black opaque plastic was placed over each stack. Fresh hatchery water was constantly circulated through each of the 16 stacks at approximately 10 L/minute/stack. Water temperature and dissolved oxygen concentrations were monitored routinely.

After the eggs were loaded into Heath trays, they were left undisturbed until they reached the eyed stage at approximately 300 ATU's (Accumulated Thermal Units – product of water temperature times the number of incubation days). At the eyed stage each egg batch was shocked, rid of dead eggs and then counted to produce a survival rate. Shocking was conducted to eliminate dead eggs from each tray since they can be a medium for fungus growth, which could spread to live eggs. Shocking was carried out by siphoning eggs through a 3cm plastic hose from the Heath trays into a pail located on the floor. The eggs were dropped a distance of approximately 25-30cm from the end of the hose to the surface of the water in the bucket. The act of shocking breaks the yolk membrane in dead eggs causing them to turn white within 24 hours, making them identifiable and easily separated from live eggs whose membranes remain intact. After shocking, the eggs were put back into the Heath tray from which they originated and allowed to sit for 24 to 48 hours. The following day, eggs were placed in picking trays

and all dead eggs were removed (Photograph #15). Both live and dead eggs were counted to estimate mortality and survival rates and to keep accurate production numbers.



Photograph #15: Dead egg removal.

After shocking and picking of dead eggs was complete, the total number of live eggs was estimated by weighing out eggs on a scale until a weight of 50g (usually requiring >500 eggs) was reached. Once the total number of eggs in 50g was acquired, hatchery staff divided 50g by the number of eggs to get the average weight for each egg. This procedure was repeated for each female. All dead eggs from this point forward were subtracted from the overall egg tally to keep track of hatchery production in 2007/08.

To measure the fecundity for a given female all of the eggs from the female were weighed and then the total weight was divided by the #g/egg to get the number of viable eggs per female. This number was added to the number of dead eggs that were picked prior to weighing, to get a total female fecundity.

Once eggs had been shocked, picked and counted, all live eggs were returned to their respective Heath trays where they were left to hatch and emerge. Hatching usually occurs at approximately 500-550 ATU's, while emergence usually occurs at approximately 900-1,000 ATU's. Throughout the incubation period, each Heath stack was treated with a Parasite S bath three times a week for a 15-minute period at a concentration of 1,600 ppm (~0.166 L of parasite S @ 1600 ppm X 15 minutes). The Parasite S was applied through a drip bucket to control fungus growth on eggs.

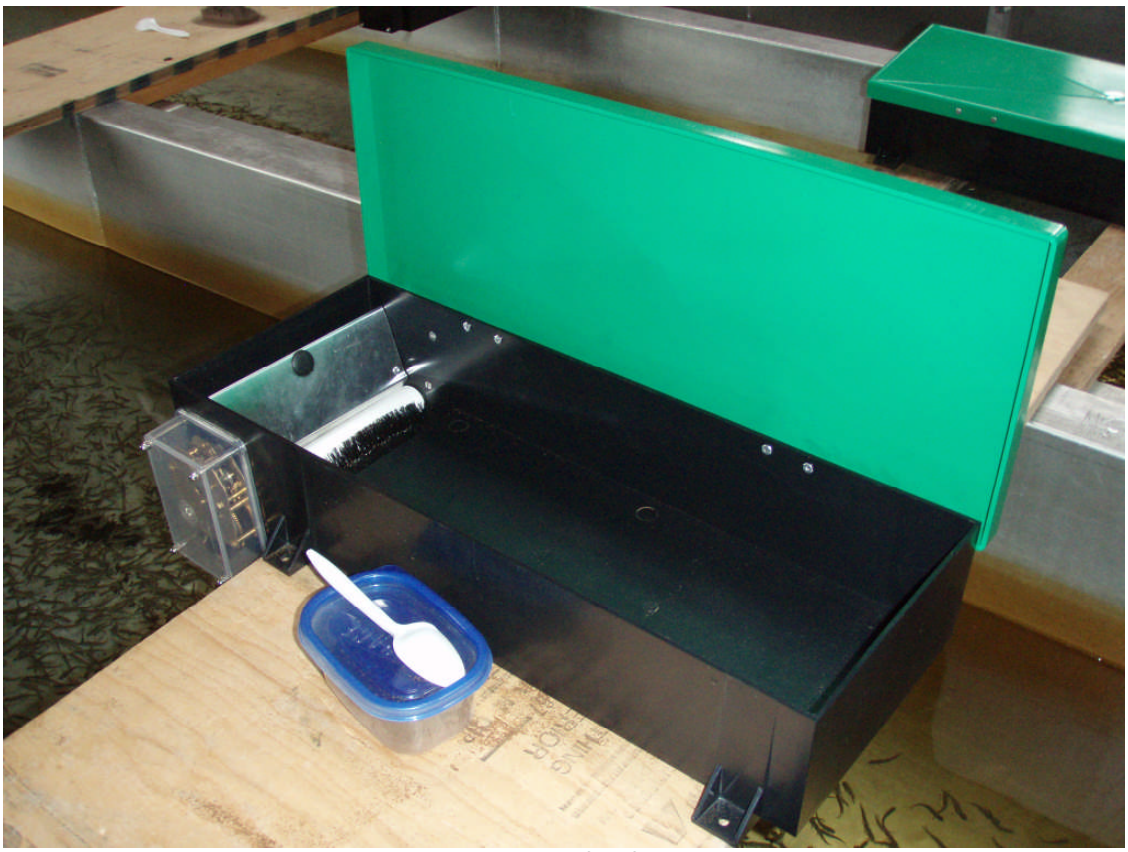
4) Fry Ponding and Rearing

Fry were initially checked to determine if they were ready for ponding at approximately 830 ATU's, normally sockeye fry are ready to be ponded between 830-940 ATU's (pers. comm. A. Stobbart, 2007). Ideally, fry should be moved from the incubators before they totally absorb their yolk sacs when they are referred to as being "buttoned up". Fry are ready to be moved when the ventral red slit has shrunk to approximately 60-70% of its original size, extending almost from the vent to the gills. Fry usually weigh approximately 0.1g when they are ready to be ponded. To test a group's readiness for ponding, approximately 10 fry were dropped in a Capilano trough and their behaviour was observed. If they showed signs of swimming to the surface and feeding normally they were deemed ready to be ponded and the rest of the brood from that particular incubator was transferred.

All Kitwanga sockeye fry were reared in one of seven aluminium Capilano troughs (Photograph #16). The troughs were given a unique identifier, which would be important because not all fry would be reared on the same schedule. The troughs were named, Fud, Kit, Lip, Izy, Bob, Joe and Hat. Although the Kispiox Hatchery had ample rearing capacity (>1,200,000 fry to 1g), rearing densities were kept low to reduce stress and competition. In all cases Capilano trough stocking densities were kept below 20,000 fry / trough (less than 20 kg of fry / trough). Capilano troughs were set in line with each other in pairs and a constant supply of fresh water at 100 L/min. was circulated through the two troughs.

Photograph #16: Capilano trough where sockeye fry were reared in 2008.

Fry were fed a daily ration of Ewos fish feed based on their average body weights. In 2007/08, unlike the previous year, fry were fed with mechanical wind-up clock belt feeders (Photograph #17). Newly ponded fry were fed an Ewos starter mash size "00" almost every 15-20 minutes or approximately 20 times per day for the first 3 or 4 weeks. Once the fry had tripled in size to approximately 0.3g the feeding regime was cut in half to 10 feedings a day and fry were switched to an Ewos crumble size "0". By the time fry reached 0.6g and larger they were switched to an Ewos micro size "1" and fed only five times a day.



Photograph #17: Automatic fish feeders used in 2008.

In order to keep an ongoing accurate record of hatchery production, all dead fry were counted and subtracted from the live egg counts.

5) Fry Release

Fry were released into Gitanyow Lake in the summer of 2008, after reaching at least 1.0g in size. The intent of the Kitwanga sockeye enhancement program was to mark every fish that left the hatchery so that they could be distinguished from the production of wild sockeye in Gitanyow Lake. The mark of choice for the program was an adipose fin clip, which would last throughout the life of the sockeye, making them recognizable as hatchery produced fish. The main purpose of the mark was so that GFA staff could recognize hatchery produced fish as smolts during the operation of the and again as adults returning as spawners at the KSEF in future years. This would allow GFA staff to assess

fry to smolt survival and smolt to spawner survival for all Kitwanga sockeye in years to come, giving a direct measure of the success of the enhancement program. Fry were fin clipped by GFA and GWA staff at the Kispiox Hatchery. Once fry had reached at least 1g they were starved for a period of 24 hours, anaesthetised with MS 222 and then adipose fin clipped using surgical scissors. Care was taken to cut as close to the body as possible without harming the fish. Fry were then fed for several days after clipping and then starved again for 24-48 hours in order to prepare them for relocation to Gitanyow Lake. Fry were transported from the Kispiox Hatchery in the back of a truck equipped with a 700L tote of hatchery water. Tote water was fed a constant supply of air and moved in groups not exceeding 25,000 per trip. The total transport time to the lake took approximately 1.5 hours. Fry were dip netted out of each Capilano trough, placed into buckets and then gently poured into the tote. At the lake fry were drained out of the transport tote through a 4" tube into a second tote located in a boat on Gitanyow Lake. Fry were then boated to the centre of the lake in the upper basin and dip netted from the tote and release directly to the lake.

Results and Discussion

The results section of this report is laid out in a format to discuss brood stock collection, manual spawning, female fecundity, egg incubation, virology, fry ponding, rearing and release and other program findings.

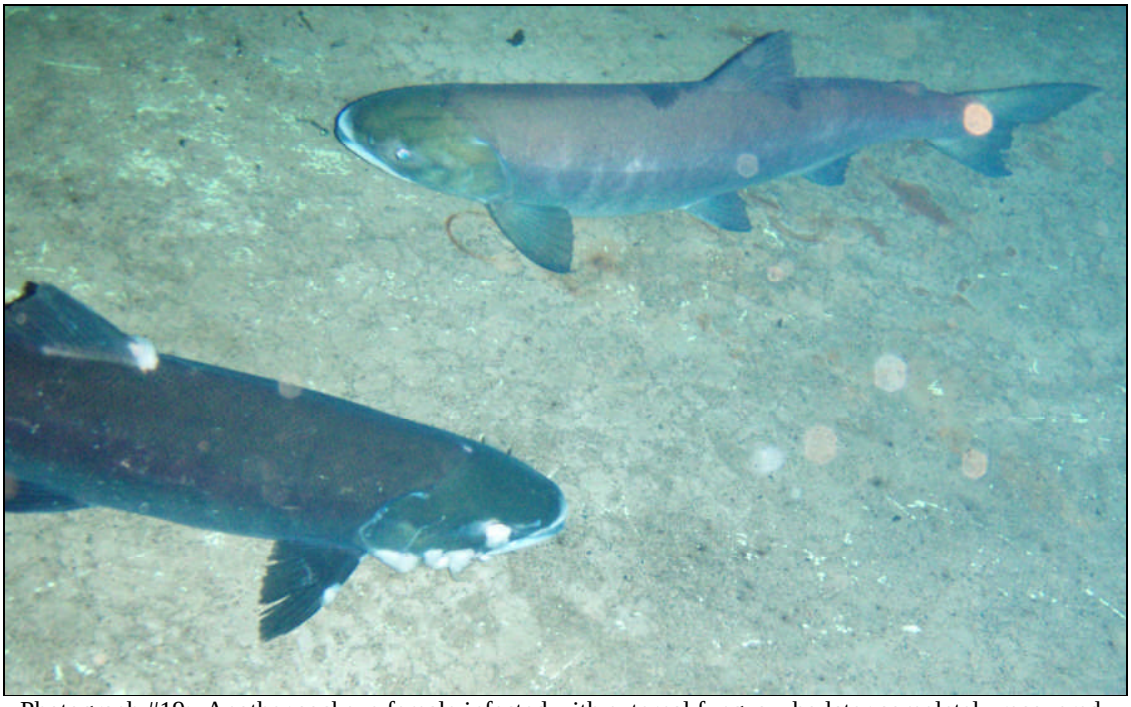
The production goals for 2007-08 were double from the previous year therefore GFA crews hoped to be able to catch approximately 140 sockeye (1:1 sex ratio) for brood stocking purposes. However, the overall Kitwanga sockeye escapement in 2007 was extremely poor and only 240 adults returned to the system (Cleveland, 2008a). Because the Kitwanga sockeye enhancement program was still under development (only year 2 of a pilot) it was decided that only a few adults (n=12) would be taken for brood stocking purposes in this low return year. This decision was made jointly by the GFA and the DFO in order to conserve the few wild fish that returned to the system in 2007.

1) Brood Stock Collection

Adult green sockeye were collected at the KSEF for brood stock collection purposes on September 6, 2007. In total 12 adult sockeye, 6 females and 6 males were relocated to the Kispiox Hatchery in one trip. Fish were transported in water collected from the Kitwanga River and water temperatures remained fairly consistent at approximately 11ºC. Dissolved oxygen concentrations in the transportation bin were kept between 9-15 ppm. The hatchery raceway was colder than river water with a value of approximately 7ºC. At the hatchery sockeye were dip netted from the tote, injected with Oxyvet and then placed directly into the raceway. Sockeye appeared to be extremely relaxed in the raceway, showing no signs of distress after relocation. All sockeye were moved successfully to the Kispiox hatchery with a 100% survival rate.

Of all the sockeye held in captivity for brood stock collection purposes in 2007-08, only one female died before ripening. The female that died developed a serious external fungus that eventually spread to much of her body. She was found dead in the raceway on October 4, 2007, 28 days after being moved to the hatchery (Photograph #18). Other sockeye in the raceway developed mild cases of external fungus, but completely recovered, presumably do to the positive effects of the Parasite S drip administered to the raceway 2-3 times a week (Photograph #19). Parasite S treatments were administered between September 10 and November 12, 2007 and in total 25 treatments were initiated.

Photograph #18: Fungus covered sockeye female that eventually died from the infection. Photograph taken on September 30, 2007.



Photograph #19: Another sockeye female infected with external fungus who later completely recovered. Photograph taken on September 30, 2007.

One female and one male sockeye were found to be sexually ripe on November 1, 2007. A GFA crew spawned the pair and used their gametes in conjunction with the *"Kitwanga Sockeye Salmon Spawning Habitat Improvement Initiative"*. This undertaking was part of another project implemented by the Gitanyow Fisheries Authority in 2007/08 to assess egg to fry survival along the lakeshores of Gitanyow Lake where Kitwanga sockeye spawn naturally. No spawners were observed using the lakeshore spawning grounds in 2007, therefore GFA decided to utilize hatchery held fish as brood stock for the undertaking (Kingston, 2009).

In 2007-08 all hatchery held sockeye matured over a similar schedule allowing GFA staff to spawn all four females with the five males on November 14, 2007. However, it was noted that at least one of the females had partly expired her eggs shortly prior to manual spawning because several hundred sockeye fry were found rearing in the bottom of the raceway in the beginning of April, 2008. It was later determined that these fry must have originated from when the adults were being held in the raceway. That means that at least a pair of sockeye had actually spawned successfully and their offspring were able to incubate, hatch and produce viable free swimming fry in the cement raceway with no gravel medium. These fry, once discovered (1st week of April) were moved to a Capilano trough (more details to follow in the *"Fry Rearing, Ponding and Release"* section of the report).

GFA staff frequented the lakeshore spawning grounds along Gitanyow Lake in the fall of 2007, in hopes of supplementing raceway held fish with a few lakeshore spawners. A total of 18 visits to the various lakeshore spawning sites were performed from September 8 – November 20, 2007. Of these visits only 2 sockeye were observed on September 8, 2007 at Site #1, and then 10 more at Site #3 on September 10, 2007. All 12 sockeye observed were not paired and did not show any typical spawning behaviour. Other areas of the lakeshore were also inspected in 2007, but no other sockeye were observed and no fresh redds were found in 2007. These results seem to indicate that of the few sockeye that did escape to the system in 2007, they either spawned at other deep water locations where they were not readily visible or that they died prematurely before they could reproduce.

In total Kitwanga sockeye adults held for hatchery brood stock collection purposes spent 70 days in captivity in a cement raceway at the Kispiox Hatchery. Of the 12 sockeye moved to the site, 11 were successfully spawned yielding a holding survival rate of 92%.

2) Manual Spawning

All of the 2007-08 egg takes for the enhancement program were conducted in one day. In total 4 females were spawned with 5 males. For the most part the brood stock extraction and manual spawning was conducted as planned and no setbacks were experienced.

3) Female Fecundity

The average fecundity for a Kitwanga sockeye based on 2007 egg take results was 3,382 eggs per female (including the female used for the lakeshore egg survival studies). As

mentioned earlier one female had partially spawned in the raceway during holding, therefore the actual fecundity is probably slightly higher. The maximum fecundity encountered was 4,460 eggs per female and the minimum was 2,497 eggs per female.

The 2007 sockeye fecundity is slightly higher than what was reported in 2006 at 3,067 (Cleveland, 2008). Groot and Margolis (1998) estimated average sockeye fecundity at 2,000 – 4,000 eggs per female in most populations and that years spent in the ocean is the primary criteria that determines a females fecundity. At the time that this report was written sockeye ages for 2007 females used for brood stocking were not available. However, based on average ages collected from Kitwanga sockeye at the KSEF in 2007 it was determined that 60% of the females spent 3 years in the marine environment. This compares to 2006 where 97% of the females were documented to have spent 2 years in the ocean (Cleveland, 2008).

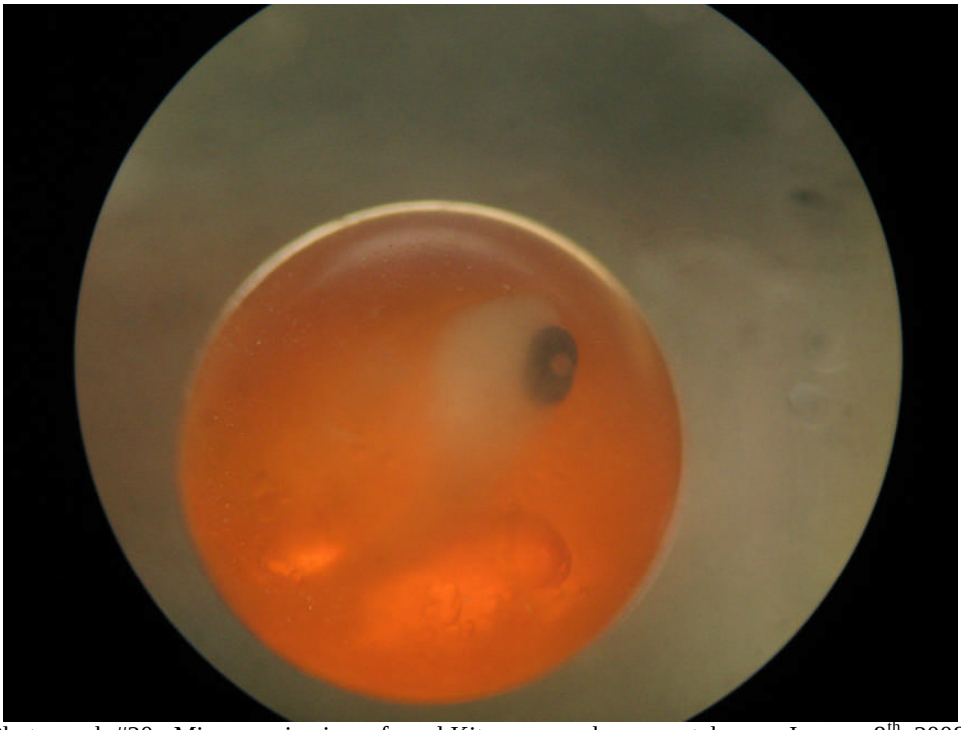
Kitwanga sockeye eggs were small with an average weight of only 0.083g and ranging from 0.072g to 0.092g (n=2,444). The 2007 egg weights were quite similar to what was observed in 2006 where average egg weights were 0.087g (Cleveland, 2008). A reference search for average Skeena sockeye egg weights produced only a few examples, the best from Scully Creek in the Lakelse system, and the Babine River which both showed similar egg weight averages of 0.146g per egg (Groot & Margolis, 1998). Given that Kitwanga sockeye are lacustrine spawners it is likely that the smaller egg size observed in 2006 and 2007 is a local adaptation. This adaptation has probably formed to promote embryo survival in lakeshore gravel given that the development often takes place under reduced oxygen conditions (Kingston, 2009).

4) Egg Incubation

All eggs used in 2007-08 for Kitwanga hatchery sockeye production were fertilized on November 14, 2007. The hatchery water in 2007-08 during egg incubation was almost a constant 6.9ºC. Therefore, it was predicted that all the eggs would reach the eyed stage by December 19, 2007, hatch by February 12, 2008 and emerge by March 31, 2008 (Fisheries and Oceans Canada, 2003). The eggs were checked to determine their progress after 48 days of incubation (>300 ATU's) and shocked using the drop method on January 2, 2008. After 48 hours, dead eggs were picked from each egg lot and the live eggs were returned to the incubators. In total the four females yielded 13,173 eggs, where 1,166 were found to be unfertilized or dead. The total live eggs eyed post shocking was estimated at 12,237 (Photograph #20).

Survivability of eggs from manual spawning to the post shock stage was high with a mean overall survival rate of 91.1%. Three of the four females yielded high fertilization / survival rates to the post shock stage of 95.0% – 99.3%. The fourth female showed poorer results of 74.7%. An examination of the dead eggs from all four females showed that most (>95%) were not fertilized. Unfertilized eggs showed clearly in most samples that the blastodisc had collapsed to form an irregular patch on the surface of the yolk, which is a common feature of an unfertilized egg. Overall, egg survival rates in 2007-08 were higher than 2006-07 where fertilization / survival rates were 85% (Cleveland,

2008). In total eggs / alevin spent 138 days in the Heath trays incubating before being moved to the Capilano Troughs for rearing.



Photograph #20: Microscopic view of eyed Kitwanga sockeye egg taken on January 8th, 2008.

5) Disease Screening

All four Kitwanga sockeye females used for brood stocking purposes in 2007-08 were screened for the infectious hematopoietic necrosis virus (IHN) and or the *Renibacterium salmoninarum* (BKD). Kidney tissue samples and ovarian fluid from each female sockeye was shipped by air to the Pacific Biological Station (PBS) in Nanaimo, BC within 24 hours of being collected. PBS staff analysed samples within 72 hours of receiving them. Results from disease screening of the brood stock were received on December 6th and were negative for both IHN and BKD.

6) Fry Ponding and Rearing

Kitwanga sockeye were ponded at approximately 0.1g in size on March 31, 2008 for the heath tray raised fry, while raceway raised fry were ponded approximately one week later. Fry from females 1 and 2 were ponded together in a Capilano trough (Cap) labelled "Joe", while fry from females 3 and 4were moved to Cap "Lip". Raceway fry were moved to Cap "Hat" and raised in isolation.

Fry counts were kept by subtracting all dead fry from the ongoing production tally initiated at the egg stage, and estimation of average fry weights were performed regularly throughout the program (usually twice a month). Water temperatures in the Cap troughs remained at a constant 6.5ºC and D.O. levels at approximately 13 mg/L for the duration

of fry rearing. Fry were fed on preset schedules based on their size (Photograph #21). Two belt feeders were mounted on each of the three troughs. The initial feedings were conducted by hand so that hatchery staff could observe proper intake. Once most of the fry were determined to be feeding, hatchery staff switched to mechanical belt feeders. Staff loaded feeders each morning and ran a mechanical spring timer for 12 hours. A string was placed across the front of the belt portion of the feeder to help the feed fall off the belt (avoid sticking).

Photograph #21: Fry congregating under a feeder.

On March 31, 2008 Cap Joe was loaded with approximately 6,660 fry, while Cap Lip was loaded with approximately 5,347. Approximately one week later Cap Hat was loaded with approximately 338 fry originating from the raceway.

Fry in Joe and Lip were raised under similar temporal and spatial conditions and both showed similar growth rates. However, fry in Joe were found to be slightly larger at ponding and remained larger until release (Table #1). Fry in Lip and Hat were very similar in size (Table #1), therefore on June 5, 2008, Hat fry were moved to Lip in order to simplify the hatchery operation (reduce number of Cap's requiring attention).

Table #1: Kitwanga sockeye fry production information from 2007-08.

Female #	Cap	Date Ponded	Date	# Days	# Fry	Avg. Weight (g)	Increase in % BW	Avg. % BW increase/day
1 and 2	Joe	31-Mar	31-Mar-08	0	6660			
			15-Apr-08	15	6652	0.27		
			24-Apr-08	24	6649	0.29	6.90%	0.77%
			8-May-08	38	6640	0.40	27.50%	1.96%
			22-May-08	52	6631	0.60	33.33%	2.38%
			5-Jun-08	66	6627	0.87	31.03%	2.22%
			20-Jun-08	81	6624	1.12	22.32%	1.49%
			1-Jul-08	92	6623	1.47	23.81%	2.16%
			7-Jul-08	98	6613	1.52	3.45%	0.57%
3 and 4	Lip	31-Mar	31-Mar-08	0	5,347			
			15-Apr-08	15	5336	0.22		
			24-Apr-08	24	5336	0.24	8.33%	0.93%
			8-May-08	38	5326	0.36	33.33%	2.38%
			22-May-08	52	5306	0.47	23.40%	1.67%
			5-Jun-08	66	5303	0.66	28.79%	2.06%
			20-Jun-08	81	5634	0.90	26.67%	1.78%
			1-Jul-08	92	5631	1.16	22.41%	2.04%
			7-Jul-08	98	5624	1.23	5.69%	0.95%
Raceway	Hat	1st week of April	31-Mar-08	0				
			15-Apr-08	15				
			24-Apr-08	24				
			8-May-08	38				
			22-May-08	52	338	0.45		
			5-Jun-08	66	335	0.61	26.23%	1.87%
			20-Jun-08	Moved to Lip				

Note: BW = body weight, Avg. = average.

Overall, Kitwanga sockeye fry increased their body weight an average of 1.74% per day (min. = 0.57%, max. 2.38% per day). Growth rates were quite similar between Cap groups where Joe, Lip and Hat yielded average % daily growth rates of 1.65, 1.69 and 1.87 respectively. Joe fry were approximately 19% larger than Lip fry by the time the first weights were collected on April 15, 2008 and this size advantage persisted right up to release. Joe fry averaged 0.27g in size at the first weigh in, while the average Lip fry weight was 0.22g. Joe fry averaged 1.52g just prior to release, while Lip fry only weighed 1.23g (Figure #3).

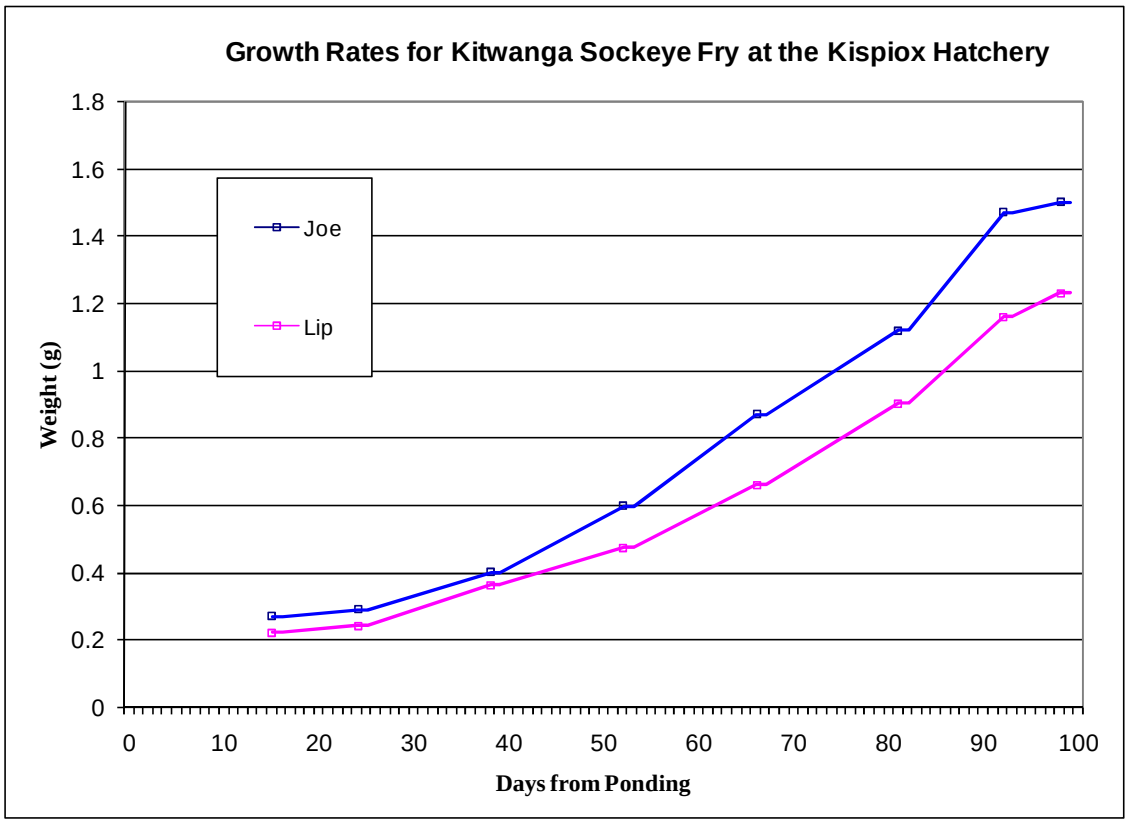


Figure #3: Kitwanga sockeye fry growth rates in grams from shortly after ponding.

All hatchery fry were adipose fin clipped on July 7, 2008 at the Kispiox hatchery by a crew of 7 experienced clippers. In total 12,237 fry were clipped and only 19 of the clipped fry died from the handling exercise. Fry were released back into their respective Cap troughs.

7) Fry Release

On July 13, 2008 all fry were starved in order to prepare them for transport and release to Gitanyow Lake the following day. On July 14, 2008 GFA staff moved all fry in one trip from the hatchery to the lake. Fry were dip netted into buckets and poured into the transportation bin filled with hatchery water. It took approximately 1 hour and 20 minutes to reach the lake where a boat was ready to transport fry to the desired release location in the lake. Once at the lake fry were drained from the transportation bin through a 4" tube to another bin located in the boat (Photographs #22-23). Fry were then transported to the release spot, which took about 5 to 10 minutes. Fry were released as one large group in the deeper part of the upper basin of Gitanyow Lake (Figure #4). Fry behaviour post release was observed from the surface and on a depth sounder mounted underneath the boat. Fry were seen diving in clouds towards the bottom of the lake almost immediately after release. The clouds as observed on the sounder could be seen at a depth of approximately 8m for approximately one minute before the boat and or the fry drifted off.

Figure #4: Satellite view of Gitanyow Lake with red star demonstrating the 2007-08 fry release location.

Kitwanga sockeye fry spent a total of 105 days in the hatchery before being released into Gitanyow Lake on July 14, 2008. A total of approximately 12,216 marked fry were successfully released in 2007-08. It is expected that the fry will stay in the lake until the spring of 2009 when they should smolt and emigrate to the ocean. GFA intends on documenting hatchery and wild smolt production in 2009 at the KsF, which was rendered operational for the first time in the spring of 2008.

The overall fry survival rate for the 2007-08 enhancement project was estimated at 99.0% (from ponding to release).

Photograph #22: GFA staff preparing to move fry from the transportation bin. Photograph taken on July 14, 2008.

Photograph #23: Fry loaded in holding bin being prepared for transport to release location on Gitanyow Lake. Photograph taken on July 14, 2008.

8) Other Findings

The Gitanyow Fisheries Authority operated a modified incline plane trap at the outlet of Gitanyow Lake to determine if any of the 2007-08 sockeye hatchery fry left the lake shortly after release (Photograph #24). The trap was installed on July 10, 2008 and was fished until July 18, 2008. During this period water levels in the Kitwanga River were low and the IPT appeared to be fishing successfully. In total 2 redsided shiners (*Richardsonius balteatus*), 28 prickly sculpins (*Cottus asper*) and 3 mountain whitefish were caught during this period. No sockeye fry were caught. This would suggest that unlike what was observed in 2006-07, Kitwanga fry did not leave the lake after release in 2008. The modified trap was 2.44m wide and 0.91m deep. It was equipped with wings that extended from the upstream corners of the IPT to shore in a "V" formation. The wings were made of 1/8" nylon mesh and extended from the surface of the river to the bottom. The only sections of the river that remained open, were two small areas < 2m wide at the end of the wings (not attached to shoreline) and directly beneath the IPT (0.5m-1m opening depending on the level of the river).

Photograph #24: Upstream view of modified IPT trap used on the Kitwanga River in 2008.

Conclusions and Recommendations

In 2007-08 the Gitanyow Fisheries Authority, with help from the Gitxsan Watershed Authorities, were successful in culturing Kitwanga sockeye for the second consecutive year. Production goals for 2007-08 were set at 200,000 fry, however because very few adults sockeye escaped to the Kitwanga River in 2007 only 12,000 eggs were collected. For this year brood stock was only collected by holding green sockeye till maturity at the Kispiox Hatchery. All sockeye were spawned at once in mid November 2007 and then ponded by the end of March 2008. Egg to fry release survivals were high, and all fry were adipose fin clipped and released into Gitanyow Lake by mid July 2008. Unlike what was observed in 2007, no fry were found leaving the lake shortly after release.

Based on results from both 2006-07 and 2007/08 programs, GFA recommends that the following strategies be implemented in future enhancement projects to improve production results:

- In years of high adult sockeye escapement brood stock should be collected off of lakeshore spawning grounds. This method is the simplest and most cost effective means of acquiring brood stock. If escapements are low adults should be held in the hatchery rather than in lake net-pens. Hatchery held sockeye are more secure, easier to work with and can be treated regularly with Parasite S to prevent infections and abnormalities.

- Continue to use automated feeders to provide an optimal feeding regime for fry and to minimize human / fry interaction.

- Attempt to manipulate the development of eggs taken on different spawning dates in order to synchronized release schedules with what is seen naturally in Gitanyow Lake. Studies should be undertaken to refine natural emergence timing for Kitwanga sockeye in Gitanyow Lake. One avenue for hatchery manipulation of eggs and fry development could come from the installation of chillers to slow down egg development.

- Attempts should be made to release fry in July when water levels in Gitanyow Lake have receded to more normal levels, rather than in May or June when waters levels are higher and flow through currents are stronger. It is believed that early release fry have a higher tendency to leave the lake immediately rather than staying for one year as observed in the wild.

- There should be some means (smolt trap or fence) in place to assess whether fry leave the lake soon after release and to monitor fry to smolt success from the hatchery program.

- Pursue a fry marking system that could differentiate hatchery produced sockeye from different year classes.

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