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Shoal Harbour Creek Gravel Placement 2016:
Phase 1

Report Prepared By:
Marie-Josée Gagnon (B.Sc)
gagnonmariejosee@yahoo.ca

Mainland Enhancement Salmonid Species Society (M.E.S.S.S.)
General Delivery; Simoom Sound (BC), V0P 1S0

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1. Project Background and Rationale

The primary objective of this project is to increase the quantity and quality of coho spawning gravel in the fourth reach of Shoal creek and along the Moore Worthington tributary. The need for this project was identified by a habitat assessment conducted by the Mainland Enhancement Salmonid Species Society (M.E.S.S.S.) during the summer of 2015. This gravel placement project implements recommendations made in the final report, which is accessible at the following link:
https://www.dropbox.com/sh/a699qpioh2to63o/AACPCFhBsk9j5Jcf4qwppVGva?dl=0

Detailed here are the results of phase 1 of the project which consists of gravel placement along 4 subsites in reach #4 downstream from the road bridge located 2.5km along the Shoal M/L. Subsites begin at the road bridge 1600m upstream from the estuary and extend 1465m downstream (Figure 2). Limited gravel in this reach was identified as potentially limiting to coho recruitment. Phase 2 and 3 of this project will consist of adding gravel along the Moore Worthington tributary, downstream from the road culvert 2km along the Shoal M/L and, upstream from another culvert near the 3km mark along the Connector M/L.

Returning coho typically migrate from the Shoal Harbour estuary to Bridie Lake at 2300m during the late summer and into fall. They will hold in freshwater and subsequently migrate downstream to spawn from late October to December. Reach #5 from 1600m to 2300m consists of marshland and provides excellent rearing habitat. However there is little suitable spawning habitat between 1200m to 2300m and silting throughout, which obscures most of the spawning gravel. Consequently, coho must travel over 1km to lower reaches to find suitable spawning habitat. Accordingly, gravel placement along reach #4 would cut down the travelling distance of coho migrating down from Bridie Lake to spawn. Adding gravel may decrease the energy expenditure of coho travelling downstream to spawn and lower their exposure to predators. Ultimately, the objective is to increase the freshwater productivity of the coho in Shoal Harbour creek.

2. Study Area

Watershed Code: 90-6300-340/905557500276
Latitude/Longitude Mouth: 50^{o} 43’ 53” N; 126^{o} 28’ 53” W

Shoal Creek drains northwest into Shoal Harbour on Gilford Island. The system is fed from Bridie Lake and a swamp at its head, as well as runoff from the surrounding watershed. There are several tributaries that flow into the stream. Shoal creek enters the harbour on the right and an active logging road parallels the creek on the left-hand side. The accessible length is 3.5 km and the watershed area is 20 km^2. The riparian area is open and allows easy travel with some woody debris but very little undergrowth.

The water flow is regulated by Bridie Lake, beaver dams in reach #5 as well as several unnamed small lakes in the upper reaches. There are some signs of flooding in the stream, and the 1988 DFO report reports flash flooding in the past. This may have flushed pre-existing gravel along reach #4 downstream. Logging impacts several decades ago have also contributed to siltation and may have increased soil erosion between 1200-1600m.

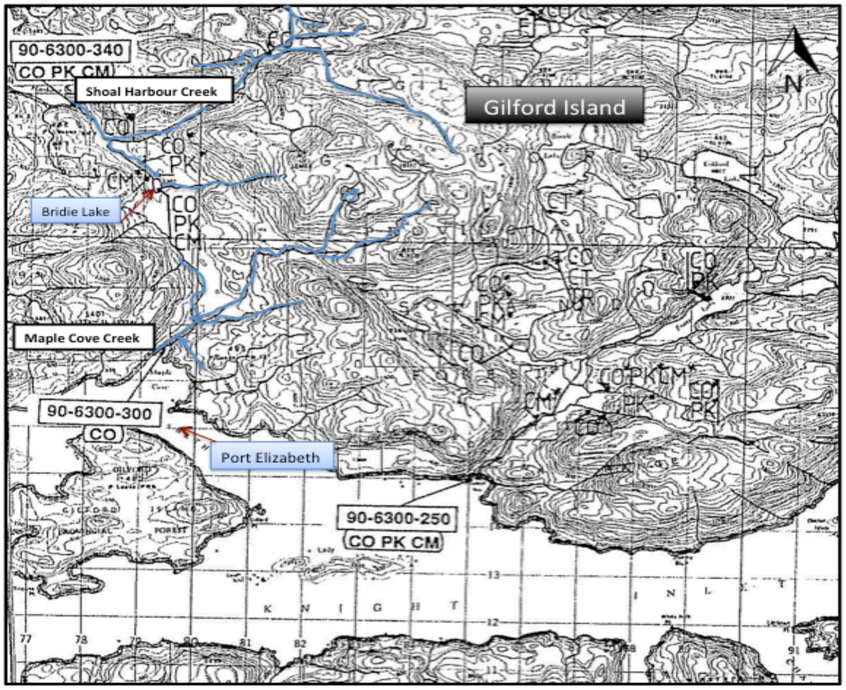

Figure 1. Fisheries Report Topographical Map (1988), outlining salmon bearing watersheds including Shoal Harbour and Maple Cove surveyed during the 2015 habitat assessments.

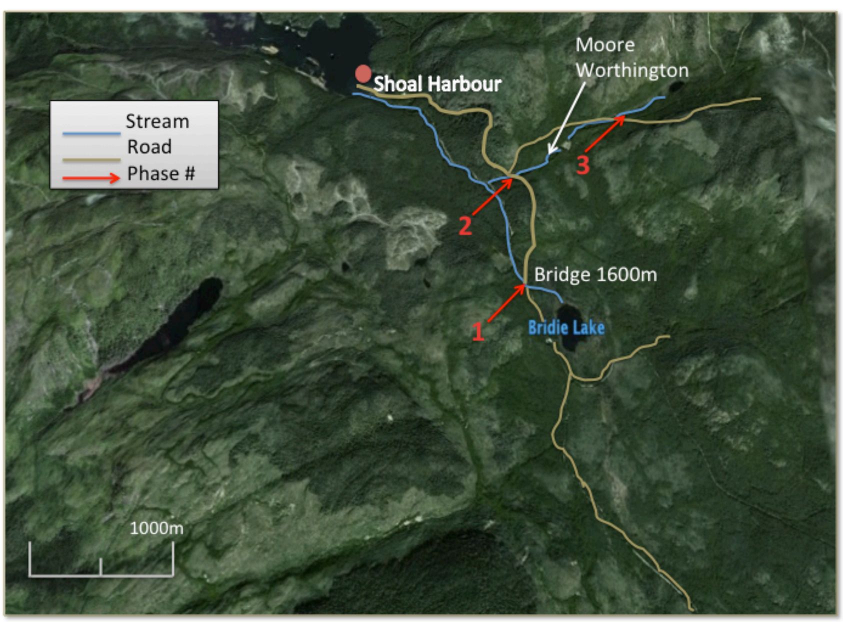

Figure 2. Map of Shoal Creek including phase 1 at 1600m where gravel was placed at 4 subsites and phase 2 and 3 along the Moore Worthington tributary where gravel placement sites have been proposed. These are planned to be completed during the summer of 2017.

3. Watershed Historical Information

Shoal Harbour is the site of some of the first logging on Gilford Island. Billy Proctor's 'Full Moon Tide' reports that starting around 1886, the Powell River Company built a fore and aft road up to the lake. Logging activity has been nonstop since that first road was put in, right up to the present day. There was extensive logging near Bridie Lake and along the fore and aft road from 1918-1928. The watershed was subsequently logged with truck logging in the 1980s. However the valley has recovered well. Ironside was also logging in the vicinity of the watershed and had a floating camp in the estuary that closed down in 2010. The camp was re-opened in 2016 and active logging is currently underway in cutblocks around Shoal M/L, Connector M/L as well as new roads built by Tri-X.

4. Escapement History – 1953-2014

Earlier records show that Shoal creek supported a peak escapement of 3500 coho, but spawning capacity had declined to less than 60 coho in the past 15 years. There has been no records of adult coho sightings in reach #4 during the past decade. However fry surveys in this reach at 1500m and at the road bridge between May 19-24th, 2015 revealed a total of 45 coho, 8 cutthroat and 1 sticklebacks.

The escapement summary Shoal Harbour creek from 1954 to 2014 is as follows:

YEAR	SHOAL HARBOUR CREEK						
	Pink	Chum	Coho		Pink	Chum	Coho
2014	687	37	3	**1983**	6	250	50
2013	75	307	10	**1982**	6	250	50
2012	214	54	8	**1981**	0	300	100
2011	29	198	2	**1980**	0	350	200
2010	11	1	11	**1979**	N/A	1000	200
2009	164	116	16	**1978**	0	350	25
2008	1	30	0	**1977**	0	200	75
2007	0	0	0	**1976**	25	900	200
2006	present	199	29	**1975**	25	400	25
2005	present	184	0	**1974**	40	1000	75
2004	81	present	57	**1973**	50	4000	100
2003	0	43	20	**1972**	200	3000	200
2002	0	0	0	**1971**	0	750	0
2001	6	11	60	**1970**	N/A	25	25
2000	25	50	100	**1969**	0	200	25
1999	0	19	0	**1968**	0	200	75
1998	0	0	0	**1967**	0	1500	75
1997	0	0	1	**1966**	75	200	25
1996	100	46	2	**1965**	0	400	0
1995	0	32	30	**1964**	400	3400	200
1994	N/A	32	30	**1963**	0	1500	0
1993	N/A	55	N/A	**1962**	0	3500	0
1992	3	150	6	**1961**	0	3500	400

1991	N/A	50	N/A	**1960**	400	3500	400
1990	N/I	N/I	N/I	**1959**	N/A	3500	750
1989	N/A	50	N/A	**1958**	25	7500	200
1988	N/A	2500	N/A	**1957**	N/A	1500	750
1987	0	1100	0	**1956**	0	3500	1500
1986	75	259	70	**1955**	N/A	3500	3500
1985	N/A	1900	N/A	**1954**	N/A	15000	3500
1984	N/A	5000	100	**1953**	N/A	7500	1500

Table 1. Salmonid escapement records for Shoal Harbour creek from 1953-2014 (observed); N/A: no data.

5. Gravel Placement Sites

Phase 1 of the project consists of 4 gravel subsites along reach #4, downstream from the 1600m road bridge, 2.5 km along the Shoal M/L road. Phase 2 will be located at the culvert downstream of Moore Worthington just below the Connector M/L turnoff while Phase 3 will be located upstream from a second culvert crossing Moore Worthington 1km along the Connector M/L (identified as 3km on the Connector M/L).

Reach #4 between 1200-1600m is heavily silted, dominated at 80% by fines/sand and littered with SWD and organic debris. This section can notably be turbulent during winter floods. The banks in this reach are undercut and there is high abundance of large woody debris instream. The stream locations and coordinates of phase 1 subsites are as follows:

Gravel Site (m)	Spawning Habitat (m)	Coordinates	
		N	W
Bridge	1600	50° 43' 209"	126° 28' 132"
SHO1	1555	50° 43' 209"	126° 28' 158"
SHO2	1515	50° 43' 216"	126° 28' 162"
SHO3	1465	50° 43' 222"	126° 28' 181"

Table 2. GPS coordinates of phase 1 gravel subsites and respective distance upstream from the estuary.

6. Methodology

Phase 1 of the Shoal Creek gravel placement project was completed from August 7th – 17th of 2016. A total of 10 tons of gravel were dropped at 3 strategic locations in half ton bags this past June. Under the supervision of Chris Bennett, gravel deliveries were made by Bella and her tugboat deckhands at 2 locations along Shoal M/L and 1 location along the Connector M/L road.

Gravel site selection criteria were based on preferred spawning conditions of coho salmon and accessibility to gravel drop sites. Other considerations included hydraulic considerations such as bankfull widths, water depth, tractive force at various flows, and the presence of existing boulders, large woody debris and back-eddies that would reduce tractive forces and limit the downstream migration of the gravel. Chris Bennett flagged potential gravel placement sites in Phase 1 and 2. Subsites selected had areas of sufficient depth for water cover at low flows. They were also located along low gradient habitat in slow flowing ripples and pool tail outs to promote gravel retention.

The minimum pre-gravel placement water depth of these sites during dry conditions was 4cm. Generally, a good rule of thumb to determine the minimum depth of the gravel placement is a depth that is $1/10^{th}$ of channel width (Slaney and Zaldokas, 1997). Gravel placement in areas prone to drying up were avoided. General guidelines for width and length of gravel placement is to create square shaped deposits with length equal to the channel width. A target area of $11.7m^2$ was set for each gravel placement at each site as this is the minimum area preferred by coho for spawning (Bjornn and Reiser, 1991).

The gravel size was determined from observation of native gravel in the area and species utilization. It is recommended to choose gravel that is suitably mixed with complex sizes similar to the historic condition for the stream reach. Typically, coho require washed ¼ to 2 ½ inch round with a mix of 10% cobble and a few boulders (Bjornn and Reiser, 1991). The cobble acts to create aeration sites for the substrate as well as invertebrate habitat. The boulders facilitate aeration, invertebrate and emergent fry habitat while helping to stabilize the entire bed.

The size of the crew for Phase 1 varied from 2 to 3 people. All work was completed manually using buckets and shovels. Each person carried 2 buckets approximately ¼ full, from the road to each site. Relative effort was quantified by keeping track of the number of buckets carried to each subsite in a specific amount of time as well as the number of tons moved during a specific amount of time.

Measurements of stream habitat parameters were also taken. This included water quality parameters using the Hanna 9823 multiparameter (water temperature, pH, % dissolved oxygen) as well and stream depth, bankfull width and wetted width.

7. Results

Stream Parameters	Bridge	SHO1	SHO2	SHO3
pH	7.45	6.33	6.75	6.43
Water Temperature (^oC)	19.09	18.85	18.2	17.20
% Dissolved Oxygen	74.1	64.7	62.9	44.2
Bankfull Width (m)	2.9	9.4	4.2	5.2
Wetted Width (m)	2.6	5.6	3.6	2.5
Initial Depth (cm)	5.3	5.5	4.3	4.6

Table 3. Stream parameters of 4 gravel placement subsites from 1465-1600m measured from August 7^{th} to August 17^{th}, 2016.

Gravel Placement Parameters	Bridge	SHO1	SHO2	SHO3
Quantity (# of Tons)	1.25	0.75	1	1
Area (m^2)	11.86	10.66	12.48	11.72
Number of buckets	92	60	114	126
Total time required (hours)	3h00	2h10	2h50	3h00

Table 4. Gravel placement parameters for 4 subsites reflecting effort invested, spawning habitat area created and quantity of gravel added at each subsite.

A total of 4 tons were placed along 4 gravel subsites downstream from the bridge between 1600m and 1465m. Every person carried the same relative amount of weigh in each bucket and 2 buckets were carried during each trip. The average weight of each bucket was 20.4 pounds. An average of 0.36 tons of gravel/hour, 35.6 buckets/hour were moved by a 2.5 person crew. In other words, each crew member carried an average of 14.25 buckets of gravel per hour, moving a total weight of 290.7 pounds of gravel per hour. (The crew consisted of 2 people for half of the project's duration and 3 people for the other half).

Lastly, it should be noted that an effort was made to place boulders downstream of gravel sites to increase retention. At high discharges, the boulders reduce scouring by creating roughness in the streambed, which reduces tractive force.

8. Pictures: Phase 1

Figure 3**.** Top left: Bertie and Chris loading gravel at deposit site (bridge); Top right: Before photo of 1600m bridge subsite; Bottom: Gravel placement: 1.25 tons added between August 7th-17th, 2016.

Figure 4. Top: Before photos of SHO1 at 1555m displaying pool downstream of gravel placement site. Bottom: Gravel placement after photos: 0.75 tons added between August 14th and 17th, 2016.

Figure 5. Top: Before photos of SHO2 at 1515m displaying gravel placement site and unstable banks. Bottom: Gravel placement after photos: 1 ton added between August 14th and 17th, 2016.

Figure 6. Top: Before photos of SHO3 at 1465m displaying gravel placement site and accumulation of small woody debris. Bottom: Gravel placement after photos: small woody debris was removed and 1 ton was added between August 14th and 17th, 2016.

9. Discussion

Freshwater rearing species such as coho are limited by the amount and quality of rearing area. In fact, research indicates that in many coastal systems, it is the amount of suitable winter habitat that limits coho production. These habitats provide protection from high discharge during winter flood events as well as protective cover from predators. In addition, there is often a strong relationship between smolt abundance and the amount of off-channel habitat available in a system. There is excellent rearing habitat between the Bridie Lake at 2300m and the road bridge at 1600m and a series of off-channel refuge areas. Accordingly, Shoal creek has excellent potential to support coho populations.

As established by the 2015 Shoal Harbour habitat assessment, rearing habitat is not limiting to coho recruitment. However spawning habitat was lacking in the vicinity of holding rearing areas. Various habitat parameters mentioned by Bjornn and Reiser (1991) were cited as being important before and during spawning (Table 5). For instance, the number of spawners in a stream is a function of the total area available for spawning and the average area required for each redd. Other important parameters for spawning include substrate composition, water quality and water quantity (Table 5). Such parameters were used as guidelines during this project. This data can notably be useful for establishing optimum spawning escapement targets.

Recommended Parameters during Migration/Spawning	**Coho Salmon (Bjornn and Reiser, 1991)**
Water Temperature (upstream migration)	7.2-15.6^{o}C
Depth (upstream migration)	0.18m
Velocities (upstream migration)	2.44m/s
Temperature (spawning)	4.4-9.4^{o}C
Temperature (incubation)	4.4-13.3^{o}C
Average redd area	2.8m^2
Area per spawning pair	11.7m^2

Table 5. Recommended habitat parameters by Bjornn and Reiser (1991) for coho salmon during upstream migration and spawning.

As established, suitable coho spawning habitat in Shoal creek was previously located 1200m downstream from Bridie Lake. The 2016 Shoal gravel placement increased the usable, functional, spawning habitat in the stream's upstream portion of reach #4 by 46.02m^2. All sites met the minimum area requirement of 11.7m^2 except for SHO1 (Table 4).

Small woody debris along each site was removed prior to gravel placement work. A larger instream log along site SHO3 was also removed to increase suitable gravel placement area and to stabilize stream discharge. An attempt to minimize erosion problems along site SHO2 were also made by creating a gravel wall along the slopping muddy bank (Figure 7b). The hope is that this will help minimize siltation and sedimentation under higher flowing conditions.

The size of the gravel chosen for this project was optimal for spawning coho and the depth of subsites pre and post gravel placement, met the recommended criteria. Coho salmon require gravel that is small enough to be moved by the fish and large enough to allow good intragravel water flow to the incubating eggs and developing alevins. This ensures that the environment in the nest is supplied with a constant flow of water that delivers oxygen and removes waste. A lack of clean spawning gravel of the appropriate size can limit coho production in some systems as spawners may be forced to build redds in secondary locations where egg survival will be reduced.

Inspections to date, after high flows, indicate that phase 1 of the project has been successful. All sites demonstrated good retention and there were no siltation issues on the gravel. Sites were visited on 3 occasions from October 27th to November 13th. No coho were observed spawning in the gravel and no redds were spotted. However unidentified fry were seen around the gravel 10 minutes after placement beneath the bridge and at SHO1. A cutthroat trout of an approximate size of 25cm was also seen holding in SHO2 while gravel placement work was underway (Figure 7c).

Figure 7a. Bank erosion of site SHO2 caused by unstable, slopping muddy banks; b) Bank stability mediation: gravel placement along slopping sections; c) Cutthroat trout observed holding in newly placed gravel along SHO2; d) Typical views of reach #4 (1200-1600m) with silted sandy substrate, high SWD build up and flat grassy banks.

10. Recommendations

The methods used to place the gravel were effective, working with the constraints of resources and volunteers. Given the intensity and high physical demands of the work involved it is recommended that a larger crew of volunteers be made available for future gravel placement work. A larger crew would increase the efficiency of the overall operation.

It is recommended that Phase 2 and 3 be completed between June and mid-July of 2017. There are 2 tons of gravel at the bottom of Moore Worthington and 2 tons at top on the Connector M/L (phase 2 and 3 respectively). A total of 2.5 tons of gravel remains at the Phase 1 drop site. Subsites SHO1-03 downstream from the bridge could easily be extended or supplemented depending on gravel retention a year from now.

Gravel may remain following the completion of Phase 2 and 3. In this event, Billy Proctor creek would be recommended as a system that could benefit from the creation of additional spawning habitat. Billy Proctor is a coho bearing tributary of Shoal creek. It is accessible by driving along a small overgrown side road at the junction between Shoal M/L and Maple Cove M/L. A total of 24 coho have been observed in the system during the past 5 years.

Lastly, tracking of the gravel through surveys of depth and area information, as well as usage by spawning coho should continue. Surveys should track retention, fish usage and should include inventories of the overall coho spawning habitat, working towards the target of supporting an increased number of spawning pairs. This will identify areas where supplemental gravel may be required, supply information on the site suitability and help determine future site selection for gravel placement.

Acknowledgments

The success of the initial phase of this project can be attributed to the collaborative efforts of many individuals. Thank you to Chris and Hannah for writing the grant proposal and providing funding for this project. Once again, Chris Bennett was readily available when called upon and we thank him for coordinating the gravel deliveries and for guiding the selection of gravel placement subsites. We also thank Bella and her tugboat deckhands for volunteering her time to drop 10 tons of gravel along gravel placement sites.

This completion of this project would not have been possible without the help of Chris Guinchard and Bertie Warren who were part of the 3 person crew for Phase 1 of this project. In addition to their physical strength, both provided valuable input during throughout gravel placement work. Their expertise was much appreciated.

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