Early Life History and Critical Rearing Habitat Requirements of Cowichan River Chinook Salmon

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Abstract

Between March 4 and June 23, 2014, juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Cowichan River were enumerated and sampled weekly at night by snorkel crews to track abundance and behavior from natal spawning areas to the estuary. Counts and sampling occurred at eight representative index sites, typically consisting of a single stream edge 50 m in length, established in the upper, middle and lower river including several intertidal locations. Crews also documented juvenile Chinook spatial distribution and habitat preferences including physical structure and micro site velocities for comparison to existing habitat suitability curves. Additional surveys of a wide range of intertidal habitats assisted in estimating the relative abundance of stream-reared and estuary-reared fry through the rearing period. Seven river and side channel sites peaked between 13.6 and 60.2 observed fish per lineal metre (FPM) from mid-April to mid-May, while intertidal index and non-index surveys rarely exceeded 2 FPM. Observed abundance over time contrasted significantly with 1991-2002 downstream programs that used rotary screw traps (RST) to capture sub-yearling Chinook. Our data suggest that the fry population distributed from upper river spawning areas to occupy all suitable edge habitat, from natal to intertidal reaches, until a minimum size was attained for outmigration. We postulate that mainstem and large side channel edge habitats had the capacity to accommodate the predicted 2014 fry production, leading to low abundances documented in the estuary especially in March and April – a common result in past studies which supports a theory of distribution in the river rather than migration to the estuary or ocean. We concluded mainstem and large side channel edge habitats with suitable velocities and intact overstream and/or instream riparian vegetation cover were critically important for Chinook fry rearing, particularly early in the season.

1.0 Introduction

Arguably the most iconic and valued salmon species on the Pacific Coast, Chinook Salmon (*Oncorhynchus tshawytscha*) continue to garner a high profile and considerable concern for their long term sustainability. In the Cowichan Valley on Vancouver Island, Chinook are of particularly special interest. The Cowichan River's Chinook stock has always been highly valued by Cowichan Tribes, forming the basis of a significant annual fishery for food and ceremonial purposes. Local sport fishers have high regard for the stock because until recently a majority of ocean migrants remained resident in the Salish Sea for their marine adult phase (Komori 2010), providing good year-round angling opportunities. More recent coded wire tag recovery data show a wider distribution beyond the Salish Sea, including west coast Vancouver Island, Washington and Oregon. From a fish agency perspective, Cowichan Chinook have been considered an indicator stock for the lower Strait of Georgia (now part of the Salish Sea) since the mid-1980s. Accordingly, and as a result of wide ranging but generally declining returns to 2009 (DFO escapement data; http://www.pac.dfo-mpo.gc.ca/gis-sig/maps-cartes-eng.htm), the stock has been the focus of increased conservation and enhancement programs, enumeration projects and assessment efforts.

Figure 1. Location of Cowichan River watershed on southern Vancouver Island, BC.

Most recently, Cowichan Chinook have become a focus for the Salish Sea Marine Survival Project (SSMSP), a joint initiative established in 2010 by the Pacific Salmon Foundation (Vancouver, BC) and Long Live the Kings (Seattle, WA). The SSMSP seeks to "…determine the primary factors affecting the survival of juvenile salmon and steelhead in the

Salish Sea" (http://marinesurvivalproject.com/the-project, accessed January 2015). To aid in this initiative and build knowledge around Cowichan Chinook river and estuarine early life history, BC Conservation Foundation (BCCF) proposed to closely track wild Chinook fry from natal spawning sites to their final rearing habitats in the lower Cowichan River and inner estuary over a single season.

Primary objectives were to:

- examine abundance and behavior of Chinook fry from natal spawning/incubation sites in the Cowichan River to rearing habitats in the estuary over the course of the 2014 spring season;
- differentiate relative abundance of stream-reared versus estuary-reared Chinook migrant groups;
- describe the spatial distribution and critical habitat requirements prior to smolting in May or June;
- compare growth rates for stream-reared versus estuary-reared fry groups over time;
- assess habitat limiting factors for Chinook fry in Cowichan River and estuary (qualitative in this first year); and,
- characterize interactions (if any) between wild and hatchery Chinook fry prior to ocean entry.

This report describes 2014 project results and suggests stock assessment and research activities to further aid our understanding of Cowichan Chinook early life history from the river to the inner estuary.

To better interpret study results, it is useful to frame juvenile counts and observations by the strength of the brood year return that generated the fry population. DFO and Cowichan Tribes operate a full stream, floating panel counting fence in Duncan, 6.75 km above tide water. The fence is generally functioning in early September and runs until late October or until the river exceeds ~70 m^3/s (130% of MAD). Due to high water in October 2013, DFO combined fence and dead pitch mark/recovery data to generate the Chinook escapement. The official estimate for 2013 natural spawners[1], including hatchery returns, was 6,680 (http://pacgis01.dfo-mpo.gc.ca/Mapster30/#/SilverMapster). Though this abundance is the highest on record since 2000, DFO data indicates it is low relative to the 1990s (mean 14,222; range 6,000-22,300) and similar to the 1980s (mean 7,215; range 4,022-11,200; Fig. 2).

Using DFO's 2013 fence and dead pitch data (2,010 adult females, 85 Jills) and assuming fecundities of 3,850 eggs/3-5 yr-old female and 2,900 eggs/Jill, potential egg deposition adjusted for retention was estimated at 6.9 million (S. Baillie, Stock Assessment Biologist, DFO, Nanaimo, pers. comm.). Annual egg to fry survival rates estimated by DFO for wild Cowichan Chinook between 1990 and 2002 ranged from 1.3 to 12.9% (Nagtegaal *et al*. 1997, 1998, 2000, 2004a, 2004b; Nagtegaal and Carter 2000; Tompkins 2005) and averaged 5.8%. These rates may have been slightly conservative as allowance for egg retention was not evident in the reviewed field studies. Though recent egg to fry survival was likely higher as a result of sediment remediation projects (e.g., Stoltz Bluff 2006), we used this average and the 2013 egg deposition estimate to conservatively approximate total natural fry production at 400,000 in 2014. Recent improved returns per spawner data (W. Luedke, Section Head, South Coast Stock Assessment, DFO, Nanaimo, pers. comm.) also lead us to believe average egg to fry survival rates have improved relative to 1990-2002. Applying the entire range of rates documented in that era, total natural fry production in 2014 could have ranged from as low as 90,000 to as high as 890,000.

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[1] DFO defines Natural Spawners as "sexually maturing fish that have returned to the artificial / natural spawning grounds and have full potential to spawn and naturally pair".

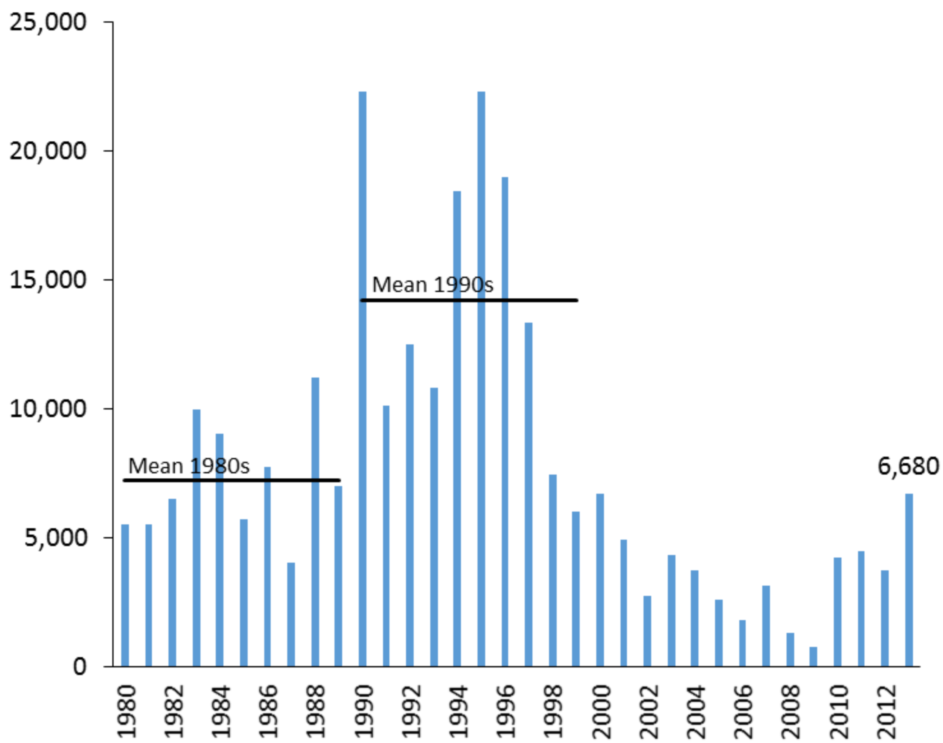

Figure 2. Cowichan River Chinook adult and jack natural spawners, 1980-2013 (DFO data). Data includes both wild and hatchery returns, but excludes all removals for hatchery and non-hatchery purposes.

2.0 Methods

During project planning in late February, zones where potential index sites could be established were identified in the upper, middle and lower Cowichan River mainstem, with the lower zone further divided into side channel and tidally influenced channels. These zones were well distributed and, if studied simultaneously and over time, could generate results that reflect the population as a whole and allow nuances between site-specific groups of fry to be examined. Because post-emergent Chinook fry are faithful to cover during the day for the first couple of months and are more easily observed and captured in the dark, our survey program was designed around early night time observations and sampling. To keep data comparable, night time surveys and sampling were planned for the length of the study, from early March to late June.

During initial daytime reconnaissance, crews identified and marked specific index sites representative of the zone. On the mainstem and lower river side channel, index sites consisted of a 50 m length of stream edge habitat (i.e., one bank only), with upstream and downstream extents marked with flagging tape. Seasonal high flows and logistics meant that the bank on which an index site was located was dictated by road and trail access – no safe night time river crossings were possible. Because typical mean monthly flows in March and April were more than sufficient to fully wet the Cowichan's relatively intact channel, riparian habitats and vegetated gravel bars were typically inundated and made for tricky access, snorkeling and fish capture. On smaller, intertidal blind-end channels, index sites consisted of delineated sections of the whole channel, including both banks.

The majority of observations and sampling occurred in darkness, between one and six hours after sunset. Generally, three crews of 2-4 experienced, swiftwater certified personnel conducted the surveys and sampling. The first crew covered upper and middle river index sites. A second crew completed lower mainstem and side channel index sites, and a third crew covered intertidal index sites on mainstem bifurcations entering the estuary and in blind-end channels. Crews at each site were generally comprised of the same personnel to standardize observer efficiency between surveys. Daytime surveys occurred infrequently and only to compare night versus day time observed abundances or investigate additional habitat types and develop appropriate night time safety plans.

2.1 Fry Abundance

Once daylight had passed and flashlights were needed to access study areas, two person teams snorkeled each index site in an upstream direction. Surveys occurred before any other sampling or activity that would disturb fish. Wearing black neoprene dry suits, extraction vests and throw bags, snorkelers employed 400 or 825 lumen dive lights (Underwater Kinetics models C8 eLED or Light Cannon eLED) to spot fish and arm-mounted slates to record salmonid juveniles by species and size class (with focus on Chinook), plus non-salmonids as encountered.

In all cases from the high water early season to lower water conditions in June, snorkelers attempted to effectively cover the entire width of the stream margin where fish were holding. No dive fins were employed. In early season high flows when fish were small and only occupying the first metre or two of habitat from the wetted edge, snorkelers split the 50 m index into two sections, pulling themselves up the streambank single file using gravel, woody debris or vegetation. Slowly surveying in an upstream direction generally allowed observation of undisturbed fish as we progressed, and reduced the likelihood of counting fish more than once (if they fled, they would most often do so downstream) or attracting or displacing fish into or out of the site from sediment or algae disturbances. In lower mainstem sites with heavy flow, snorkelers remained together for safety but surveyed in single file. In this case, the first snorkeler's results were used for the site unless the other counted a greater number of a particular species or age class (uncommon). With the exception of the Major Jimmy #1 index site, later in the season, when fish were larger and observed using a wider stream margin, snorkelers surveyed side by side in parallel lanes to maintain coverage of holding fish. For Major Jimmy #1 in May and June, fish were spread across the entire channel but snorkelers maintained counts in the right half of the channel only. In all cases, the goal was to achieve the most effective and consistent coverage of Chinook fry present in the index site. During most surveys, snorkelers would hold farther out in heavier water in an effort to evaluate if fish were actively migrating or being swept downstream.

Counts recorded on slates were actual, unexpanded counts. To standardize and compare results, these counts were subsequently converted to observed fish per lineal metre, or FPM. Fish beyond the limits of observation due to transparency or obstruction (e.g., thick instream vegetation or LWD) were not included, but snorkelers recorded an estimated observer efficiency for Chinook fry in the site as a whole, based on their ability to physically survey the site and transparency at time of survey. Effective transparencies, to the nearest half metre, were estimated and recorded for each survey. Notes were made of habitat or water velocity preferences, predation, feeding behaviors or instances of unusual interactions between or among species.

In the intertidal blind-end channel index, conditions allowed for fish counts or fish sampling, but not both in one evening. Comprised of thick organic sediments, the beds of these channels were easily disturbed regardless of whether crews walked or swum them, and flushing rates were low. Surveys were timed to occur during low to moderate tides because high tides tended to spread fish across areas too difficult, complex or large to survey effectively. Survey conditions were best if the flood or ebb was underway and snorkelers were able to survey channel sections against the prevailing currents.

As a trial to assess Chinook fry residency in index sites, crews used visible implant elastomer tags (VIE; Northwest Marine Technologies Inc.; http://www.nmt.us/products/vie/vie.shtml) to mark fish sampled from index sites and sight-recapture them during subsequent surveys. Fish were lightly anaesthetized and fluorescent orange VIE tag(s) were injected into dorsal fin rays. Fish were fully recovered before release into the index site.

2.2 Fry Sampling

Once snorkel counts were completed, crews used dip nets or pole seines to capture representative samples of salmonids in the index, with a focus on Chinook. Used in the first half of the study while fry were small, dip nets were either 20 x 15 cm with fine green mesh (aquarium style) or 40 x 40 cm with 0.5 cm knotless stretch mesh and aluminum frames/handles. In the latter half of the study crews employed either a one-person pole seine 2 m wide by 1.3 m high with 0.5 cm knotless stretch mesh, or a two-person pole seine 3.6 m wide by 1.4 m high with 1.0 cm knotless stretch mesh. Typically, a two person crew in dry suits used headlamps and bank-mounted flashlights to seine a representative and manageable portion of the index site that contained concentrations of Chinook juveniles. If numbers were low, sampling continued until crews estimated they had at least 30 Chinook from each site.

All species captured were counted. All Chinook in the catch were briefly anaesthetized with a dilute clove oil solution (several drops of 1:10 clove oil:ethanol in 2-4 litres of water), counted, examined for condition, marks, fin clips or PIT tags (using a PIT tag reader), and measured for fork lengths using a 300 mm length board. For data comparisons, the significance level was set at .05. Approximately every two weeks at middle and upper river sites, Chinook fry weights were also measured using battery operated top loading scales accurate to 0.1 g (Ohaus model CS200, or MyWeigh model i2600). Less frequently, weights were measured at lower river side channel and intertidal channel sites. Weight data were used to calculate an index of condition of fish sampled using Fulton's condition factor $K=Weight(g)/(Length(cm)^3)$ (Fulton 1904), and a scaling factor of 100,000. For other salmonids, a random grab (up to ~30) of each species/age class were anaesthetized and measured for fork length, but no minimum sample numbers were required. Examples of the catch were occasionally photographed.

Intertidal blind-end channels were easily disturbed, often reducing transparency to less than 0.3 m for snorkelers. In disturbed conditions fish could not be seen to be captured by snorkelers, and seemed able to evade large nets in the channel's low velocities. Because these channels' banks were vertical and often 2 m or more in height, deploying large nets was difficult, particularly over the deep sediments. Sampling the blind-end channel was accomplished most efficiently during a low to moderate tide, with snorkelers slowly swimming along an undisturbed bank, against the channel's slow flood or ebb (thereby always working in clean water), and capturing individual Chinook, Coho (*O. kisutch*) or Chum (*O. keta*) with small dip nets (20 x 15 cm). Regardless of species, undisturbed fish were generally quite approachable in the dark with dive lights. Personnel with buckets on the bank would maintain a constant supply of empty dip nets for the snorkelers, allowing them to focus on the fishing and proceed along the channel in a minimum of disturbance.

2.3 Habitat Surveys

While general physical habitat data for each site were collected throughout the study period, more detailed information was collected at particular sites and times through the study. Environmental parameters such as river discharge, water temperatures, weather, transparency estimates and tide conditions, where applicable, were recorded during weekly surveys by each crew. Real-time preliminary discharge was available on Water Survey of Canada's web-based hydrometric site (https://wateroffice.ec.gc.ca/) for Cowichan River at Lake Cowichan (#08HA002) and at Duncan (#08HA011). Spot temperatures were recorded with hand-held digital thermometers (river sites). Hourly temperatures were recorded using stationary data loggers (Onset, model HOBO Pro v2 in river; Solinst, model LTC F30/M10 in intertidal salt marsh channel) or downloaded from Water Survey of Canada (lake outlet station, #08HA002). To the nearest half metre, visibility while snorkeling was estimated and recorded by each crew for each survey. Tides were noted in advance of surveys from DFO's web site (http://www.tides.gc.ca/eng/station?sid=7310) for station #7310 – Cowichan Bay, for planning purposes.

In "late" spring conditions when Chinook fingerlings were generally finishing their outmigration (i.e., June), crews used methods and a modified Level 1 habitat survey data form from Johnson and Slaney (1996) to record for each index site:

- UTM location, river kilometre (using Google Earth and assuming 0.0 km = Tzouhalem Road bridge over the Cowichan River's North Arm);
- local gradient;
- mean bankfull channel width (using a laser range finder);
- mean width of edge habitat holding Chinook fry (estimated and/or calculated using observed Chinook holding locations);
- mesohabitat type/composition adjacent to stream edge index sites;
- riparian vegetation (type, stage, canopy closure, species, importance as Chinook fry cover);
- % of total wetted surface area in which Chinook were rearing that was occupied or covered by LWD, SWD, boulder, cutbank, deep pool, overhanging vegetation or instream vegetation; and,
- streambed material (dominant, sub-dominant, D50, D90, B-axis lengths) beneath rearing Chinook fry from six transects spaced top to bottom.

The latter five parameters were also recorded in "early" spring (post fry emergence; e.g., March) for comparison to the late spring results. Though riparian vegetation mix and abundance changed only marginally from the beginning to the end of the study, late spring surveys allowed confirmation of species composition and their relative importance as cover particularly in the early season (as flows declined and wetted edges receded through spring, riparian vegetation functioned as fish cover less and less).

Gradients were determined for index sites and the reach in which they were located. For index sites, a surveyor's rod and level and a 50 m tape were used to measure surface water gradient through the length of the studied edge. Reach gradients were determined using 1:20K TRIM contour data from the BC Geological Survey's website (http://www.mapplace.ca/).

Photographs were taken of various habitats, sampling events, specimens and index sites from upstream and downstream photo points over time.

2.3.1 Water Velocity Sampling

In mid and upper mainstem index sites, crews used calibrated current velocity meters (Swoffer model 2100, 5 cm propeller) to measure velocities at locations where Chinook juveniles were observed rearing. Coincident with conducting the initial fry count (i.e., undisturbed conditions), snorkelers dropped 15 cm galvanized spikes with flagging tape at specific locations where individual or groups of Chinook fry were observed holding. By the end of each count, a total of 15 spikes were deployed through each index site, marking the full range of microhabitats being used by Chinook, especially locations where large concentrations were observed.

Crews then measured each spike location's mean velocity (6/10 of the depth from the stream surface; Province of BC 2009) as well as the velocity 5 cm above the substrates that fry were observed holding over. This latter measurement was most representative of the microhabitat velocities that fish preferred – past BCCF studies in night time early spring conditions have shown juvenile salmonids typically demonstrate a strong affinity for substrates and the bottom of the water column (Gaboury *et al.* 2012). For both measurements, velocity sampling intervals were set at 20 seconds. In addition to velocities, crews estimated the number of fish using the microsite and recorded water depth, substrate type and distance from shore.

Later in the season and as an alternative to documenting velocity characteristics at individual microsites within the index site, crews also performed standard depth/velocity transect measurements (Province of BC 2009) across representative widths of the index site. This technique was adopted in May once juvenile Chinook sizes ranged widely and fry were observed to be more evenly occupying an index site's cross section, from slower, shallow habitats out to faster and deeper habitats.

3.0 Results

A total of eight index sites (Fig. 3) were surveyed 15 times (~weekly) over the March 13 to June 23 study period. In the upper and middle mainstem, crews established indexes immediately above 70.2 Mile Trestle (river km 40.6) and at Stoltz Pool (river km 25.7). In the lower mainstem and side channel zone, index sites were established in Major Jimmy Side Channel (#1 and #2), and at Mainstem #2. Lastly, three sites were established in the intertidal zone, one each on the Cowichan North Arm's left and right banks near Tzouhalem Road bridge, and in a small, right *bank*, blind-end salt marsh channel entering the North Arm 1,275 m downstream of the Tzouhalem Road.

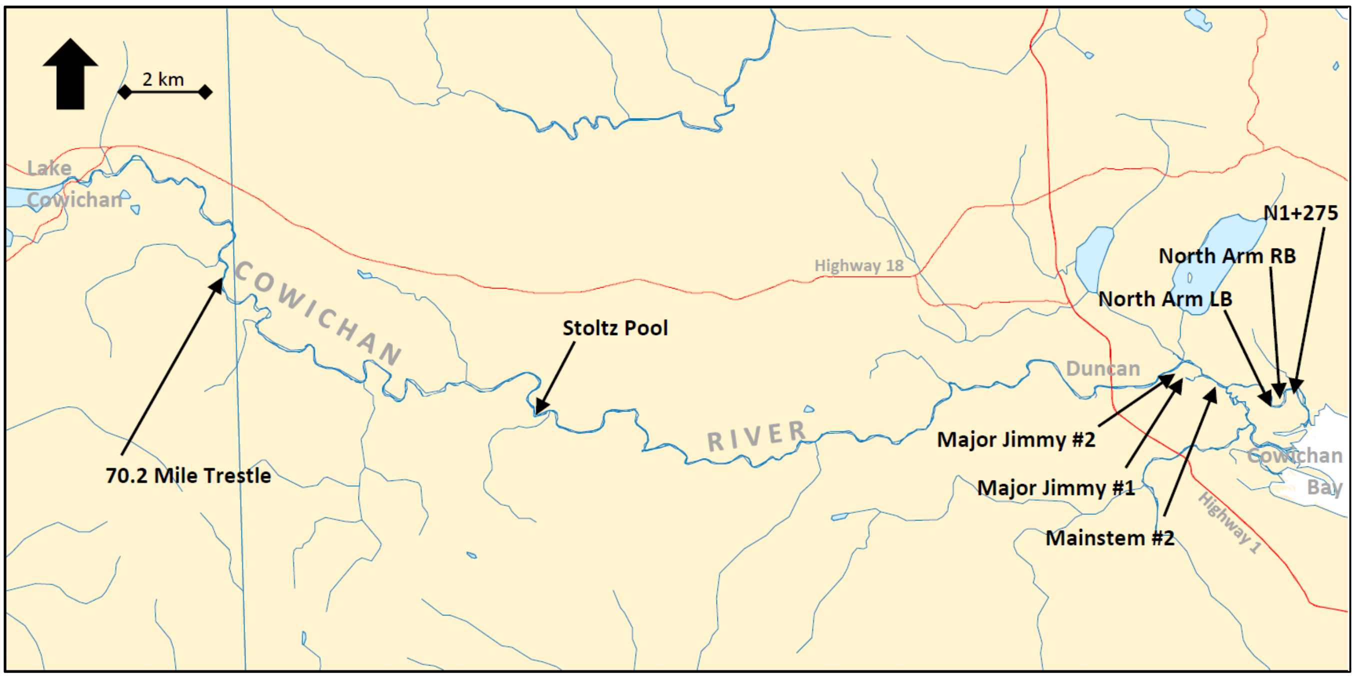

Figure 3. Index sites studied on the Cowichan River, spring 2014.

A number of these sites were used in a previous Chinook fry study (Pellett *et al.* 2013) including Stoltz Pool (1 survey: May 30, 2013), Major Jimmy Side Channel #1 and Mainstem #2 (9 times each, between April 3 and June 25) and North Arm Right Bank (7 times between May 7 and June 25). Most of the data from 2013 were collected in daytime hours and are therefore not directly comparable.

In addition to surveys at regular index sites, reconnaissance and/or sampling occurred at several locations in the inner estuary to assess Chinook presence and abundance relative to index sites over time, and whether replicate snorkel techniques, at night or during the day, could be useful to describe Chinook behavior or locate numbers sufficient to justify sampling efforts. Such reconnaissance occurred mainly in the first half of the study and was integrated with regular surveys (Table 1).

Table 1. Activities completed through the study period.

Week #	Week Dates	Tide During Survey	Survey Times	Snorkel Surveys			CH Sampling		CH Habitat	
				Recons; Presence & Abundance	Counts (CH/m of edge or channel)	Elastomer Tag Mark/Recap Trials	Lengths	Weights	Descriptions	Depths & Velocities
10	Mar 2-8	LOW	Day	E			E		G - E	
11	Mar 9-15	LOW, Eb	Day & Night	E L U	E L U		E L U		G - E L U	
12	Mar 16-22	HIGH, Fd	Night	E L	E L U		L U		G - E L U	L U
13	Mar 23-29	LOW, Fd	Day & Night	E	E L U	U mark	E L U		G - E L U	L
14	Mar 30-Apr 5	HIGH, Eb	Night		E L U	E mark, U recap	E L U		G - E L U	U
15	Apr 6-12	LOW, Fd	Night	L	E L U	E & U recap	E L U		G - E L U	U
16	Apr 13-19	Eb to LOW, then Fd	Day & Night	E L	E L U	E & U recap	L U	L	G - E L U	U
17	Apr 20-26	Day: LOW Eb; Night: MED Fd	Day & Night	E	E L U	E & U recap	E L U	L	G - E L U	U
18	Apr 27-May 3	HIGH, Eb	Night		E L U	E & U recap	E L U	L	G - E L U	U
19	May 4-10	MED, Fd	Day & Night	E	E L U	E & U recap	L	E U	G - E L U	
20	May 11-17	MED, Eb	Night		E L U	E & U recap	E L U	E L	G - E L U	U
21	May 18-24	MED, Fd	Night		E L U	E & U recap	E U	U	G - E L U	U
22	May 25-31	MED, Eb	Day & Night	L	E L U	E & U recap	U *		G - E L U	U
23	Jun 1-7	HIGH, Fd	Night		E L U	E & U recap	E L U	U	G - E L U	U
24	Jun 8-14	LOW, Fd	Night		E L U	E & U recap	E U	U	G - E L U	U
25	Jun 15-21				No surveys					
26	Jun 22-28	MED, Fd	Night		E L U	E & U recap	L U	U	D - E L U	U

KEY:	E	Estuary and Tidally Influenced Channels	Eb	Ebbing
	L	Lower River, Mainstem and Side-Channels	Fd	Flooding
	U	Upper/Mid River	G	General
	*	Daytime sampling and PIT tagging of CH at Vimy Pool	D	Detailed

3.1 Environmental Parameters during Study

Stream discharge during the study ranged dramatically from a high of 172 m^3/s on March 9 to a low of 3.7 m^3/s in the end of June. Night time index site surveys occurred at flows as high as 118 m^3/s (March 19) and as low as 6.2 m^3/s (June 23; Appendix A).

From a naturally falling hydrograph, the Cowichan River was brought "on control" starting May 5, 2014 when Catalyst Paper Corp. commenced lake outlet storage weir operations under their Provincial water license (email dated May 7 from B. Houle, Catalyst Paper Corp, Crofton, BC). Following its current operational Rule Curve, Catalyst reduced lake outflows daily by approximately 3 m^3/s until May 20 when outflows reached 15 m^3/s (27% mean annual discharge, or MAD), a minimum flow identified in the Rule Curve for the period May 1 to June 14. Outflow was maintained at 15 m^3/s until June 10 when, with shrinking storage volumes and a variation order in hand, Catalyst commenced daily 0.5 m^3/s reductions in outflow until June 20, when discharge from the weir was leveled off at 7 m^3/s (13% MAD; email dated June 25 from B. Houle). These manipulations of flow in the Cowichan River are clearly evident in Water Survey of Canada's provisional discharge record (Appendix A), and no doubt generally have a significant effect on juvenile Chinook migration behavior. Because mainstem tributaries below the lake are all small, lake outflows tend to dictate rearing and migration conditions, particularly in late spring and through summer.

Cowichan mean daily water temperatures, recorded hourly at river km 4.0, ranged from about 5°C in early March to 19°C at the end of June (Appendix A). Daily variation ranged from a low of 0.9°C in March to a high of 2.9°C in June.

At 52% of normal, snow basin indices on Vancouver Island were low as of March 1, 2014 (http://bcrfc.env.gov.bc.ca/bulletins/watersupply/archive/2014/2014_Mar1.pdf). By June 1, this dropped further to just 35% of normal, auguring a dry summer on the Cowichan.

Other than in March when it was ~130% of normal, rainfall during the study was at or below long term means at Environment Canada weather stations in Lake Cowichan and nearby Shawnigan Lake (http://climate.weather.gc.ca/index_e.html#access).

3.2 Upper and Middle River

Upper and middle river surveys commenced March 13 (Table 1, Appendix B). In mainstem flows of 103 m^3/s, crews in late afternoon daylight examined stream margins at Stoltz Pool and 70.2 Mile Trestle (Fig. 3) and looked for potential index sites with reasonable access. Velocities were too high for effective and safe snorkeling along portions of the stream margin, but certain sections were closely inspected. While no Chinook fry (or fish of any kind) were observed along 170 m of edge surveyed at Stoltz Pool, a total of 95 Chinook, mostly in discrete groups (e.g., 60, 15, 10, 5), were observed over 50 m of edge at 70.2 Mile Trestle. These fish used dense vegetation (*Salix* spp.) or grass inundated with no more than 30 cm of quiet water.

Portions of these two areas were re-surveyed that same night. At Stoltz Pool, 107 Chinook were counted over 23 m of edge. Coho pre-smolts (n=57) and Rainbow parr (*O. mykiss*; n=18) were also present. At 70.2 Mile Trestle, 214 Chinook, 35 Coho pre-smolts and 21 Rainbow parr were counted. Visibility was estimated at 8.5 and 3.5 m at 70.2 Mile Trestle and Stoltz Pool, respectively[2]. Following these counts and considering the reasonable observation conditions and access at the two sites, crews establish permanent index sites at both locations (Appendix C, Photos 1-8).

3.2.1 Fry Abundance – Upper and Middle River

From the initial survey, Chinook fry abundance gradually increased at both indexes until a peak was counted in mid to late May (Fig. 4). At 70.2 Mile Trestle, the highest count occurred May 14 with 1,348 Chinook fry over the 50 m index (27 fry/metre, or FPM); a similarly high abundance was counted May 28 (24.3 FPM). The highest count at Stoltz Pool was 726 (14.5 FPM) and occurred May 21. At both sites, a less dominant peak appeared to occur around the second week of April. By the last survey on June 23, Chinook fry abundance in both index sites dropped to the lowest levels documented during the study, 0.08 and 0.76 FPM at 70.2 Mile Trestle and Stoltz Pool, respectively.

[2] While the 70.2 Mile Trestle index site (river km 40.6) receives flow from the lake that is typically low in total suspended solids, Stoltz Pool (river km 25.7) is downstream of a chronic sediment source area known as Block 51 (river km 37-40).

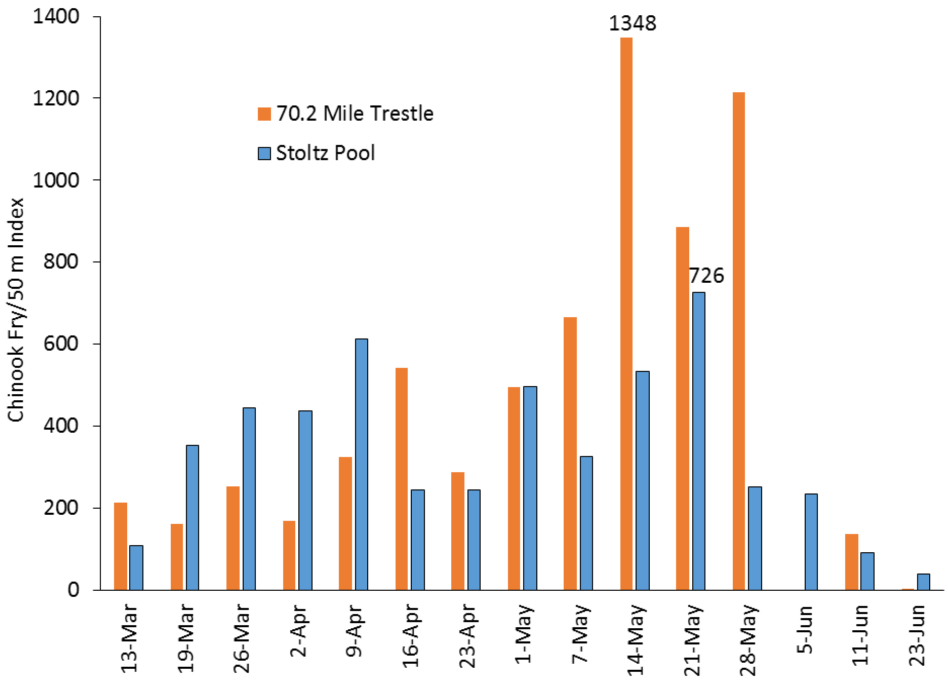

Figure 4. Chinook fry counts at 70.2 Mile Trestle and Stoltz Pool index sites over the study period.

At 70.2 Mile Trestle, other salmonid juveniles including Coho fry and pre-smolts, Rainbow fry and parr, and Chum fry were present in all surveys but in lower abundance than Chinook in all but the last two dates. Though they were occupying different habitats within the index, Coho fry outnumbered Chinook 6:1 on June 11. Rather than Coho numbers increasing, this was due to Chinook fry abundance dropping as outmigration continued. By June 23, Rainbow parr also outnumbered remaining Chinook. Brown Trout parr (*Salmo trutta*) and Threespine Stickleback (*Gasterosteus aculeatus*) were the only other species observed in the 70.2 Mile Trestle index site during the study period.

During the afternoon of March 26, 30 Chinook fry randomly sampled from the 70.2 Mile Trestle index site were VIE tagged and released where they were captured. Fork lengths averaged 43 mm (range 38-47 mm). In darkness four hours later at 2220h, snorkelers observed five tags within the index site, plus one tag holding 5 m downstream of the site's extent. On three of the next four weekly surveys, VIE tagged fish were subsequently observed in or just outside of the 70.2 Mile Trestle index site. A single tag was counted inside the index site during the April 2 and April 9 surveys. Four tags were observed just above the top of the index on the 23rd of April, 28 days after being tagged at that location.

At the Stoltz Pool index site, other salmonids present over the study included the same species/age classes observed at 70.2 Mile Trestle. Chinook fry were more abundant in all surveys except June 23, when their outmigration was largely complete and Coho outnumbered them 14:1. Small numbers of Sculpin (*Cottus* spp.) and lamprey (*Lampetra* spp.) were counted periodically, the latter displaying spawning behavior on May 14.

In both index sites, observers noted Chinook firstly displayed a tendency to use or be in proximity (<1 m) of available cover whenever possible, and secondly to hold low in the water column, often on or within 5-10 cm of habitat substrates. This was in contrast to Chum fry which displayed less affinity for cover and a tendency to hold in the upper half of the water column, often in the top 20% of any given water depth.

Hatchery origin Chinook were likely present during snorkel counts on May 21 at Stoltz Pool when 9.2% of the subsequent sample catch were adipose fin clipped (AFC), and on May 28 at 70.2 Mile Trestle when 14.8% of the catch were AFC. Despite snorkelers' efforts, fish movement and observation conditions rarely enabled 100% confirmation that an individual Chinook was missing its adipose fin. That said, snorkelers did on occasion observe Chinook of notable size that may have been of hatchery origin. Though AFC Chinook were not sampled at these two sites during any other surveys, it is possible that counts shortly after the two lake outlet releases (~105,000 on both April 23 and May 15) may have included small numbers of hatchery origin fish.

3.2.2 Fry Sampling – Upper and Middle River

Fry sampling showed wild Chinook lengths increased in both 70.2 Mile Trestle and Stoltz Pool over the study, but not always steadily. Starting on March 13 at roughly 40 mm at both sites, mean lengths of sampled fish regularly increased by 0.7 mm/week until May 1, and then by 3.2 mm/week on average through June 23 (Fig. 5). Data suggest a plateauing of fork lengths after the third week of May, most likely the result of outmigration of larger individuals.

On May 28 at 70.2 Mile Trestle, a slight sampling bias may have occurred towards catching a greater proportion of the site's larger Chinook than normal. Fry sub-sampled for lengths were from a daytime Chinook PIT tag project and, due to extraordinary effort, may have sampled a greater proportion of thalweg habitat than the regular night time two-person pole seine crew would have. Therefore, a greater number of larger Chinook holding in heavier water were likely sampled.

More generally, crews were confident following early surveys and reconnaissance that they were sampling a representative proportion of the population within each index site, as fish were concentrated along quieter stream margins and absent from deeper and swifter habitats. Late in the study as the range of lengths within the population increased, crews suspected larger fish may have been underrepresented because habitats farther away from stream margins became more challenging to sample. This may have been another reason why fork lengths of fish sampled appear to plateau in late May.

Some sampling intervals were incomplete due to conflicting logistics in related studies (e.g., PIT tag program) or unavoidable events such as windfalls that temporarily blocked site access.

During the study, the largest wild Chinook sampled from these indexes were 83 mm on May 21 at Stoltz Pool, and 87 mm on June 11 at 70.2 Mile Trestle. The smallest were 37 and 34 mm at these sites, respectively, on March 13.

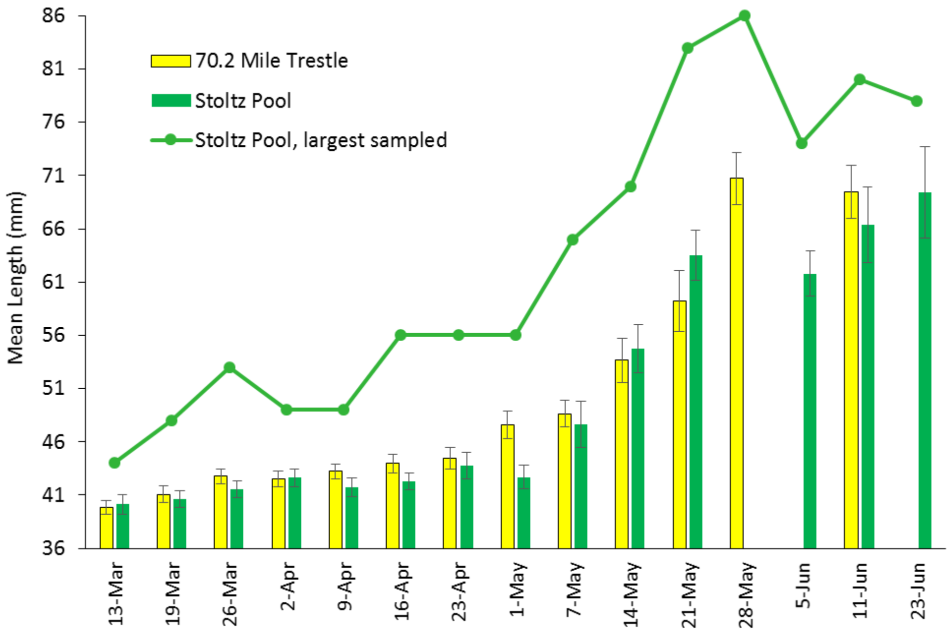

Figure 5. Mean fork lengths of wild Chinook fry sampled from 70.2 Mile Trestle and Stoltz Pool index sites. Error bars represent 95% confidence intervals for each sample mean.

Condition factors of wild Chinook fry at the Stoltz Pool index site appeared to increase between May 7 and June 11, but not significantly (Fig. 6). Condition factor of Stoltz Pool Chinook appeared to drop in the latter half of June, although sample size was small and the change was not significant. Condition factors of wild Chinook at the 70.2 Mile Trestle index were 1.16 on May 7 and 1.18 on June 11, very close to those documented at Stoltz Pool. On occasion, nighttime windy conditions made measuring weights challenging, and crews opted to take weights at one or the other site only.

Lengths and occasionally weights of Coho fry and pre-smolts, Chum fry, and Rainbow fry and parr were opportunistically recorded throughout the study and are available in project data files. Chinook juveniles were the priority and no minimum numbers of other species were ever collected.

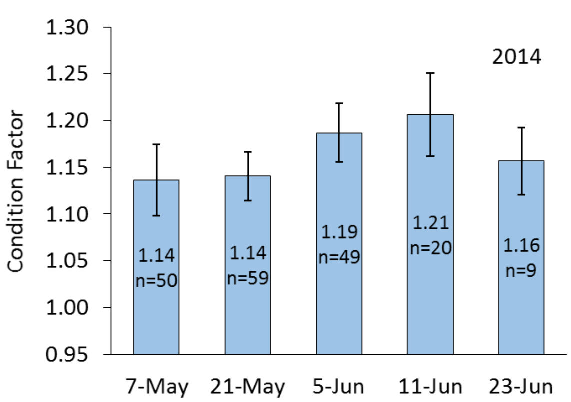

Figure 6. Mean condition factors of wild Chinook sampled between May 7 and June 23, 2014 at Stoltz Pool. Error bars represent 95% confidence intervals for each sample mean.

Where sampled and as anticipated, hatchery origin Chinook were substantially larger on average than their wild counterparts (Fig. 7). On May 21 at Stoltz Pool, six AFC Chinook caught averaged 88 mm in length (range 81-94 mm) and 7.4 g in weight, while a catch of 59 wild Chinook averaged 66 mm (range 43-83 mm) and 3.1 g, less than half the mean weight of AFC fish. On May 28 at the 70.2 Mile Trestle index, the only other occasion during which AFC Chinook were sampled in the upper river, 11 sub-sampled hatchery fish averaged 90 mm in length (range 81-96 mm), while a sub-sample of 49 wild Chinook averaged 71 mm (range 54-86 mm).

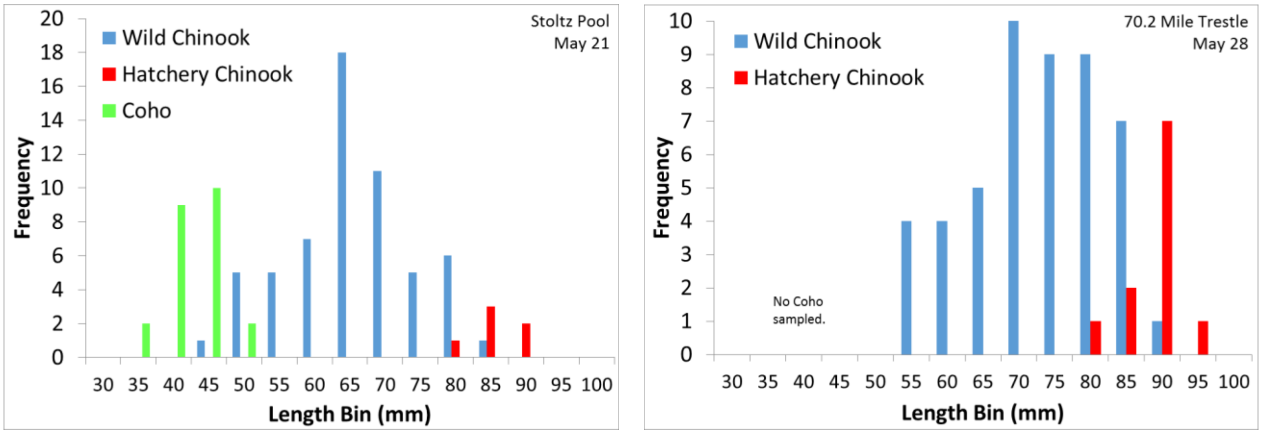

Figure 7. Length frequency histograms of wild and hatchery origin Chinook at Stoltz Pool on May 21 and at 70.2 Mile Trestle on May 28.

3.2.3 Habitat – Upper and Middle River

While crew access was an influential factor, the upper and mid river index sites were largely chosen because they represented well the quality of streamside and riparian habitats available along the majority of the Cowichan River. They were both located inside Cowichan River Provincial Park, a significant though discontinuous corridor of dedicated parkland that extends from river km 14.2 at the end of Jeffries Road, upstream to river km 47.5, just short of the outlet of Cowichan Lake at river km 48[3]. Over most of this distance, the park extends out from both banks as undisturbed, mature, second growth forest classified as a CWHxm1 biogeoclimatic variant (Province of BC 2003). Where the park does not include the river or one of its banks, lands are typically private rural parcels and hobby farms with minimally disturbed riparian areas. Downstream of the park's extents to Duncan, the majority of the river corridor lies within Cowichan Tribes reserve lands and is largely undeveloped. Though portions of the river show minor riparian area or shoreline impacts from recreational use, many areas are unused and close to pristine. As a result, the quality of stream edge habitats found in the 70.2 Mile Trestle index, with the Trans Canada Trail just downstream, and in the Stoltz Pool index, with its proximate boat launch and recreational trails, is similar to that of stream edge habitats found throughout the upper and middle river.

Local reach gradients (within 1 km) at both index sites were calculated to be 0.4%. Riparian zones featured mature, mixed conifer/deciduous forest that offered less than 20% canopy in both instances (Appendix D).

[3] Based on a Google Earth mapping of river kilometre markings, assuming the Tzouhalem Road bridge over the river's North Arm = 0.0 km.

70.2 Mile Trestle Index (Appendix C, Photos 1-4)

Situated on the river's left bank, the 50 m-long 70.2 Mile Trestle index site was adjacent to a stable riffle and glide, ending in a short pool just upstream of the trestle. The adjacent thalweg was located right of centre within the 35 m wide bank full channel, allowing somewhat quieter water on the index side. During March flows, the glide was fast and heavy and appears well-blended with the upstream riffle. In June, the adjacent riffle was more defined and the glide shrinks somewhat (Appendix D). Overall the index site had close to zero gradient in a near-base flow condition.

As described in *Methods*, the following measures or descriptions relate to either an "*early*" season in March when flows were heavy and riparian habitats were largely inundated, or a "*late*" season in June when flows were closer to base flow and riparian habitats were typically dry. Measures and further descriptions are detailed in Appendix D.

Along the index, the average width of edge habitat supporting rearing Chinook <u>in early conditions</u> was 2.3 m. Of the total wetted surface area *that held rearing Chinook*, 90% had at least one of the standard seven cover types. Specifically, instream vegetation, overhanging vegetation and small woody debris (SWD) occupied 65, 10 and 15% of the area containing Chinook, while only 10% of this area holding fish had no cover component. Chinook were faithful to thick shrub submerged in 30 cm of water or less, with little to no velocities other than wave action. Dominant vegetation included willow (*Salix* spp.), grasses (*Poaceae* spp.) and Red Alder (*Alnus rubra*) among others. All vegetation was bare, though submerged stems were often draped with leaves and organic detritus that improved the quality of cover. Substrate diameters generally declined from the top of the site to the bottom; D50 and D90 ranged from 85 to 17 mm and from 190 to 42 mm, respectively (Appendix D).

<u>In late conditions</u>, the average width of edge habitat supporting rearing Chinook was 6.8 m. An estimated 25% of the total wetted surface area *that held rearing Chinook* offered standard cover. Types of cover used were wholly different than those used in early conditions, namely boulder (15%) and deep pool (10%). None of the bank and bar vegetation inundated in March was wetted in June; new vegetation such as wildflowers were often the closest to water but still out of the wetted perimeter. Chinook utilized open water with greater depths and velocity (see below). Beneath rearing Chinook, gravel and cobble were dominant and sub-dominant, respectively. From the top of the site to the bottom, D50 and D90 declined from 92 to 24 mm, and from 340 to 126 mm, respectively (Appendix D).

Stoltz Pool Index (Appendix C, Photos 5-8)

Also on river left, the 50 m-long Stoltz Pool index site was along an inside bend and adjacent to a typical riffle-pool-glide sequence with bedrock control on right bank. Suitable spawning habitat was nearby and bank full channel width was 39 m. Pushing again the bedrock, the thalweg was again right of centre, creating somewhat quieter water on the index side. During heavy flow in March, the riffle was less defined, similar to 70.2 Mile. It becomes more defined in June and both the pool and glide components shrink slightly (Appendix D). In a near-base flow condition and because of the riffle portion, the Stoltz Pool index has a local gradient of 0.74%. The following measures and descriptions relate to "*early*" or "*late*" season conditions as described above. Measures and further descriptions are detailed in Appendix D.

Mean width of edge habitat supporting rearing Chinook <u>in early conditions</u> was 1.6 m. Of the total wetted surface area *that held rearing Chinook*, 95% had at least one of the standard seven cover types. In this instance, instream vegetation dominated the index site. Overhanging vegetation and small woody debris were often present, but judged to be subordinate to the instream vegetation in all respects. Only 5% of the area holding Chinook had no cover component, though this area was always within 2 m of vegetation. As was observed at 70.2 Mile Trestle, Chinook were loyal to thick willows several metres in height and inundated with 10-40 cm of water. Senesced Reed Canary Grass (*Phalaris arundinacea*) was prevalent and also commonly used as cover. Within the shrub line, velocities were often low and caused by wave action alone. In addition to willows, grasses and occasional rush (*Juncus* spp.) or sedge (*Cyperaceae* spp.), dominant vegetation included Red Alder, Black Cottonwood (*Populus balsamifera* ssp*. Trichocarpa*) and Red Osier Dogwood (*Cornus stolonifera*). Rotting leaves and organic detritus were common among submerged vegetation stems and helped improve the quality of cover. Substrates were generally sand and small gravel, with D50 and D90 across six transects ranging from 2 to 30 mm and 2 to 66 mm, respectively (Appendix D).

<u>In late conditions</u>, the average width of edge habitat supporting rearing Chinook was 6 m. An estimated 60% of the total wetted surface area *that held rearing Chinook* offered standard cover. Similar to 70.2 Mile Trestle, types of cover used in the lower water were boulder (30%) and deep pool (30%). None of the bank and bar vegetation inundated in March was wetted in June. Although smaller individuals still used quiet, shallower habitats along with new emerged Steelhead fry, Chinook mostly utilized open water further from shore with greater depths and velocity (see below). Beneath rearing Chinook, gravel and sand were dominant and sub-dominant, respectively. From six transects spaced over the length of the index, average D50 and D90 varied from 21 to 62 mm, and from 83 to 290 mm, respectively (Appendix D).

As expected, microhabitat analysis at both 70.2 Mile and Stoltz Pool index sites showed that Chinook juveniles preferred greater *velocities, depths* and *distance from shore* over time and with increasing fork length. Relationships of velocities and distance from shore to fork length were strong at both index sites (Fig. 8).

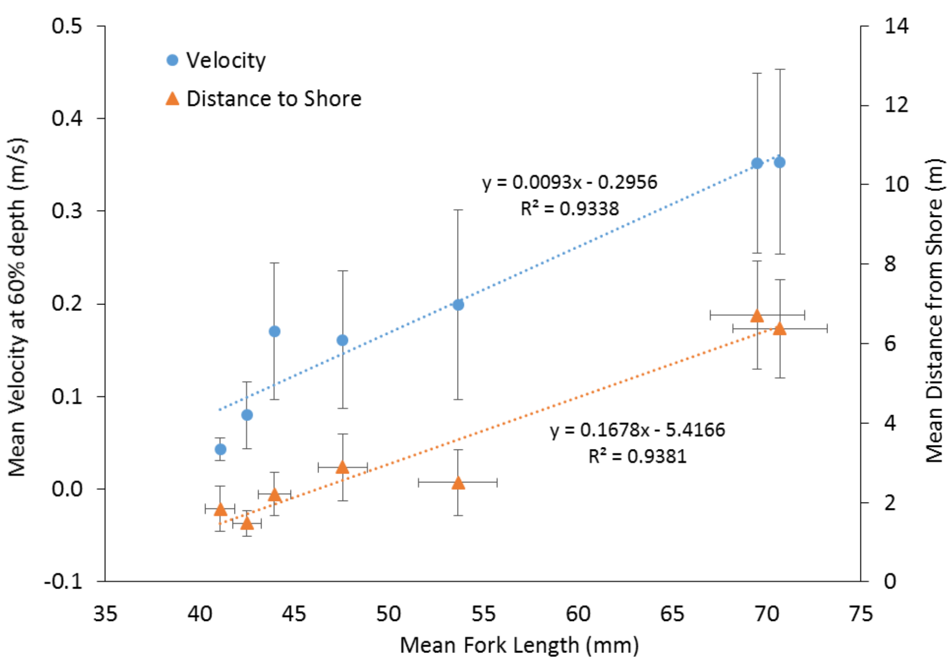

Figure 8. Relationships of velocity (at 60% depth) and distance from shore to Chinook fork length at 70.2 Mile Trestle index site, March 19 to June 11, 2014. Error bars represent 95% confidence intervals around means. Horizontal error bars for distance to shore are also applicable to velocity.

Comparing our results with current day habitat suitability indices (HSI; developed by BC Fish, BC Hydro, WUP Delphi, etc.), we found early Cowichan Chinook fry were using velocities that were similar or higher than those predicted by "early" spring velocity curves (Fig. 9, left). However, velocities preferred by late Cowichan fry were slightly less than those predicted by standard curves. It should be noted that our results were based on fewer data points than established curves typically are. Differences may be explained by sample timing; early and late Cowichan fish sampled could have been larger and smaller on average, respectively, than the average sizes of fish upon which the early and late HSI curves were built.

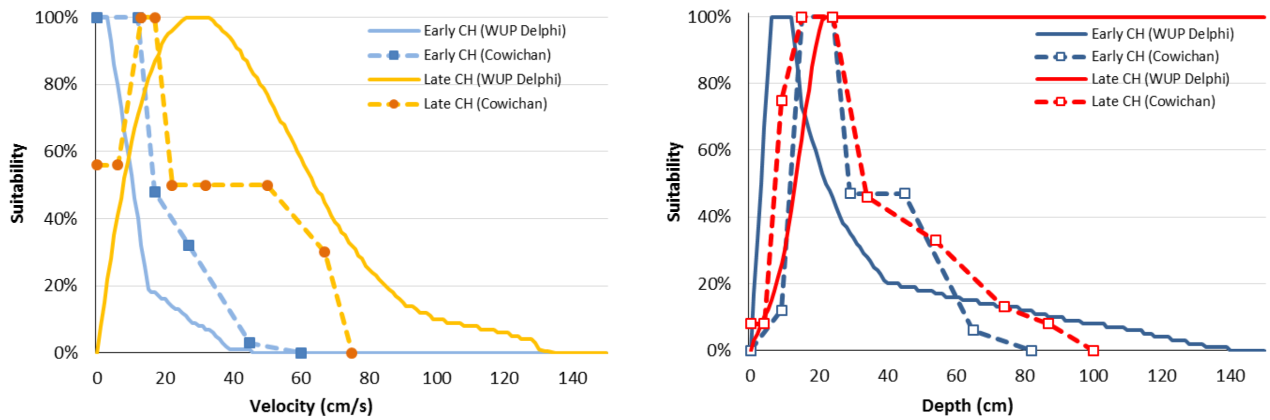

Figure 9. ***Early*** **and** ***late*** **velocities (left) and depths (right) preferred by Cowichan Chinook juveniles in 2014 compared to standard HSI curves (BC Fish, BC Hydro, WUP Delphi, etc.) for early "spring" and later "summer" rearing Chinook.**

Similarly, depths preferred by early Cowichan Chinook fry were slightly greater on average than those predicted by standard HSI curves (Fig. 9, right). Conversely, late Cowichan fry appeared to prefer slightly lower depths compared to predictions from standard late fry curves. Once again, these results are likely explained by sample timing where fish were larger or smaller on average than those used to build the curves.

3.3 Lower Mainstem and Side Channel

Lower mainstem and side channel surveys commenced March 13 (Table 1, Appendix B). Seeking to establish repeatable index sites, crews conducted daylight reconnaissance of edge habitats along the lower mainstem's right bank (river km 1.5 to 4.0), and along easily accessed portions of the south side channel network (river km 1.0-4.5) that includes Major Jimmy Side Channel and Hatchery Side Channel. That night, crews snorkeled one side channel section and two mainstem edges to develop safety procedures and evaluate early fry abundance levels. The crew lightly sampled one of the latter edges. From March 13 onwards, Chinook were present in virtually all lower mainstem and side channel surveys.

On March 19, crews established 50 m index sites at Major Jimmy SC #1 and Mainstem #2 (Fig. 3; Appendix C, Photos 9-13, 18-21). Due to an increase in mainstem discharge over the previous week, the former was sampled only (dip nets), and the latter was surveyed to obtain fish counts.

For the third survey on March 26, both index sites were considered representative and safe to survey, and were generally counted and sampled on a weekly basis thereafter.

Major Jimmy SC #2 index site (Fig. 3; Appendix C, Photos 14-17) was established April 9 and surveyed until flow dropped to zero on June 5. A second lower mainstem side channel site, it replaced a proposed Hatchery Side Channel site where a smolt fence was installed by Cowichan Tribes in late March.

Effective visibility generally varied from 2.5 to 4 m but remained sufficient for counts and species identification.

3.3.1 Fry Abundance - Lower Mainstem and Side Channel

Chinook fry abundance increased from early surveys in March and peaked in late April and early May (Fig. 10). While peaks in the side channel index sites were relatively short in duration, peak abundance at Mainstem #2 appeared to occur gradually over a period of a month.

Highest counts in side channel index sites were 680 (13.6 FPM) at Major Jimmy SC #1 on April 16, and 3,015 (60.3 FPM) at Major Jimmy SC #2 on April 23. These densities were 2.5 and 5 times that of the next highest counts at each of these sites, respectively, over the study. In contrast, five sequential counts between April 9 and May 7 at Mainstem #2 averaged 604 fry (range 470-690) or just over 12 FPM.

The lowest Chinook abundances were documented at the end of the study, when counts dropped to close to zero by June 11. It should be noted that at Mainstem #2, edge velocities were low at this point in time and deeper, faster habitats away from shore could not be thoroughly surveyed for remaining Chinook.

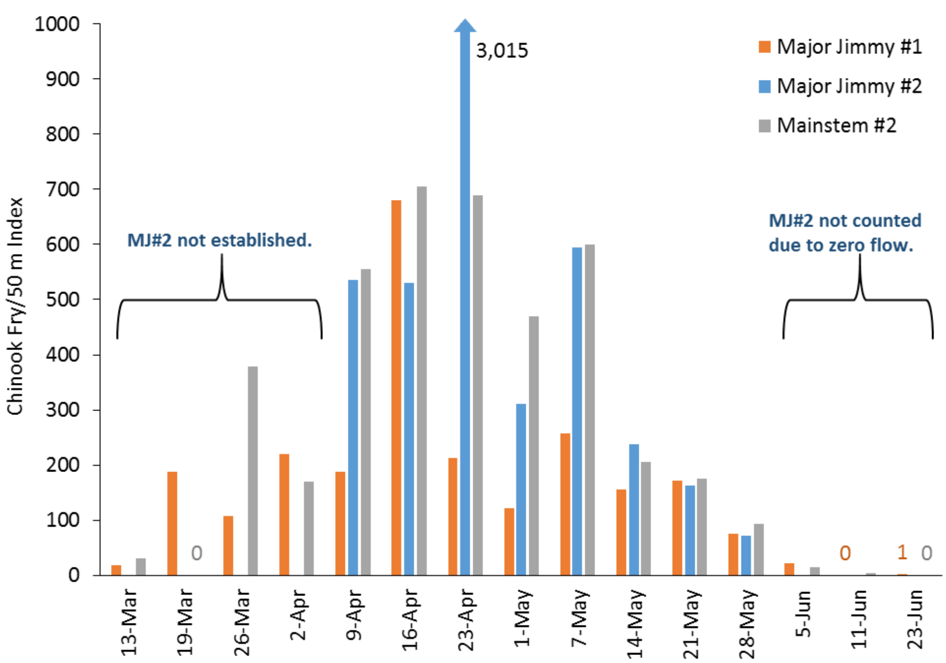

Figure 10. Chinook fry counts at Major Jimmy SC #1, Major Jimmy SC #2 and Mainstem #2 index sites over the length of the study.

Coho fry and pre-smolts, Rainbow parr and Chum fry were counted in each of the lower mainstem and side channel index sites. Low numbers of Rainbow fry were also counted in the two side channel sites. At one to three times the densities of Chinook, Chum numbers peaked April 9 on the mainstem and April 16 in the side channels. While Mainstem #2 Coho fry numbers peaked May 28 and never surpassed peak numbers of Chinook, their numbers in the side channel sites grew consistently, surpassed those of Chinook after mid-May, and were highest on the last day of survey. Rainbow parr counts peaked on April 9 in both side channel sites and on April 16 at Mainstem #2. Over the study, Rainbow parr were least abundant in Mainstem #2 index (max=10, April 16) and most abundant in the Major Jimmy #2 index (max=39, April 9). Though Rainbow parr and Chinook fry were often in proximity, very few instances of parr being aggressive towards or preying on Chinook juveniles were noted.

Adult Steelhead (*O. mykiss*; 1 pair) and Cutthroat (*O. clarki*; n=2) were counted in the side channel sites April 9-23 and on June 23, respectively.

Other commonly observed species included moderate numbers of Stickleback and Sculpin (up to 240 and 102, respectively; both at Major Jimmy SC #2). Between April 16 and May 28, several Pacific Lamprey (*L. tridentata*) adults were observed, sometimes spawning, in Major Jimmy #2. Peamouth Chub (*Mylocheilus caurinus*) were the only other fish counted in the lower mainstem and side channel sites (Major Jimmy SC #1, June 5 and 23) during the study period. No Brown Trout were observed.

At all three index sites, observers again noted Chinook in proximity (<1 m) of available cover and generally holding low in the water column, often on or within 5-10 cm of habitat substrates. For the most part Chum fry held in the upper half of the water column. In Major Jimmy SC sites in mid-April, they were observed mid channel, beyond index site perimeters, actively migrating just beneath the surface in large numbers (i.e., thousands/minute).

No hatchery origin Chinook were ever positively identified during snorkeling or sampling in Mainstem #2 or in either of the Major Jimmy side channel index sites. It should be noted that only fish counts occurred at these sites after May 1 and May 14, respectively, and only one release of hatchery origin fish occurred prior to that (105,000 on April 23 below Cowichan Lake outlet).

3.3.2 Fry Sampling - Lower Mainstem and Side Channel

In lower mainstem and side-channel index sites, Chinook fry sampling commenced on March 13 and ended June 11. As flows and fish numbers receded in Major Jimmy side channel, finding adequate numbers of Chinook post-count for a representative sample became difficult – after mid-May, crews focused on counts only. Similarly, Mainstem #2 index counts declined as fish remaining became more faithful to the deeper, heavier water 2+ m offshore. Crews were not only seeing fewer fish, but those in sight were logistically difficult to catch.

Through three samplings in March, mean Chinook fork length did not change significantly at any of the three index sites (Fig. 11). By April 9, mean lengths were significantly larger than those measured in March and, in side channel sites, increased thereafter by an average of 0.54 mm/day to mid-May. Growth was similar to that seen in the Campbell River by Levings *et al.* (1986) who documented rates of 0.46 to 0.55 mm/day.

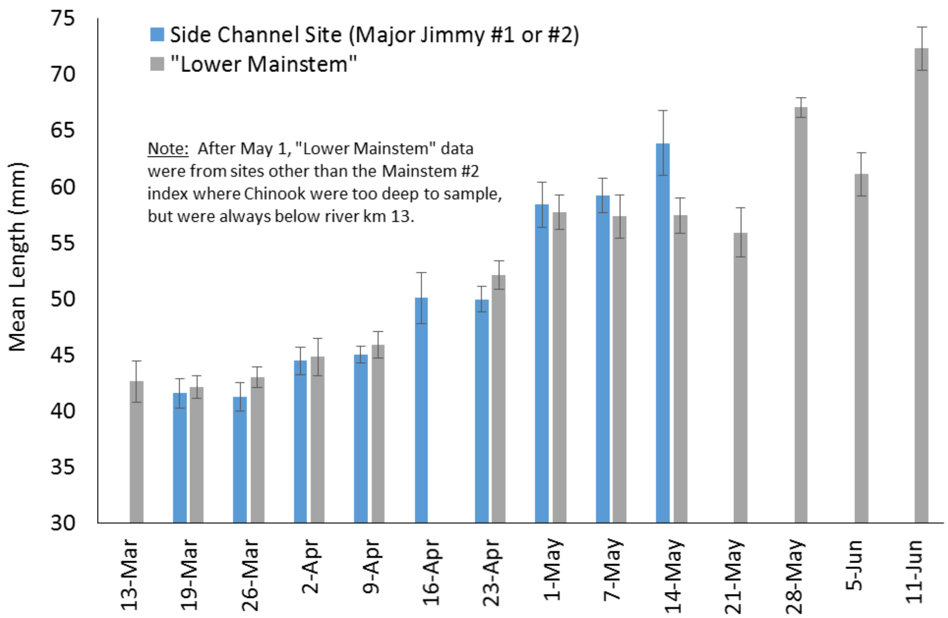

Figure 11. Mean fork lengths of wild Chinook fry sampled from lower mainstem and side channel index sites. Error bars represent 95% confidence intervals for each sample mean.

Mean lengths at the Mainstem #2 index steadily increased through April. After May 1, sampling data were only available from other lower mainstem sites above and below Mainstem #2. These data suggest mean size did not always increase weekly but results in some instances were biased towards smaller Chinook juveniles and may have under represented larger individuals holding in deeper, faster habitats. As evidence of this, the May 28 lower mainstem data point (Fig. 11) was generated from a related Cowichan Chinook PIT tag project that used larger seines and powered inflatables to capture juveniles in larger riffles, runs and pools. Methods used were likely more effective at capturing a representative sample from that area. Using this data, mean lengths of Chinook sampled in the lower mainstem also increased regularly from April 9 to the end of May by an average of 0.44 mm/day.

The largest wild Chinook sampled in Mainstem #2 or Major Jimmy side channel index sites were 78 mm on May 14 and 72 mm on May 8, respectively, the last time each of those sites were sampled.

Mean condition factors of Chinook sampled from lower mainstem and side channel index sites varied but became more consistent towards the end of sampling (Fig. 12). Early variability may have been related to spawning timing and influenced by the presence of newly emerged fry among fry that had been out of the gravel for three or four weeks. Across three surveys between mid-April and mid-May, mean pooled condition factors for Chinook sampled in Major Jimmy side channel index sites (1.039 ± 0.045, α=0.05) were significantly higher (two sample t-Test, $p < 0.01$) than those of fish sampled in the Mainstem #2 index site (0.973 ± 0.12, α=0.05).

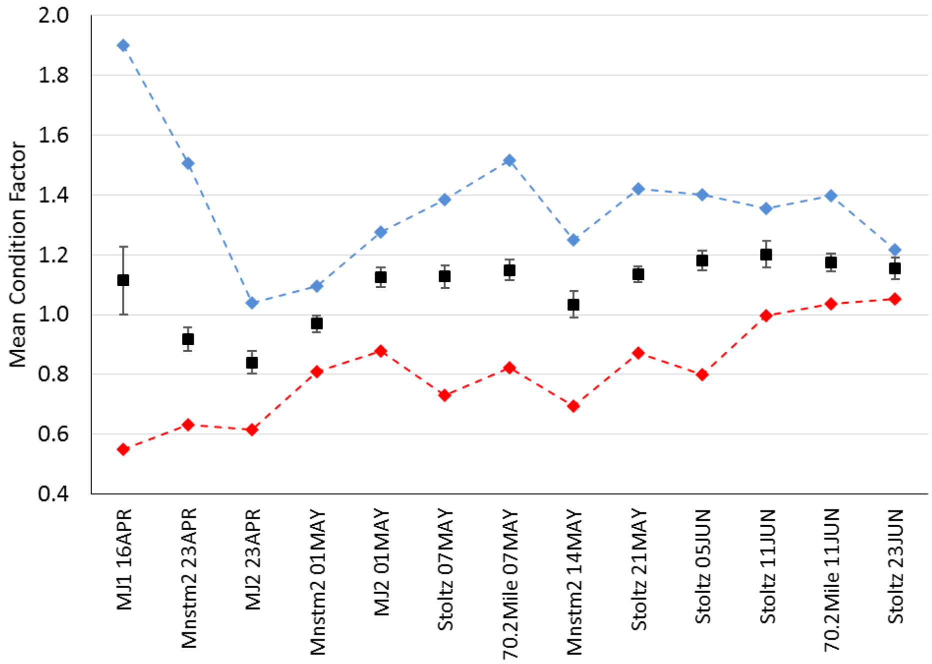

Figure 12. Mean condition factors of Cowichan Chinook sampled at upper and lower mainstem and side channel locations over the study period. Error bars represent 95% confidence intervals for each sample mean. For each sample, fish with the highest (blue) and lowest (red) factors are also shown.

Over the two weeks during which they peaked in abundance (April 9-16), Chum fry were on average 7 to 12 mm smaller than Chinook fry. Between April 9 and May 1, Coho fry were on average 8 to 17 mm smaller than Chinook fry. Coho yearlings or pre-smolts averaging 105 mm (range 83-120 mm) were first sampled on May 8 in a Major Jimmy index site (though first observed there on March 19).

3.3.3 Habitat - Lower Mainstem and Side Channel

Though Mainstem #2, Major Jimmy #1 and Major Jimmy #2 index sites were in close proximity to each other (Fig. 3), their physical habitats and flow regimes were substantially different. Similarities were limited to local reach gradient (~0.2%) and forest type/stage; all three sites were situated in mature stands of alder and cottonwood (Appendix D). Riparian species mix was also similar, with Red Osier Dogwood playing a significant role at each of the sites providing overstream and, at times, instream vegetation cover. Though close to the estuary, none of the sites experience anything other than freshwater regardless of tides.

Major Jimmy side channel receives water naturally from a stable lateral log jam located on an outside bend at mainstem km 3.6. In recent years, flows diverted through the jam do not typically persist past June or when mainstem discharge drops below ~10 m^3/s. On June 11, 2014 when mainstem discharge was 14 m^3/s (Appendix A), flow leaving the mainstem into Major Jimmy side channel was estimated at 0.10 m^3/s.

Major Jimmy side channel also received water from John Charlie side channel which, in turn, was fed by two sources: a licensed diversion further up the mainstem, and a continuous outfall from a nearby commercial hatchery. These sources supply water year round and represent the only flow in Major Jimmy side channel once the natural feed from the mainstem log jam dries in early summer. The John Charlie side channel enters Major Jimmy side channel at a point 150 m down its length.

Mainstem #2 Index (Appendix C, Photos 18-21)

The 50 m-long Mainstem #2 index site was located on river right (south bank) primarily adjacent to a long run unit transitioning into a short rip rap scour pool. Bankfull channel width was 44 m. Encouraged by a slight bend to the north, the channel's thalweg was right of centre but weakly defined, increasing velocities along most of the index site edge. Essentially flat, gradient through the index site was close to zero. Part of the area's historical south side flood protection works, Hatchery Dike acts as a rough road and runs parallel and immediately next to the river for about 700 m, ending less than 200 m below Mainstem #2 index. The dike heavily influences channel morphology in this reach, creating an artificially stable and relatively intact channel. Along most of dike the river was within 5 m of the road and only benefits from a thin riparian strip of mature alders and shrubs. The strip is discontinuous, made less effective by impacts of past and current fishing and/or recreational access points. Mature, mostly deciduous forests and constructed off channel habitats dominate south of the dike road and help to make the thin strip next to the river more windfirm.

As described in *Methods*, the following measures or descriptions relate to either an "*early*" season in March when flows were heavy and riparian habitats were largely inundated, or a "*late*" season in June when flows were closer to base flows and riparian habitats were typically dry. Measures and further descriptions are detailed in Appendix D.

Along the index, the average width of edge habitat supporting rearing Chinook <u>in early conditions</u> was 1.5 m. Submerged slopes were typically 1:1 and sprinkled with old rip rap embedded in cobble, gravel and fines made stable by dense, well established root systems. Of the total wetted surface area *that held rearing Chinook*, 100% had at least one of the standard seven cover types. Deep pool (35%) and overhanging vegetation (30%) provided most of the cover; smaller proportions of SWD, boulder and cutbank, plus traces of LWD and instream vegetation comprised the remainder. No portion of the index site's area that held fish had no cover component. Velocities largely dictated where Chinook could hold – fish were faithful to slower areas along the bank.   Dominant vegetation included Red Osier Dogwood, Indian Plum (*Oemleria cerasiformis*), grasses and Red Alder. The steep bank's depth and the roughness and interstitial spaces created by root systems and rip rap combined to create a thin strip of habitat attractive to Chinook. Substrates beneath rearing fish were either compacted sandy gravel/cobble or rip rap with D90 and D50 of 1,200 and 700 mm, respectively. Between rip rap and where velocities allowed, gravel, sand and silts were interspersed (Appendix D).

<u>In late conditions</u>, width of edge habitat supporting rearing Chinook varied but averaged 8 m. Adjacent to the index, the run component shrank to 60% of the index site's length, replaced with more pool. An estimated 100% of the total wetted surface area *that held rearing Chinook* offered standard cover. Estimated at 63%, deep pool cover was most dominant for Chinook in this flow condition. Boulder (i.e., rip rap) cover was also significant at 25%, and LWD and overhanging vegetation offered trace cover. Because of the incised nature of the channel, wetted width changes were relatively minor compared to upper and mid river sites, and stage had receded approximately 1.25 m. Chinook used some edge habitat but mostly open water with depth; they were almost always low in the water column, often just off the substrates. Beneath rearing individuals holding beyond the base of the rip rap, gravel with a high component of shifting sand and detritus dominated the channel bed (Appendix D).

Major Jimmy SC #1 Index (Appendix C, Photos 9-13)

Located about 350 m down the 900 m long Major Jimmy side channel, this index site extended 50 m down the right (south) bank accessible by Hatchery Road and the lower Mission Road Dike. Bankfull channel width was 12 m and the index was situated on a slow outside bend to the north, parallel to mainstem river km 3.4. The side channel's thalweg was right of centre along the entire index site's length. Local site gradient during base flow was 0.3%. The riparian zone was mostly intact; canopy was class 3 (40-70% covered).

Mission Road dike was situated immediately south and parallel to the lower two thirds of Major Jimmy SC #1 index. As part of 2013 flood protection improvements, the dike was raised and widened and its mainstem face fortified with rip rap. To accommodate these improvements, a significant portion of the side channel's right bank riparian zone between the dike and the stream edge had to be removed (live staking has since been undertaken). The remaining riparian strip was thin (<5 m) and likely functioned less effectively as a result. From a larger perspective and similar to the situation at the Mainstem #2 index, the Mission Road dike has likely impacted natural channel morphology in this side channel reach, keeping the alignments more stable than would otherwise be the case.

Along the index, the average width of edge habitat supporting rearing Chinook <u>in early conditions</u> was 1.5 m. Banks were 1 - 1.5 m in height and comprised of unconsolidated sandy gravel occasionally firmed up by root systems. In the heavier flows, 90% of the index site was glide habitat, 10% pool. Of the total wetted surface area *that held rearing Chinook*, 90% had at least one of the standard seven cover types. Overhanging vegetation (40%), instream vegetation (26%) and cutbank (20%) were the dominant cover types, with traces of deep pool and LWD comprising the balance. Dominant vegetation included Red Osier Dogwood, grasses and Red Alder and Scouler's willow (*Salix scouleriana*). Substrates beneath rearing fish were dominated by small gravel, with sand sub-dominant. In six samplings of the substrates beneath Chinook, D50 and D90 ranged from 2 to 20 mm and 12 to 58 mm, respectively (Appendix D).

Mesohabitat composition became more defined under <u>late conditions</u>, with glides shrinking and pool and riffle components increasing to 15% and 20%, respectively. Width of edge habitat supporting rearing Chinook varied but averaged 4 m. An estimated 35% of the total wetted surface area *that held rearing Chinook* offered standard cover in the form of cutbank, LWD and overhanging vegetation. No standard forms of cover were evident in 65% of the total wetted surface area *that held rearing Chinook*; fish appeared satisfied holding beneath broken water in riffles or in glides with sufficient velocity. Prevailing vegetation remained the same; a clump of invasive Japanese knotweed (*Fallopia japonica*) was also noted. Substrates were still dominated by gravel but cobble was sub-dominant. Six samplings of substrates beneath Chinook showed D50 and D90 ranged from 17 to 32 mm and 52 to 80 mm, respectively (Appendix D).

Major Jimmy SC #2 Index (Appendix C, Photos 14-17)

The second Major Jimmy index site lay between 50 and 100 m downstream of where the side channel started on the mainstem's right bank. As such, the site only received a natural feed from the mainstem log jam, and was situated 50 m upstream of where augmented flow entered from the more westerly John Charlie side channel.

At 10 m bankfull width, the Major Jimmy #2 index had slightly higher and more confined banks than Major Jimmy #1. However, its local gradients and forest type were very similar. Canopy cover was close to 70% (class 3) and this segment of the side channel flowed through mature, undisturbed deciduous forest. The index section was situated on the right bank of a straight channel segment fed by multiple braids draining the mainstem log jam further upstream.

<u>In early conditions</u>, the average width of right bank edge habitat supporting rearing Chinook was 1.5 m. Mesohabitat composition adjacent to the edge was 100% glide habitat in the heavy flows, but LWD caused some broken, riffly water. Of the total wetted surface area *that held rearing Chinook*, 60% had at least one of the standard seven cover types. Overhanging vegetation covered 30% of the occupied area, while instream vegetation, LWD and cutbank offered additional cover. Similar to Major Jimmy #1, the dominant plant species was Red Osier Dogwood, but grasses, Salmonberry (*Rubus spectabilis*), Red Alder and willow were all significant. Interestingly, crew reported that a great majority of the Chinook observed during the April 23 peak count (60.3 FPM; Fig. 10) used dense patches of submerged long grass cover (e.g., *Phalaris arundinacea* or similar). Substrates beneath rearing fish were dominated by gravel with sand sub-dominant. In four samplings of the substrates beneath Chinook, D50 and D90 ranged from 3 to 28 mm and 7 to 50 mm, respectively (Appendix D).

Crews documented <u>late season conditions</u> on May 28, the date of the last survey that occurred at Major Jimmy SC #2 index site. Flow had dropped significantly and was estimated at 0.20 m^3/s. While a run comprised half the site, 30% was riffle and 20% pool. Width of edge habitat supporting rearing Chinook varied but averaged 5 m. An estimated 20% of the total wetted surface area *that held rearing Chinook* offered standard cover in the form of LWD and overhanging vegetation. No standard forms of cover were evident in 80% of the total wetted surface area *that held rearing Chinook*. Prevailing vegetation remained the same. Gravel dominated the substrates beneath rearing Chinook, with a smaller sand component. In a typical transect across holding area, D50 and D90 were 49 and 90 mm, respectively (Appendix D).

3.4 Intertidal Mainstem and Blind-End Channels

From a lower river fish distribution and downstream migration perspective, it is useful to note that while the Cowichan's North Arm was a largely clear, unimpeded, single channel directly to Cowichan Bay, the South Arm stemmed from a natural, log jam-controlled bifurcation between river km 1.3 and 1.7. The bifurcation was the product of at least four distributaries leaving the main channel over a distance of 400 m. These distributaries then converged within 200 m to form the single thread South Arm channel. Following flood mitigation works in 2013, discharge during the base flow period were split virtually 50/50 between the North and South Arms (Fleenor 2014). At high flows, there may be a tendency for a greater proportion of total flows to continue down the North Arm. To date, there have been no studies to assess the proportion of outmigrating salmonids using either arm. Intertidal mainstem and blind-end channel daytime reconnaissance commenced in early March. Three person crews snorkeled or pole seined various tidally influenced habitats on or adjacent to the Cowichan's North and South Arms east of Tzouhalem Road (Fig. 13, Table 1, Appendix B). On March 4 during a mainstem flow of 59 m^3/s, crews snorkel

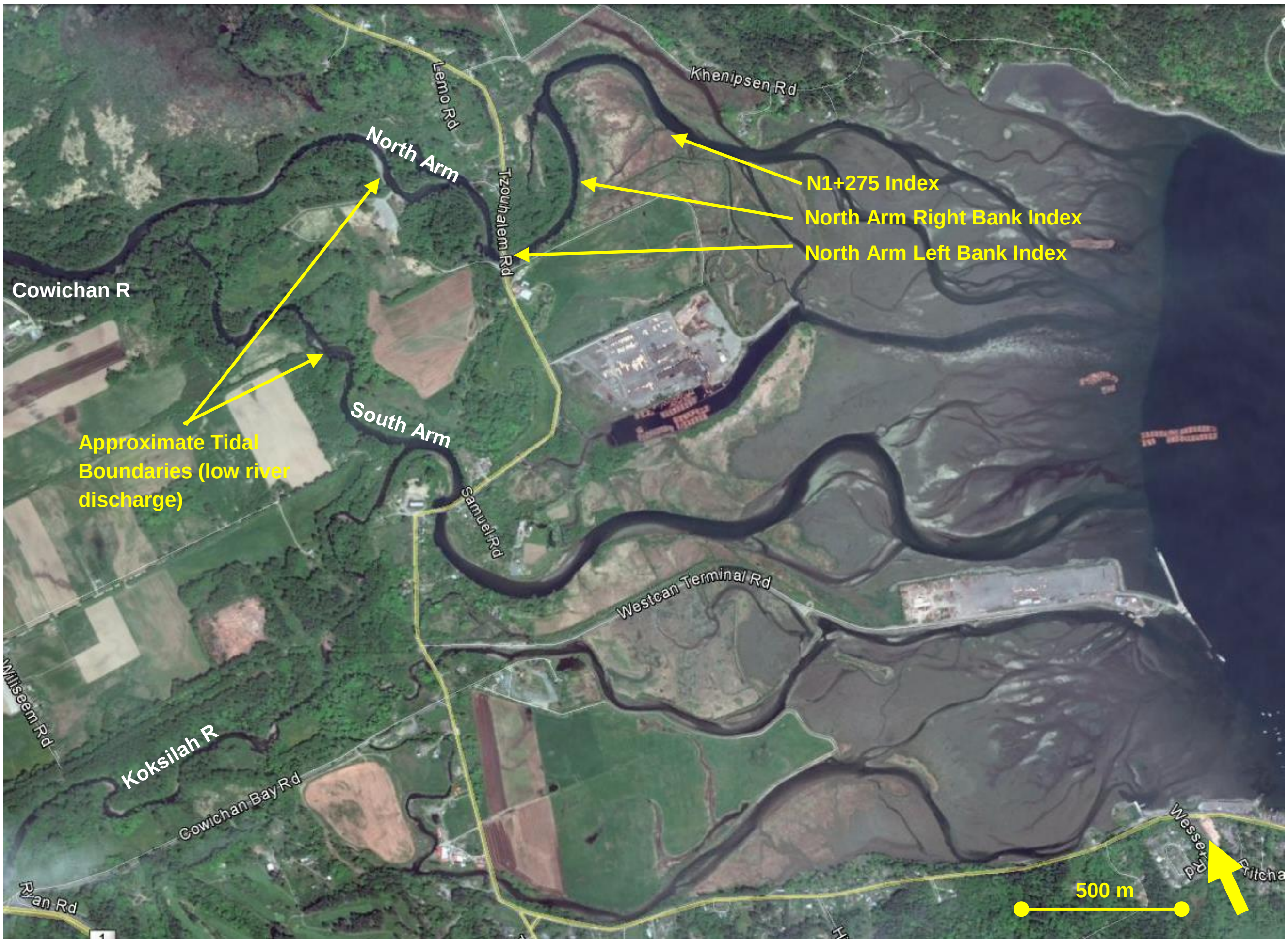

Figure 13. Google Earth image of lower Cowichan River and estuary, showing North and South Arms, approximate tidal boundaries (low flow), Tzouhalem Road and study index sites.

inspected a combined 725 m of North Arm edge habitat and 1,375 m of blind-end or slough habitat adjacent to the North Arm. Two days later during low tide and a mainstem flow of 120 m^3/s, crews pole seined 15 discrete locations 10-25 m in length in the southern half of the estuary, including eight stream edges along the Cowichan South Arm and seven stream edges along intertidal flood channels south of the Westcan Terminal Road (Fig. 13). Water levels at these latter locations were sustained exclusively by overflow from the Koksilah River[4], and were inspected to gain insight as to the relative abundance of salmonids north and south of the Westcan Causeway/Docks.

On March 13 and 19, crews continued synoptic surveys of various intertidal habitats on or adjacent to the North and South Arms to identify suitable index sites for replicate surveys. On the South Arm at the end of Samuel Road, shallow habitats difficult to survey and low observed night time densities made surveys there impractical. Conditions during moderate and high tides were no better as the area's low gradient benches meant sites quickly became too large to efficiently survey.

[4] The Koksilah River mainstem enters the Cowichan's South Arm at a point 300 m upstream of the Tzouhalem Road bridge crossing (Fig. 13).

On the North Arm, flags were set on March 19 to delineate index sections in N1+275 Channel, a sinuous natural channel complex draining a 4 ha salt marsh on the North Arm's right (south) bank (Fig. 13; Appendix C, Photos 29-32). The channel was well-connected with the North Arm at a point 1,275 m downstream of Tzouhalem Road and held reasonable numbers of juvenile Chinook during initial surveys.

Figure 14. Google Earth image of N1+275 Channel index and its named threads relative to the North Arm of the Cowichan River. West and North thread snorkel survey end points are shown (red triangles).

On March 26, index sites on two intertidal mainstem edges were established (Fig. 13). The 50 m North Arm LB (left bank; Appendix C, Photos 21-24) index spanned above, beneath and downstream of the Tzouhalem Road bridge and was studied in 2013 (Pellett *et al.* 2013). The North Arm RB (right bank; Appendix C, Photos 25-28) index was 25 m in length, located 300 m downstream of the Tzouhalem Road bridge, and accessed by the Blackley Farm dike road.

Effective visibility at intertidal mainstem index sites generally ranged from 2.5 to 4 m, more than adequate for juvenile counts and speciation.

3.4.1 Fry Abundance – Intertidal Mainstem and Blind-End Channels

Early surveys described above documented generally low numbers of Chinook fry using intertidal mainstem and off channel habitats. During the March 4 snorkel survey with one exception, only a handful of Chinook were observed over more than 2 km of edge habitat closely inspected[5]. The exception was a school of an estimated 60 Chinook fry packed into an overhanging and partially submerged Nootka rose bush along the North Arm's north bank, 1 km downstream of the Tzouhalem Road bridge. While approximately 100 m of both banks at this location were inspected, only this submerged bush held fish, and this bush was the only habitat of its kind in the 100 m inspected. The remaining habitat was either deep water at the foot of loamy, vertical banks with occasional coarse LWD (outside bend), or shallow, low gradient, sandy gravel with occasional SWD (inside bend). Leaf litter and other small organic debris had collected on the upstream side of the Nootka rose, slowing velocities for the Chinook holding inside the bush.

March 6 seining reconnaissance in the southern half of the estuary also yielded very low numbers of fry. A total of six Chinook 37-42 mm in length were caught amongst 10 Chum fry, 13 Stickleback and 442 Sculpin captured from 15 sites.

To compare early season day and night time snorkel observations, crews inspected an intertidal gravel bar with abundant LWD and SWD cover on the South Arm in both conditions on March 13. While no fish were observed over a 140 m transect during the day, Chinook fry abundance in the same area at night ranged from 0.1 to 0.5 FPM. Similarly low densities at night were observed at several other locations in mid-March.

From the first surveys in late March, observed Chinook fry abundance in both intertidal mainstem index sites unexpectedly declined over three weekly surveys through April 10 (Fig. 15). Thereafter, counts increased immediately and dramatically, peaking in the North Arm LB index at 1,165 fry (23 FPM) on April 16 and in the North Arm RB index at 623 fry (25 FPM) on April 23. From May 21 on, Chinook fry densities declined quickly to less than 0.5 FPM by June 23.

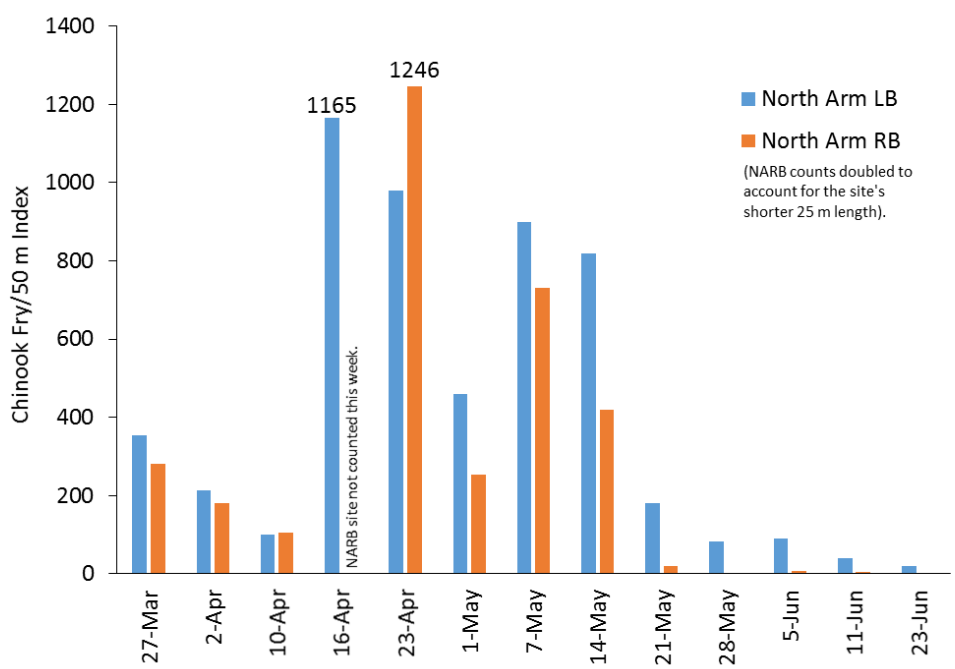

Figure 15. Chinook fry counts at North Arm LB (left bank) and North Arm RB (right bank) index sites over the study period. North Arm RB counts have been doubled to account for the index site's 25 m total length and allow densities to be compared to other 50 m index sites.

[5] Because of the early season daytime conditions, particular attention was paid to darker, complex cover where it existed, as crews did not expect many fish to be "out".

Observation conditions at North Arm index sites were influenced by tidal stage as well as the usual river flow, turbidity and weather. Because counts were typically conducted in the early evening between 2000h and 2400h over the length of the study, coincidental high tides would affect water levels at the index sites. Tides encountered during survey counts ranged from 1.2 m lows to 3.3 m highs (Chart Datum; http://www.tides.gc.ca/eng). The effects of these tides on fish behavior (and therefore counts) was not clearly identified. But because velocities slowed and bank/riparian inundation increased, the effect of high tides likely included some degree of temporary fish dispersal from edge habitats, and a corresponding decrease in counts. This effect may have been somewhat muted early in the study with high river discharge, and accentuated late in the study during lower flows. A plot of counts against instantaneous tide heights (Fig. 16) shows a fairly strong inverse relationship, suggesting counts may have been affected by "tidal dispersal".

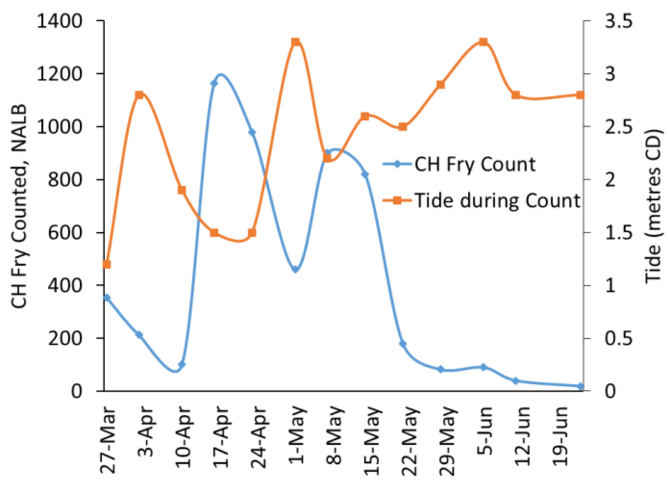

Figure 16. North Arm LB index Chinook fry counts versus tidal stage that occurred during the counts.

In particular, May 1 counts at North Arm index sites may have been strongly affected by tidal dispersal. At 3.3 m, there were no tides during counts that were higher over the study period (Fig. 16). Velocities adjacent to the index sites slowed significantly and lower gradient edges were fully inundated, providing optimal night time conditions for juveniles to forage farther from preferred holding locations. This likely explains the relatively low counts at the North Arm LB and RB index sites on May 1 (9 and 5 FPM, respectively) compared to consistently higher counts for two weeks before and after May 1 (mean of 19 and 16 FPM for LB and RB sites, respectively).

N1+275 Channel Index

Following daytime reconnaissance, two primary threads were identified and flagged for regular survey within the N1+275 Channel network. West and North threads (Fig. 14) were both discrete, blind-end channels where fish presence/abundance at any given time might indicate some preference for the habitats and/or colonization behavior. Between March 19 and June 23, crews completed nine night time surveys of West Thread and eight of North Thread. Provided snorkelers progressed against prevailing flows (dependent on tide flooding or ebbing), visibility generally varied from 1.5 to 2 m in most surveys. This was more than adequate to observe and identify juveniles using the habitat. Once fine substrate sediments were disturbed, visibility quickly declined to <0.5 m at or "downstream" of that point. While North Thread was always surveyed by a single snorkeler, the wider West Thread was most commonly surveyed by two personnel swimming side by side. Although Chinook fry were occasionally wary of dive lights, the vast majority held position and were easily counted. On occasion, snorkelers would extend surveys beyond established end points but would document the length of additional channel length surveyed.

Chinook fry were relatively low in number but observed during every survey conducted in the N1+275 Channel index threads (Fig. 17). Using all data, observed densities averaged 1.0 and 0.8 FPM in the North and West threads, respectively. In the North Thread, a peak density of 5.4 FPM occurred April 23, four times the abundance of the next

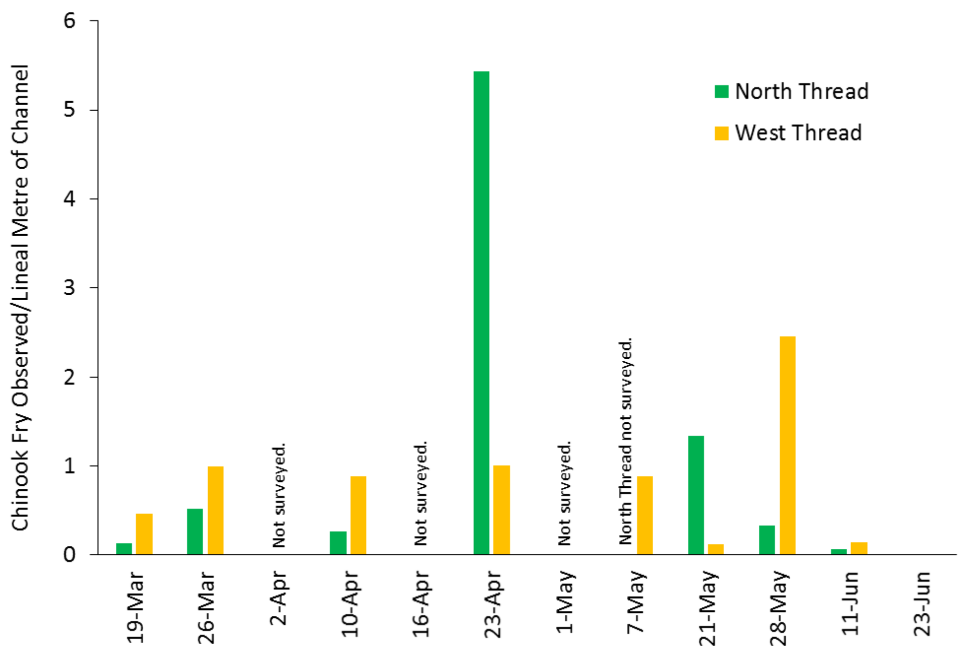

Figure 17. Chinook fry observed per lineal metre of the North and West threads of N1+275 Channel index.

highest count. In the West Thread, the peak of 2.5 FPM occurred May 28, 2.4 times the abundance of the next highest count. The substantial difference in counts between West and North threads on April 23 may have been due to the wider West thread being surveyed by one snorkeler instead of the usual two. Counts were often variable between threads – observed density in one thread was often more than double or less than half that of the other thread. However, results clearly demonstrated that Chinook fry abundance in N1+275 Channel was generally an order of magnitude lower than densities observed in mainstem index sites, whether they were a short distance upstream (e.g., Mainstem #2) or 40 km up river (e.g., 70.2 Mile Trestle). Because neither thread de-watered during low tide and each offered undercut cover, crews suspected that numbers increased with new recruits each week and that a good portion of the observed population was non-transitory.

Following almost all surveys, crew members noted the tendency of Chinook to hold close to substrates on the bottom, near the channel bank's vertical edge provided it was rough or offered overhanging vegetation, and near the undercuts at the base of channel banks. Conversely, the next most abundant salmonids, Chum fry in the early spring and Coho fry in the late spring, showed less preference for particular micro habitats and were commonly observed throughout the water column.

Distribution of Chinook over thread survey length varied by season. During early counts in March when fry were smallest, the majority were observed using more confined, upstream ends of the threads, particularly in West Thread. As the season progressed, crews noted a more even density in each thread's length. From mid-May onwards, Chinook were counted throughout the threads but highest densities were noted in the downstream ends, near and in Main Thread and the channel network's confluence with the Cowichan North Fork (Fig. 14).

In addition to Chinook, N1+275 Channel index held significant numbers of Coho and Chum fry, Threespine Stickleback and Sculpin. While Chum fry abundance was greater than Chinook only between April 10 and 23 (up to 22 FPM), Coho fry abundance exceeded that of Chinook from mid-May onward (up to 18 FPM). It should be noted that accurate Chinook counts were the priority; Chum and Coho numbers were estimates only. From hundreds in March and April, Threespine Stickleback numbers exploded on May 21 in both threads, with surveyors estimating more than 10,000 (>40 to 60 FPM) in each. A significant number appeared to be gravid. Abundance declined to between 3,000 and 5,000 thereafter. Average Sculpin fork length was ~10 cm and their numbers were fairly consistent at 50 to 100 per thread. Larger individuals up to 20 cm were occasionally noted.

A handful of Coho smolts and Peamouth Chub were counted, as were small schools (n=40 to 160) of Shiner Perch (*Cymatogaster aggregata*) late in the study period. No Rainbow, Cutthroat or Brown Trout juveniles or adults were observed.

Fry Abundance – Non Index Intertidal Sites

Non index site observations and sampling occurred in several locations in the inner estuary.

On March 26, several natural channel segments similar to those in the N1+275 network were surveyed at night south of the North Arm. In N1+380, a channel similar to N1+275 but 105 m further downstream, crews observed Chinook densities of 0.5 to 1.0 FPM on average. Peak densities as high as 3 FPM were noted at a narrow choke point where several threads draining a more southerly salt marsh met up. The narrows appeared to be an historic breach of a relic dike. Other channels and relic log pockets further east held densities of up to 0.5 Chinook/m as well as low to moderate numbers of Chum fry, Threespine Stickleback and Sculpin. No fish were observed in the South Arm's Affinity Guest House Channel 700 m downstream of Tzouhalem Road bridge, but water levels were minimal during the low tide at time of survey. In a 140 m length of left bank inside edge along the Cowichan's South Arm immediately below Tzouhalem Road, Chinook densities of 0.2 FPM were observed in addition to low numbers of Sculpin and buttoning up Chum fry.

On April 16 during a low tide, daytime surveys documented Chinook fry abundance in the Cowichan North Arm downstream of Tzouhalem Road bridge. Crews expected Cowichan fish to be generally observable, given recent mean daily water temperatures were above 9^{o}C. Estimating they were just 20% efficient because of the dense and deep (3-6 m wide) overhanging and submerged bank vegetation, crews counted an average of 4 to 8 Chinook/m on each bank of the North Arm over the first 200 m below the bridge. Due to velocity related safety concerns, only a portion of the lane holding fish could be surveyed. On each bank, large schools of fry (i.e., 500-1,000) were frequently noted at the limit of visibility. Of those inspected, school composition was estimated to range from 10:1 to 30:1 Chum:Chinook. These densities were largely repeated half a kilometre downstream over a 150 m length of each bank inspected just above Mariner's Slough. Observed densities quickly declined thereafter to less than <1 FPM once complex riparian vegetation ceased to be present on both banks.

A Koksilah River flood channel immediately south of the Westcan Causeway was also surveyed during daylight hours on April 16. Starting at Tzouhalem Road, a crew surveyed 2.7 km of channel to the end of the causeway. Channel flow at time of survey was estimated at 1.0 m^3/s and water temperature was similar to that of Cowichan River. Counts were very low, with salmonids (80 Chinook fry, 10 Coho smolts, 200 Threespine Stickleback) only observed beneath overhanging riparian shrubs in the first 60 m of channel. The remaining channel held no salmonids. Exiting the channel however, the crew noted a single school of about 400 fry using docks and boat hulls for cover near the end of causeway. Composition was estimated at 20% Chinook, 80 % Chum.

A third low tide survey on April 16 investigated abundance in the Cowichan's South Arm downstream of Tzouhalem Road for 2.75 km. In daylight, crews examined both edges through two large, stable meander bends, finishing immediately adjacent to and north of the Westcan Causeway docks. Observed in six discrete schools, a total of 1,800 Chinook juveniles were counted: 500 in four groupings spaced along the outside of the first (right bank) meander, and 1,300 in two schools along the outside of the second (left bank) meander. In all cases, Chinook were associated with water >1.0 m in depth with complex LWD and SWD, and occasional overhanging vegetation. Chinook were generally mixed with equal or greater numbers of Chum fry, plus small numbers of Coho fry and smolts and a few Sockeye smolts (*O. nerka*).

During the April 23 survey, snorkelers completed day and night time examinations of two of the smaller North Fork bifurcations and parts of the Western Forest Products (WFP) log pocket. Daytime surveys yielded few fish in the two channels 500 m in length that veer south from the North Arm and enter the log pocket's approach channel just east of the log pocket proper. A few small schools of Chinook (30-60) were observed holding along edge or LWD cover habitats. Even fewer fish were noted in the log pocket approach channel, along the eastern boom or along the southern bank[6]. There were, however, millions of euphausiids in the saltwater lens that spanned the bottom of the channel. Surveys were repeated at night when the tide was a metre higher, wetted widths of the two bifurcation channels were two or three times larger, and velocities had dropped to close to zero. Chinook were observed on the bottom throughout the channels (not top or mid-water column), on the benches and along both steep and shallow edges and rip rap. Because surveys sometimes included open water, crews tracked numbers of Chinook observed/m^2 in addition to fry per lineal metre of edge. Densities varied but averaged 0.5-2 Chinook juveniles/m^2 in most areas. The highest densities of salmonids were observed in one location along the rip rap point at the easternmost end of WFP's access road. Thousands of salmon fry (300-500 per m^2) held in the fresh/salt interface there, with highest densities within 2 m of the wetted edge. The vast majority were Chum fry, but it was estimated that Chinook comprised up to 5% of the total. Wind, waves and the incoming tide adversely affected visibility in the open log pocket and approach channel, preventing further surveys of the entrance channel.

On May 7, night time observed Chinook fry densities along edge transects 200 m in length were 0.02 and 0.07 FPM on the south and north sides of the Westcan Causeway, respectively. The surveys occurred at 2230h when the tide was fairly high (2.7 m CD) and flooding. South side edge habitats were dominated by gravels and sand with little vegetation, while north side edges had mud and sand substrates with small patchy grass and sedge islands that offered more cover.

A second May 7 night time crew surveyed estuary edge and open water habitats in secondary bifurcations of the Cowichan's North Arm, and in the excavated approach channel of the Western Forest Products log pocket. Abundance ranged from 0.05 to 2.0 fry/m^2 over the areas surveyed, averaging between 0.1 and 0.2 fry/m^2. The

[6] Due to WFP's 24-hour operations, the log pocket itself could not be safely surveyed.

highest densities were rare and only occurred over mud and sand substrates with detritus, low to moderate slopes and submerged vegetation (grasses/sedges) on the perimeter of the wetted channel. In general, Chinook were consistently observed close to substrates, edges/undercuts, or submerged marsh vegetation. Most of those observed in open water areas were virtually stationary (or moving very slowly) over the substrates, and did not appear to be feeding. Chum fry were generally less abundant than Chinook, and occasional Coho fry and smolts, Stickleback, Staghorn Sculpin (*Leptocottus armatus*) and Shiner Perch were observed.

3.4.2 Fry Sampling - Intertidal Mainstem and Blind-End Channels

Chinook fry sampling in the intertidal mainstem and inner estuary commenced March 4 and ended June 11. Due to generally low densities of Chinook in all but intertidal mainstem sites, numbers sampled in the inner estuary were often insufficient for rigorous statistical analysis. Conversely, abundance at the North Arm LB index site was consistently sufficient for meaningful sampling. Mean lengths of Chinook sampled increased from 42 to 72 mm over the study (Fig. 18), but not steadily.

As was observed in lower mainstem non-tidal sites (Fig. 11), mean length of Chinook sampled from intertidal mainstem sites appeared to “plateau” somewhat in May. This likely represented outmigration as Chinook reached a critical size threshold and were encouraged to move by dropping flows and increasing temperatures. Some of this effect might be explained by sampling bias, where larger fry were harder to sample and therefore possibly under represented. However, combining declining observed abundance with these results strongly supports the outmigration premise.

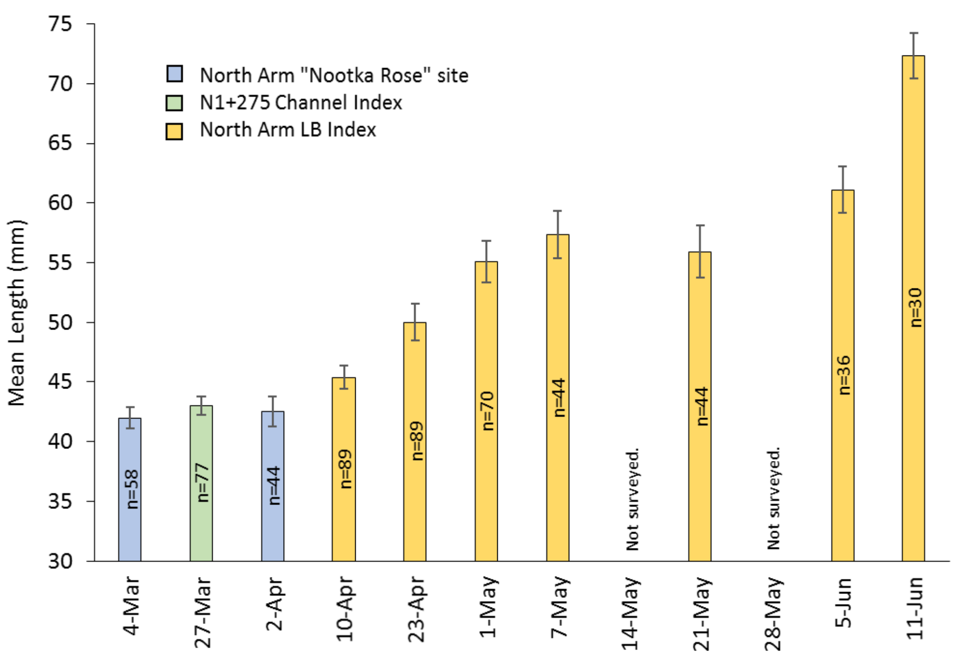

Figure 18. Mean fork lengths of wild Chinook fry sampled from North Arm LB and N1+275 Channel Index sites, and the North Arm “Nootka Rose” site. Error bars represent 95% confidence intervals for each sample mean.

Though sample sizes were sometimes small, we looked for size differences between various habitats sampled in the inner estuary. On April 2, Chinook using the N1+275 Channel index site (n=17) were essentially the same as Chinook sampled from the intertidal mainstem “Nootka Rose” site (n=44; two sample t-Test p = 0.77).

On May 14, Chinook pole seined during a daytime low tide from N1+490, a North Arm bifurcation channel, averaged 57 mm in length (n=27), while Chinook beach seined with a raft and outboard later that night from the north side of the Westcan Causeway’s industrial yard were significantly larger (two sample t-Test $p < 0.001$) at 67 mm (n=49). Rather than suggesting any difference in rearing habitat quality, these two sample sites were quite dissimilar and results likely point to a more advanced state of growth and procession to the marine environment of fish using the open flats north of the causeway. Though fully tidal in nature, the N1+490 channel was a relatively small, confined channel thoroughly flushed by river flows on a daily basis. As such, it provided more of an early stage freshwater rearing environment than did the causeway site.

Further to May 14 results of seining habitats north of the Westcan Causeway, we compared total numbers seined/m^2 to that from habitats immediately south of the causeway on the same evening using the same techniques. While two sets totaling 396 m^2 yielded 58 wild Chinook fry on the north side (0.15 fry/m^2), two sets on the south side totaling 306 m^2 yielded 2 fry (0.01 fry/m^2). In addition to the 58 wild fry on the north side, four AFC hatchery Chinook were also sampled.

3.4.3 Habitat - Intertidal Mainstem and Blind-End Channels

Though habitat characteristics of the intertidal index sites were the most diverse in the study, some aspects were similar between the North Arm LB and RB sites. Mean bankfull channel widths were 25.5 and 24.0 m, respectively. Reach gradient was less than 0.2% and both sites had local gradients of close to zero at base flow. Riparian areas were classified as young deciduous forest offering less than 20% canopy cover. Compared to the larger reach, both sites offered average quality mainstem edge rearing habitat.

Figuratively another chapter altogether, the N1+275 Channel index was one of many intertidal tributaries, sloughs, alcoves, braids, distributaries and blind-end channels that connect to the Cowichan’s North and South arms. Despite historical diking associated with farming, industry and other development in the estuary, many remnant channels on the “wrong” side of flood protection works or access roads are still visible on today’s aerial photography. Some have limited connection with the North or South arms; others are out of production from the fisheries perspective. In the *active floodplain, blind-end channel* category, the N1+275 Channel likely offers the least impaired, highest quality salmonid rearing habitat in the estuary.

North Arm LB Index (Appendix C, Photos 21-24)

Fifty metres in length on an inside bend, the North Arm LB index site was situated adjacent to a stable run unit transitioning into a short right bank scour pool between the abutments of Tzouhalem Road bridge. Channel thalweg was right of centre, fostering quieter velocities along the index edge. Local channel morphology appeared strongly influenced by the bridge crossing as well as the right bank dikes upstream (Tooshley Island Dike) and downstream (Blackley Farm Dike).

A single, solid concrete pier supported the bridge and occupied space in the middle of the index site. In the active floodplain beneath the bridge deck, a flat sandy bench with patchy grass extended from the pier to the bridge's left bank abutment. Until late April, the perimeter of the pier's footing was entirely wetted during each survey. From mid-May on, only the river side of the pier was wetted unless surveys coincided with a high tide. Crews surveyed all wetted habitats regardless.

Upstream of the bridge, the index site's riparian vegetation was dominated by tall grasses with trace Himalayan Blackberry (*Rubus discolor*) and an overstory of thick mature willow trees that, during the study, were mostly outside the wetted perimeter. Downstream of the bridge, the remainder of the index site was dominated by thick grasses (e.g., Reed Canary or similar) on a shallow bench, backed up by willow and occasional Red Osier Dogwood and Red Alder immediately upslope. The grasses would regularly be inundated to varying degrees, attracting high densities of salmonid juveniles.

"*Early*" and "*late*" season references that follow correspond to March flows with regular inundation of edge habitats and June flows when riparian edges were often dry. Further habitat information is included in Appendix D.

Average width of North Arm LB edge habitat supporting rearing Chinook <u>in early conditions</u> was 1.5 m. Most of that width was low gradient, grassy bench; the balance was steep grass and root covered cutbank transitioning to river bed gravels. Of the total wetted surface area *that held rearing Chinook*, 85% had at least one of the standard seven cover types. Instream vegetation provided 45%, with overhanging vegetation, cutbank and LWD providing 10% each and SWD and deep pool the balance. Grasses dominated the vegetation cover; tall dead stalks and long dry blades offered the most cover, while new shoots and emergent green blades doubled the cover component closer to ground. As in other index sites, micro-velocities dictated where Chinook would hold, but fry appeared most abundant in or very near thicker, "flowing" grass. Substrate beneath rearing fish was compacted sand stabilized by thick grass root systems. Scour created occasional patches of small gravel (D90 <30 mm).

<u>In late conditions</u>, width of edge habitat supporting rearing Chinook varied but averaged 5 m. In the lower discharge, 75% of the habitat adjacent to the index was glide, with the balance pool habitat. Only 25% of the total wetted surface area *that held rearing Chinook* offered standard cover in the form of deep pool (15%) and small amounts of LWD, SWD, cutbank and overhanging vegetation. Lower flows meant that much of the instream vegetation that was so dominant in the early season was no longer wetted. Three quarters of the habitat holding Chinook offered no "classic" cover for them; fry were regularly observed on gravel substrates in water greater than 20 cm in depth and flowing at 30 cm/s or more. Beneath rearing Chinook, mean substrate sizes generally decreased from the top to the bottom of the index, ranging from a D50 of 200 mm to <5 mm. Gravel with shifting sand and detritus dominated the channel bed (Appendix D).

North Arm RB Index (Appendix C, Photos 25-28)

Situated 300 m downstream of Tzouhalem Road and just 25 m long, the North Arm RB Index offered a quick verification of intertidal mainstem Chinook abundance in a representative habitat for the reach. This right bank site was similar in many ways to Mainstem #2 Index, offering above average velocities and heavily rooted steep banks with rip rap. Dominated by mature Red Alder, the riparian corridor averaged 7 m in width and was bounded (and to some degree impacted) by a hiking trail on an abandoned access road from the Blackley Farm Dike.

In early season conditions, the river alongside the index was a largely straight, deep, fast run. Average width of the edge habitat holding Chinook was 1.0 m. Of the total wetted surface area *that held rearing Chinook*, 90% had at least one of the standard seven cover types. Dominant cover included boulder (45%), LWD (25%), overhanging vegetation (10%) and SWD (10%). Willow and grasses contributed most to overhanging and instream vegetation; Himalayan Blackberry, Red Alder and Salmonberry were secondary. Of substrates beneath rearing Chinook, boulder and cobble dominated on the steep bank, providing regular interstitial cover. D50 and D90 were 600 and 1200 mm, respectively.

Though velocities declined significantly, the channel adjacent to the North Arm RB Index remained a run in late season conditions. The width of edge habitat holding Chinook grew to an average of 5 m, with larger fry distributed at depth along the streambed. Of the total wetted surface area *that held rearing Chinook*, 75% had cover. Deep pool was the most common cover (40%), with boulder (15%) and LWD (10%) of secondary importance. Substrates beneath Chinook close to the bank remained unchanged. Channel bed substrates were dominated by gravels and shifting sands.

N1+275 Channel Index (Appendix C, Photos 29-32)

Habitat in the N1+275 Channel index was assessed towards the end of the study. Changes in physical habitat from early to late season conditions were mainly related to vegetation growth but water temperatures, light, river stage, turbidity and tide also influenced habitat.

In the early season, emergent vegetation across the salt marsh drained by N1+275 Channel was in a state of senescence and only beginning to bud out. Previous season's grass, sedge and rush growth was present but commonly clumped or flattened, if not dispersed by recurring high tides and wave action across the marsh. Marsh flats immediately adjacent to channel threads were often most bare, with only dense root systems and shoots holding mud-sand soils together. Pacific Crab Apple (*Malus fusca*), the only tall vegetation bordering channel threads in the complex, was located at the upstream end of West Thread (Fig. 14).

River stage often had a significant effect on N1+275 water levels in March and April, maintaining elevated channel depths regardless of tides and, during higher tides, causing inundation of adjacent, lower-lying marsh flats (Fig. 19; Appendix A). During the higher tides, crews observed a small component of the fry population (species undetermined) leaving the channel proper and using nearby shallow areas with remnant grass cover. Late in the season, mean depths dropped to less than 30 cm during low tides, but the channel never de-watered.

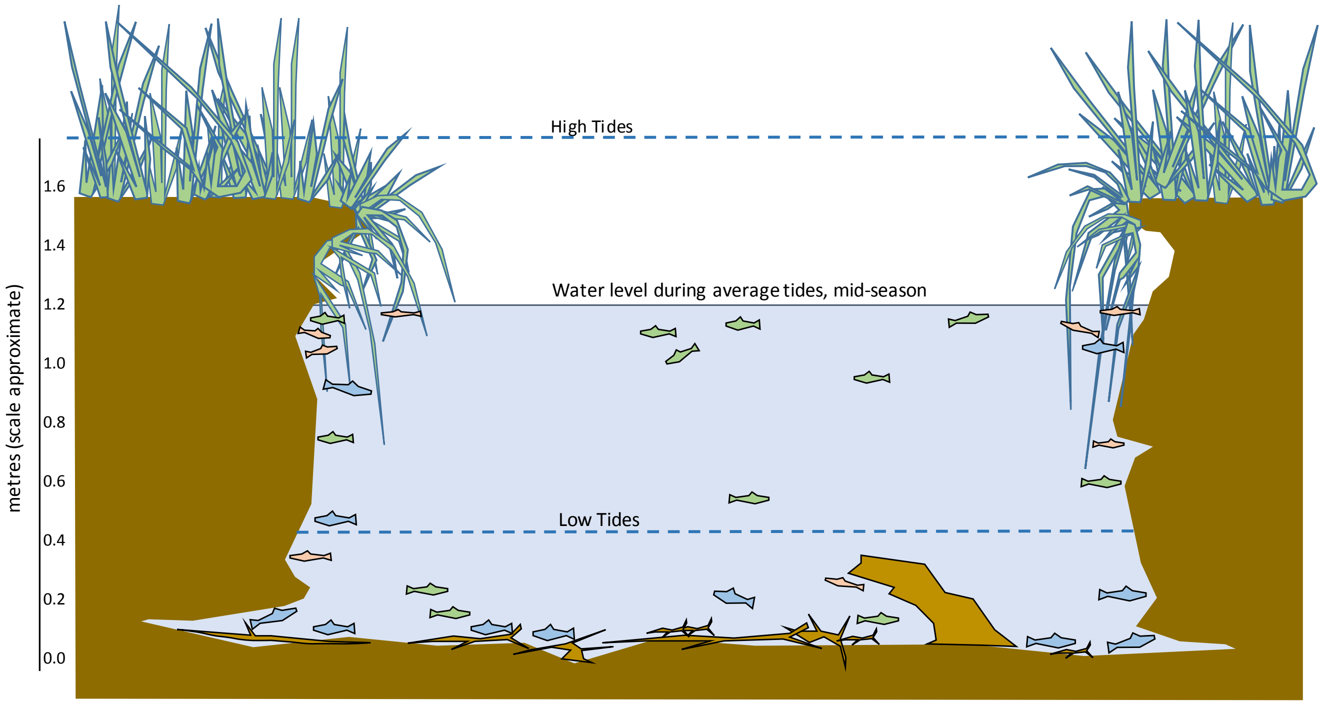

Figure 19. Cross-section sketch of typical N1+275 Channel index thread, showing habitat features and characteristic positions of Chinook (blue), Chum (green) and Coho (orange) juveniles.

Referencing a documented elevation of Khenipsen Road from provincial floodplain mapping (Province of BC 1997), we used a rod and level to survey points of the N1+275 Channel bed to put its habitat in context with Cowichan Bay tidal regimes. Channel bed elevations ranged from a high of 2.93 m Chart Datum (CD) near its confluence with the North Arm, to a low of 2.58 m CD in the West Thread, approximately 100 m southwest. The minor invert near the confluence likely helped to maintain residual pool depth of ≥0.30 m through May and June low tides. March tides in Cowichan Bay ranged from a mean high of 3.20 m CD (max=3.4) to a mean low of 1.26 m CD (min=1.0; http://www.tides.gc.ca/eng/find/region/1). In June, mean high and low tides were 3.42 (max=3.60) and 0.84 (min=0.20) m CD, respectively. From March through June, river discharge continually affected stage in N1+275 Channel over and above the tides (more so in in the early season; Appendix A), making conditions highly dynamic and difficult to predict.

By May and June, marsh vegetation was in full bloom and provided a greater degree of overhanging vegetation cover to fish in the channel threads (Fig. 19). With lower river discharge, adjacent flats along the perimeters of channels were less frequently inundated by high tides and used by juveniles.

Despite an abundance of silt and organic sediments as substrates, visibility was surprisingly reasonable in the N1+275 Channel index. Being blind-end, sediments from “upstream” did not exist. Even during the peak of the tide swing, estimates of surface velocities never exceeded 10 cm/s as the channel flooded or ebbed. This appeared to create a stable environment in which to forage, and fish were regularly observed doing so.

Thread channel widths ranged from 2.0 to 6.0 m but averaged 2.5 to 3.0 m. Banks were composed of hard pack sandy loam and were almost entirely vertical, ranging from 1.2 to 1.7 m in height. Only the Main Thread (Fig. 14) had less confined banks, possibly affected by mainstem flows or tidal action. Virtually flat, channel beds throughout the threads were the same loamy material with a substantial organic component (20-40 cm thick) and occasional SWD and LWD. There were virtually no riffles, pinch points or changes in gradient anywhere in the network.

At the base of each channel bank, a consistent undercut offered fish cover during daylight hours or low tides when water levels were residual. Snorkelers commonly observed all species actively using these undercuts. The feature was noted in all such blind-end channels surveyed, presumably an effect of low tide drainage and erosion of the loamy material making up the banks.

Of the West and North thread's surveyed surface area *that held rearing Chinook* <u>in the early season</u> scenario, crews estimated 34% had at least one of the standard seven cover types. Because they were essentially one and the same, overhanging and instream vegetation dominated with 20%, with cutbank (10%), LWD (2%) and SWD (2%) making up the balance. As much as 66% of the surveyed surface area with Chinook offered no classic cover type, although in this instance Chinook juveniles may have felt sufficiently safe on the bottom of the channel with access to the nearby undercuts (likely the "go to" cover during lowest water conditions). Various senesced sedges and grasses were most relevant as fish cover, followed by Common Cattail (*Typha latifolia*) and Nootka Rose. Historically, detailed vegetation inventories by Ducks Unlimited Canada documented Arctic Rush (*Juncus arcticus*), Tufted Hair Grass (*Deschampsia cespitosa* ssp. *beingensis*), and Lyngbye's Sedge (*Carex lyngbyei*) as the most dominant species along the threads (Hunter *et al.* 1983).

<u>In the late season</u> due to spring growth, overhanging and instream vegetation cover increased, marginally adding cover for rearing Chinook. Additional description of the N1+275 Channel index is provided Appendix D and in section 3.4.1 *Fry Abundance*, above.

4.0 Discussion/Recommendations

Given this study's reliance on experienced snorkelers working at night to individually count Chinook fry in delineated habitats, observer efficiency (OE) was obviously a key parameter affecting results. OE was not evaluated during the project. However, during a study of effectiveness monitoring of fish habitat restoration structures in nearby Chemainus and Little Qualicum rivers on Vancouver Island, night-time BCCF staff OE was evaluated with mark-recapture techniques to calibrate counts of Coho and Steelhead fry and parr using installed LWD as over-wintering habitat. Study authors found OE ranged from a low of 35% (SE=3.0%) to a high of 54% (SE=3.9%) for experienced observers in control or LWD-restored reaches (Gaboury *et al.* 2012). Professional opinion of snorkelers in our study was that OE was for the most part consistent, but might have improved somewhat in late April and early May. During this time, Chinook were less prone to concentrate in shallow vegetated edges, more apt to occupy open areas, but still unlikely to be observed in deeper and faster thalweg habitats. Habitats thought to be the most challenging to effectively count Chinook fry in were the N1+275 index threads during moderate to high tides, and the left and right banks of the North Arm Cowichan below Tzouhalem Road on April 16 (see section *3.4.1 – Fry Abundance – Non Index Intertidal Sites*). **Readers are reminded that fry count data presented herein are unexpanded, actual counts and should therefore be considered conservative in all cases**.

We successfully tracked relative abundance of Chinook juveniles over time from natal spawning areas to intertidal channels. Over the study period, index site Chinook count data suggest survey timing was appropriate, with low numbers (<5 FPM) early and late in the study, and peaks between 13.6 and 60.3 FPM well documented in April and May (Fig. 20).

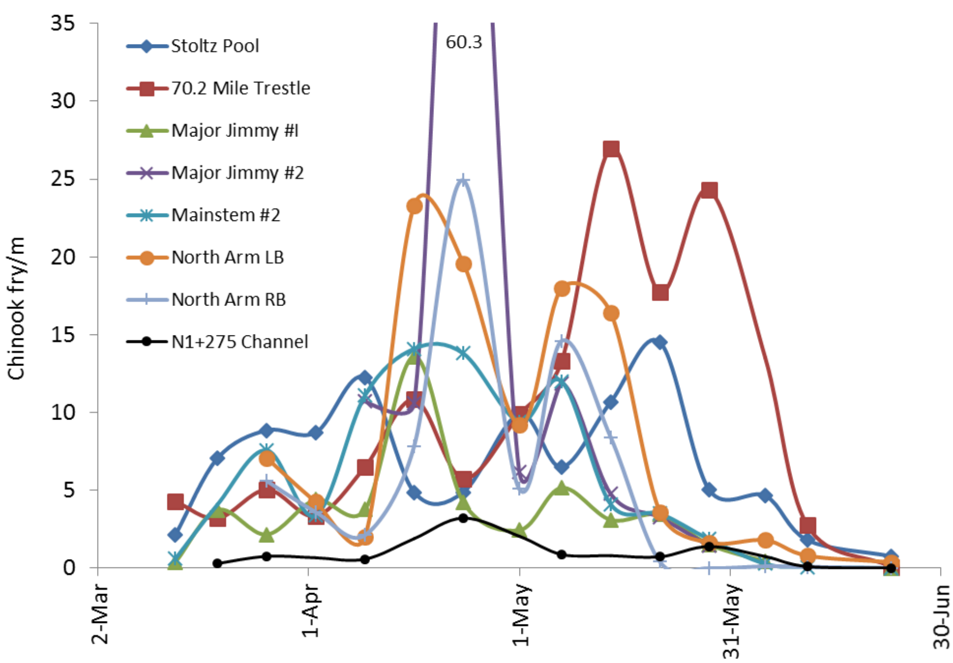

Figure 20. Cowichan River Index site observed Chinook fry per metre over the study period. N1+275 Channel data represent the mean of North and West thread densities.

The exception was the N1+275 index where densities were an order of magnitude lower, averaging 1.0 FPM and peaking at 3.2 FPM (mean of North and West thread densities). To maximize comparability of results in the estuary, survey timing needed to be flexible and geared to match tides and local conditions. However, a site reasonably surveyed one week may have been "out" the following week due to prevailing wind action and suspended sediment. This was often not evident until crews were assembled and on-site near dusk.

While Chinook abundance in lower river sites appeared to peak between mid-April and mid-May, numbers in upper river sites were highest in May, particularly at 70.2 Mile Trestle index.

To compare juvenile Chinook abundance timing observed during this study to that of previous work, we plotted our results and those of DFO RST programs between 1995 and 2002 (Nagtegaal *et al*. 1997, 1998, 2000, 2004a, 2004b; Nagtegaal and Carter 2000) on the same time scale (Fig. 21). It should be re-stated that while the DFO data are representative of counts exclusively at river km 8.0, our results include counts at upper, middle and lower river sites. The comparison highlights obvious and significant differences between results of RST and snorkel programs.

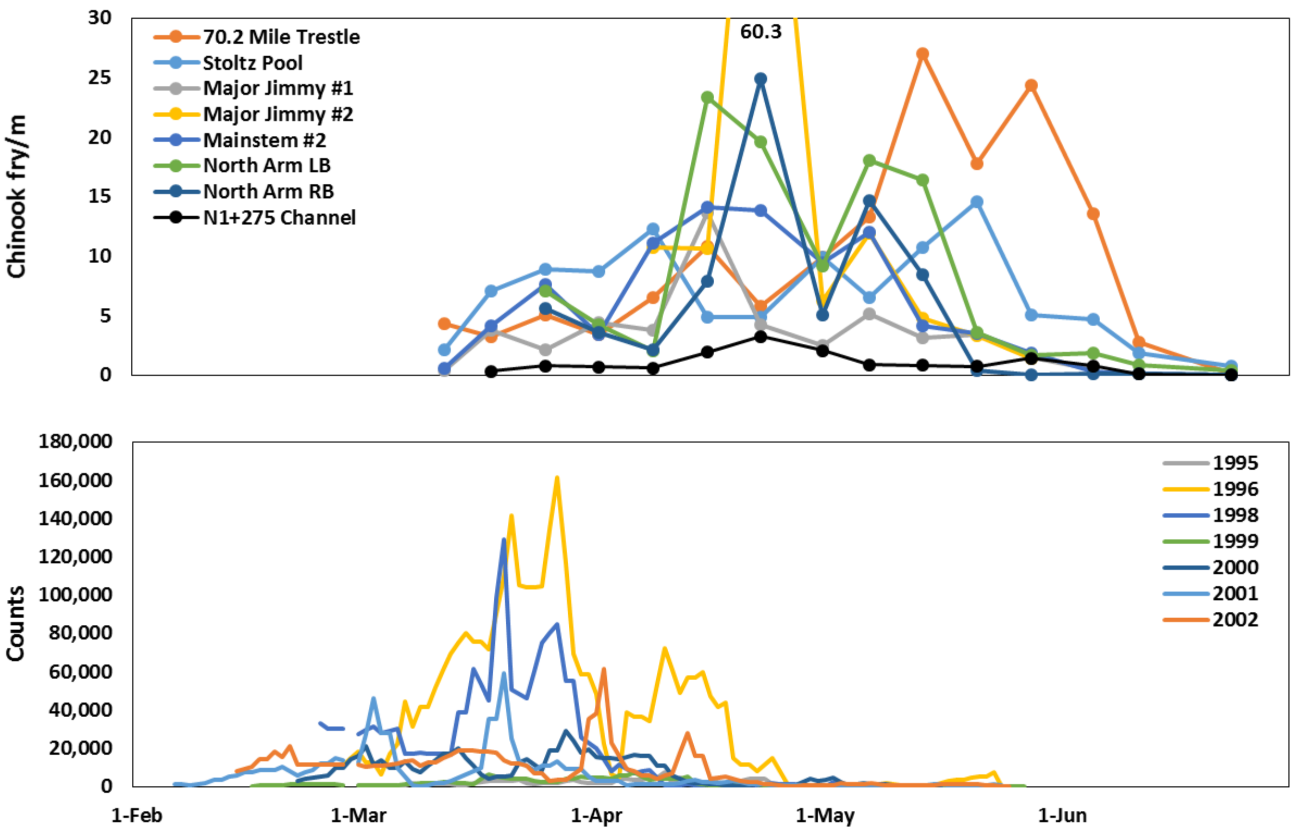

Figure 21. 2014 abundance results (Chinook observed/lineal metre; top) versus historic DFO RST data (extrapolated estimates; bottom) presented on identical time scales.

Early or "emergent fry" have been thought to comprise more than 85% of Cowichan Chinook migrants (Lister *et al.* 1971). Early fry are plainly evident and represent the bulk of migrants in DFO rotary screw trap (RST) downstream programs from 1991 to 2002 (Candy *et al.* 1996, 1996; Nagtegaal *et al*. 1997, 1998, 2000, 2004a, 2004b; Nagtegaal and Carter 2000).

However, RST avoidance or bottom-oriented migration behavior by larger "fingerling" juveniles may be significant through their outmigration period. Report authors commonly listed concerns about trap efficiency and potential trap avoidance. In a review of their trapping data, we found ratios of Chinook caught in daytime versus nighttime hours typically started at 20 to 30% in late February and early March, dropping an order of magnitude if not to zero by the end of April. Whether this was a result of migration timing/behavior or of trap avoidance was not clarified. RST programs never continued into June, often ending in mid-May due, ironically, to low catch numbers regardless of time of day. Our consistent observations of the increasing tendency of Chinook fry to hold on or just above the channel substrates, particularly as the season progresses, plausibly explains the low RST catch numbers in May and June relative to our abundance results. Additionally, in a 2014 PIT tag study on the Cowichan River, Pellett (2015, *in prep*.) found that the overwhelming majority of wild Chinook large enough to be tagged (>60 mm fork length; all caught post May 1) migrated during daylight hours. If larger "fingerling" fry are mostly migrating in the day when they can see a trap coming, and doing so on or near the bottom of the water column, RSTs that sample the upper water column may easily miss the majority of late migrants.

Despite weekly surveys of intertidal blind-end channel habitats, or periodic but wide spread surveys in a range of intertidal channel and flat habitats, no significant abundances of early migrating Chinook fry were encountered during our study. Even in the highest quality, most intact estuarine habitats such as N1+275 Channel, mean abundance rarely exceeded 2 FPM for Chinook. Though intertidal surveys were not exhaustive and produced no irrefutable result, the weight of evidence gathered did not support the concept of a large group or groups of early migrant fry successfully using the inner estuary and lower intertidal channels out to "open water", including what we observed to be "Abundance Transition Zones" (Fig. 22). *Upstream* of these zones during low tide conditions, Chinook juveniles were always encountered throughout the study using stream margin habitat with sufficient physical cover. *Within*

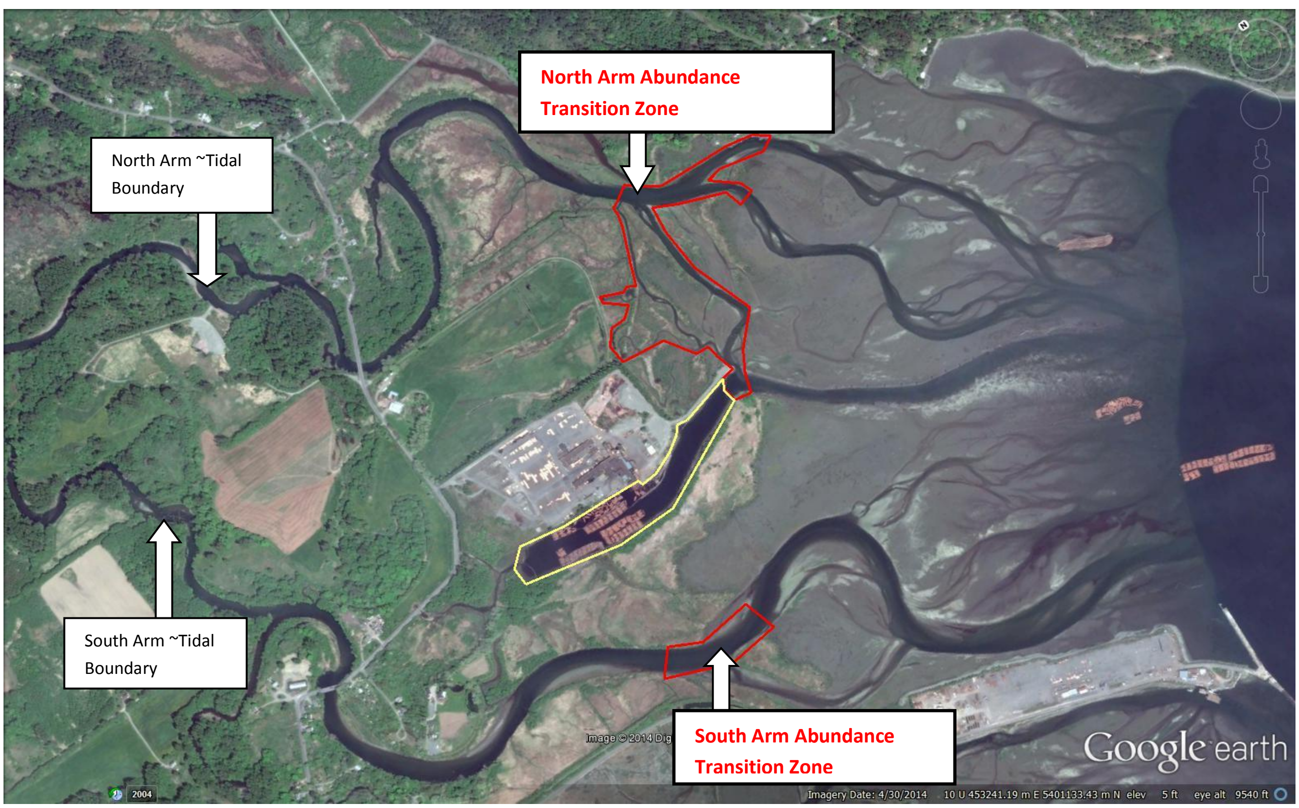

Figure 22. Lower Cowichan River and estuary, showing "Abundance Transition Zones" delineating areas of low tide juvenile Chinook presence/abundance.

these zones during low tides, Chinook were only occasionally present in the limited cover these areas offered (Appendix C, Photos 33-35). *Downstream* of these zones during low tides, Chinook were virtually absent in the remaining channels leading to open water. This study did not investigate sub-tidal habitats, but beach seines on the north shore of Cowichan Bay by Pellett (2015, *in prep*) documented densities as high as 1 Chinook/m^2 in May and June 2014.

To apply our results and "guesstimate" what the estuary might have instantaneously supported in the early season, we used Google Earth to generously estimate that up to 5,000 lineal metres of non-mainstem intertidal channel habitats might exist north of the Westcan Causeway. These habitats were assumed to have the potential to remain wetted (i.e., successfully hold rearing Chinook) through daily tide cycles in March and April, assuming typical river flows. A few were larger than N1+275 Channel, most were smaller. Because they are dry at low tides, no beach habitats were included. The only habitat not accounted for was "open water" – habitats from which historic sampling has extracted few if any fish in March and April (see below). Assuming 1 FPM (the mean density observed in the best non-mainstem intertidal habitat surveyed), the aggregate habitat could support 5,000 Chinook fry. Adjusting for observer efficiency, we could triple the number. There would presumably be some degree of replacement in this population between March and April, but it remains difficult to account for the hundreds of thousands of Chinook fry needed to support the concept of large groups rearing in the estuary. Ground truthed inventory and directed surveys of such intertidal habitats would help to confirm the use and value of these habitats to Chinook fry.

In a review of Chinook sampling in the Cowichan's estuary, large numbers have never been documented in March or April. In fact, sampled numbers have been very low to non-existent historically (Lister *et al.* 1971; Argue *et al.* 1986), during recent years reflected by DFO beach seining data (R. Sweeting, Research Biologist, DFO, Nanaimo, pers. comm.) and during this study (see section *3.4.1 – Fry Abundance – Non Index Intertidal Sites*).

To account for the large numbers evident in the RST programs in March and April and the apparent low abundance in the estuary at the same time, we wondered if the RST numbers could effectively be "housed" in the lower river. Since the initial RST program in 1991, sampling was conducted exclusively in the Pumphouse Pool at river kilometre 8.0. Chinook enumerated at the Pumphouse site could rightly be called migrants, but their subsequent behavior (timing, destination) below the sampling site was not documented. With more than 20,000 lineal metres of mainstem and large side-channel edge habitats downstream – most with little to no "local" Chinook fry production, there was and remains ample space for a large proportion of the wild production from mid and upper river spawning areas to populate and rear in lower river habitats. At 10 observed FPM, a density reached in lower mainstem index sites in the first half of April (Fig. 20), edge habitats could easily accommodate 200,000 fry. Subsequent peak abundances averaging ~20 observed FPM underscore this conclusion. Whether some degree of habitat capacity was reached was not clear; similar studies repeated following a range of brood year abundances would help to confirm this.

Though we would have liked to compare growth rates of estuary-reared and river-reared juveniles over time, this task remained incomplete. It became apparent that the logistics of sampling the same individuals multiple times would have overwhelmed the project from a staffing and budgeting perspective. Securing sufficiently large and representative samples in the estuary proper was more challenging than expected. As a result, BCCF developed a follow up project to identify the length at ocean entry of a representative adult return using otolith ablation and microchemistry techniques. This is intended to identify the relative contributions of "fry" and "fingerlings" to adult returns. At time of writing, this follow up project was resourced by DFO and was expected to generate results by mid-2015.

Trials to mark Chinook fry in index sites with VIE tags and visually recapture them during snorkel surveys were instructive overall. At 70.2 Mile Trestle index, 11% of the tag group were confirmed to have stayed in or around the index for at least 28 days, confirming residency and local rearing by a significant portion of the fry population. Results of the trial in the N1+275 Channel index suggest Chinook did not reside for more than a week in that habitat. The technique certainly proved possible, but impacts of VIE tagging of small fry were not evaluated and may have included increased mortality (tagging related), behavioral changes, displacement from the sites, increased susceptibility to predation, among others. That said, the technique may be useful to calculate populations of rearing Chinook fry within multiple "closed" sites – data that could enable instantaneous estimates of the Cowichan's standing stock.

Throughout the study, Chinook juveniles demonstrated a high affinity for edge habitat with cover composed of submerged "small stick" vegetative cover (e.g., submerged willows, Red Osier Dogwood, Nootka Rose, grasses, etc.), and especially so soon after emergence. With discharge at this time ranging from 100-200%MAD, tight schools were typically found occupying shallow (<<10 cm) stream edges choked with these types vegetation. It was clearly evident that the juvenile Chinook population most frequently used intact riparian shrub habitats on the wetted perimeter that are regularly inundated during spring discharge regimes. This was true regardless of fry size, although larger-sized "fingerling" fish later in the season used a greater diversity of habitats including LWD, and seasonal de-watering of bank and bar shrubs forced populations to alternate habitats.

Beyond any lack of classic peripheral wood/vegetative cover habitats, the following 'in-river' factors could potentially reduce Cowichan Chinook smolt yields (ignores inter-annual brood year escapements): floods/stochastic events, access/impediments to spawning migration, redd scour, redd superimposition, sedimentation, predation, degraded channel morphology (loss of pool and riffle habitat), loss of/impediments to off-channel habitat, competition (inter- and intra-specific), water quality/turbidity, loss of mid-channel LWD jams, riparian buffer conditions, flood protection works, loss of/impediments to intertidal/estuarine habitats, and others.

With respect to sedimentation (a risk factor ranked "high" by a DFO sponsored Chinook workshop in March 2013), monitoring results in 2010 and 2011 indicated that contributions during high flow events from Stoltz Bluff, historically the Cowichan's largest point source contributor, had dropped from a pre-restoration estimate of 15,000-22,000 tonnes (Oct-Mar, Burt 2008) to 1,050 and 924 tonnes in 2010/11 and 2011/12, respectively (Gaboury *et al*. 2012). Study authors suggested that fine sediments from Stoltz Bluff were not likely affecting downstream egg incubation success in recent years.

With respect to predation, no significant predator species/pits were identified during 2014 surveys. Based on observers' experience, abundances of accepted predators such sculpin or fish-eating birds did not appear unusual. Interspecific competition, however, for habitat space and/or food items in blind-end intertidal channels may at times be significant between Chinook juveniles and Threespine Stickleback. From mid to late May, Stickleback outnumbered Chinook in these "quiet water" habitats by at least 50:1. None of the lower mainstem index sites experienced those Stickleback densities. In our study, no further information was collected on how wide spread this phenomenon was across other intertidal habitats. However, large numbers of Stickleback were also caught in DFO-sponsored purse seines in Cowichan Bay (K. Pellett, Biologist, BCCF, pers. comm.), dominating the catch in some instances (https://nwsalmonprojects.basecamphq.com/projects/11892118-cowichan-research-study/files, "Trudel-Neocaligus-2014" PowerPoint).

Examinations of micro-habitat preference demonstrated a strong relationship between mean fork length of the population using the habitat and mean velocities measured at observed holding locations. Results were closely aligned to current day habitat suitability curves and emphasized the predictability of micro habitats preferred by juvenile Chinook. Strong relationships were also evident between fork length and distance from the wetted edge. When considering or designing habitat restoration intended to benefit Chinook, such information is highly pertinent and, when incorporated, has potential to improve project success rates significantly.

Our results clearly showed that from a riverine and inner estuary perspective, mainstem and large side channel edge habitats with suitable velocities and intact riparian vegetation appeared most important for Chinook fry rearing, particularly early in the season (Appendix C, Photos 36-38). If either of these characteristics was lacking, Chinook abundance was adversely affected. Abundance was highest when "small stick" vegetation was present, particularly instream. Though the importance of lower mainstem habitats in general has been discussed previously (Lill *et al*. 1975; Kumori 2010), our results suggested the rest of the mainstem also supported significant numbers of rearing fish where edge habitats were intact and flourishing, and that it was as important as the lower river. The amount of intact riparian habitat that acts as overstream or instream cover along mainstem and large side channels may be a limiting factor for Chinook in years of high fry production. Loss of such habitat due to flood protection, farming and residential/industrial development has likely reduced the Cowichan's capacity to support rearing Chinook throughout the river, but especially below Allenby Bridge. From this point downstream between March and April, every lineal metre of bank appeared to become populated, or not, according to two stream edge characteristics: cover and velocity.

Observations suggested side channels needed to have sufficient discharge before Chinook were consistently present. Early reconnaissance of channels with half the volume and size of the Major Jimmy side channel found little Chinook utilization except at pinch points or gradient changes where velocities increased. If over or instream vegetation was present, numbers were higher yet.

Given that Chinook fry were observed, albeit in low abundances, in virtually all intertidal habitats including blind-end channels in the first half of the season, the historic loss of these habitats may constitute a secondary limiting factor, particularly in years following increased escapements with higher production and potential for fry displacement to the estuary. Many such channels in the Cowichan's inner estuary are cut off or poorly connected due to diking and/or erosion protection.

In spring 2014, Cowichan Hatchery Chinook were released in two groups and 100% of the standard production were adipose fin clipped (AFC)[7]. A total of 105,000 fish averaging 4 g were released in the upper river just below Cowichan Lake during the morning and early afternoon of April 23, and a comparable number was released at a similar location on May 15 (DFO data). Including results from BCCF's related PIT tag study (Pellett 2015, *in prep.*), 30 fish sampling events between April 23 and June 23 identified proportions of wild vs. hatchery juveniles using river and intertidal habitats (Fig. 23). Twenty events encountered no AFC fish whatsoever; seven of the remaining 10 showed that AFC

[7] Approximately 2,500 hatchery Chinook were graded out early as "smalls" and neither adipose fin clipped or coded wire tagged. All of these fish were PIT tagged as part of BCCF's Cowichan 2014 Chinook PIT tag project (Pellett 2015, *in prep*).

fish represented from 0.9% to 21.6% of the total number sampled from that habitat. Proportions in the remaining three events were not definitive as Chinook that were too small for PIT tagging were released immediately without being counted. Throughout this time, our sampling continued to follow a weekly regime, and AFC fish were encountered within the first and second weeks post-release, but not after that with one exception: 7.5% of Chinook (4 of 53) beach seined at night off the north side of the Westcan Causeway on May 14 (22 days post-release) were of hatchery origin.

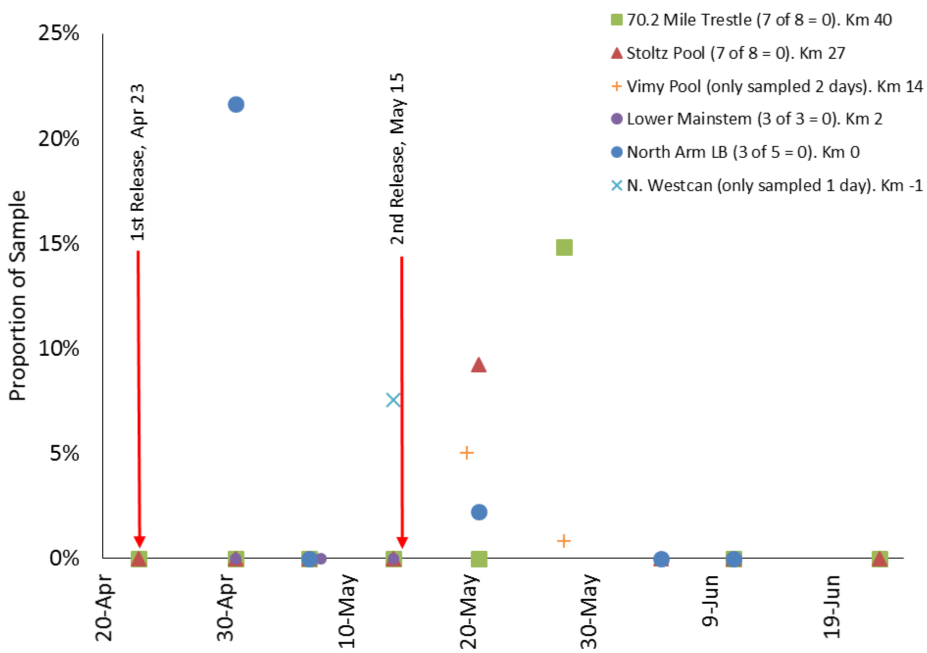

Figure 23. Sampling days and locations where hatchery origin juvenile Chinook were encountered.

Further to these interactions, we documented that the mean lengths of hatchery Chinook, where sampled, were slightly larger than the largest of wild Chinook sampled. Assuming hatchery fish were as fit as their wild counterparts, and given the species' preference for specific velocities, rearing hatchery fish might be spatially separate from wild fish, seeking slightly higher velocities. However, given the range of lengths of hatchery fish, habitat overlap would almost certainly occur.

The following stock or habitat assessment and research activities can improve our understanding of Cowichan Chinook early life history from the river to the inner estuary:

- Life History Research. Otolith ablation and microchemistry analysis could be used to determine the length at ocean entry of a representative adult return. This will help focus habitat restoration and stock recovery efforts because we will know the degree to which "fry" and "fingerlings" each contribute to current day adult recruits. At time of writing, a single analysis of the 2013 return year adults was underway, but analysis of additional years would increase confidence in results.
- Inventory and Protection of Lower River Riparian Habitats. In a review of current datasets, there appeared to be no detailed inventory of the condition of overstream and instream vegetation in the lower mainstem and adjacent side channels that, dependent on flows, acts as fish habitat. Such inventory could form the basis of a long term riparian rehabilitation program. Results of an application by BCCF to the provincial Habitat Conservation Trust Foundation for pilot project funding are expected in March 2015.

- Habitat Use Assessment Using PIT Tags. Continue work commenced in 2014 (Pellett 2015, *in prep*.) to confirm timing and duration of use of various habitats including mainstem, side channel and estuary by size and origin using PIT tag technology. Funded in year one by Pacific Salmon Commission and Salish Sea Marine Survival Project.
- Juvenile Standing Stock Population Estimate. An instantaneous population estimate prior to emigration would greatly improve subsequent survival estimates, particularly those of early marine stages (i.e., sub-yearling). This might be accomplished through a well-designed multiple "closed site" mark re-capture using VIE tags.
- Estuary Rearing Habitat Inventory. Closely examine all intertidal habitats to determine their current and, with rehabilitation, potential ability to support rearing Chinook. Prioritize subsequent restoration based on potential to create optimal conditions for salmonids, particularly Chinook. Possibly include assessments of the effectiveness of the proposed 2015 Westcan Causeway breach (see next).
- Abundance Evaluation – North vs. South of the Westcan Causeway. Though far from exhaustive, sampling during this study lent weight to the perception that the Westcan Causeway affects natural distribution of Chinook fry and other salmonids, delaying if not restricting recent Cowichan migrants from utilizing habitats in the southern third of the estuary. Additional coincidental sampling of similar habitats north and south of the causeway from late April to mid-June would help to clarify this issue. If completed, a pending project by Cowichan Estuary Restoration and Conservation Association to breach the causeway will have obvious implications to this activity.
- Spring Run Chinook Timing, Distribution and Abundance. Identify the presence/abundance, timing and distribution of the remnant spring run of Cowichan Chinook. Determine and deliver effective strategies to recover this run and promote its sustainability.

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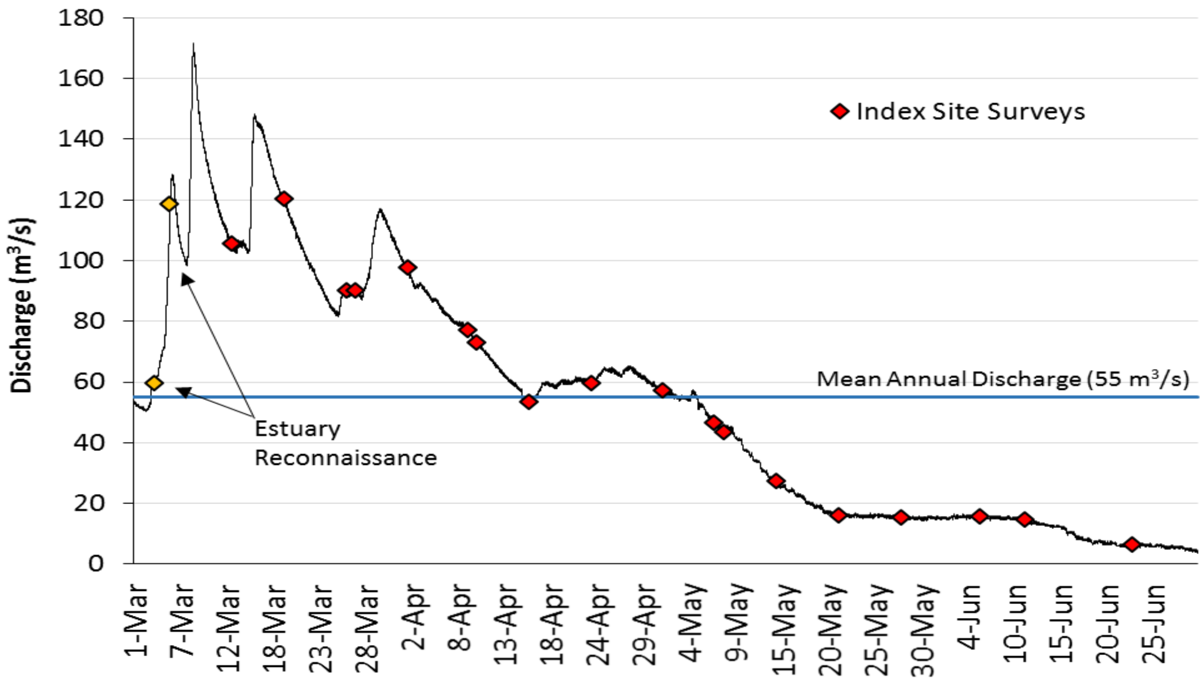
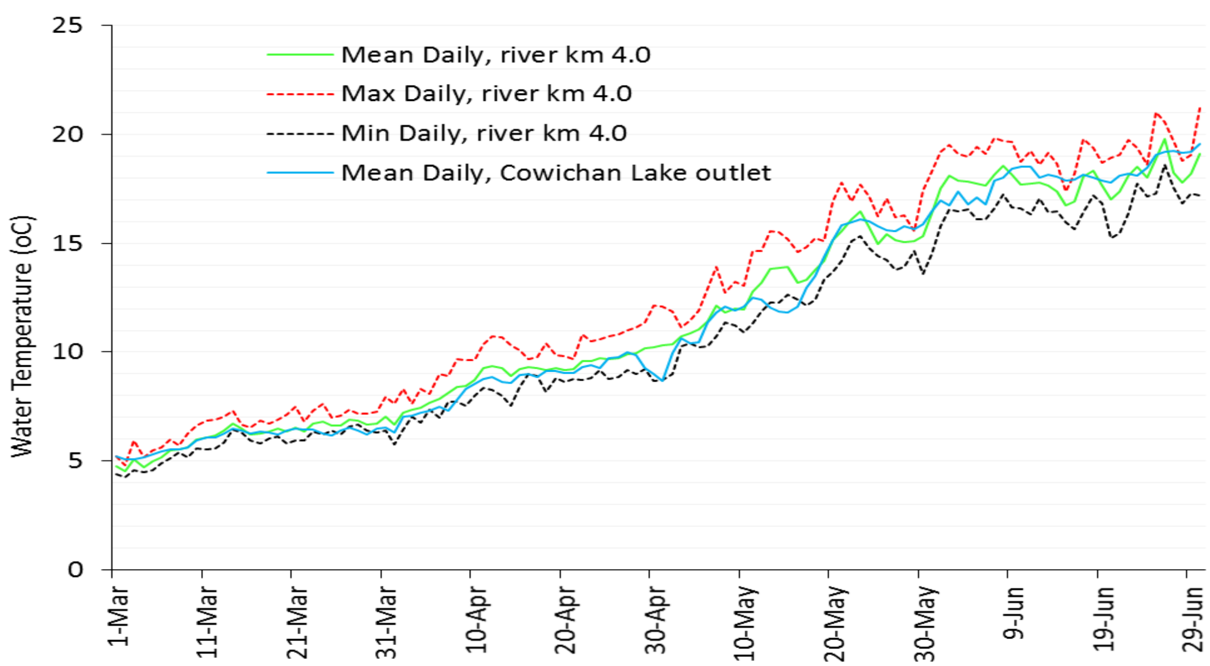
Appendix A: Environmental Parameters.

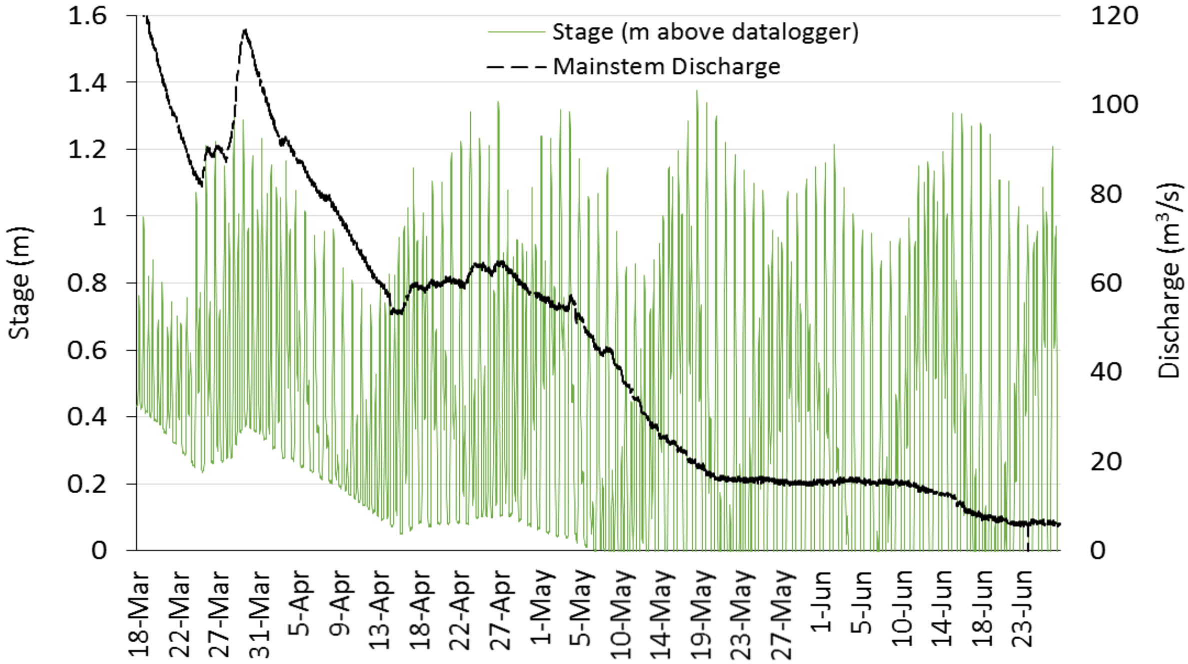


Cowichan River provisional discharge, March 1 – June 30, 2014. Data from Water Survey of Canada website (http://wateroffice.ec.gc.ca/) for station 08HA011, "Cowichan River near Duncan", located at river km 6.8.

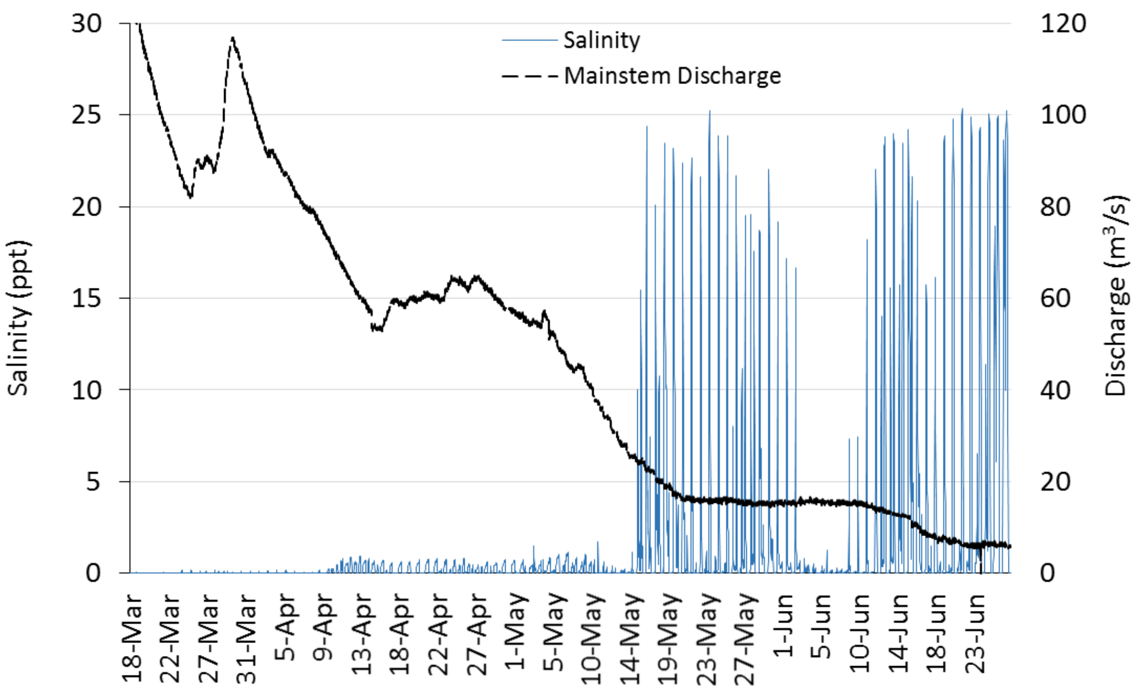


Cowichan River water temperature, March 1 – June 30, 2014, recorded at river km 4.0 and at lake outlet.

Appendix A, continued. **Environmental parameters during the study.**

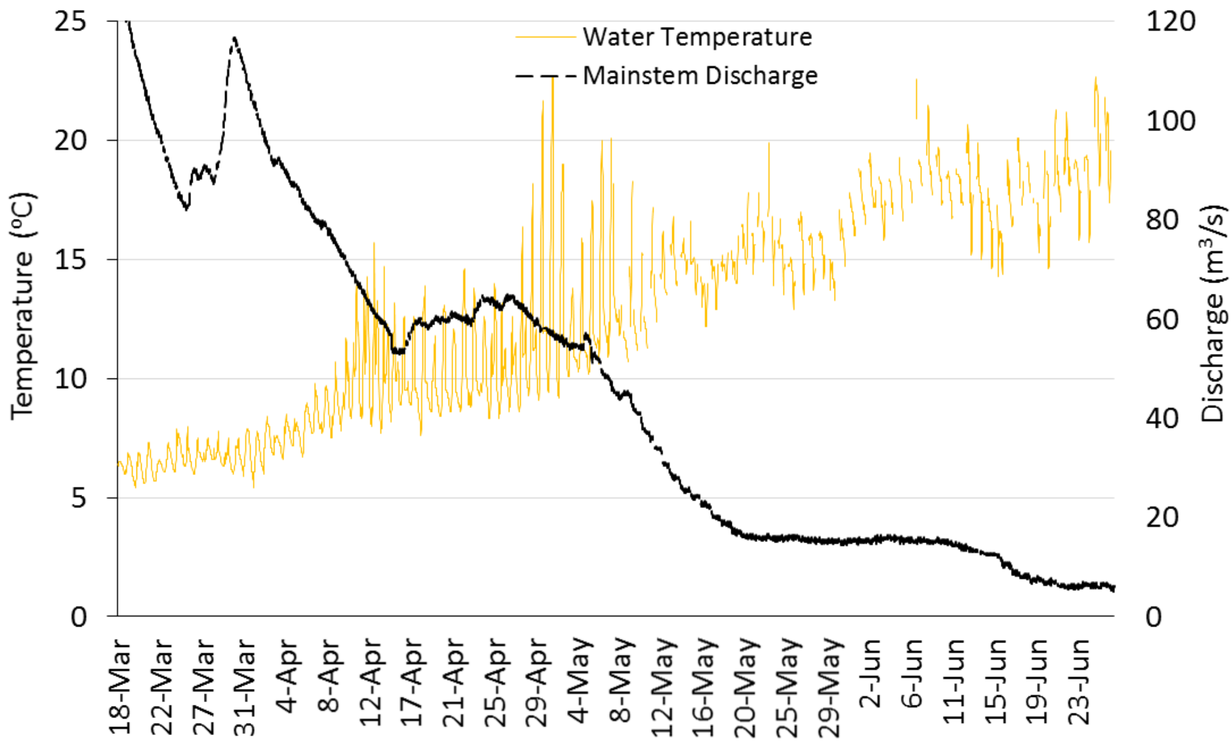


Water levels recorded in the blind-end N1+275 Intertidal Channel, March 18 - June 27. Until May 7, mainstem discharge maintained water levels regardless of daily tides. Afterwards, the channel held residual levels only.



Salinities recorded in the blind-end N1+275 Intertidal Channel, March 18 - June 27. Until May 15, mainstem discharge overwhelmed any tidal salt wedge. Afterwards, high tides strongly influenced channel salinities.

Appendix A, continued. **Environmental parameters during the study.**



Water temperatures recorded in the blind-end N1+275 Intertidal Channel, March 18 - June 27. Hourly records from the latter half of season when the datalogger de-watered during low tides are omitted.

Appendix B: Weekly Survey Reports (under separate cover).

Appendix C: Photographic Record.

	
Photo 1. 70.2 Mile Trestle index site. View looking upstream, early fry season (March).	Photo 2. 70.2 Mile Trestle index site. View looking downstream, early fry season (March).
	
Photo 3. 70.2 Mile Trestle index site. View looking upstream from same location as photo 1, late fry season (June).	Photo 4. 70.2 Mile Trestle index site. View looking downstream from same location as photo 4, late fry season (June).

Appendix C, continued

Photo 5. Stoltz Pool index site. View looking downstream at complex instream cover (instream vegetation, SWD), early fry season (March).

Photo 6. Stoltz Pool index site. View looking downstream at end of site, early fry season (March).

Photo 7. Stoltz Pool index site. Underwater view of complex instream vegetation and SWD, late fry season (June).

Photo 8. Stoltz Pool index site. View looking downstream at end of site, from same location as photo 6, late fry season (June).

Appendix C, continued

	
Photo 9. Major Jimmy side channel index site #1. View looking upstream, early fry season (March).	Photo 10. Major Jimmy side channel index site #1. View looking downstream, early fry season (March).
	
Photo 11. Major Jimmy side channel index site #1. View looking upstream from same location as photo 9, mid fry season (April).	Photo 12. Major Jimmy side channel index site #1. View looking downstream from same location as photo 10, mid fry season (April).

Appendix C, continued

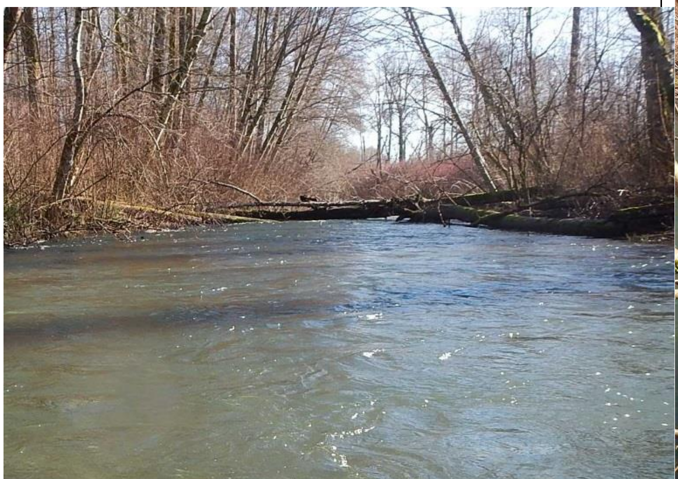
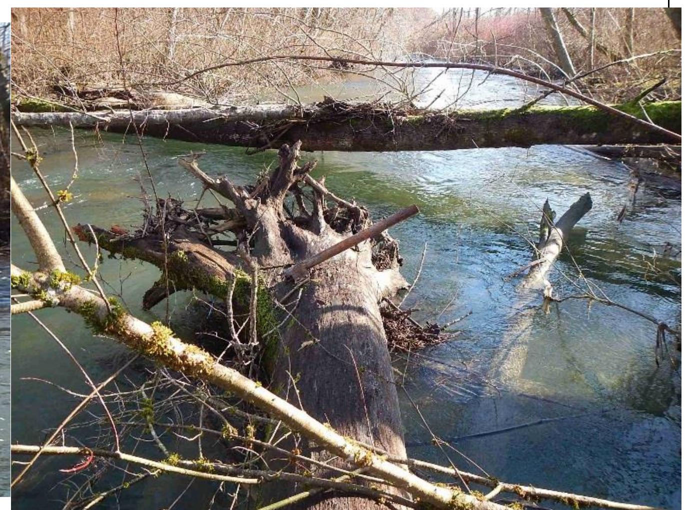
	

Photo 13. Major Jimmy side channel index site #2. View looking downstream from top of site, early fry season (March).	Photo 14. Major Jimmy side channel index site #2. View looking downstream at mid-site, early fry season (March).

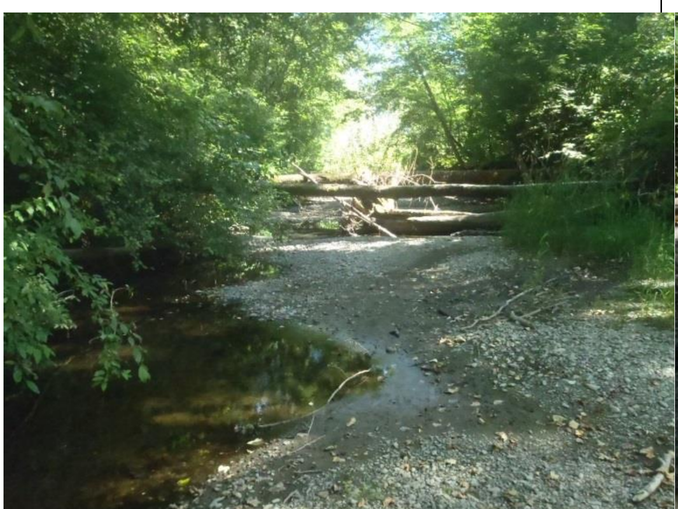



Photo 15. Major Jimmy side channel index site #2. View looking downstream from same location as photo 13, after late fry season (July; flow=0).	Photo 16. Major Jimmy side channel index site #2. View looking downstream at mid-site, from same location as photo 14, after late fry season (July; flow=0).

Photo 17. Mainstem #2 index site. View looking upstream, mid fry season (April).

Photo 18. Mainstem #2 index site. View looking downstream, early fry season (March). Flags are at site’s mid point; log sweeper is downstream end.

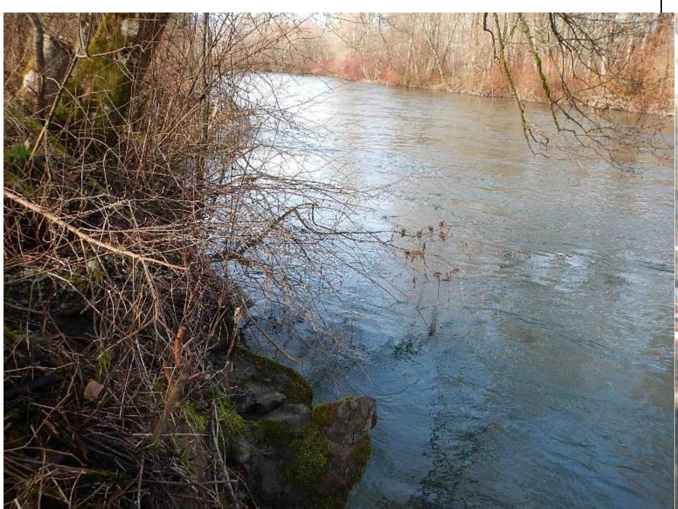
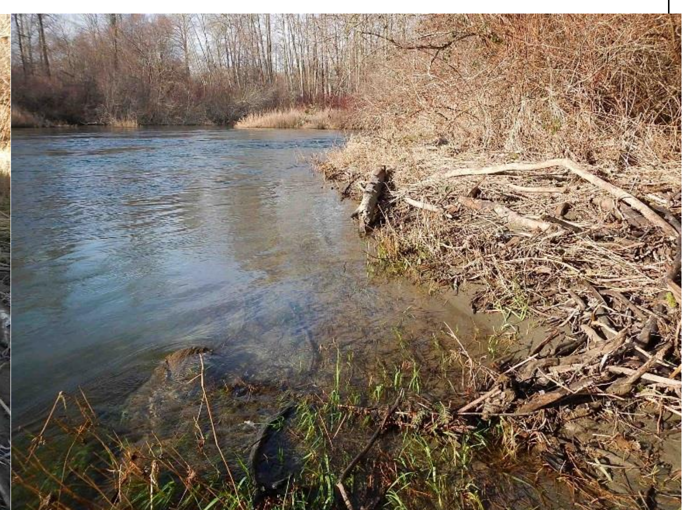


Photo 19. Mainstem #2 index site. View looking upstream from mid-point of site, early fry season (March).

Photo 20. Mainstem #2 index site. Underwater view of submerged grass/SWD habitat used by Chinook, early fry season (March).

Appendix C, continued

	
Photo 21. North Arm Left Bank index site. View of lower half looking cross-stream from Tzouhalem Rd bridge, early fry season (March).	Photo 22. North Arm Left Bank index site. View of lower half looking downstream from Tzouhalem Rd bridge, early fry season (March).
	
Photo 23. North Arm Left Bank index site. View looking upstream from beneath Tzouhalem Rd bridge, early fry season (March).	Photo 24. North Arm Left Bank index site. View looking upstream from mid-point of site, early fry season (March).

Appendix C, continued

	
Photo 25. North Arm Right Bank Index. View looking upstream, early fry season (March).	Photo 26. North Arm Right Bank Index. View looking downstream, early fry season (March).

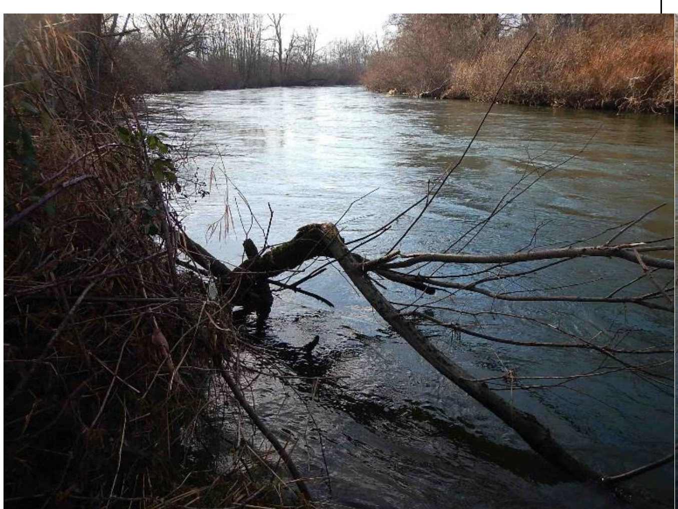
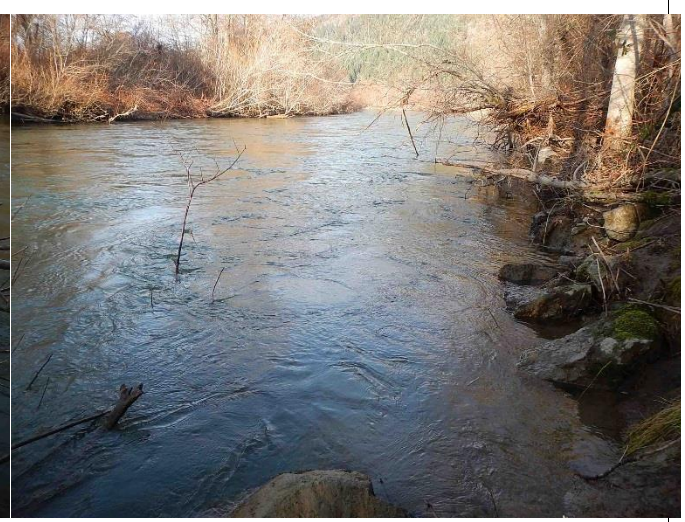

	

Photo 27. North Arm Right Bank Index. View looking upstream, early fry season (March, following flood).	Photo 28. North Arm Right Bank Index. View looking downstream, early fry season (March, following flood).

	
Photo 29. N1+275 Salt Marsh Channel index site (West Thread; March 27, 1900h, tide ebbing to 1.2 m low at 2113h). View looking west from confluence of north, west and south threads.	Photo 30. N1+275 Salt Marsh Channel index site (West Thread; March 27, 1900h, tide ebbing to 1.2 m low at 2113h). Snorkelers dipnetting salmonid fry for sampling.
	
Photo 31. N1+275 Salt Marsh Channel index site (Main thread, March 3, 1130h, tide ebbing to 1.5 m low at 1311h). View looking east from Main thread towards Cowichan North Arm, during site reconnaissance.	Photo 32. N1+275 Salt Marsh Channel index site (North thread, March 3, 1130h, tide ebbing to 1.5 m low at 1311h). View looking north of lower North thread from Main thread, during site reconnaissance.

Appendix C, continued

Photos 33-34. Upstream and downstream views of North Arm bifurcation channel N1+490 during low tide, May 21.

Photo 35. Downstream view of North Arm bifurcation channel N1+490 during moderate to high tide.

Photos 36-38. Clockwise from top: downstream, upstream at river level, and underwater views of the North Arm left bank “Nootka Rose” sampling site.

Appendix D: Index Site Habitat Surveys

STREAM EDGE INDEX SITE: 70.2 Mile	River km 40.6. Left bank, via TCT, just upstream of 70.2 Mile Trestle. UTM coords: 10U 426333 m E, 5406183 m N	
Bankfull Channel Width (m):	35	
Gradient (%)	0.0 / 0.4	50 m Site's surface water gradient at base flow / Reach gradient.
Riparian Vegetation: Type:	M	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous
Stage:	MF	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest
Canopy:	1	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered

HIGH FLOW CONDITION (early fry)

Habitat Type adjacent to 50 m edge: Riffle % 5 | Pool % 10 | Glide% 85

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 2.3 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

Cover	%
LWD	-
SWD	15
Boulder	-
Cutbank	-
Deep Pool	-
Overhanging Veg	10
Instream Veg	65
CH Area w Cover (%; sum of above):	90

Veg Species (in order of abundance or relevance as fish habitat): *Salix lucida* (Pacific willow), *Salix scouleriana* (Scouler's willow), *Phalaris arundinacea* (reed canary grass), *Populus balsamifera ssp. trichocarpa* (black cottonwood), *Cornus stolonifera* (red osier dogwood), *Rubus discolor* (Himalayan

Bed Material (beneath rearing CH):

Dom: G | Sub-Dom: C | (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	Sample No. #1	#2	#3	#4	#5	Mean
0	85	190	One D50 sample per transect.					
10	43	120						
20	30	55						
30	19	45						
40	17	50						
50	17	42						

LOW FLOW CONDITION (late Fingerlings; mainstem = 5 m^3/s)

Habitat Type adjacent to 50 m edge: Riffle % 15 | Pool % 10 | Glide% 75

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 6.8 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

Cover	%
LWD	-
SWD	-
Boulder	15
Cutbank	-
Deep Pool	10
Overhanging Veg	-
Instream Veg	-
CH Area w Cover (%; sum of above):	25

Veg Species (in order of abundance or relevance as fish habitat): Same species present as above, but no vegetation in or near wetted perimeter ATOS (only dry cobble and gravel)

Bed Material (beneath rearing CH):

Dom: G | Sub-Dom: C | (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	Sample No. #1	#2	#3	#4	#5	Mean
0	92	340	100	90	73	126	73	92
10	60	256	66	50	60	60	66	60
20	23	106	23	30	23	20	20	23
30	22	183	30	20	20	23	26	24
40	25	126	30	26	26	23	20	25
50	24	126	23	23	23	23	26	24

STREAM EDGE INDEX SITE: Stoltz Pool	River km 25.7. Left bank, access via Stoltz Provincial Park. UTM coords: 10U 434124 m E, 5402222 m N
Bankfull Channel Width (m):	39.3
Gradient (%)	0.74 / 0.4 — 50 m Site's surface water gradient at base flow / Reach gradient.
Riparian Vegetation: Type:	M — N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous
Stage:	MF — INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest
Canopy:	1 — 1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered

HIGH FLOW CONDITION (early fry)

Habitat Type adjacent to 50 m edge: Riffle % 15 Pool % 45 Glide% 40

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 1.6 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

Cover	%
LWD	-
SWD	-
Boulder	-
Cutbank	-
Deep Pool	-
Overhanging Veg	-
Instream Veg	95
CH Area w Cover (%; sum of above):	95

Veg Species (in order of abundance or relevance as fish habitat): *Salix scouleriana* (Scouler's willow), Salix lucida (Pacific willow), *Phalaris arundinacea* (reed canary grass), *Populus balsamifera ssp. trichocarpa* (black cottonwood), *Cornus stolonifera* (red osier dogwood), *Rosa nutkana* (Nootka rose),

Bed Material (beneath rearing CH):

Dom: Sand Sub-Dom: Gravel (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	Sample No. #1	#2	#3	#4	#5	Mean
0	7	50	2	5	13	9	4	7
10	17	33	25	16	23	13	8	17
20	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
30	3	10	5	3	2	2	3	3
40	13	30	5	5	4	35	14	13
50	30	66	10	39	35	32	32	30

LOW FLOW CONDITION (late Fingerlings)

Habitat Type adjacent to 50 m edge: Riffle % 25 Pool % 40 Glide% 35

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 6.0 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

Cover	%
LWD	-
SWD	-
Boulder	30
Cutbank	-
Deep Pool	30
Overhanging Veg	-
Instream Veg	-
CH Area w Cover (%; sum of above):	60

Veg Species (in order of abundance or relevance as fish habitat): Same species present as above, but no vegetation in wetted perimeter ATOS (only dry gravel and cobble)

Bed Material (beneath rearing CH):

Dom: G Sub-Dom: S (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	Sample No. #1	#2	#3	#4	#5	Mean
0	21	83	13	30	23	13	26	21
10	62	106	42	37	54	86	91	62
20	47	131	46	66	51	33	43	48
30	28	136	33	30	23	30	26	28
40	37	186	50	50	30	30	26	37
50	36	290	43	40	36	36	33	38

Appendix D, continued

STREAM EDGE INDEX SITE: Major Jimmy Side Channel #1 Adjacent to River km 3.4. Right bank via Boys & Hatchery Rds. UTM coords: 10U 450600 m E, 5402439 m N

Bankfull Channel Width (m):		12	
Gradient (%)		0.3 / 0.2	50 m Site's surface water gradient at base flow / Reach gradient.
Riparian Vegetation:	Type:	D	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous
	Stage:	MF	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest
	Canopy:	3	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered

HIGH FLOW CONDITION (early fry)

Habitat Type adjacent to 50 m edge: Riffle % - Pool % 10 Glide% 90

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 1.5 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

LWD	2	%
SWD	-	%
Boulder	-	%
Cutbank	20	%
Deep Pool	4	%
Overhanging Veg	40	%
Instream Veg	26	%
CH Area w Cover (%; sum of above):	90	%

Estimated Discharge ATOS: 3-4 m^3/s

Veg Species (in order of abundance or relevance as fish habitat): *Cornus stolonifera* (red osier dogwood), *Poaceae spp.* (grasses), *Alnus rubra* (red alder), *Salix scouleriana* (Scouler's willow), *Rubus discolor* (Himalayan blackberry), *Rubus spectabilis* (Salmonberry), *Oemleria cerasiformis* (indian plum)

Bed Material (beneath rearing CH):

Dom: G Sub-Dom: S (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	Sample No. #1	#2	#3	#4	#5	Mean
0	20	58	26	20	18	16	18	20
10	19	32	18	22	18	15	20	19
20	sand	12	sand	sand	sand	sand	sand	sand
30	8	45	15	12	7	2	3	8
40	19	40	22	20	18	15	19	19
50	16	50	20	18	15	13	15	16

LOW FLOW CONDITION (late Fingerlings)

Habitat Type adjacent to 50 m edge: Riffle % 20 Pool % 15 Glide% 65

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 4 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

LWD	10	%
SWD		%
Boulder		%
Cutbank	20	%
Deep Pool		%
Overhanging Veg	5	%
Instream Veg		%
CH Area w Cover (%; sum of above):	35	%

Estimated Discharge ATOS: 0.2 m^3/s

Veg Species (in order of abundance or relevance as fish habitat): Same species present as above, plus a few wild flower species in low abundance. Some *Fallopia japonica* (Japanese knotweed).

Bed Material (beneath rearing CH):

Dom: G Sub-Dom: C (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	Sample No. #1	#2	#3	#4	#5	Mean
0	27	80	26	20	28	30	34	28
10	32	80	18	22	40	32	48	32
20	17	70	sand	22	20	18	10	18
30	20	52	30	28	20	12	10	20
40	30	65	47	28	30	25	22	30
50	26	69.4	30	24	28	23	24	26

Appendix D, continued

STREAM EDGE INDEX SITE: Major Jimmy Side Channel #2 Adjacent to River km 3.0 Right bank via Boys & Hatchery Rds. UTM coords: 10U 450396 m E, 5402587 m N

Bankfull Channel Width (m):		10	
Gradient (%)		0.3 / 0.2	50 m Site's surface water gradient at base flow / Reach gradient.
Riparian Vegetation:	Type:	D	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous
	Stage:	MF	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest
	Canopy:	3	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered

HIGH FLOW CONDITION (early fry)

Habitat Type adjacent to 50 m edge: Riffle % - Pool % - Glide% 100

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 1.5 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

LWD	10	%
SWD	-	%
Boulder	-	%
Cutbank	5	%
Deep Pool	-	%
Overhanging Veg	30	%
Instream Veg	15	%
CH Area w Cover (%; sum of above):	60	%

Estimated Discharge ATOS: 3-4 m^3/s

Veg Species (in order of abundance or relevance as fish habitat): *Cornus stolonifera* (red osier dogwood), *Rubus spectabilis* (salmonberry), *Poaceae spp.* (grasses), *Alnus rubra* (red alder), *Salix spp.* (willow).

Bed Material (beneath rearing CH):

Dom: G Sub-Dom: S (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean
			Sample No.					
0	6	15	6	10	7	4	4	6
10	28	50	22	32	36	30	20	28
20								
30	3	7	2	2	3	2	4	3
40								
50	13	25	17	6	15	11	16	13

LOW FLOW CONDITION (late Fingerlings)

Habitat Type adjacent to 50 m edge: Riffle % 30 Pool % 20 Glide % 0 Run % 50

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 5 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

LWD	18	%
SWD	-	%
Boulder	-	%
Cutbank	-	%
Deep Pool	-	%
Overhanging Veg	2	%
Instream Veg	-	%
CH Area w Cover (%; sum of above):	20	%

Estimated Discharge ATOS: <0.20 m^3/s

Veg Species (in order of abundance or relevance as fish habitat): Same species as above, with additional forbes and wildflowers in low abundance.

Bed Material (beneath rearing CH):

Dom: G Sub-Dom: S (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean
			Sample No.					
0 10 20 30 40 50	49	90	45	50	66	36	48	49

Appendix D, continued

STREAM EDGE INDEX SITE: Mainstem #2			River km 1.75. Right bank via Boys & Hatchery Rds, Hatchery Dike Rd. UTM coords: 10U 451525 m E, 5402170 m N								
	Bankfull Channel Width (m):		44								
	Gradient (%)		0.0 / 0.2	50 m Site's surface water gradient at base flow / Reach gradient.							
	Riparian Vegetation:	Type:	D	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous							
		Stage:	MF	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest							
		Canopy:	1	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered							

HIGH FLOW CONDITION (early fry)	**Habitat Type adjacent to 50 m edge:**		Riffle %	-	Pool %	20	Glide%	-	Run%	80	
	Within the 50 m edge site:										
		Cover:	Average width of edge hab w CH:	1.5	m						
			% of the total wetted surface area **in which CH were rearing** occupied or covered by:								
			LWD	3	%						
			SWD	10	%						
			Boulder	10	%						
			Cutbank	10	%						
			Deep Pool	35	%						
			Overhanging Veg	30	%						
			Instream Veg	2	%						
	0.15		CH Area w Cover (%; sum of above):	100	%						
	50										
	0.003		Veg Species (in order of abundance or relevance as fish habitat):	*Cornus stolonifera* (red osier dogwood), *Oemleria cerasiformis* (indian plum), *Poaceae spp.* (grasses), *Alnus rubra* (red alder), *Rosa nutkana (Nootka rose), Rubus spectabilis* (Salmonberry), *Rubus discolor* (Himalayan blackberry)							
		Bed Material (beneath rearing CH):									
			Dom:	B	Sub-Dom:	C	(S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)				
			B-Axis diameters (mm; estimates):			Sample No.					
			Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean
			0	700 (edge only)	1200 (edge only)	No samples taken. Majority of substrates beyond remnant rip rap at base of streambank were sands and silts, with shifting organics.					
			10								
			20								
			30								
			40								
			50								

LOW FLOW CONDITION (late Fingerlings)	**Habitat Type adjacent to 50 m edge:**		Riffle %	-	Pool %	40	Glide%	-	Run%	60	
	Within the 50 m edge site:										
		Cover:	Average width of edge hab w CH:	8	m						
			% of the total wetted surface area **in which CH were rearing** occupied or covered by:								
			LWD	5	%						
			SWD	-	%						
			Boulder	25	%						
			Cutbank	2	%						
			Deep Pool	63	%						
			Overhanging Veg	5	%						
			Instream Veg	-	%						
			CH Area w Cover (%; sum of above):	100	%						
			Veg Species (in order of abundance or relevance as fish habitat):	Same vegeation species present as above, with wetted edge species less inundated.							
		Bed Material (beneath rearing CH):									
			Rip rap edge - Dom:	B	Sub-Dom:	C	(S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)				
			Beyond rip rap - Dom:	S	Sub-Dom:	G	(S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)				
			B-Axis diameters (mm; estimates):			Sample No.					
			Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean
			0	600	1200	No samples taken of rip rap at depth or substrates on the bottom of the channel towards the thalweg.					
			10								
			20								
			30								
			40								
			50								

Appendix D, continued

STREAM EDGE INDEX SITE: North Arm LB	River km 0.00. Left bank beneath Tzouhalem Rd. UTM coords: 10U 452691 m E, 5401662 m N	
Bankfull Channel Width (m):	25.5	
Gradient (%)	0.0 / 0.2	50 m Site's surface water gradient at base flow / Reach gradient.
Riparian Vegetation: Type:	D	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous
Stage:	YF	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest
Canopy:	1	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered

HIGH FLOW CONDITION (early fry)

Habitat Type adjacent to 50 m edge: Riffle % - Pool % 15 Glide% 15 Run% 70

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 1.5 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

LWD	10	%
SWD	5	%
Boulder	0	%
Cutbank	10	%
Deep Pool	5	%
Overhanging Veg	10	%
Instream Veg	45	%
CH Area w Cover (%; sum of above):	85	%

Veg Species (in order of abundance or relevance as fish habitat): *Poaceae spp.* (grasses), *Salix spp.* (willows), *Rubus discolor* (Himalayan blackberry), *Cornus stolonifera* (red osier dogwood).

Bed Material (beneath rearing CH):

Dom: S Sub-Dom: G (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean
0	Sand	4	Sand.					Sand
10								
20								
30								
40		10	Sand, with a thin outside edge of small gravel.					Sand
50								

LOW FLOW CONDITION (late Fingerlings)

Habitat Type adjacent to 50 m edge: Riffle % 0 Pool % 25 Glide% 75

Within the 50 m edge site:

Cover: Average width of edge hab w CH: 5 m

% of the total wetted surface area **in which CH were rearing** occupied or covered by:

LWD	5	%
SWD	3	%
Boulder	0	%
Cutbank	1	%
Deep Pool	15	%
Overhanging Veg	1	%
Instream Veg	0	%
CH Area w Cover (sum of above):	25	%

Veg Species (in order of abundance or relevance as fish habitat): Same species as above (still flooded during high tides but less thoroughly now that river Q is lower).

Bed Material (beneath rearing CH):

Dom: G Sub-Dom: S (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm):

Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean
0	200	900	15	15	10	13	23	15
10	33	90	33	28	33	50	20	33
20	40	90	40	40	40	30	50	40
30	33	40	33	28	33	33	20	29
40	20	30	20	20	20	10	30	20
50	<5	10	<5	<5	<5	<5	<5	<5

STREAM EDGE INDEX SITE: North Arm RB			River km -0.3. Right bank 300 m downstream of Tzouhalem Rd bridge. UTM coords: 10U 452691 m E, 5401662 m N								
	Bankfull Channel Width (m):		24								
	Gradient (%)		0.0 / 0.2	25 m Site's surface water gradient at base flow / Reach gradient.							
	Riparian Vegetation:	Type:	D	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous							
		Stage:	YF	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest							
		Canopy:	1	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered							

HIGH FLOW CONDITION (early fry)

Habitat Type adjacent to 50 m edge:		Riffle %	-	Pool %	-	Glide%	-	Run%	100		
Within the 50 m edge site:											
	Cover:	Average width of edge hab w CH:	1	m							
		% of the total wetted surface area **in which CH were rearing** occupied or covered by:									
		LWD	25	%							
		SWD	10	%							
		Boulder	40	%							
		Cutbank	-	%							
		Deep Pool	-	%							
		Overhanging Veg	10	%							
		Instream Veg	5	%							
		CH Area w Cover (%; sum of above):	90	%							
		Veg Species (in order of abundance or relevance as fish habitat):	*Salix spp.* (willows), *Poaceae spp.* (grasses), *Rubus discolor* (Himalayan blackberry), *Alnus rubra* (red alder), *Rubus spectabilis* (salmonberry).								
	Bed Material (beneath rearing CH):										
		Dom:	B	Sub-Dom:	C	(S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)					
		B-Axis diameters (mm):			Sample No.						
		Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean	
		0	700 (edge only)	1200 (edge only)	No samples taken. Majority of substrates beyond remnant rip rap at base of streambank were sands and silts, with shifting organics.						
		10									
		20									
		30									
		40									
		50									

LOW FLOW CONDITION (late Fingerlings)

Habitat Type adjacent to 50 m edge:		Riffle %	-	Pool %	-	Glide%	-	Run%	100		
Within the 50 m edge site:											
	Cover:	Average width of edge hab w CH:	5	m							
		% of the total wetted surface area **in which CH were rearing** occupied or covered by:									
		LWD	10	%							
		SWD	5	%							
		Boulder	15	%							
		Cutbank	-	%							
		Deep Pool	40	%							
		Overhanging Veg	5	%							
		Instream Veg	-	%							
		CH Area w Cover (sum of above):	75	%							
		Veg Species (in order of abundance or relevance as fish habitat):	Same species as above.								
	Bed Material (beneath rearing CH):										
		Rip rap edge - Dom:	B	Sub-Dom:	C	(S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)					
		Beyond rip rap - Dom:	S	Sub-Dom:	G	(S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)					
		B-Axis diameters (mm):			Sample No.						
		Station (m from top of site):	D50	D90	#1	#2	#3	#4	#5	Mean	
		0	600	1200	No samples taken of rip rap at depth.						
		10									
		20									
		30									
		40									
		50									

Appendix D, continued

INDEX SITE: N1+275 Salt Marsh Channel		Off North Arm, right bank, 1.275 m downstream of Tzouhalem Rd bridge. UTM coords: 10U 453352 m E, 5401787 m N
Bankfull Channel Width (m):		N1+275: 2 to 6; North Arm adjacent: 50
Gradient (%)	~0.0 / ~0.0	Site's surface water gradient at low tide / Reach gradient.
Riparian Vegetation: Type:	S	N-unvegetated, S-Shrub/herb, C-Coniferous forest, D-Deciduous forest, M-Mixed Conifer/deciduous
Stage:	SHR (salt marsh)	INIT-initial stage, SHR-shrub/herb stage, PS-pole/sapling stage, YF-young forest, MF-mature forest
Canopy:	1	1 - 0-20% covered, 2 - 20-40% covered, 3 - 40-70% covered, 4 - 70-90% covered, 5 - >90% covered

LOW to MED LOW TIDE CONDITION DURING MAR/APR (Fry Timing)

Habitat Type: Intertidal blind-end channel draining salt marsh to Cowichan's North Arm. Incised channel fed by multiple threads. Complex remains fully wetted through low tides. Regular inundation of adjacent saltmarsh benches during high tides.

Within the channel lengths surveyed:

Cover: Width used by CH juveniles: Channels averaged 3 m (range 2-6 m) in width. CH used entire width but preferred banks with overhanging/submerged grass cover, or "pocket" cutbanks at base.

% of the total wetted surface area **in which CH were rearing** occupied or covered by (assumes mean channel width of 3 m):

LWD	2	%
SWD	2	%
Boulder	-	%
Cutbank	10	%
Deep Pool	-	%
Overhanging Veg / Instream Veg	20	%
CH Area w Cover (%; sum of above):	34	%

Notes:
1. Most surveys were timed to occur when depths were 1 m or less, so deep pool cover not applicable.
2. Overhanging and instream vegetation combined into one cover component.
3. Grasses still in state of senescence offered less cover.

Veg Species (in order of abundance or relevance as fish habitat): *Carex spp.* (sedges), *Poaceae spp.* (grasses), *Malus fusca* (Pacific crab apple), *Typha latifolia* (common cattail), *Carex pellita* (woolly sedge), *Schoenoplectus spp.* (bulrush), *Rosa nutkana* (Nootka rose). Grasses/sedges were just starting to bud.

Bed Material (beneath rearing CH):

Dom: Silt | Sub-Dom: Sand | (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm): Not applicable. Channel banks were vertical, 2-3 m in height, and composed of silt and sand. A thick layer (20-40 cm) of silts, organic debris with occasional SWD dominated the channel bed.

LOW to MED TIDE CONDITION DURING MAY/JUNE (Fingerling Timing)

Habitat Type: Intertidal blind-end channel draining salt marsh to Cowichan's North Arm. Incised channel fed by multiple threads. Complex remains fully wetted through low tides. Limited inundation of adjacent saltmarsh benches during high tides.

Within the 50 m edge site:

Cover: Width used by CH juveniles: Channels averaged 3 m (range 2-6 m) in width. CH used entire width, but preferred to hold over channel bottom substrates.

% of the total wetted surface area **in which CH were rearing** occupied or covered by (assumes mean channel width of 3 m):

LWD	2	%
SWD	2	%
Boulder	-	%
Cutbank	10	%
Deep Pool	-	%
Overhanging Veg / Instream Veg	25	%
CH Area w Cover (sum of above):	39	%

Notes:
1. Most surveys were timed to occur when depths were 1 m or less, so deep pool cover not applicable.
2. Overhanging and instream vegetation combined into one cover component.
3. Grasses in full spring growth offered more cover.

Veg Species (in order of abundance or relevance as fish habitat): Same vegetation species as above, but grasses and sedges had growth out and were providing additional overhanging vegetation cover.

Bed Material (beneath rearing CH):

Dom: Silt | Sub-Dom: Sand | (S<2mm, G<64mm, C<256mm, B>256mm, R>4000mm)

B-Axis diameters (mm): Not applicable. Channel banks were vertical, 2-3 m in height, and composed of silt and sand. A thick layer (20-40 cm) of silts, organic debris with occasional SWD dominated the channel bed.