Coho Salmon (*Oncorhynchus kisutch*) fry population dynamics in Carnation Creek

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Abstract:

Salmon are keystone species to multiple environments and are heavily relied upon by many different organisms. This study compares the populations of rearing Coho salmon fry (*Oncorhynchus kisutch*) at pre-established sampling sections of Carnation Creek. This population data was collected during the summer as part of the more extensive Carnation Creek Watershed study, which is the longest continuous study of logging and fish interactions in North America. Lineal density of fish was calculated for all sections within the years 2011 and 2013. The results indicate that section 8 had a significantly higher density than all other sections in 2013 but there was no significant difference among section during 2011, although section 8 had one of the higher lineal densities. This indicates that the conditions at section 8 were the most beneficial to rear Coho salmon fry. The conditions present that could be the major influence include: stream flow rate, food availability, and habitat type. No section's habitat data was available for this study; therefore no conclusion can be made whether habitat was the cause of this preference.

Introduction:

Salmon are a keystone species in both freshwater and marine environments in the Pacific Northwest (Miller 1996). They are anadromous fishes that hatch and grow within a freshwater system for up to several years before migrating to the ocean to mature for one to four years, depending on species (Healy 2009, Pinsky et al. 2009, Loring & Gerlach 2010). After growing in marine waters, they return to their native stream to spawn and die (Miller 1996, Healy 2009, Pinsky et al. 2009, Loring & Gerlach 2010). All species of salmon are voracious predators, attacking any food source that will fit in their mouths and they fill a necessary niche as primary predators in multiple ecosystems (Page 2007). On the west coast of Canada there are five species of salmon present: Chinook (*Oncorhynchus tshawytscha),* Coho (*Oncorhynchus kisutch),* Sockeye (*Oncorhynchus nerka),* Chum (*Oncorhynchus keta*), and Pink (*Oncorhynchus gorbuscha)* (Hartman et al. 1982, Miller 1996, Jaeger & Mikesell 2002, Pinsky et al. 2009)

In the Pacific Northwest, salmon are also essential for the survival of many apex predators, such as bears, sharks, whales, and seals (Miller 1996). These individuals rely on salmon spawning runs as a main source of food (Hocking & Reynolds 2011). Along with providing sustenance to predators, salmon also transport many marine nutrients to the streams when returning to spawn. Decomposition of the spawned out adults supplies many nutrients necessary for riparian areas to thrive, without which a large decline would occur in both salmon predator populations and the overall health of riparian areas (Hocking & Reynolds 2011). Based on the salmon population's effects on the environment and the reliance predators have on salmon, they are a vital component of the Pacific Northwest ecosystem.

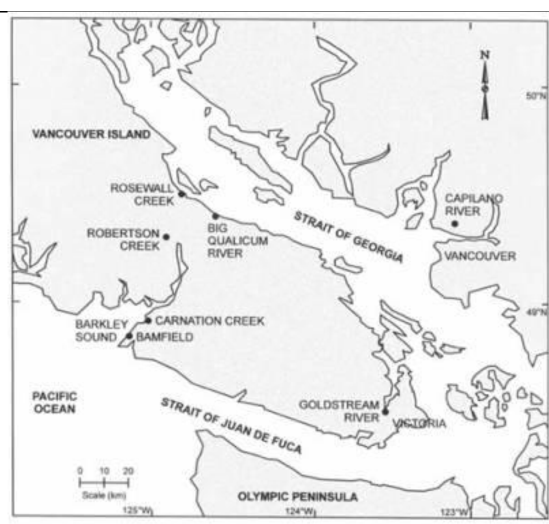
Salmon are an integral part of the way of life of many first nations groups along the west coast of Canada (Knowler et al. 2003, Healy 2009). The first nation's people, especially those that live in remote locations where jobs are scarce, fish for salmon in both subsistence and commercial fisheries (Knowler et al. 2003, & Loring & Gerlach 2010). Due to the reliance of small communities on salmon, a poor years return of adult fish negatively affects the local economy as well as the areas ecosystems (Loring & Gerlach 2010). In addition to being a primary food and income source to the natives, salmon are a central part of their culture (Miller 1996). Therefore, a poor salmon run would have both economic and cultural significance to the native people of the Pacific Northwest.

The Carnation Creek Watershed project has been in operation since 1970 and is the oldest ongoing salmon fry studies in North America (Hogan et al. 1998, Hartman & Scrivener 1990). Initiated to study the effects of logging on a small, west coast rain forest stream and its impact on the stream's fish populations, the project includes measurement of parameters such as seasonal water levels, precipitation, and stream conditions as well as abundance of rearing salmonid fry (Hartman et al. 1982). Data collected throughout this 43 year-long study includes data from pre-logging, logging, and post logging periods (Hartman & Scrivner 1990, Holtby 1988). Coho salmon are the most abundant fish species, but the watershed also contains populations of Rainbow trout (*Oncorhynchus mykiss*), Cutthroat trout (*Oncorhynchus clarkii*), two species of sculpin (*Cottus aleuticus* and *Cottus asper*), and a small run of chum salmon (*Oncorhynchus keta*) within its estuarine waters (Hogan et al. 1998).

The objective of this particular study is to determine the lineal densities of *O. kistuch* at pre-established sections along Carnation Creek three times each year for both sample years. The three sampling periods each year will be averaged and compared among each other to see which sections are able to house the highest density of Coho salmon fry. This data indicates the fry's preference on habitat present at the sections with the largest densities present. However, no section's habitat data was available; therefore no significant results could be determined on the fry's preferred habitat choice based solely off the density data.

Study site

Carnation Creek (49N, 125W) is found on the west coast of Vancouver Island, Canada and drains into Barkley Sound (Figure 1a) (Tschaplinski et al. 1998, Tschaplinski 2012). This remote stream is about 7.8km long and the entire watershed covers approximately 10km^2 (Hartman et al. 1982) (Figure 1b). Anadromous fish, such as *O. kisutch* fry, only have access to the lower 3.5km of the stream, which consists primarily of pools with rock and gravel substrates connected by riffles. Pools are usually formed around logs and other debris and it is hypothesized that the pools are the preferred habitat for Coho fry, as they have calmer waters and have a higher potential for more cover from high stream flows and predators. (Hartman et al. 1982) It is further hypothesized that the sections with the most pools will have the highest Coho salmon fry populations.



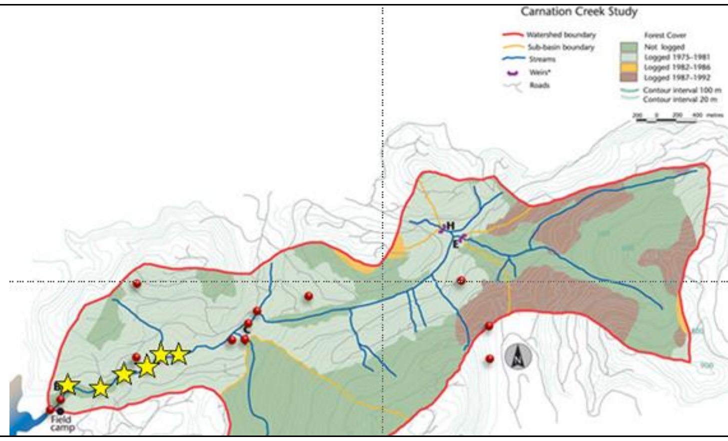


Figure 1.a. Carnation Creek's location on Vancouver Island (top) and b. all study sections located within the watershed (bottom) (Tschaplinski 2012)

Methods and Materials:

The population survey of Coho salmon fry (*Oncorhynchus kisutch*), Coastrange sculpin (*Cottus aleuticus*), Prickly sculpin (*Cottus asper*), Rainbow trout (*Oncorhynchus mykiss*), and Cutthroat trout (*Oncorhynchus clarkii*) within the Carnation Creek watershed was conducted three times each year for the years 2011 and 2013. Sampling occurred during June, August and September and each sampling period ranged from six – ten days in duration. A total of nine sections have been established to sample fish populations and have been sampled every year of the 40 year term of the study. Six of the sections are in anadromous waters, and three sections which are not included in the analysis, are used only by resident cutthroat trout.

Figure 2. *O. kisutch* fry bearing sections in the Carnation Creek watershed

The survey of fish populations was accomplished by multiple passes using a combination of seine netting and electrofishing to achieve total removal of fish from each section following procedures developed by Seber and LeCren (1967). The top and bottom end of each section was netted off, and the first pass was made with a seine net. This followed by a pass with an electrofisher, and the combined passes constituted one run. Sampling occurred from the bottom to the top of the section, against the flow of the stream. Two runs were conducted at each seeection, with a third run necessary if the catch of run two was higher than 15% that of run one's catch. Poor weather conditions, such as rain and high water levels, and large quantities of debris within the stream were the main factors that would require a third run to be completed (Bayley & Herendeen 2000). After processing, the catch was returned from where the fish were caught and the stop nets were removed.

Results:

Coho salmon fry were the dominant fish species located within Carnation Creek, as shown in Fig 3. Coho fry salmon populations were significantly different between 2011 and 2013, with 2013 having significantly (two-sample T-test; $T= 12.01$, $P= 0.000$; $P > 0.005$) more fish (Fig 4.).

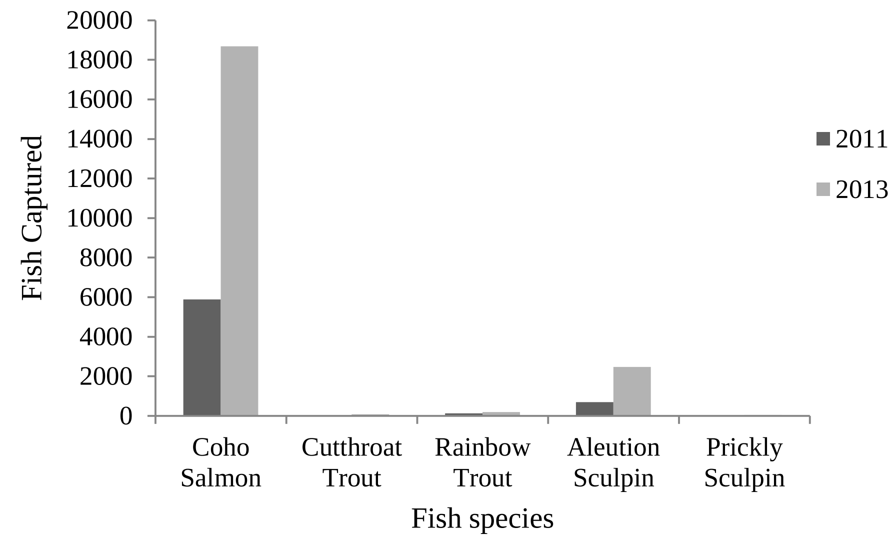


Figure 3. Fish count within Carnation Creek show Coho Salmon fry are the most abundant fish species located within the creek.

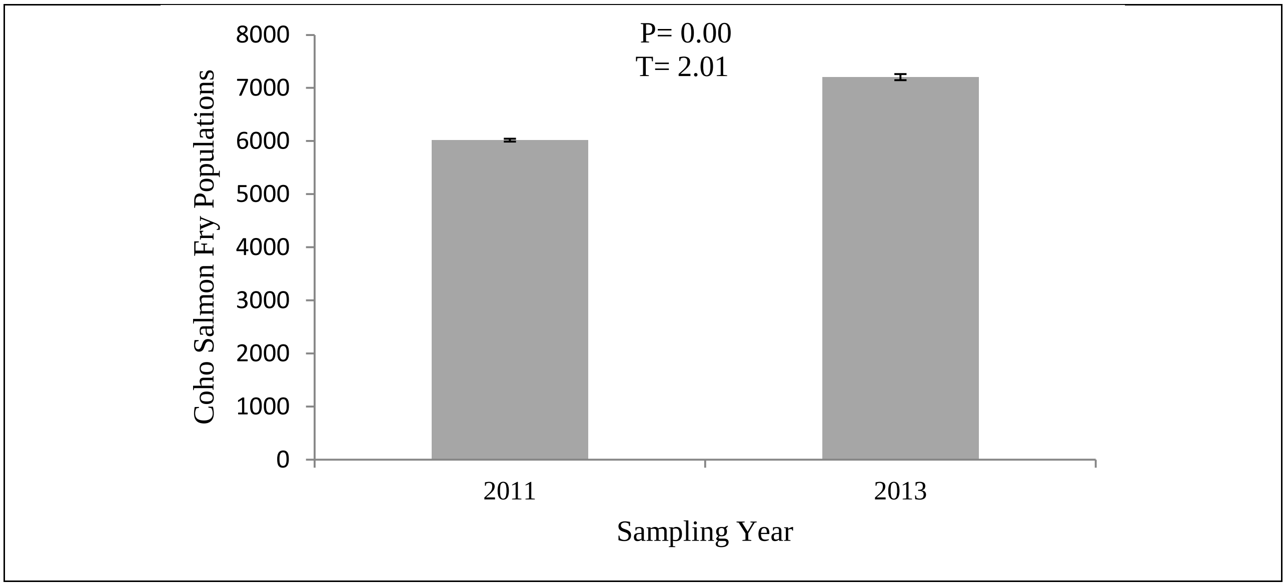
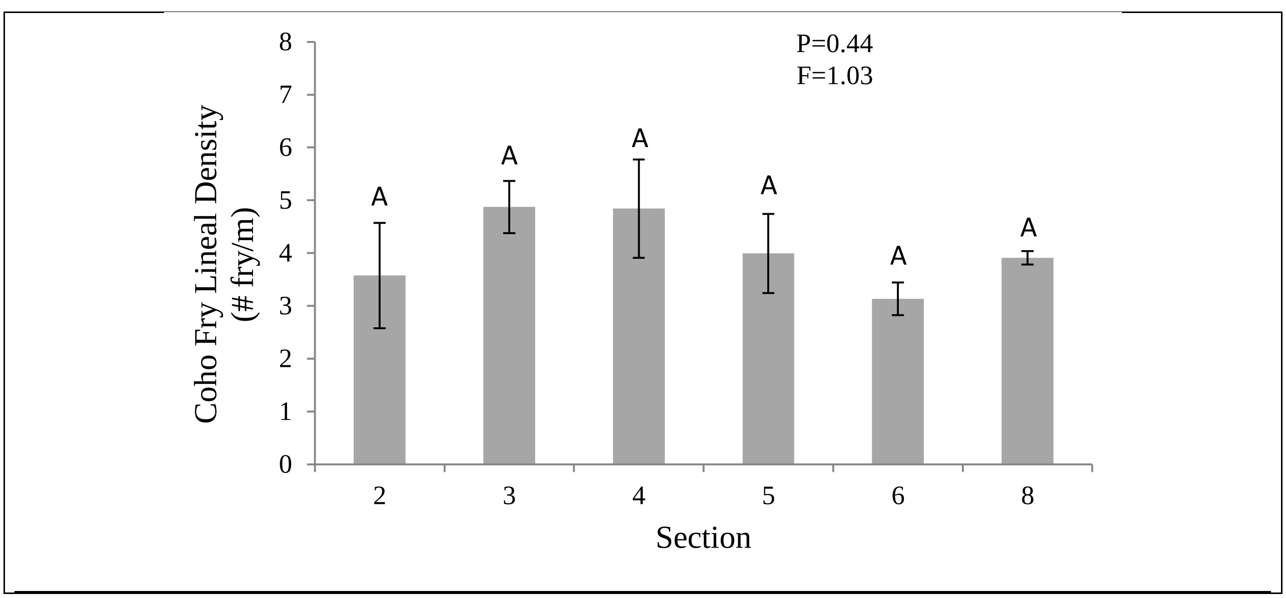


Figure 4. The 2013 sampling year (bottom) had significantly more Coho fry than the 2011 sampling year (top).

Average Coho salmon fry lineal densities in 2011 were not significantly different between sections (one-way ANOVA; F=2.28, P=0.112; P > 0.05), with all sections statistically similar, proven by a Tukey Test (Fig 5). During the sampling year 2013, the average Coho fry lineal densities among the sections were significantly different (one-way ANOVA; F=15.36, P=0.000; P > 0.05), with sections 2 and 8 significantly different from the rest (Fig 5).



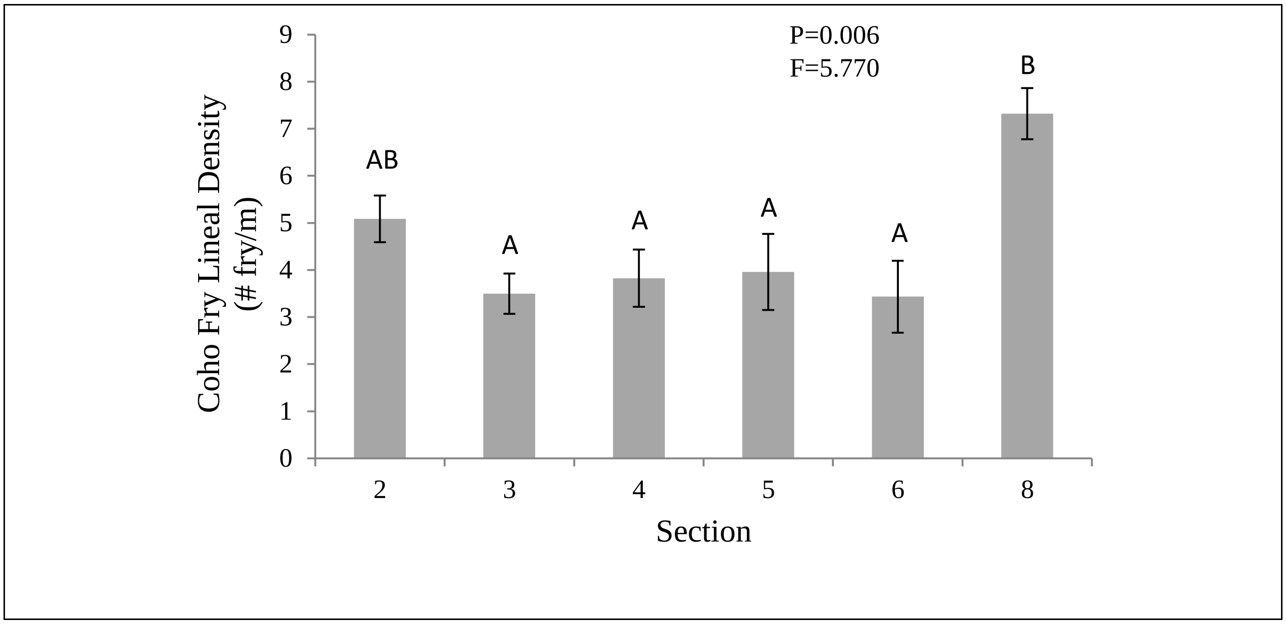


Figure 5. Coho salmon fry population's lineal densities from 2011 (top) and 2013 (bottom). In 2013, section 8 had significantly more fry present than all other sections; in 2011, all sections experienced similar fry densities.

Discussion:

Of the various trout, salmon, and sculpin species present in Carnation Creek, Coho fry (*O. Kisutch)* are the dominant species at all sections. However, Coho fry populations varied during each sampling period at all sections, illustrating the fact that some habitats will be more advantageous towards Coho fry than others. Overall, Carnation Creek's sections vary from areas of high and low populations of Coho salmon fry, believed to be a result of a combination of habitat type, area, water levels, cover and food availability present at each section. This is shown with the varying populations in 2011 and 2013. Over those two sampling years, section 8 had one of the higher lineal densities for Coho salmon fry, with the lineal density in 2013 being significantly higher than any other section during that year. These values could be due to various factors mentioned earlier, such as habitat type, water level and flow rate, and food availability.

Around 1.5 times longer than other sample sections, section 8 possesses a large area of varying habitats which could ultimately affect the population of fry. Both sides of the section house dense vegetation, with the roots holding together the stream's banks. This prevents soil erosion and regulates surface runoff into the salmon's habitat, thereby aiding their survival (Tschaplinski & Hartman 1983, Knowler et al. 2003, Romanuk & Levings 2006). The addition of large woody debris due to high water levels is a major factor in the structure of the stream's sections and therefore a major proponent on what habitat will be present at each section (Tschaplinski & Hartman 1983, Roni & Quinn 2001, Rosenfeld et al. 2000).Stream size will also have a strong impact on the density of fry located within that particular area (Rosenfeld et al. 2000). This combination of present habitat and a large area providing ample food and cover results in section 8 having the largest population of rearing Coho salmon fry in the study area

In addition to habitat present, water level and flow rate also plays a large role in the section's ability to rear large densities of Coho salmon fry. Too large a deviation from optimum stream flow has been found to result in poor rearing and spawning habitat for salmon (Jaeger & Mikesell 2002). Section 8's habitat consists of deeper pools with large volumes of in-stream debris as well as areas of shallower, faster moving riffle habitats (Hartman et al. 1982, Rosenfeld et al. 2000). Due to the presence of the deep pools, section 8 perennially contains large quantities of water, meaning even during times of drought, the section has suitable habitat for the fry, thereby increasing their survival rate relative to less favorable section further down the creek that annually possess lower levels of water.

Food availability can impact the ability of section to successfully rear large populations of animals (Ballinger 1977). This principle is no different for salmon fry (Metcalfe et al. 1999). Similar to water flow rate, there is an optimum amount of food in an area which varies from location to location. It was discovered that areas with high amounts of available food can also bring in lots of predators, therefore making the area more dangerous than areas with lower amounts of available food (Heithaus et al. 2002). This can be good for large populations of salmon fry as it will allow those that don't get predated upon enough food to mature and successfully leave the stream, however it can be just as detrimental towards their survival. The fry may be forced to areas that don't have quite as much food as the areas with high amounts of food yet also have high levels of predation (Heithaus et al. 2002). Therefore, food availability is a very difficult factor to quantify and remains a partial mystery as to what levels of food in an area promotes fry population growth and which don't.

Ultimately, if the conditions aren't at a level high enough to promote salmon fry survival, the marine environment will be negatively impacted. With less fry being reared in streams, fewer survive to maturity within the marine environment, which ultimately harms many different facets of the marine ecosystem (Kruse 1998). Commercial, subsidence, and recreational fishermen will be negatively impacted by poor salmon runs (Jaeger & Mikesell 2002, Knowler et al. 2003, Loring & Gerlach 2010, Hocking & Reynolds 2011). In addition to humans, many predators within the Pacific Northwest ecosystem require salmon as a form of energy, such as bears, seals, and killer whales (Hocking & Reynolds 2011). As the salmon's lifecycle ends after spawning, the nutrients from the decomposing body are collected and used by the vegetation on the stream banks, which ultimately aid in the protection of the juvenile salmon fry (Romanuck & Levings 2006, Healy 2009, Hocking & Reynolds 2011). Based off these complex interactions, high populations are required for life in the Pacific Northwest to continue the way it has been in the past (Healy 2009).

Overall, Carnation Creek has undergone many alterations over the years, from the 41% of its entire basin being logged to an entire lack of logging happening today (Hartman et al. 1982, Holtby 1988). While these alterations are years in the past, it is possible that they could still be impacting the creek. With no logging occurring during the sampling years of this study, all alterations to the physical environment were done naturally and therefore the fluctuation of the salmon fry populations between the two sampling years was natural also. However, this doesn't rule out the possibility that the alterations made via logging many years ago aren't still altering the physical structure of the creek, but that is difficult to study. The Coho salmon fry in carnation creek were determined to be rearing at about 57% that of their pre-logging levels over a decade ago (Tschaplinski et al.1998). Due to this decline and the fact that there have been severe cases where streams were impacted by human development enough that salmon populations have been extirpated from that stream system (Miller 1996). Due to this reliance, any activities that could potentially impact supporting populations of rearing salmon need to be monitored closely.

Further studies are required in order to ascertain what the optimum conditions are for Coho salmon fry rearing. These studies are potentially an avenue to further understand the salmon fry's requirements to successfully reach maturity in both the freshwater and marine ecosystems. Since all small streams, creeks, and tributaries have unique ecosystems surrounding them and with human alterations of environments worldwide becoming more common, the protection of instream habitats is paramount (Hicks et al. 1991, Battin et al. 2007). Without protection of the specific habitats, these systems will potentially see a decline in fish populations unless further studies are completed to help determine what humans need to do to prevent this decline.

Acknowledgements

This study is a report of a small segment of a long-term interdisciplinary study on Carnation Creek. Due to this, many people have had an input on this study and all deserve recognition. First and foremost, I wish to thank Dr. P. Tschaplinski for both the ability and the data in which to conduct this project. I also wish to thank the field crew of P. Bruce, S. Voller, and A. Westerhoff, without whom the data never would have been collected.

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