A Baseline Population Study of Juvenile Salmonids in Baker Creek, a Disturbed Lowland Stream

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Executive Summary

Puget Sound lowland streams provide valuable spawning and rearing habitat for populations of anadromous salmon and trout. Many of these lowland streams have been transformed by the anthropogenic changes resulting from urbanization. Understanding baseline population numbers and periodicity of habitat use in Puget Sound lowland streams is the first step in the decision making process towards establishing salmon recovery plans. This study was undertaken to: 1) gather data that would inform decision-making processes, and 2) better understand fisheries resources and how the rapidly changing landscape may be impacting the health of Baker Creek. The City of Bellingham's Public Works Department Environmental Resources Division installed a smolt trap in Baker Creek during the spring of 2003. Smolt traps are passive sampling devices that capture migratory fish as they move upstream and downstream in river systems. The trap was installed near the mouth of Baker Creek between Birchwood Avenue and Squalicum Parkway (Figure 1).

Results from the study indicate three main findings: 1) an outstanding diversity of salmonid and trout species currently utilize the Baker Creek system, 2) Baker Creek currently provides habitat to support multiple species of fish and age classes and 3) habitat loss and stormwater pollution may be undermining the health of the salmonids currently using the system.

Cutthroat and coho dominated the out-migration with a total catch of 380 cutthroat and 188 coho, respectively. Species caught during the study included: cutthroat, coho, steelhead, chum, brown bullhead catfish, yellow perch, stickleback, Pacific lamprey, sculpin, and large mouth bass. Multiple age classes of coho, steelhead, cutthroat were caught in the trap.

Results show that peak out-migration for all species coincided with significant rain events. In fact, 68% of the entire out-migration happened on six “rain days” during the study. Peak out-migration is usually seen as a bell-shaped curve with gradual increases and decreases from the zenith indicating gradual out-migration over time. The smolt out-migration in Baker Creek appears sharply spiked indicating the majority of out-migration occurred during brief windows of time. This out-migration pattern is explained by the large amount of impervious surfaces contained in the Baker Creek watershed.

Twenty-five percent of the lower half of the watershed is covered with impervious surfaces. Impervious surfaces prevent rain from infiltrating into the soil and moving into the creek slowly. Instead, rainwater flows rapidly over asphalt and cement into storm drains, which drain directly into streams creating a very “flashy” hydrologic regime with higher high flows and lower low flows than an undisturbed system. These surface flows also pick up pollutants from parking lots, streets, rooftops, and yards and transport chemicals and pathogens into the receiving water body. This pollutant-laden water adversely impacts fish.

After two separate storm events dead juvenile salmon were found in Baker and Squalicum creeks. Dead juvenile coho and cutthroat smolts were found upstream and downstream of the trap as well as in the trap. Coho mortalities accounted for 16% of the total coho catch over the sampling season and the dead cutthroat accounted for 5% of the total cutthroat catch over the sampling season.

In an effort to understand why fish were dying, water quality samples were taken for chlorine, turbidity, nutrients, soluble organic compounds, and 13-priority pollutant metals. The tests did not detect any single pollutant in concentrations high enough to cause fish mortality. The synergistic impact of multiple pollutants is extremely difficult to test for and often impossible to identify although it is believed to be the cause of the fish mortalities. It is unclear why coho were more affected than cutthroat. This phenomenon is not an isolated occurrence. Acute urban fish die offs have been well documented in many urban areas in the Puget Sound Basin. The Maritime Heritage Hatchery near the mouth of Whatcom Creek has been experiencing urban stormwater induced fish mortality for over a decade. Recently, Dr. Nat Scholz, a research zoologist with NOAA’s Ecotoxicology Program has found salmon mortalities (including premature spawn mortality) in multiple urban areas of Puget Sound. He believes water quality is probably the cause and continues to study the issue (Personal communication).

Much of the Baker Creek watershed is in the City of Bellingham’s Urban Growth Area (UGA). A recent study indicates more than 30,000 people will move to Bellingham over the next 20 years (ECONorthwest, 2002). This astounding population growth indicates build-out of the UGA and stresses that protection and enhancement strategies for the fisheries resources in Baker Creek *must be* incorporated into future land use planning decisions.

Recommendations

- During the next 5 years, additional fish utilization studies should be conducted in all Bellingham streams. These assessments will provide fisheries information essential in guiding both private and public project development and implementation to ensure ongoing protection of Bellingham's fisheries resources. According to Karr et al., (2003), water quality programs should use biological assessments as the first level of assessment in prioritizing and planning further investigations, such as traditional physical and chemical assessments, to diagnose the factors responsible for the degraded conditions. Without the establishment and application of biological criteria, water quality monitoring may not reveal biological degradation until it is too late to mount an effective response.

- Information from this and future fisheries studies should be used by the Public Works, Planning, and Parks Departments to guide projects such as:

    - Development of policy governing the regulation and enforcement of riparian and wetland buffer widths;

    - Prioritization of culvert retrofits and replacements that facilitate fish passage;

    - Determination of appropriate stormwater detention requirements;

    - Implementation of Low Impact Development (LID) practices;

    - Prioritization of land acquisitions;

    - Prioritization of salmon habitat restoration projects;

    - Parks and trails development;

    - Protection and maintenance of wildlife corridors; and

    - Development of operational and maintenance procedures in City parks and riparian areas.

- Future water quality sampling done in conjunction with smolt trap operation should be designed to capture samples at appropriate spatial and temporal scales to provide better understanding of the relationship between water quality impairments and fish mortality. For example, sampling should occur during the rising limb and the peak of the hydrograph (i.e., the beginning and middle of a storm). Water quality sampling locations should be scattered throughout the watershed to determine pollutant source locations and hot spots.

- Future studies examining the duration of out-migrations over a range of disturbed watersheds should be conducted to determine if increased urbanization affects the timing and duration of salmonid migrations. These studies could examine loss of habitat complexity and hydrological modifications with associated salmonid migratory responses.

- This study highlights the need for the City of Bellingham to develop a Low Impact Development ordinance or incentive program to integrate resource protection with the inevitable impacts associated with growth.

Introduction

The Endangered Species Act listing of several stocks of Puget Sound salmon as threatened with extinction focused restoration and monitoring activities in many streams in the Pacific Northwest. Understanding baseline population numbers and periodicity of habitat use in those streams is the first step in establishing recovery plans. Puget Sound lowland streams provide spawning and rearing habitat for threatened and endangered populations of anadromous salmon and trout. Many of these lowland streams have been transformed by anthropogenic changes resulting from urbanization. The deleterious effects of urbanization have been well documented; including riparian vegetation removal, channel alterations, culvert construction, introduction of exotic species, increased sedimentation, pollution, and temperature loads (Beechie et al., 1994; Leopold, 1968; Hammer, 1972; Klein, 1979; Booth, 1991). Establishing baseline species composition and salmonid numbers is essential for the recovery of salmon stocks and the restoration of their habitat.

To better understand the fisheries resource in Baker Creek and how the rapidly changing landscape may be impacting the health of Baker Creek, the Environmental Resources Division operated a smolt trap between April and June 2003. The trap was installed near the mouth of Baker Creek (River Mile 0.1) between Birchwood Avenue and Squalicum Parkway (Figure 1). The trap collected out-migrating fish from the entire Baker/Spring Creek watershed for two months. Results from this study will provide a better understanding of fish utilization and habitat requirements in Baker Creek and can be applied to the understanding of how the rapidly changing landscape may be impacting the aquatic environment of Baker Creek.

Baker Creek is a tributary of Squalicum Creek, which drains into Bellingham Bay. Baker Creek watershed is rapidly changing from a rural watershed to an intense retail and commercial center. For example, the upper portion of the watershed, which is more rural, contains less than 5% impervious surface area, while the more developed lower portion contains more than 25% impervious surface area. Spring Creek drains into Baker Creek at river mile 0.79. The Spring Creek watershed is dominated by commercial and industrial land uses. The entire Baker Creek watershed, including Spring Creek, has a drainage area of approximately 5,580 acres (City of Bellingham, 1995). The impervious land cover for the entire Baker Creek watershed averages 12%.

Some aquatic species may be negatively affected when impervious surfaces constitute as little as 2% of a watershed's area; other species may be affected when impervious surface area is 10 to 12% (EPA-URL, 2003). In streams where 11-25% of the drainage basin is covered with impervious surfaces, the streams are negatively impacted and can be expected to experience salmon habitat and water quality degradation with further development (Giannotti and Prisloe, 2002).

Figure 1. Location of the Baker Creek smolt trap and the Squalicum Creek sub basin drainage. The placement of the trap was selected to ensure sampling of the entire Baker and Spring creek watersheds.

Methods

Smolt traps are passive sampling devices that capture migratory fishes as they move upstream or downstream in river systems. The smolt trap used in this study is a modified Washington Department of Fish and Wildlife (WDFW) design that was utilized by Mark Downen (1999) for thesis research. The V-shaped weir utilizes large screen panels to funnel fish into a live box while allowing water and small debris to pass through the mesh (Figure 2). The 3- x 6-foot panels were covered with ½- x ½-inch mesh screens, and were positioned to span the entire stream channel. To ensure no fish could pass under the weir, the bottom 16 inches of the weir was flashed with polyethylene plastic that extended far enough in front of the weir to be covered with gravel bags. All panels were latched together with wooden and metal supports and anchored in the stream with 7-foot steel fence posts. The combination of flow and weir design guides fish into the live box. The live box is made of wood and stands 3 feet tall by 4 feet long by 2 feet wide. The box was installed to keep water levels in the box at a minimum of 8 inches. The side of the live box was covered with ½- x ½-inch mesh screens. There were two wooden baffles inside the live box that created a refuge area from the high velocities for the captured fish. An adult migration tube was installed to allow spawning anadromous fish to navigate upstream of the weir without impediments.

Storm pulses created a very flashy flow regime for Baker Creek and required that the weir be built with extra reinforcement. Due to the high concentration of impervious surfaces in the lower watershed, the creek can be quickly loaded with stormwater runoff. Light rain caused the creek level to rise 1.5 feet in a matter of minutes, and even higher when debris clogged the screens. On three separate instances water levels overtopped the weir and live box, or went around the weir due to large amounts of stormwater. These flood pulses were usually very short in duration, lasting from one-half hour to several hours. The smolt trap was modified over the course of the sampling period to adjust for high flows. To accommodate the high flows and keep the trap operating two additional panels were added to the outside of the weir extending it past the bankful mark on each side of the creek. Steel wires were attached to the panels above the water perpendicular to the flow for additional support and stability during flash flows. Two high water pressure release panels were engineered into the weir. These panels could be pulled out during heavy rainstorms, thus allowing water and debris unobstructed passage downstream.

The trap and live box were checked a minimum of two times per day during normal and low flows. Routine inspections and site visits were done at 7:30 a.m. and 5:00 p.m. During high flows and peak migration, the trap was checked at least four times a day depending on the flow, amount of debris, and number of fish migrating at that time. On each visit, all fish captured in the live box were removed for identification, enumeration, and measurement (Figure 3). Fish were sedated with tricaine MS-22 prior to handling. Fork lengths (measurement from tip of snout to caudal tail fork) were taken on the first ten anadromous fish for each species. Fish were processed and placed in a recovery bucket as quickly as possible. After recovery, fish were placed downstream of the trap to continue their migration. Water temperature and water level were recorded on each visit. The trap was removed on June 5, 2003, due to declining water levels.

Figure 2. Picture taken during the dismantling of the smolt trap. Notice that water levels are below visquene on right side of weir. One of the pressure relief valves can be seen on the left side of the weir. The live box is at the center of the photo.

Figure 3. Placing specimens into the viewing chamber. This process allowed for easy viewing of key anatomical features to determine proper species identification. A fork length (snout to inside fork of tail) was recorded. The fish were then given time to recuperate from the anesthetic and then released downstream of the weir.

Results and Discussion

Many different fish species rely on Baker Creek to provide habitat for various life processes. Through this study we were able to better understand which species utilize Baker Creek during which stages of their life histories. According to the data, the watershed currently provides habitat to support over-wintering multiple age classes of a diversity of salmonid species.

In this study, length measurements were used to determine salmonid age. Age class information provides insight into habitat and foraging needs of fish during certain times of the year. For example, adult salmon stop feeding when entering freshwater and look for suitable substrate to serve as spawning gravel. Stream substrate is more important than food to adult salmon. Young salmon fry feed on insects and fine particulate organic matter and rely on root wads, trees, and boulders for cover and refuge from high flows. For young salmon, food and cover are more important than substrate. Therefore, habitat needs are specific to species and to the particular stage of development of that species. To maintain sustainable fishery resources, the watershed as a whole must be able support these diverse requirements.

Data collected during this study about species richness, diversity, age class distribution, and seasonal migration can be used to help understand which habitat types are needed to support fish inhabiting Baker and Squalicum creeks. The results can be used to identify areas that are meeting the needs of salmon and other fish species and those that are not. Information about habitat requirements can be used to guide Bellingham's growth, development, and overall management of its riparian resource.

Based on results from a 1999 habitat survey, many segments of Squalicum Creek are lacking large woody debris, which provides juvenile habitat (Welch and Welch, 1999). This report goes on to mention that many segments of Squalicum Creek contain hardened or armored banks, which can further reduce juvenile habitat, stress young fish, and potentially reduce pool/rearing habitat. The availability of suitable adult spawning habitat varies dramatically throughout Squalicum Creek. Spawning habitat diminishes in frequency with distance from the mouth and is packed and often compacted, particularly in the lower reaches (Welch and Welch, 1999). Similarly, sections of Baker Creek have hardened and armored banks and the creek system as a whole lacks large woody debris. The same observations made by Welch and Welch (1999) on Squalicum Creek easily apply to Baker Creek.

Information about species diversity and age class distribution can also be correlated with water quality data. The City of Bellingham's Urban Streams Monitoring Program has been collecting water quality data since 1990. This information can help to determine, for example, which areas of the creek are simultaneously being utilized by fish as well as failing to meet water quality standards. Such information can help planners and land managers to make responsible, environmentally and economically balanced decisions. A recent review of Washington's Water Quality criteria (Karr et al., 2003) found that traditional physical and chemical monitoring are "blind" to biological conditions. The paper recommended that biological criteria be adopted in conjunction with chemical and physical assessments to monitor overall stream health.

Out-Migration Patterns
In Baker Creek, cutthroat and coho salmon (Table 1) dominated out-migration, with numbers totaling 380 cutthroat and 188 coho. Other fish species caught in the trap included steelhead, chum, brown bullhead catfish, yellow perch, stickleback, Pacific lamprey, sculpin, and large mouth bass.

The first cutthroat smolt was caught on April 17 and the last cutthroat was caught on May 23. On two separate storm occasions, there were over 100 out-migrating cutthroat smolt within a 24-hour period, representing over 50% of the total run. There were three size classes of cutthroat indicating three different age classes (Figure 4). The presence of these three age classes suggest the Baker Creek watershed currently contains the necessary habitat to support the distinct habitat needs of these three different life stages. Juvenile cutthroats ranging from 40 to 80 mm are considered “fry.” Fry have just emerged from the gravel and are foraging in the system. Cutthroat ranging from 130 to 260 mm represent the juvenile stages of cutthroat. This size class encompasses smolts leaving the system for the estuary and other juveniles that are known to move up and down the river system prior to smoltification. The two adult fish measuring greater than 280 mm are sea run adults returning to spawn.

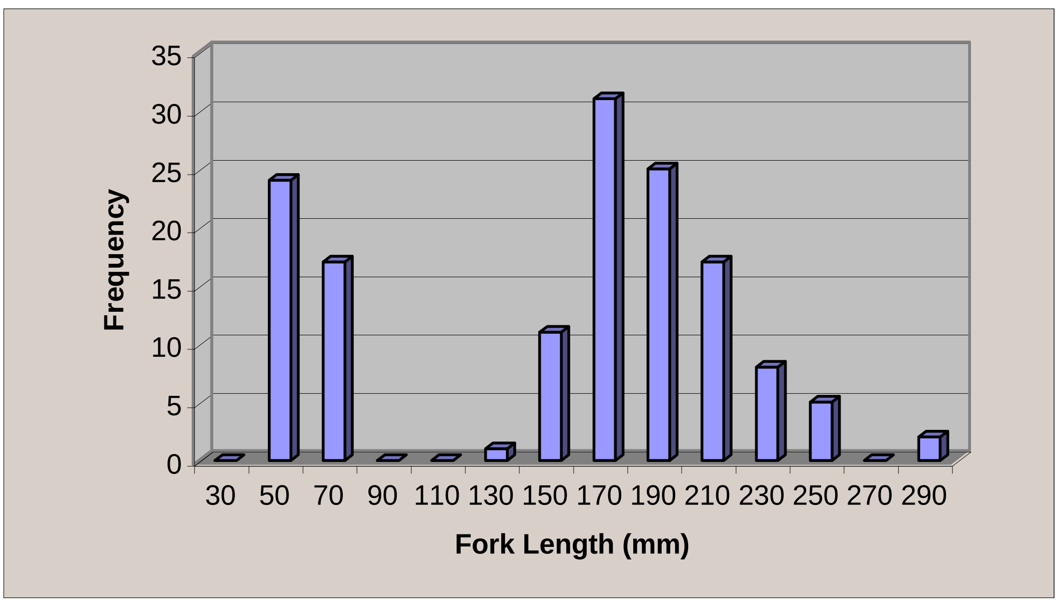

Figure 4. Cutthroat size and age class frequency distribution from the 2003 Baker Creek smolt trap study. The three distinct size classes represent fry, juveniles and smolts, and adults.

Coho smolts were first seen out-migrating on April 17,and the last out-migration was seen on May 25. On May 4, 41% of the total coho run out-migrated during a single storm event. This study found that the Baker Creek watershed supports two age classes of coho (Figure 5). Coho ranging from 40 to 90 mm represent the fry life stage. These fish have just emerged from the gravel and are seeking habitat that provides foraging for growth and refuge from predation and stream velocity. Coho ranging from 100 to 160 mm represent the life stage of smolts. These fish have overwintered and have found the necessary food and shelter to enable them to grow to the minimum size needed for the smoltification process to begin.

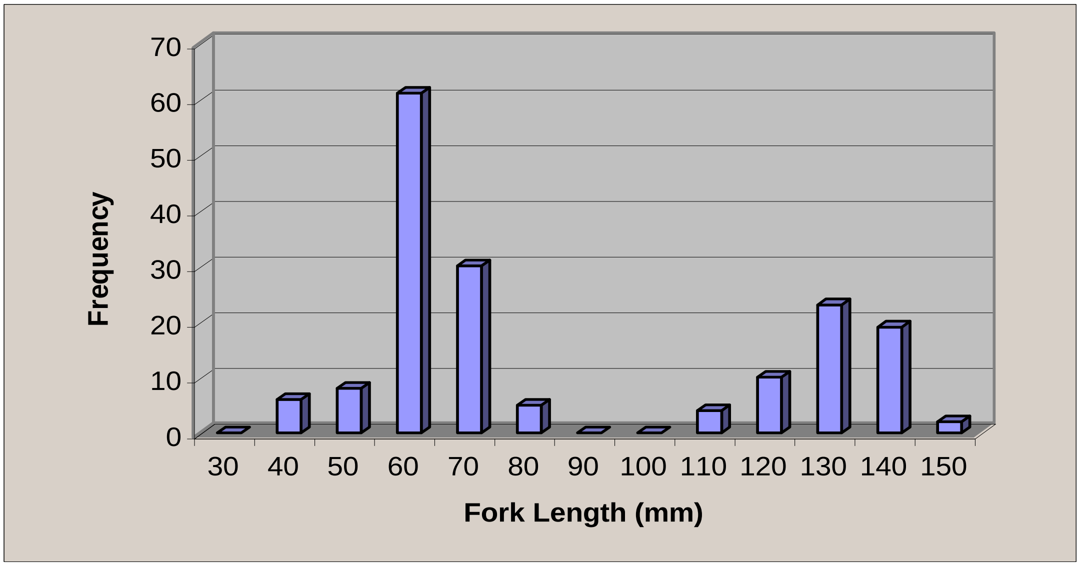

Figure 5. Coho size and age class frequency distribution from the 2003 Baker Creek smolt trap study. The two distinct size classes represent fry and smolt life stages.

Steelhead smolts were first captured out-migrating on April 21, and the last smolt was captured on May 19. On April 24, 40% of the total out-migration for steelhead occurred in accordance with a single storm event. This study found that Baker Creek watershed has three age classes of steelhead (Figure 6). One fry in the size range between 100 and 120 mm was found. Steelhead between 150 and 230 mm represent the juvenile age classes. No distinction between smolts and resident juveniles was assessed. The two fish trapped above 700 mm were both adults.

All salmonid species show increased out-migration when discharge increased from rain events (Figure 7). Results show that 68% of the entire out-migration happened on the six rain days during the study. (A rain day is defined by more than 0.1 inches of rain falling within a 24-hour period.) Out-migration is usually seen as a bell shaped curve with gradual increases and decreases from the zenith, indicating gradual out-migration over time. The smolt out-migration in Baker Creek appears sharply spiked indicating the majority of out-migration occurred during brief windows of time.

Salmonids have adapted to using flushes (increased water flow and volume from rain events) as an energy saving means of downstream transport. The intensity of anthropogenically created flood pulses combined with loss of complex habitat may essentially “flush” smolt down the system. Spiked out-migration patterns indicate fish moving out to sea on flood pulses that are caused by increased impervious surface area and decreased stream channel complexity. Additional research indicates that the magnitude of peak flows increased as the percentage of watershed area covered by impervious surfaces increased in Puget Sound lowland streams (Cramer et al., 1999).

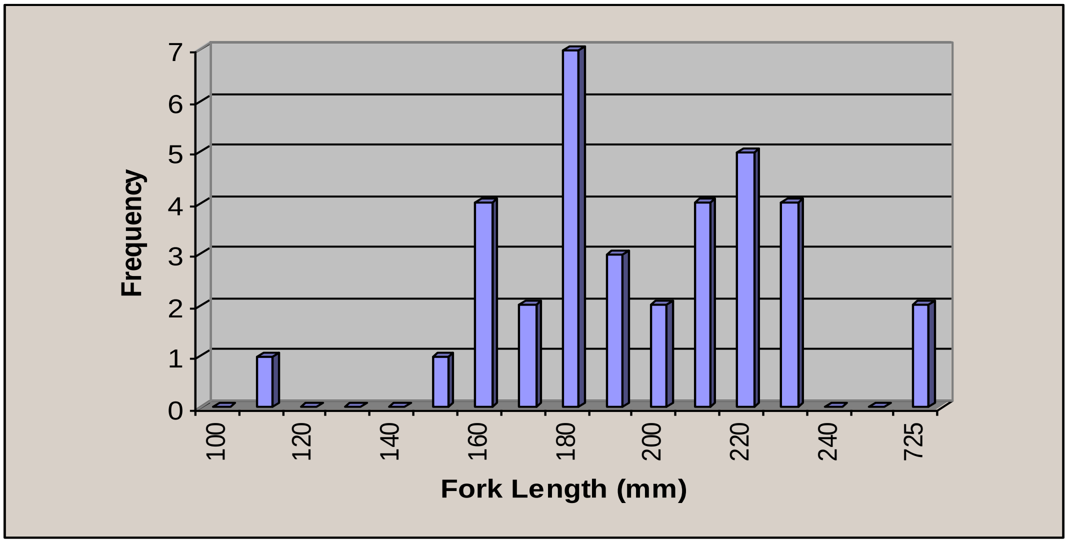

Figure 6. Steelhead size and age class frequency distribution from the 2003 Baker Creek smolt trap study. The three distinct size classes represent fry, juveniles and smolts, and adults.

Lamberti et al. (1989) found that hydraulic retention, which can increase flood abatement, was positively related to habitat complexity. In the Squalicum Creek watershed it is possible that discharge is a migratory clue nested within increasing daylight hours (photoperiod) (Downen, 1999). Research in the Columbia River basin indicates that stream flow correlated positively with out-migration rate and explained more of the variation in migration rates than did other variables (Giorgi and Stevenson, 1997).

Table 1. Total Catch for the Baker Creek Smolt Trap 2003.

Species	No.	Species	No.
Cutthroat	377	Pacific Lamprey	1
Cutthroat adults	3	Stickleback	2
Steelhead	43	Sculpin	1
Steelhead adults	2	Yellow Perch	3
Coho	188	Large Mouth Bass	1
Chum	14	Brown Bullhead	6

During the first three weeks of the study, hundreds of small chum and coho fry were seen moving through the screen mesh both along the weir and in the live box. Mesh size on the screens was ½- x ½-inch; thus the trap was not meant to capture small fry but, rather, to allow them to pass freely through the trap. Therefore, the small number of chum (14) and coho (110) fry caught in the trap does not accurately reflect the densities of chum and coho fry present in the system. The majority of coho fry appeared in the live box late in the smolt season. Water levels had dropped below the height of the polyethylene plastic on the weir and fry had no alternatives for swimming downstream except into the live box.

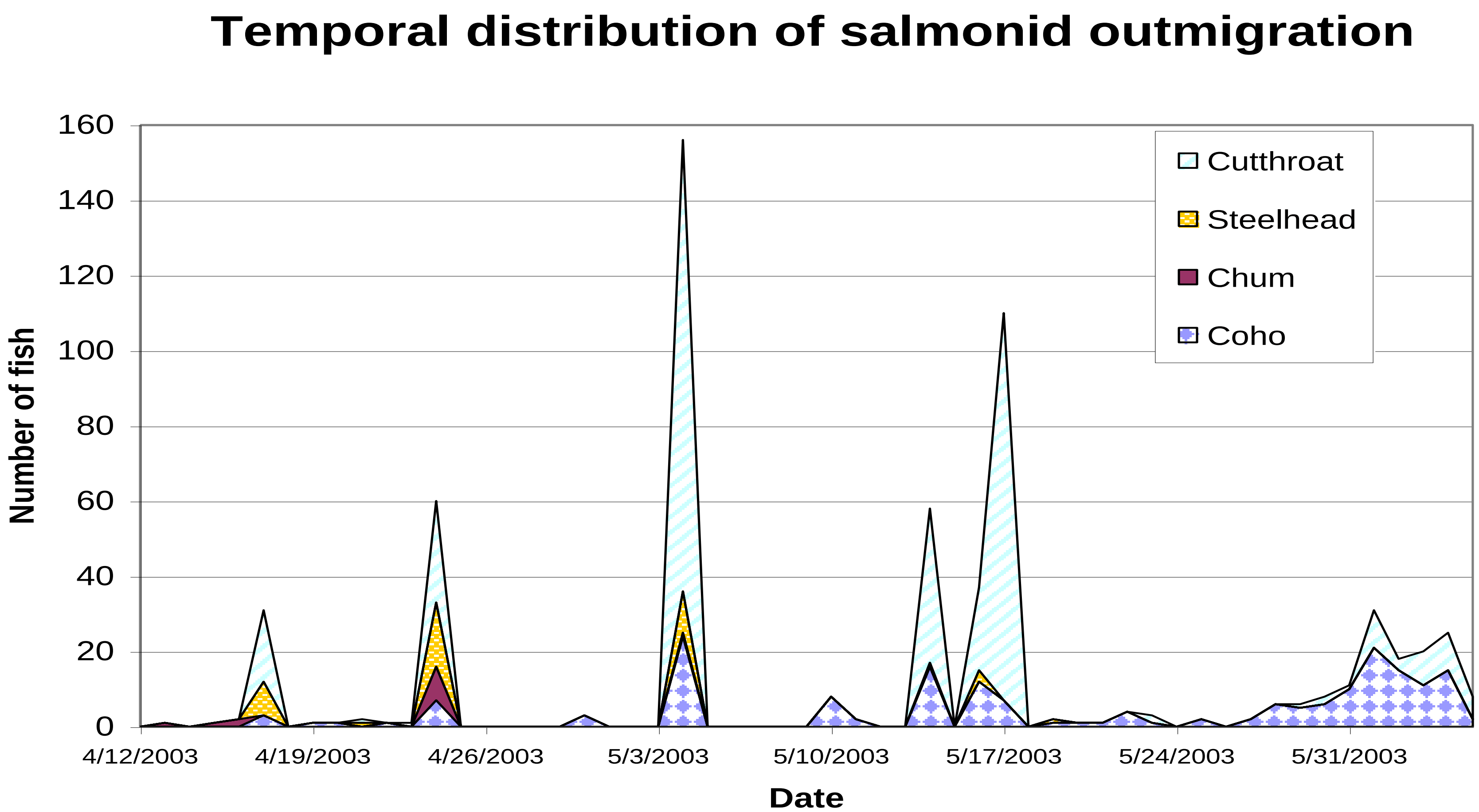

Figure 7. Temporal distribution of salmonid downstream migration in the Baker Creek system during the spring of 2003. The graph is a representation of the total catch (fry and smolts) for all salmonids.

High-Flow Events

On several occasions, water levels in the creek rose over two feet within twenty minutes of the beginning of light rains. During three separate instances, water levels overtopped the weir and live box, or went around the weir due to large amounts of stormwater leaving the system. Modifications were made to the trap to ensure the trap was secure and fully functioning. The first instance was on April 17, when high flows went around the weir. The next day crews installed two additional panels to the outside of the weir extending it past the bankful mark on each side of the creek. On April 24, high flows overtopped the weir and live box from 5:00 p.m. to 7:30 a.m. Crews then installed pressure-relief valves on the outer two panels. On May 14, these valves were opened for one hour. On May 16, the valves were opened at 11:00 p.m. and left open until the following morning. The overflow events allowed fish to pass through the trap uncounted. Thus, fish numbers reported here are an underestimate of true numbers of out-migrants.

Fish Mortalities

After two separate storm events, dead juvenile salmon were found in Baker and Squalicum creeks. Dead juvenile coho and cutthroat were found upstream and downstream of the trap as well as in the trap. Coho mortalities accounted for 16% of the total fry and smolt catch for the sampling season. The cutthroat mortalities accounted for 5% of the total fry and smolt catch for the sampling season. Of the entire coho smolt out-migration, 52% were found dead. This illustrates the phenomenon affected coho smolts more than coho fry and other species exposed within the system. Why these mortalities affected one particular species and one age class of that species is still unknown.

In an effort to understand why fish were killed, water quality samples were tested for chlorine, turbidity, nutrients, soluble organic compounds, and thirteen priority pollutant metals. Timing of water quality sampling during storm events is critical in capturing the concentration levels of potential pollutants. Due to staff schedules and the short duration of the flood pulses, the water quality samples were taken after the main flood pulse had passed. Thus, sample results may underestimate concentration values that were present during the storm. The water quality tests did not detect any single pollutant in concentrations high enough to cause fish kills. The synergistic impact of multiple pollutants is extremely difficult to test for and often impossible to identify, although it is believed to be the cause of the fish kills. It is unclear why coho were more affected than cutthroat.

On June 19, Doug Huddle from WDFW collected live fish samples for analysis to explain the fish kill. Due to the low water levels in the creek, sampling was limited to the stream section between Squalicum Parkway and Birchwood Avenue; ten coho and two resident steelhead were collected in this area. Dr. Jedd Varney, a Fish Pathologist from WDFW Hatchery Program, analyzed these twelve fish. Varney assessed that no external parasites or bacteria caused the fish mortalities, although the fish contained the sub-lethal protozoa *Trichodina*. The most significant findings were that all fish had hypertrophic or swollen gills, a sign of environmental stress. Varney believes the combined effects of swollen gills and increased temperature, turbidity, or trace pollutants associated with a storm event could indeed cause fish kills. The exact cause of the fish kills is still unknown, but indicators appear to point to environmental conditions created by urban stormwater runoff. Why coho smolts seem most affected by this phenomenon is still unknown. Similar occurrences have been observed annually at the Maritime Fish Hatchery, and to date no specific source has been identified in the fish kills.

Field and laboratory studies demonstrate that juvenile salmon exposed to polluted environments exhibit developmental abnormalities ranging from subcellular effects to changes in immune function and growth. In many cases the effects of polluted environments alter physiological processes in fish to the point where the potential for survival is reduced. Adverse effects may be site-specific, habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (NOAA Fisheries URL, 2003).

Recommendations

- During the next 5 years, additional fish utilization studies should be conducted in all Bellingham streams. These assessments will provide fisheries information essential in guiding both private and public project development and implementation to ensure ongoing protection of Bellingham's fisheries resources. According to Karr et al., (2003), water quality programs should use biological assessments as the first level of assessment in prioritizing and planning further investigations, such as traditional physical and chemical assessments, to diagnose the factors responsible for the degraded conditions. Without the establishment and application of biological criteria, water quality monitoring may not reveal biological degradation until it is too late to mount an effective response.

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