PREDATION OF JUVENILE SALMONIDS BY PREDATORY FISHES IN THE LOWER CEDAR RIVER, 1999

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ABSTRACT

We sampled predatory fishes in the Cedar River (river kilometers 0-1.4) From February to June, 1999 to monitor how a flood control project affected predation levels of sockeye salmon fry (*Oncorhynchus nerka*) and juvenile chinook salmon (*O. tshawytscha*). A wide variety of habitat changes occurred in the lower Cedar River, each modification appeared to have an effect on predator abundance or predator consumption rates of sockeye salmon fry. Because of the rarity of predation of juvenile chinook salmon, it was difficult to determine if there was any effect due to the flood control project. We used electrofishing equipment and beach seines to collect fish; however, the vast majority of fish sampled were collected with electrofishing equipment. We examined the stomach contents of 376 salmonids, 810 cottids, and 8 other predatory fish. Data were compared to 1995 to 1996 pre-project sampling.

Catch rates with beach seines were low. A total of 18 predator-size fish was collected from 19 sets. Pre-project beach seining catch rates in 1995 and 1996 were substantially higher. Reduced catch in 1999 may have been due to reduced fishing efficiency of the beach seine or related to the fish abundance.

Overall catch rates of trout and coho salmon in the slow-water reach were similar to pre-project catch rates (1995 and 1996). However, catch of coho salmon in May, 1999 was substantially higher than during pre-project conditions. In 1999, catch rates of cottids were reduced along the left bank where the instream structure was removed. Catch rates of cottids were also reduced along the right bank at sites 2 and 3, presumably due to an increase in fine sediments. In the fast-water reach, the abundance of trout appeared to be enhanced due to the addition of rip-rap along the left bank.

Predation of sockeye salmon fry occurred primarily in the slow-water reach. Preliminary assessment of predation rates in the slow-water reach indicated that they were higher in 1999 than during pre-project conditions. Further analyses will be conducted when fry abundance data is available. Increased predation rates were probably a result of reduced water velocities which increased migration time of fry. Predation rates also appeared to be higher in the fast-water reach, however, higher light intensity was most likely the cause. The diet of predatory fishes was composed primarily of sockeye salmon fry in April, and during the hatchery release nights in February and March. In May and June, predation of sockeye salmon fry was low. Instead, predatory fishes switched to alternative prey such as aquatic insects, and catostomid eggs and larvae. Only one juvenile chinook salmon was found in the stomach samples. A 88 millimeter fork length chinook was found in a large cutthroat trout that was collected in June.

Overall, predation rates on sockeye salmon fry increased as predicted but the total predation was somewhat lower than expected because predator abundance was less than expected. The amount of available habitat for predators of sockeye salmon fry was increased and the total abundance of predators was greater but the removal of instream structure and an increase in fine sediments resulted in a predator abundance that was not as large as expected.

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INTRODUCTION

Predation of emigrating juvenile salmonids by other fishes can be a significant source of mortality (Hunter 1959; Foerster 1968). After emerging from their redds, most sockeye salmon (*Oncorhynchus nerka*) fry immediately emigrate downstream to a lake environment where they reside for the next year. Although sockeye salmon fry reduce their vulnerability to predators by emigrating at night, predation rates can still be quite high. For example, Foerster (1968) estimated that losses to predatory fishes can range from 63 to 84%. Sockeye salmon fry emigrating in the Cedar River are vulnerable to predation by several species of piscivorous fish. Recent work in the lower 1.7 km of the Cedar River has indicated that cottids (*Cottus spp.;* 4 species), cutthroat trout (*O. clarki*), rainbow trout/steelhead (*O. mykiss*), and juvenile coho salmon (*O. kisutch*) are important predators of sockeye salmon fry (Tabor and Chan 1996a,b).

In 1995 and 1996, the U.S. Fish and Wildlife Service (FWS) conducted an inventory of predatory fishes in the lower 1.7 km of the Cedar River to estimate predation on sockeye salmon fry and determine how dredging and other associated habitat changes from the flood control project may affect the overall predation levels. Results indicated that predation of sockeye salmon fry occurred primarily in low-velocity areas and a dredging project that would reduce water velocities would probably create additional foraging sites for predatory fishes and increase predation on sockeye salmon fry migrating to Lake Washington (Tabor and Chan 1996a,b). The section of the river that was considered the slow-water reach (low-velocity water) had mid-channel depths > 1.5 m and had average mid-channel velocities < 0.6 m/second when streamflow was < 600 cfs. The lower Cedar River was dredged in the summer of 1998 by the U.S. Army Corps of Engineers. During the sockeye salmon outmigration period, the distance of low-velocity, mainstem area was approximately 570 m in 1995 and 430 m in 1996, whereas it was approximately 910 m in 1999. As sediments move downstream, the size of the low-velocity area will gradually be reduced and eventually some additional dredging may be needed.

In addition to sockeye salmon fry, juvenile chinook salmon (*O. tshawytscha*) also migrate through the lower Cedar River. Because juvenile chinook salmon are considerably larger than sockeye salmon fry, they are not as vulnerable to predatory fishes. However, they are still vulnerable to large trout and large sculpin. Chinook salmon also appear to be consumed primarily in low-velocity areas and thus, a dredging project that would reduce water velocities may also increase predation of chinook salmon.

The FWS monitored predation levels for 2 years after the dredging occurred. The first year of monitoring was completed in 1999. To complete our evaluation of the dredging project on predation of sockeye salmon fry, we also monitored predation levels again in 2000. This report presents results from 1999 sampling efforts.

OBJECTIVES:

1). Compare the abundance, species composition, and length frequency of predatory fishes from pre-project (1995 and 1996) conditions to post-project conditions (1999) in the lower Cedar River.

2). Compare pre-project and post-project consumption rates of sockeye salmon fry and juvenile chinook salmon by predatory fishes.

3). Determine overall predation rates and the impact that the flood control project has on sockeye salmon fry survival.

4). Determine if overall predation is greater than, equal to, or less than anticipated by the pre-project analysis.

STUDY SITE

The study site was the lower 1.7 kilometers (km) of the Cedar River. At this location, the river channel is mostly straight except for a bend at the upstream end (Figure 1). The major habitat modification in the lower Cedar River was dredging of the main channel. The channel was deepen to approximately 2.5 to 3 m depth from North Boeing Bridge to Logan Avenue Bridge. However, by the time we started sampling, much of the channel from Logan Avenue Bridge to South Boeing Bridge was filled in due to head cutting and sediments moving downstream. Besides deepening the channel, the instream structure was altered along the left bank from river kilometer (Rkm) 0.3 to 1.7. From Logan Avenue Bridge to South Boeing Bridge, vegetation along the left bank was removed and much of it was replaced with rip rap. From Rkm 0.3 to South Boeing Bridge, vegetation along the left bank was removed. The bank was filled in with dredged material and consequently, covered up shoreline structures, such as bulkheads, undercut banks, woody debris and overhanging vegetation. Vegetation and instream structure along the right bank was relatively unchanged.

We divided the lower Cedar River into two study reaches: a slow-water reach from North Boeing Bridge to Rkm 0.9 and a fast-water reach from South Boeing Bridge to Logan Avenue Bridge. The slow-water reach was essentially backed-up water from Lake Washington. Typically, the lake level increases 0.6 m from February 15 to May 1. Therefore, water velocities in the slow-water reach will depend on streamflow as well as lake level. The size of the slow-water reach will also vary somewhat with lake level. When the lake was low in February and March there was a sharp boundary between the slow-water and fast-water reach at Rkm 0.9. The water depth dropped sharply from approximately 0.8 m to 2.5 m. However, as the lake level rose, the area between Rkm 0.9 and South Boeing Bridge became more or less a transitional area. We did not sample this area.

The slow-water reach was pool-type habitat with low water velocities across the channel width (under normal streamflow conditions), fine substrates (mud and sand), and the water depth was typically at least 2 m deep. The fast-water reach was riffle habitat across most of the channel width. The substrate was mostly gravel and the depth was generally shallow, < 1 m depth. The transitional area was glide-type habitat with gravel and sand substrate, and moderate depth (1 to 2 m depth).

Prior to the flood control project (1995-1998), the slow-water reach was substantially smaller and got smaller each year. In 1995, this reach was approximately 570 m in length. By 1998, it was only approximately 300 m in length from just upstream of the boat ramp to North Boeing Bridge.

METHODS

The basic approach of this study was to repeat the sampling procedures used in 1995 and 1996 (Tabor and Chan 1996a,b).

FIELD COLLECTIONS

Catch. Predators were collected with electrofishing equipment and beach seines. Electrofishing equipment was used to sample along the shoreline and beach seines were used to sample the mid-channel areas. To compare catch from pre-project to post-project conditions, we collected fish primarily at the same sites used in 1995 and 1996 sampling (Tabor and Chan 1996a,b). Three beach seining sites, four boat electrofishing transects, and five backpack electrofishing transects were used (Figure 1, Table 1). Electrofishing sites were designated as left (westside) or right (eastside) bank. A boat electrofisher was used to sample much of the shoreline downstream of the South Boeing Bridge. Two sites in the upper section of the dredged area were used to compare to downstream sites. Sampling was done from February to June. In Feburary and March, sampling was done on release nights of hatchery sockeye salmon fry because of low numbers of wild fry. From April to June, only wild fry were available on the nights sampled. We assumed that hatchery and wild fry were equally vulnerable to predators. Previous data collected from the Cedar River has not indicated any major differences between the two groups (R. Tabor, unpublished data).

Because the mid-channel area was substantially deeper than in 1995 or 1996, a different beach seine was used. The original seine was 30 m in length with a maximum depth of 2 m in the wings and 2.4 m in the middle (bag). The wings were made of 20-millimeter (mm) stretch mesh and the bag was made of 6-mm stretch mesh. In 1999, we used a 30-m-long net with a depth of 3.7 m along the entire length of the seine. The wings were made of 38-mm stretch mesh and the bag was made of 9-mm stretch mesh. To pull the seine through the water at the same rate as in the pre-project study, we needed the net to have larger mesh sizes. To deploy the net and pull it in took approximately 3 to 5 minutes, similarly to the pre-project study. As before, the net was deployed from a small inflatable raft and set parallel to shore. The net was set close to the shoreline and then pulled to the opposite shore. Because the wetted width was wider than during pre-project conditions, the area sampled was somewhat larger.

Fish processing. After capture, fish were anesthetized with MS-222, identified to species, and length was measured to be nearest mm. For cottids, the total length (TL) was measured, while for all other fish, the fork length (FL) was measured. Fish < 500 g were weighed to the nearest gram. Larger fish were weighed to the nearest 10 g. Rainbow trout and steelhead were difficult to separate and thus, were grouped together as rainbow trout/steelhead. Additionally, some small trout were difficult to identify to species and were categorized as unidentified trout.

Stomach contents of fish were removed using a gastric flushing apparatus. Gastric lavage has been shown to be effective in removing stomach contents for many fish species (Light et al. 1983). All sizes of trout and coho salmon were sampled. We only collected stomach samples from cottids ≥ 50 mm TL. Cottids < 50 mm TL can occasionally consume sockeye salmon fry (R. Tabor, unpublished data) but we assumed their overall consumption was insignificant in relation to larger sculpin. All stomach contents were put in plastic bags, placed on ice, and froze. Samples remained frozen until laboratory analysis.

Population size. To estimate the overall abundance of predatory fishes, population sizes were estimated with a mark-recapture methodology (Ricker 1975). Salmonids were estimated with a single census while cottids were estimated with a multiple census methodology. Population estimates were undertaken in late April or early May, 1999, similar to estimates done in 1995 and 1996. Both the initial collection and recaptures were done with electrofishing equipment. Salmonid mark and recapture collections were done on the same night, while cottid surveys were done over a 2 to 8 day period. Salmonids were marked with an opercle punch. Sculpin were marked with non-toxic acrylic paint, which was injected with a 0.5 mm by 25 mm needle into the base of the anal fin (left or right side). After fish were captured, they were anesthetized with MS-222, marked, allowed to recover, and released along the same transect from which they were captured. We waited at least 2 hours between release time and recapture collections. We assumed that fish movements were minimal during this short time period, and the fish had recovered and were behaving similarly to unmarked fish.

LABORATORY ANALYSIS OF STOMACH SAMPLES

In the laboratory, samples were thawed, examined with a dissecting scope, and divided into major prey taxa. We attempted to identify fish to species. Insects and crustaceans were identified to order, while other prey items were identified to major taxonomic groups. Each prey group was blotted by placing the sample on tissue paper for approximately 10 seconds. Prey groups were weighed to the nearest 0.001 g.

Prey fishes that were slightly digested were easily identified to species. Fishes in more advanced stages of digestion were identified to family, genus, or species from diagnostic bones, gill raker counts, pyloric caeca counts, or vertebral columns. The FL of prey fishes was measured to the nearest mm. If a fork length could not be taken, the original FL's of prey fishes were estimated from measurements of standard length, nape-to-tail length, or diagnostic bones.

DATA ANALYSIS

Catch. Comparisons between pre- and post-project conditions includes data from 1995 and 1996. However, additional data were collected in the lower Cedar River in 1997 (Tabor, Chan, and Hager 1998) and 1998 (unpublished data). To increase sample sizes these data were used where appropriate.

Calculations of catch rates were used to compare pre- and post-project conditions. In most cases, the distance electrofished was the same year to year and the catch was compared directly. If the distance was different, catch per 100-m shoreline was calculated. Catch rates were divided into bi-monthly time periods. For each site, the 1995 to 1998 average catch of each bi-monthly time period was calculated and compared to 1999 with paired t-tests. Data were log transformed because the data were multiplicative rather than additive (Zar 1984). Mean fish lengths of pre- and post-project conditions were also compared with a t-test. Length data from 1995 to1998 was combined.

Diet analysis. Percent of diet was calculated to determine how important sockeye salmon fry and other prey are to the overall diet of cottids and other fish. To reduce bias from different sized fish, prey weights were converted to percent body weight. Percent diet by prey category was then calculated from that ratio.

Consumption rates were determined for individual predatory fish by examining the digestive state of individual sockeye salmon fry. Based on reconstruction of the original weights of sockeye salmon fry, a digestion rate model of torrent sculpin was used to determine how recently the fry were ingested. Original lengths and weights of sockeye salmon fry were estimated from regression equations. Consumption rates were an estimate of predation that occurred during the night of sampling.

RESULTS

CATCH

The primary predatory fishes collected in the lower 1.7 km of the Cedar River included 77 cutthroat trout, 165 rainbow trout/steelhead, 403 coho salmon, and 1,456 cottids (four species). In addition, we also collected eight smallmouth bass (*Micropterus dolomieui*), one mountain whitefish (*Prosopium williamsoni*), and one yellow perch (*Perca flavescens*). Catch rates of predatory fishes were low in February and March but increased substantially in April to June. Trout ranged in size from 73 to 398 mm FL (Figure 2). Fifty-five percent were between 150 and 200 mm FL. The proportion of rainbow trout to cutthroat trout decreased each month (Figure 3). In March, 83% of the trout collected were rainbow trout/steelhead but by June only 18% of the trout were rainbow trout. As expected, catch of coho salmon increased dramatically in May, when coho salmon smolts typically outmigrate to the lake. The vast majority of coho salmon were between 90 and 120 mm FL (Figure 2). Sculpin as large as 221 mm TL were collected, however, most were between 50 and 100 mm TL (63%). Few coastrange sculpin (*C. aleuticus*), riffle sculpin (*C. gulosus*), or torrent sculpin (*C. rhotheus*) were ≥ 100 mm TL, whereas large numbers of prickly sculpin (*C. asper*) ≥ 100 mm TL were collected (Figure 4). Eighteen fish were collected with beach seines; and 2,112 fish were collected with electrofishing equipment.

Slow-water reach

Beach seining. Beach seining was attempted on five dates from March 8 to May 12. We only completed one set on the first date because the net got caught on some woody debris during the second set which tore a large hole in the net. A total of 19 sets were completed on the other four dates. On March 16 and April 5 we did day and night sets, while on April 20 and May 12 we only did night sets. Catch rates were surprisingly low throughout the study. During day sets (N = 7), only one predator-size fish was collected, a small steelhead (approximately 350 mm FL). Because the fish was considered an adult spawning fish, no stomach sample was taken and it was released shortly after capture. The only other fish caught during the day were two small sculpin < 50 mm TL. In night sets (N = 12), a total of 17 predator-size fish were collected; 9 prickly sculpin, 5 coho salmon smolts, 1 mountain whitefish, 1 torrent sculpin, and 1 coastrange sculpin. Other fish collected at night included 80 small sculpin < 50 mm TL, 8 juvenile chinook salmon, and 111 sockeye salmon fry. Substantially more predators were collected during pre-project beach seining efforts (1995 and 1996), including a total of 36 trout collected from 36 sets. Other fish captured included 13 coho salmon smolts, 9 mountain whitefish, 51 prickly sculpin, 47 coastrange sculpin, and 7 torrent sculpin.

Electrofishing. Several cutthroat and rainbow trout/steelhead were collected on each sampling date at site 1 (Figure 5). Sixty-six percent of the trout were collected on the left bank. Many of the trout were collected near the North Boeing Bridge. There was no significant difference in overall catch rates of trout in site 1 between 1999 and 1995-97 (paired t-test; $P = 0.23$).

There was no significant difference in overall catch rates of coho salmon in site 1 between 1999 and 1995 to 1997 (paired t-test; $P = 0.34$); however, this was largely because of the small sample size of dates in May when substantial numbers of coho salmon were present. Catch rates in May were substantially higher in 1999 (May 20; 87 fish/100-m shoreline), than in 1995 (May 16; 5 fish/100-m shoreline), or 1996 (May 22; 2 fish/100-m shoreline). Coho salmon were so numerous on May 20, 1999 that we subsampled the transects. We estimated that the total catch would have been 460 fish if the entire transect was electrofished.

Catch rates of coho salmon at boat electrofishing transects were substantially higher in May than during other months (Figure 5). Several trout and coho salmon were also collected at the other boat electrofishing sites (5R and 5L). Combined, a total of 43 trout (mean, = 1.9 fish/100-m shoreline) and 102 coho salmon (mean, = 4.6 fish/100 m) were collected from five sampling dates. In 1996 and 1998, these sites were sampled with backpack electrofishing equipment and a total of only 12 trout (mean, = 1.4 fish/100 m) and five coho salmon (mean, = 0.7 fish/100 m) were collected. On May 10, 1999, we also conducted a supplemental boat-electrofishing transect, site 2L, to estimate catch rates at other locations. Along a 186-m transect, 10 trout (5.4 fish/100-m shoreline) and 25 coho salmon (13.4 fish/100-m shoreline) were collected.

Prickly sculpin were the dominant cottid at site 1, representing 99% of the cottid catch. Large prickly sculpin were primarily collected at site 1. Of the 31 prickly sculpin $\geq$ 150 mm TL collected, 29 were from site 1. Prickly sculpin were also the dominant cottid at the other slow-water sites (2,3, and 5), and overall made up 64% of the cottids collected. Riffle sculpin made up 31% of the catch at these sites. Few coastrange sculpin or torrent sculpin were collected in the slow-water reach.

The removal of instream structure along the left bank (bulkheads, undercut banks, woody debris and overhanging vegetation were removed) had a large negative effect on the abundance of predatory fishes. At site 5R, where instream structure was present, catch rates were significantly higher for trout (paired t-test, $P < .001$), coho salmon (paired t-test, $P = 0.03$), and cottids (paired t-test, $P = 0.002$) than on the opposite bank, 5L (Figures 5, 6) which had little instream structure. We also compared the catch of cottids of the right (structure present) and left (no structure) bank at site 3. Catch rates were significantly higher on the right bank (paired t-test, $P < 0.001$) than the left bank and on average the catch was 3.6 times higher on the right bank than the left bank (Figure 6). The few fish that were collected along the left bank, were usually collected around a small pile of woody debris. In 1996, when both banks had instream structure, catch rates were not significantly different (paired t-test, $P = 0.34$). In 1999, the mean size of cottids was not significantly different between banks (left, 70.6 mm TL; right, 73.3 mm TL; t-test, $P = 0.33$).

Comparisons of catch rates between years at the same site also indicated that removal of instream structure had a large effect on the abundance and size of predatory fishes. Site 3L, which had all the shoreline structure removed, was only sampled in 1999 and 1996. Catch rates were significantly higher in 1996 (paired t-test, $P = 0.018$). Catch rates in 1996 ranged from 16.6 to 53.5 cottids/100 m of shoreline. During the same period, catch rates in 1999 ranged from only 4.4 to 7.2 cottids/100 m of shoreline. Cottids were also significantly larger in 1996 than 1999 (t-test, $P =$ 0.002). The mean size of cottids $\geq$ 50 mm TL in 1996 was 80 mm TL (maximum length, 147 mm TL), whereas in 1999, the mean size was 70.5 mm TL (maximum length, 124 mm TL). Site 5L was sampled only once prior to 1999, however, the same trend was apparent: fewer cottids were collected in 1999, and those that were collected were small.

Although the shoreline habitat was not modified at sites 2 and 3, the catch rates of cottids were significantly higher during pre-project conditions (1996-98) than in 1999 (t-tests; site 2, $P = 0.007$; site 3R, $P = 0.005$). For both sites, the average catch rates of cottids were a little over twice as high in 1996-1998. The reduction in cottid abundance was due to a sharp decline in catch of prickly sculpin, torrent sculpin, and coastrange sculpin. Catch of riffle sculpin was not significantly different (paired t-test; $P = 0.80$). Size of cottids was not significantly different at site 3 between 1996-1998 (mean, 74.3 mm TL), and 1999 (mean, 73.3 mm TL, t-test, $P = 0.24$).

Fast-water reach

Electrofishing. The right bank and left bank of site 7 had very different catch rates. Trout were abundant along the left bank but only occasionally collected along the right bank (Figure 7). In contrast, most coho salmon collected were caught on the right bank. The catch rates of cottids were similar, however, riffle sculpin and torrent sculpin were primarily collected along the right bank and coastrange sculpin, prickly sculpin, and torrent sculpin were collected along the left bank (Figure 7). Fish caught on the left bank were also generally much larger than those caught on the right bank. The average length of cottids (94 mm TL) caught on the left bank was considerably larger than those from the right bank (67 mm TL). The average length of trout caught was similar between the two banks; however, this was because one large spawned-out male cutthroat trout (398 mm FL) was caught on the right bank. Most of the trout (55%) collected along the right bank were < 130 mm FL, whereas only 17% of those from the left bank were < 130 mm FL.

Site 7 was only sampled routinely in 1996 and 1999. Catch rates of cottids were not significantly different between years. However, catch rates were substantially higher in May and June in 1996 than in 1999.

POPULATION SIZE

Population estimates were only conducted at Sites 1, 2, and 3 (Table 2). Sites 5 and 7R were not done due to the presence of several juvenile chinook salmon. Site 7L was not done due to the fast current and difficulty in returning marked fish to the same area they were captured. An overall population size was also estimated for the entire slow-water reach. If only catch rates were available for a particular site, the population size was based on the catch ratio between that site and a similar site that had a population estimate. If catch rates were not available, population size was estimated by using population densities from other sites with similar habitat.

At site 1, we were able to mark and recapture good numbers of trout, coho salmon, and prickly sculpin (Table 2). According to Ricker (1975), there is little chance of statistical bias for single censuses if $MC/N > 4$ (see Table 2). For trout and coho salmon, MC/N was > 4 (Table 2). This bias can be ignored for multiple census whenever the number of recaptures is 4 or more (Ricker 1975). Twenty-three prickly sculpin were recaptured at site 1.

We estimated the population size of trout was 50 fish (9.4 fish/100-m shoreline) at site 1 (both banks combined). Density of trout in site 1 was used for population estimates of the remaining slow-water area and then adjusted by differences in catch rates. If no catch information was available, we used trout densities from nearby sites that had the same type of habitat. We estimated the total trout population size for the slow-water area (lower 911 m) to be 125 fish. In 1995, the population estimate of trout in the lower section (sites 1 and 2) was 77 fish (9.7 fish/100-m shoreline). Therefore, the densities of trout in 1999 and 1995 appeared to be quite similar. The amount of slow-water habitat was much larger in 1999 than 1995 which accounts for the difference in population size.

The population size of coho salmon at site 1 on April 28 was estimated to be 113 fish (Table 2). Catch rates indicated coho salmon abundance increased dramatically in May after our population estimate was conducted. Using the catch rate-population size ratio and difference in the catch rates between site 1 and site 5, our rough estimate of the total number of coho salmon in the slow-water reach was 343 for April 28, 721 for May 10, and 7,100 for May 18. In 1995, we estimated 342 coho salmon on May 3 and 277 coho salmon on May16. Comparing 1999 population sizes of coho salmon to prior estimates can be difficult because most coho salmon inhabit the lower Cedar River for a relatively short time and their abundance can vary greatly day to day. However, our population estimates as well as catch rates indicate a much larger number of coho salmon inhabited the slow-water reach in 1999 than in 1995 or 1996.

Approximately 2,000 prickly sculpin ≥ 50 mm TL were estimated to inhabit site 1 (Table 2). The density of prickly sculpin in site 1 (3.8 fish/m of shoreline) was similar to the density estimate from April, 1996 (4.0 fish/m of shoreline).

At sites 2 and 3 our recapture rates were generally low (Table 2). If the number of recaptures is < 4 there is a high probability of statistical bias (Ricker 1975). Thus, an individual recaptured fish can have a large impact on the population estimate. Low numbers of recaptures resulted in relatively large confidence intervals. However, based on catch rates, as well as population estimates, cottids appear to be substantially less abundant in 1999 than in 1996. Population density for site 3 was 3.9 cottids/m of shoreline in 1999 and 9.6 cottids/m in 1996.

DIET ANALYSIS

We examined the stomach contents of 1,194 fish, which included 210 trout, 166 coho salmon, and 810 cottids (Tables 3,4). From these, a total of 1,115 salmonid fry were observed. We were able to identify 85% of the salmonid fry as sockeye salmon. The remainder were too digested to be identified to species and could only be classified as unidentified salmonid fry. Based on their size and lack of other salmonid species in the stomach samples, we assumed these unidentified salmonids were sockeye salmon fry. Additionally, catch data from a fry trap at Rkm 0.7 (D. Seiler, WDFW, personal communication, 2000) indicates almost all similar-sized fry were sockeye salmon fry, suggesting these remaining unidentified salmonid fry were most likely sockeye salmon fry.

Only one juvenile chinook salmon was found from all the predators examined. The chinook salmon was a smolt-sized fish that was recovered from a cutthroat trout stomach. Because chinook salmon fry and juveniles are considerably larger than sockeye salmon fry there was little chance of a chinook salmon fry being mistaken as a sockeye salmon fry.

Slow-water reach

Predation rates of sockeye salmon fry. Because fry abundance data were unavailable at the time of this report and predation rates vary widely with fry abundance and streamflow (Tabor, Chan, and Hager 1998), it is difficult to make comparisons between years with just a few sample dates. However, samples collected in 1999 do suggest that predation rates were increased in the slow-water reach from pre-project conditions. For example, trout predation rates were > 5 fry/predatory fish/night at site 1 in March, 1999 with streamflows > 900 cfs (Table 5). During pre-project sampling, similar predation rates of fry was only observed at streamflows < 600 cfs. At streamflows > 600 cfs, little predation was observed; however, sample sizes were small. On March 25, 1999, cottid predation was 0.84 freshly-ingested fry/predatory fish/night following a hatchery release of 333,000 fry (Table 5). Given the streamflow (919 cfs) and fry abundance, we expected the predation rate to be < 0.2 fry/stomach (Tabor, Chan, and Hager 1998). For example, during similar conditions in 1997 (777 cfs, 7.3°C, and 315,000 fry on March 13, 1997) predation was only 0.15 freshly-ingested fry/stomach.

Preliminary analysis of predation at site 3 also indicated an increase in predation rates. The overall predation rate of cottids was higher in 1999 (0.21 fry/stomach; N = 158) than in 1995 to 1998 (0.11 fry/stomach; N = 310), despite higher flows and lower fry abundance.

Overall predation rates at site 2 were similar between 1999 and 1995-1998. Predation in 1999 was 0.167 fresh fry/stomach and 0.170 fresh fry/stomach in 1995-1998.

At site 5, there appeared to be a large difference in predation rates in 1999 compared to 1996. Site 5 was the shoreline of a riffle in 1996, while in 1999, it was part of the slow-water reach. In 1996, no predation of sockeye salmon fry was observed from 7 trout, 3 coho salmon, and 24 cottids. In 1999, trout averaged 2.7 fry/stomach (N = 36), coho salmon averaged 1.7 fry/stomach (N = 46), and cottids averaged 0.9 fry/stomach (N = 60).

Salmonid Diet. During the hatchery release nights in February and March, the vast majority of the diet of salmonids was composed of sockeye salmon fry (Figure 8). Sixty-five percent of the salmonids collected in February to March had consumed sockeye salmon fry (Table 3). In April, sockeye salmon fry was the most important prey item of salmonids, representing over 90% of the diet of coho salmon and cutthroat trout, and 69% of the diet of rainbow trout. The maximum number of fry seen in a salmonid stomach was 66 from a 255 mm FL rainbow trout collected in April. After April, predation of sockeye salmon fry was substantially reduced in all salmonids. They appeared to switch to alternative prey such as aquatic insects, fish eggs, and larval fish. The only species that consumed fry to any large extent was cutthroat trout. In May, almost half of the cutthroat trout had consumed fry, which made up 26% of the overall diet. Predation rates of rainbow trout and coho salmon were low in May (Table 3) and made up a small portion of their diet, 9% and 2%, respectively. During May, fish eggs were abundant in the diet of salmonids (Figure 8). This was particularly noticeable in cutthroat trout; they made up over half of the diet of cutthroat trout in May. Based on size and appearance, the eggs appeared to be primarily catostomid eggs. Fish eggs were also important in the diet of coho salmon and rainbow trout, however, aquatic insects were the dominant prey type, making up over 78% of the diet of coho salmon and 52% of the diet of rainbow trout. In June, little predation of sockeye salmon fry occurred; instead the diet of salmonids was primarily composed of aquatic insects and larval catostomids (Figure 8). Over 600 larval catostomids were found from 31 salmonid stomach samples (Table 3). Other prey fish (chinook salmon and cottids) were also important in the diet of cutthroat trout in June. The diet of coho salmon in June included 41% terrestrial insects.

The only juvenile chinook salmon that was seen in any stomach sample was observed from a 238 mm FL cutthroat trout caught on June 5 at site 5R. The chinook salmon was 88 mm FL.

Cottid Diet. During hatchery releases in February and March, as well as April, the diet of prickly sculpin 50 to 124 mm TL was mostly sockeye salmon fry and oligochaetes (Figure 9). Other prey fish (cottids, lamprey, and adult longfin smelt, *Spirinchus thaleichthys*) were the most important prey category in the diet of prickly sculpin ≥ 125 mm TL in February to April. These large sculpin also consumed large numbers of cottid eggs. Several sockeye salmon fry were consumed by prickly sculpin 125 to 149 mm TL but predation of fry was rare in prickly sculpin ≥ 150 mm TL.

Sockeye salmon fry were present in only 13% of the prickly sculpin sampled in May and no fry were present in June (Table 3). In May and June, aquatic insects became the dominant prey type of prickly sculpin 50 to 99 mm TL. Fish eggs, apparently catostomid eggs, were the dominant prey item of prickly sculpin 100 to149 mm TL in May. Only one prickly sculpin was collected in May and it had only consumed a few aquatic insects. In June, prickly sculpin 50 to 149 mm TL consumed large numbers of larval catostomids. A total of 859 larval catostomids were found from 126 stomach samples. Prickly sculpin ≥ 125 mm TL consumed primarily other fish (lamprey and cottids) and crayfish in June.

In April, May, and June, our sample size of prickly sculpin ≥ 150 mm TL was relatively small (N = 6) . Two of these fish had large crayfish in their stomachs. The other fish had consumed little or no other prey

The diet of riffle sculpin during the hatchery release nights and during April consisted primarily of sockeye salmon fry, aquatic insects, and oligochaetes (Figure 10). Predation of sockeye salmon fry was low in May, representing only 8% of the diet. No predation was observed in June. In May and June, the diet of riffle sculpin consisted of oligochaetes and aquatic insects. Unlike prickly sculpin, riffle sculpin consumed few catostomid eggs and larvae in May or June.

Small numbers of torrent sculpin and coastrange sculpin were collected in the lower reach. They showed the same general trend as the other cottid species, consuming sockeye salmon fry during hatchery release nights and in April. However, few fry were consumed in May or June.

Fast-water reach

Predation rates of sockeye salmon fry. The overall predation rate of cottids at site 7R was slightly higher in 1999 (0.23 fry/stomach; N = 122) than in 1995-1998 (0.17 fry/stomach; N = 70) despite higher flows and lower fry abundance. Coho salmon and trout showed the same trend, however, sample sizes were small.

Salmonid Diet. Low numbers of sockeye salmon fry were consumed by salmonid predators in the upper reach throughout the study period (Table 4). In March and April, rainbow trout consumed a wide variety of prey types which included aquatic insects, fish eggs (mostly cottid eggs), oligochaetes, snails, and algae (Figure 11). The few cutthroat trout and coho salmon collected in March and April had consumed mostly sockeye salmon fry. In April, one cutthroat trout (144 mm FL) was collected with 20 sockeye salmon fry. However, little predation was observed in the other 13 rainbow trout and 1 cutthroat trout collected in April. In May, the diet of all salmonids was dominated by fish eggs (apparently catostomid eggs). Predation of fry in May was only seen in one salmonid (N = 22), a coho salmon with six fry. Rainbow trout and cutthroat trout consumed mostly aquatic insects in June (Figure 11). No predation of fry was observed. No coho salmon were collected in June. Unlike the lower reach, no larval catostomids were consumed by salmonids in the upper reach.

Cottid Diet. Predation of sockeye salmon fry in the upper reach was observed in all four cottid species (Table 4). Overall, predation rates were similar between species. Predation rates were generally higher along the right bank. Ninety-one percent of the predation of fry by cottids was from the right bank, yet only 71% of the fish sampled were from the right bank. Sockeye salmon fry were an important prey item in the diet of cottids in the upper reach during the March hatchery release nights and the month of April (Figure 12). Other prey items included oligochaetes, aquatic insects, fish eggs, and small cottids. In May, fry were only present in the diet of riffle sculpin and torrent sculpin, representing 7 % and 11% of their diet, respectively. Oligochaetes and aquatic insects were the primary prey items in May. No predation of sockeye salmon fry was observed in June. Aquatic insects were the dominant prey type of all cottid species. Oligochaetes and crustaceans (amphipods, isopods, and crayfish) were also important in the diet in June.

DISCUSSION

A wide variety of habitat changes occurred in the lower Cedar River as a result of the flood control project. Each modification appeared to have an effect on predator abundance or predator consumption rates of sockeye salmon fry. The most noticeable modifications included deepening the channel and removing shoreline structures such as bulkheads, undercut banks, woody debris and overhanging vegetation.

Deepening the channel resulted in reduced water velocities. Typically, sockeye salmon fry are consumed in low-velocity areas (Tabor, Chan, and Hager 1998). Predation of sockeye salmon fry within the lower Cedar River in 1999 occurred primarily in the slow-water reach. Most likely, sockeye salmon fry moved through the slow-water reach slower and probably were more vulnerable to predators. Preliminary assessment of predation rates indicated that they increased at site 1, which was slow-water habitat before and after the dredging. Prior to 1999, little predation of fry was observed at streamflows over 700 cfs but in 1999, predation was apparent at streamflows over 900 cfs. Increased predation was most likely due to reduction in water velocities and subsequent delay in sockeye salmon fry emigration.

Deepening the channel also greatly increased the size of the slow-water reach. Although the density of most predators was not increased, the overall abundance of potential predators of sockeye salmon fry was increased because of the increase in slow-water habitat. From 1995 to 1998, the size of the slow-water reach got progressively smaller each year. After the dredging, the slow-water reach in 1999 was 56% larger than in 1995 and almost 200% larger than in 1998.

Another possible effect of deepening the channel was an increase in the size of predators. The best site to examine the difference in size was site 5R, where the depth was greatly increased following the dredging. Unlike most other sites, the shoreline structure appeared to be the same during pre- and post-project conditions. Also, water velocities in the area sampled were slow before and after the dredging. The mean size of cottids at this site increased from 73 to 92 mm TL. However, some of the difference may have been due to gear bias between boat and backpack electrofishing (R. Tabor, unpublished data). Other studies have also shown the relationship between cottid size and depth. Mason and Machidori (1976) observed that large prickly sculpin occupied the deepest locations in pools, and intermediate-sized prickly sculpin were found at shallower depths. Field tests with mottled sculpin (*C. bairdi*) have demonstrated this differential depth selection when different size classes occupy the same area (Freeman and Stouder 1989). The positive relationship between fish size and depth has also been observed in other freshwater fishes (Power 1987; Harvey and Stewart 1991). In the lower Cedar River, an increase in cottid size may have resulted in higher predation rates of sockeye salmon fry. The highest consumption rates of prickly sculpin generally occur in fish 75 to 125 mm TL. During pre-project conditions, most of the cottids at site 5R were < 75 mm TL and incapable of consuming large numbers of fry.

Unlike other predators, coho salmon density was much higher in 1999 than in 1995. There are several possibilities for the observed increase which include: 1) increase in overall abundance of juvenile coho salmon in the Cedar River; 2) sample dates coincided with peak coho salmon abundance; 3) sample dates coincided with peak prey availability; 4) sample dates coincided with low predation risk; and, 5) dredging improved coho salmon habitat. The 1997 escapement of adult coho salmon (parent stock for 1999 juveniles) in the Lake Washington basin was slightly higher than the 1993 escapement (S. Foley, WDFW, personal communication, 2000) but this should only account of a small part of the difference. Because juvenile coho salmon are more migratory than the other predator species, their abundance may vary greatly day to day. We may have sampled when coho salmon were very abundant in 1999 and sampled in 1995 when coho salmon abundance was relatively low. On May 18 and 20, 1999, we sampled shortly after a rain event, streamflows increased from 570 to 772 cfs. The increase in flows may have triggered a large downstream movement of coho salmon. Because almost all coho salmon stomachs contained large amounts of food, prey availability appeared to have been high following the rain event. Associated with the increase in streamflow was also an increase in turbidity which may have reduced predation risk to piscivorus birds. How the deepened channel and lower water velocities affected the migratory behavior of coho salmon is unclear. A deep, slow pool may improve the habitat conditions for juvenile coho salmon and thus they may spend more time in the lower Cedar River than they would have prior to the dredging. In large rivers, juvenile coho salmon prefer large, deep pools with woody debris (Peters 1996). Most likely the increase in the density of coho salmon was caused by a combination of factors including improved habitat condition, high prey availability, decreased predation risk, and increased downstream movement of coho salmon.

The increase in coho salmon abundance probably did not significantly increase the overall predation of sockeye salmon fry because few fry were available in mid-May when coho salmon were abundant. On May 18 and 20, when large numbers of coho were present, only 4 fry were found in 67 stomach samples. Consumption of fry by coho salmon would probably be much higher if fry were abundant and streamflows were low.

From the South Boeing Bridge downstream to Rkm 0.3, all instream and riparian structure on the left bank was either removed or covered over with gravel. Originally the shoreline had bulkheads, undercut banks, woody debris and overhanging vegetation. After the project was completed, no habitat structure was available besides a few small piles of small woody debris. Comparison of the right bank to the left bank at sites 3 and 5 indicated the abundance of salmonids and cottids ($\geq$ 50 mm) was substantially greater on the right bank on all sampling dates. Some pre-project sampling of the left bank with backpack electrofishing equipment was done in 1996, 1997, and 1998. All samples indicate a higher abundance of cottids during pre-project conditions. Instream structures such as woody debris and undercut banks that provide cover are an important component of salmonid habitat and thus increase the carrying capacity of streams (Bjornn and Reiser 1991). It also appears to be important for cottids as well. Earlier work on the Cedar River delta indicated that the abundance of prickly sculpin was substantially higher near areas with large woody debris than areas without (Tabor, Chan, and Hager 1998).

The abundance of cottids in sites 2 and 3 (right bank) was reduced from pre-project conditions, which was apparently due to an increase in fine sediments. Although we were unable to measure the amount of fine sediments, we noticed a substantial increase just from walking along the transect during electrofishing transects. During sampling in 1996 to 1998, we could easily walk along the transect but in 1999 we had difficulty walking through the deep fine sediments. Many small rock outcroppings were covered over with fine sediments. Harvey (1986) indicated high sedimentation rates could reduce populations of riffle sculpin. In a survey of lentic systems in the Cedar River basin, the only locations that no cottids were observed were two small lakes where contained extensive soft sediments (R. Tabor, unpublished data).

Although limited data is available to compare to pre-project conditions, we believe that the abundance of trout ≥ 100 mm FL increased substantially following the addition of rip rap at site 7L. Previously, electrofishing was done once at this site (left bank, site 5), on May 16, 1995. The only salmonid collected over a 47-m length of shoreline was one newly-released hatchery rainbow trout (131 mm FL). In 1999, an average of 7.3 rainbow trout and 2.2 cutthroat trout were collected over a 60-m length of shoreline. On the opposite bank, which was shallower with some small woody debris and no rip rap, few trout were collected (mean, 0.8 rainbow trout and 0.7 cutthroat trout) over a 162-m transect. At other backpack electrofishing sites in the lower 3 km of the Cedar River, few trout have been collected. The only other site where large numbers of rainbow trout have been seen is at a similar rip rap site near the I-405 bridge. Additionally, few trout were seen at site 7L during pre-project 1995 snorkeling counts. Snorkeling counts will be repeated in 2000, to more directly compare to pre-project conditions. Rip rap probably provides good winter habitat because rainbow trout are usually close to cover during this time period. Large rip rap is often preferred over smaller rip rap and other smaller substrates (Lister et al. 1995). Beamer and Anderson (1998) found subyearling and older rainbow trout had a preference for riprap banks during the winter in the Skagit River.

Another change at the upper section was an increase in light intensity. On the left bank, there is a building with several lights near the lower part of transect 7L. During pre-project conditions, light intensity levels in the river were lower because many of the lights were blocked by trees along the streambank. Peak light intensity levels recorded near the building during pre-project conditions was 0.035 lumens/ft^2, whereas during post-project conditions the peak levels were 0.223 lumens/ft^2. Predation rates at site 7R were probably higher in 1999 than in 1996 to 1998 due to the increase in light intensity levels. Although we do not have any pre-project data at site 7L, predation in 1999 is probably related in some degree to the light intensity levels. Earlier work in laboratory experiments (Tabor, Brown, and Luiting 1998) and field trials in the Cedar River (Tabor et al. 2001) have demonstrated that increased light causes sockeye salmon fry to stop migrating, move to the shore, and thus be more vulnerable to predators. Much of the predation at site 7R before 1999 may also be attributed to increased light. At sites with similar habitat but with low light intensity levels, predation rates during hatchery releases were very low (R. Tabor, unpublished data). Predation rates for all habitat types appear to be higher in Renton than at upstream locations.

Based on their diet, trout, coho salmon, and cottids appeared to be opportunistic predators that did not actively select juvenile salmonids, but consumed prey items as they were encountered. Predatory fishes appeared to forage primarily on prey items that were abundant and switched to alternative prey as the original prey items became scarce or the alternative prey item became more abundant. In February and March, hatchery sockeye salmon fry were abundant on release nights and made up a significant proportion of the predatory fishes' diet on those nights. Wild sockeye salmon fry were often consumed in late-March and April, when they were at their peak abundance (Seiler and Kishimoto 1997). Adult longfin smelt and eggs were common in the diet of cottids, during the peak of the spawning run in March (Tabor and Chan 1996a). In May and June, aquatic insects were common in the diet. Many aquatic insects emerge during the late-spring (Hynes 1970; Kerst and Anderson 1974) and are probably more available to predatory fishes. Sibley and Brocksmith (1996) found that the abundance of aquatic insects in the lower Cedar River was much higher in June than April. Catostomid eggs were important in the diets in May which corresponds to the observed spawning activity of adult catostomids, presumably largescale suckers (*Catostomus macrocheilus*). In June, we have observed large numbers of larval catostomids in the lower Cedar River as well as in the stomachs of predatory fishes.

As a whole, each species appeared to forage opportunistically; however, within each species there did appear to be some specialization between individuals. Most of the predation of sockeye salmon fry was often confined to a few individuals. On a given transect we may have had a few trout with over 20 fry each in their stomachs and then have several other similar-sized trout that had not consumed a single fry. Some of these other trout may have consumed primarily caddisflies or cottids, suggesting they were foraging on the bottom. Other trout may have preyed on terrestrial insects and aquatic insect exuvia, suggesting they were foraging on drift. Differences between individuals may reflect differences in foraging locations within the water column and/or differences in search patterns. Food specialization was also apparent in cottids but not as prominent as in trout. Food specialization has been demonstrated in brook trout (*Salvelinus fontinalis*), rainbow trout, cutthroat trout (Bryan and Larkin 1972), and brown trout (*Salmo trutta*) (Birdcut and Giler 1995).

The reason for the reduced catch rates of beach seining is unclear. Reduced catch was either due to reduced fishing efficiency of the net, or related to fish abundance. We used a different net because the channel was considerably deeper than during pre-project sampling. The net was deeper with larger mesh sizes so that we could pull in the net at the same speed as before. The net appeared to fish effectively. However, on some nights in 1999, we observed adult suckers close to the bottom but we were unable to capture them, unlike in 1995 and 1996. Perhaps the net was slightly off the bottom and they swam under the net, or the fish could swim easily around the net. The wetted channel width was much greater in 1999 because the sandbars we used to fish from in 1995 and 1996 were removed. The wetted channel width was approximately one-third to one-half narrower during 1995 and 1996 sample periods. Thus, the fish were spread out over a larger area and may have been able to easily swim around the net. Whereas before, fish were in a narrower channel and they could be easily encircled. The net probably needed to be two or three times as long to effectively encircle the fish.

Alternatively, low catch rates with beach seines may simply reflect a lower abundance of predators. Instream structure along the left bank was removed during the project. In 1995 and 1999, we often set the net close to the left bank and many of the predators we collected may have been associated with that structure. During the winter and spring, salmonids and cottids are very close to cover during the day but move out to forage at night. Therefore, the lack of instream structure may have reduced the abundance of salmonids and cottids. Most right bank structures within the beach seining area were still in place in 1999 but some of the complexity was lost due to an increase in fine sediments.

Predation of chinook salmon in the study reach appeared to be low; however, we were unable to sufficiently sample in February when juvenile chinook would have been most abundant (D. Seiler, WDFW, unpublished data). According to D. Seiler there are two groups of migrants in the Cedar River: a large early group that outmigrates to Lake Washington as fry (mid-January to mid-March) and a smaller late group that outmigrates as substantially larger juveniles (mid-May to early-July). Juvenile chinook are probably only occasionally consumed in May to July because they are relatively large (approximately 60 to 110 mm FL) and are not vulnerable to most predatory fishes. Probably only the largest trout (i.e., > 225 mm FL) would be able to capture juvenile chinook salmon. From mid-January to mid-March, juvenile chinook salmon are more abundant and more vulnerable to predators, however, the abundance of predatory fishes is usually low during this time period. Because of the rarity of predation of juvenile chinook salmon, it is difficult to determine if there was any effect due to the flood control project.

Overall, predation rates on sockeye salmon fry increased as predicted but the total predation was somewhat lower than expected due to the reduction of predator abundance in some locations. The slow-water reach was much larger and deeper than during pre-project conditions thus the amount of available habitat for predators of sockeye salmon fry was increased. Thus, the total abundance of predators was greater than during pre-project. However, because of the removal of instream structures and an increase in fine sediments, the predator abundance was not as large as would be expected. In upcoming years, the size of the slow-water reach should decrease as sediments move downstream and fill in this reach. However, high-flow events may improve the habitat for predators as woody debris is deposited and fine sediments are removed.

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Table 1. – Location and distance of beach seining sites and electrofishing transects used to collect predatory fishes in the lower 1.7 km of the Cedar River, February to June, 1999. The river mouth is defined as the downstream end of the North Boeing Bridge.

Gear type Site #	Location	Distance from river mouth (m)	Distance sampled (m)
Beach seining			
1	Midchannel/Right bank	335-425	approx. 70-90
2	Midchannel/Left bank	540-630	approx. 70-90
3	Midchannel/Right bank	650-740	approx. 70-90
Boat electrofishing			
1	Right bank	20-338	318
1	Left bank	20-234	214
5	Right bank	688-911	223
5	Left bank	688-911	223
Backpack electrofishing			
2	Right bank	348-420	72
3	Right bank	428-608	180
3	Left bank	428-608	180
7	Right bank	1400-1564	164
7	Left bank	1520-1580	60

Table 2. – Population estimates of salmonids (**A**), smallmouth bass (**A**), and cottids (**B**), in the lower Cedar River, April to May, 1999. Salmonids and smallmouth bass population estimates were conducted at one location (site 1 R,L) on April 28, 1999. Cutthroat trout and rainbow trout were combined into one estimate. Cottid population estimates were conducted at three locations. The population estimate at site 1 is only for prickly sculpin but at sites 2 and 3 it represents a combined estimate of four species. N = population estimate; CI = 95% confidence interval. MC/N indicates the probability of statistical bias, if > 4 the probability of bias is < 2% (Ricker 1975).

A. Salmonids and smallmouth bass - single mark-recapture methodology

Species	Number marked (M)	Catch (C)	Number of recaptures (R)	N	Lower CI	Upper CI	MC/N
Trout	24	21	10	50	28	97	10.0
Coho salmon	19	33	5	113	54	262	5.5
Smallmouth bass	1	1	1	2	1	4	0.5

B. Cottids - multiple mark-recapture methodology

Site #	Date	Number caught (C)	Number of recaptures (R)	Number marked at large (M)	Number marked (less removed)	N	Lower CI	Upper CI
1R,L	April 28	139	0	0	139			
	April 29	169	10	139	159			
	April 30	83	13	298	--			
	Total		23		298	2009	1402	3303
2R	May 3	18	0	0	18			
	May 7	14	1	18	13			
	May 11	15	1	31	--			
	Total		2		31	239	100	3585
3R	May 3	29	0	0	29			
	May 7	16	1	29	15			
	May 11	21	0	44	--			
	Total		1		44	694	248	13880

Table 3.-- Salmonid fry and other prey fish consumed by predatory fishes (≥ 50 mm TL) in the lower 0.9 km of the Cedar River, February to June, 1999. Fish were collected with boat and backpack electrofishing equipment.

Predators			Salmonid fry consumed					Other fish			
Date Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum # /stomach	Lamprey	Cottids	Larval fish	Other fish
February-March											
Salmonids	**46**	**9**	**278**	**20**	**6.5**	**65**	**41**	**0**	**3**	**0**	**0**
Cutthroat trout	5	0	81	5	17.2	100	41	0	0	0	0
Rainbow trout	28	11	158	5	5.8	54	26	0	3	0	0
Coho salmon	13	8	39	10	3.8	77	10	0	0	0	0
Cottids	**170**	**22**	**137**	**28**	**1.0**	**33**	**22**	**5**	**15**	**0**	**4**
Coastrange sculpin	4	75	1	0	0.3	25	1	0	0	0	0
Prickly sculpin	137	24	123	22	1.1	33	22	4	15	0	4
Riffle sculpin	26	0	11	4	0.6	35	5	1	0	0	0
Torrent sculpin	3	33	2	2	1.3	33	2	0	0	0	0
Smallmouth bass	**2**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
April											
Salmonids	**103**	**15**	**309**	**46**	**3.4**	**35**	**66**	**0**	**0**	**0**	**2**
Cutthroat trout	13	23	47	8	4.2	62	17	0	0	0	0
Rainbow trout	44	18	169	25	4.4	20	66	0	0	0	0
Coho salmon	46	9	93	13	2.3	41	13	0	0	0	2
Cottids	**154**	**14**	**85**	**35**	**0.8**	**40**	**10**	**0**	**2**	**0**	**1**
Coastrange sculpin	1	100	0	0	0	0	0	0	0	0	0
Prickly sculpin	110	18	68	22	0.8	35	10	0	1	0	1
Riffle sculpin	39	0	17	10	0.7	54	2	0	0	0	0
Torrent sculpin	4	0	0	3	0.8	75	1	0	1	0	0
Smallmouth bass	**2**	**50**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
May											
Salmonids	**118**	**7**	**44**	**17**	**0.5**	**19**	**23**	**0**	**0**	**0**	**2**
Cutthroat trout	13	15	31	5	2.8	46	23	0	0	0	1
Rainbow trout	13	23	3	1	0.3	23	2	0	0	0	0
Coho salmon	92	3	10	11	0.2	14	6	0	0	0	1
Cottids	**175**	**10**	**31**	**4**	**0.2**	**12**	**8**	**7**	**0**	**0**	**1**
Prickly sculpin	120	13	26	3	0.2	13	8	7	0	0	1
Riffle sculpin	47	2	3	0	0.1	6	1	0	0	0	0
Torrent sculpin	8	13	2	1	0.4	25	2	0	0	0	0
Smallmouth bass	**2**	**50**	**1**	**0**	**0.5**	**50**	**1**	**0**	**0**	**0**	**0**
June											
Salmonids	**31**	**3**	**1**	**1**	**0.1**	**6**	**1**	**0**	**1**	**631**	**1**
Cutthroat trout	23	0	1	0	0.04	4	1	0	1	571	1
Rainbow trout	3	33	0	0	0	0	0	0	0	51	0
Coho salmon	5	0	0	1	0.2	20	1	0	0	9	0
Cottids	**137**	**7**	**0**	**0**	**0**	**0**	**0**	**3**	**3**	**862**	**0**
Coastrange sculpin	3	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	126	8	0	0	0	0	0	3	3	859	0
Riffle sculpin	8	0	0	0	0	0	0	0	0	3	0
Smallmouth bass	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
Yellow perch	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 4.-- Salmonid fry and other prey fish consumed by predatory fishes ($\geq$ 50 mm TL) at river kilometer 1.4-1.6 of the Cedar River, March to June, 1999. Fish were collected with backpack electrofishing equipment.

Predators			Salmonid fry consumed					Other fish			
Date / Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum # /stomach	Lamprey	Cottids	Larval fish	Other fish
February-March											
Salmonids	**29**	**17**	**15**	**5**	**0.7**	**24**	**5**	**0**	**2**	**0**	**0**
Cutthroat trout	3	33	4	0	1.3	33	4	0	0	0	0
Rainbow trout	22	18	4	5	0.4	18	5	0	2	0	0
Unidentified trout	2	0	2	0	1.0	50	5	0	0	0	0
Coho salmon	2	0	5	0	2.5	50	5	0	0	0	0
Cottids	**22**	**5**	**6**	**5**	**0.5**	**45**	**2**	**0**	**1**	**0**	**1**
Coastrange sculpin	4	0	1	0	0.3	25	1	0	1	0	1
Prickly sculpin	2	50	1	0	0.5	50	1	0	0	0	0
Riffle sculpin	5	0	1	2	0.6	60	1	0	0	0	0
Torrent sculpin	11	0	3	3	0.5	45	2	0	0	0	0
April											
Salmonids	**19**	**5**	**32**	**0**	**1.7**	**21**	**20**	**0**	**0**	**0**	**0**
Cutthroat trout	2	0	20	0	10.0	50	20	0	0	0	0
Rainbow trout	13	8	2	0	0.2	8	2	0	0	0	0
Coho salmon	4	0	10	0	2.5	50	6	0	0	0	0
Cottids	**27**	**15**	**16**	**3**	**0.7**	**37**	**4**	**0**	**1**	**0**	**0**
Coastrange sculpin	2	0	1	0	0.5	50	1	0	0	0	0
Prickly sculpin	5	20	1	0	0.2	20	1	0	0	0	0
Riffle sculpin	10	20	7	3	1.0	60	3	0	0	0	0
Torrent sculpin	10	10	7	0	0.7	20	4	0	1	0	0
May											
Salmonids	**22**	**9**	**3**	**3**	**0.3**	**5**	**6**	**0**	**0**	**1**	**0**
Cutthroat trout	8	13	0	0	0	0	0	0	0	1	0
Rainbow trout	10	0	0	0	0	0	0	0	0	0	0
Coho salmon	4	25	3	3	1.5	25	6	0	0	0	0
Cottids	**74**	**12**	**5**	**0**	**0.1**	**4**	**2**	**0**	**0**	**2**	**2**
Coastrange sculpin	8	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	14	7	0	0	0	0	0	0	0	0	0
Riffle sculpin	19	16	3	0	0.2	11	2	0	0	0	1
Torrent sculpin	33	15	2	0	0.1	3	2	0	0	2	1
June											
Salmonids	**8**	**13**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**0**
Cutthroat trout	4	0	0	0	0	0	0	0	0	0	0
Rainbow trout	4	25	0	0	0	0	0	0	0	0	0
Cottids	**51**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**0**
Coastrange sculpin	9	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	8	0	0	0	0	0	0	0	0	1	0
Riffle sculpin	14	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	20	0	0	0	0	0	0	0	0	5	0

Table 5. – Predation rates of sockeye salmon fry by predatory fishes (fry/predatory fish/night) in the slow-water reach of the lower 1.7 km of the Cedar River, February-June, 1999. Streamflow, water temperature, and the number of hatchery sockeye salmon fry released is also given. The date given is the date at the beginning of the night. N = the number of predatory fish sampled.

					Predation of sockeye salmon fry					
					Trout		Coho salmon		Cottids	
Site #	Date	Streamflow (cfs)	Temp. (°C)	Fry released	N	fry/fish/ night	N	fry/fish/ night	N	fry/fish/ night
1 R,L	Feb. 11	905	5.7	562,000	0	-	0	-	20	0.05
	March 3	982	6.2	429,000	0	-	0	-	23	0.00
	March 9	968	6.1	399,000	9	7.22	0	-	19	0.11
	March 24	919	7.7	333,000	18	5.39	1	5.00	49	0.84
	April 14	570	8.7	0	22	4.05	17	3.41	41	0.10
	April 28	765	8.8	0	22	0.27	16	0.00	26	0.04
	May 17	683	9.9	0	3	6.67	43	0.00	3	0.00
	May 19	671	10.2	0	11	0.00	24	0.00	44	0.00
	June 13	427	15.8	0	14	0.00	0	-	68	0.00
2 R	March 3	982	6.2	429,000	0	-	0	-	10	0.00
	March 23	683	8.6	333,000	0	-	0	-	10	0.10
	April 11	593	9.0	0	0	-	0	-	19	0.05
	May 3	805	8.8	0	0	-	0	-	18	0.50
	May 24	605	14.0	0	0	-	0	-	6	0.00
	June 17	485	14.8	0	0	-	0	-	27	0.00
3 R,L	Feb. 11	905	5.7	562,000	0	-	0	-	13	0.54
	March 2	1160	6.2	215,000	0	-	0	-	12	0.00
	March 23	683	8.6	333,000	0	-	0	-	22	0.77
	April 11	593	9.0	0	0	-	0	-	32	0.25
	May 3	805	8.8	0	0	-	0	-	17	0.06
	May 24	605	14.0	0	0	-	0	-	31	0.00
	June 17	485	14.8	0	0	-	0	-	31	0.00
5 R,L	March 9	968	6.1	399,000	2	0.00	2	0.00	8	0.50
	March 24	919	7.7	333,000	4	6.00	9	2.89	11	1.64
	April 14	570	8.7	0	13	6.00	13	1.46	16	0.63
	May 10	593	10.6	0	12	0.58	25	0.12	39	0.18
	June 7	453	11.3	0	12	0.08	5	0.00	2	0.00

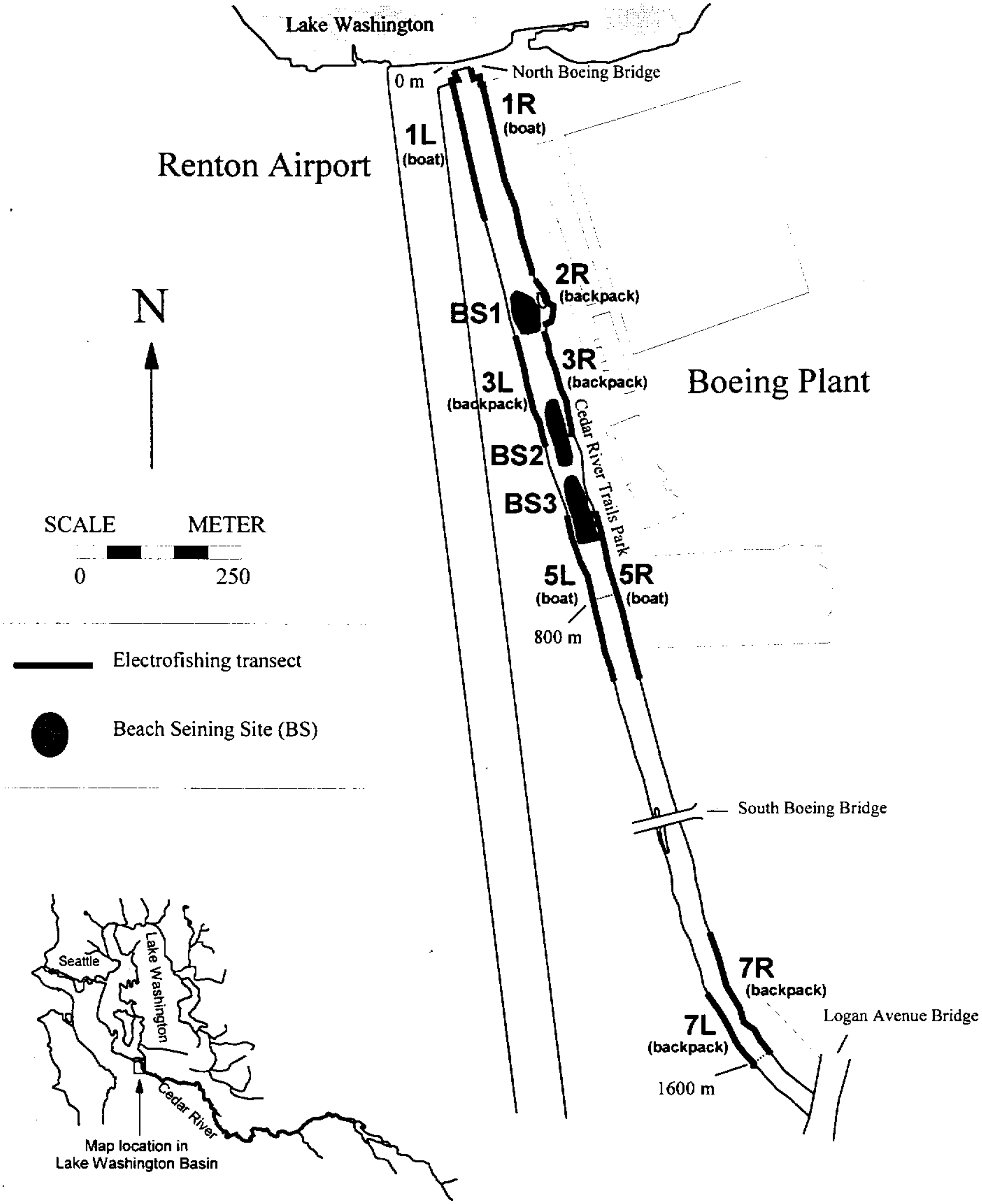


Figure 1. Electrofishing and beach seining sites used to collect predatory fishes in the lower Cedar River, Febuary to June, 1999. L and R indicate left (westside) or right (eastside) bank. Type of electrofishing is indicated in parentheses.

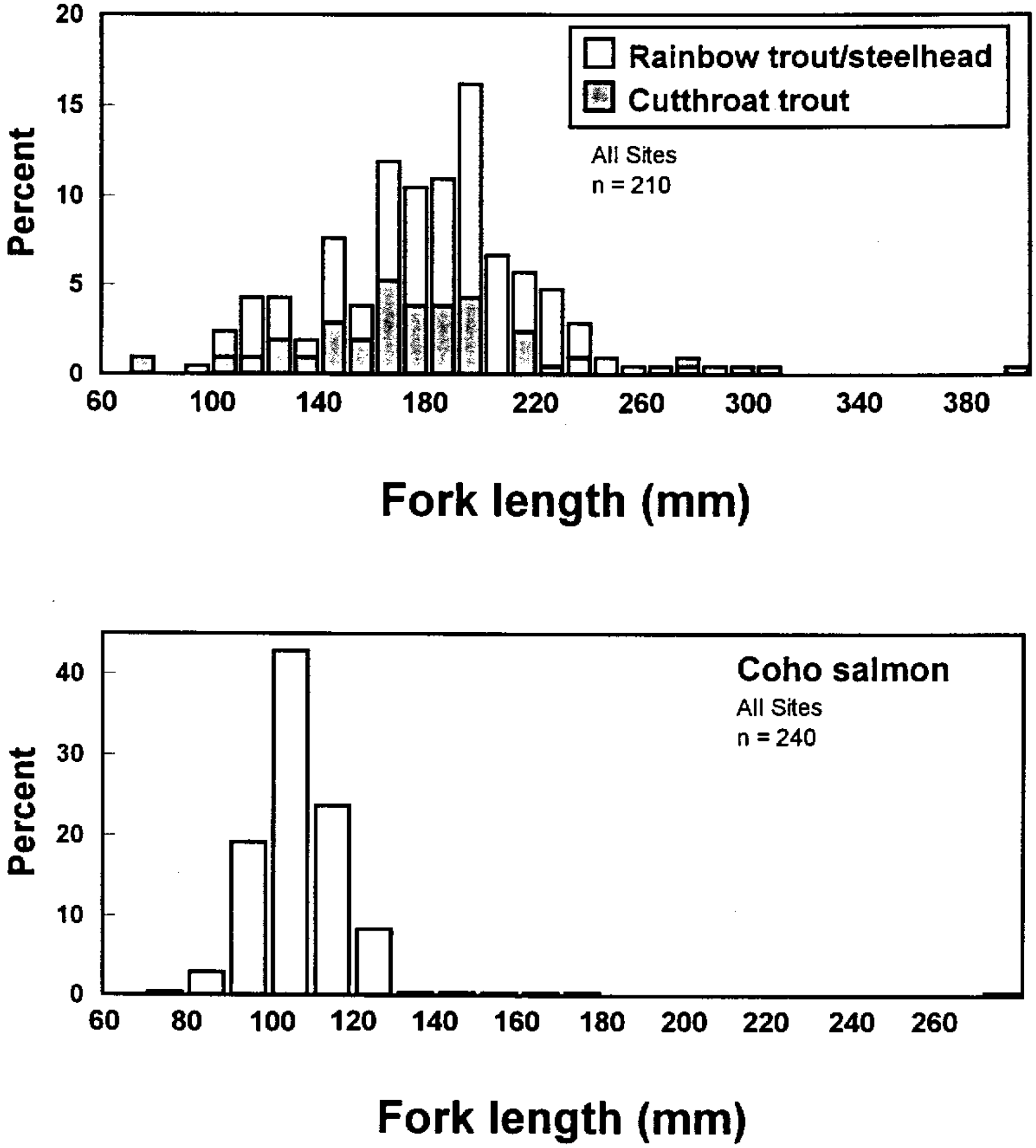


Figure 2. Length frequencies (10 mm increments) of salmonid predators collected in the lower Cedar River, February to June, 1999. Fish were collected by electrofishing equipment.

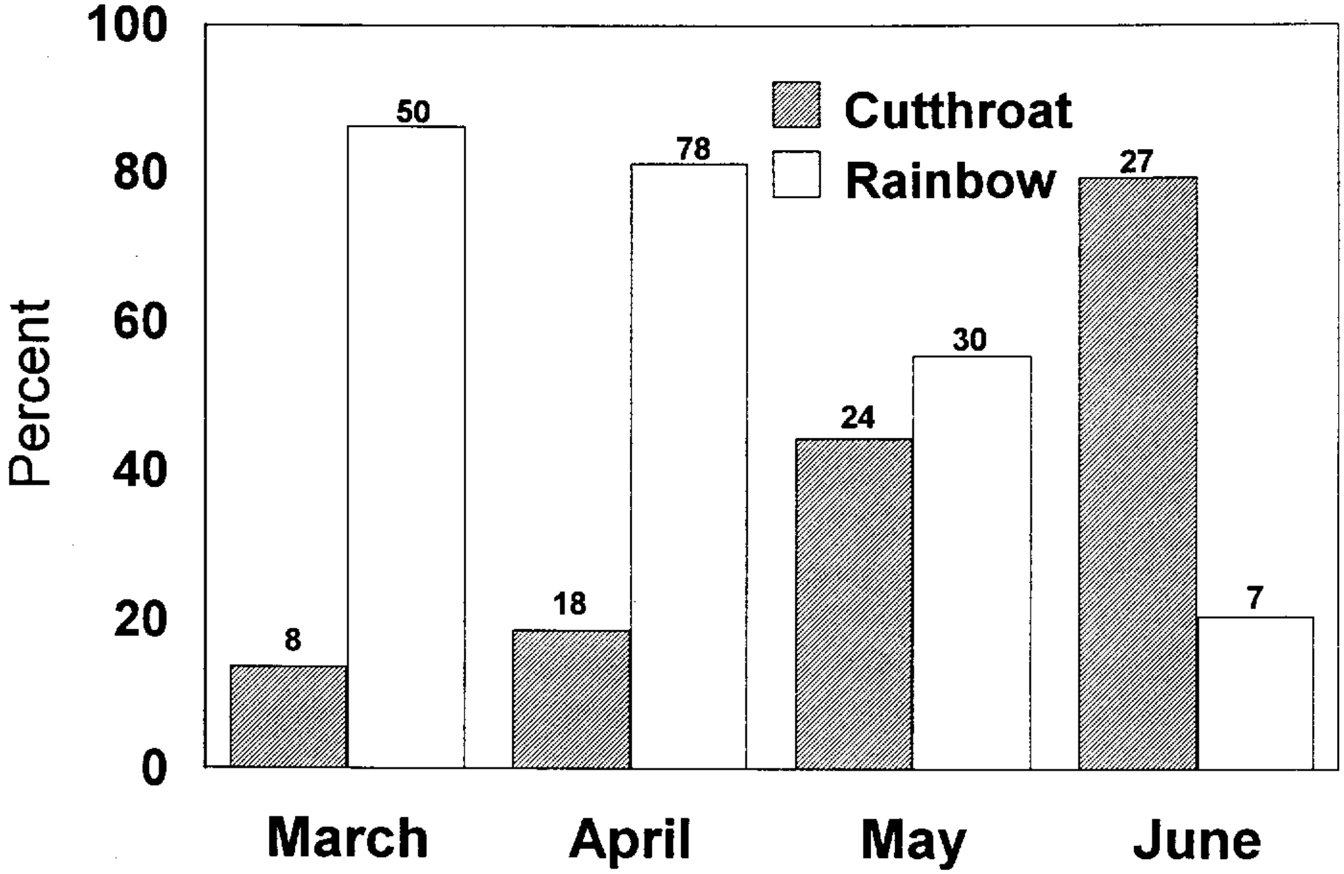


Figure 3. Percent of total trout catch (by month) that is made up of cutthroat trout or rainbow trout in the lower Cedar River, 1999. The total catch for each month is indicated above each bar.

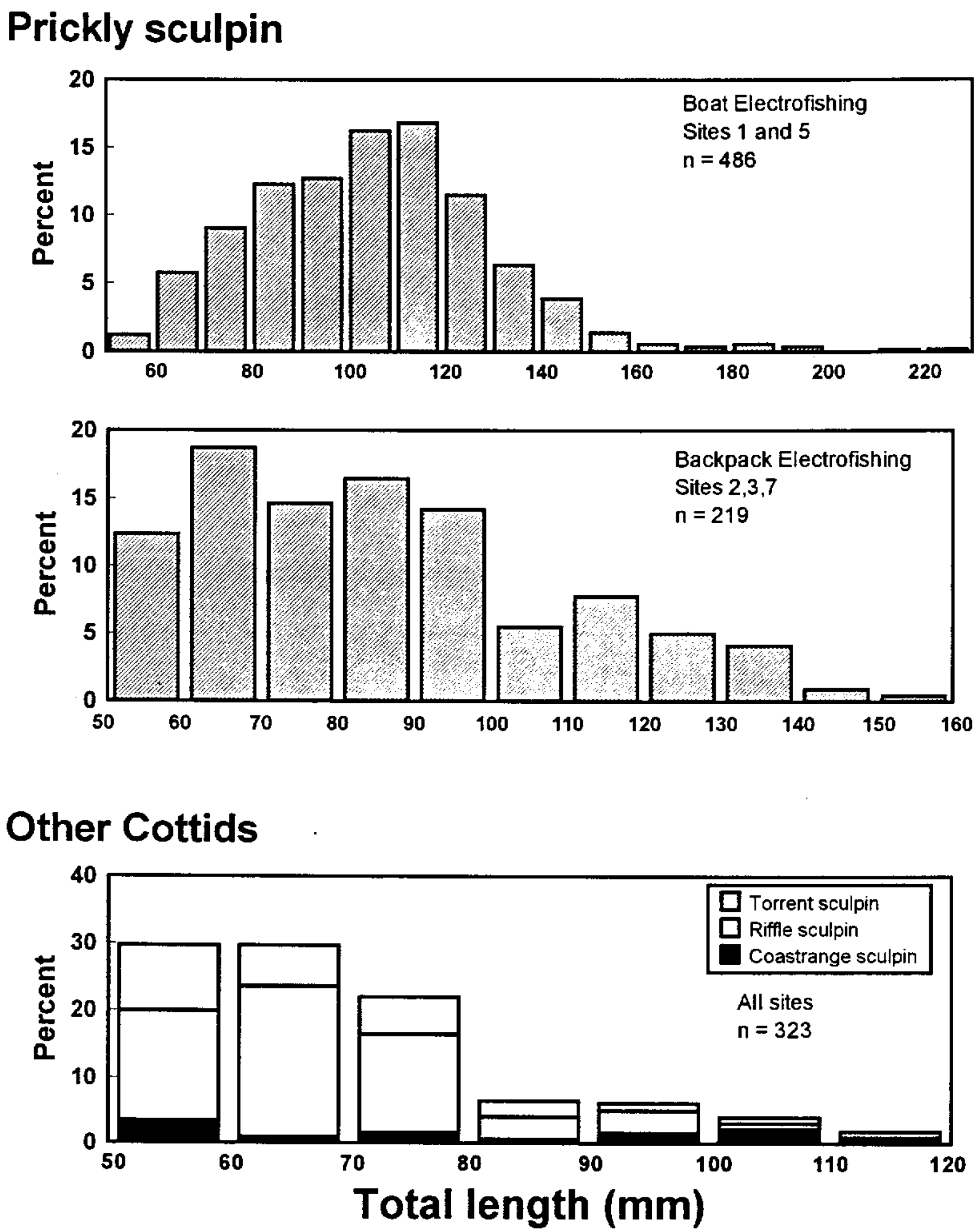


Figure 4. Length frequencies (10 mm increments) of four cottid species ≥ 50 mm TL collected in the lower Cedar River, February to June, 1999. Prickly sculpin were collected with boat and backpack electrofishing equipment, while the vast majority of the other cottids were collected with backpack electrofishing.

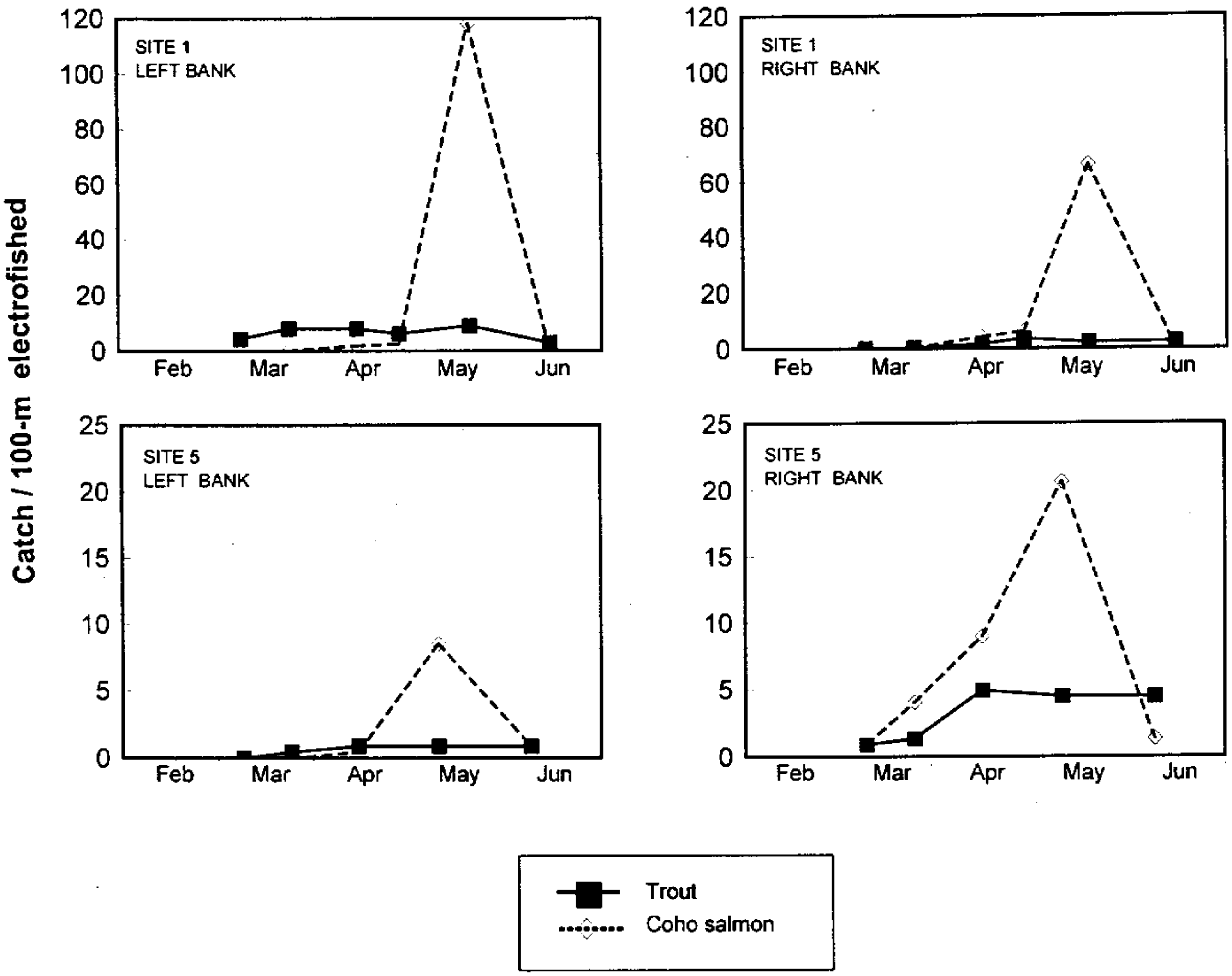


Figure 5. Electrofishing catch (number/100 m of shoreline) of salmonids in the slow-water reach (river kilometer 0-0.9) of the lower Cedar River, February to June, 1999. All fish were collected with boat electrofishing equipment. Trout includes cutthroat trout, rainbow trout/steelhead, and unidentified juvenile trout.

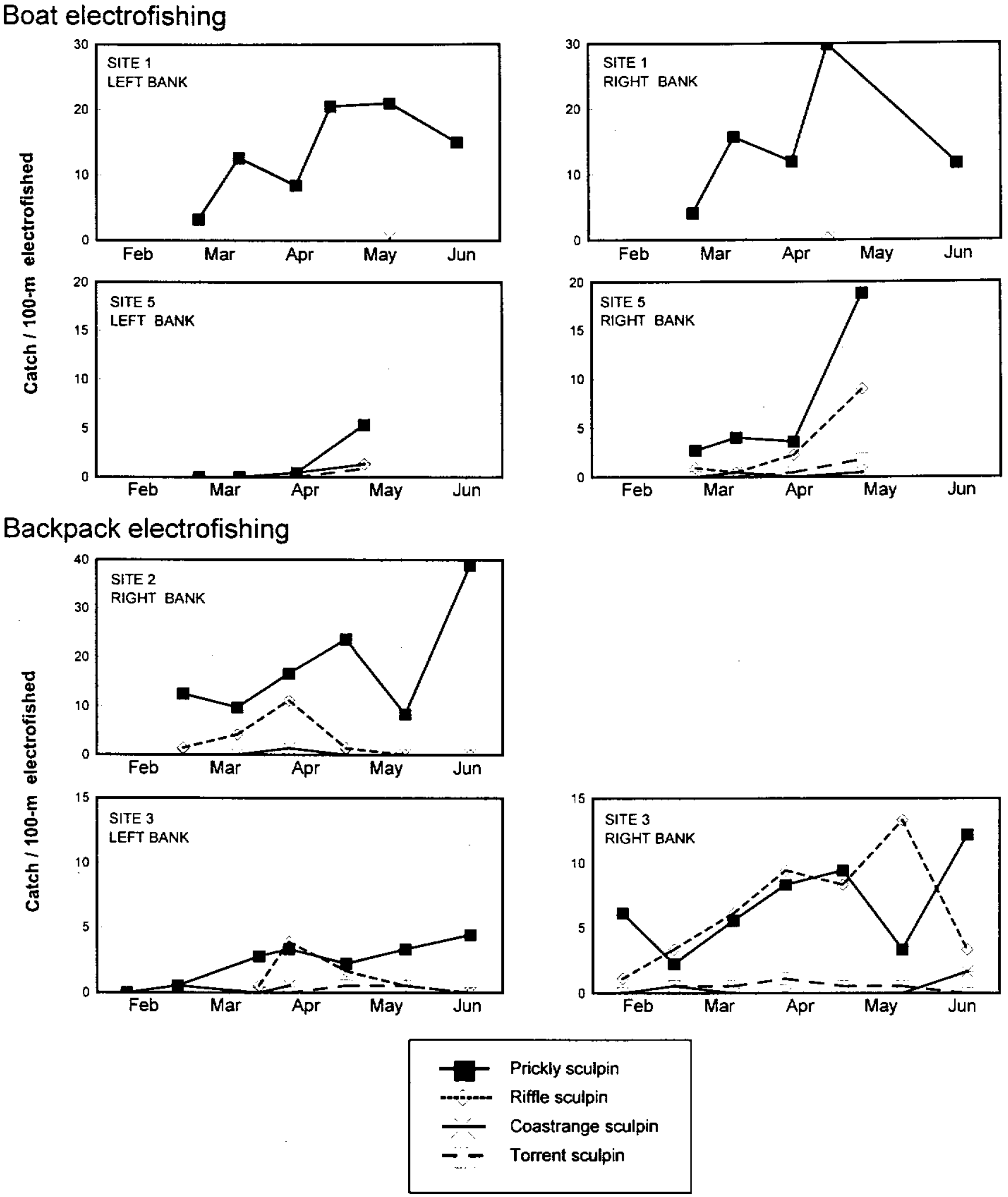
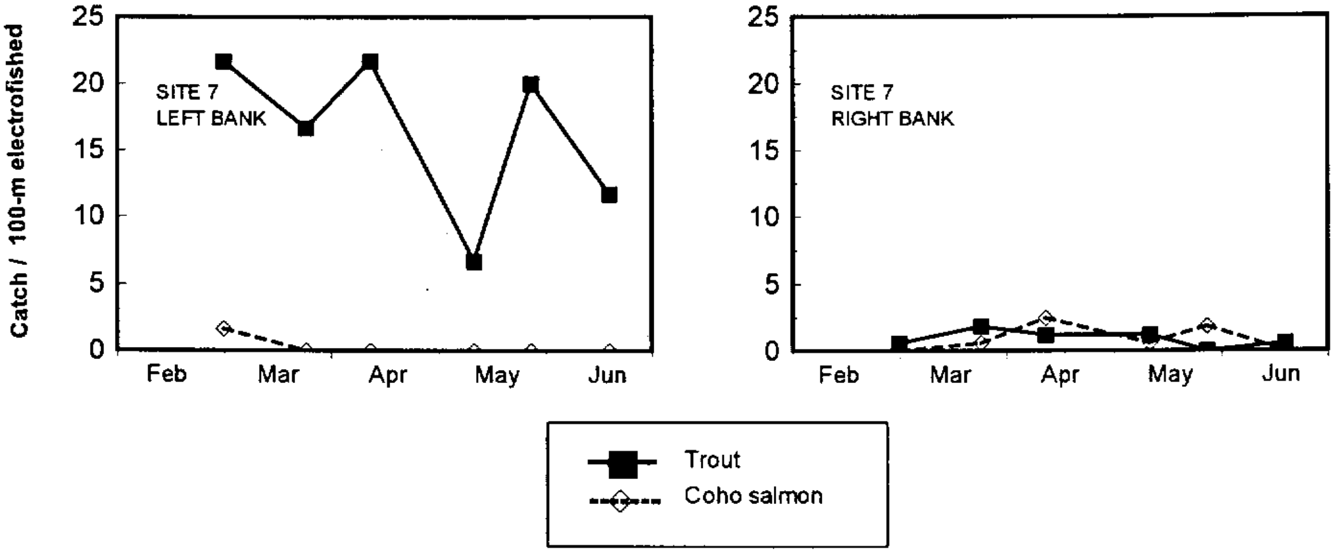


Figure 6. Electrofishing catch (number/100 m of shoreline) of four cottid species ($\geq$ 50 mm TL) in the slow-water reach (river kilometer 0-0.9) of the lower Cedar River, February to June, 1999. Catch during high turbidity events was not included.

Salmonids



Cottids

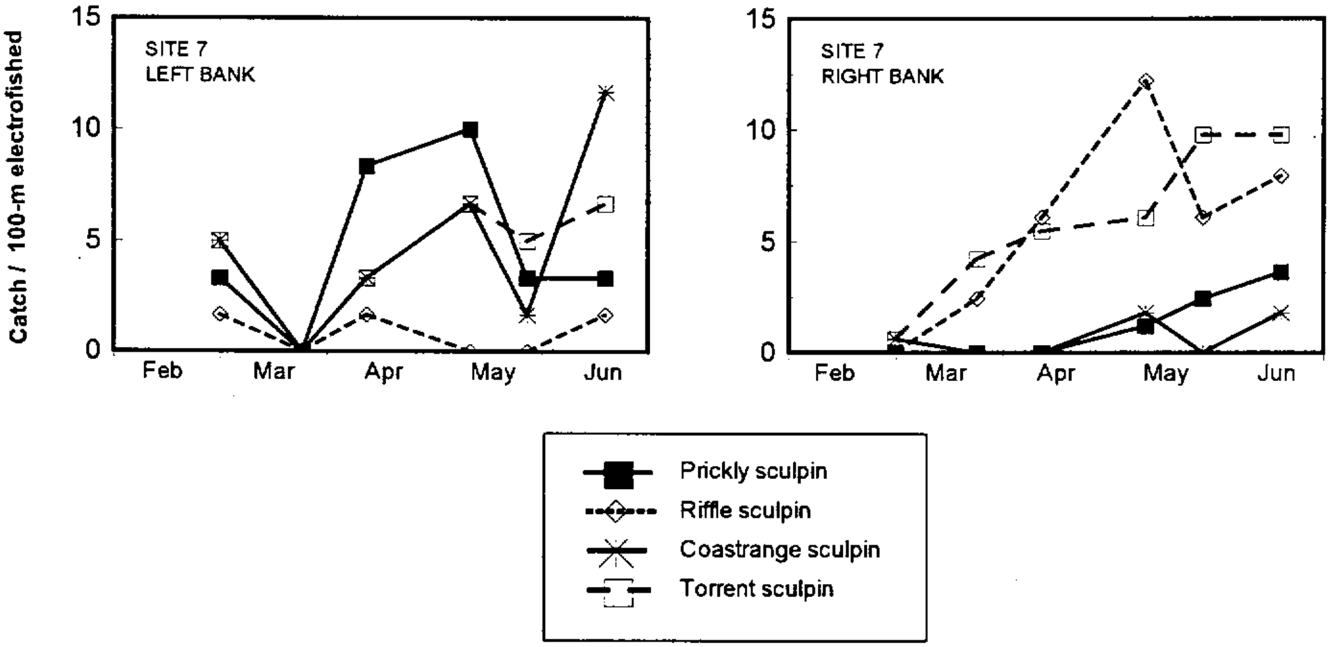


Figure 7. Electrofishing catch (number/100 m of shoreline) of salmonids and cottids ($\geq$ 50 mm TL) in the fast-water reach (river kilometer 1.4-1.6) of the lower Cedar River, February to June, 1999. All fish were collected with backpack electrofishing equipment. Trout includes cutthroat trout, rainbow trout/steelhead, and unidentified juvenile trout.

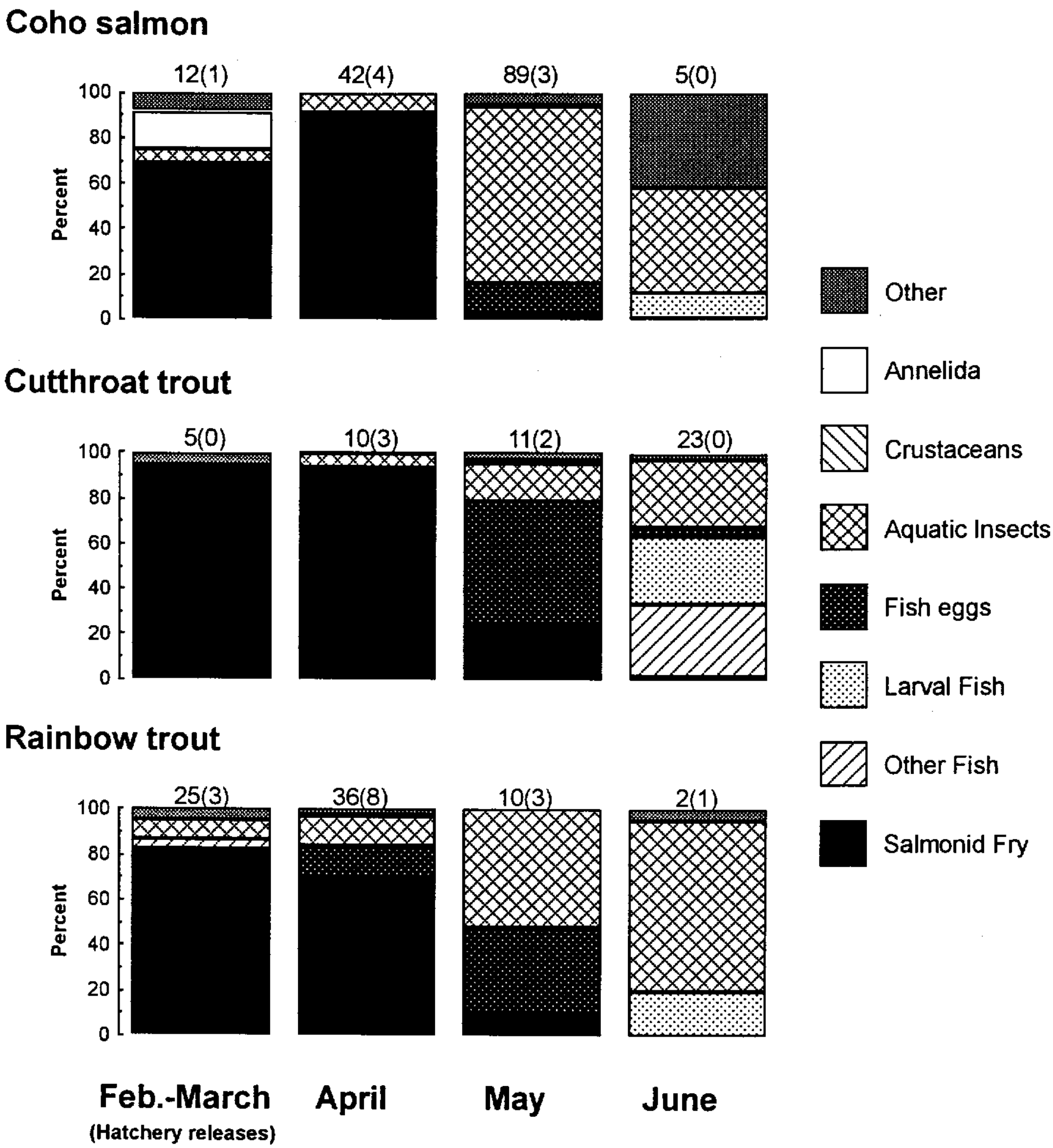


Figure 8.-- Composition (percent by weight) of ingested food for three salmonid species in the lower 0.9 km of the Cedar River, February to June, 1999. Number of predator stomachs that contained prey is given above the graph; the number of fish with empty stomachs is in parentheses.

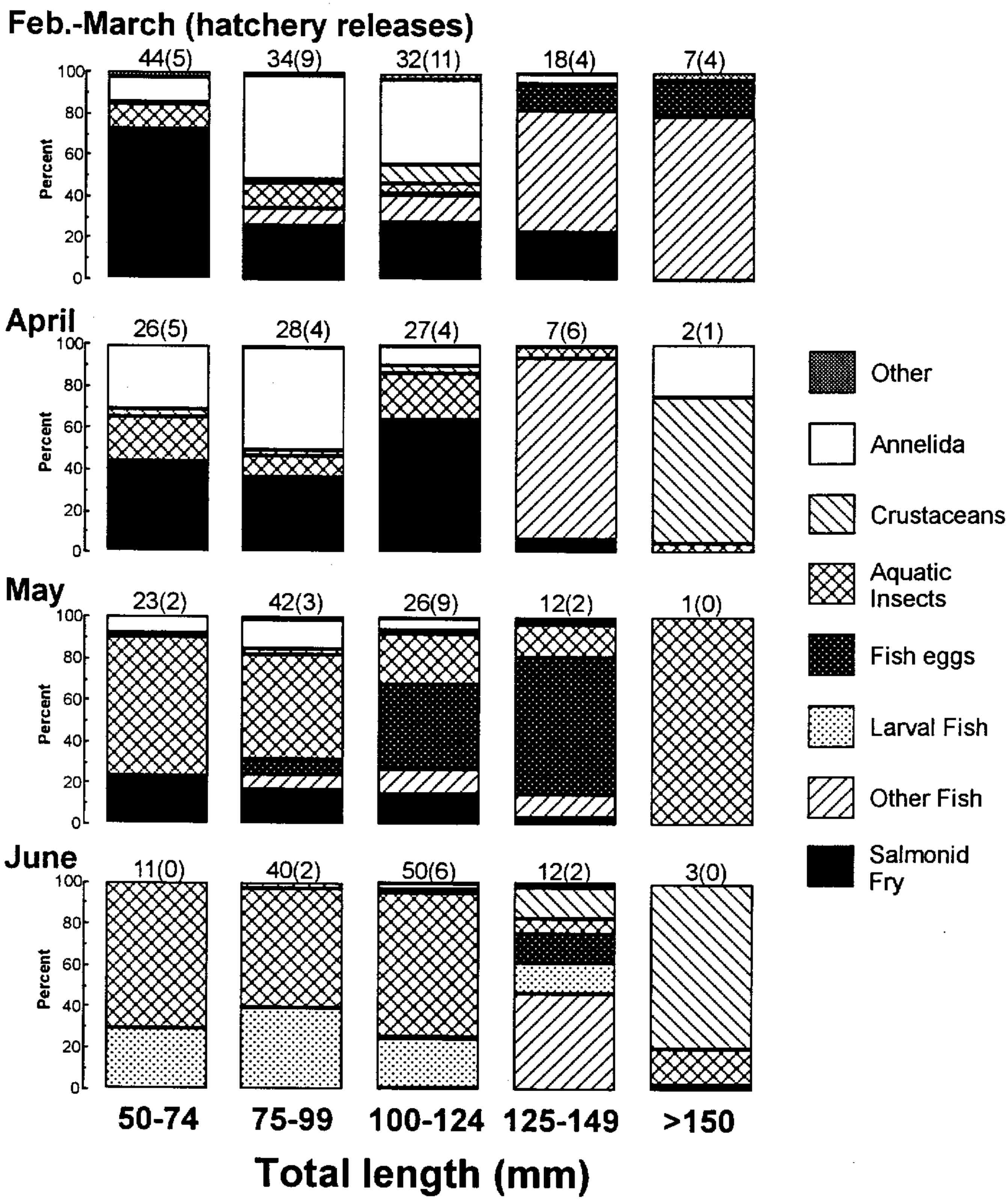


Figure 9.-- Composition (percent by weight) of ingested food for five size categories of prickly sculpin ($\geq$ 50 mm TL) in the lower 0.9 km of the Cedar River, February to June, 1999. Number of predator stomachs that contained prey is given above the graph; the number of fish with empty stomachs is in parentheses.

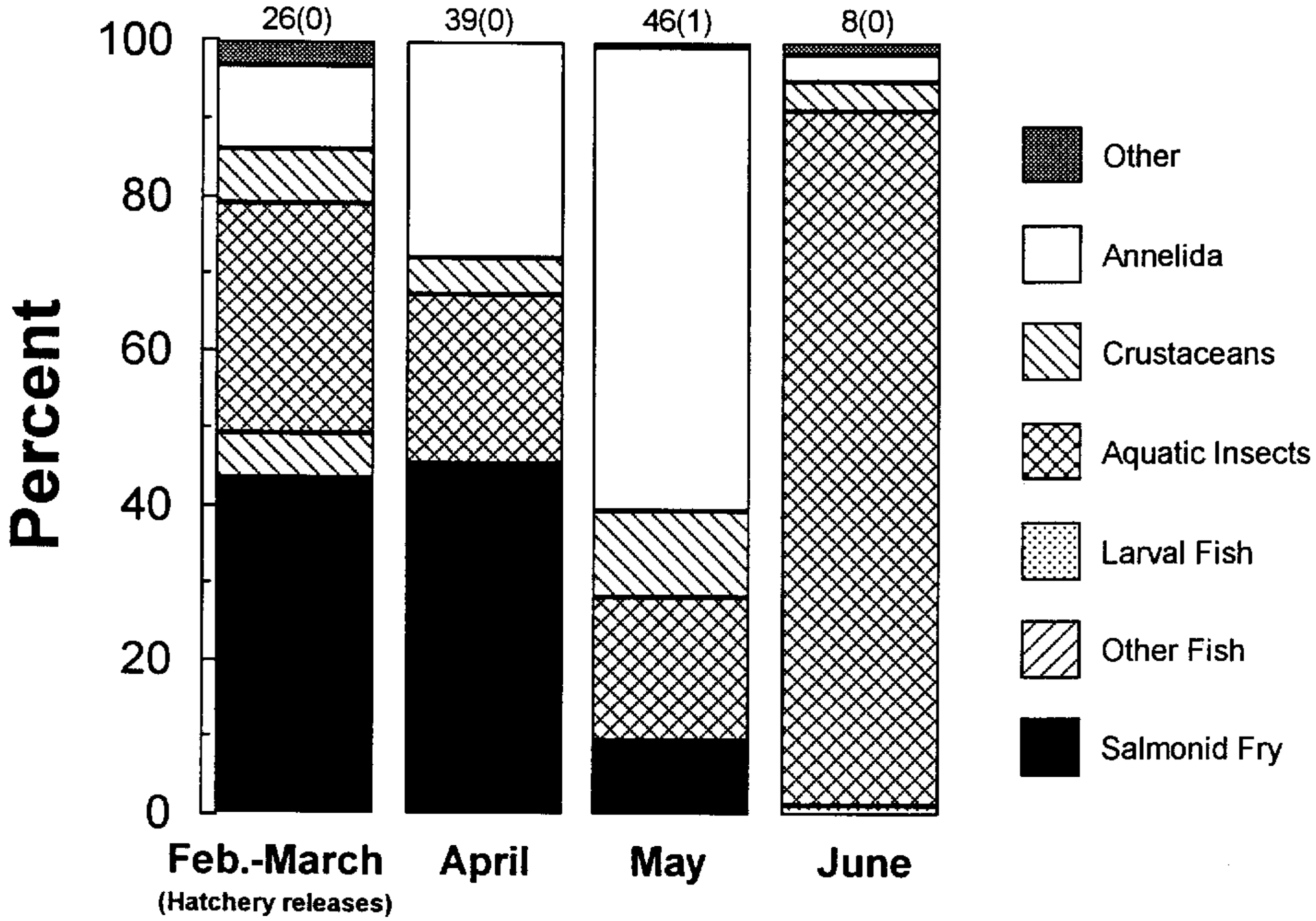


Figure 10.-- Composition (percent by weight) of ingested food for riffle sculpin (≥ 50 mm TL) in the lower 0.9 km of the Cedar River, February to June, 1999. Number of predator stomachs that contained prey is given above the graph; the number of fish with empty stomachs is in parentheses.

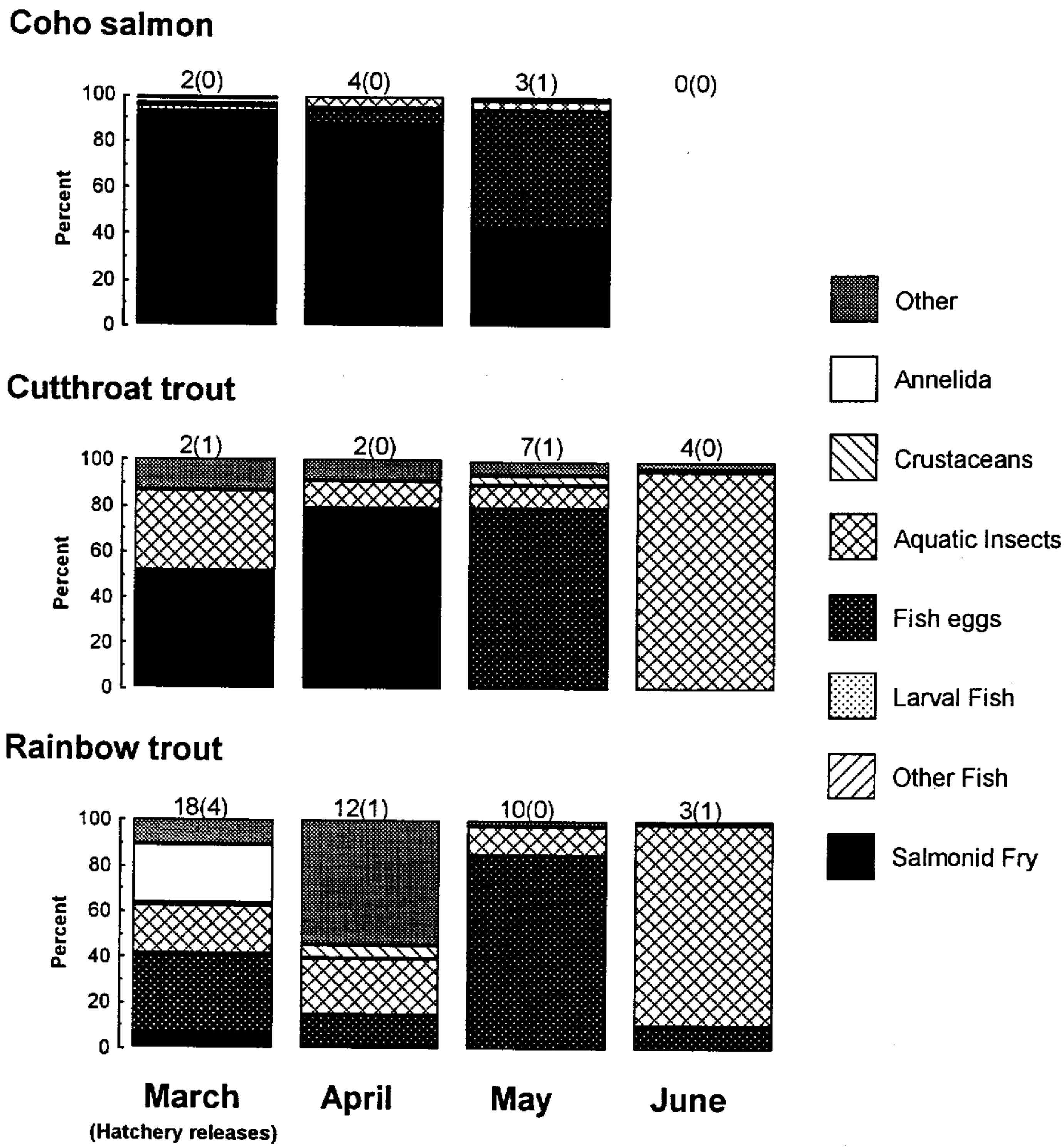


Figure 11.-- Composition (percent by weight) of ingested food by three salmonid species at river kilometer 1.4-1.6 of the Cedar River, March to June, 1999. Number of predator stomachs that contained prey is given above the graph; the number of fish with empty stomachs is in parentheses.

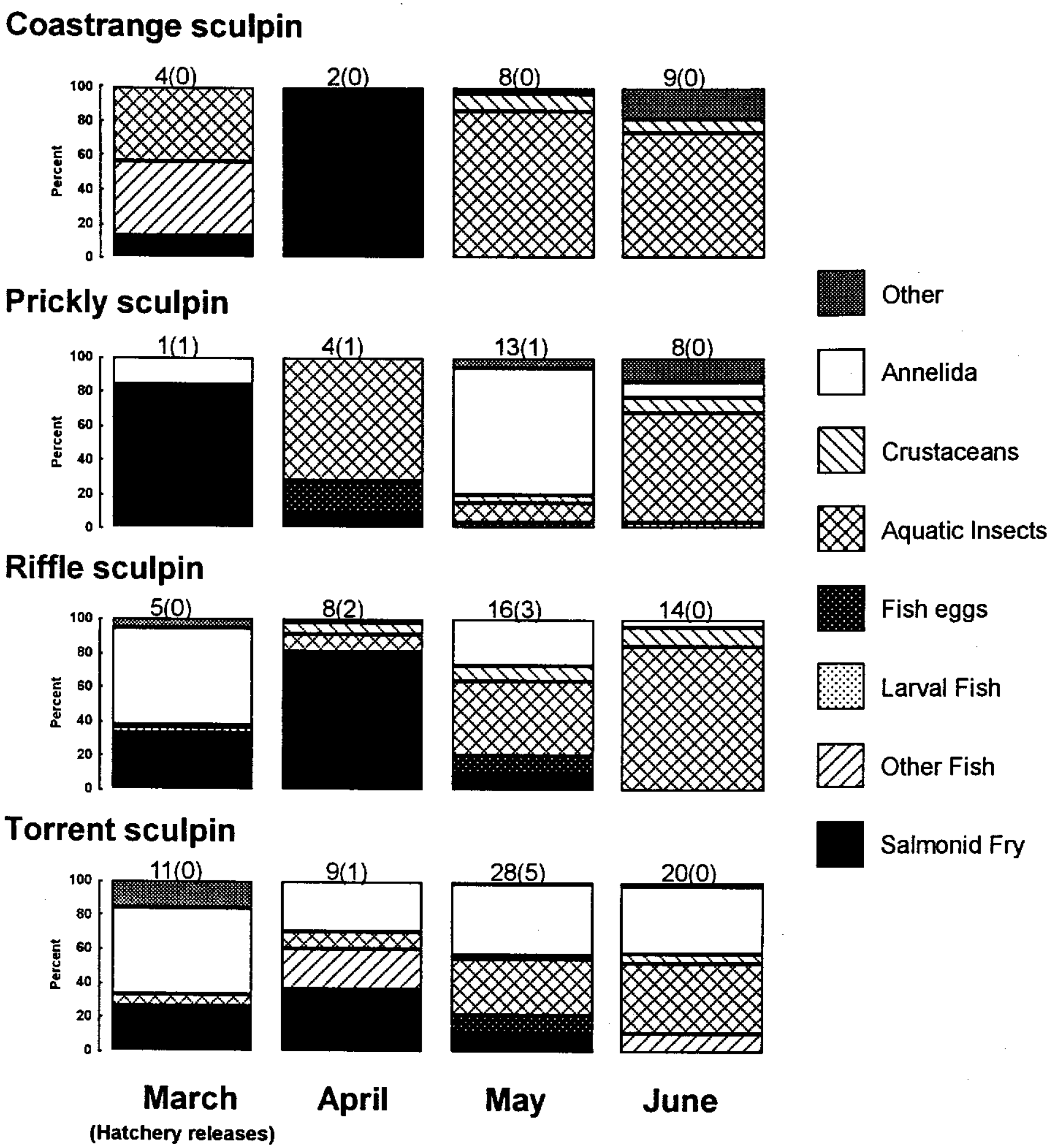


Figure 12.-- Composition (percent by weight) of ingested food by four cottid species ($\geq$ 50 mm TL) at river kilometer 1.4-1.6 of the Cedar River, March to June, 1999. Number of predator stomachs that contained prey is given above the graph; the number of fish with empty stomachs is in parentheses.