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Western Washington Office
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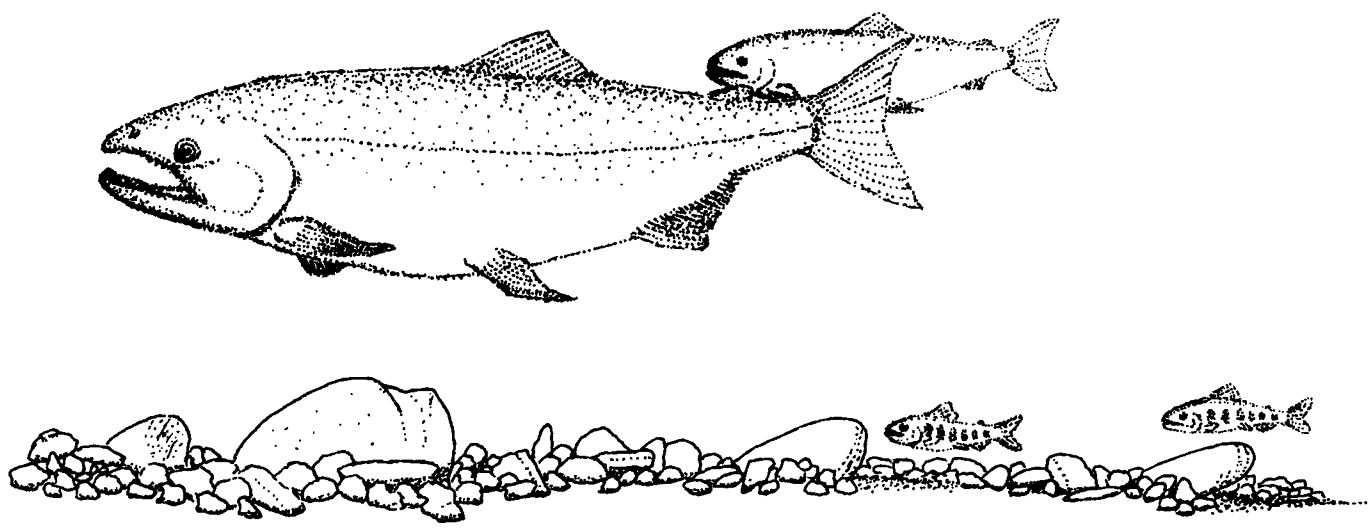

PREDATION OF SOCKEYE SALMON FRY BY COTTIDS AND OTHER PREDATORY FISHES IN THE CEDAR RIVER AND SOUTHERN LAKE WASHINGTON, 1997

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ABSTRACT

From February-June 1997, we sampled cottids and other predatory fishes in the Cedar River (river kilometers 0-22) and southern Lake Washington to better understand their role as predators of emigrating sockeye salmon fry (*Oncorhynchus nerka*). Fish were collected from a variety of habitat types. We primarily used electrofishing equipment to collect fish. We examined the stomach contents of 1,453 cottids and 111 other predatory fish.

In southern Lake Washington, a total of five salmonid fry were observed out of 262 stomach samples of prickly sculpin (*Cottus asper*) examined. Although their overall predation rate was low, prickly sculpin may be an important predator of sockeye salmon fry because their population size is quite large. Cottids were substantially more abundant at cobble habitat areas than at sandy habitat areas. We were unable to collect an adequate sample of sculpin in deeper areas.

Predation rates were low at most sites in the Cedar River, presumably because of constantly high streamflow levels throughout the sample period. In the lower river and along shoreline areas, predation rates were low in February and March but increased substantially in April and May. Predation was particularly noticeable in side-channel sites. Overall, predation of sockeye salmon fry occurred primarily in slow velocity areas when fry were abundant. At mid-channel sites, where water velocities were moderate to high, little predation of sockeye salmon fry was observed. The only mid-channel location where any predation was observed was at rkm 0.5 where water velocities were < 0.4 m/s. The number of cottids ≥ 50 mm total length (TL) appeared to be related to the substrate size. At sites with only gravel and sand, few cottids ≥ 50 mm TL were observed while at sites dominated by cobble substrate, large numbers of cottids were present. The abundance of woody debris also appeared to be positively related to cottid abundance. This was most noticeable at the delta site. In February and early March, few cottids were present on the delta. However, as the water level rose and several pieces of woody debris were inundated, cottids increased in abundance.

Predation of sockeye salmon fry at off-channel sites peaked in May and June. Some predation was observed as late as June 19 at the outlet to Cavanaugh Pond. The highest predation rates occurred at the outlets to the off-channel sites. Many of the sockeye salmon fry consumed by cottids at the outlet to Cavanaugh Pond were substantially larger than newly-emerged fry. This suggested some amount of rearing occurred in Cavanaugh Pond. Little predation of sockeye salmon fry was observed at tributary sites; however, limited sampling was conducted at these sites.

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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 63-84%. 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 prickly sculpin (*Cottus asper*), torrent sculpin (*C. rhotheus*), 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). Because of their abundance and predation rates, cottids appear to be the most important predators of sockeye salmon fry.

All of the earlier cottid predation work was done in the lower 1.7 km of the Cedar River and along the shoreline of southern Lake Washington. Little work has been done on cottids in other sections of the Cedar River. In addition, work in Lake Washington focused on prickly sculpin > 100 mm total length (TL). However, recent work in the Cedar River indicated that prickly sculpin < 100 mm TL consumed large numbers of sockeye salmon fry in comparison to larger prickly sculpin. To get a more complete picture of cottid predation on sockeye salmon fry, we proposed to sample all cottids ≥ 50 mm TL and also sample other areas of the Cedar River and southern Lake Washington.

Predation rates of sockeye salmon fry by cottids appeared to be related to streamflow levels and habitat type. We observed low predation rates at streamflow levels > 17 m^3/s; however, few cottids were collected due to the poor water visibility. Seiler and Kishimoto (1996) found that survival rates of hatchery sockeye salmon fry in the Cedar River (from Landsburg Dam at river kilometer (rkm) 35.1 to a fry trap at rkm 0.7) were correlated significantly with streamflow. Areas of reduced water velocities such as pools or backwaters were the major locations of sockeye fry predation (Tabor and Chan 1996a). The role that other factors such as habitat type, substrate, light levels, turbidity, depth, and fry abundance have on sockeye fry predation by cottids is not well understood. We propose to examine the various factors that may influence predation levels of cottids. This type of information will enable biologists to better manage both wild and hatchery sockeye salmon fry.

In recent years, the sockeye salmon population in the Lake Washington basin has been at critically low levels. During the past eight years the escapement goal of 350,000 has only been reached once (1996 return). As recently as 1995, a record low return of 26,000 fish was observed. The proposed project would be an integral element of ongoing Lake Washington studies which have been trying to identify factors in the decline of sockeye salmon in the Lake Washington basin. The studies are part of a Lake Washington sockeye management plan which was developed four years ago. In the management plan, major research needs were identified.

Study Element VI stated that predation of fry in the river needs to be investigated. This project directly addresses this identified need.

Objectives

A) Determine predation rates of cottids on sockeye salmon fry in the lower Cedar River and southern Lake Washington.

B) Determine predation rates of cottids in other areas of the Cedar River.

C) Determine important factors (streamflow, habitat type, substrate, and other factors) affecting predation on sockeye salmon fry by cottids.

D) Identify management actions to help reduce the overall predation levels on sockeye salmon fry. Possible management actions might include reducing artificial lighting, modifying hatchery release strategies, adjusting daily flow patterns, or evaluating habitat modifications.

STUDY SITE

The study site was the lower 22.2 km of the Cedar River and the southern end of Lake Washington (Figure 1). We also sampled two off-channel sites and two tributaries within the Cedar River basin.

Lake Washington.--Lake Washington is a large monomictic lake (Figure 1) with a total surface area of 9,495 hectares and a mean depth of 33 m. The lake typically stratifies from June through October. Surface water temperatures range from 4-6°C in winter to over 20°C in summer. Over 78% of the shoreline is comprised of residential land use. During winter (December to February) the lake level is kept low at an elevation of 6.1 m. Starting in late February the lake level is slowly raised to 6.6 m by May 1 and 6.7 m by June 1.

We sampled predators along 4.4 km of shoreline in southern Lake Washington (Figure 2). The shoreline is highly developed with industrial and residential structures. Along the entire west shore and a small part of the east shore are residential homes with private docks and other shoreline structures. Renton Airport, Boeing plants, and a power plant are located on the south shoreline and several cement, steel, and wooden structures are present (Figure 2). Much of the east shore is contained within Gene Coulon Memorial Beach Park. Part of the park contains large wooden booms and docks; however, much of this shoreline is relatively undeveloped.

Cedar River.--The Cedar River is the main tributary for the Lake Washington basin. The river originates at approximately 1,220 m elevation and over its 80-km course falls 1,180 m. The lower 35.1 km are accessible to anadromous salmonids. Landsburg Dam (Figure 3), a water diversion structure, prevents fish from migrating further upstream. Base streamflow level in the winter and spring is 10.6 m^3/s.

A sockeye salmon hatchery, operated by the Washington Department of Fish and Wildlife (WDFW), is located just below Landsburg Dam. Currently the facility incubates 17 million eggs annually. Within the next few years the hatchery will be expanded to incubate 34 million eggs. Each fall, adult sockeye are collected from the river and spawned. Eggs are then incubated at the hatchery and fry are generally released shortly after the yolk sac is absorbed. Fry are released one hour after sunset at either the hatchery or are hauled downstream and released at rkm 3.5.

At the beginning of the sampling period, the delta was generally shallow with little habitat complexity. Water flowed through four main channels around three islands. The substrate was a mix of silt, sand, and gravel. As the lake level slowly rose in March and April, the islands and a large amount of large woody debris were inundated. Water velocities were also reduced. Much of the lower 0.5 km of the Cedar River was slow velocity water that was backed up from Lake Washington. The amount of backed-up water varied depending on lake level and streamflow. The shoreline of this section consisted of steep banks, which are armored or stabilized by wooden structures (bulkheads), riprap, and gabions.

Above rkm 0.8, the river was mostly riffle and glide habitat with few pools. Most pools appeared to be associated with bank stabilization sites (i.e., rip rap). Little large woody debris was present in the main channel. The substrate of the lower 3 km was mostly gravel. Larger substrate was rare. At upstream sites, larger substrates were more prevalent. Cobble was the dominant substrate type at many upstream locations.

Off-channel sites.--The two off-channel sites sampled were the Elliot groundwater spawning channel and Cavanaugh Pond. Both sites are heavily used by adult sockeye salmon for spawning. Cavanaugh Pond is an abandoned gravel pit adjacent to the Cedar River at rkm 10.3-11.1 (Figure 4). Cavanaugh Pond drains through a narrow outlet at rkm 10.3 on the Cedar River. The area of the pond is approximately four hectares with a maximum depth of 2.3 m. The substrate of most of the pond is mud/silt with abundant macrophyte beds. Sockeye salmon spawn primarily along the north shore where the substrate is sand and gravel and there is groundwater seepage from the Cedar River. The north shore is separated from the Cedar River by a levee. Additional inflow into the pond occurs from two small tributaries along the southeast shore, however little spawning occurs in this area. In 1996-1997, the peak count of adult sockeye salmon (live fish only) in Cavanaugh Pond was 1,895 on December 11, 1996. Peak spawning in Cavanaugh Pond is somewhat later than in the Cedar River.

The Elliot groundwater spawning channel is located at rkm 7.2. The channel was constructed in 1995 to enhance spawning area for sockeye salmon. The channel is 189 m long with an average wetted width of 4.2 m. Water depths vary depending on flows in the Cedar River. In 1996-1997, the peak count of adult sockeye salmon (live and dead) in the spawning channel was 606 on December 3, 1996. Similarily to Cavanaugh Pond, peak spawning is somewhat later than in the Cedar River.

Tributaries.-- We also conducted some preliminary sampling on two tributaries of the Cedar River, Peterson Creek and Rock Creek (Figure 3). Petersen Creek enters the Cedar River at rkm 22.2. Sockeye salmon have been observed to spawn in the lower 1.9 km (B. Priest, King County, pers. comm.). Petersen Creek has not been surveyed on a regular basis. A limited number of surveys indicate that small numbers of sockeye salmon spawn in this system. However, a survey in 1992 did observe 80 adult sockeye salmon in a short section (rkm 1.3-1.9) of the creek.

Rock Creek enters the Cedar River at rkm 28.7. Sockeye salmon have been observed to spawn in the lower 2.3 km. Rock Creek has been surveyed on a regular basis by King County. In 1996-1997, the peak count of adult sockeye salmon (live and dead fish) in Rock Creek from rkm 0.3-1.0 was 200 on December 3, 1996. Peak spawning appears to be somewhat later than in the Cedar River.

METHODS

Fish Collections

Cottids were collected at several sites in the lower Cedar River and southern Lake Washington (Table 1). Most sites were sampled three to four times during the sample period (February-May). Sampling occurred either during the night or shortly after dawn. In general, sampling began at least two hours after dusk to allow fish to begin feeding. Sampling was scheduled to occur on hatchery release nights and other nights when mostly wild fry were present. On hatchery release nights, we began sampling after we had allowed enough time for most of the hatchery fry to pass through the study reach. Passage time estimates were determined by D. Seiler of WDFW who supervises the fry trap operations at rkm 0.7.

After capture, stomach contents of cottids were removed using a gastric flushing apparatus modified from Foster (1977). Gastric lavage has been shown to be effective in removing stomach contents for many fish species. For example, Light et al. (1983) found the technique removed 100% of the stomach contents of slimy sculpin (*C. cognatus*). All stomach contents were put in plastic bags, placed on ice, and later froze. Samples remained frozen until laboratory analysis. If we were not able to finish processing cottids for stomach samples due to time constraints, cottids were given a lethal dose of MS-222, 95% ethyl alcohol was injected into their abdominal cavities to retard digestion, and they were frozen whole.

Lake Washington.-- Along the shoreline, cottids in the southern end of Lake Washington were also collected with electrofishing equipment (Figure 1). We used both boat and backpack electrofishing equipment. Boat electrofishing was done primarily to collect other species of fish as part of another study. Sampling occurred every three weeks from February to the first week of June. Cottids are often difficult to sample with boat electroshocking equipment because they can be difficult to see, especially in turbid conditions, and the large dip nets are difficult to maneuver around cobble and boulders where cottids often occur. We selected four other sites to collect additional cottids with backpack electrofishing equipment. Sampling in shallower water and using small dip nets, we were able to more efficiently collect large numbers of cottids; however, we were only able to effectively sample in water < 1.2 m deep. We sampled three sites along cobble/gravel shoreline and one along a sand/mud shoreline. Sampling was done every three to four weeks from February through April.

Minnow traps (Rickard 1980) and baited tout lines were used to sample deeper areas. A total of 24 minnow traps were set among 6 sites. Because catch rates were poor on our first night of trapping, we did some testing of different bait types (catostomid carcasses, cat food, and earthworms) at two sites where cottids were known to be abundant. Because catch rates were poor for all types of bait used, we discontinued use of minnow traps. At one of the test sites, we also tried a short trot line (12 hooks) baited with earthworms. This single trot line captured more cottids than 12 minnow traps. Due to time constraints, we were only able to use trot lines on one additional day. Each trot line consisted of 50 hooks spaced two meters apart. Two trot lines were set in Gene Coulon Park, one line was set at a depth of 10 m and the other at 3 m. The lines were set shortly after dusk and retrieved 3-4 hours later.

Cedar River.-- Several shoreline, mid-channel, and off-channel sites were selected based on accessability, habitat type, water velocities, amount of artificial lighting, proximity to lower-river hatchery release point, and location of earlier sampling efforts (Figures 2,3, and 4). Fish were collected primarily with electrofishing equipment. However, beach seines and small aquarium nets were also used at some locations. A boat electrofisher was used to sample the shoreline of the lower 300 m of the Cedar River which is relatively deep and was accessible by boat. Most shoreline and mid-channel sites were sampled with a backpack electrofishing unit. In shoreline sites, stunned fish were collected visually with small dip nets and the aid of a 12-V spotlight for illumination. In mid-channel sites, stunned fish were collected passively with two block nets that were placed just downstream of the area shocked. This technique was only used in areas with strong current velocities. Each block net was 74-cm wide and 31.5-cm high with a 4-mm stretch mesh. Each block net was held against the substrate with the help of a 2-m handle. The two block nets were placed next to each other and perpendicular to the current. Each time the nets were set, we only sampled 3 m upstream of the nets to minimize movement of fish around the nets. Thus for each set, we sampled an area of 4.44 m^2. After shocking the fish, they were removed from the nets and placed in a holding bucket. We then moved 5-10 m upstream and repeated the process. At each site we did three to eight sets over a total distance of 20-40 m. At sites where stunned fish were collected visually with dip nets, catch rates only included cottids ≥ 50 mm TL because smaller fish were easily overlooked. However, for sites where stunned fish were collected with block nets, catch rates also included cottids < 50 mm TL.

At mid-channel sites that had low current velocities, we used beach seines. Because of high streamflow levels during the sample period, there were few sites that could be sampled effectively with beach seines. We used two different seines depending on the size of the area we were able to sample. The larger seine was 25 m in length with a depth of 2 m. The wings were made of 10-mm stretch mesh and the bag was made of 3-mm stretch mesh. The smaller seine was 10 m in length with a depth of 1.5 m. Mesh size was 8-mm stretch mesh. No bag was present. One to three seine sets were made at each site.

At off-channel sites, where numerous sockeye salmon redds were present, we collected cottids primarily with small aquarium nets to minimize damage to the redds. Cottids were collected by snorkelers who slowly swam along a shoreline transect. When a cottid was observed it was captured with a small aquarium net. Because cottids are difficult to find during the day, we only used this type of sampling at night. Small head lamps were used illumination. Initially, we also used beach seines to collect cottids, but this proved to be ineffective and was abandoned. The outlets to off-channel sites were also sampled and we used backpack electrofishing equipment similarly to shoreline transects.

Population size.-- To estimate the total fry consumed at each site, population sizes of piscivorous fishes were needed. Population sizes of shoreline transects were estimated primarily with an adjusted Petersen mark-recapture method (Ricker 1975). Both the initial collection and recapture were accomplished with electrofishing equipment. We assume that electrofishing, marking, and handling has minimal effect on the survival of cottids. Barrett and Grossman (1988) found that electrofishing did not adversely affect the short-term (30 d) survival of mottled sculpin (*C. bairdi*). As part of another study, we kept 147 prickly sculpin that were collected during mark-recapture sampling and placed them in a small net-pen for one to four days. They were then transferred to circular tanks and held under laboratory conditions. After 30 days, their survival rate was 97%. Thus, it appeared that our electrofishing and handling did not substantially affect the short-term survival rate of cottids.

After capture, cottids were anesthetized with MS-222. Lengths were measured to the nearest mm. Cottids were marked with non-toxic acrylic paint (Hill and Grossman 1987), which was injected with a 0.5-mm by 25-mm needle into the base of the anal fin. In some preliminary work, a small number of prickly sculpin (N = 10) were injected with acrylic paint and held under laboratory conditions in a circular tank at 12°C. After 60 days, no loss of marks was seen. Hill and Grossman (1987) reported retentions of 84% after 10 weeks and found that marks at the base of the pectoral, pelvic, or anal fins gave the best results. After the cottids were marked, they were allowed to recover and then released along the same transect where they were caught. Both the marking and recapture occurred on the same night or on two consecutive nights. We assumed that movements of cottids was minimal during this short time period. Other studies have demonstrated that movements of cottids are generally restricted to a small area (e.g., Brown and Downhower 1982).

At mid-channel sites, we estimated the population size of cottids by multiplying the area shocked times a catch efficiency estimate. At two sites, three 0.44-m^2 locations were shocked to calculate a catch efficiency. We repeatedly shocked each location until we were reasonably sure that no cottids remained.

Environmental measurements

Each time a site was sampled, we attempted to collect information on light intensity levels (lumens/m^2), turbidity (NTU), and water temperature (°C) at each site for each night of sampling. However, some data points were missing because the light intensity meter and turbidometer were not available for part of the study. A general habitat survey was done at each site to collect information on depth, water velocities, substrate, and habitat type. Because streamflow levels were usually within a narrow range throughout the sample period, we conducted a habitat survey once for each site. A measuring tape was laid along each shoreline and mid-channel transect. Habitat measurements of beach seining sites were taken along one transect that was perpendicular to shore in the middle of the site. After the total distance (width for beach seining sites) was determined, we broke each transect into 8-10 equal sections. At the beginning of each section, we collected information on depth, width, velocity, and substrate. The width of the transect was the width of the area sampled to collect cottids. At each section, three equally-spaced depth measurements were taken across the width of the transect. At the midpoint, two water velocity measurements were taken. One was taken just enough above the substrate to allow the propellor to spin. The other was taken at 60% of the total depth, which characterizes the average velocity (Schuett-Hames et al. 1994). At the same spot, the percentage of different substrate types within a 2-m-diameter circle was visually estimated. Substrate was classified into five categories: silt (sediment size, < 0.1 mm), sand (0.1-2 mm), gravel (2-20 mm), cobble (20-200 mm), and boulders (> 200 mm). Within each section, information on large woody debris, other instream structure, and overhanging vegetation was noted. Pieces of large woody debris were categorized as small, medium, large, or rootwad according to Schuett-Hames et al. (1994). Pieces outside of the wetted area were not counted. Other types of instream structure such as gabions, bulkhead, and instream vegetation were also noted. The percentage of overhanging vegetation was visually estimated for each section. Overhanging vegetation was described as vegetation that was 3 m or less above the water line. We felt this type of overhanging vegetation would provide shade during most of the day and provide a visual block to aerial predators.

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 $\approx$ 10 s. 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 (Hansel et al. 1988), gill raker counts, pyloric caeca counts, or vertebral columns. The fork length of prey fishes was measured to the nearest mm. If a fork length was not taken, the original fork lengths of prey fishes were estimated from measurements of standard length, nape-to-tail length (Vigg et al. 1991), or diagnostic bones (Hansel et al. 1988).

Percent of diet was calculated to determine how important sockeye salmon fry and other prey were to the overall diet of cottids. To reduce bias from different-sized fish, prey weights were converted to percent body weight (Hyslop 1980). Percent diet by prey category was then calculated from that ratio.

RESULTS

Cottids

Species distribution

There are five, or perhaps six, species of cottids in the Cedar River. Two species, riffle sculpin (*C. gulosus*) and reticulate sculpin (*C. perplexus*), are often difficult to distinguish from each other. The two species are usually separated by the presence (riffle) or absence (reticulate) of palatine teeth. In comparison to coastal populations of riffle sculpin, the palatine teeth of riffle sculpin from the Cedar River are quite small and easy to overlook. In addition, the teeth may be on one side of the mouth and not the other or be missing altogether. Both species may be present in the Cedar River as well as hybrids of the two species. Because of the uncertainty and difficulty in identifying the two species in the field, we combined these cottids into one group: riffle/reticulate.

Both prickly sculpin and riffle/reticulate sculpin only inhabited slow water habitats. However, their distribution overlapped at just a few sites, at rkm 0.5-0.6 and Cavanaugh Pond. In the Cedar River, prickly sculpin were only collected at a few sites. They were the dominant cottid species in the lower 0.6 km of the river. Upstream they were only occasionally encountered. No prickly sculpin were collected upstream of rkm 4.7 in the Cedar River mainstem. In the two lotic systems that were sampled, Lake Washington and Cavanaugh Pond, prickly sculpin were the dominant cottid species. In both systems, prickly sculpin ≥ 125 mm TL were present. Continual high streamflow levels may have limited the movement of prickly sculpin to other shoreline sites. For example, at shoreline site 1 (rkm 1.9-2.0) in 1997, few prickly sculpin were collected, whereas in 1996, they were common from March through June when streamflow levels were considerably lower than in 1997.

Riffle/reticulate sculpin were common along many shoreline sites in the Cedar River but were rarely encountered at mid-channel sites. Riffle/reticulate sculpin appeared to be most numerous in side channels and alcoves where water velocities were low. Riffle/reticulate sculpin made up all but one of the cottids collected (89 of 90) in the Elliot spawning channel. Riffle/reticulate sculpin were also abundant in Petersen Creek at rkm 2.3, just below the outlet of Petersen Lake. Water velocities were also slow at this site.

Torrent sculpin and coastrange sculpin (*C. aleuticus*) were widespread throughout the areas sampled. Torrent sculpin was found at most sites except the shoreline sites of Lake Washington and Cavanaugh Pond. However, a few torrent sculpin were collected at the Lake Washington delta site and they were the dominant cottid at the outlet to Cavanaugh Pond. Large torrent sculpin (≥ 100 mm TL) were often abundant in low-velocity, shoreline sites. Large torrent sculpin were also present in some mid-channel areas if large cobble was present such as site 7 at rkm 21.9. Smaller torrent sculpin were often abundant at many mid-channel sites. However, they were rare at the two lower mid-channel sites where only gravels were present.

Coastrange sculpin were found primarily at mid-channel sites. Sites with larger substrate tended to have larger coastrange sculpin. Small coastrange sculpin (< 50 mm TL) were often abundant at the two lower mid-channel sites. Small numbers of coastrange sculpin were also collected along shoreline transects in the Cedar River and Lake Washington. In Lake Washington, coastrange sculpin were found primarily in cobble substrate but there was few of them in comparison to prickly sculpin. No coastrange sculpin were collected in Cavanaugh Pond.

Shorthead sculpin (*C. confusus*) were the dominant sculpin species in Rock Creek riffles, comprising 73% (19 of 26) of the cottids caught . Lab identification of preserved cottids from Cedar River mid-channel sites indicated that some shorthead sculpin were overlooked during field work and misidentified as coastrange sculpin. However, preserved samples and an additional survey of mid-channel sites on July 27, 1997 indicated that shorthead sculpin were only present at the furthest upstream sites at rkm 17.2 and 21.6. Based on the July 27 survey, shorthead and coastrange sculpin appeared to be in equal numbers at rkm 21.6, while at rkm 17.2, coastrange sculpin were 2.5 times more abundant. Thus, it appears that the number of shorthead sculpin that were misidentified and stomach-sampled was small and probably would not significantly affect the results.

Catch and Abundance

Lake Washington.-- In Lake Washington, shoreline cottid abundance was related to substrate size. Significantly more cottids ≥ 50 mm TL were collected in the gravel/cobble shoreline than the sand/mud shoreline (Figure 5). We did not collect information on the number of cottids < 50 mm TL, however they also appeared to be abundant in the gravel/cobble shoreline. In the sand/mud site, no cottids < 60 mm TL were observed (Figure 6).

Catch rates of cottids along the gravel/cobble shoreline increased from March to April as water temperatures increased (Figure 5). However, no samples were taken in May and June when water temperatures were often > 15°C. No similar increase in catch was observed at the sand/mud site.

Lower Cedar River and Delta (rkm 0.0-0.8).-- Due to safety concerns, we only sampled the lower river with the boat electrofisher when streamflow levels were < 22 m^3/s. Because of continual high streamflows, this level was rarely present (Figure 7). We only sampled the lower river with the boat electrofisher on two occasions, March 17 and May 21. Because of high velocities along the shoreline, cottids were difficult to collect and thus, catch rates were generally low on both sample dates.

At the two shallow shoreline sites (sites 4 and 5) catch rates were low in February and March, but increased substantially in May and June. At the beach seining site, catch rates were low throughout the sample period (February-April).

At the delta site, few cottids were collected in February and early-March. In late March and April, catch rates were substantially higher (Figure 8). Annually, from March 1 to May 1 the water level of Lake Washington is brought up 0.6 m. As the water level rose in 1997 at the delta site, woody debris was inundated, water velocities were lower (at the same streamflow), and the area sampled was slightly deeper. During this time period, water temperatures also increased.

Shoreline (rkm 1.4-22.2).-- In February, catch rates along shoreline sites were quite low (Figure 9). At some sites, total catch was close to zero. As water temperatures rose in March-June, catch rates increased substantially. Estimates of population sizes were done at five shoreline sites (Tables 2 and 3). The highest density of cottids was observed at a side-channel pool with rip-rap. Sizes of cottids varied greatly from site to site. Areas that were deeper with large substrate such as rip rap generally had larger cottids.

Mid-channel (rkm 0.5-21.6).-- The number of large cottids (≥ 50 mm TL), appeared to be related to substrate size. Sites with large amounts of cobble such as site 6 tended to have a greater abundance of cottids ≥ 50 mm TL. The lower two sites which consisted almost entirely of gravel and sand had few cottids ≥ 50 mm TL present. Instead, large numbers of cottids < 50 mm TL were often present.

Because we were unable to sample all sites in February and May, we were unable to make comparisons for all sampling periods. However, we did sample all sites during a two-week period from March 17- April 1 (Figure 10), which clearly showed the relationship between catch and substrate size. Other factors, such as embeddedness and water velocity, may also influence population sizes.

The population sizes of mid-channel sites were estimated by the number caught with electrofishing (one pass) times the catch efficiency (Table 4). Estimates of catch efficiency indicated we collected an average of 78% of the cottids ≥ 50 mm TL on the first pass. However, we were only able to do two sites (three samples each) for catch efficiencies. Further work needs to be done to get a more accurate catch efficiency value. In addition, catch efficiency may change with substrate type and velocity.

Off-channel habitats.-- Catch rates of cottids in the outlet of the Elliot spawning channel peaked in May at the same time that the abundance of fry in the spawning channel appeared to be at its highest (based on snorkel observations). At the outlet to Cavanaugh Pond, catch rates peaked in early June. Sockeye salmon fry were rarely observed in either outlet. We assume that fry quickly move through these narrow corridors. Catch rates of cottids were not estimated for snorkeling transects due to the large difference in catch rates between snorkelers. In Cavanaugh Pond sites 4 and 5, which are in a small confined area where the outlet may have been partially blocked, (Figure 4) large numbers of sockeye salmon fry were observed in May and June. We only saw small numbers of sockeye salmon fry in sites 6 and 7, which are adjacent to the open water (Figure 4).

The population sizes of cottids at the outlets of both off-channel habitats were estimated. The density of cottids appeared to be higher at these sites than most other sites (Table 2,3). No attempt was made to estimate the abundance of cottids in Cavanaugh Pond or Elliot spawning channel.

At both Elliot spawning channel sites, few large (≥ 100 mm TL) cottids were observed (Figure 11). Small cottids (< 50 mm TL) also appeared to be rare at these sites. At the outlet to Cavanaugh Pond, large cottids made up 16% of the catch. Most of the large cottids were prickly sculpin which were not present at the Elliot spawning channel sites. The mean TL of cottids at sand/mud sites 4, 5, and 7 was 92, 96, and 95 mm, respectively (Figure 12). At the cobble/gravel transect (site 6), the mean size was only 74 mm TL. Forty-four percent of cottids collected at sites 4, 5, and 7 were ≥ 100 mm TL, whereas only 5% were at site 6. Almost all of the large cottids were prickly sculpin.

Tributaries (Petersen and Rock creeks).-- Due to time constraints, we were only able to sample Rock Creek and Petersen Creek once. The mean size of cottids collected in pools in Rock Creek was 86 mm TL. Whereas, in riffles the mean size was only 67 mm TL. Two cottids (143 and 133 mm TL) captured in a pool in Rock Creek were the largest torrent sculpins collected at any site in 1997. In Petersen Creek, cottids ranged in size from 50-85 mm TL and the mean size was 66 mm TL.

A small group of approximately 30 sockeye salmon fry was observed at the edge of one pool in Rock Creek. Another fry was collected in the mid-channel block nets. Thus, sockeye salmon fry were present but nothing is known about their abundance and movements. No sockeye salmon fry were observed in Petersen Creek. However, due to the tannic color of the water, fry could have been overlooked.

Stomach analysis

Lake Washington.-- Out of 262 stomachs samples examined from the shoreline of Lake Washington, only 5 sockeye salmon fry were observed (Table 5). Four of the five fry were from cottids that were captured in transects adjacent to the delta. The other fry was from a cottid captured at the Gene Coulon sand/mud site (N = 27). Of 115 cottid stomach samples from Gene Coulon cobble/gravel sites, no sockeye salmon fry was found. However, one chinook salmon fry (38 mm FL) was found in the stomach of a 93 mm TL prickly sculpin that was collected on February 3. Non-salmonid prey fish made up 6% of the overall diet of shoreline cottids. Other prey fish included ten cottids and four juvenile yellow perch (*Perca flavescens*).

In February, the most important prey item of prickly sculpin and coastrange sculpin was *Neomysis* (55% and 61%, respectively; Figure 13). From March to April, the importance of *Neomysis* was greatly reduced. In May-June, no *Neomysis* were present in their diet. The diet of prickly sculpin in April-June was dominated by oligochaetes. Other important prey items were fish eggs, larval chironomids, isopods, amphipods, and leeches. The primary prey item of coastrange sculpin (N = 20) was larval chironomids, which were present in 70% of the stomachs examined and represented 45% of the overall diet. Other important prey items were *Neomysis* and oligochaetes. No prey fish or fish eggs were observed in coastrange sculpin stomachs.

In general, the diets of prickly sculpin from the two substrate types (cobble/gravel and sand/mud) were similar (Figure 13). With few exceptions, cottids from both habitats consumed the same prey items. The only major difference was that fewer *Neomysis* were consumed by prickly sculpin from the sand/mud habitat.

In deeper nearshore areas, the only prey fish observed in 17 prickly sculpin was three unidentified fish (Table 5). Although we were unable to identify the prey fish, they did appear to be the same size and have the same characteristics of sockeye salmon fry. Isopods were the most important prey item. Other prey items included amphipods, larval chironomids, and gastropods.

Forty-seven percent of the prickly sculpin that were caught with baited trot lines had an empty stomach. Prickly sculpin collected at nearby shoreline locations had substantially fewer empty stomachs. It is unknown if the difference was due to different feeding rates or that cottids caught on trot lines more frequently regurgitate their stomach contents than shoreline cottids caught with electrofishing equipment.

Lower Cedar River and Delta (rkm 0.0-0.8).-- Compared to 1995 and 1996 sampling, predation rates of sockeye salmon fry by cottids in the lower river in 1997 were relatively low. The major difference between 1997 and the other two years was the higher streamflow levels in 1997 (Figure 7). In addition, the predation rates we observed in 1997 were probably an overestimate of the average predation rate for 1997, because we were only able to safely sample the lower river with the electrofishing boat when streamflow levels were reduced below 22 m^3/s. During 1997 (February-May), streamflows were usually > 28 m^3/s. No predation was observed in limited February sampling. Some predation was observed in April-May samples; however, predation was generally low (Table 6; Figure 14). An analysis of predation of fry by prickly sculpin in the lower Cedar River for the past three years indicated that predation was positively related to fry abundance during low streamflow (10-13 m^3/s; Figure 15). No such relationship was observed for high streamflow (18-25 m^3/s); however, the sample size was small (N = 3). Additionally, at low streamflow (10-13 m^3/s), predation rates were substantially higher than at high streamflow (18-25 m^3/s; Figure 15).

Similar to results of 1996 (Tabor and Chan 1996a), prickly sculpin ≥ 100 mm TL consumed few sockeye salmon fry (2% of diet by weight) in comparison to prickly sculpin 50-99 mm TL (32%). Prickly sculpin ≥ 100 mm TL usually consumed much larger prey fish than sockeye salmon fry. Other prey fish made up 48% of their overall diet. Cottids and lamprey were the primary fish consumed. Additionally, one chinook salmon fry (33 mm FL) was found in the stomach of a 102 mm TL prickly sculpin. In March, only one adult longfin smelt (*Spirinchus thaleichthys*) was observed from 12 stomach samples of prickly sculpin ≥ 125 mm TL. In contrast, prickly sculpin ≥ 125 mm TL in March 1996 averaged 0.51 smelt/stomach. Differences are probably due to the abundance of spawning longfin smelt which may be 10 times more abundant on even-numbered years than odd-numbered years (Moulton 1974). Fish eggs (mostly cottid eggs), which were present primarily in May samples, made up 21% of their overall diet. Relatively large crayfish were the only invertebrate that was important in the diet (8%). Besides sockeye salmon fry, the diet of prickly sculpin 50-99 mm TL consisted primarily of aquatic insects (34%) and oligochaetes (23%). The diet of both coastrange sculpin and prickly sculpin 50-99 mm TL was similar (Figure 16), except salmonid fry were less important in the diet of coastrange sculpin (16% versus 32%) and aquatic insects were more important (44% versus 34%).

Shoreline (rkm 1.4-22.2).-- Along shoreline transects, little predation of sockeye salmon fry was observed in February and March (Table 7; Figure 14). Predation rates of fry were substantially higher in April and May. Much of the observed predation occurred at two sites, near the I-405 bridge and at the side-channel pool at rkm 9. There appeared to be large variation in predation rates between sites.

Few other prey fish were observed and made up only 2.5% of their overall diet. Other prey fish included a lamprey, four cottids, and nine unidentified larval fish. Besides sockeye salmon fry, other important diet items included aquatic insects (primarily plecopterans, ephemeropterans, and trichopterans) and oligochaetes (Figure 17).

Mid-channel (rkm 0.5-21.6).-- Few prey fish of any kind were consumed by cottids at mid-channel sites (Table 8). Of 200 stomachs examined, only one well-digested fry was found. The only other prey fish consumed were two small cottids. Some fish eggs were consumed and based on date and size, they were probably catostomid eggs. The diet of cottids at mid channel was dominated by aquatic insects, making up over 90% of the diet by weight (Figure 18). Ephemeropterans were the most common insects consumed and accounted for 40% of their diets. Consumption of simulids was common at mid-channel sites, whereas they were rare in the stomachs of cottids at other locations. Other common aquatic insects in their diet included plecopterans, chironomids, and trichopterans.

Off-channel habitats.-- At both off-channel sites, consumption of sockeye salmon fry was common in May and June (Tables 9 and10; Figure 14). Consumption of fry was highest at the outlets of the off-channel sites. Peak consumption occurred on May 21 at the outlet to Elliot spawning channel and June 5 at the outlet to Cavanaugh Pond. Sockeye salmon fry were not observed in cottid stomachs from Cavanaugh Pond until April 17. Also, no fry were observed during night snorkeling until April 17. The mean size of sockeye salmon fry consumed by cottids in Cavanaugh Pond and at the outlet was significantly larger than at the other sites (t-test, $P < 0.001$; Figure 19). This was especially evident on the June 5th sample at the outlet. Many of the consumed fry were 3-5 times larger by weight than typical sockeye salmon fry consumed at other locations. Length frequency of the consumed fry suggests a bimodal distribution (Figure 19)- a group of smaller individuals that was typical of the size of fry observed in the Cedar River and, a second group of larger individuals that probably reared for some time in the pond environment. Fry consumed at the outlet were significantly larger than those consumed in the pond (t-test, $P < 0.001$; Figure 19). Large fry were also observed in the pond along some snorkeling transects; however, only two large sockeye salmon fry (3% of consumed fry) were observed in the stomachs sampled. The mean size of sockeye salmon fry consumed at the Elliot spawning channel and its outlet was not significantly different than fry consumed in the Cedar

River (t-test, P = 0.086 and 0.068, respectively). Additionally, no large sockeye salmon fry were observed in the spawning channel during snorkeling observations. Although some rearing may occur in the Elliot spawning channel, it doesn't appear to be nearly as extensive as in Cavanaugh Pond.

Few other prey fish were consumed by cottids at either off-channel site. Most other prey fish were from stomach samples collected at the outlets of the spawning channel and Cavanaugh Pond. Other prey fish included lamprey ammocoetes, juvenile catostomids, and cottids.

In the Elliot spawning channel, the two most important diet items of cottids were larval chironomids and sockeye salmon fry (Figure 20). Larval chironomids were present in 97% of the stomachs examined. Amphipods (82% of stomach examined) and larval coleopterans (44%) were also common in their diet. The diet of cottids in the outlet was somewhat different from cottids in the spawning channel (Figure 20). Besides sockeye salmon fry, oligochaetes and ephemeropteran nymphs were the dominant prey items.

Within Cavanaugh Pond, the highest predation rates were observed at site 4 which is a narrow channel (Figure 4). The number of fry/stomach at this site in May and June was 1.8 and 0.9, respectively. For the other three sites, the mean number of fry/stomach in May and June was 0.5 and 0.2, respectively. Adult sockeye salmon spawn within the narrow channel and along the shoreline of an adjacent small inlet. A small beaver dam at the downstream end of the channel may have delayed emigration of fry. We observed large numbers of fry in this channel in May and June.

The overall consumption of prey by cottids in Cavanaugh Pond appeared to be higher than at most other locations (assuming that the diel feeding pattern is similar between locations). The amount of aquatic invertebrates present in their stomachs (mean = 0.83% of body weight) was the highest of any location. Cottids consumed large numbers of isopods, amphipods, leeches, larval chironomids, larval coleoptera, and ephemeropteran nymphs. Only 5 of 207 (2.4%) stomachs were empty. Because of the large number of salmon carcasses, the productivity of the pond was probably quite high, which apparently resulted in abundant prey. Except that prey fish were relative more important, the diet of cottids in the outlet to Cavanaugh Pond was similar to the diet of cottids in the pond (Figures 21 and 22).

Tributaries (Petersen and Rock creeks).-- A total of 23 cottid stomachs was examined from Petersen Creek and 28 from Rock Creek. No sockeye salmon fry were observed in any stomach sample (Table 11). One 34 mm FL non-sockeye salmonid (probably a coho salmon fry) was in the stomach of a 70 mm TL torrent sculpin from Rock Creek. No other prey fish was observed in stomach samples from either creek. Similarly to cottids from Cedar River mid-channel sites, the diet of cottids from the riffle sites in Rock Creek was almost entirely made up of aquatic insects. The diet of torrent sculpin from pools in Rock Creek was also dominated by aquatic insects (78% by weight); however, oligochaetes (14%) and fish (5%) were also present. In Petersen Creek, the diet of torrent sculpin was also composed almost entirely of aquatic insects. Riffle sculpin in

Petersen Creek primarily consumed aquatic crustaceans which included isopods (34% by weight) and amphipods (27%). Aquatic insects made up only 30% of the diet.

Other species

Catch.-- Overall, few other predators were collected. Other predators included 24 cutthroat trout, 35 rainbow trout, 51 juvenile coho salmon and one yellow perch. Forty-five percent of the trout were collected in the lower river. Most of these were collected with the electrofishing boat on May 27, which included ten rainbow trout that appeared to be newly-released hatchery fish (mean, 130 mm FL; range, 102-142 mm FL). Most juvenile coho salmon were collected in side channels or at the outlets to off-channel habitats.

Stomach analysis.-- Although predation rates of sockeye salmon fry by other predatory fishes in the Cedar River were usually higher than by cottids, all predators followed the same general trends between locations. Predation was most pronounced at the outlets to the off-channel sites and in the lower river. For example, at the outlet to the Elliot spawning channel a 195 mm FL cutthroat trout had consumed 23 sockeye salmon fry. Unlike cottids, predation rates were low at shoreline sites; however, at sites where predation of fry by cottids was observed, other predatory fish were rarely collected. At sites where other predatory fish were collected, predation rates of all predators including cottids were extremely low.

Similarly to prior years (Tabor and Chan 1996a,b), cutthroat trout generally had higher predation rates at most sites than rainbow trout or juvenile coho salmon. Seventy percent of newly-released hatchery rainbow trout had consumed sockeye salmon fry (mean; 1.3 fry/stomach). In contrast, seven large rainbow trout (mean, 355 mm FL; range 276-407 mm FL), that were also collected on the same date and at the same location had only consumed one fry. The stomachs of these large rainbow trout contained large amounts of filamentous algae and a few aquatic insects.

DISCUSSION

A primary objective of this study was to determine predation over a wide range of streamflow levels. Unfortunately, due to record snow pack, streamflows were constantly high throughout the study (Figure 7). Thus, on a river-wide scale, we were only able to examine predation of fry by cottids under high streamflow levels. However, at a smaller scale, we did determine predation rates at several sites which represented a wide range of water velocities. We believe this does provide some insight into the relationship between streamflow and predation. The results clearly showed that predation rates were substantially higher in low-velocity sites (< 0.5 m/s) such as the shoreline and side channels. We would expect that as streamflow is lowered, the mean water velocity would decrease and a greater percent of the cross-sectional area would have water velocities < 0.5 m/s.

In addition, as the streamflow levels are reduced, predators such as cottids and salmonids would be confined to a smaller area and more likely to encounter sockeye salmon fry. The average depth would be lower and fry would thus be closer to the substrate. The only high-velocity site where any appreciable predation occurred was also the shallowest. At low streamflow levels, sockeye salmon fry may be more likely to encounter a back eddy or side channel, where they would be more vulnerable to predation.

Also, turbidity levels are often positively related to streamflow levels. Trout and salmon, which are visual feeders, may have reduced ability to prey on sockeye salmon fry when turbidity levels are increased. In a lab experiment, Ginetz and Larkin (1976) found that predation rates of rainbow trout were reduced when turbidity was increased. The effect of increased turbidity on cottids is not well known. Results of recent laboratory experiments indicated that both prickly sculpin and torrent sculpin were able to forage on fry effectively in complete darkness (Tabor et al. 1998). Thus, cottids must use some other sensory mechanism besides vision. Most likely cottids use their lateral line system to detect the movements of fry. Hoekstra and Janssen (1985) demonstrated that mottled sculpin were able to feed on mobile prey with just their lateral line system. Night snorkeling observations of cottids in the field also indicated that cottids seem to react to movements of fry. In Elliot spawning channel and Cavanaugh Pond, fry were often quite numerous yet cottids did not appear to pursue fry if they were motionless. However, when the fry were startled by a light shined directly at them and darted away, sculpin would become very active and strike at moving fry.

Temperature also appeared to be an important factor affecting cottid abundance and predation rates. In February, when water temperatures were < 6°C, few cottids were collected and those that were collected had consumed few prey items. At these low temperatures, digestion rates will also be considerably slower and thus the time between meals will be longer. Other studies have found that cottids feed during the winter (Daiber 1956; Rickard 1980); however, few studies have looked at their winter abundance or feeding rates. The reason for the low numbers of cottids in the Cedar River is unclear. Cottids may be less active and remain deep in the substrate during day and night. Therefore, catch rates would be reduced during the winter.

In Carnation Creek on Vancouver Island, most prickly sculpin and coastrange sculpin reportedly buried themselves in the streambed to overwinter (Ringstad 1982). The remaining cottids moved into tributaries and backwaters to overwinter. Prickly sculpin may inhabit deep waters of Lake Washington or Cavanaugh Pond during the winter and move into shallow areas as the water temperature rises.

Low abundance and low feeding rates of cottids in the winter may also be due in part to prey availability. In the Cedar River, prey availability may be low in the winter due to a low abundance of aquatic insects and other invertebrates. Additionally, few sockeye salmon eggs or fry would be available. Thus, cottids may remain in the substrate during the winter and move to areas of high prey abundance as the temperature rises. Foote and Brown (in press) have shown that cottids move seasonally to areas of higher prey availability.

Substrate size appeared to have an important effect on cottid size and abundance. For gravel and larger substrates, size of cottids was usually positively related to substrate size. Besides substrate size, other factors such as water depth, water velocities, and species composition also appeared to influence cottid size and abundance. As substrate size is increased the size of interstitial space is increased, which probably allows space for cottids to forage and seek refuge. Cottids that are greatly different in size may not be able to coexist because of the risk of predation. Small cottids are often preyed on by larger cottids. The relationship between cottid size and substrate size was most apparent at the mid-channel sites where the substrate was usually of uniform size within an individual site. Many shoreline sites had different substrate types along the transect, thus making it difficult to assess the relationship between substrate size and cottid size. However, some shoreline sites had rip-rap banks along the entire length. At these sites cottids were generally quite large in comparison to nearby transects with smaller substrate.

At sand and smaller substrates of the shoreline of Lake Washington and Cavanaugh Pond, cottids < 60 mm TL were rare. Larger cottids were present but usually in low abundance. In the Cedar River, cottids of all sizes were rare in sand/mud substrates unless some type of refuge (woody debris, cobble, or boulders) was nearby. At all these sites, small cotiids may be vulnerable to predation by larger cottids and other piscivorous fishes. Large cottids would be vulnerable to predators during the day and thus they probably only occupy these habitats during the night. During the day they probably move into deeper water where they would be less vulnerable to visual predators. The deeper substrates of Lake Washington consist of fine sediments. Large cottids are probably present throughout the day and night. Predation risk is probably lower in this area due to continual low light levels which limit visual predators. In Lake Michigan, slimy sculpin in shallow areas were nocturnal, whereas those in deep water show no diel pattern (Brandt 1986).

At some shoreline sites, the abundance of cottids appeared to be related to the amount of woody debris. Along a shoreline transect, few cottids would be seen in open areas, but near woody debris, several cottids would often be seen. The slow-water species, prickly sculpin and riffle sculpin, appeared to inhabit woody debris more often than the other species. Lonzarich and

Quinn (1995) found that coastrange sculpin showed no preference for areas with woody debris. The relationship between cottid abundance and woody debris was particularly apparent at the delta site. In February and early March, when the woody debris was out of the water, few cottids were present. As the water level rose and the woody debris was inundated, cottid numbers increased dramatically. This could have been due in part to warmer temperatures, slower water velocities, and an increase in depth. However, during the same time period in 1995, no woody debris was present and cottids were rarely seen. In 1995, the site was a little deeper due to prior dredging projects but this should have resulted in a greater density of cottids, not less. Additionally, in 1997 we collected most cottids in close proximity to woody debris. Whereas in open areas, cottids were rarely seen.

With one notable exception, predation of sockeye salmon fry by other fishes was similar to findings of prior years in that predation occurred primarily in low-velocity areas and predation rates were higher than by cottids. The one notable exception was the high rate of predation of fry by newly-released hatchery rainbow trout. From 1995 and 1996 combined, only one sockeye salmon fry was found from 38 stomachs of newly-released hatchery rainbow trout from the lower Cedar River. In contrast, 70% of the trout in 1997 had consumed sockeye salmon fry. The major difference between the three years was the abundance of fry in 1997. Approximately 30,000 fry emigrated on the single date we sampled in 1997 (Seiler and Kishimoto 1997b). On dates that hatchery trout were collected in 1995 and 1996, the highest daily number of emigrating fry was only 17,900 (Seiler and Kishimoto 1996, 1997a). In 1997, hatchery rainbow trout averaged 1.3 fry per stomach. This number may have been higher if streamflows were lower. Hatchery trout appear to primarily inhabit the slow backwater habitat of the lower Cedar River. Their impact on sockeye salmon fry survival is probably limited to this habitat for the last few weeks of the fry emigration period. Overall, newly-released rainbow trout probably did not have a large impact on sockeye salmon fry survival in 1997. However, hatchery trout could have an impact on sockeye survival if flows are low, trout are stocked earlier and closer to the Cedar River, fry emigration is delayed, and the area of slow water in the lower Cedar River is increased due to dredging.

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Table 1.-- Location of sampling sites used to collect cottids and other predatory fishes in Lake Washington and Cedar River, February-June, 1997. Backp.-dip = backpack electrofishing with dip nets; Boat electrof. = boat electrofishing; Min. trap = minnow trap; Backp.-block = backpack electrofishing with block nets.

Site category site number	Location	Gear	Left or right Bank	River kilometer
Lake Washington				
Shoreline				
1	Gene Coulon swimming beach	Backp.-dip		
2	Gene Coulon Park	Backp.-dip		
3	Gene Coulon Park	Boat electrof.		
4	South shore	Boat electrof.		
5	West shore	Boat electrof.		
6	West side vacant lot	Backp.-dip		
Deeper nearshore areas				
1	Gene Coulon P. - 3 m depth	Min. trap; tout line		
2	Gene Coulon P. - 10 m depth	Min. trap; tout line		
Lower Cedar River				
1	Detla	Backp.-dip		0
2	Renton Airport	Boat electrof.	L	0.2
3	Cedar River Park	Boat electrof.	R	0.2
4	Cedar River Park	Backp.-dip	R	0.3
5	Cedar River Park	Backp.-dip	R	0.6
6	Cedar River Park	Beach seine	R	0.5
Shoreline - Cedar River				
1	Lower Cedar River Park	Backp.-dip	R	1.9
2	Under 405 bridge	Backp.-dip	L	2.7
3	Just above 405 bridge	Backp.-dip	L	2.7
4	Renton Community Center	Backp.-dip	R	2.9
5	Riverview Park side channel	Backp.-dip	L	4.5
6	Riverview Park	Backp.-dip	L	4.7
7	Jones Road side-channel	Backp.-dip	R	9.0
8	Jones Road side channel pool	Backp.-dip	R	9.0
9	Levee off of 201St. Pl. SE	Backp.-dip	L	17.2
10	Royal Arch Park pool	Backp.-dip	L	22.2
11	Royal Arch Park side channel	Backp.-dip	L	22.2
Midchannel sites - Cedar River				
1	Cedar River Park	Backp.-block	R	0.5
2	Cedar River Trail	Backp.-block	L	2.2
3	Jones Road	Backp.-block	R	9.3
4	Cavanaugh Pond Levee	Backp.-block	L	10.5
5	Levee off of 201St. Pl. SE	Backp.-block	L	17.2
6	Highway Bridge	Backp.-block	L	21.6
Offchannel sites				
1	Outlet ot Elliot spawning channel	Backp.-dip	L	8.0
2	Elliot spawning channel	Snorkel		
3	Outlet to Cavanaugh Pond	Backp.-dip	L	10.3
4	Cavanaugh Pond, outlet west alcove	Snorkel		
5	Cavanaugh Pond, west alcove	Snorkel		
6	Cavanaugh Pond, north wall	Snorkel		
7	Cavanaugh Pond, east mud flats	Snorkel		
Tributary sites				
1	Mouth of Petersen Creek	Backp.-dip	L,R	0.1
2	just below Petersen Lake	Backp.-dip	L,R	2.5
3	Rock Creek - riffles	Backp.-block	L,R	0.5
4	Rock Creek - pools	Backp.-dip	L,R	0.5

Table 2. Petersen population estimates of cottids > 49 mm TL in the Cedar River, May-June, 1997. Population estimates represent a combined estimate of four species: prickly, coastrange, torrent, and riffle/reticulate sculpin.

Habitat type river kilometer	Site	Date	Number marked M	Catch C	Number of recaptures R	Population estimate N	Sample Variance V (N)	95% Confidence Intervals Lower	Upper
Lower River									
0.3	4	June 4	33	52	8	200.2	3328.1	107.3	827.6
0.6	5	June 5	75	97	8	827.6	62195.4	443.3	1692.7
Shoreline									
1.9	1	June 4	32	35	1	594.0	111078.0	180.0	1080.0
2.9	4	June 2	41	27	5	196.0	4312.0	92.6	594
4.7	6	May 19	41	18	8	88.7	413.8	47.5	181.4
9	7	June 2	19	15	6	45.7	146.9	22.7	100
9	8	June 2	56	70	17	224.8	1986.0	143.5	371.3
Off-channel									
8	1	May 21	62	131	10	756.0	43659.0	428.7	1528.4
10.3	3	June 4	63	42	20	131.0	399.4	86.5	208.5

Table 3. Density estimates of four species of cottids in the Cedar River, May-June, 1997. Initially, the four species were combined to calculate a cottid population estimate for each transect. Density estimates for each species were based on the percent of catch for each transect. The 95% confidence intervals (CI) were calculated from the CI's in Table 2 divided by the area (m^2). Density estimates are for cottids > 49 mm TL.

Habitat type river km	Site	Cottid species	Percent of catch	N	Shoreline length (m)	Number/m	Area (m^2)	Number/m^2	95% Confidence Intervals Lower	Upper
Lower River										
0.3	4	Coastrange	7.8	16	71.3	0.22	178	0.09		
		Prickly	77.9	156	71.3	2.19	178	0.88		
		Riffle/reticulate	9.1	18	71.3	0.26	178	0.10		
		Torrent	5.2	10	71.3	0.15	178	0.06		
		Total	100	200	71.3	2.81	178	1.12	0.60	4.65
0.6	5	Coastrange	3.0	25	181	0.14	469	0.05		
		Prickly	76.8	636	181	3.51	469	1.36		
		Riffle/reticulate	13.4	111	181	0.61	469	0.24		
		Torrent	6.7	56	181	0.31	469	0.12		
		Total	100	828	181	4.57	469	1.76	0.95	3.61
Shoreline										
1.9	1	Coastrange	18.2	108	166	0.65	664	0.16		
		Prickly	16.7	99	166	0.60	664	0.15		
		Riffle/reticulate	16.7	99	166	0.60	664	0.15		
		Torrent	48.5	288	166	1.73	664	0.43		
		Total	100	594	166	3.58	664	0.89	0.27	1.63
2.9	4	Coastrange	61.0	120	88	1.36	270	0.44		
		Prickly	0.0	0	88	0.00	270	0.00		
		Riffle/reticulate	0.0	0	88	0.00	270	0.00		
		Torrent	39.0	76	88	0.87	270	0.28		
		Total	100	196	88	2.23	270	0.73	0.34	2.20
4.7	6	Coastrange	32.7	29	50	0.58	160	0.18		
		Prickly	3.8	3	50	0.07	160	0.02		
		Riffle/reticulate	21.2	19	50	0.38	160	0.12		
		Torrent	42.3	38	50	0.75	160	0.24		
		Total	100	89	50	1.77	160	0.56	0.30	1.14
9	7	Coastrange	23.8	11	49	0.22	50	0.22		
		Prickly	0.0	0	49	0.00	50	0.00		
		Riffle/reticulate	28.6	13	49	0.27	50	0.26		
		Torrent	47.6	22	49	0.44	50	0.44		
		Total	100	46	49	0.93	50	0.92	0.45	2.00
9	8	Coastrange	32.1	72	18.1	3.99	44	1.64		
		Prickly	0.0	0	18.1	0.00	44	0.00		
		Riffle/reticulate	64.3	145	18.1	7.99	44	3.28		
		Torrent	3.6	8	18.1	0.44	44	0.18		
		Total	100	225	18.1	12.42	44	5.11	3.26	8.44
Off-channel										
8	1	Coastrange	16.8	127	60	2.11	180	0.70		
		Prickly	0.0	0	60	0.00	180	0.00		
		Riffle/reticulate	35.1	266	60	4.43	180	1.48		
		Torrent	48.1	364	60	6.06	180	2.02		
		Total	100	756	60	12.60	180	4.20	2.38	8.49
10.3	3	Coastrange	0.0	0	17.5	0.00	104	0.00		
		Prickly	11.4	15	17.5	0.85	104	0.14		
		Riffle/reticulate	4.5	6	17.5	0.34	104	0.06		
		Torrent	84.1	110	17.5	6.30	104	1.06		
		Total	100	131	17.5	7.49	104	1.26	0.83	2.00

Table 4. Catch rates and population estimates of cottids in mid-channel areas of the Cedar River, February-June 1997. Catch and population estimates represent a combination of three species: coastrange, shorthead, and torrent sculpin.

				All cottids			Cottids > 49 mm TL		
River kilometer	Site	Date	Number of sets	Number	Number per set	Number per m²	Number	Number per set	Number per m²
0.5	1	Feb. 19	4	50	12.50	3.71	0	0.00	0.00
0.5	1	March 6	5	46	9.20	2.73	0	0.00	0.00
0.5	1	March 17	6	80	13.33	3.96	0	0.00	0.00
0.5	1	April 6	5	86	17.20	5.11	1	0.20	0.06
2.2	2	Feb. 18	6	272	45.33	13.47	2	0.33	0.10
2.2	2	March 17	6	187	31.17	9.26	4	0.67	0.20
2.2	2	May 19	5	13	2.60	0.77	6	1.20	0.36
9.3	3	Feb. 5	8	5	0.63	0.19	5	0.63	0.19
9.3	3	Feb. 19	7	20	2.86	0.85	15	2.14	0.64
9.3	3	April 3	5	22	4.40	1.31	17	3.40	1.01
9.3	3	May 21	5	83	16.60	4.93	56	11.20	3.33
10.5	4	Feb. 18	7	16	2.29	0.68	4	0.57	0.17
10.5	4	March 10	5	16	3.20	0.95	15	3.00	0.89
10.5	4	April 3	8	32	4.00	1.19	20	2.50	0.74
10.5	4	June 5	3	36	12.00	3.56	17	5.67	1.68
17.2	5	Feb. 19	6	36	6.00	1.78	6	1.00	0.30
17.2	5	April 8	7	97	13.86	4.12	14	2.00	0.59
21.6	6	April 8	5	66	13.20	3.92	24	4.80	1.43
21.6	6	May 7	5	100	20.00	5.94	52	10.40	3.09
21.6	6	June 11	3	88	29.33	8.71	55	18.33	5.45

Table 5.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) along the shoreline and at two nearshore depths of southern Lake Washington, Febuary-June, 1997. Shoreline fish were collected with electrofishing equipment and nearshore fish were collected with baited minnow traps and baited trot lines.

Predators			Salmonid fry consumed					Other fish			
Depth / **Date** / Site / Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum	Other salmonids	Lamprey	Cottids	Other fish
Shoreline 0-1.5 m depth											
February											
Cobble/gravel											
Coastrange sculpin	3	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	48	15	0	0	0	0	0	1	0	2	3
Sand/mud											
Prickly sculpin	6	17	0	0	0	0	0	0	0	0	0
Mixed											
Prickly sculpin	3	0	0	1	0.33	33	1	0	0	0	1
March											
Cobble/gravel											
Coastrange sculpin	5	20	0	0	0	0	0	0	0	0	0
Prickly sculpin	37	11	1	0	0.03	3	1	0	0	1	1
Sand/mud											
Coastrange sculpin	1	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	19	16	0	0	0	0	0	0	0	6	1
Mixed											
Prickly sculpin	2	0	0	0	0	0	0	0	0	0	0
April											
Cobble/gravel											
Coastrange sculpin	11	18	0	0	0	0	0	0	0	0	0
Prickly sculpin	49	20	0	0	0	0	0	0	0	1	0
Sand/mud											
Prickly sculpin	23	22	1	0	0.04	4	1	0	0	0	2
May-June											
Cobble/gravel											
Prickly sculpin	34	6	1	0	0.03	3	1	0	0	0	4
Sand/mud											
Prickly sculpin	9	22	0	0	0	0	0	0	0	0	0
Mixed											
Prickly sculpin	20	18	0	1	0.05	5	1	0	0	0	0
Nearshore 3 m depth											
February 13											
Prickly sculpin	2	0	0	0	0	0	0	0	0	0	0
April 27											
Prickly sculpin	7	14	0	0	0	0	0	0	0	0	2
Nearshore 10 m depth											
April 27											
Prickly sculpin	8	75	0	0	0	0	0	0	0	0	1

Table 6.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) and other predatory fish in the lower 0.8 km of the Cedar River, Febuary-June, 1997. 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	Other salmonids	Lamprey	Cottids	Other fish
February											
Coastrange sculpin	8	25	0	0	0	0	0	0	0	0	0
Prickly sculpin	4	25	0	0	0	0	0	0	0	0	0
March											
Cutthroat trout	3	67	1	0	0.33	33	1	0	0	0	0
Rainbow trout	1	0	0	1	1.00	100	1	0	0	0	0
Coastrange sculpin	10	10	0	1	0.10	10	1	0	0	0	0
Prickly sculpin	64	28	9	2	0.17	11	5	1	0	5	2
Riffle/reticulate sculpin	1	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	3	0	1	0	0.33	33	1	0	0	0	0
April											
Cutthroat trout	2	0	20	10	15.00	100	17	0	0	4	0
Rainbow trout	2	0	2	0	1.00	100	1	0	0	0	0
Coho salmon	1	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	15	13	2	0	0.13	13	1	0	0	0	5
Prickly sculpin	67	3	22	5	0.40	30	2	0	1	6	1
Riffle/reticulate sculpin	3	0	0	2	0.67	33	2	0	0	0	0
Torrent sculpin	4	0	4	0	1.00	50	3	0	0	0	0
May-June											
Cutthroat trout	3	0	18	1	6.33	67	12	0	0	0	0
Rainbow trout	7	0	0	1	0.14	14	1	0	0	0	0
Hatchery rainbow trout	10	0	12	1	1.30	70	3	0	0	0	0
Coho salmon	1	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	1	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	57	0	13	6	0.33	19	3	0	5	4	0
Riffle/reticulate sculpin	3	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	2	0	0	0	0	0	0	0	0	1	0
Yellow perch	1	100	0	0	0	0	0	0	0	0	0

Table 7.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) and other predatory fish in low-velocity shoreline areas of the Cedar River (rkm 1.4-22.2), Febuary-June, 1997. 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	Other salmonids	Lamprey	Cottids	Other fish
February											
Coho salmon	5	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	6	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	2	0	0	0	0	0	0	0	0	0	0
March											
Cutthroat trout	4	0	0	0	0	0	0	0	0	0	0
Rainbow trout	10	0	1	0	0.10	10	1	0	0	0	0
Coho salmon	14	0	1	0	0.07	7	1	0	0	0	0
Coastrange sculpin	9	11	1	0	0.11	11	1	0	0	0	0
Prickly sculpin	1	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	7	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	11	0	1	0	0.09	9	1	0	0	1	0
April											
Cutthroat trout	1	0	1	0	1.00	100	1	0	0	0	0
Rainbow trout	2	0	0	0	0	0	0	0	0	0	0
Coho salmon	3	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	45	9	16	4	0.44	20	3	0	1	0	4
Prickly sculpin	9	11	4	2	0.67	44	2	0	0	1	0
Riffle/reticulate sculpin	22	5	2	5	0.32	14	1	0	0	0	1
Torrent sculpin	38	3	19	1	0.53	21	7	0	0	0	5
May-June											
Rainbow trout	1	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	13	23	0	0	0	0	0	0	0	1	0
Prickly sculpin	2	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	35	6	12	2	0.40	26	6	0	0	0	1
Torrent sculpin	27	11	1	2	0.11	11	1	0	0	1	0

Table 8.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) in high-velocity mid-channel sites of the Cedar River (rkm 0.5-21.6), Febuary-May, 1997. 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	Other salmonids	Lamprey	Cottids	Other fish
February											
Coastrange sculpin	19	5	0	1	0.05	5	1	0	0	5	0
Torrent sculpin	8	13	0	0	0	0	0	0	0	0	0
March											
Coastrange sculpin	10	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	4	50	0	0	0	0	0	0	0	0	0
April											
Coastrange sculpin	61	11	0	0	0	0	0	0	0	0	0
Torrent sculpin	26	8	0	0	0	0	0	0	0	0	0
May											
Coastrange sculpin	27	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	21	5	0	0	0	0	0	0	0	0	0

Table 9.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) and other predatory fish in Elliot spawning channel and its outlet, Febuary-June, 1997. In the spawning channel, fish were collected with either small dip nets while snorkeling or beach seines. In the outlet, backpack electrofishing equipment was used.

Predators			Salmonid fry consumed					Other fish			
Site / Date / Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum	Other salmonids	Lamprey	Cottids	Other fish
Spawning Channel											
February											
Riffle/reticulate sculpin	3	0	0	0	0	0	0	0	0	0	0
March											
Riffle/reticulate sculpin	2	0	0	0	0	0	0	0	0	0	0
April											
Riffle/reticulate sculpin	27	0	17	3	0.74	41	4	0	0	0	1
May											
Riffle/reticulate sculpin	20	0	8	2	0.50	45	2	0	0	0	0
Torrent sculpin	1	0	1	0	1.00	100	1	0	0	0	0
June											
Riffle/reticulate sculpin	15	0	11	0	0.73	60	5	0	0	0	0
Outlet											
February											
Coho salmon	1	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	4	0	0	0	0	0	0	0	0	1	0
Riffle/reticulate sculpin	7	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	6	0	0	1	0.17	17	1	0	0	0	0
March											
Coho salmon	8	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	3	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	6	17	1	0	0.17	17	1	0	0	0	0
Torrent sculpin	14	7	0	0	0	0	0	0	2	0	0
April											
Coho salmon	2	0	11	0	5.50	100	7	0	0	0	0
Riffle/reticulate sculpin	12	0	17	6	1.92	83	6	0	0	0	0
Torrent sculpin	9	0	9	3	1.33	56	3	0	0	0	1
May											
Cutthroat trout	3	0	38	2	13.33	100	23	0	0	0	0
Rainbow trout	1	0	19	0	19.00	100	19	0	0	0	0
Coastrange sculpin	8	0	4	0	0.50	38	2	0	0	0	0
Riffle/reticulate sculpin	20	0	14	0	0.70	30	5	0	0	0	1
Torrent sculpin	12	0	21	4	2.08	83	8	0	0	0	1
June											
Cutthroat trout	3	0	39	3	14.00	100	26	0	0	0	0
Riffle/reticulate sculpin	10	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	10	0	2	1	0.30	30	1	0	0	0	0

Table 10.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) and other predatory fish in Cavanaugh Pond and its outlet, March-June, 1997. In the pond, fish were collected with either dip nets while snorkeling or beach seines. In the outlet, backpack electrofishing equipment was used.

Predators Site Date Species	N	% Empty stomachs	Salmonid fry consumed: Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum	Other fish: Other salmonids	Lamprey	Cottids	Other fish
Pond											
March											
Prickly sculpin	34	6	0	0	0	0	0	1	0	0	0
Riffle/reticulate sculpin	4	0	0	0	0	0	0	0	0	0	0
April											
Prickly sculpin	8	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	6	0	2	0	0.33	17	2	0	0	0	0
May											
Prickly sculpin	69	4	46	12	0.84	22	6	0	0	0	2
Riffle/reticulate sculpin	20	0	6	4	0.50	25	4	0	0	0	0
June											
Prickly sculpin	54	0	22	1	0.43	13	8	0	0	0	1
Riffle/reticulate sculpin	12	0	0	4	0.33	17	2	0	0	0	0
Outlet											
March											
Coho salmon	9	0	1	0	0.11	11	1	0	0	0	0
Prickly sculpin	1	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	2	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	6	0	0	0	0	0	0	0	0	0	1
April											
Coho salmon	2	0	0	0	0	0	0	0	0	0	0
Prickly sculpin	1	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	5	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	5	0	3	0	0.60	40	2	0	0	0	0
May											
Prickly sculpin	2	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	1	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	17	6	10	1	0.65	35	4	0	1	0	1
June 5											
Cutthroat trout	1	0	16	0	16.00	100	16	0	0	0	0
Prickly sculpin	10	10	32	1	3.30	90	5	0	0	0	0
Riffle/reticulate sculpin	3	0	2	0	0.67	33	2	0	0	0	0
Torrent sculpin	16	13	14	0	0.88	50	4	0	0	0	3
June 16											
Prickly sculpin	1	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	22	0	4	0	0.18	14	1	0	1	0	0

Table 11.-- Salmonid fry and other prey fish consumed by cottids (>49 mm TL) and other predatory fish near the mouths of Petersen Creek and Rock Creek, 1997. 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	Other salmonids	Lamprey	Cottids	Other fish
Peterson Creek - pools only											
March 31											
Cutthroat trout	2	0	0	0	0	0	0	0	0	0	0
Coho salmon	3	0	0	0	0	0	0	0	0	0	0
Coastrange sculpin	1	0	0	0	0	0	0	0	0	0	0
Riffle/reticulate sculpin	8	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	14	0	0	0	0	0	0	0	0	0	0
Rock Creek											
May 9											
pools											
Cutthroat trout	2	0	0	0	0	0	0	0	0	0	0
Rainbow trout	1	0	0	1	1	100	1	0	0	0	0
Coho salmon	2	50	0	0	0	0	0	0	0	0	0
Torrent sculpin	16	6	0	0	0	0	0	1	0	0	0
riffles											
Shorthead sculpin	8	0	0	0	0	0	0	0	0	0	0
Torrent sculpin	4	0	0	0	0	0	0	0	0	0	0

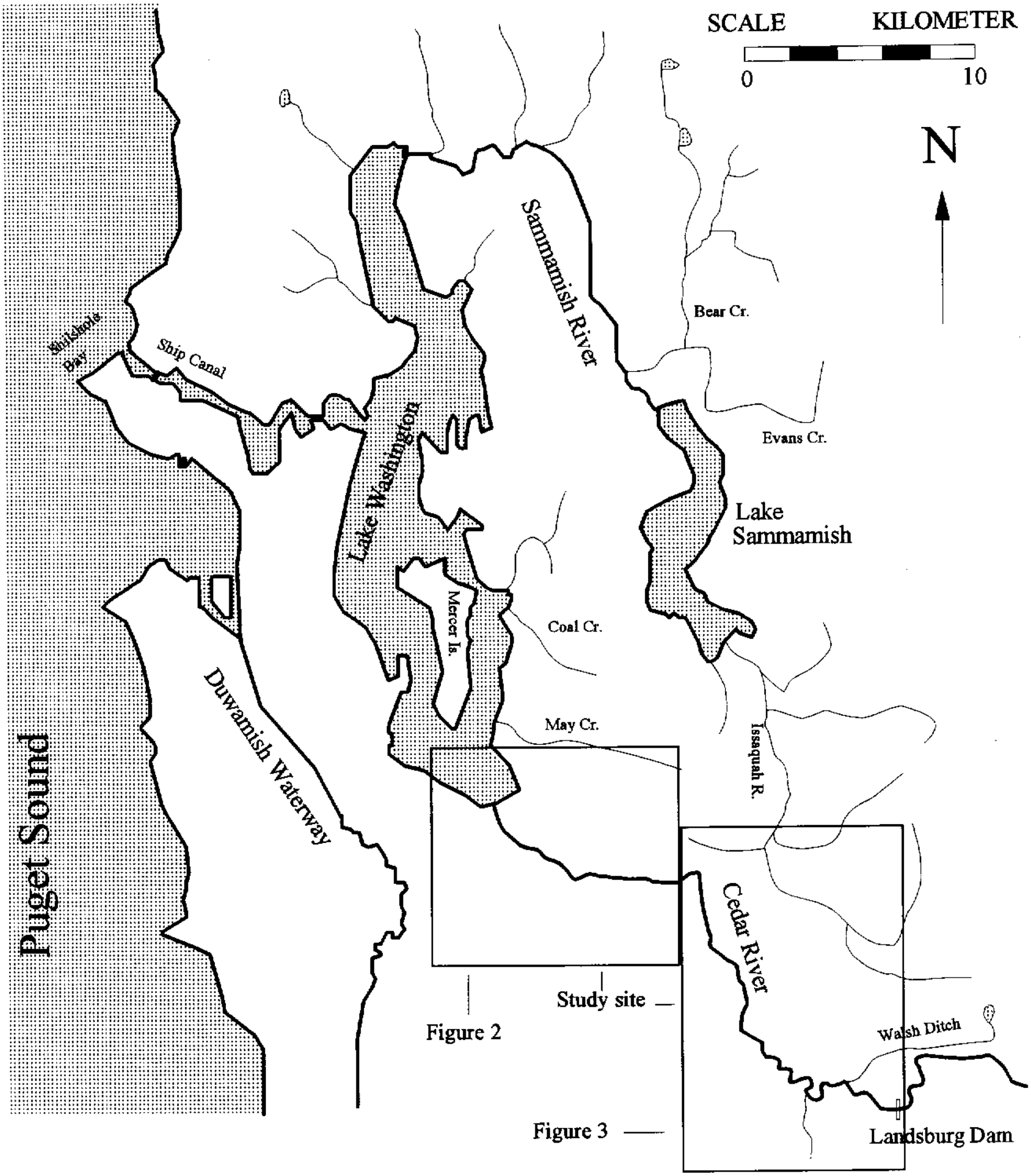

Figure 1.-- Map of Lake Washington drainage basin and location of study site, February-June, 1997.

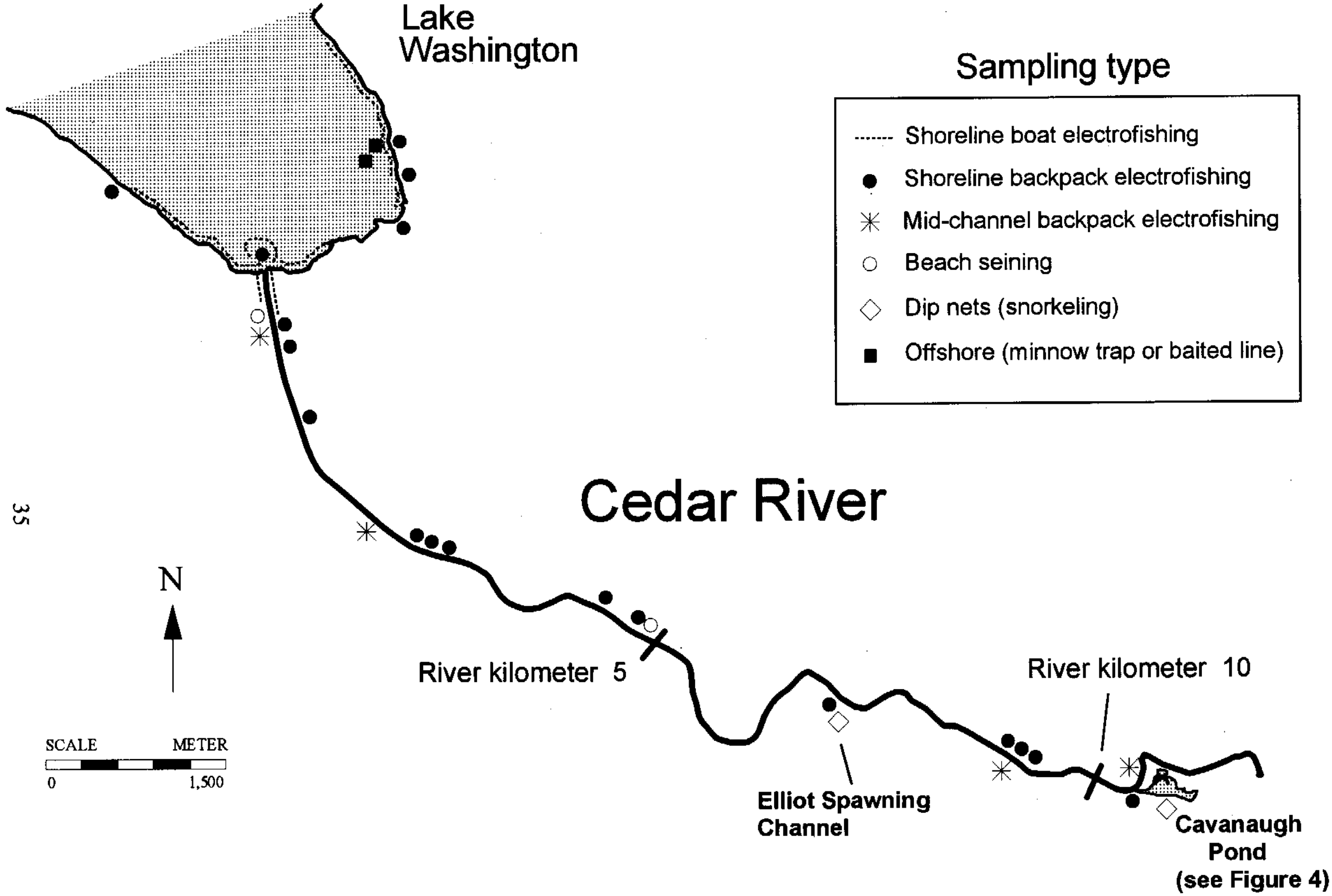

Figure 2.-- Sample sites used to collect cottids in southern Lake Washington and the lower 12 km of the Cedar River, Febuary-June, 1997.

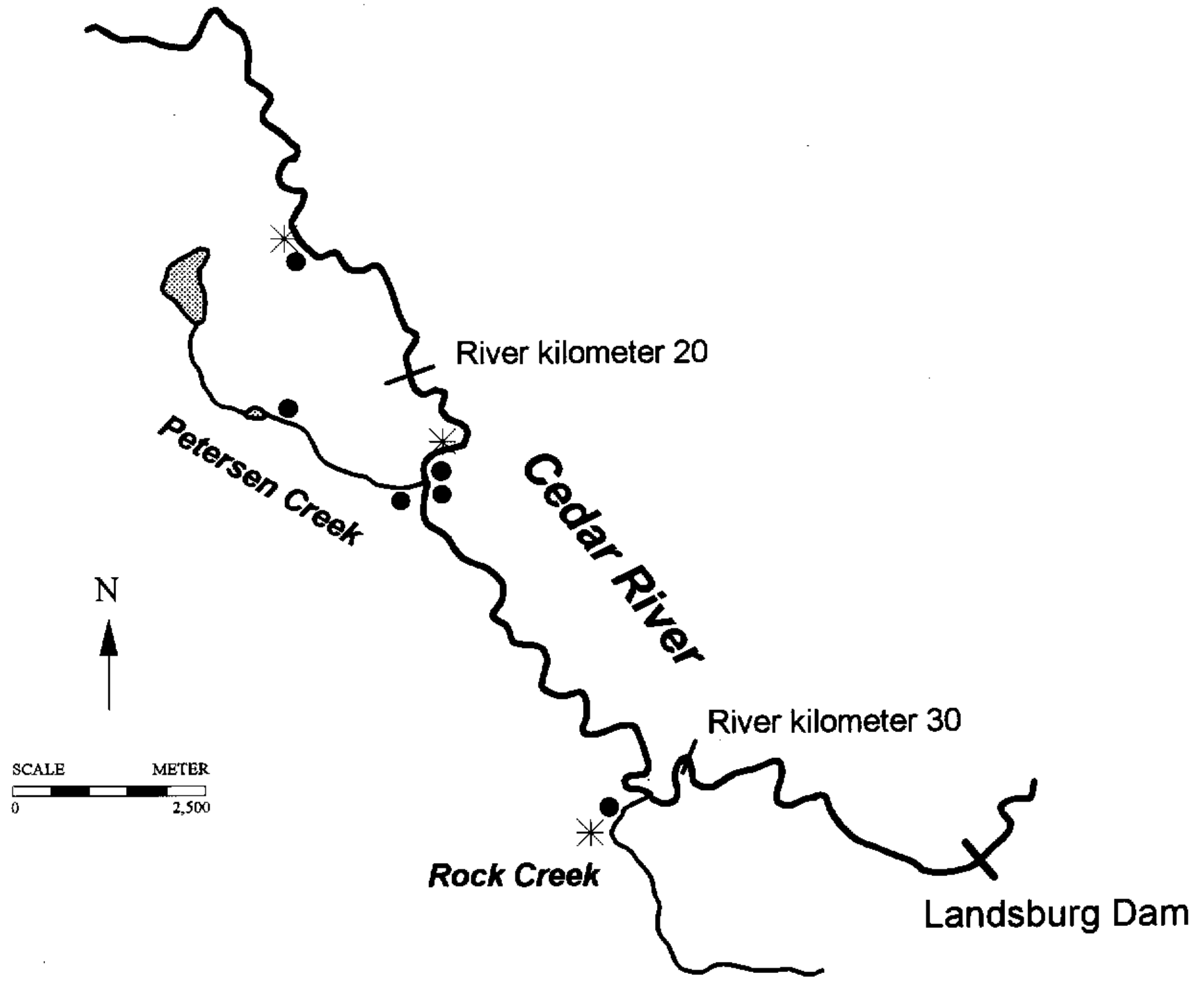

Figure 3.-- Sample sites used to collect cottids in the Cedar River (river kilometer 12-34) and two tributaries, Febuary-June, 1997. All shoreline (circles) and mid-channel (asterisk) electrofishing sites were done with backpack equipment.

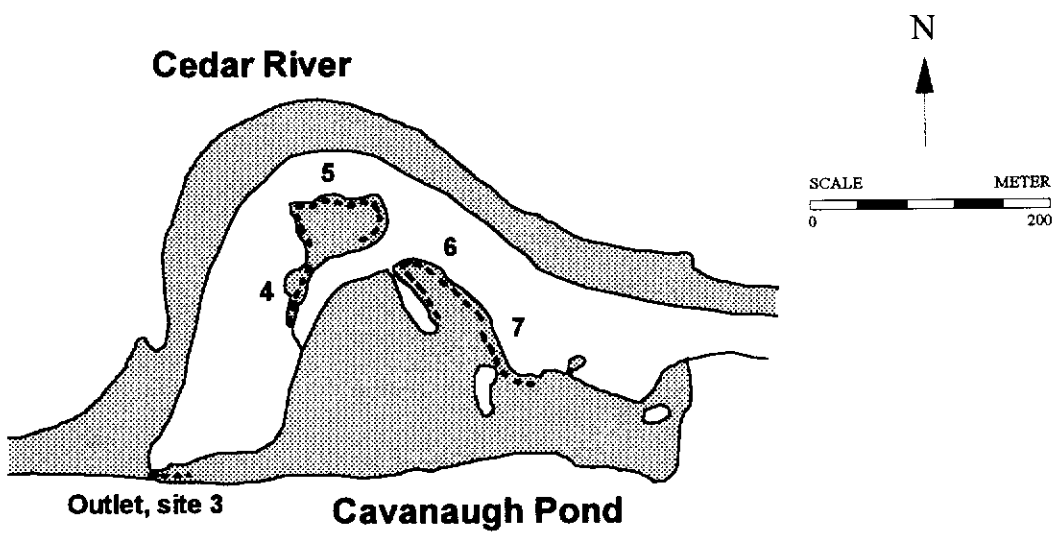

Figure 4.-- Sample sites used to collect cottids in Cavanaugh Pond, March-June, 1997. At sites 4-7, cottids were collected along snorkel transects with small dip nets. At the outlet, fish were collected with backpack electrofishing equipment. Preliminary sampling also included beach seining which was done between site 6 and 7 (March 6, 1997).

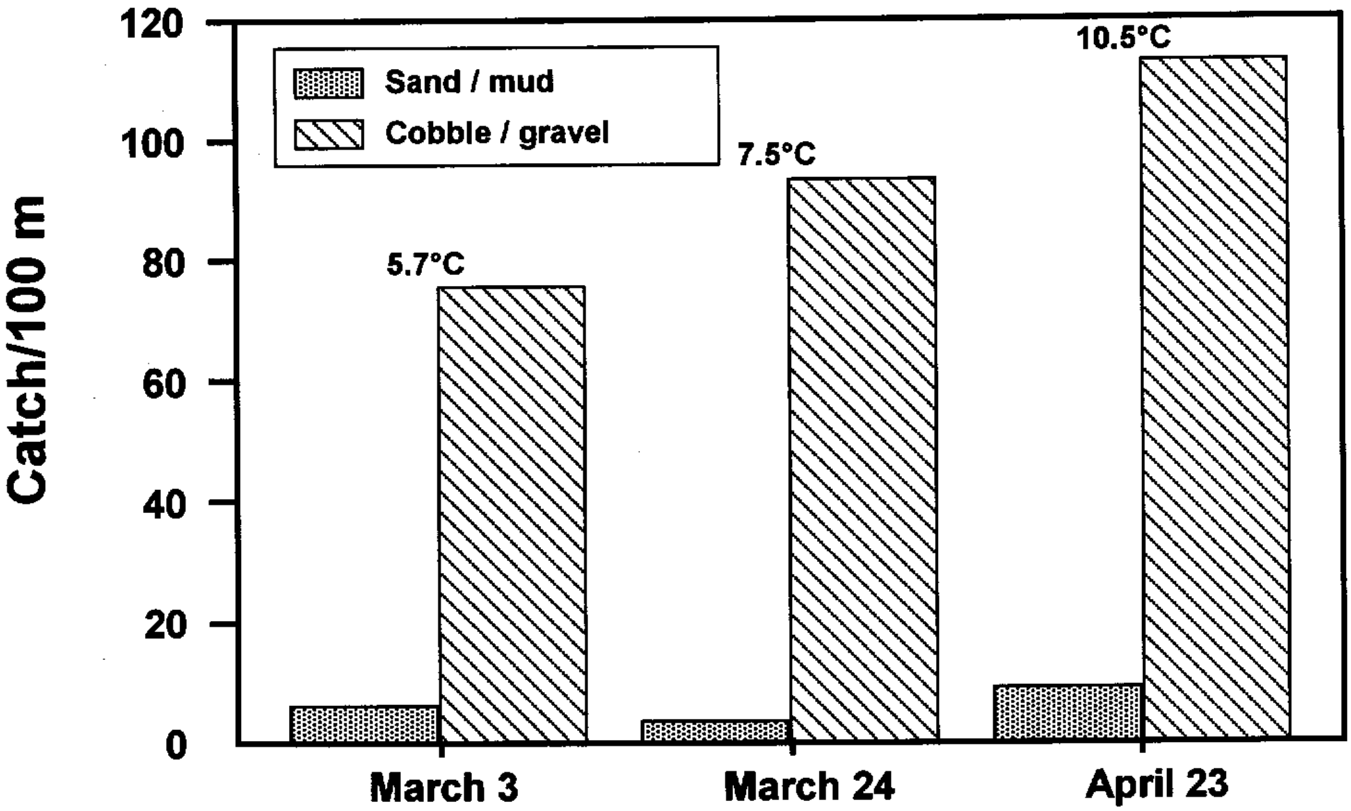

Figure 5. -- Catch rates (catch/100 m) of cottids (prickly sculpin and coastrange sculpin combined) at two sites along the shoreline of Gene Coulon Park, Lake Washington, March-April, 1997. Surface water temperatures are given above each date.

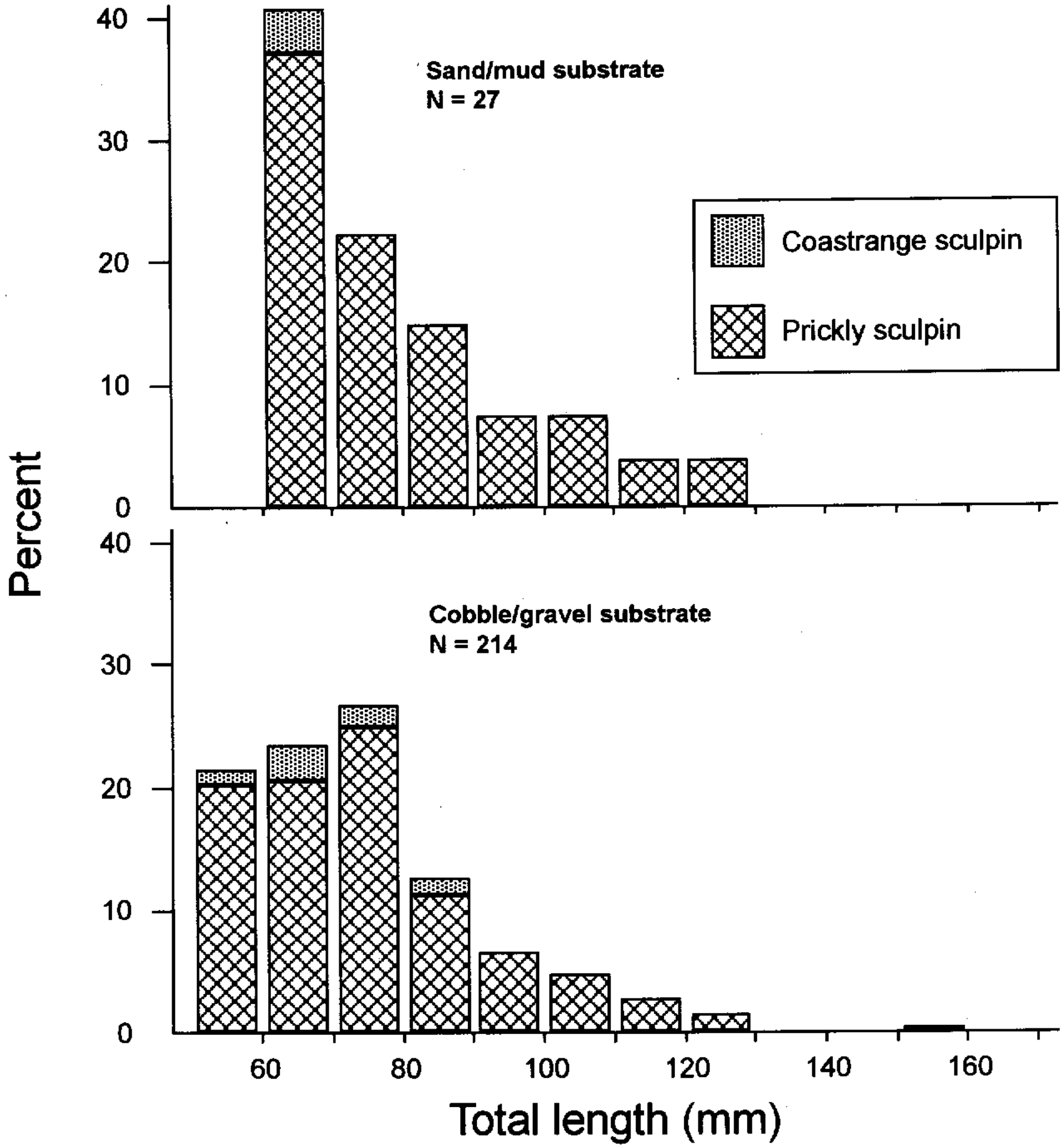

Figure 6.-- Length frequencies of cottids from two substrate types along the shoreline of Gene Coulon Park, Lake Washington, February-April, 1997. Percentages were calculated from pooled data of all cottid species and sampling dates.

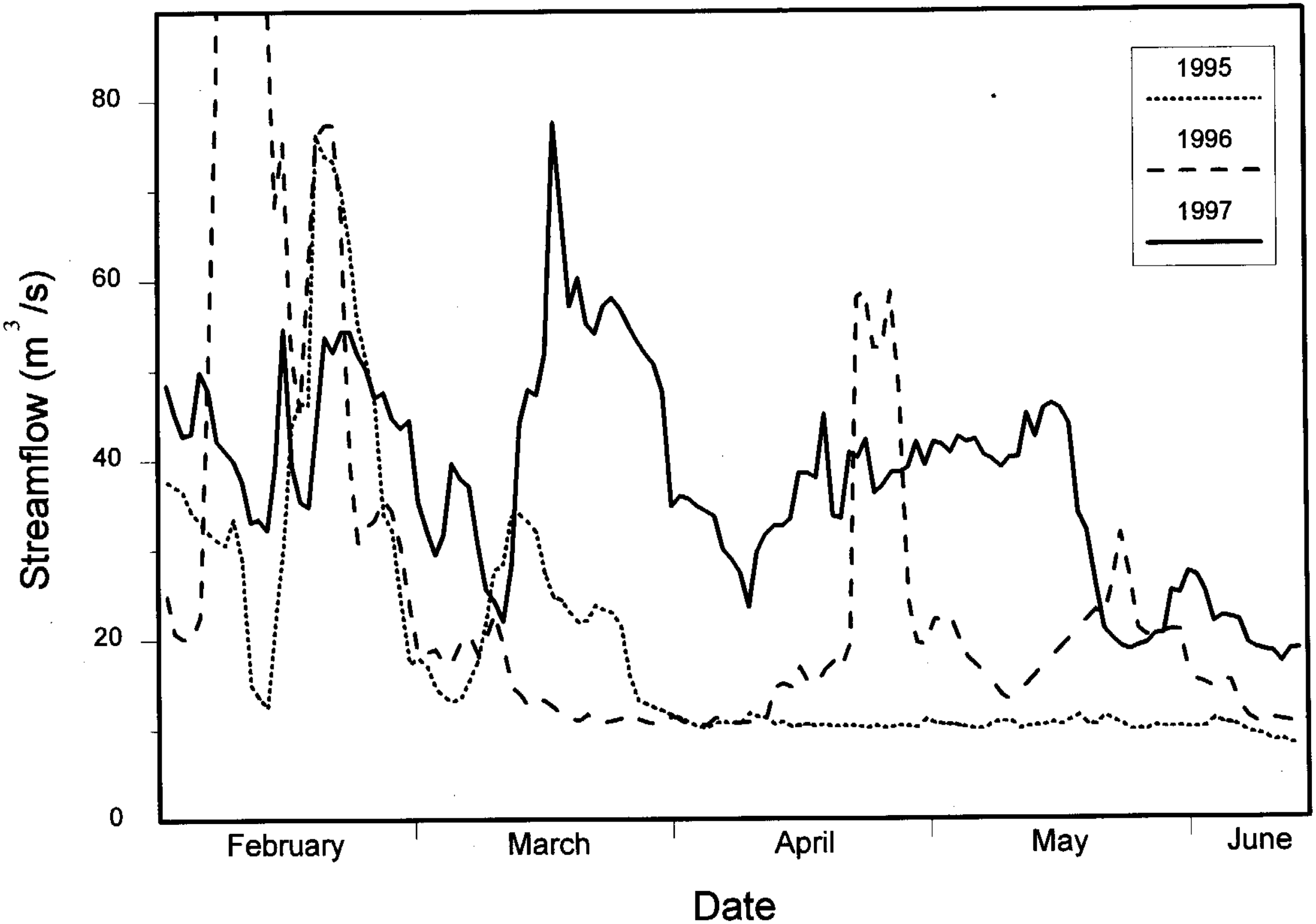

Figure 7.-- Daily streamflow levels (m ^{3}/s) of the Cedar River at the USGS Renton gauge (rkm 2.6) for February1-June 15, 1995-1997 (USGS, unpublished data).

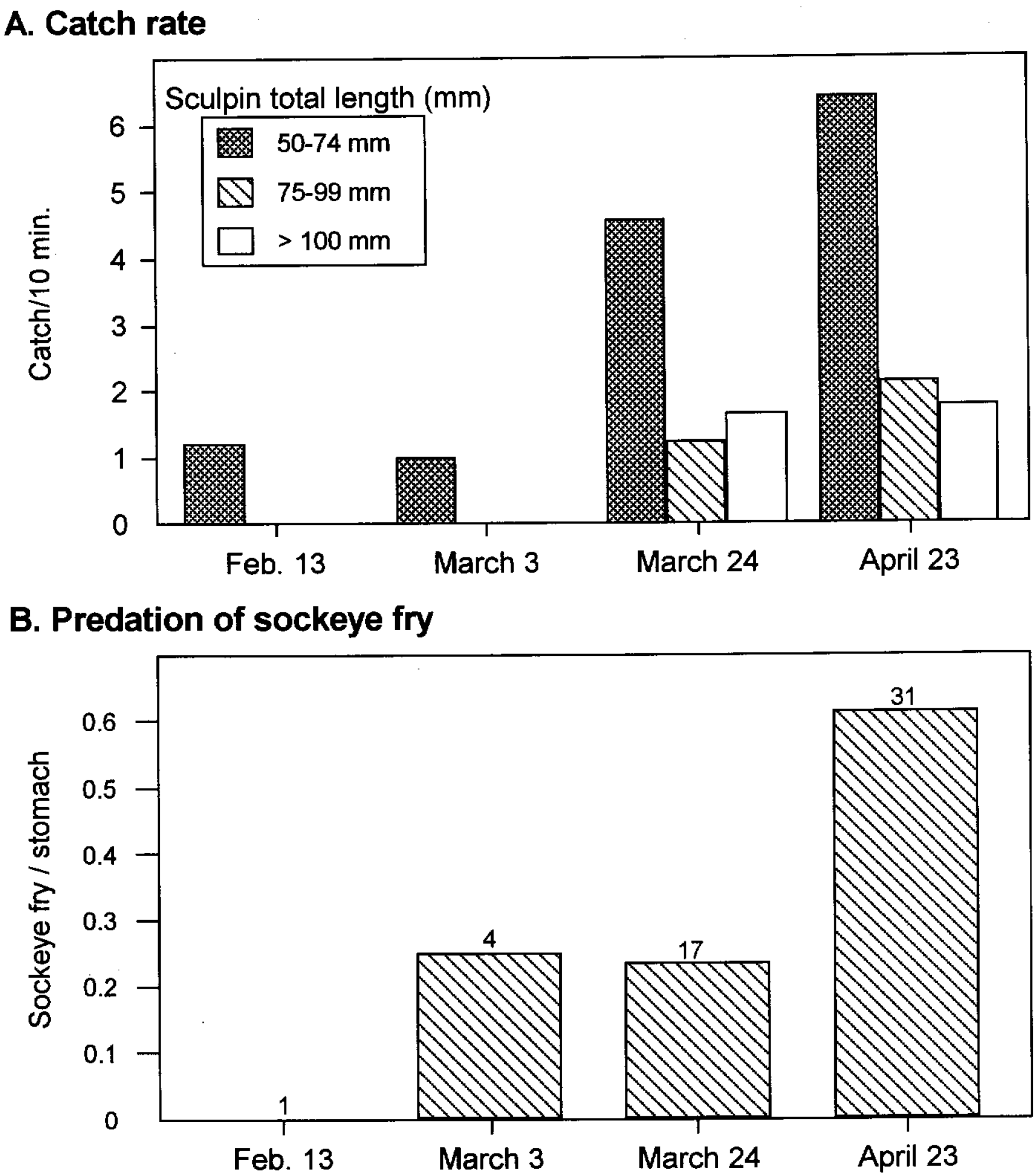

Figure 8.-- Catch rates of cottids and predation of sockeye salmon fry by cottids at the Cedar River delta site, February-April, 1997. The number of cottid stomachs examined is given above the second graph.

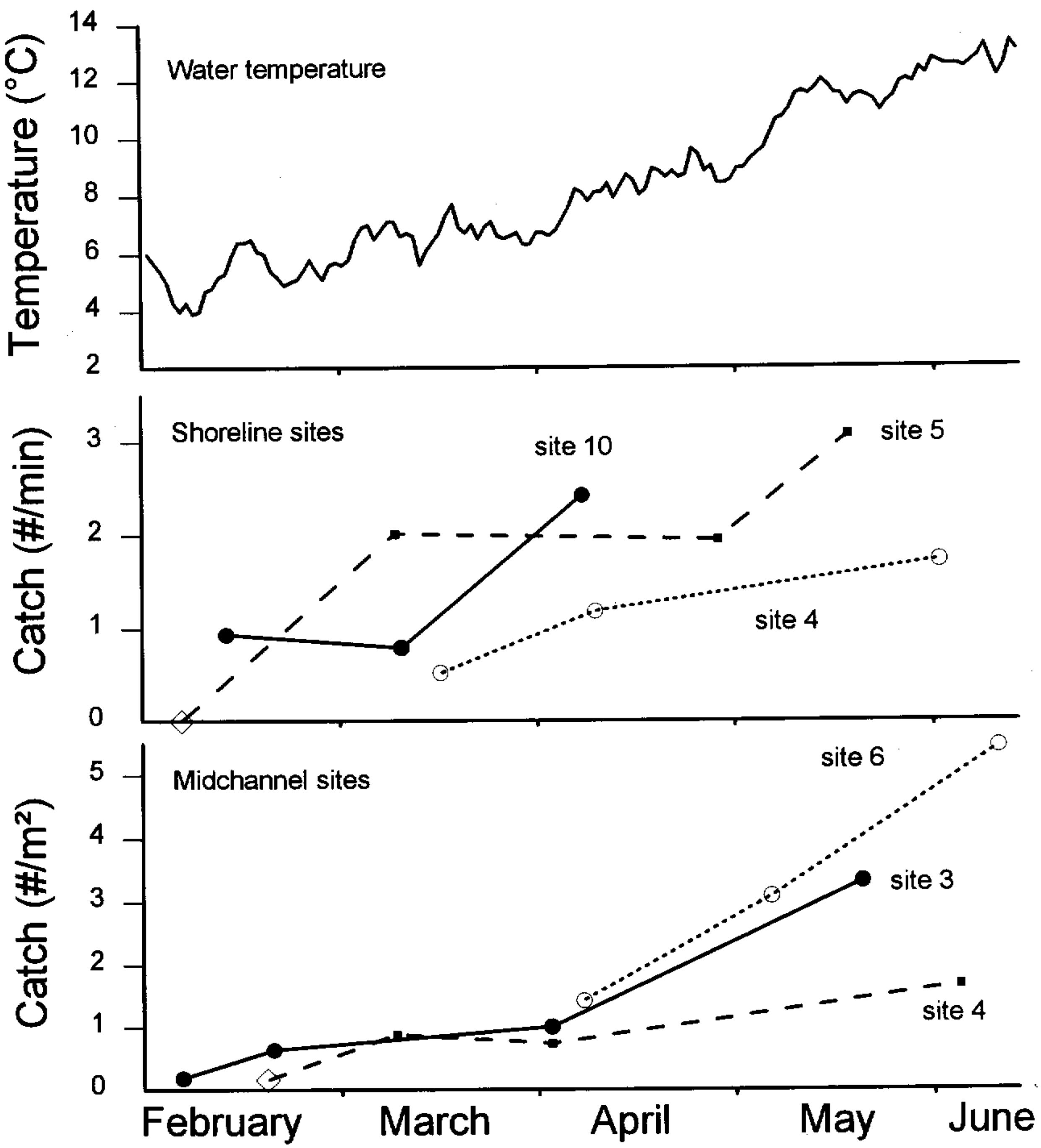

Figure 9.-- Mean daily water temperature (rkm 2.6; USGS unpublished data) and catch rates of cottids > 50 mm TL at three shoreline (catch/ minute of electrofishing) and three midchannel sites (catch/m²) in the Cedar River, February-June, 1997.

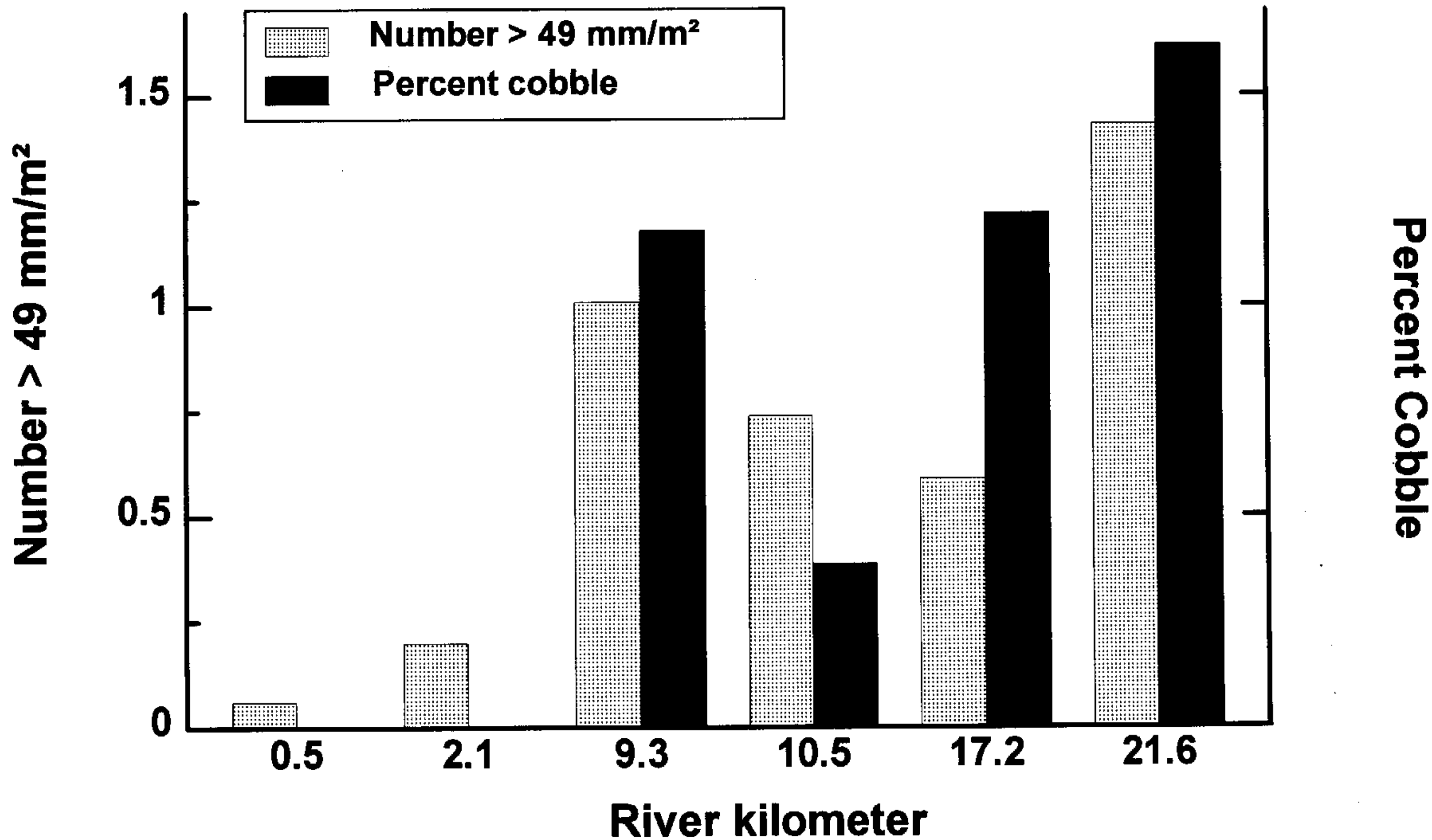

Figure 10.-- Relationship between the the number of cottids > 49 mm TL and the percent of large substrate (% cobble) in high-velocity mid-channel sites in the Cedar River, March-April, 1997.

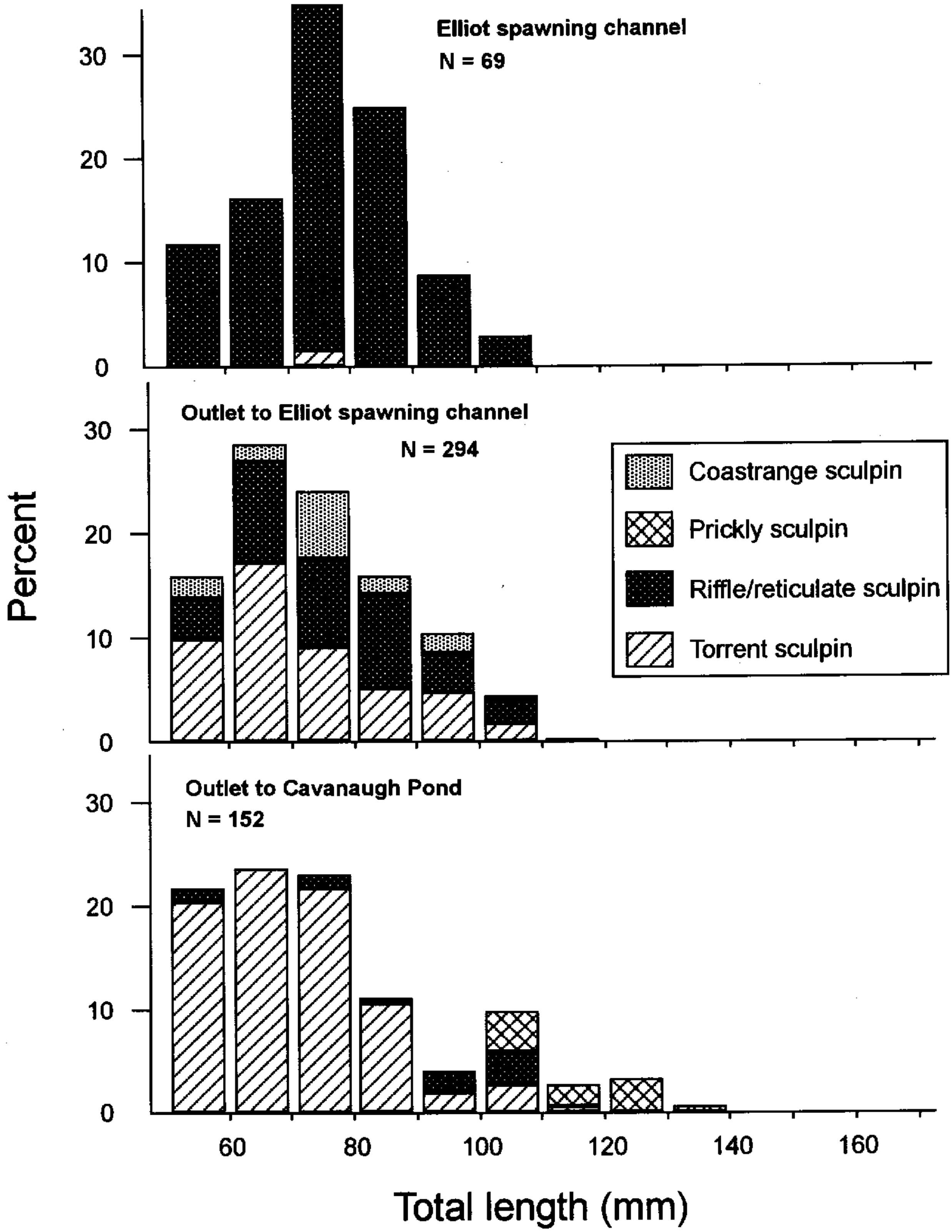

Figure 11.-- Length frequencies of cottids from three off-channel locations of the Cedar River, February-June, 1997. Percentages were calculated from pooled data of all cottid species and sampling dates.

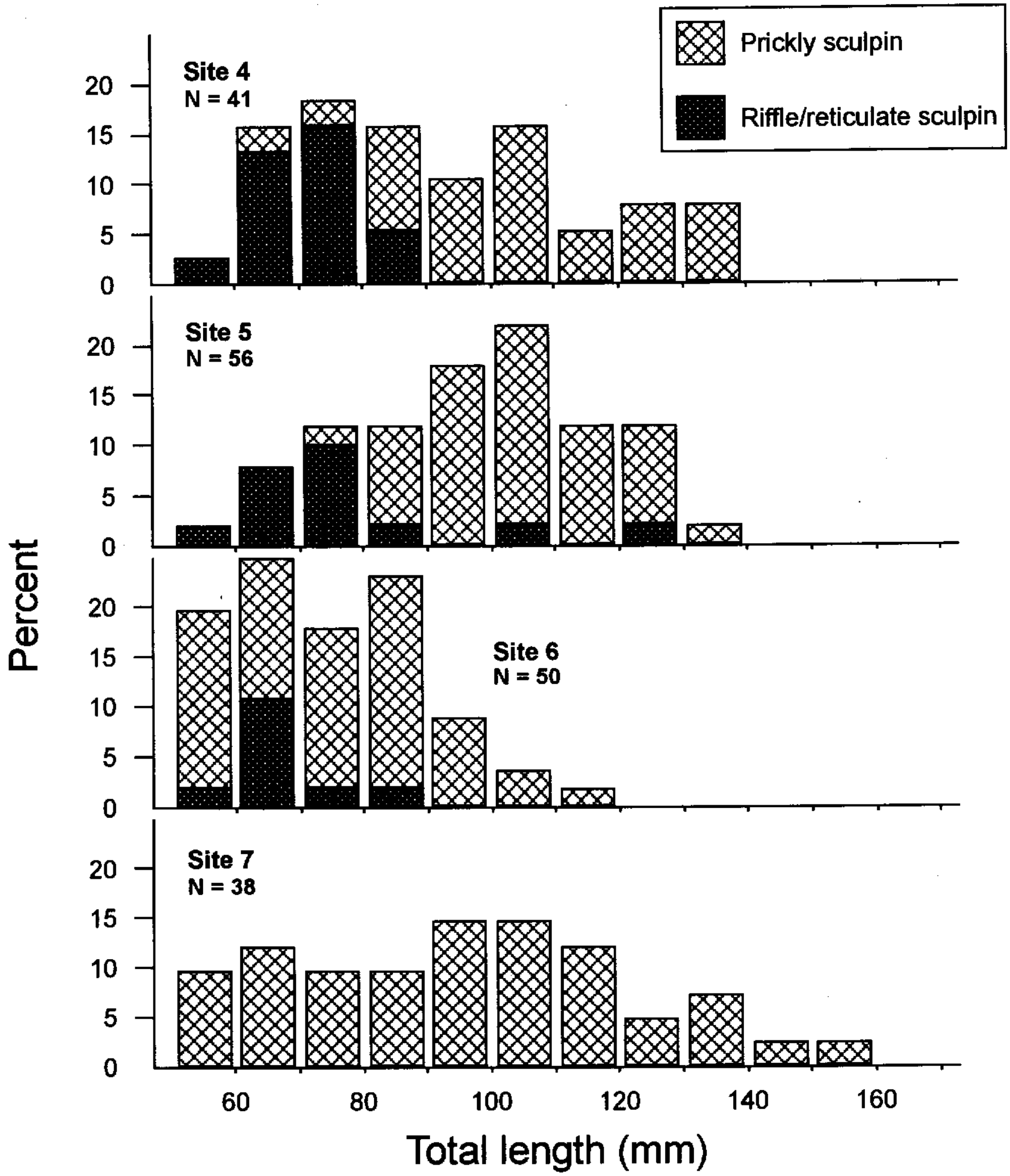

Figure 12.-- Length frequencies of cottids from four sites in Cavanaugh Pond, March-June, 1997. Percentages were calculated from pooled data of all cottid species and sampling dates.

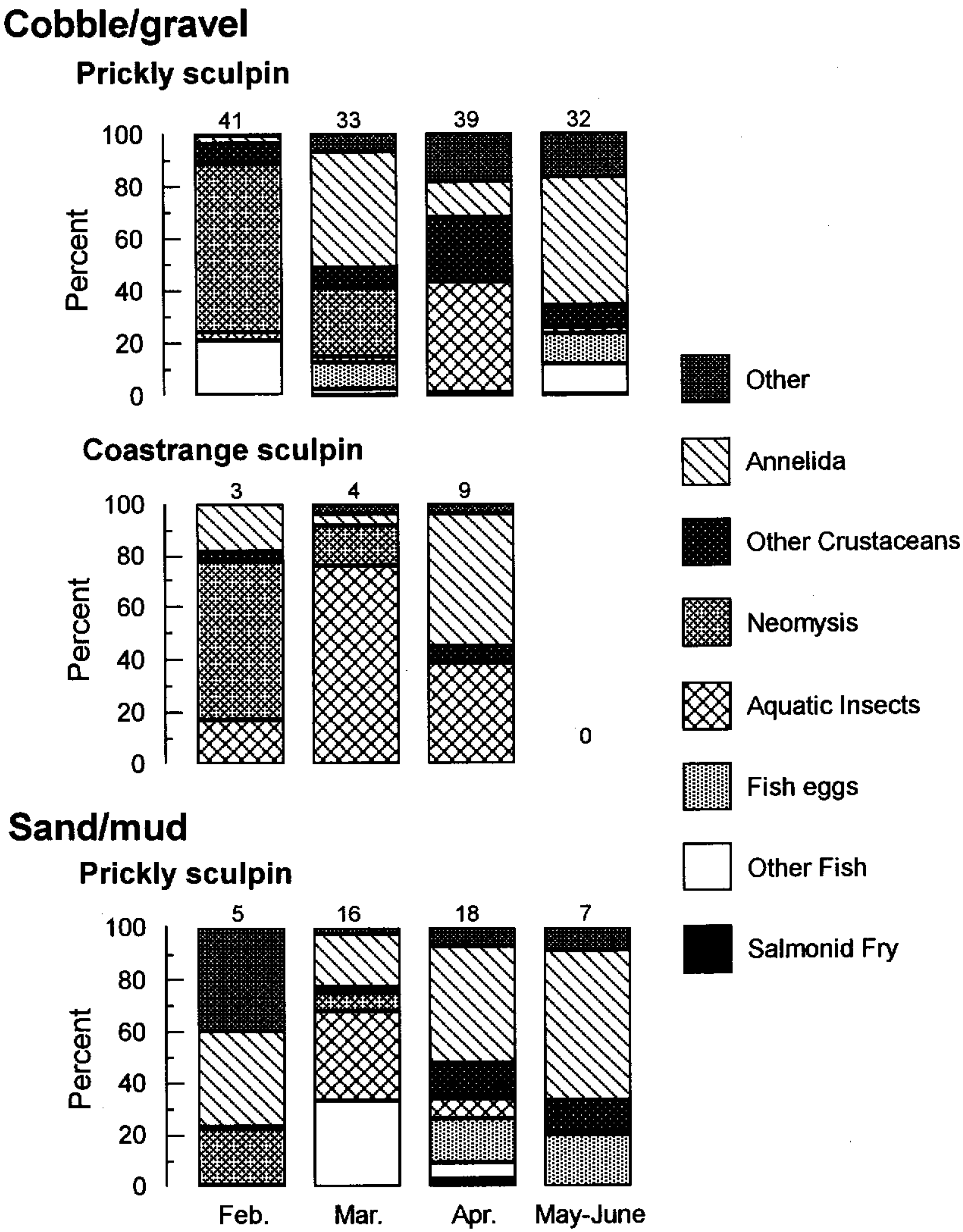

Figure 13.-- Composition (percent by weight) of ingested food for two species of cottids (> 49 mm TL) from shoreline areas of Lake Washington, February-June, 1997. Few coastrange sculpin were collected from sand/mud shoreline areas. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.

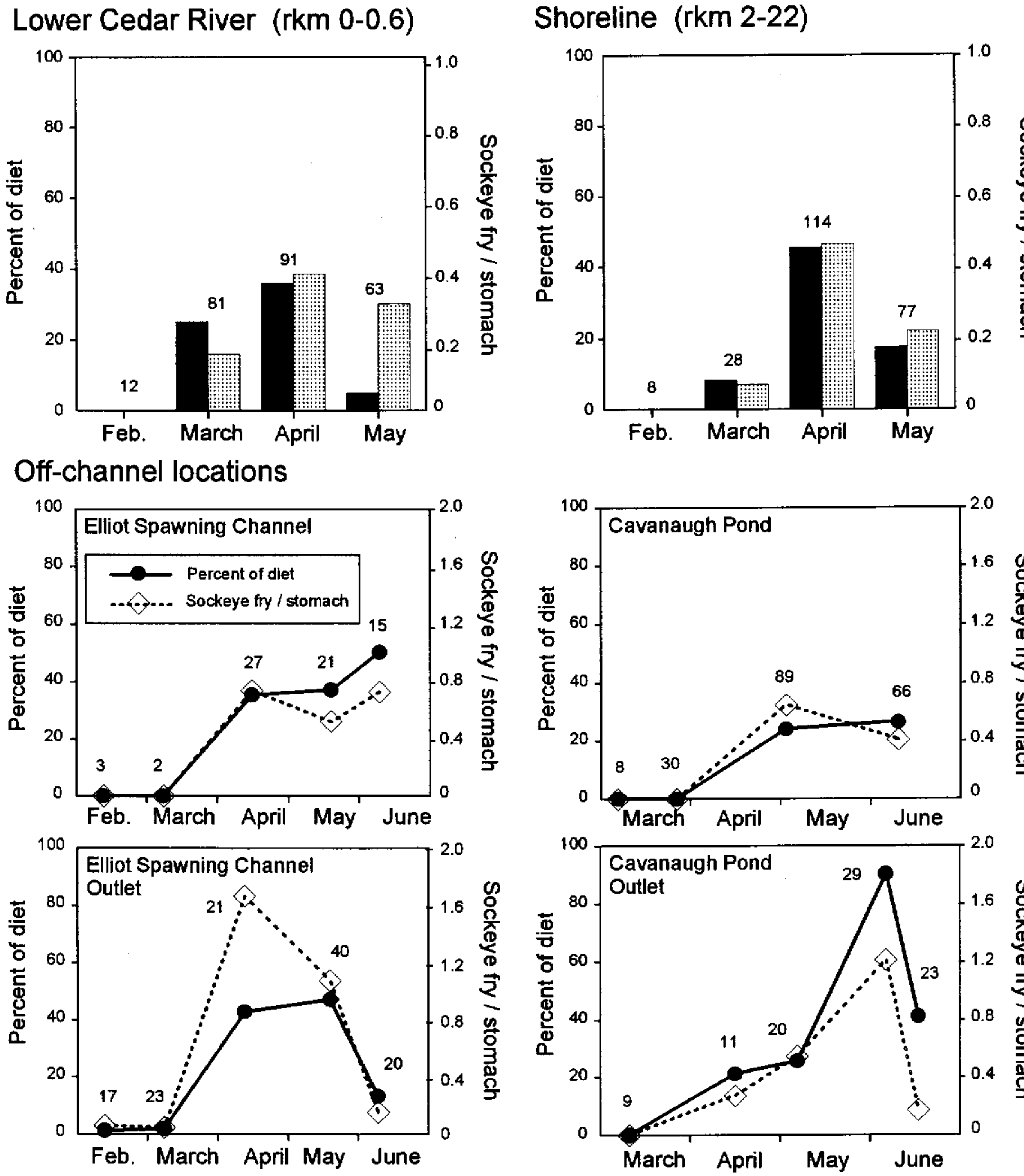

Figure 14.-- Overall percent of diet (by wet weight) composed of sockeye salmon fry (solid bars or lines) and the overall number of sockeye salmon fry per stomach (shaded bars or dashed lines) for cottids in the lower river, shoreline, and off-channel sites of the Cedar River,February-June, 1997. Cottid species, sample sites and dates were combined by month for lower river and shoreline data. Cottid species and sample sites were combined by date for off-channel data. The number of stomach samples is given above each date or month cottids were collected. rkm = river kilometer.

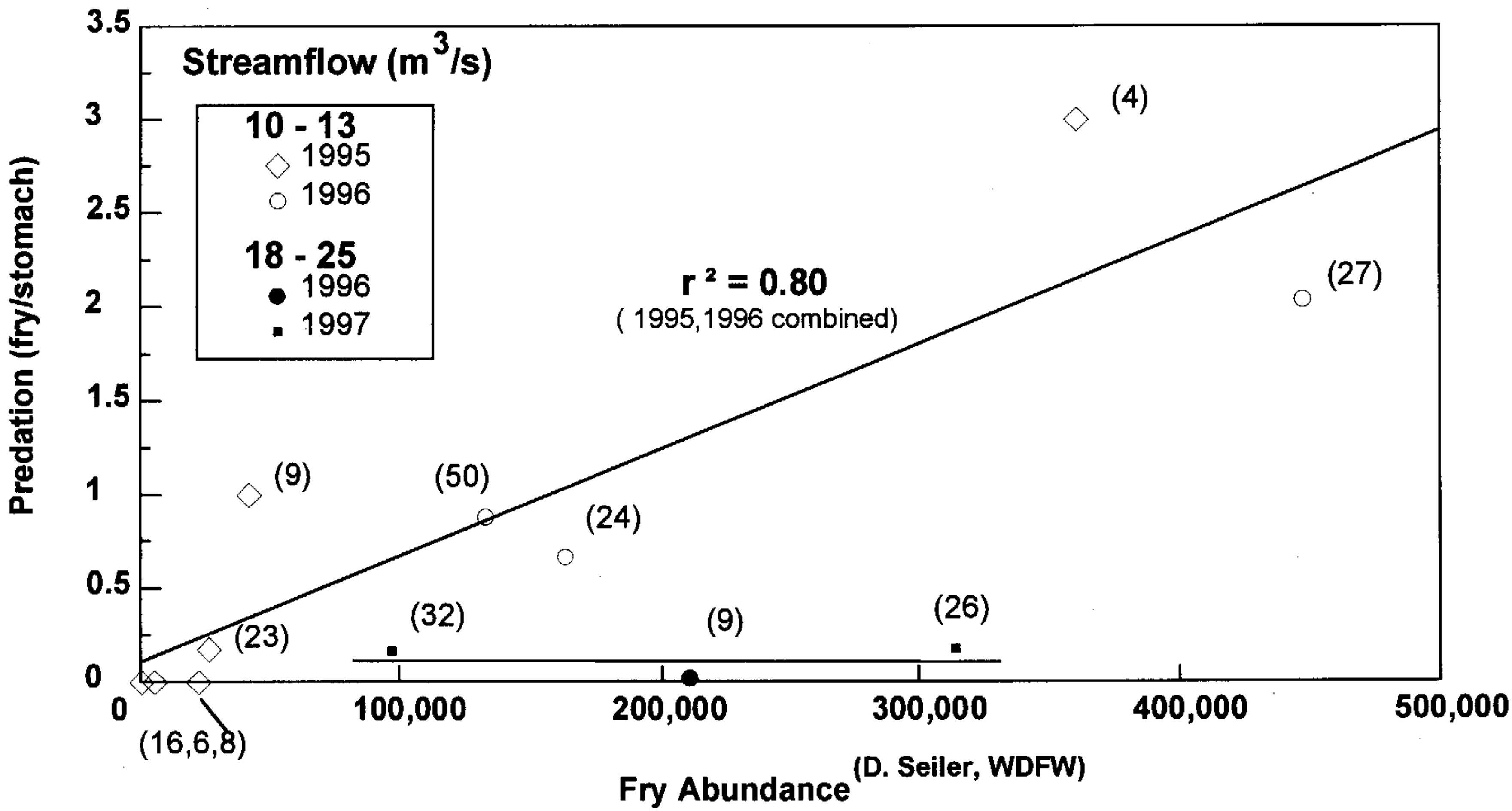

Figure 15.-- Predation (freshly ingested fry/stomach) of sockeye salmon fry by prickly sculpin in the lower Cedar River (rkm 0.0-0.5) at two streamflow categories (open or solid symbols), March-May, 1995, 1996, and 1997. Fry abundance is the number of fry that were estimated to have outmigrated before the sculpin were collected (same night). Sample sizes are given in parentheses.

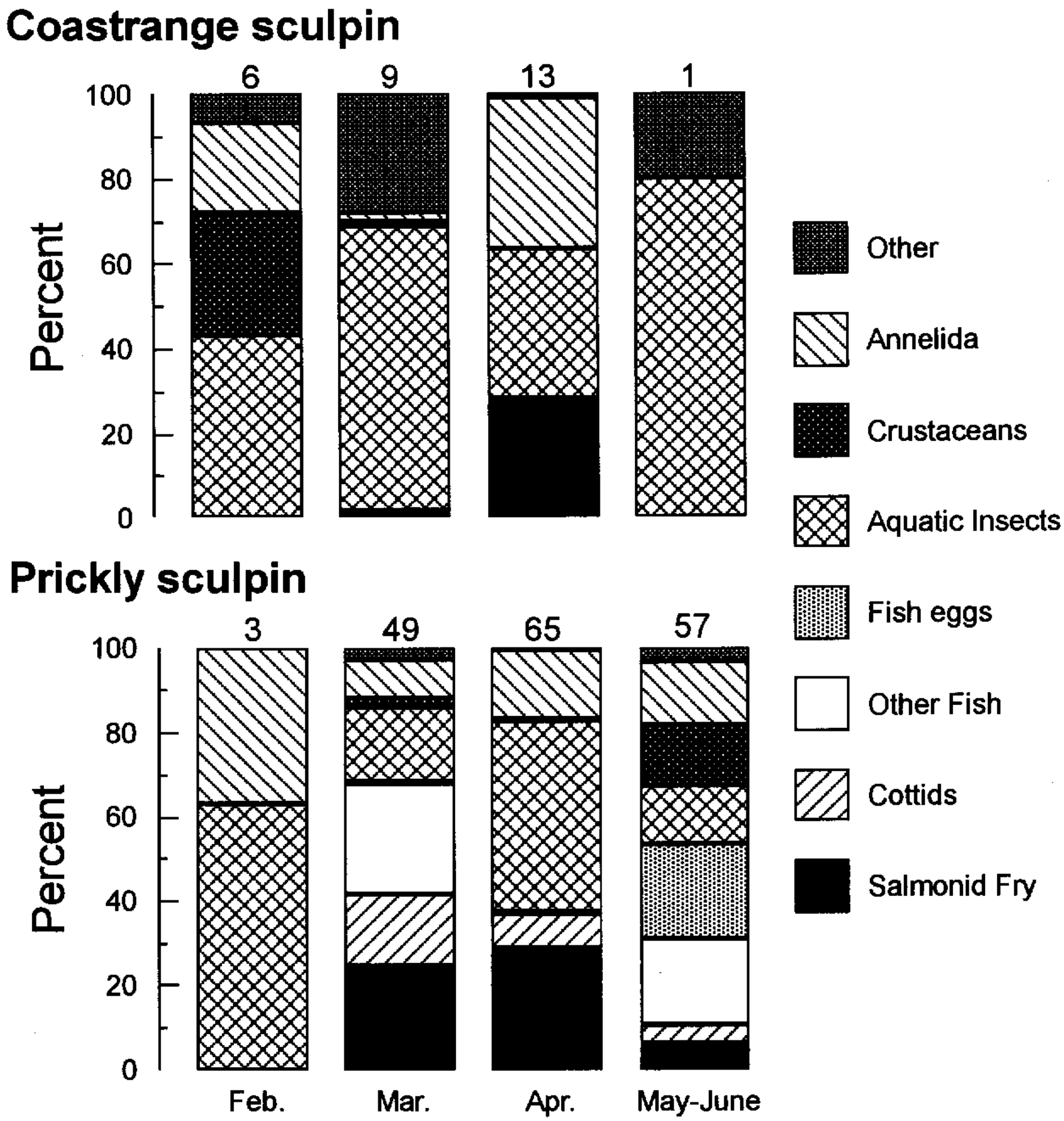

Figure 16.-- Composition (percent by weight) of ingested food for two species of cottids (> 49 mm TL) in the lower 0.8 km of the Cedar River, February-June, 1997. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.

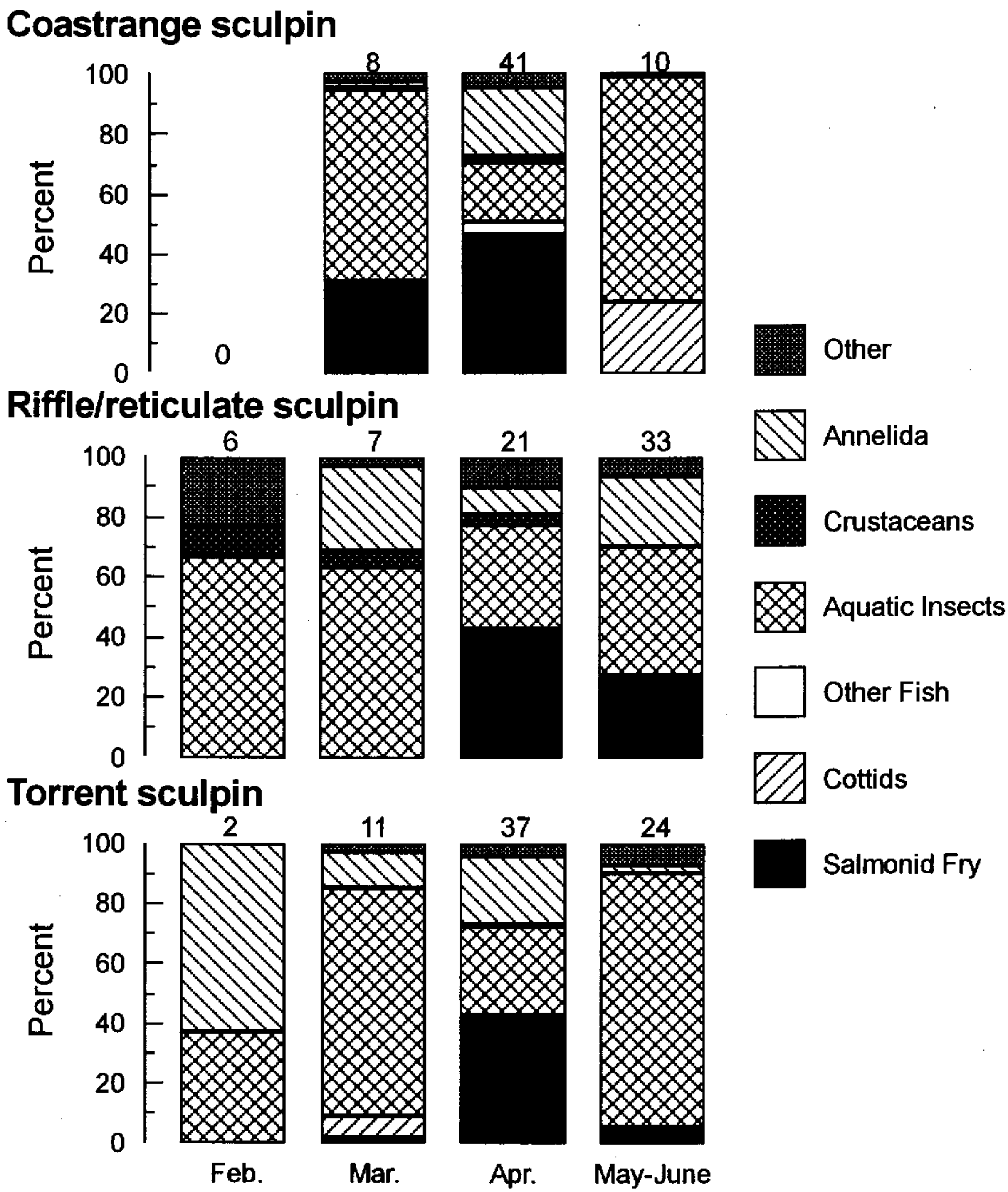

Figure 17.-- Composition (percent by weight) of ingested food for three species of cottids (> 49 mm TL) in low-velocity shoreline areas of the Cedar River (rkm 1.4-22.2), February-June, 1997. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.

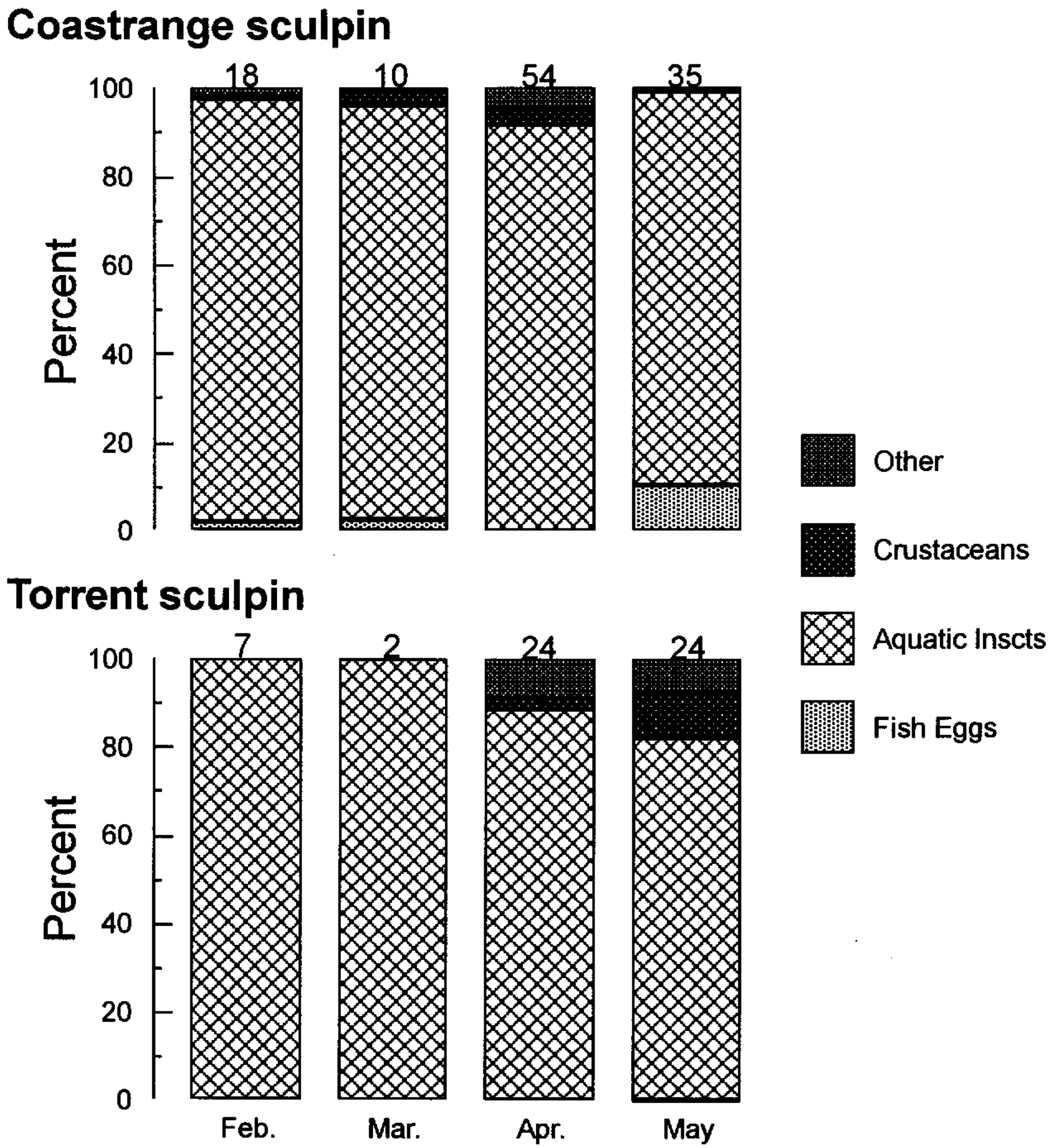

Figure 18.-- Composition (percent by weight) of ingested food for two species of cottids (> 49 mm TL) in high-velocity midchannel sites in the Cedar River (rkm 0.5-21.6), February-May, 1997. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.

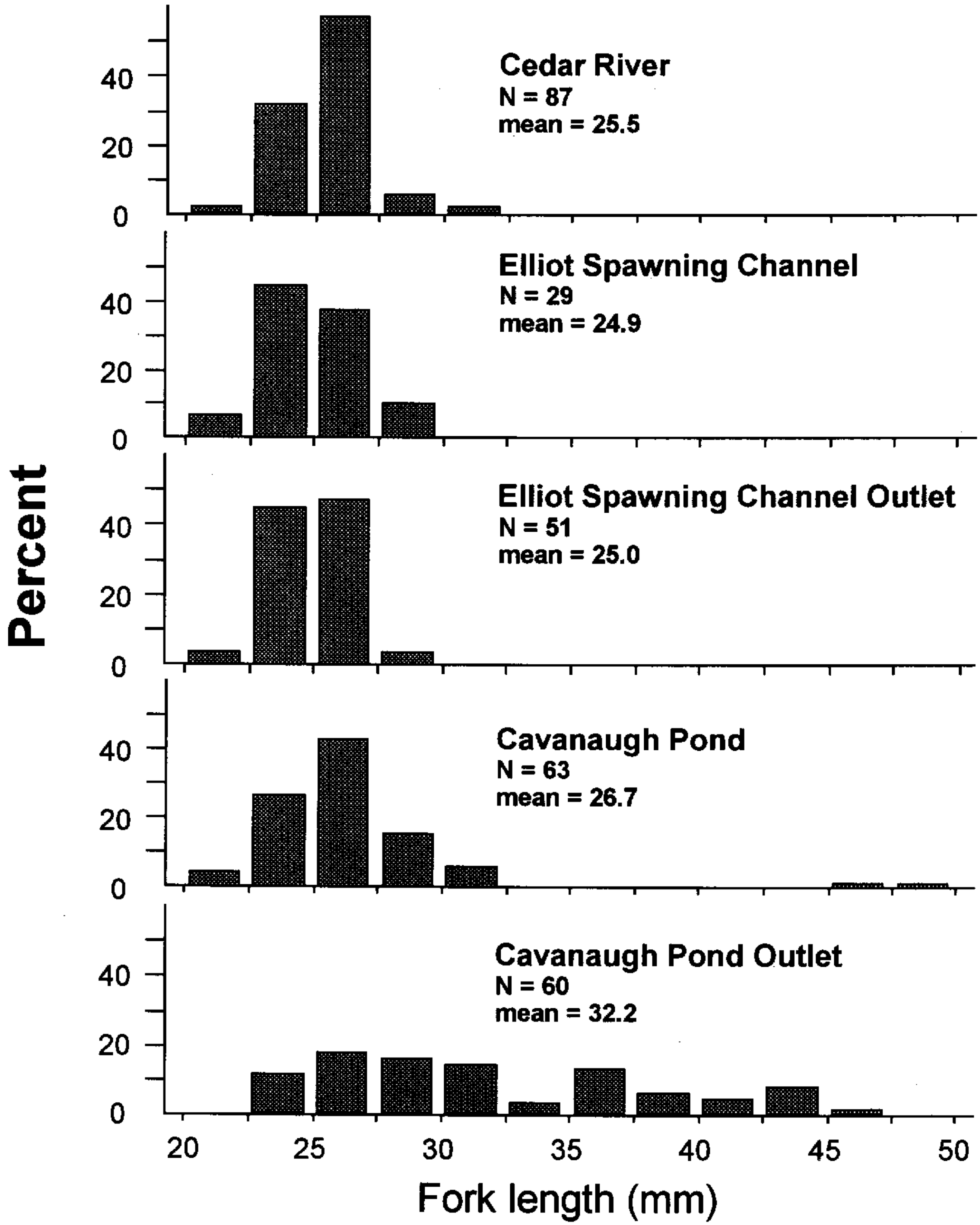

Figure 19.-- Length frequencies of sockeye salmon fry ingested by cottids in the Cedar River mainstem and two off-channel sites, Elliott spawning channel and Cavanaugh Pond, February-June, 1997. Percentages were calculated from pooled data of all cottid species and sampling dates.

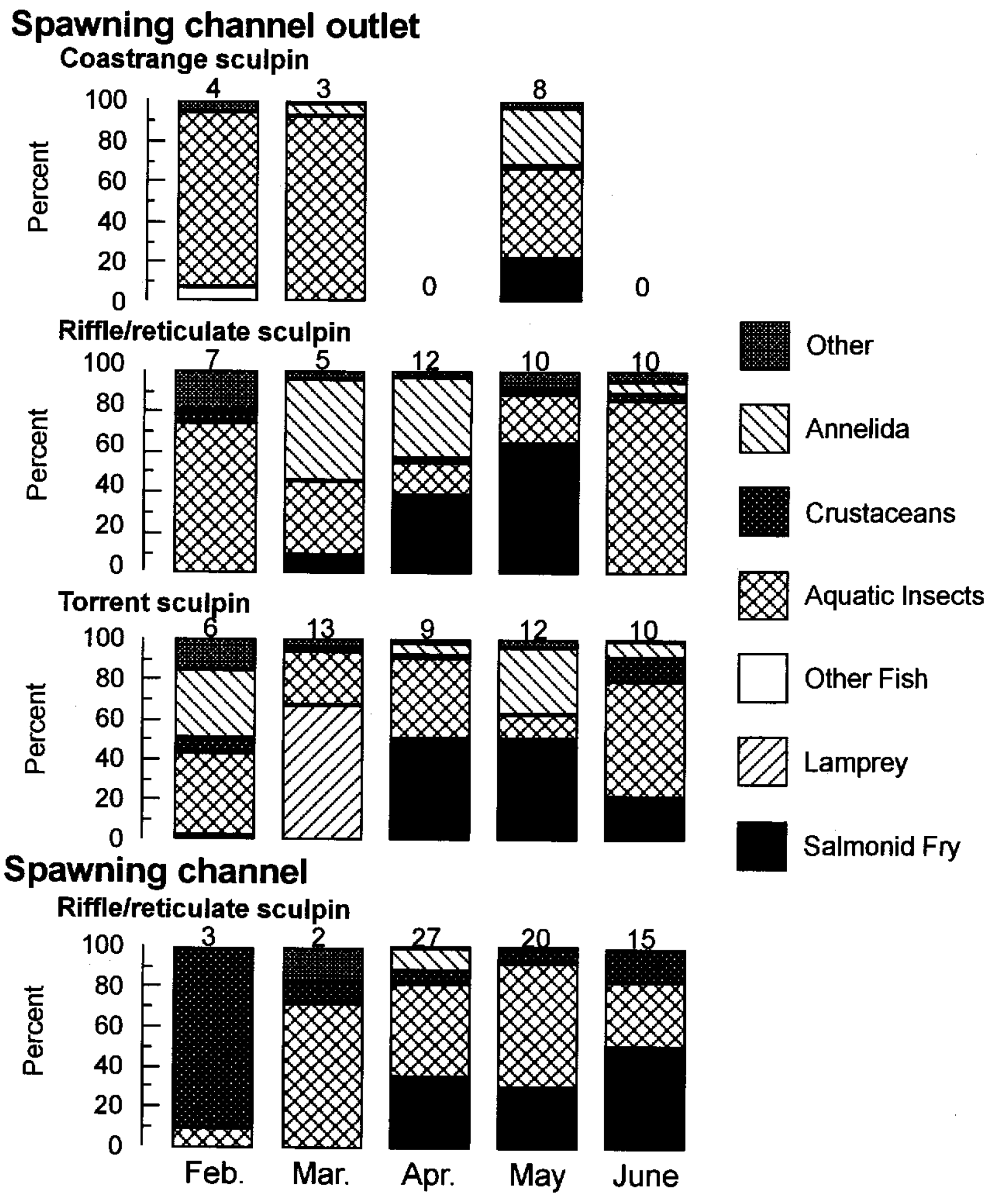

Figure 20.-- Composition (percent by weight) of ingested food for three species of cottids (> 49 mm TL) in the Elliot spawning channel and its outlet, February-June, 1997. Besides riffle sculpin, the only other cottid collected in the spawning channel was one torrent sculpin. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.

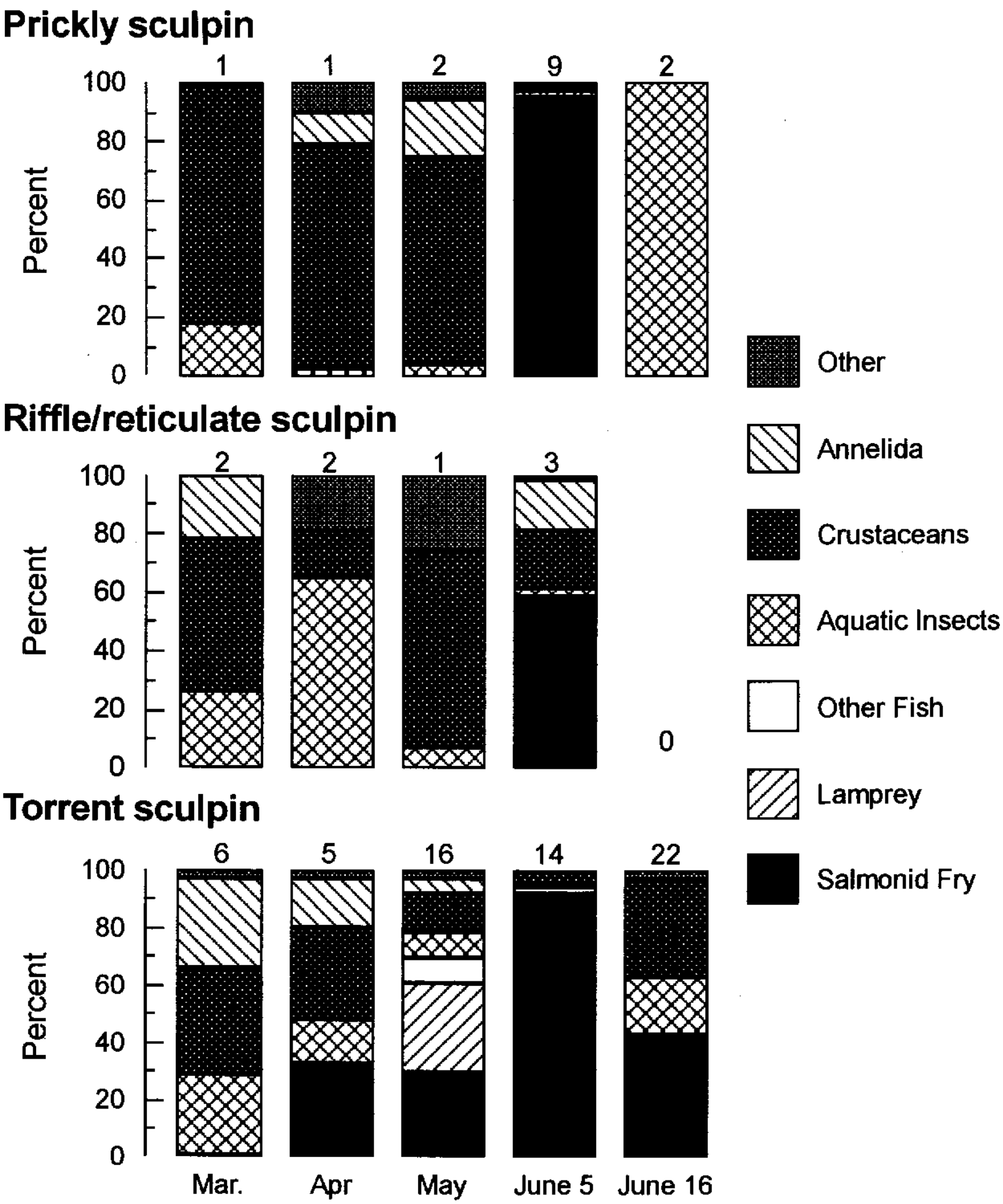

Figure 21.-- Composition (percent by weight) of ingested food for three species of cottids (> 49 mm TL) in the outlet to Cavanaugh Pond, March-June, 1997. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.

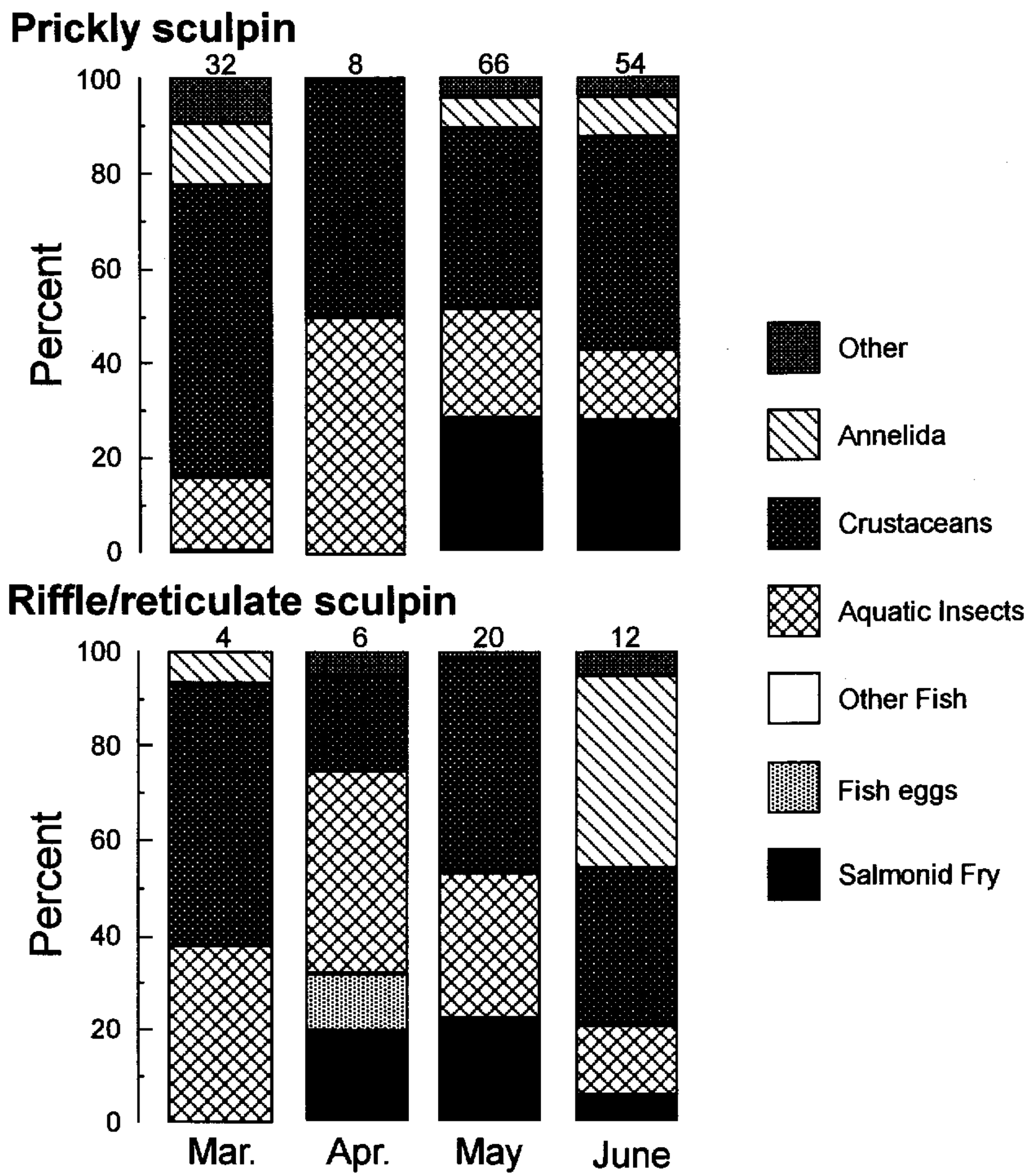

Figure 22.-- Composition (percent by weight) of ingested food for two species of cottids (> 49 mm TL) in shoreline areas of Cavanaugh Pond, March-June, 1997. Prey weights of individual fish were converted to percent body weight to reduce bias from different-sized fish. Number of cottid stomachs that contained prey items is given above each graph.