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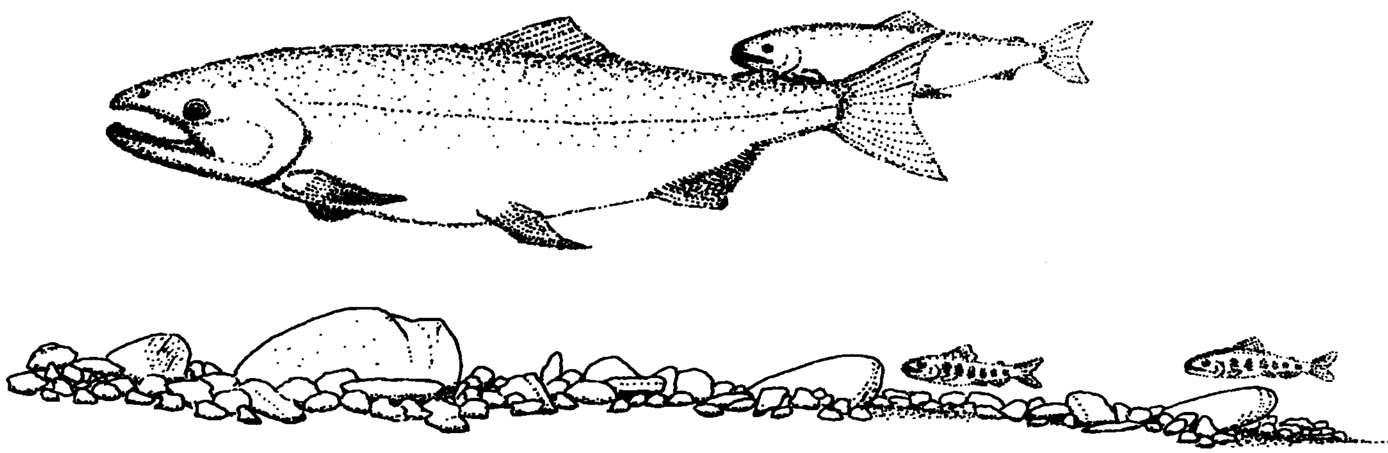
PREDATION ON SOCKEYE SALMON FRY BY PISCIVOROUS FISHES IN SOUTHERN LAKE WASHINGTON, 1996



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PREDATION ON SOCKEYE SALMON FRY BY PISCIVOROUS FISHES IN SOUTHERN LAKE WASHINGTON, 1996

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ABSTRACT

From February-May 1996, we conducted the second part of a two-year inventory of piscivorous fishes in southern Lake Washington to estimate predation on sockeye salmon fry (*Oncorhynchus nerka*). Fish were collected primarily along the shoreline with electrofishing equipment. Some fish were also collected with gill nets (nearshore and offshore). We examined the stomach contents of 489 fish. In general, low predation levels were observed in the littoral zone of southern Lake Washington. Cutthroat trout (*O. clarki*) was the only species observed to be an important predator of sockeye salmon fry. Ninety-seven percent of the observed sockeye salmon fry were consumed by cutthroat trout. Consumption of sockeye salmon fry by cutthroat trout was only seen in fish < 250 mm FL. Longfin smelt (*Spirinchus thaleichthys*) was the most important prey item of cutthroat trout > 250 mm FL. The only other species observed to have consumed sockeye salmon fry was yellow perch (*Perca flavescens*). In May, smallmouth bass (*Micropterus dolomieui*) > 250 mm FL preyed on newly-released rainbow trout (*O. mykiss*). However, no other salmonids were seen in smallmouth bass stomachs. Other species examined for stomach analysis included: rainbow trout/steelhead, juvenile coho salmon (*O. kisutch*), mountain whitefish (*Prosopium williamsoni*), brown bullhead (*Ictalurus nebulosus*), largemouth bass (*M. salmoides*), and prickly sculpin (*Cottus asper*).

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INTRODUCTION

In rivers, predation of emigrating sockeye salmon fry (*Oncorhynchus nerka*) by other fishes can be a significant source of mortality (Foerster 1968; Beauchamp 1995). However, little work has been done on predation of fry during their first weeks in the lake environment. After sockeye salmon fry emigrate to a lake they often reside in the littoral zone for a short period (Martz et al. 1996). During this time, fry may be particularly vulnerable to piscivorous fishes because of their small size and limited swimming ability.

Additionally, predators may congregate at the mouth of the Cedar River to prey on sockeye salmon fry as they enter Lake Washington. In other systems, predators often congregate at river mouths in response to emigration of juvenile salmonids (Meacham and Clark 1979; Collis et al. 1995). In 1995, few predators were present at the mouth of the Cedar River during the sockeye salmon fry emigration period (Tabor and Chan 1996b). However, the abundance of predators at the river mouth may have increased in 1996 because the habitat complexity at the river mouth was greatly increased. Recent floods in November, 1995 and February, 1996 resulted in the addition of woody debris and the formation of some small islands.

This report describes the results of the second part of a two-year study to determine the importance of predation on sockeye salmon fry survival. The objectives of this study were to: 1) continue our survey of piscivorous fishes in southern Lake Washington, 2) determine if there is a numerical response by predators to the mouth of the Cedar River during the sockeye salmon fry emigration, 3) estimate relative consumption of sockeye salmon fry by piscivorous fishes.

STUDY SITE

The study site was the southern end of Lake Washington (Figure 1). The Cedar River, which discharges into southern end of the lake, is the main tributary for the Lake Washington basin. During normal flows, much of the lower 600 m of the Cedar River is slow velocity water that is backed up from Lake Washington. The amount of backed-up water varies depending on lake level and discharge. 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.

Lake Washington is a large monomictic lake in western Washington (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.

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.

The portion of the southern Lake Washington littoral zone that can be effectively sampled with an electrofishing boat is close to the shore and relatively narrow. Two notable exceptions are the Cedar River delta and a large shallow area near a small island in the southeast corner of the lake (Figure 2). The delta extended approximately 300 m from the river mouth.

Two large flood events (>200 m^3/s; U.S. Geological Survey, unpublished data) during winter 1995-96 had altered the Cedar River delta characteristics that existed during the previous year's sampling period (Tabor and Chan 1996b). In general, substantial amounts of substrate and woody debris from the Cedar River had deposited on the delta. This deposition made the delta significantly shallower and increased habitat complexity, eliminating large areas of the site that were previously accessible to boat electrofishing. Sampling was generally restricted to the delta margins and several channels that had cut through the delta during high river discharge. Areas of the delta accessible to boat electrofishing expanded over the study period as the lake level increased. At the edge of the delta the bottom drops off rapidly to 20 m.

The shallow area around the island in the southeast corner consisted of sand and silt with some large woody debris. Due to time constraints this area was not sampled in 1996. The remaining littoral zone of southern Lake Washington was composed of sand and gravel, with a few patches of cobbles and small boulders along the east shore.

METHODS

Piscivorous fishes were sampled in the southern end of Lake Washington during the emigration period of sockeye salmon fry (February - June). Electrofishing and gill netting equipment were used to sample predators. Electrofishing and gill netting sites were sampled once every two to three weeks throughout the emigration period.

<u>**Electrofishing**</u>.-- The littoral zone of the lake were sampled with a 6-m Smith-Root electrofishing boat. We used 60-Hz direct current to shock fish. Percent output was adjusted to deliver 4-5 amps of electricity to the water.

In 1995, we established 15 transects in the littoral zone of Lake Washington. Transect boundaries were chosen based on changes in habitat and easily recognizable landmarks. We were able to sample virtually the entire shoreline of the study area. However, due to large catches after late May, we regularly sampled nine transects (64% of total length) which were representative of the other transects (Table 1). Four were sampled during the day (2, 4, 14, 15) and five were sampled at night (3, 5, 6, 7, 11). We additionally sampled west shore transects 10 and 12 when time permitted. All transects were shoreline transects except one. The non-shoreline transect was located on the delta, which extended approximately 300 m from the lower Boeing Bridge. We made one pass along each transect. Sampling was conducted along the perimeter and shallows of the exposed delta and in the channels cut through the delta, where depths generally ranged from 0.25-2.5 m. For transects along the south and east shores, we passed parallel to shore where the water depth was approximately 2-4 m. Along the west shore, which has numerous boat docks, we shocked the perimeter of each accessible boat dock, where water depths sampled ranged from 1-7 m. Effort was considerably greater per shoreline distance at the dock transects. Lengths of transects were measured with a hip chain (Table 1). Distances from the mouth of the Cedar River were also determined.

<u>**Gill netting**</u>.-- Beginning in March, variable mesh horizontal gill nets (floating and sinking) were utilized in the offshore surface and benthic areas where electrofishing equipment could not effectively collect predators. Each net was 42.7 m (140 ft) long, 1.8 m (6 ft) deep, and consisted of 6 panels of white polyfilament mesh. Stretched mesh size ranged from 3.8 to 10.2 cm (1.5 to 4.0 inches) in 1.3 cm (0.5 inch) increments. Nets were set from a 5.8 m (19 ft) Radon boat from Washington Department of Fish and Wildlife, using the combination of a concrete anchor, a float, and a jack light at the ends of each net. Nets were generally deployed just before dusk. Nets were checked every 2-3 hours, the catch removed, and then the nets were immediately redeployed in approximately the same location (surface nets could be checked with out moving them). Gill netting was terminated at dawn. Net placement consisted of nearshore and offshore bottom sets and offshore surface sets made perpendicular to the shoreline. Sites were generally located off of the west shore and off of the Cedar River delta. Sample depths ranged from the lake surface to 24 m.

Catch rates for gill netting were not calculated for this report. This report includes only the analysis of the stomach contents of predators captured by gill nets, excluding northern squawfish (*Ptychocheilus oregonensis*). Gill net catch rates as well as northern squawfish stomach analysis will be reported in the future, upon the completion of another study effort being undertaken by Muckleshoot Indian Tribe, Washington Department of Fish and Wildlife, and University of Washington.

Predator Data.-- After capture, fish were anesthetized with MS-222, identified to species, and fork length (FL) was measured to be nearest millimeter. Total length (TL) was used for cottids. Fish < 500 g were weighed to the nearest gram. Larger fish were weighed to the nearest 10 g. Fork lengths of cutthroat trout (*O. clarki*), rainbow trout (*O. mykiss*), juvenile coho salmon (*O. kisutch*), smallmouth bass (*Micropterus dolomieui*), and yellow perch (*Perca flavescens*) were compared between 1995 and 1996 using a Student's *t* test. Other species were not included due to small sample sizes or difficulty in collecting an unbiased sample with electrofishing equipment (i.e., cottids). Analysis only includes fish caught with electrofishing equipment and fish ≥ 100 mm FL (except yellow perch, we only included fish ≥ 140 mm FL). Smaller fish were not included because they may have been overlooked during electrofishing.

We separated *O. mykiss* into rainbow trout/steelhead and hatchery rainbow trout based on body coloration, body shape, and the presence of eroded fins. There was some degree of qualitative assessment in making these distinctions. Resident rainbow trout and steelhead were combined in the analysis, because of the difficulty in distinguishing the two unless the steelhead were smolted. During this study 292,000 hatchery rainbow trout were planted in Lake Washington.

Catch rates.-- Catch rates were analyzed with a three-way analysis of variance (Zar 1984) to compare catch between years (1995 and 1996), time of year, and time of day (day and night). We calculated catch per unit effort (CPUE) for each transect as the number caught per 100 m. Catch per distance shocked and per time shocked gave similar results. Sample dates were divided into 10-day time periods. For species that had a significant time period effect, a Tukey's multiple comparison test (Zar 1984) was used to identify which time periods were different from other time periods. Eight lake electrofishing transects were included in the analysis. The delta was excluded due to the radical change in habitat characteristics between years. Catch rates were not calculated for prickly sculpin (*Cottus asper*) because they were difficult to collect with the dip net and thus catch was not related to their abundance but to the amount of effort put forth by the person dip netting.

To compare catch between locations within the study site, we grouped transects into three major areas (east/west lake shore, south lake shore near Cedar River, and delta). Because no day sampling was conducted at the south lake shore near Cedar River or at the delta, we only compared sites that were sampled at night. Three transects in the lower 450 m of the Cedar River (Tabor and Chan 1996a) were also included in our location comparisons. We selected river sampling dates that were comparable to lake sampling dates. A total of five sampling nights were used to compare locations. Catch per 100 m and catch per 10 minutes were calculated to normalize the data.

Fish Movements.-- Movements of predatory fish were determined with individually-numbered thread tags. After fish were captured during routine sampling, they were anesthetized with MS-222 and tagged just behind the dorsal fin. Due to time constraints, we only tagged fish that were likely to be piscivorous (> 145 mm FL). Fish were released at the middle of the transect (electrofishing) where they were captured, or near the area of capture (gill netting) after nets had been pulled at dawn. In subsequent sampling, the location and tag number of recaptures were recorded. Distance moved was estimated from the shoreline distance between the release and recapture sites. Fish recaptured in adjoining electroshocking transects were not considered to have moved substantially.

Stomach samples.-- After capture, stomach contents of most fish 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 98% of the stomach contents of brook trout (*Salvelinus fontinalis*) and 100% for slimy sculpin (*C. cognatus*). All stomach contents were put in plastic bags, placed on ice, and later froze. Samples remained frozen until laboratory analysis. Because gastric lavage is ineffective for some types of fish, such as ictalurids and cyprinids, we sacrificed these fish and the stomach (ictalurids) or entire digestive tract (cyprinids) was removed.

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 15 s. Prey groups were weighed to the nearest 0.001 g. To reduce bias from different sized fish, prey weights were converted to percent body weight (Hyslop 1980).

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 could not be 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).

RESULTS

Catch

Catch rates of electrofishing in the southern part of Lake Washington were generally low in February and March (Figure 3). Catch rates of most fish species were highest in May and June. Cutthroat trout was the only species that had significantly higher catch rates in 1996 than 1995 ($F = 7.90$, df = 1,78, $P = 0.0063$). There was no significant difference between years for the other species. Day and night catch rates were not significantly different for most species, the exception was yellow perch which were caught more often at night ($F = 8.92$, df = 1,78, $P = 0.0038$).

When we analyzed catch rates between different areas, catch rates using distance shocked or time shocked gave similar results (Figures 4,5). The lowest catch rates were observed in the river delta. In comparison of southern Lake Washington and lower Cedar River catch rates, the east and west shores of the lake had the highest catch rates of most salmonids and non-salmonids. This is a markedly different result from the 1995 sample period, when catch rates of most salmonids in the lower Cedar River were higher than catch rates of salmonids in the lake (Tabor and Chan 1996b).

<u>**Salmonidae**</u>.-- Catch rates for cutthroat trout were highest at the east and west shores of southern Lake Washington (Figures 4,5), with the catch rate decreasing as sampling approached the lower Cedar River. No cutthroat trout were captured on the delta. Catch rates peaked in early May but were only significantly higher than catch rates in late February-mid March. Most cutthroat trout (64%) were between 120-180 mm FL. Only one fish (0.6%) captured during electrofishing was > 300 mm FL. Cutthroat trout collected in 1996 were significantly smaller than fish collected in 1995 (Figure 6). We assumed this occurred because few cutthroat trout > 250 mm FL were collected in 1996 (Figure 7).

Fourteen cutthroat trout were captured with gill nets. Fish ranged between 190-485 mm FL (mean, 338 mm FL). Nine (64%) of these gill netted fish were greater than 300 mm FL.

Rainbow trout appeared to be generally well distributed throughout the sample area, but in relatively low abundance. Total catch for each sampling day generally remained unchanged throughout the sample period, with no notable peak period of abundance (Figure 3). No significant difference was detected between the sampling time periods in 1995 and 1996 ($F = 0.31$, df = 1,78, $P = 0.93$). Rainbow trout ranged between 124-280 mm FL. The mean fork length of rainbow trout was not significantly different between 1995 and 1996 (Figure 6). Two rainbow trout (258 and 375 mm FL) were captured with gill nets.

A total of 292,000 hatchery rainbow trout (mean, 20.8 g) were released during our sampling period. Fish were released along the west shore at either Rainier Beach Park, Stan

Sayres Park, or Magnuson Park or on the east shore at Newport Shores (4.3, 9.5, 20.0, and 8.7 km, respectively, from the mouth of the Cedar River). They were released over a 15-day period beginning on May 15, 1996. Consequently we captured hatchery rainbow trout only during our late May sample. Highest catch rates were along the east shore in Gene Coulon Park.

Very few coho salmon smolts were captured at any of the sites before mid-April. Catch rates in early May were significantly higher than the other time periods. Most coho salmon (74%) sampled from the lake were captured during one sample in early May. Highest catch rates were along the east shore. The majority of coho salmon captured in the lake (60%) were between 100-120 mm FL (Figure 7). This was also true for the lower Cedar River, where 67% of the coho salmon smolts were between 100-120 mm FL. Juvenile coho salmon collected in 1996 were significantly smaller than fish collected in 1995 (Figure 7).

A total of 20 mountain whitefish (*Prosopium williamsoni*) were collected between late February and mid-April. No mountain whitefish > 150 mm FL were captured after April. Most mountain whitefish (75%) were captured along the west shore of the lake. No mountain whitefish were captured on the delta. Mountain whitefish collected for stomach analysis ranged between 160-365 mm FL (mean, 277 mm FL).

Eleven mountain whitefish were captured with gill nets. Size of fish collected for stomach analysis ranged between 272-406 mm FL (mean, 350 mm FL).

Cyprinidae.-- Similar to 1995, electrofishing catch rates of northern squawfish were low. Only four fish were collected. Three fish were > 300 mm FL (range, 306-436 mm FL). The other northern squawfish was 127 mm FL.

A total of 115 northern squawfish were captured with gill nets. Size of fish ranged between 159-514 mm FL (mean, 350 mm FL).

Ictaluridae.-- Small numbers (*N* = 6) of brown bullhead (*Ictalurus nebulosus*) were collected in southern Lake Washington. Two were captured during gill netting. All brown bullheads were captured in May, with the exception of one individual captured in late March. Size of brown bullhead ranged between 162-316 mm FL (mean, 206 mm FL).

Centrarchidae.-- A total of 66 smallmouth bass were collected in the southern end of Lake Washington. Catch rates of the last sampling time period (late May-early June) were significantly higher than the other time periods except the early May time period. However, the early May catch rates were not significantly different than the other time periods. The majority of smallmouth bass (83%) were observed along the east shore from Gene Coulon Park to Coleman Point. Only three smallmouth bass were collected along the west shore. Smallmouth bass collected in 1996 were significantly smaller than fish collected in 1995 (Figure 6). In 1996, most smallmouth bass were < 200 mm FL whereas in 1995 most smallmouth bass were > 250 mm FL.

Small numbers of largemouth bass (*N* = 5; *M. salmoides*) and pumpkinseed (*N*=11; *Lepomis gibbosus*) were also collected. Four of the largemouth bass were collected along the east shore in Gene Coulon Park and one along the south shore near Boeing. Largemouth ranged between 120-454 mm FL. Most pumpkinseed were captured near a marina/small boulder area in Gene Coulon Park. Other pumpkinseed were collected along the south shore or at other sites on the east shore. Size of pumpkinseed ranged between 82-155 mm FL.

One small black crappie (88 mm FL; *Pomoxis nigromaculatus*) was captured in May along the south shore area of the lake.

One warmouth (*Chaenobryttus gulosus*) was collected in February along the east shore. Prior fish collections in Lake Washington have not indicated the presence of warmouth (Wydoski 1971; Pfiefer, WDFW, unpublished data).

Percidae.-- Yellow perch appeared to be well distributed in the lake, although few were captured in the area of the delta. Catch rates of yellow perch were substantially higher in May than in earlier samples. Yellow perch ranged between 130-299 mm FL. The mean size of yellow perch collected in 1996 was similar to those collected in 1995 (Figure 6).

Fourteen yellow perch were captured during gill netting and ranged between 145 and 320 mm FL (mean, 197 mm FL). Yellow perch were captured throughout the gill net sampling period, but most (50%) were captured during a sample taken in late May.

Cottidae.-- A total of 60 prickly sculpin were collected by electrofishing. Fish ranged between 85-192 mm TL (mean, 126 mm TL). Catch rates were not calculated for prickly sculpin due to the limitations of the boat electrofishing gear in sampling benthic habitats in many of the sample areas. Low water visibility during parts of the study period, made collecting fish inhabiting benthic areas difficult. In addition, the large dip nets utilized for boat electrofishing were less effective in capturing cottids in areas of uneven cobble and boulder substrate and submerged structure.

Thirteen prickly sculpin were captured with gill nets. Fish ranged between 117-210 mm TL (mean, 156 mm TL).

Fish Movements

A total of 189 fish were marked with individually-numbered thread tags. Sixteen fish were recaptured during the sampling period (Tables 2,3). No fish were recaptured a second time. Overall, movement of fish was minimal. All but two of the recaptured fish were collected at either the same location that it was released or at an adjacent transect. We were unable to detect any movement of fish to the mouth of the Cedar River. The fish that were released in the lower reach of the Cedar River and recaptured had moved little. In contrast to 1995 results, none of the upper and middle reach fish were recaptured.

Salmonidae.-- Most of the marked and recaptured fish were cutthroat trout (Table 4). Little movement of cutthroat trout was observed. Seven of the 12 recaptured cutthroat trout were collected in the same location as they were released. Four were collected in an adjacent transect. The one cutthroat trout that moved appreciably from its release site, moved approximately 600 meters along the east shore.

Of 32 rainbow trout marked only two were recaptured. One was recaptured at an adjacent transect to where it was released. The other was recaptured a considerable distance from its release site. The shoreline distance between its release and recapture site was approximately 2,800 m.

Other fish.-- Only one of 21 marked smallmouth bass was recaptured. No movement was detected. One of seven marked prickly sculpin from the lower Cedar River was recaptured. The fish was recaptured in the same transect that it was released and appeared to be in the same area of the transect where it was captured and released. Three largemouth bass were also marked. None of these fish were recaptured.

Stomach analysis

Salmonidae.-- The vast majority of sockeye salmon fry (97%) observed in the stomach samples were observed in cutthroat trout stomachs (Table 4). Consumption of fry was highest in cutthroat trout < 200 mm FL. Salmonid fry were only observed in 4% of the cutthroat trout stomachs examined. In fact, 81% of the fry were observed from just two stomach samples. A 194 mm FL individual had consumed 18 salmonid fry and a 143 mm FL fish had consumed 7 salmonid fry. Two juvenile chinook salmon, that were consumed by fish < 200 FL, were the only other salmonids consumed. A total of 49 adult longfin smelt (*Spirinchus thaleichthys*) were observed in cutthroat trout stomachs (Tables 4,5). All but one were consumed by cutthroat trout > 200 mm FL. The most smelt observed in an individual fish was 11 in a 430 mm FL fish. Other prey fish consisted primarily of larval fish that were present in samples collected on May 30. Most larval fish consumed were catostomids; however, some larval cottids were also consumed.

All ingested sockeye salmon fry were found in cutthroat trout that were collected at night. A total of 31 fry were present from 96 cutthroat trout collected at night. No sockeye salmon fry were observed in 53 cutthroat trout collected during the day.

In February-April, the diet of cutthroat trout < 200 mm FL was made up primarily of large macroinvertebrates. The two most important prey items included oligochaetes (68%) and the megalopteran, *Sialus* sp. (9%). Whether the oligochaetes were of terrestrial or aquatic origin is unknown. For cutthroat trout > 200 mm FL, adult longfin smelt comprised 87% of the diet. Besides longfin smelt, little else was present in the stomachs of cutthroat trout ≥ 300 mm FL.

All but one stomach sample taken in May were from cutthroat trout < 250 mm FL. Various invertebrates made up the vast majority of the overall diet. Chironomid pupae were present in 90% of the stomachs but only made up 19% of the overall diet by weight. In contrast, crayfish were only found in 8% of the fish but made up 23% of the diet. Other important prey items included *Daphnia* (12%), prey fish (10%), terrestrial insects (10%), larval trichoptera (mostly leptocerids, 9%), and fish eggs (5%).

Few prey fish were present in rainbow trout stomachs. Out of 26 stomach samples examined, only two longfin smelt and two unidentified fish were present. The two smelt were from a 375 mm FL rainbow trout that was collected with a nearshore gill net. All other rainbow trout examined were < 300 mm FL.

The diet of rainbow trout in March-April consisted primarily of aquatic insects which included larval and pupal chironomids, larval megaloptera (*Sialus* sp.), adult coleoptera, and larval trichoptera. Longfin smelt, gastropods, and isopods made up most of the remainder of the diet. In May, *Daphnia* was the most important prey item. Chironomid pupae were also important in the diet. Besides an unidentified prey fish, little else was present in their stomachs.

The diet of newly-released hatchery rainbow trout ($N = 26$) collected in May was dominated by zooplankton (77% by weight, Figure 10). In contrast, zooplankton made up only 3% of the diet in May-June, 1995. Chironomid pupae and terrestrial insects were also common in their stomachs and accounted for 7% and 6% of the diet, respectively. The only fish present in hatchery rainbow trout stomachs were larval catostomids which made up 4% of the diet. Of the 52 larval catostomids consumed, 41 were consumed by one individual fish.

Aquatic and terrestrial insects comprised the majority of the diet of juvenile coho salmon. The most important prey items were chironomid pupae which were present in 76% of the stomachs and represented 52% of the diet. Other insects included larval trichoptera, larval megaloptera (*Sialus sp.*), adult chironomids, and various terrestrial insects. Other important prey items included zooplankton (12%) and oligochaetes (4%). In contrast to 1995, no fish remains were seen in any coho salmon stomach.

Contents of the 22 mountain whitefish stomachs examined included mostly benthic macroinvertebrates. The primary prey items were larval trichoptera (24%), larval chironomids (23%), gastropods (18%), and larval ephemeroptera (12%). The only prey fish ingested was one unidentified larval fish.

The only other salmonids sampled for stomach analysis were two juvenile chinook salmon that were collected on May 30. The stomachs contained mostly zooplankton. Some aquatic and terrestrial insects were also present.

Cyprinidae.-- All three large northern squawfish examined (> 300 mm FL) had empty digestive tracts. The only other northern squawfish sampled was 127 mm FL and had consumed a 108 mm TL lamprey ammocoetes. Little else was present.

Ictaluridae.-- Only six brown bullhead stomachs were examined for diet analysis. Similar to 1995 results, fish eggs made up over 90% of the diet. The remainder of the diet included mostly benthic macroinvertebrates such as oligochaetes and hirudinea. Some plant material was also present. Fish remains included one small cottid and one unidentified larval fish.

Centrarchidae.-- May 30 was the only date that salmonids were observed in smallmouth bass stomachs. Salmonids were only present in smallmouth bass > 250 mm FL. Out of six stomach samples of smallmouth bass > 250 mm FL, a total of three trout and two unidentified salmonids were present. All salmonids were probably newly-released hatchery rainbow trout. Prey lengths were similar to the size of hatchery trout. Also, electrofishing observations indicated that newly-released rainbow trout were the most abundant salmonid along shoreline transects. Overall, salmonids made up 42% by weight of the diet of smallmouth bass > 250 mm FL. Besides salmonids, prey fish consisted of adult longfin smelt, yellow perch and three-spine stickleback (*Gasterosteus aculeatus*). The non-fish component of their diet (33%) consisted primarily of crayfish (Figure 11). The diet of smallmouth bass 150-250 mm FL consisted almost entirely of crayfish (58%) and cottids (38%). Smallmouth bass 100-150 mm FL consumed primarily small cottids (58%), *Neomysis* (17%) and crayfish (12%).

Even though water temperatures were < 10°C, the two largemouth bass (427 and 450 mm FL) collected on March 11 had been actively foraging. Stomach contents included three-spine stickleback and adult longfin smelt (Figure 11). The only largemouth bass (278 mm FL) collected in April had only consumed a single megalopteran (*Sialus sp.*). In May, only one small largemouth bass (133 mm FL) was collected. Its stomach contained 29 larval yellow perch (≈ 13 mm TL), 3 larval catostomids, and one *Neomysis*.

The stomach of the one warmouth collected was empty.

Percidae.-- The catch of yellow perch was significantly higher during late May and early June of 1995 and 1996 then during other sampling periods. Most stomach samples of yellow perch were taken during the last week of May. On earlier dates, few yellow perch were seen and many that were collected had empty stomachs (48%). Of the 38 stomach samples collected during the last week of May, one contained a sockeye salmon fry. Eleven of these samples contained larval cottids (≈ 10-22 mm TL). As many as 80 larval cottids were observed in a stomach sample. The only other fish remains observed were a few bones from a three-spine stickleback. Prey fish present in stomach samples from earlier dates (N=21) consisted of one three-spine stickleback.

Larval cottids and fish eggs made up 43% and 26%, respectively of the overall diet of yellow perch. The fish eggs appeared to be mostly cottid eggs, based on their size and adhesiveness. Other prey items were mainly benthic macroinvertebrates, which included

Neomysis (17%), gastropods (6%), and aquatic insects (4%).

Cottidae.-- A total of 63 prickly sculpin stomachs were examined. No sockeye salmon fry or other salmonids were found. However, eight of 17 stomachs examined from March-April contained prey fish which included adult longfin smelt, yellow perch, three-spine stickleback and cottids. Fish were present in prickly sculpin > 125 mm TL. In May, few prey fish were present in prickly sculpin stomach samples. However, some yellow perch and cottids were consumed by prickly sculpin > 135 mm TL.

The diet of prickly sculpin > 125 mm TL in March-April consisted primarily of prey fish while the diet of fish 75-125 mm TL consisted mostly of benthic invertebrates such as isopods, amphipods, and larval trichoptera (Figure 12). Oligochaetes of unknown origin were also an important prey item. Similarly to 1995, fish eggs were an important prey item for all size categories of prickly sculpin in May (Figure 12). Overall, fish eggs made up 66% of the diet by weight and were present in 47% of the stomachs examined. The fish eggs appeared to be mostly cottid eggs, based on their size and adhesiveness. Other important prey items included crayfish, oligochaetes, and prey fish.

Stomach contents of the only coastrange sculpin (*C. aleuticus*) collected consisted entirely of small larval chironomids.

DISCUSSION

Catch

Catch of cutthroat trout was significantly higher in 1996 than 1995. Because of differences in environmental conditions and prey abundances (i.e., zooplankton and longfin smelt), it is difficult to determine if the increase in catch was due to a population increase in southern Lake Washington or some other factor. A major difference between the two years was an increase in turbidity in 1996 (Figure 13). In other studies, increases in electrofishing catch have been noted during periods of elevated turbidity (Kirkland 1962; Shively et al. 1991). The reactive distance of visual predators is greatly reduced with increased turbidity (Vinyard and O'Brien 1976; Crowl 1989). Thus, in turbid waters, the electrofishing boat may be able to approach closer to fish. In addition, fish may be closer to the surface and more likely to be captured.

A key question concerning cutthroat trout in Lake Washington is whether their population size has been increasing. Although there is no direct evidence of such an increase, some information would suggest that the population is currently larger than it was 20 years ago. In an earlier review of Lake Washington basin fishes, Wydoski (1971) considered cutthroat trout a common fish within the drainage area but did not consider it a common fish in Lake Washington. In contrast, our results would indicate that cutthroat trout is common in Lake Washington. Some anglers have indicated that cutthroat trout are more often captured in recent years than 10 or 20 years ago (E. Warner, Muckleshoot Indian Tribe, personal communication). By comparing 1970's to 1980's gill net catches, D. Beauchamp (personal communication) concluded that the Lake Washington cutthroat trout population had increased. Urban development, which appears to have little impact on cutthroat trout, may result in increased cutthroat trout populations as other fishes are impacted. Scott et al. (1986) compared the fish populations of two streams in the Lake Washington basin. The biomass of cutthroat trout in Kelsey Creek, an urban stream, was more than twice that in Bear Creek, a pristine control stream. In contrast, the biomass of coho salmon and other fish was much lower in Kelsey Creek than Bear Creek. Thus as the Lake Washington basin becomes more urbanized and the overall population of cutthroat trout increases, the number of cutthroat trout in Lake Washington should also increase.

The size of cutthroat trout and smallmouth bass was significantly smaller in 1996 than 1995. Few fish > 250 FL were collected in 1996. Higher turbidity levels in 1996 may have reduced our ability to see these fish, especially if they were in deeper water than the smaller fish. This was particularly noticeable for smallmouth bass. In 1995, many of the large smallmouth bass were captured near the bottom in relatively deep water. However, in 1996, we were often unable to adequately see this area due to increased turbidity. Changes in environmental condition such as turbidity may also alter the behavior of some predators and thus change their vulnerability to electrofishing equipment. The size of juvenile coho salmon was also significantly smaller in 1996 than 1995. However, because juvenile coho salmon were compared over a narrow size range, differences were probably due to other factors such as summer low conditions in Lake Washington tributaries.

Although we only collected 14 cutthroat trout with gill nets, there was an obvious difference in size of cutthroat trout collected with gill nets versus electrofishing. Ninety-three percent of the gill net-caught cutthroat trout were > 250 mm FL, whereas only 9% of electrofishing caught cutthroat trout were > 250 mm FL. Even six of the seven cutthroat trout caught with nearshore gill nets were > 250 mm FL. Nearshore gill nets were set in two of the same areas that were electrofished. These results are in agreement with nearshore gill net catches of Beauchamp et al. (1992), who also collected few cutthroat trout < 250 mm FL. Gill nets may select for larger fish due to the mesh sizes used. Alternatively, larger cutthroat trout may be more active at twilight and night than smaller trout and thus more vulnerable to gill nets. Also, large cutthroat trout may be better at avoiding an electrofishing boat because larger fish have higher maximum swimming speeds (Weihs and Webb 1983) and are more wary (Grant and Noakes 1987) than smaller fish. To get an accurate picture of the cutthroat trout population, sampling should include electrofishing, gill nets, and perhaps other gear types.

From February-June, cutthroat trout in southern Lake Washington appeared to inhabit the nearshore area extensively. In 1995 and 1996 our shoreline catch rates of cutthroat trout peaked in May and declined in June as water temperatures rose. We were unable to determine their relative use of the nearshore and offshore areas. In an earlier study of cutthroat trout in Lake Washington, Beauchamp et al. (1992) found winter gill net catches were much higher in the nearshore than the offshore area. During the rest of the year, catch rates were higher in the offshore area. In sympatric populations in British Columbia lakes with rainbow trout (Nilsson and Northcote 1981) or Dolly Varden trout (Andrusak and Northcote 1971), cutthroat trout predominantly inhabited the nearshore area. However, in allopatric populations, cutthroat trout were scattered throughout the lake in the spring and summer.

Habitat use may also be related to size. Small cutthroat trout may inhabit the nearshore area until they reach a certain size. They may not be able to move offshore until they are large enough to avoid capture by offshore predators. Other fish species have similar ontogenetic habitat shifts that appear to be related to predation risk (Werner 1986). For example, rainbow trout have been shown to inhabit the nearshore area until they are 110-130 mm FL (Wurtsbaugh and Modde 1988). Larger cutthroat trout may be temporary residents of the nearshore area. They may only use the nearshore area on a daily or seasonal basis.

Similar to 1995, few predatory fish were seen in the delta. Although the delta had some woody debris for cover, the delta was probably a risky habitat for most fish because it was shallow and was inhabited by a large number of piscivorous birds. Preliminary results of gill net catch rates indicate there may have been an increase in some predators (especially northern squawfish) just offshore of the delta. Diet analysis indicated that this increase would have been due to the availability of longfin smelt. No consumption of sockeye salmon fry was observed near the delta.

Predation

Similarly to 1995 results, cutthroat trout appeared to be the most important predator of sockeye salmon fry in southern Lake Washington. Of the 82 salmonid fry observed in stomach samples for 1995 and 1996 combined, 82% were observed in cutthroat trout stomach samples. Cutthroat trout was the only species observed to have consumed salmonid fry in both 1995 and 1996. In addition, cutthroat trout was the only species observed to consume sockeye salmon presmolts. In other lentic systems, cutthroat trout often have higher predation rates of juvenile sockeye salmon than other predators (Foerster 1968; Beauchamp et al. 1995). In Lake Ozette, Washington, cutthroat trout had a per-capita predation rate that was 25 times greater than predation by northern squawfish (Beauchamp et al. 1995). In summarizing the relative importance of different predators in Cultus Lake, Foerster (1968) considered one cutthroat trout equivalent to five northern squawfish or 20 coho salmon.

In comparison to other lakes, predation of juvenile sockeye salmon by cutthroat trout appeared to be low. Of the 300 cutthroat trout stomachs examined from 1995 and 1996, sockeye salmon fry or presmolts were present in 4.7% of the stomachs and made up 5% of the diet. Beauchamp et al. (1992) also found the predation rate of sockeye salmon by cutthroat trout in Lake Washington to be low. In contrast, Ricker (1941) collected 829 cutthroat trout in Cultus Lake, British Columbia from February-June (1936-1938) and found sockeye salmon fry or fingerlings had been consumed by 22% of the fish and made up 61% of the diet by volume. Narver (1975) found that 14% of the cutthroat trout in Great Central Lake, British Columbia in May and June had consumed either sockeye smolts presmolts or fry. In Eva Lake, Alaska, 36% of the cutthroat trout collected in July and August had consumed sockeye salmon fry or juvenile coho salmon (Armstrong 1971). Differences in predation rates between Lake Washington and other lakes were probably due to the availability of sockeye salmon or other prey. Lake Washington has more species of forage fish than the other lakes studied. The primary prey fish of cutthroat trout in Lake Washington is longfin smelt, which does not occur in the other lakes studied. The gear types used may also account for some of the differences. Most studies used gill nets or angling to collect fish, which tended to sample mostly large cutthroat trout (> 250 mm FL). We tended to collect cutthroat trout < 250 mm FL with electrofishing equipment.

In general, cutthroat trout are more piscivorous than other sympatric salmonids. In southern Lake Washington, cutthroat trout commonly consumed prey fish such as longfin smelt, juvenile salmonids, cottids, and larval fish. Rainbow trout and juvenile coho salmon rarely consumed prey fish other than larval fish. Nilsson and Northcote (1981) found that in a sympatric population, rainbow trout exploited limentic surface and midwater prey whereas cutthroat trout utilized more littoral prey and were much more piscivorous. Studies of other lentic systems have also indicated that cutthroat trout are often more piscivorous than rainbow trout (Idyll 1942; Wurtsbaugh and Modde 1988).

In 1995 and 1996, the vast majority of predation on sockeye salmon fry was observed in cutthroat trout less than 250 mm FL. Larger cutthroat trout typically consumed larger prey fish such as longfin smelt and sockeye salmon presmolts. In contrast, Beauchamp et al. (1992) only found sockeye salmon fry in cutthroat trout > 250 mm FL in Lake Washington. However, they had a small sample size for cutthroat trout < 250 mm FL and could easily have missed predation of sockeye salmon fry by this size class. As juvenile sockeye salmon grow, they probably become a preferred prey item of larger cutthroat trout. In addition, small cutthroat trout may then no longer be able to effectively pursue and capture larger juvenile sockeye salmon.

Because we collected few fish that had consumed sockeye salmon fry, we were unable to identify any general shoreline area where predation of fry was concentrated. Consumption of sockeye salmon fry appeared to be scattered throughout the study area. In general, predators collected in locations close to the mouth of the Cedar River had the highest number of fry per stomach but predator abundance was relatively low in these areas. The highest predation rates were observed along the south and west shores. In both 1995 and 1996, the highest catch rates of cutthroat trout were along the east shore, however the number of fry per cutthroat trout stomach was lowest in this area.

In 1995 and 1996, predation of sockeye salmon fry appeared to occur primarily at dusk or during the night. Of 81 cutthroat trout collected during the day (1995 and 1996 combined) only two sockeye salmon fry were present. In contrast, 65 fry were present from a total of 213 cutthroat trout examined from night sampling. In addition, many of the fry were little digested, thus indicating that they were probably consumed at dusk or during the night. Beauchamp et al. (1992) found that cutthroat trout in the offshore zone consumed juvenile sockeye salmon from 1700-2200 h. In stomach samples of rainbow trout, smallmouth bass, yellow perch, prickly sculpin, and juvenile coho salmon, we only found fry in fish collected at night. However, the results may be somewhat biased because 87% of these species were collected at night.

Besides cutthroat trout, the only other species observed to have consumed sockeye salmon fry in 1996 was yellow perch. Although only one sockeye salmon fry was observed out of 58 stomachs examined, yellow perch could be an important predator of sockeye salmon fry because of their apparent large population size. Nelson (1975) estimated there were 55,900 age 2+ and older yellow perch in Lake Washington in 1971-74. The current population size is unknown, however the population may have increased due to the expansion of Eurasian watermilfoil (*Myriophyllum spicatum*). Further sampling of yellow perch is needed to determine their overall predation rate of sockeye salmon fry as well as their current population size. Because yellow perch are abundant and rarely consume salmonid fry, a large sample size (perhaps 1000 fish) is needed to accurately determine their predation rate of salmonid fry.

Yellow perch would probably only prey on sockeye salmon fry in late May and June. The peak emigration period of sockeye salmon fry in mid March-April is also the spawning season of yellow perch. Little food is consumed by yellow perch during this time period. In January to mid March, yellow perch inhabit deep water (Nelson 1975) and probably have little spatial overlap with sockeye salmon fry. After June, most juvenile sockeye salmon have moved offshore and would have little spatial overlap with yellow perch, who primarily inhabit the littoral zone.

Unlike 1995, we did not observe any sockeye salmon fry in the stomachs of smallmouth bass, rainbow trout, prickly sculpin, and juvenile coho salmon. This may have been due in part to the lower abundance of sockeye salmon fry in 1996 than 1995. In 1995 the estimated number of emigrants was 14,578,000 while in 1996 there were only 5,835,000. Other prey (especially zooplankton) may have been more abundant in 1996 than 1995 and helped reduce predation pressure on sockeye salmon fry. In 1995, we also had larger sample sizes for all four species, which would have increased the probability of detecting a rare prey item such as sockeye salmon fry. Additionally, visual predators may not have been able to locate sockeye salmon fry due to increased turbidity levels in 1996 (Figure 13).

CONCLUSIONS

1) In general, predation levels of sockeye salmon fry by predatory fishes were low along the shoreline of southern Lake Washington, based primarily on electrofishing and some gill nets catches.

2) Similar to 1995, we did not observe an increase of predators at the mouth of the Cedar River during the sockeye salmon fry emigration.

3) In 1995 and 1996, cutthroat trout appeared to be the most important predator of sockeye salmon fry in southern Lake Washington. The vast majority of predation on sockeye salmon fry was observed in cutthroat trout less than 250 mm FL.

4) Catch rates of cutthroat trout were higher in 1996 than 1995. However, it is unclear if this is a result of an increase in the abundance of cutthroat trout in southern Lake Washington or due to differences in environmental conditions.

5) Besides cutthroat trout, the only other species observed to have consumed sockeye salmon fry in 1996 was yellow perch. Although only one sockeye salmon fry was observed out of 58 stomachs examined, yellow perch could be an important predator of sockeye salmon fry because of their apparent large population size.

6) Other predators such as smallmouth bass, rainbow trout, prickly sculpin, and juvenile coho salmon did not consume any sockeye salmon fry. This may have been due to the lower abundance of sockeye salmon fry in 1996 than 1995 or greater availability of other prey such as zooplankton.

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Table 1.--Sample sites used to collect predatory fishes in southern Lake Washington, 1996. Distances of electrofishing transects and nearshore gill net sites were measured along the shoreline from the mouth of the Cedar River. The river mouth is located at the downstream side of the lower Boeing Bridge.

Sample Type Site #	Location	Day/Night	Index or supplemental site	Distance from river mouth (m)	Distance sampled (m)
Electrofishing transects					
2	West shore	D	I	746 - 1187	441
3	West shore	N	I	485 - 746	261
4	West shore	D	I	184 - 485	301
5	South Shore	N	I	0 - 184	184
6	Delta	N	I	0 - 302	464
7	South Shore	N	I	50 - 523	473
10	East shore	N	S	1308 - 1445	137
11	East shore	N	I	1475 - 1875	400
12	East shore	N	S	1875 - 2219	344
14	East shore	D	I	2406 - 2574	168
15	East shore	D	I	2574 - 2763	189
Gill netting sites					
Nearshore sinking nets					
1	Delta	N	I	300	--
4	West shore	N	I	746	--
Offshore floating nets					
2	Delta	N	I	500	--
5	West shore	N	I	746	--
Offshore sinking nets					
3	Delta	N	I	500	--
6	West shore	N	I	746	--

Table 2.--Number of marked and recaptured thread-tagged predaceous fishes in the lower Cedar River and southern Lake Washington, 1996. The mean number of days was calculated from the date of release to the recapture date of each fish.

Location Reach Species	Number Marked	Number Recaptured	Mean number of days	Number moved more than 200 m
Cedar River				
Upper Reach				
Cutthroat trout	3	0	-	-
Rainbow trout	3	0	-	-
Middle Reach				
Cutthroat trout	3	0	-	-
Rainbow trout	4	0	-	-
Prickly sculpin	5	0	-	-
Lower Reach				
Cutthroat trout	20	4	11	0
Rainbow trout	5	0	-	0
Smallmouth bass	2	0	-	-
Prickly sculpin	2	1	29	0
Lake Washington				
Cutthroat trout	100	8	28.9	3
Rainbow trout	20	2	26.5	2
Smallmouth bass	19	1	24	0
Largemouth bass	3	0	-	0
Subtotals				
Cutthroat trout	126	12	22.9	3
Rainbow trout	32	2	26.5	2
Smallmouth bass	21	1	24	0
Largemouth bass	3	0	0	0
Prickly sculpin	7	1	29	0
Total	189	16	23.8	5

Table 3.--List of recaptured thread-tagged fishes in the lower Cedar River and southern Lake Washington, 1996. Location: E = east shore of Lake Washington, S = south shore, W = west shore, LR = lower river (0-500 m). Distance (m) is the shoreline distance from the mouth of the Cedar River. Distance moved was calculated from the mid-point of the transect where the fish was released to the mid-point of the recapture transect; negative numbers indicate movement away from the river mouth.

		Release			Recapture				
Species	Fork length (mm)	Date	Location	Distance (m)	Date	Location	Days (#)	Distance (m)	Distance moved (m)
Salmonids									
Cutthroat trout	210	18-Mar	LR	0	26-Mar	LR	8	169	-169
Cutthroat trout	209	26-Mar	LR	219	4-Apr	LR	9	219	0
Cutthroat trout	159	22-May	LR	169	5-Jun	LR	14	358	-189
Cutthroat trout	296	22-May	LR	169	4-Jun	LR	13	169	0
Cutthroat trout	162	28-Feb	W	616	11-Mar	W	12	616	0
Cutthroat trout	151	11-Mar	W	967	6-May	W	56	616	351
Cutthroat trout	151	11-Mar	W	967	2-May	W	52	967	0
Cutthroat trout	177	2-May	W	967	6-May	W	4	616	351
Cutthroat trout	185	28-Feb	E	1675	27-Mar	E	28	1675	0
Cutthroat trout	164	11-Mar	E	1675	16-Apr	E	36	1675	0
Cutthroat trout	145	27-Mar	E	2047	15-Apr	E	19	2669	-622
Cutthroat trout	237	6-May	E	1675	30-May	E	24	1675	0
Rainbow trout	278	27-Mar	S	92	4-Apr	LR	8	169	-261
Rainbow trout	213	15-Apr	W	335	30-May	E	45	2490	-2825
Other fish									
Smallmouth bass	162	6-May	E	2490	30-May	E	24	2490	0
Prickly sculpin	174	6-Mar	LR	219	4-Apr	LR	29	219	0

Table 4.-- Salmonid fry and other prey fish consumed by predatory fish collected with electrofishing equipment in southern Lake Washington, February-May, 1996. Fish were collected along nine shoreline transects. Calculations of fry/stomach, frequency of occurrence, and maximum number of fry includes sockeye salmon fry and unidentified salmonid fry.

Predators			Salmonid fry consumed					Other fish			
Date / Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum	Other salmonids	Smelt	Larval fish	Other fish
February 26,28											
Cutthroat trout	8	0	1	0	0.13	13	1	0	0	0	1
Mountain whitefish	6	17	0	0	0	0	0	0	0	0	0
Largemouth bass	1	100	0	0	0	0	0	0	0	0	0
Smallmouth bass	3	67	0	0	0	0	0	0	0	0	0
Warmouth	1	100	0	0	0	0	0	0	0	0	0
March 11											
Cutthroat trout	16	6	0	0	0	0	0	0	6	0	1
Rainbow trout	3	0	0	0	0	0	0	0	0	0	0
Coho salmon	1	0	0	0	0	0	0	0	0	0	0
Mountain whitefish	5	0	0	0	0	0	0	0	0	0	0
Largemouth bass	2	0	0	0	0	0	0	0	2	0	1
Smallmouth bass	3	33	0	0	0	0	0	0	4	0	2
Yellow perch	1	0	0	0	0	0	0	0	0	0	0
March 27											
Cutthroat trout	29	14	27	2	1.00	17	18	2	9	0	3
Rainbow trout	7	43	0	0	0	0	0	0	0	0	1
Mountain whitefish	3	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	3	100	0	0	0	0	0	0	0	0	0
Yellow perch	1	100	0	0	0	0	0	0	0	0	0
Prickly Sculpin	2	50	0	0	0	0	0	0	0	0	0
April 15-16											
Cutthroat trout	36	6	0	1	0.03	3	1	0	4	0	0
Rainbow trout	4	50	0	0	0	0	0	0	0	0	0
Coho salmon	8	13	0	0	0	0	0	0	0	0	0
Mountain whitefish	6	33	0	0	0	0	0	0	0	1	0
Largemouth bass	1	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	2	100	0	0	0	0	0	0	0	0	0
Yellow perch	3	33	0	0	0	0	0	0	0	0	0
Prickly Sculpin	9	11	0	0	0	0	0	0	1	0	3
May 2,6											
Cutthroat trout	40	8	0	0	0	0	0	0	3	1	1
Rainbow trout	6	0	0	0	0	0	0	0	0	0	1
Coho salmon	28	14	0	0	0	0	0	0	0	0	0
Brown Bullhead	2	0	0	0	0	0	0	0	0	1	1
Smallmouth bass	21	19	0	0	0	0	0	0	0	8	18
Yellow perch	9	56	0	0	0	0	0	0	0	0	0
Prickly Sculpin	15	13	0	0	0	0	0	0	0	0	2

Table 4.-- continued

Predators			Salmonid fry consumed					Other fish			
Date Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum	Other salmonids	Smelt	Larval fish	Other fish
May 30											
Cutthroat trout	20	5	0	0	0	0	0	0	0	131	0
Rainbow trout	4	25	0	0	0	0	0	0	0	0	0
Hatchery trout	26	0	0	0	0	0	0	0	0	52	0
Coho salmon	4	25	0	0	0	0	0	0	0	0	0
Chinook salmon	2	0	0	0	0	0	0	0	0	0	0
Northern squawfish	4	75	0	0	0	0	0	0	0	0	1
Brown bullhead	2	50	0	0	0	0	0	0	0	0	0
Largemouth bass	1	0	0	0	0	0	0	0	0	32	0
Smallmouth bass	34	18	0	0	0	0	0	5	0	45	14
Yellow perch	31	35	1	0	0.03	3	1	0	0	207	1
Coastrange sculpin	1	0	0	0	0	0	0	0	0	0	0
Prickly Sculpin	25	16	0	0	0	0	0	0	0	1	0
Total											
Cutthroat trout	149	7	28	3	0.21	5	18	2	22	132	6
Rainbow trout	24	25	0	0	0	0	0	0	0	0	2
Hatchery trout	26	0	0	0	0	0	0	0	0	52	0
Coho salmon	41	15	0	0	0	0	0	0	0	0	0
Chinook salmon	2	0	0	0	0	0	0	0	0	0	0
Mountain whitefish	20	15	0	0	0	0	0	0	0	1	0
Northern squawfish	4	75	0	0	0	0	0	0	0	0	1
Brown bullhead	4	25	0	0	0	0	0	0	0	1	1
Largemouth bass	5	20	0	0	0	0	0	0	2	32	1
Smallmouth bass	66	27	0	0	0	0	0	5	4	53	34
Warmouth	1	100	0	0	0	0	0	0	0	0	0
Yellow perch	45	40	1	0	0.02	2	1	0	0	207	1
Coastrange sculpin	1	0	0	0	0	0	0	0	0	0	0
Prickly Sculpin	51	16	0	0	0	0	0	0	1	1	5

Table 5.-- Salmonid fry and other prey fish consumed by predatory fish collected with gill nets in southern Lake Washington, March-May, 1996. Fish were collected with nearshore and offshore gill nets near the delta and along the west shore. Calculations of fry/stomach, frequency of occurrence, and maximum number of fry includes sockeye salmon fry and unidentified salmonid fry.

Predators			Salmonid fry consumed					Other fish			
Date Species	N	% Empty stomachs	Sockeye fry	Unidentified salmonid fry	Fry/ stomach	Frequency of occur. (%)	Maximum	Other salmonids	Smelt	Larval fish	Other fish
March 14, 20											
Cutthroat trout	2	0	0	0	0	0	0	0	2	0	0
Rainbow trout	2	0	0	0	0	0	0	0	2	0	0
Mountain whitefish	1	0	0	0	0	0	0	0	0	0	0
Brown bullhead	1	0	0	0	0	0	0	0	0	0	0
Yellow perch	2	0	0	0	0	0	0	0	0	0	1
Prickly Sculpin	3	0	0	0	0	0	0	0	2	0	3
April 8											
Cutthroat trout	7	0	0	0	0	0	0	0	21	0	0
Smallmouth bass	1	100	0	0	0	0	0	0	0	0	0
Prickly Sculpin	2	50	0	0	0	0	0	0	0	0	1
April 25											
Cutthroat trout	4	0	0	0	0	0	0	0	4	0	1
Mountain whitefish	2	0	0	0	0	0	0	0	0	0	0
Yellow perch	5	60	0	0	0	0	0	0	0	0	0
Prickly Sculpin	1	0	0	0	0	0	0	0	0	0	0
May 28											
Cutthroat trout	1	0	0	0	0	0	0	0	0	0	0
Mountain whitefish	2	0	0	0	0	0	0	0	0	0	0
Brown bullhead	1	0	0	0	0	0	0	0	0	0	0
Yellow perch	7	14	0	0	0	0	0	0	0	60	0
Prickly Sculpin	6	17	0	0	0	0	0	0	0	0	2
Total											
Cutthroat trout	14	0	0	0	0	0	0	0	27	0	1
Rainbow trout	2	0	0	0	0	0	0	0	2	0	0
Mountain whitefish	5	0	0	0	0	0	0	0	0	0	0
Brown bullhead	2	0	0	0	0	0	0	0	0	0	0
Smallmouth bass	1	100	0	0	0	0	0	0	0	0	0
Yellow perch	14	29	0	0	0	0	0	0	0	60	1
Prickly Sculpin	12	17	0	0	0	0	0	0	2	0	6

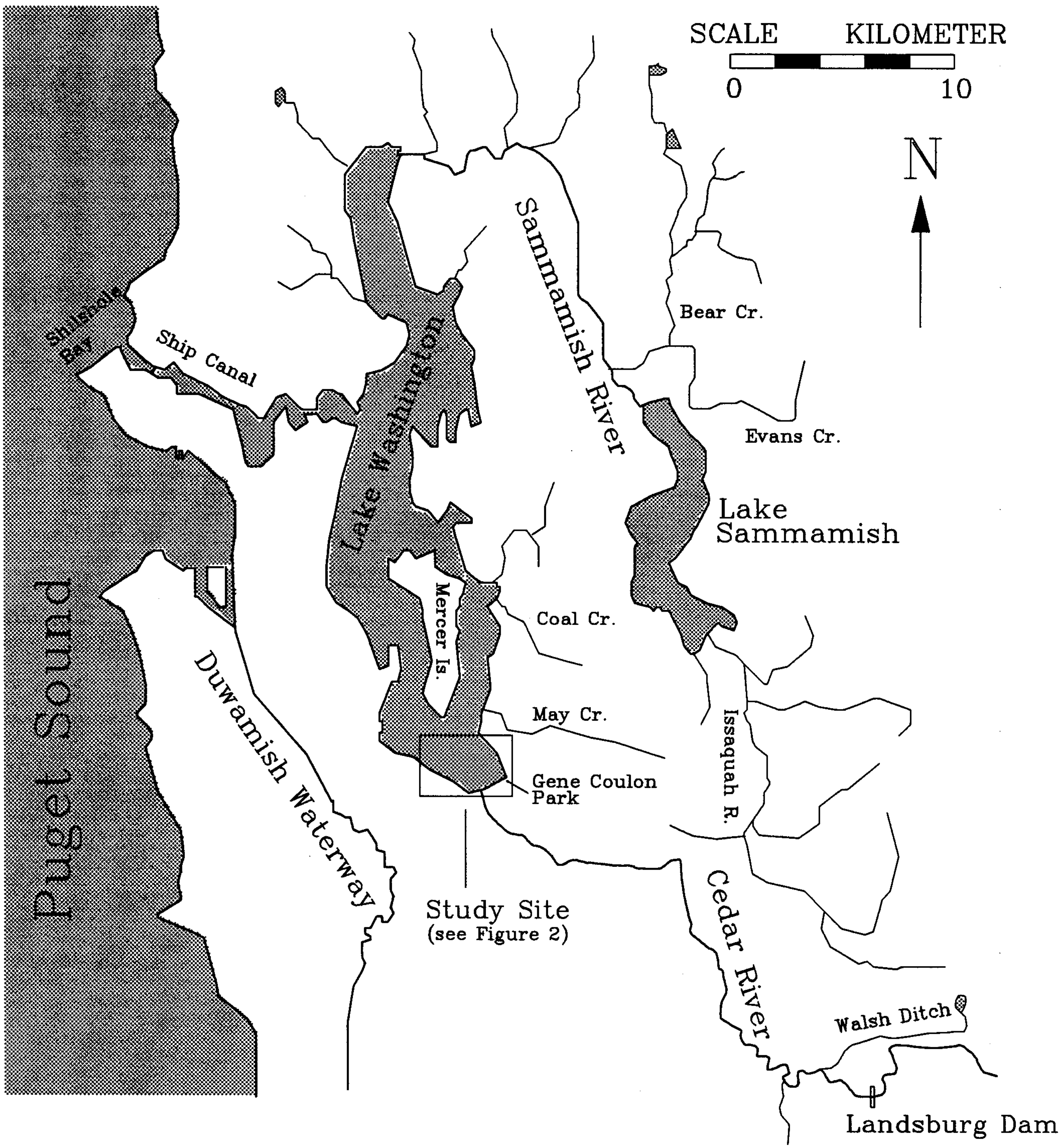

Figure 1.-- Map of Lake Washington drainage basin and location of study site.

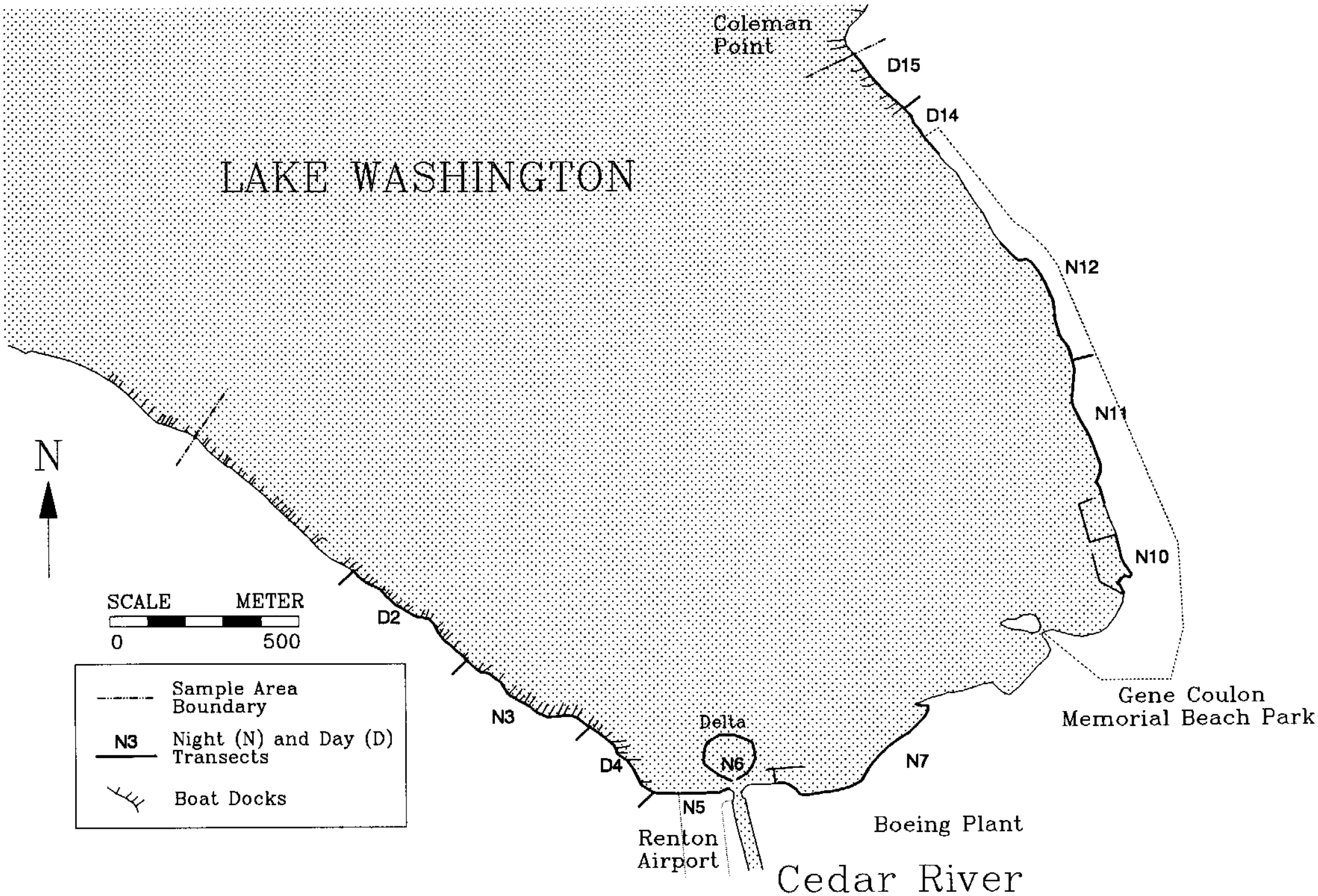

Figure 2.-- Sample sites used to collect predatory fishes in southern lake Washington.

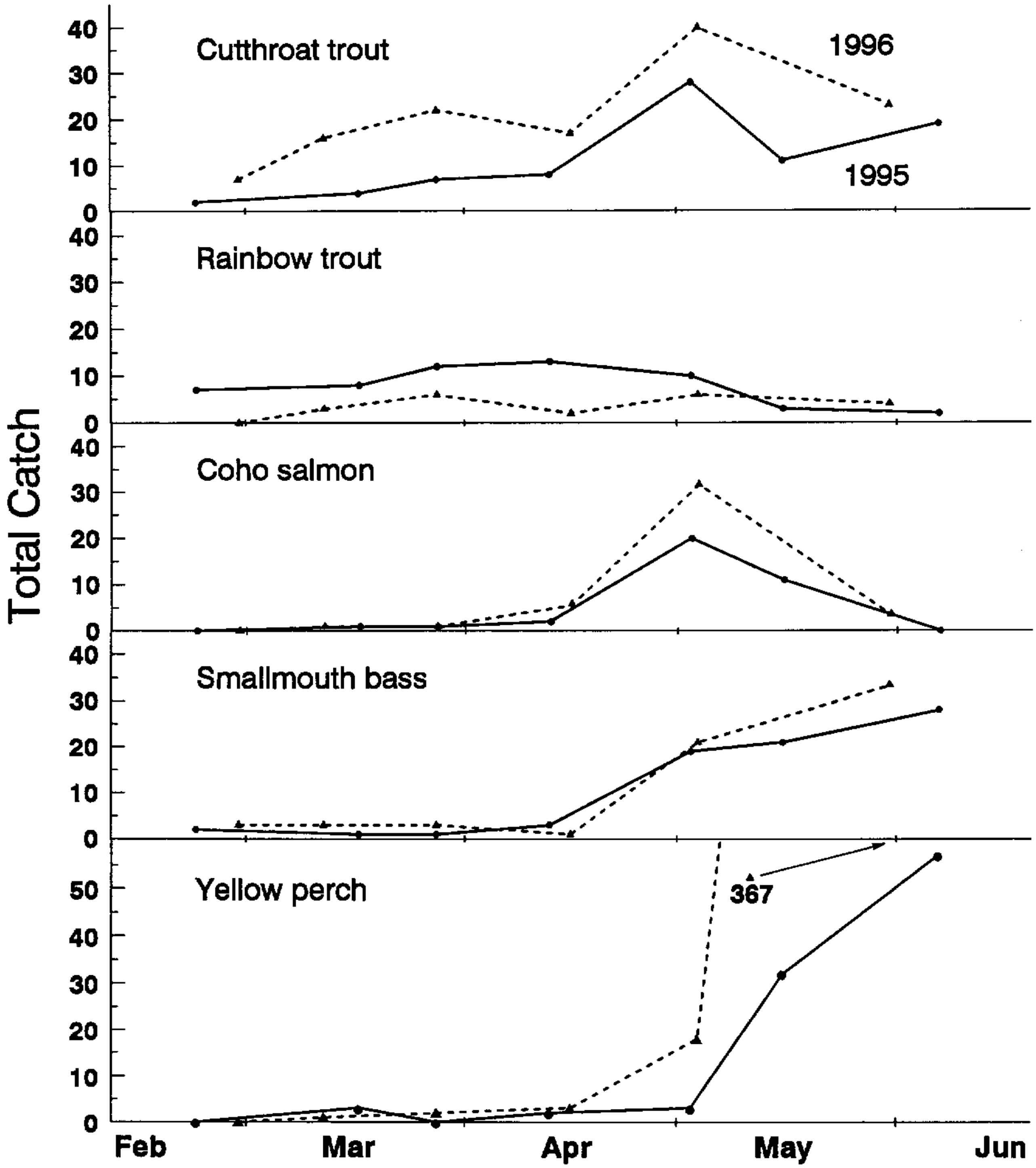

Figure 3.-- Total catch of predatory fishes collected by electrofishing in southern Lake Washington, February-May, 1996. Total catch includes only fish ≥ 100 mm FL except yellow perch which were ≥ 140 mm FL. Values represent the total catch of eight nearshore electrofishing transects for each date. Solid lines are 1995 and dashed lines are 1996.

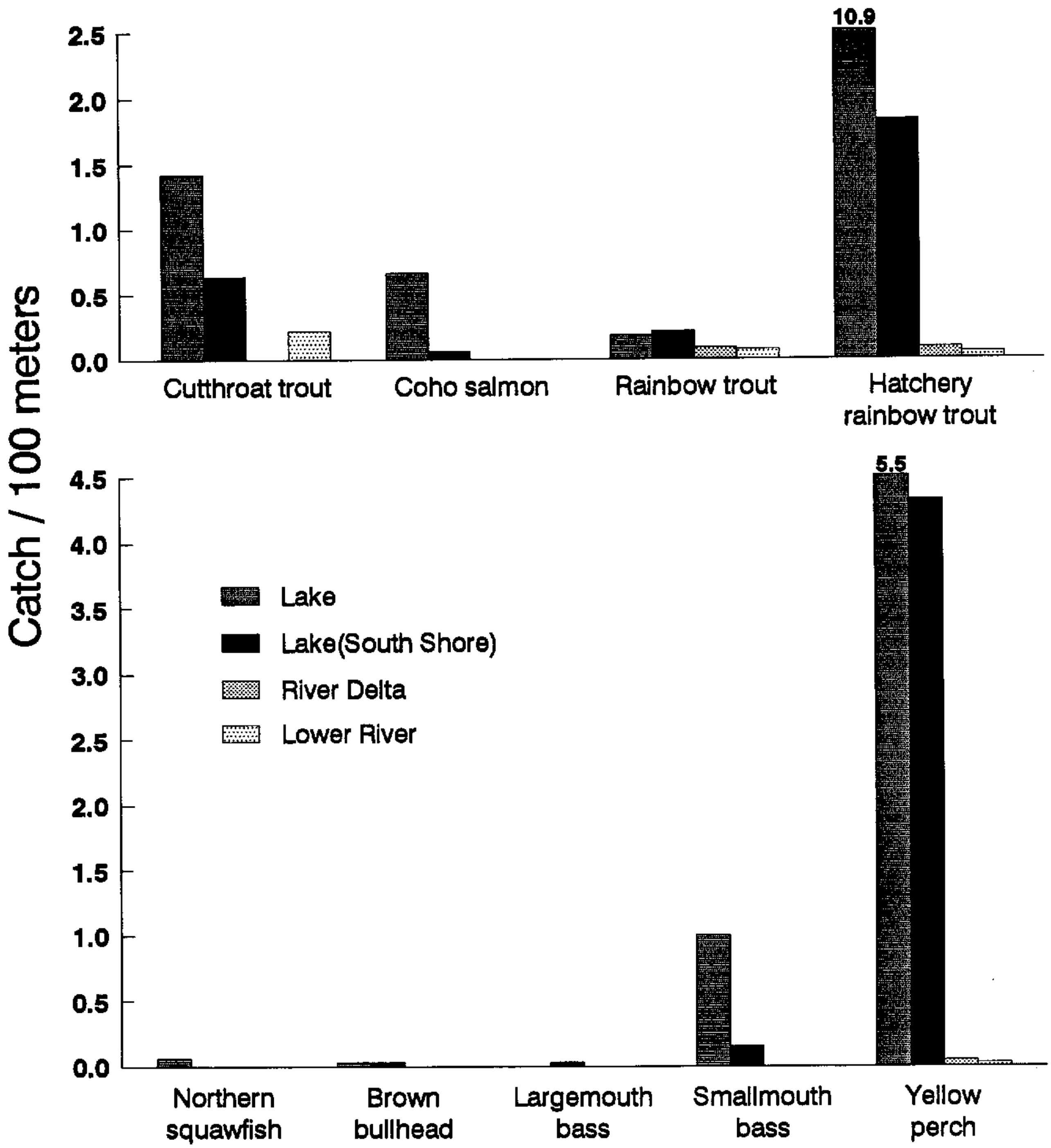

Figure 4.-- Catch (number/100 m) of predatory fishes from three areas of southern Lake Washington and the lower 400-m of the Cedar River, February-May, 1996. Values represent the catch per distance (100 m) shocked from five night-sampling periods.

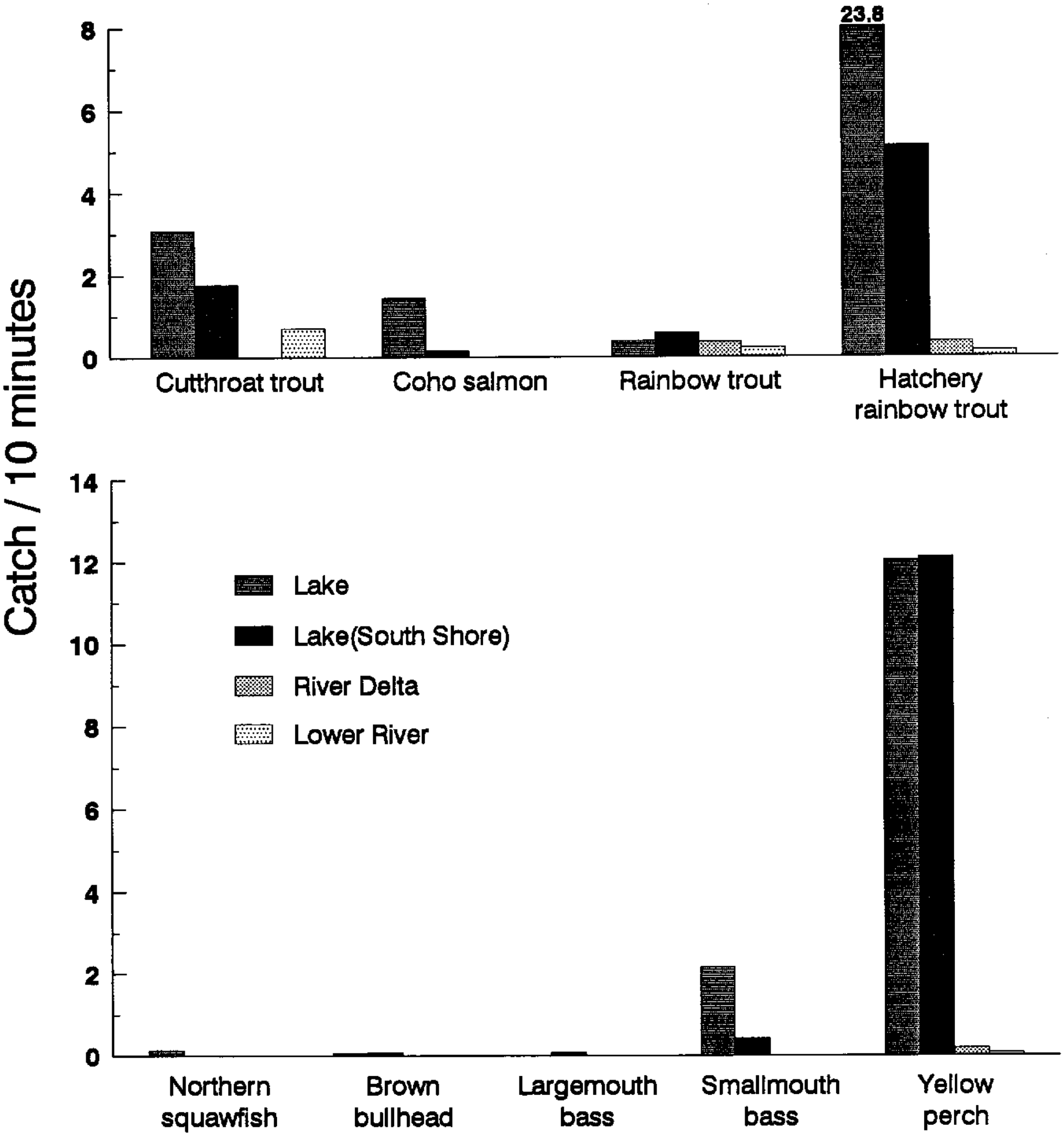

Figure 5.-- Catch (number/10 min) of predatory fishes from three areas of southern Lake Washington and the lower 400-m of the Cedar River, February-May, 1996. Values represent the catch per amount of time (10 min) shocked from five night-sampling periods.

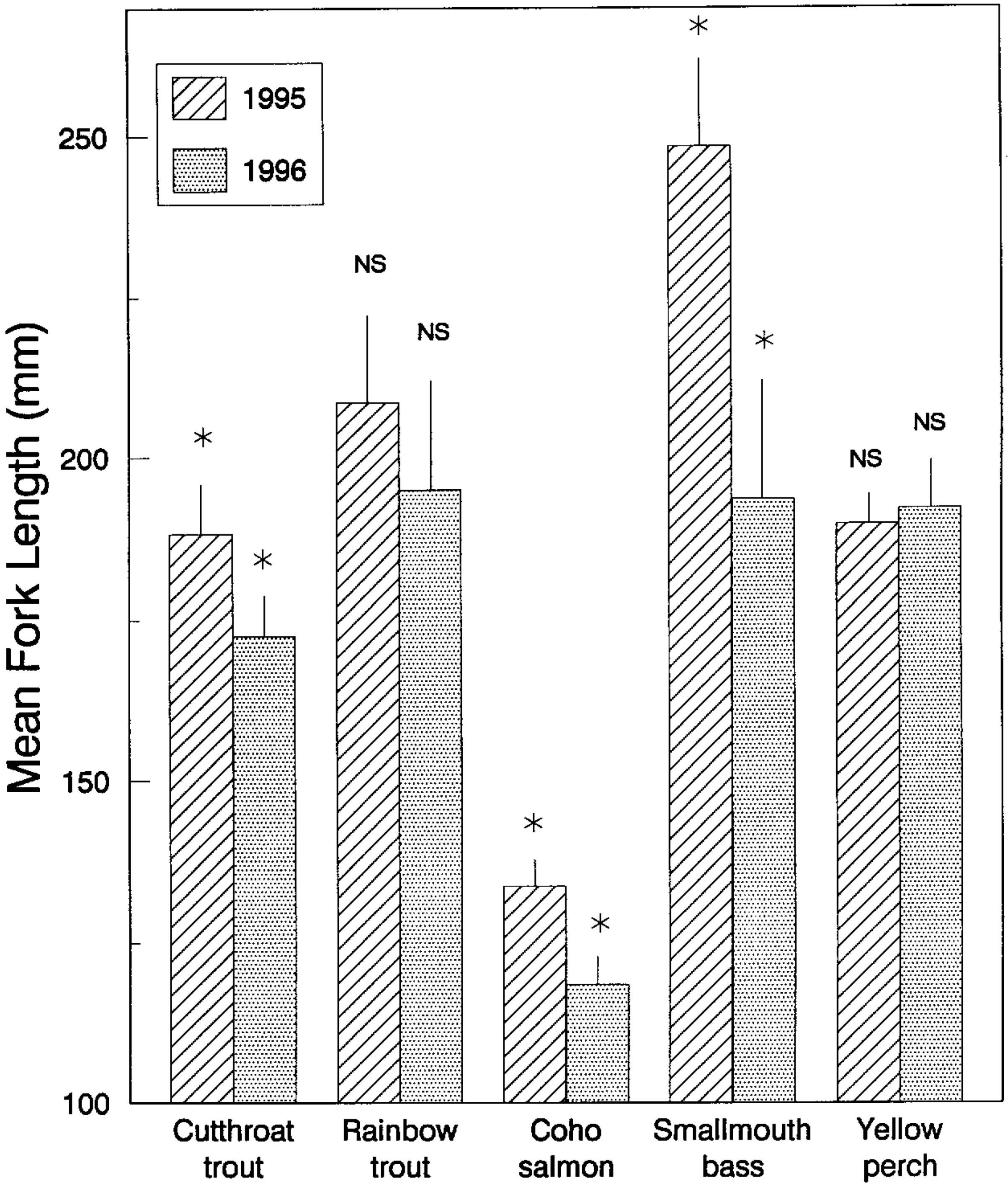

Figure 6.-- Mean fork length of fish caught in southern Lake Washington, 1995 and 1996. Fish were collected with electrofishing equipment. NS = not significant; an asterisk indicates a significant difference between years ($\alpha = .05$). Fork lengths were compared with a student's t-test. Error bars indicate ± 2 SE of the mean.

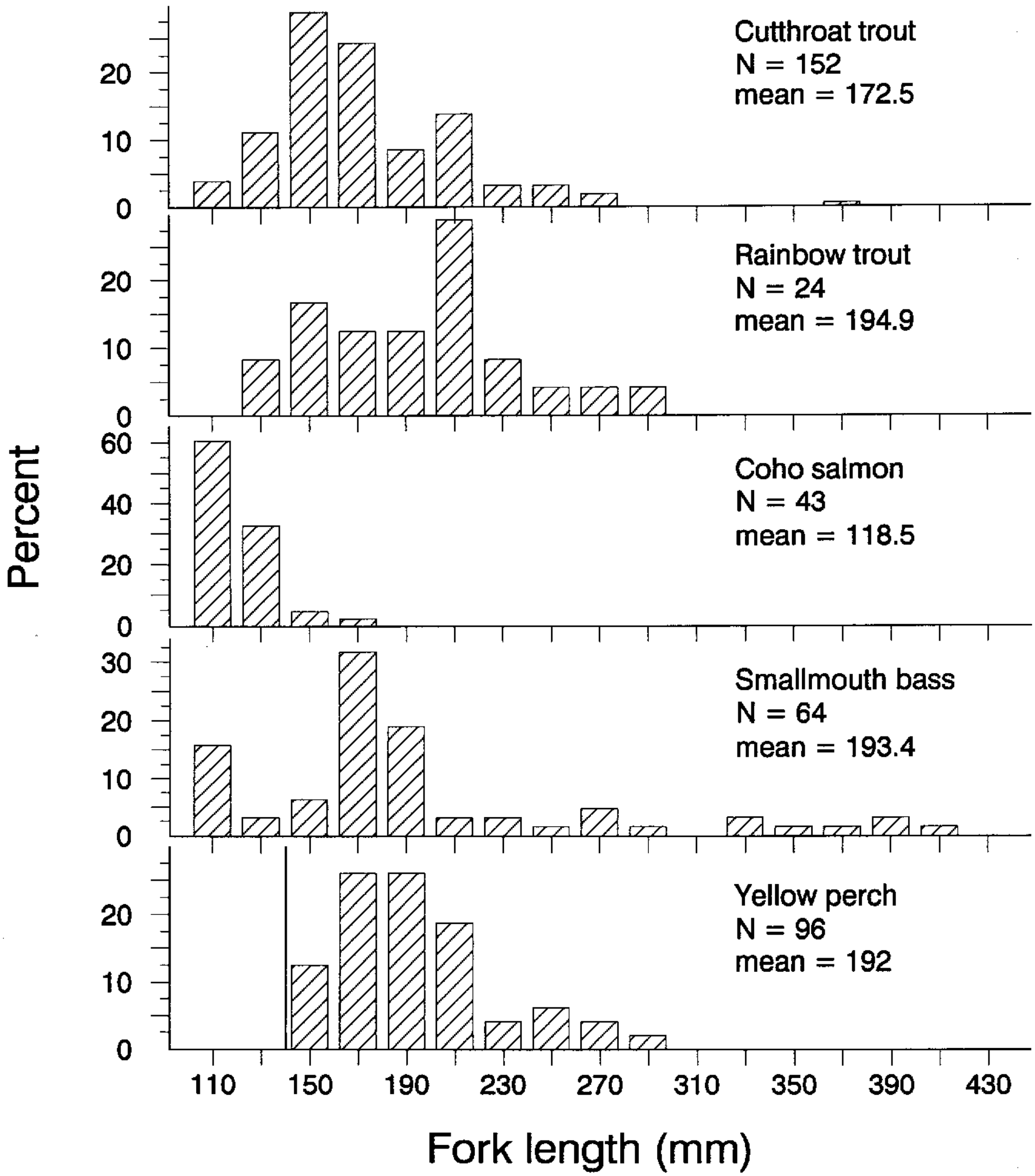

Figure 7.-- Length frequencies of predatory fishes ≥ 100 FL (yellow perch ≥ 140 mm FL) collected by electrofishing in southern Lake Washington, February-May, 1996. Smaller fish were not included because they may have been overlooked during electrofishing. Sample size and mean fork length are also given.

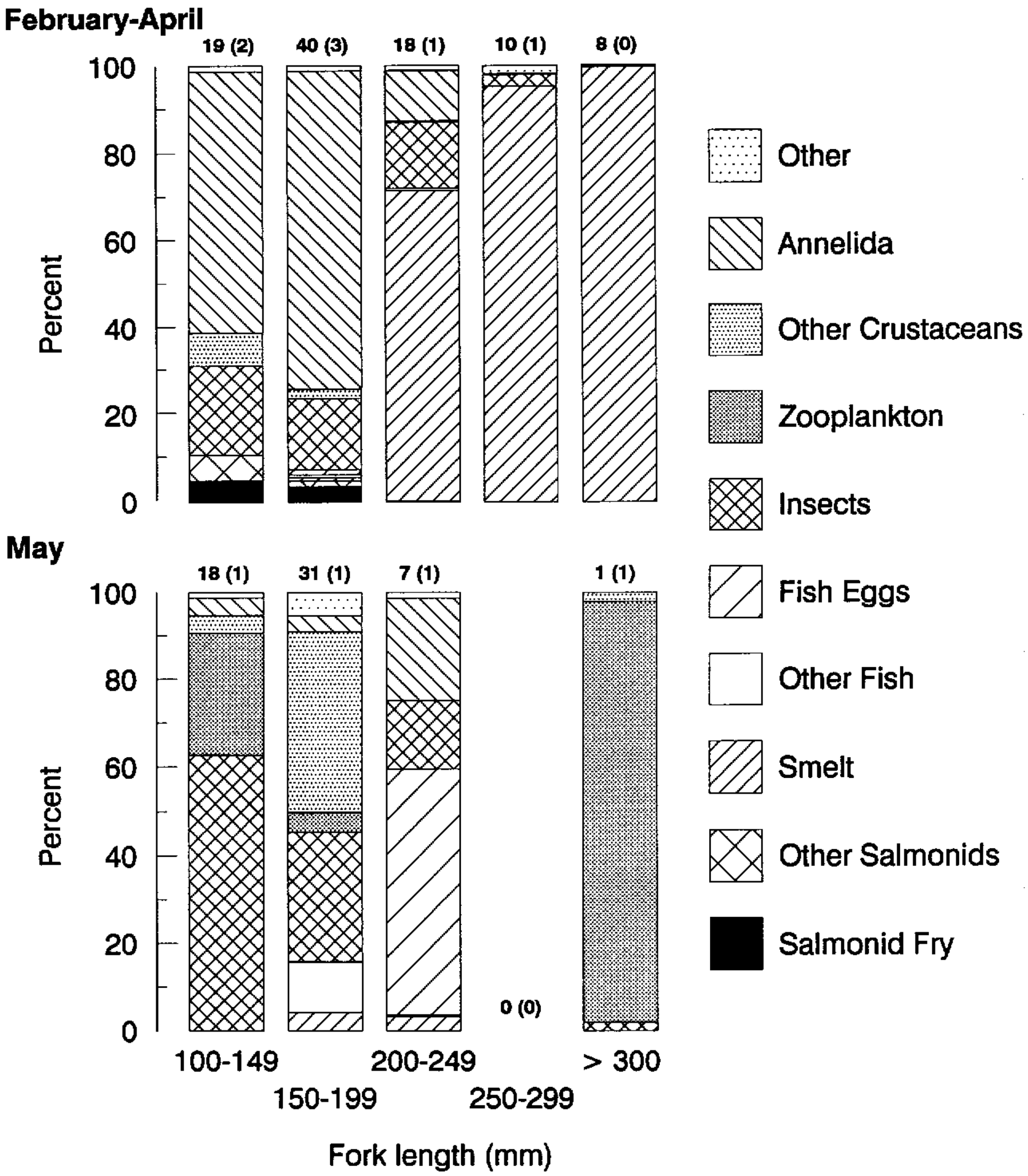

Figure 8.-- Composition (percent by weight) of ingested food for five size categories of cutthroat trout in southern Lake Washington, 1996. Percents were calculated from pooled data. Number of predator stomachs that contained prey items is given above the graph; the number of fish with empty stomachs is in parentheses.

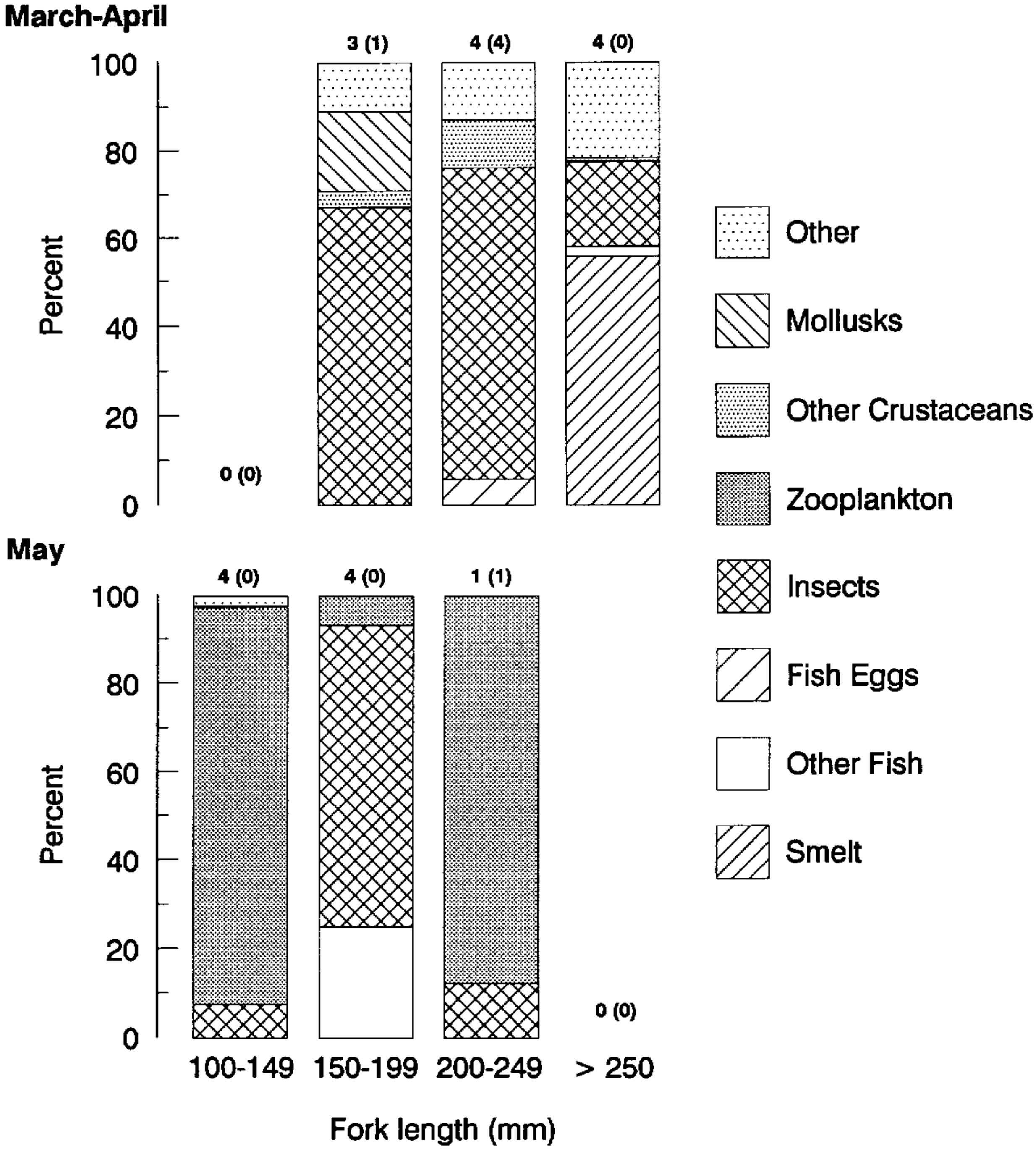

Figure 9.-- Composition (percent by weight) of ingested food for four size categories of rainbow trout/steelhead in southern Lake Washington, 1996. Percents were calculated from pooled data. Number of predator stomachs that contained prey items is given above the graph; the number of fish with empty stomachs is in parentheses.

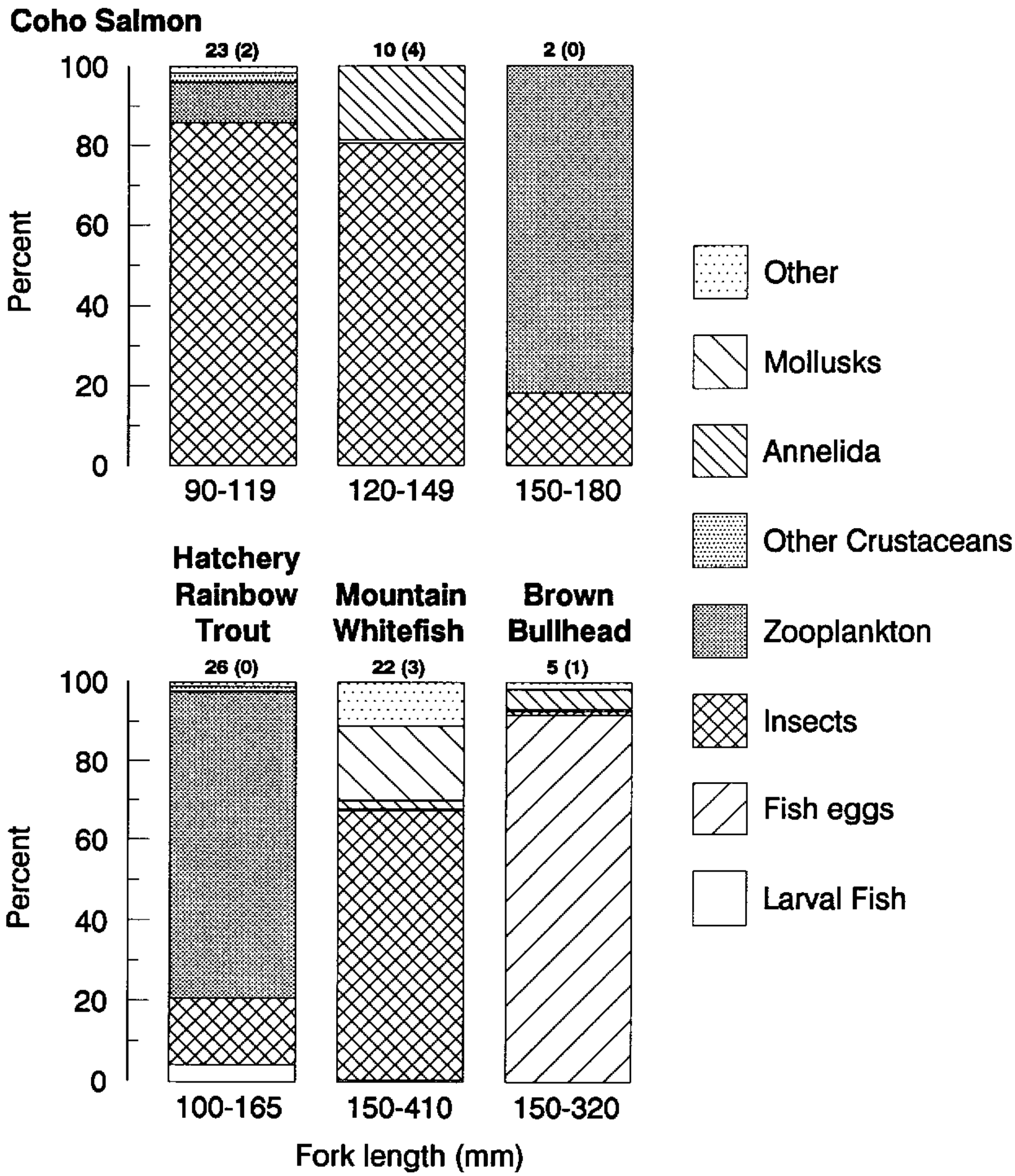

Figure 10.-- Composition (percent by weight) of ingested food for juvenile coho salmon, hatchery rainbow trout, mountain whitefish and brown bullhead in southern Lake Washington, February-May, 1996. Percents were calculated from pooled data. Number of predator stomachs that contained prey items is given above the graph; the number of fish with empty stomachs is in parentheses.

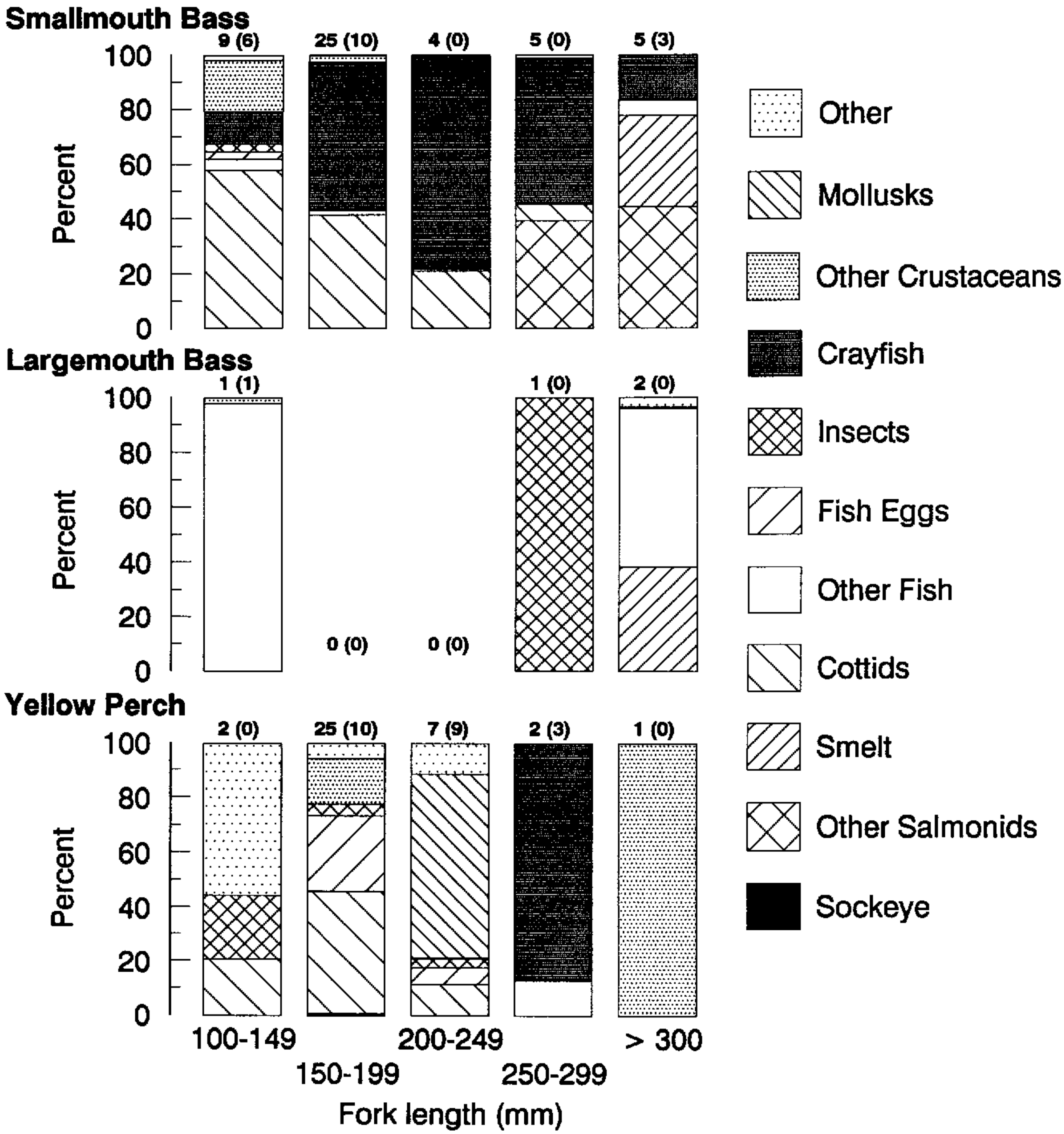

Figure 11.-- Composition (percent by weight) of ingested food for five size categories of smallmouth bass, largemouth bass, and yellow perch in southern Lake Washington, February-May, 1996. Percents were calculated from pooled data. Number of predator stomachs that contained prey items is given above the graph; the number of fish with empty stomachs is in parentheses.

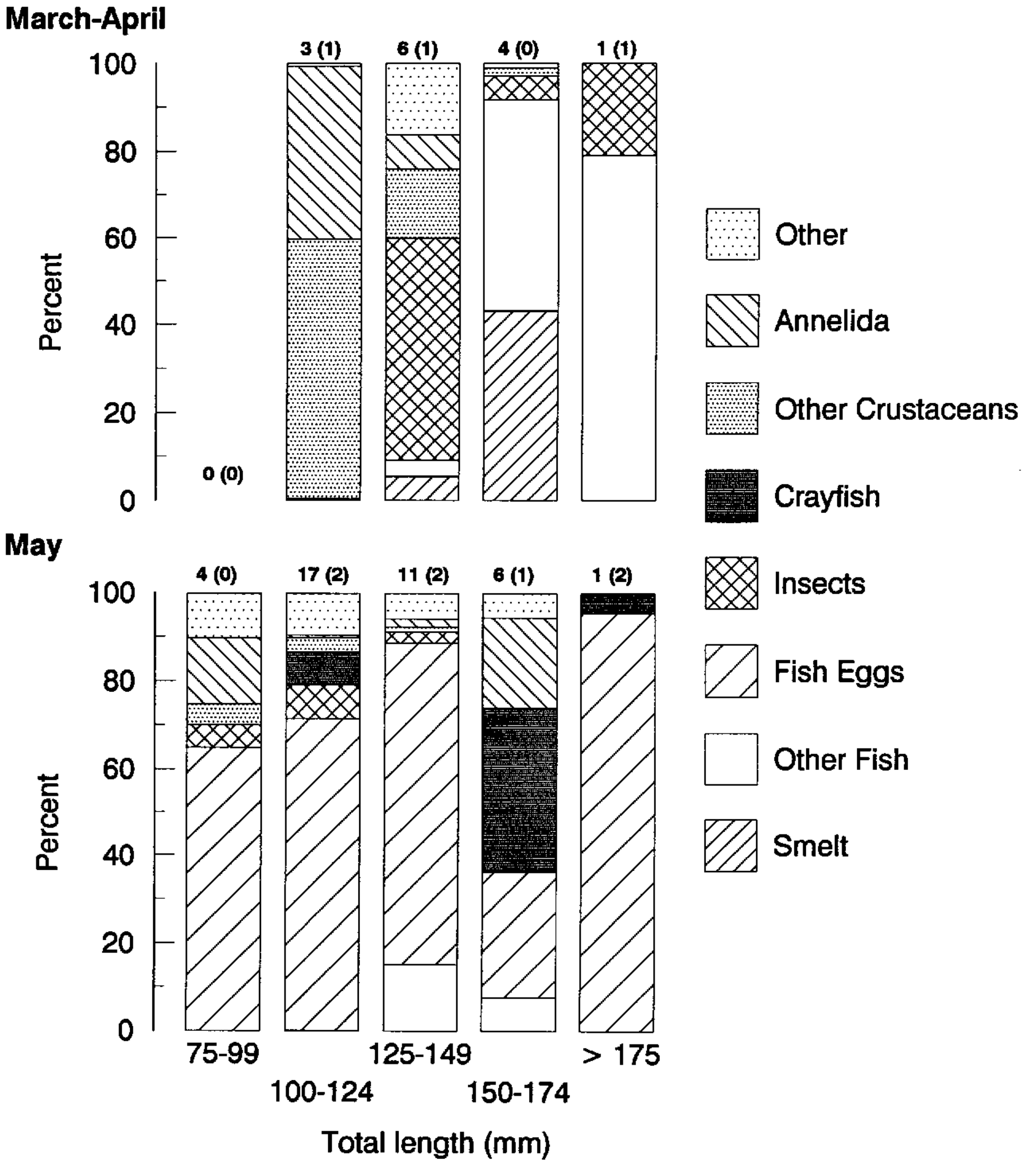

Figure 12.-- Composition (percent by weight) of ingested food of five size categories of prickly sculpin in southern Lake Washington, 1996. Percents were calculated from pooled data. Number of predator stomachs that contained prey items is given above the graph; the number of fish with empty stomachs is in parentheses.

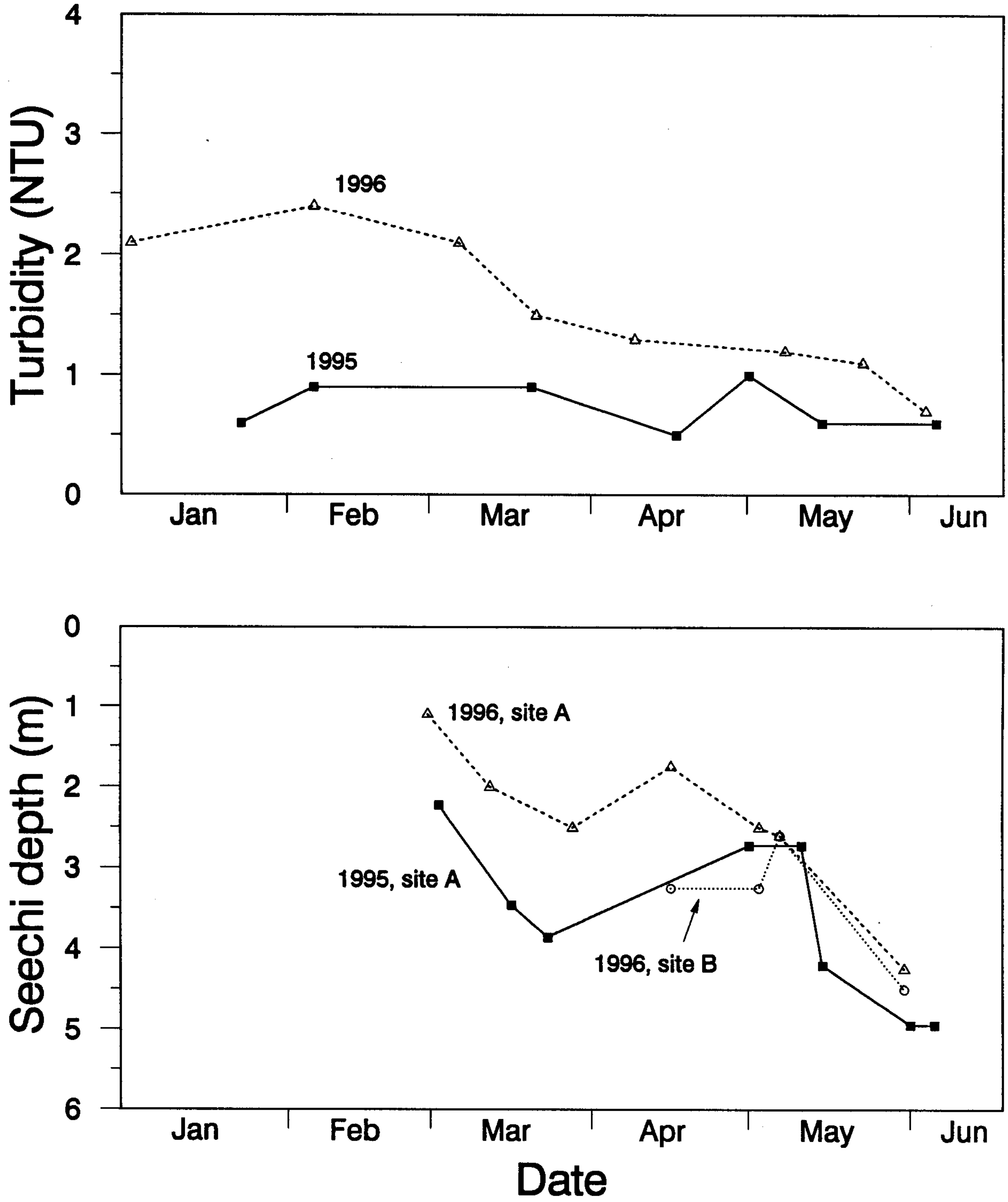

Figure 13.-- Turbidity levels (NTU, nephelometric turbidity units) and Secchi disk transparencies (m) for southern Lake Washington, January-June, 1995 and 1996. Turbidity data was collected by the Water Pollution Control Department of King County. Samples were taken just offshore of the delta at 1 m depth. Secchi disk transparencies were taken just offshore from the log booms at the south end (A) and north end (B) of Gene Coulon Park. Water depth at both locations was approximately 10-12 m.