AN ABSTRACT OF THE THESIS OF

Steven M. Hurley for the degree of Master of Science in Fisheries Science presented on June 22, 1993. Title: Distribution and Characteristics of an Isolated Population of Coastal Cutthroat Trout (Oncorhynchus clarki) in Streams of Triangle Lake Basin, Oregon.

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Abstract approved: ______________________________
Gary A. Lamberti

This research focused on features of a genetically isolated population of cutthroat trout (*Oncorhynchus clarki*) in the Triangle Lake basin of coastal Oregon. A falls at the outlet of Triangle Lake has blocked upstream migration of trout and anadromous salmonids into the basin. Cutthroat trout were found throughout the six study streams of the Triangle Lake basin in association with other native fishes and introduced warmwater fishes. Warmwater species (e.g. Centrarchidae) were restricted largely to the lakes of Triangle Lake basin, and did not comprise a significant part of the stream fish fauna. Salmonids and cottids dominated the upper forested reaches of the basin, whereas non-salmonids dominated the lower reaches. The middle reaches contained a transitional fish community between the upper and lower reaches.

Reach type was a major factor influencing cutthroat trout density and size distribution. Areal densities of cutthroat trout were highest in the upper reaches and lowest in the lower reaches with the exception of 0+ cutthroat trout, which occurred at similar densities in all reaches. The highest frequency of 1+ cutthroat trout occurred in the middle reaches, whereas the highest frequency of 0+ cutthroat occurred in the lower reaches. Within reaches, channel unit type influenced the density and age structure of cutthroat trout. Pools and rapids had the highest

densities of cutthroat trout, whereas riffles, glides, and cascades had lower densities. Larger trout were found primarily in pools and rapids.

Planted steelhead fry (Oncorhynchus mykiss) were found in two streams, Congdon Creek and Lake Creek. Although most steelhead fry leave the basin as smolts, some steelhead appear to become resident and may hybridize with native cutthroat trout.

Cutthroat trout spawning was observed from late December 1987 through late May 1988. Differences in the time and place of spawning may serve to genetically isolate two populations of cutthroat trout in Triangle Lake basin. One population may be lake dwelling as adults and spawn lower in the basin in late spring. The other population may be stream dwelling and spawn in the winter during higher flows, which allows them to spawn in the upper reaches of the basin.

Distribution and Characteristics of an Isolated Population of Coastal Cutthroat Trout (*Oncorhynchus clarki*) in Streams of Triangle Lake Basin, Oregon

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INTRODUCTION

Background

The Triangle Lake basin consists of Triangle Lake and the portion of Lake Creek and its tributaries upstream of Triangle Lake (**Figure 1**). Many small streams drain directly into Lake Creek, as well as into Swartz, Congdon, and Swamp Creeks, which are major tributaries to Lake Creek. Triangle Lake basin is significant due to the effects of Triangle Lake Falls. Historically, the falls at the outlet of Triangle Lake have blocked the passage of migratory salmonid fishes into Triangle Lake basin. The falls may have been created in the Pleistocene era, a time of high precipitation, uplift, and landsliding that created the steep-walled valleys of the coast range (Baldwin, 1976). Triangle Lake also may have been formed at this time.

The geomorphology of Triangle Lake basin is unique compared with that of other coastal basins. The fault block slip that formed Triangle Lake deposited deep alluvium that created a large flat valley atypical of western Oregon coastal basins (Baldwin, 1976). Most of Lake Creek, as well as the lower parts of its major tributaries, tends to be slow moving and marshy, with dirt banks of various heights. For the most part, the flatter portions of the basin are used for agriculture, whereas the headwaters are managed for timber production. Approximately 40 percent of the basin, mostly in the upper reaches, is owned by the Bureau of Land Management (BLM) (USDA, BLM, 1987). The remainder of the land in the upper reaches is owned largely by private timber companies.

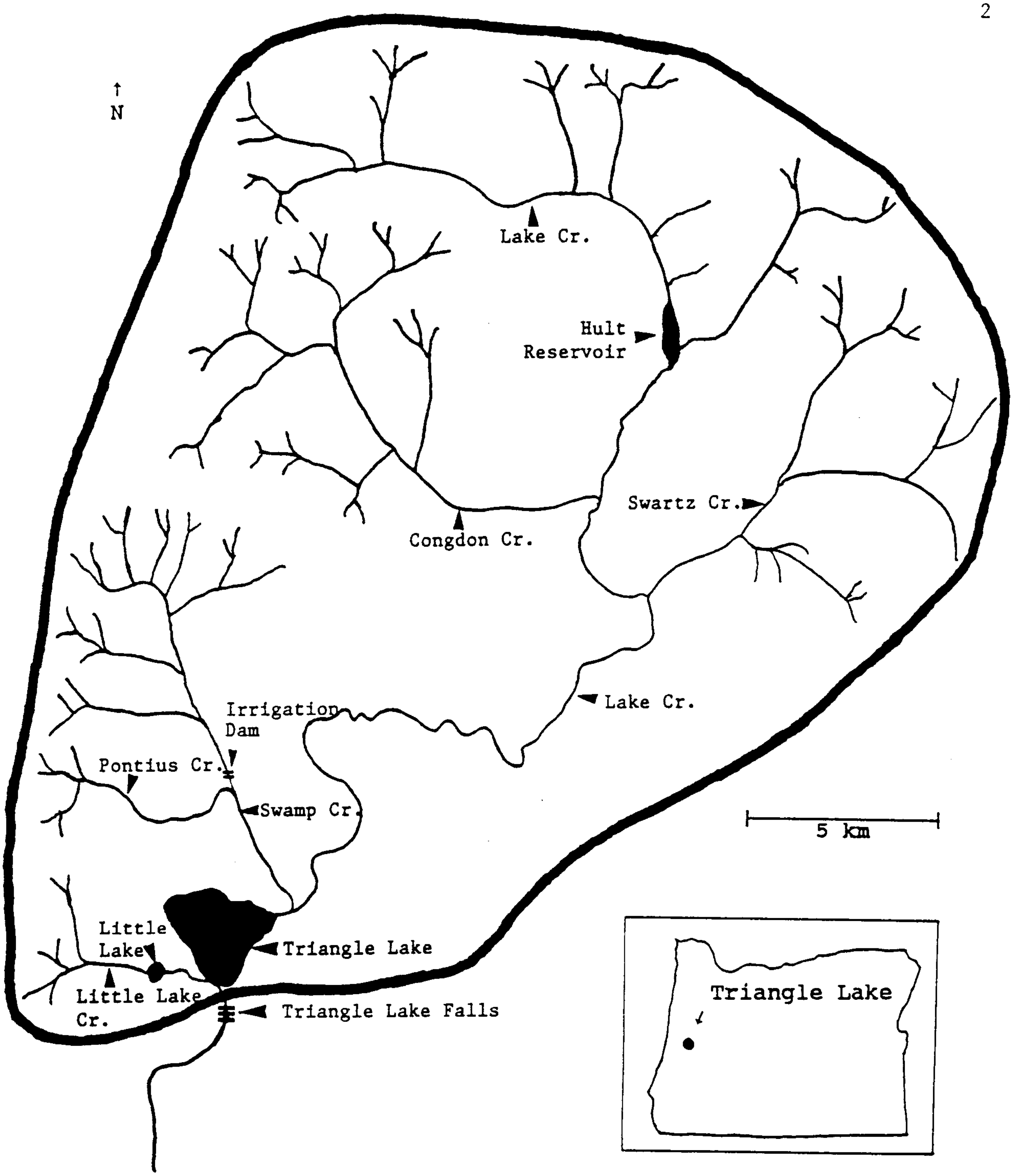


Figure 1. Triangle Lake basin study streams.

As anadromous fish passage is not possible over Lake Creek Falls, fishery improvements (stream structures, run augmentation) on federal and private land have been limited to fish planting. Juvenile coho salmon (Oncorhynchus kisutch) and juvenile winter steelhead (Oncorhynchus mykiss) have been planted in streams above Triangle Lake since 1982 (Salmon and Trout Enhancement Program Records, 1987). These fish return as adults and tend to aggregate below the falls, attempting to pass. Most of the fish drop back downstream and spawn in Fish Creek, which enters Lake Creek below the falls (Armantrout, 1987, personal communication). In April 1987, the BLM Eugene District completed the Lake Creek Aquatic Habitat Management plan, which includes proposals for implementing passage over Lake Creek Falls and Hult Reservoir (**Figure 1**).

The only fisheries project known in Triangle Lake basin is a wooden fish ladder constructed at the outflow of Hult Reservoir about 40 years ago (Armantrout, 1987, personal communication). At present this ladder is inoperable, but it may have provided passage for salmonids moving upstream from Triangle Lake in the past.

Sawmill dams that blocked fish passage are known to have existed on the lower parts of Congdon and Swartz creeks (Armantrout 1987, personal communication). This has resulted in a drastic change in present stream morphology, as sediment that accumulated behind the dams has been slowly downcut by the streams, resulting in a somewhat marshy, meandering condition. At present, the dams have been eliminated and fish passage is possible. Another small dam located on Swamp Creek is used for irrigation. The date of construction and periods of operation are not known. The dam appears to be a temporary structure that is raised and lowered as needed to irrigate.

A 1965 survey of the Triangle Lake basin conducted by the Oregon Department of Fish and Wildlife (ODFW) (Saltzman, 1965) documented 203 km of stream habitat usable by salmonids above Lake Creek Falls. Recent BLM surveys have put the total at around 162 km (USDA, BLM, 1987). The bulk of available fish habitat has been heavily altered by human activity. Agriculture in the lower section of Lake Creek and its major tributaries has led to severe loss of riparian vegetation in some areas. Extensive exposed banks and their resultant erosion have led to high levels of silt in Lake Creek. The forested upper reaches have mostly been harvested for timber, with riparian vegetation now averaging 20 to 30 years old. Many streams have very little woody debris.

In the summer of 1986, the Eugene District of the BLM collected samples of cutthroat trout (Oncorhynchus clarki) from several locations in Triangle Lake basin, as well as from below Triangle Lake Falls. The population below Triangle Lake was isolated above a falls approximately 6.4 km upstream on Greenleaf Creek, a tributary of Lake Creek. Genetic analysis by Oregon State University (OSU) indicated that cutthroat trout below Triangle Lake falls were substantially different from those in Triangle Lake (Sharpe, 1987). Within Triangle Lake basin, some hybridization between cutthroat and rainbow trout has taken place (Sharpe, 1987). It is possible that some steelhead juveniles stocked above Hult Reservoir have remained in the basin and become resident (Armantrout, 1987, personal communication).

There has been some question as to whether the cutthroat trout above Triangle Lake Falls constitute a genetically distinct population. In the past, cutthroat trout were observed spawning in June, which is not typical for this species (Saltzman, 1965). Two populations of cutthroat trout may exist in Triangle Lake basin: one that spawns in late winter (typical of coastal populations) and another that spawns in May (Bond, personal communication, by Behnke, 1979). Spawning surveys conducted by the BLM Eugene District verify that some late spring spawning does occur. The difference in time of spawning might genetically isolate the two populations. In Odell Lake, in the Oregon Cascade Mountains, a similar situation occurs with two introduced stocks of kokanee, which do not hybridize due to differences in time and place of spawning (Averett, 1966).

Previous studies

Past basin studies have reported differential habitat utilization by salmonids related to stream size, stream morphology, and species interaction. Chapman (1966) examined several studies relating fish use to the physical environment. He suggested that in stream dwelling, natural salmonid populations, density is regulated mainly by the physical environment and is less influenced by biotic interactions. He further speculated that a minimum spatial requirement for fish appears to be present regardless of food supply. In contrast, experimental work in areas of low water velocity suggest that food availability can override cover as a factor in determining cutthroat density in Oregon Cascade Mountain streams (Wilzbach, 1985). Wilzbach et al. (1986) attributed differences in growth rates of cutthroat trout to varying invertebrate drift densities and to different foraging efficiencies related to canopy cover and substrate crevices.

Ely (1979) found cutthroat trout to be smaller, younger, and more abundant in headwater reaches than in lower reaches of several Willamette River (Oregon) and coastal tributaries. He attributed this to downstream migration at age 2 to 3 years. Upper reaches of Columbia River tributaries were found to be dominated by cutthroat trout when steelhead and coho salmon also existed in the streams (Hess, 1982). In the Parks Creek drainage in the Oregon Cascades, brook trout (Salvelinus fontinalis) were found only in deep pools and low gradient areas near cover, whereas cutthroat trout were found throughout the system (Wetherbee, 1982).

In the South Fork Hoh River basin in Olympic National Park, Washington, densities of coho salmon were highest in stable side channels and terrace tributaries, while juvenile steelhead densities were highest in side channels and lower valley wall streams (Sedell, 1984). In that basin, cutthroat trout were restricted to upper valley wall tributaries. In Oregon coastal streams, densities of juvenile coho were greatest in low gradient streams, while cutthroat densities were highest in high gradient, larger streams (Swartz, 1990). In Puget Sound (Washington) streams, agricultural activities had the greatest impact on habitat for cutthroat trout, but these activities also reduced the winter habitat for salmonids in general (Chapman and Knudsen, 1980). After clearcut logging without stream buffers, cutthroat trout populations were severely depressed and remain low for eight years after the logging in Needle Branch, a tributary to Drift Creek in coastal Oregon (Mooring and Lantz, 1975). Timber harvest in the Oregon coast range was found to be detrimental to cutthroat trout in first to third order tributaries (Swartz, 1990).

In the Sacramento-San Joaquin drainage systems of California, adult native fish have been found mainly in larger streams, lakes, and sloughs, while young fish mostly inhabit small tributary streams (Moyle et al., 1982). In midwestern streams, young fish, from 0 to 2 years, were found primarily in upstream areas and in riffles (Schlosser, 1982). In the presence of coho and steelhead, cutthroat trout increased in upstream reaches, while the number of coho and steelhead declined with distance upstream (House, 1980).

Salmonid densities and size distribution have also been found to differ due to variation in microhabitats and woody debris abundance. In tributaries to the Clearwater River in Idaho, 0+ steelhead were associating with gravel and cobble substrates in summer, but moved to cobble and boulder substrates in the autumn (Johnson, 1985). During the summer in Porcupine Creek in southeast Alaska, total salmonid biomass was positively related to the amount of large organic debris, and coho salmon biomass, in particular, was directly related to pool cover (Murphy, 1984). In Oregon coastal streams, 0+ coho, 1+ steelhead, and resident trout (rainbow and cutthroat) occupied pools to a greater degree than glides and riffles, while 0+ steelhead and trout occupied pools, riffles and glides equally (Hicks, 1989). In Steamboat Creek in the Oregon Cascades, 1+ steelhead used deeper riffles to a greater degree than shallow riffles, while 0+ steelhead were less restricted in their choice of habitat regarding depth (Dambacher, 1991). In southern Ontario streams, trout biomass was correlated with (1) several physical features including percent pool area, mean maximum summer temperature, and a variable representing pools and overhead cover and (2) biotic features including biomasses of periphyton, piscivorous fish, and small benthic invertebrates (Bowlby and Roff, 1986). Trout biomass was negatively correlated only with piscivore abundance. With warmer water temperatures the distribution of steelhead trout was influenced by the presence of red-side shiner (Reeves et al., 1987). Cutthroat trout were found to use channel units with velocities intermediate between coho (which used the slowest velocity habitats) and steelhead (which used high velocity pools and riffles (Bisson et al., 1988). In the western Oregon Cascades, emergent cutthroat numbers were related to the abundance and quality of lateral habitats (stream margins, backwaters, and side channels) (Moore and Gregory, 1988).

While riparian shading has been found to limit salmonid production in some California and Oregon streams (e.g. Murphy et al., 1981, Hawkins et al., 1983), the physical structure of the channel was found to be more important for Washington salmonid populations (Salo et al., 1981). In the Smith River drainage of western Oregon, cutthroat trout numbers were positively correlated with elevation, percent canopy, and percent shade, but negatively correlated with average and maximum width, maximum depth, volume, surface area, and minimum temperature (Duke, 1980). Second growth logged sections (12-35 years old) of small Cascade Mountain streams reshaded by deciduous canopy were found to have lower trout biomass than old growth sites (Murphy and Hall, 1981). In coastal Oregon, stream flow was the major factor affecting trout growth and production (Nickelson, 1974).

Cutthroat trout abundance also is influenced by water temperature and substrate composition. Cutthroat prefer water where maximum temperatures are consistently below 22°C but can withstand temperatures as high as 26°C if considerable nighttime cooling occurs (Behnke and Zarr, 1976, by Hickman and Raleigh, 1982). The greatest activity level for cutthroat trout is reported to occur at 15°C (Dywer and Kramer, 1975, by Hickman and Raleigh, 1982). Cutthroat trout fry were found to overwinter in shallow, low velocity stream margins, with rubble providing the principle cover (Bustard and Narher, 1975, by Hickman and Raleigh, 1982). When fines exceed 10% of the substrate in riffle-run habitats, the value of these habitats as cover for juvenile cutthroat trout can be impaired (Hickman and Raleigh, 1982).

Additional research is needed to improve our understanding of salmonid distribution, abundance, and habitat use at the scale of entire basins. Few past studies have focused on coastal cutthroat trout populations. A better understanding of the relationships between salmonids and non-salmonids, as well as of salmonid dynamics in relation to different habitat associations, is vital to basin-wide efforts to enhance or introduce naturally reproducing salmonid populations.

The purpose of this research was to determine:

- the distribution and species composition of fish in streams of the Triangle Lake basin, Oregon,
- the size distribution and density of native cutthroat trout from basin, reach, and habitat perspectives, and
- the physical variables influencing the size distribution and density of native cutthroat trout.

This research provided an opportunity to analyze the habitat use of cutthroat trout in a coastal basin largely devoid of other competing salmonids.

HUMAN AND FISH HISTORY IN TRIANGLE LAKE BASIN

Human settlement of Triangle Lake basin began in earnest in the late 1800s. The valley originally was covered with old growth western red cedar (Thuja plicata) and Douglas fir (Pseudotsuga menziesii) although a marsh (202-243 ha) covered the west side of Triangle Lake (Rust, 1984). A good wagon road to Triangle Lake was constructed in 1886 (Lomox, 1935), and a post office was established at Blachly, approximately 5 km east of Triangle Lake in 1892 (McArthur, 1926).

In the early 1900s, extensive logging began in the Triangle Lake basin. Fred Rust began steam donkey logging in the upper reaches of Lake Creek in 1901 (Rust, 1984). In 1904, the Horton brothers built a mill in the vicinity, and another mill apparently was built on Triangle Lake as late as 1927.

The only salmonids known to occur naturally in the Triangle Lake basin are cutthroat trout (Oncorhynchus clarki). Early settlers reported good trout fishing in Triangle Lake (Rust, 1984). The ODFW sampled fish in Triangle Lake, Hult Reservoir,and Little Lake in 1960, 1961, and 1964. All of the cutthroat trout caught were over 1 year old, and most apparently had spent 2 years in streams before entering the lakes (Saltzman, 1965). The time spent by cutthroat trout in streams as opposed to lakes was determined by comparison of scale annuli from fish taken from lakes and streams in the Triangle Lake basin. In Triangle Lake, the cutthroats appeared to become sexually mature at around 11 cm and 3 years of age, whereas in Little Lake and Hult Reservoir, immature fish older than 3 and 5 years, respectively, were found (Saltzman, 1965).

Before 1956, adult Pacific lamprey (Lampetra tridentada) were observed passing Triangle Lake Falls (Armantrout, personal communication). A creel survey in 1950 by Bond and Pitney revealed that one-third of the trout in Triangle Lake had lamprey scars (ODFW, 1961). Bond speculated that they might have been inflicted by semi-parasitic brook lamprey, with dull teeth that lacked tenacity, or by small Pacific lamprey heading to sea and beginning carnivory early (Armantrout, personal communication). However, the Pacific lamprey population in Triangle Lake basin is now thought to be extinct.

Squawfish (Ptychocheilus oregonensis) and largescale suckers (Catostomus macrocheilus) have been known to inhabit Triangle Lake since 1952 (ODFW, 1987). Suckers have been observed spawning in Lake Creek, 3.2 km above Triangle Lake (Saltzman, 1965). A 1964 electroshocking survey found only salmonids at river kilometer (Rkm) 1.6 of both Swartz and Congdon Creeks, indicating that the upper limit of roughfish distribution was below this point in the basin (ODFW, 1987). It is not known whether squawfish and suckers are native or were introduced into the basin (ODFW, 1987).

Sunfish (Centrarchidae) have been found in Triangle Lake since the earliest gillnetting sampling (ODFW, 1987). Species present include largemouth bass (Micropterus salmoides), bluegill (Lepomis macrochirus), and black crappie (Pomoxis nigromaculatus). Brown bullhead (Ictalurus melas) and yellow perch (Perca flavescens) have also been collected from Triangle Lake (ODFW, 1987). The date of warmwater species introduction is unknown.

Non-native salmonids have been stocked sporadically in Triangle Lake basin since 1952 (ODFW, 1987). Both adult and juvenile coho salmon have been planted in Triangle Lake and its tributaries. Catchable and fingerling rainbow trout have been planted in Triangle Lake, while winter steelhead fingerlings have been planted in basin tributaries. The stocking of kokanee salmon (*Oncorhynchus nerka*) in Triangle Lake ceased in 1976; however, kokanee now reproduce naturally in basin streams and inhabit Triangle Lake as adults (McLeod, 1987, personal communication).

THE STUDY AREA

All study areas were located upstream of Triangle Lake, on Congdon, Swartz, portions of Swamp, and Lake Creeks (**Figure 1**). The upper portions of the study streams are forested, and managed for timber production. Riparian vegetation tends to be dominated by red alder (Alnus rubra) and big-leaf maple (Acer macrophyllum) in early seral stages. The lower portions of the study streams have broad, flat valley floors and are used for agriculture, particularly cattle grazing. Riparian vegetation, sparse in places, consists of red alder and willow (Salix spp.). Intrusions into riparian areas and stream channels by cattle are common.

Pre-study surveys revealed that three major types of stream habitat are found in the Triangle Lake basin. In general, as one moves from the Lake Creek valley to the headwaters, the streams change from low gradient and silt dominated reaches to higher gradient reaches dominated by coarse substrates. Segments of the study streams were designated as lower, middle, or upper reaches (**Figure 2**), based on a set of specific criteria (**Table 1**).

Congdon Creek

The lower 1.6 km of Congdon Creek is an agricultural, lower reach. Good stream shading is provided by a thin buffer of red alder along most of the reach. This part of Congdon Creek is totally within private ownership, and cattle currently graze the meadow by the stream.

From river kilometer (Rkm) 1.6 to Rkm 3.2, Congdon Creek is designated as middle reach. This part of Congdon Creek has suitable habitat for salmonids. Riparian

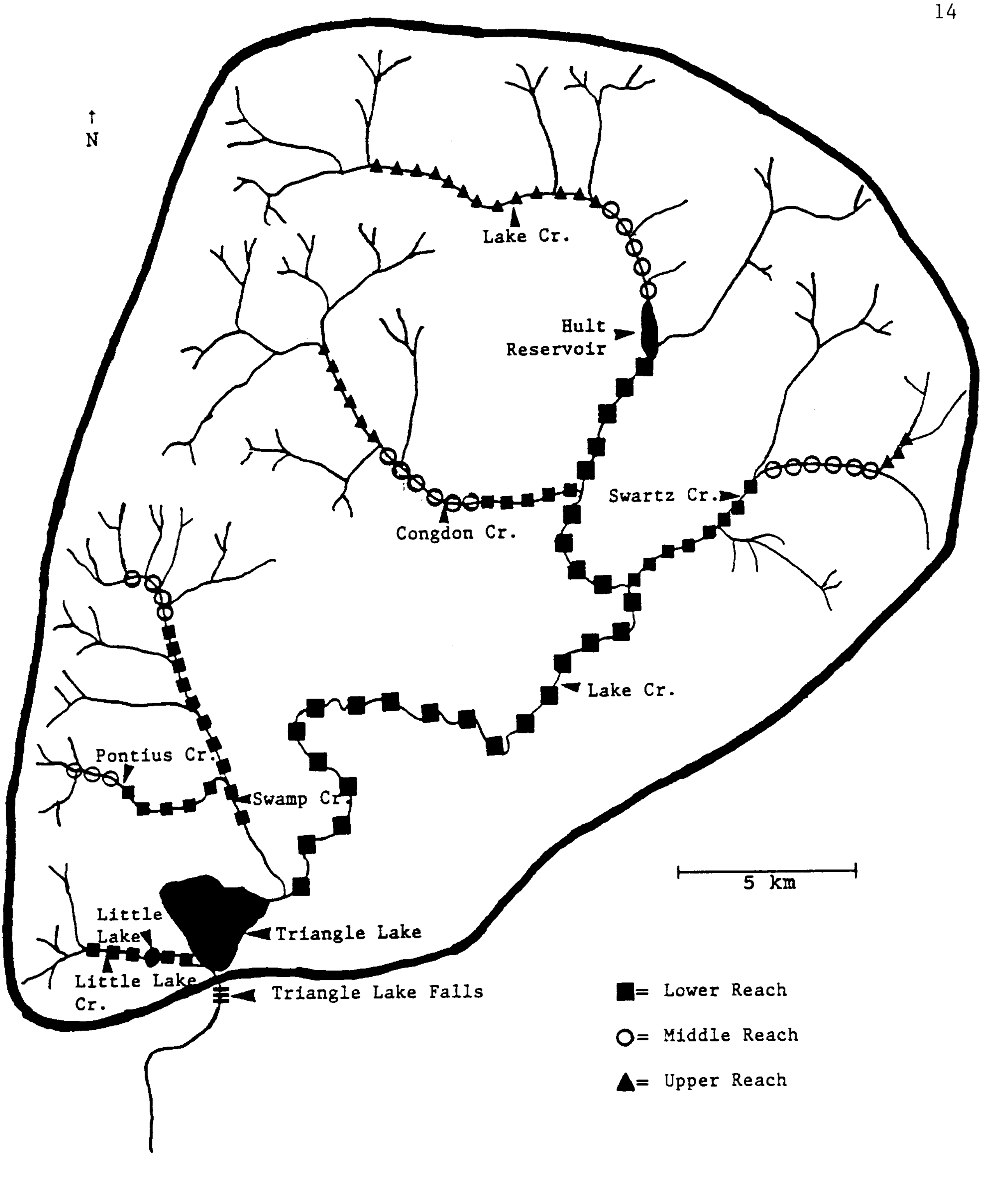


Figure 2. Pre-study reach type designations for the six study streams in Triangle Lake basin.

Table 1. Criteria used for designation of reach types in Triangle Lake basin.

Reach	Criterion
Lower	• Average valley floor width at least 20 times greater than the average active channel width • Stream gradient < 1% • Over 70% pool habitat • Substrates dominated by fine particles (sands, silts or small gravel) less than 2.5 cm • Land use is agricultural
Middle	• Average valley floor width 10 to 20 times the average active channel width • Stream gradient 1-2% • Pool habitat 50-70% • Substrates dominated by medium particles (large gravel or small gravel) from 2.5 to 6 cm • Land use is predominantly timber production
Upper	• Average valley floor width < 10 times average active channel width • Stream gradient > 2% • Pool habitat < 50% • Substrate dominated by coarse particles (cobble, rubble, boulders or bed rock) greater than 6 cm • Land use is timber production

vegetation is dominated by red alder and big leaf maple about 40 years old, and stream shade is generally good. Spawning substrates are plentiful and of good quality. Instream woody structure and cover for fish is plentiful along this part of Congdon Creek. This reach is presently owned by Bohemia Corporation, and logging has recently occurred on the adjacent slopes.

From Rkm 3.2 to its headwaters, Congdon Creek is considered upper reach. Riparian vegetation consists mostly of very young alder, 10 to 20 years old, and stream canopy is near 100% in most places. Most of the upper reaches of Congdon Creek were logged 10 to 15 years ago. Instream woody structure is generally lacking in this part of Congdon Creek, and cover for fish is restricted to interstitial areas around boulders.

Swamp Creek

From Rkm 0 to Rkm 3.2, Swamp Creek is a lower reach. Along the lower 1.6 km, stream shade is almost absent. A thin buffer of red alder exists along the upper 1.6 km of the lower reach, providing over 70% canopy along most of the reach. Cattle grazing is heavy along Swamp Creek, particularly along the lower 1.6 km. Many banks are unstable and eroding, which contributes to the silty conditions found in this reach. The entire reach is in private ownership.

From Rkm 3.2 to Rkm 4.0, Swamp Creek is a middle reach. Habitat in this reach is considered good for salmonids. Riparian vegetation consists of mixed deciduous and coniferous trees, primarily big leaf maple, red alder, Douglas fir, and western red cedar 60 to 80 years old. Recent logging has occurred on some of the adjacent slopes.

Most of the upland forest is 20 to 40 years old, and is owned by the BLM and used for timber production.

Lake Creek

The lower 11.2 km of Lake Creek is lower reach. Stream canopy ranges from 50% to 70%, as a narrow buffer of red alder is found along most of the reach. Scattered conifers and small woodlots are found along this part of Lake Creek. Most of the valley area is pasture used for grazing cattle. Many banks along this reach are unstable and the streambed is dominated by silt. All of this reach is in private ownership.

Above Hult Reservoir, the character of Lake Creek changes considerably. From Rkm 14.4 to Rkm 15.6, Lake Creek is considered a middle reach. Stream canopy is over 70%, and the riparian zone has not been recently logged. Riparian vegetation is dominated by red alder and big leaf maple 40 to 60 years old. Spawning substrates and woody debris are plentiful along this reach, which is in BLM ownership.

From Rkm 15.6 to its headwaters, Lake Creek is considered an upper reach. Stream canopy is nearly 100%, as the riparian zone is dominated by young alder less than 30 years old. Almost all of this area has been recently logged, with forests of 20 to 30 years old. Spawning substrates and woody debris are scarce along all of this reach. Except for the lower 0.8 km, this reach is in BLM ownership.

Swartz Creek

The lower 3.2 km of Swartz Creek are considered lower reach. The upper 1.6 km of this reach has, in the past, been used for grazing. However, the pastures were planted with Douglas fir about 10 years ago. Conditions in the lower 3.2 km of Swartz Creek are similar to those in Swamp Creek, but bank instability is not as severe. Shading is moderate along most of this section. Riparian vegetation consists of red alder and big leaf maple of 30 to 40 years old throughout this reach, and some Douglas fir 15 to 20 years old in the upper 1.6 km of this reach. All of this reach is in private ownership.

From Rkm 3.2 to Rkm 4.8, Swartz Creek is middle reach. Stream canopy closure is between 80% and 100%, with the exception of some open areas around beaver ponds. All of the hill slopes of this reach were logged about 20 years ago. Riparian vegetation consists of red alder and big leaf maple 40 to 50 years old, with some scattered older conifers.

From Rkm 4.8 to Rkm 5.6, Swartz Creek is considered upper reach. Canopy cover is near 100% due to the smaller size of the stream at this point. Riparian vegetation is dominated by red alder and big leaf maple approximately 40 years old, with some older red cedar and western hemlock. All of this reach is owned by the BLM and is used for timber production.

Pontius Creek

The lower 1.6 km of Pontius Creek is a lower reach. Shading is sparse along much of the stream, ranging from 20% to 50%. Unstable banks are not a major problem along

Pontius Creek, as the pastures tend to be used for hay production rather than for grazing. Riparian vegetation is dominated by willow and sedges, with some scattered red alders. While spawning substrates are abundant, woody debris in the stream channel is scarce. All of this reach is privately owned.

From Rkm 1.6 to Rkm 2.8, Pontius Creek is considered a middle reach. A major change occurs at this part of the stream. The reach is considered good to excellent for salmonids. Riparian vegetation is big leaf maple and alder 60 to 80 years old, with scattered red cedar and western hemlock. Stream canopy is from 70% to 80%. Both spawning substrates and woody debris are abundant. All of this reach is owned by the BLM and the land use is designated for timber production.

Little Lake Creek

From the mouth upstream 2.4 km, Little Lake Creek is a lower reach. Stream canopy ranges from 20% to 60%. An intermittent stream buffer exists on about one-half of the reach. Riparian vegetation is dominated by red alder, with a few scattered woodlots used to grow Douglas fir. Most of the riparian zone is used for grazing or hay production. Some unstable banks exist, but they are less severe than those on other streams in the basin. Spawning substrates and woody debris is restricted to the upper 1.0 km of this reach. All of this reach is privately owned.

METHODS

Fish were sampled from the study streams during the summers of 1987 and 1988. Habitat inventory of the study reaches took place in the summer of 1989. Fish sampling was performed prior to habitat inventory due to the availability of volunteer labor during the summers of 1987 and 1988. All fish and habitat data were collected between May and October during summer low flows. Average flow during this time period was only 9% greater in 1989 than in 1988 (U.S. Geological Survey, 1988, 1989). No disturbances in Triangle Lake basin (such as debris torrents) were observed in 1988 or 1989. Conditions in the basin were considered similar between years. Spawning surveys were conducted between May 1986 and December 1988.

Fish Sampling

In the summer of 1987, fish populations were sampled at various locations in the six study streams to determine general trends and patterns. These data were not included in any statistical analyses. In the summer of 1988, sections of the study streams were divided into study reaches (see **Table 1**) and designated as upper, middle, or lower reaches. The study streams were third-order or larger. Samples sites were selected by systematic sampling from a random sampling point (Dixon et al., 1983). The study reaches were divided into 32 sample points per km, from which a random starting point was selected. The random starting point on the stream was the first sample site. At this site and at 0.3 km intervals upstream and downstream from the starting point, the stream was divided into sample sites. Fish were sampled at each site with a Smith-Root D12 backpack electroshocker. For the lower reach of Lake Creek, sampling sites were set at intervals of 2 km from the starting point due to the longer length of this reach. This sampling procedure resulted in an average of 7 sample sites per reach. Some study reaches contained greater than 7 sample sites. Lake Creek had 5 sample sites.

At the sampling sites, the stream was divided into channel units based on a specific set of criteria (**Table 2**). Five consecutive upstream channel units, up to a maximum of 30 m of stream, were sampled. Each channel unit was blocked with nets at both ends to minimize fish escapement.

A multiple pass removal procedure was performed to estimate fish density in each channel unit (Armour et al., 1983). An effort was made to achieve a probability capture of at least 0.5. If capture probabilities were less than 0.5, then another habitat was randomly selected. At least two passes were made in each channel unit to a maximum of four passes. Some fish density estimates (less than 1%) could not be used in the analyses due to poor capture probabilities. Salmonids were identified, counted, and measured for forklength to the nearest mm. Cutthroats were distinguished from rainbows by the presence of red slashes on the throat. Non-salmonids, except for cottids, also were identified, counted, and measured for forklengths to the nearest mm. Cottids were counted but not measured.

For each channel unit, measurements were made of midchannel length, average width, maximum depth, and average depth. Visual estimates were made of the surface area of various types of cover within the unit. Pools were designated as either scour, trench, plunge, or dammed, based on a specific set of criteria (**Table 3**).

Table 2. Criteria for designation of channel unit types in Triangle Lake basin.

Unit Type	Criterion
Cascade	• gradient 6-10% • typically shallow; depth < 5% average stream width, but deeper pockets may be present • fast turbulent water; 40-100% turbulent flow • dominated by coarse substrate (particles > 6 cm)
Rapid	• gradient 3-5% • typically shallow; depth < 5% average stream width, but deeper pockets may be present • fast flowing water; 15-39% turbulent flow • dominated by coarse substrate (particles > 6 cm)
Riffle	• gradient 1-2% • typically shallow; depth < 5% average stream width • fast flowing water; 5-14% turbulent flow • dominated by medium substrate (particles 2.5 - 6 cm)
Glide	• transitional unit between riffles and pools; gradient < 1% • depth < 10% of the average stream width • slowly flowing or calm water; 0-4% turbulent flow • dominated by fine substrate (particles < 2.5 cm)
Pool	• gradient < 0.5% • depth > 10% of the average stream width • slowly flowing or calm water; no turbulent flow • dominated by fine substrate (particles < 2.5 cm)

Table 3. Criteria for designation of pool types in Triangle Lake basin.

Pool Type	Criterion
Scour Pool	• formed by lateral or horizontal deflection of flow • deepest on the outside of the stream bend • some noticeable flow
Trench Pool	• elongate depression in the substrate • deepest in mid-channel • noticeable flow
Plunge Pool	• formed by a sudden gradient change (boulders, wood) • deepest at base of fall • some turbulence, slight noticeable flow
Dammed Pool	• formed by channel obstruction that backs up flow • deepest area is several meters behind obstruction • no noticeable flow; mostly quiet backwater

Habitat Inventory

A habitat inventory was performed on all of the study reaches using a systematic random sampling procedure (Dixon et al., 1983). Channel units (pools, glides, riffles, rapids, and cascades), were designated based on the criteria used for sampling fish. For each channel unit, visual estimates of substrate composition were made using the criteria for substrate sizes applied to reach types (see **Table 1**). For each 10th channel unit from a random starting point, exact measurements were made of unit length, wetted channel width, active channel width (width of the channel at bankfull stream flow), and valley floor width. The other channel units were enumerated. Estimates of pool and glide percentage for each study reach were made by extrapolating the average surface area of the measured units to all channel units in the study reach.

The average active channel width and valley floor width for each study reach were calculated from the measurements taken at each 10th unit. This was converted to a ratio of the valley floor width to the channel width, or the valley floor width index (Lamberti et al., 1989). Gradient estimates for the study reaches were made using topographic maps.

Spawning Surveys

In order to determine the run timing of spawning native cutthroats or other salmonids in the Triangle Lake basin, several index areas were surveyed monthly, and redds and fish were counted (**Figure 3**). Spawning surveys in 1986 and 1987 were sporadic and incomplete. In 1988, a regular pattern of surveys was completed for eight index areas.

Statistical Analyses and Data Manipulation

In order to establish a grouping of reach types among individual study reaches, a cluster analysis (clusb3) was performed on the habitat inventory data. This is a divisive clustering algorithm developed for use on the Oregon State University mainframe by C.D. McIntire (Botany Department) and W.S. Overton (Statistics Department) in 1972 (Smith, 1987). The data were arranged in a matrix containing 14 samples (the study reaches) and the following 6 attributes.

1. % pool and glide habitat
2. % fine substrate (particles < 2.5 cm)
3. % medium substrate (particles 2.5 to 6 cm)
4. % coarse substrate (particles > 6cm and bedrock)
5. % gradient, and
6. ratio of valley floor to channel width (valley floor width index)

Fish sample data were analyzed using Statgraphics Version 3.0. For the fish sampling data, multiple pass estimates of salmonid numbers were calculated for each channel unit ($\hat{N}$) and converted to an areal density, based on the surface area of the individual channel unit. The following two-pass formula was used; $\hat{N} = \frac{u_1}{1 - u_2/u_1}$ where u_1 = number of fish captured on the first pass and u_2 = number of fish captured on the second pass (Armour et al., 1983). If more than two passes were required to obtain a good estimate, than a more complex multiple pass formula was

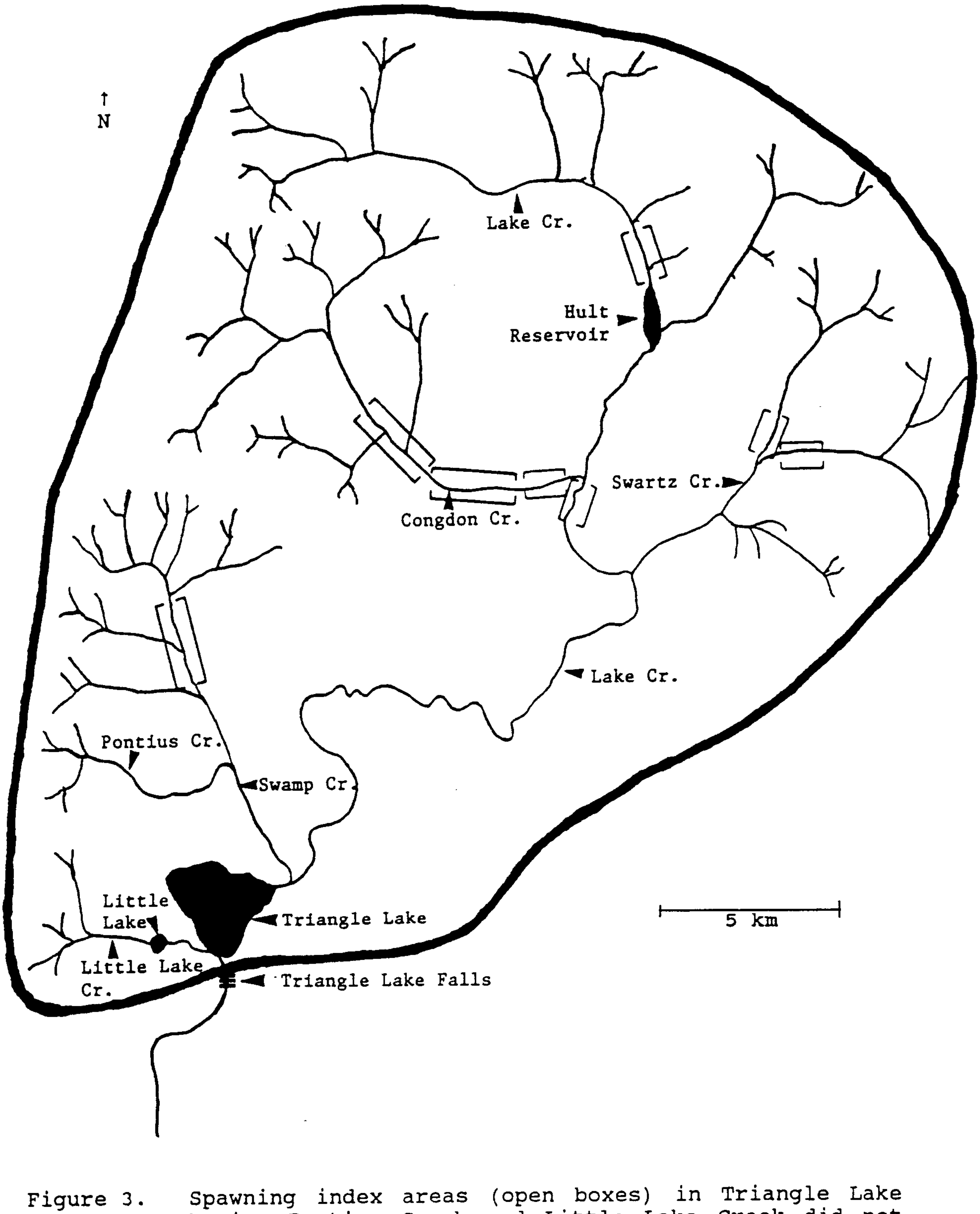


Figure 3. Spawning index areas (open boxes) in Triangle Lake basin. Pontius Creek and Little Lake Creek did not contain index areas.

used. These estimates were then compiled in a matrix containing 221 observations (fish/m^2 for a given channel unit) on 37 variables (e.g., channel unit type, area of cover, depth, number) (**Table 4**).

To compare the different salmonid densities among study reach groupings, the density for each channel unit was weighted by multiplying the estimated fish density of the individual channel unit by the proportion of that channel unit type (pool, riffle, etc.) in the study reach (Krebs 1989). A derivative of the following formula was used to calculate the weighted average for the reach: stratum weight = $W_h = N_h/N$ where N_h = the size of stratum (the number of possible sample units in stratum h) and N = the size of the statistical population. For example, if 70% of the area sampled was pool in the lower reach of Congdon Creek, then the densities of fish in the pools for Congdon Creek were multiplied by 0.7, to obtain a weighted average for the reach.

Extrapolation between fish densities in the sample sites and the habitat inventory was done for each study reach. The salmonid density for each channel unit type (pool, riffle, etc.) was multiplied by the area of that particular channel unit type within the study reach. The estimated number of fish derived from this extrapolation was then divided by the total area of stream estimated from the habitat inventory to determine areal fish density. A 95% confidence interval was calculated for each study reach density extrapolation. This was $t_{\alpha=.05,\ df=n-1}$ times the standard error of the multiple pass estimate (Armour et al. 1983). As with density estimates, the estimate of the variance was weighted to reflect the proportions of each channel unit type found in the study

Table 4. Example of data matrices used in statistical analysis of fish density and fish size data. All data in m (length) or m^2 (area) unless otherwise indicated.

Fish Density Data

Cutthroat Density	Channel Unit Type	Average Depth	Maximum Depth	Channel Unit Area	Reach Type
0.0030	Riffle	0.5	0.7	500	Upper
0.0200	Pool	1.1	2.0	650	Middle
0.0010	Cascade	1.0	0.9	400	Lower
0.0005	Glide	0.4	0.6	250	Upper

Fish Size Data

Cutthroat Fork Length (cm)	Channel Unit Type	Average Depth	Maximum Depth	Channel Unit Area	Reach Type
6.5	Glide	0.2	0.6	350	Lower
8.5	Pool	0.9	1.3	200	Upper
9.7	Pool	1.3	2.5	600	Middle
4.5	Rapid	0.5	1.7	150	Upper

reaches (Krebs 1989). Weighted variation between the sample sites was also included in the 95% confidence interval (Hankin, 1986).

The forklength of each salmonid was compiled in a matrix similar to the fish density data (**Table 4**). This resulted in a matrix of 1,620 observations and 21 variables.

Analysis of variance (ANOVA) was conducted on the log-transformed forklength data to detect statistical differences among various groups. For significant ANOVAs, Tukey's Test was used to conduct unplanned comparisons among groups. Due to the bimodal distribution of fish size seen among reach types, the forklength data was divided into 0+ cutthroat trout (fish < 8.0 cm) and 1+ cutthroat trout (fish ≥ 8.0 cm). As a bimodal distribution was not evident between channel unit types, these data were not divided into 0+ and 1+ fish for analysis of fish size between channel unit types.

Log transformations did not produce a normal distribution of cutthroat densities due to the large number of zeros (no cutthroat found in the habitat). Therefore, the Kruskal-Wallis non-parametric test (K-W) was used to determine if cutthroat trout densities differed among 3 or more groups. If there were only 2 groups, the Kolmogorov-Smirnov two-sample test (K-S) was used.

In order to analyze correlations among cutthroat trout size, density, and the multiple pass estimate, and with habitat variables, the Pearson product-moment correlation coefficient was calculated. Only data with values > 0 were used in the analysis.

RESULTS

Salmonid Spawning

Trout redds were observed in various locations in Triangle Lake basin between May 1986 and December 1988 (**Figure 4**). During 1988, spawning was monitored monthly on 5.1 km of stream, consisting of eight index areas (**Figure 3**). Trout redds were observed between December and May, with peak spawning in March (**Figure 5**). A smaller surge of spawning was observed in May. Total spawning in 1988 was 16 redds per km in the index areas. However, these areas had high quality spawning habitat, and trout spawning for the entire basin probably was much lower.

Kokanee salmon were observed spawning in the lower 1.6 km of Congdon Creek and in Lake Creek near Congdon Creek in November 1987. No kokanee were seen in 1988.

Species Composition and Fish Distribution

Both warmwater and coldwater fish inhabited Triangle Lake basin (**Table 5**). Cutthroat trout (Oncorhynchus clarki) and sculpin (Cottus spp.) were found throughout the basin and in all study reaches (**Table 6**). Rainbow trout (Oncorhynchus mykiss) were found only in Congdon Creek and in Lake Creek above Hult Reservoir.

Warmwater fish and rough fish do not appear to be a significant part of the fish fauna in the streams of Triangle Lake basin, as they make up less than 1% of the fish found in Little Lake Creek and Lake Creek. One bluegill (Lepomis macrochirus), one largemouth bass (Micropterus salmoides), and two largescale suckers (Catostomus macrocheilus) were captured at the lowest sample

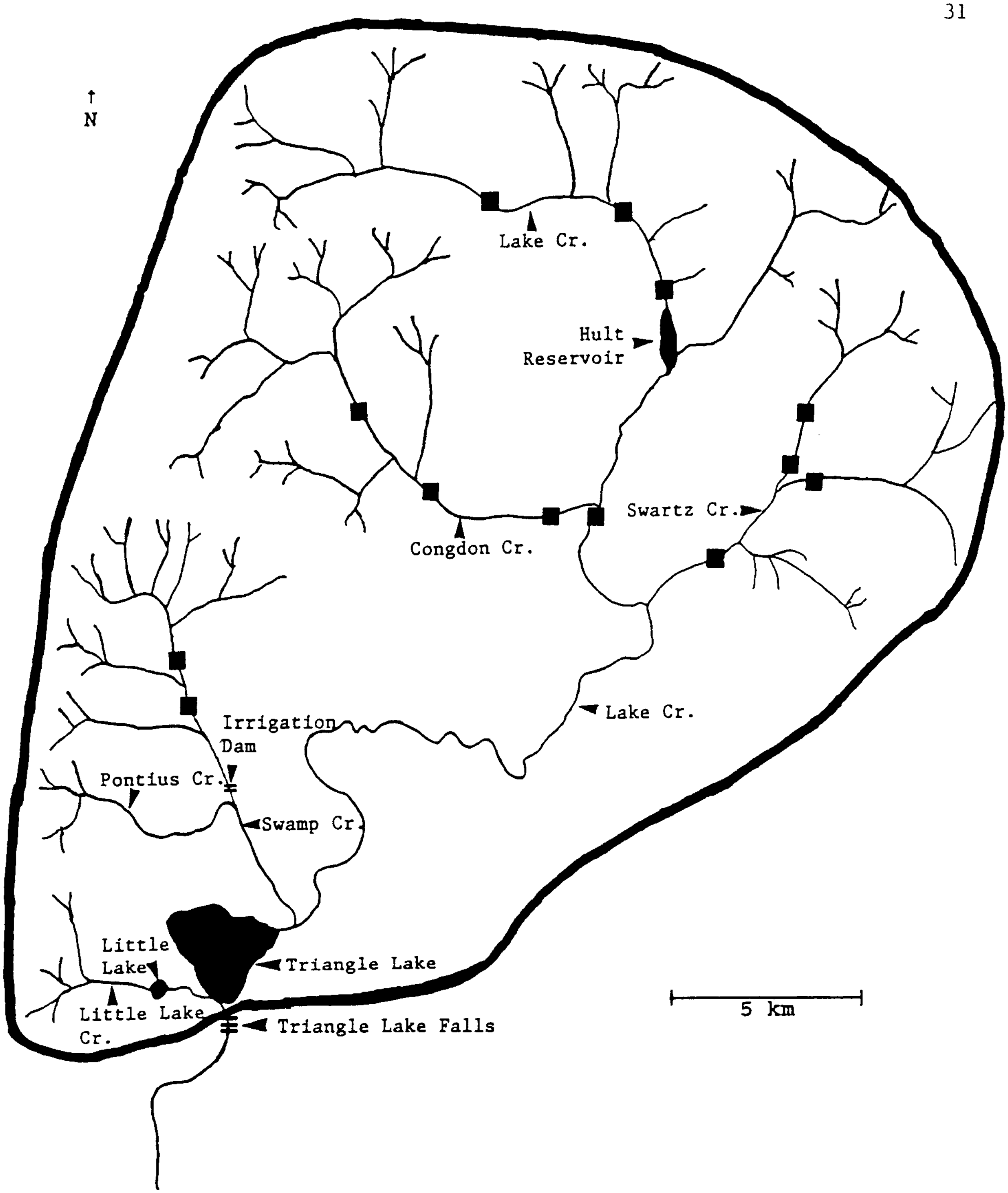


Figure 4. Areas of concentrated cutthroat trout spawning (squares) in Triangle Lake basin.

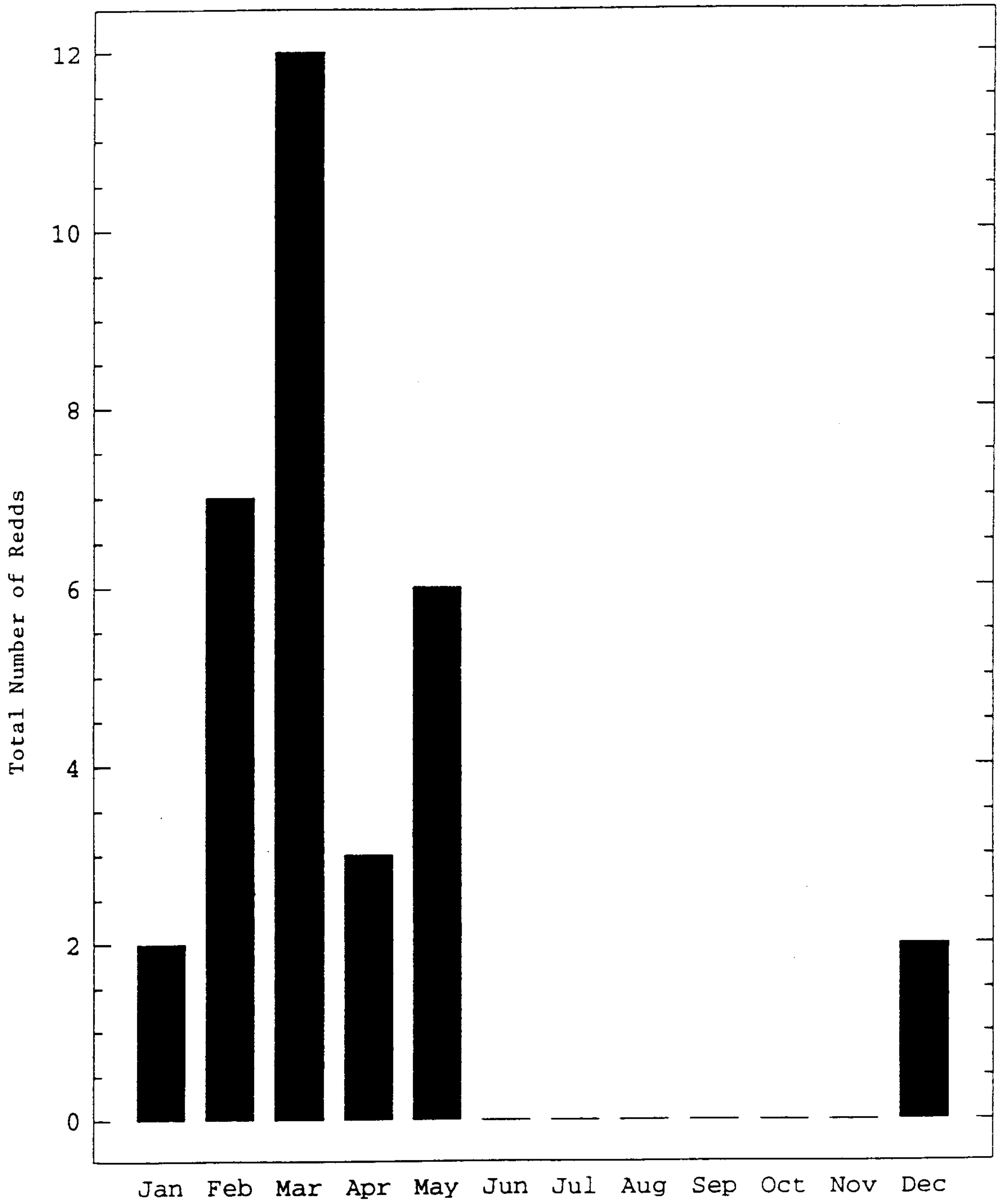


Figure 5. Cutthroat trout redd observations by month on eight index areas in Triangle Lake basin. January 1988 to December 1988.

Table 5. Fish species known to inhabit Triangle Lake basin, summer 1988.

Scientific Name	Common Name
Catostomidae	
Catostomus macrocheilus	largescale sucker
Centrarchidae	
Lepomis macrochirus	bluegill
Micropterus salmoides	large mouth bass
Pomoxis nigromaculatus	black crappie
Cottidae	
Cottus spp.	sculpins
Cyprinidae	
Rhinichthys osculus	blackside dace
Richardsonius balteatus	red-side shiner
Ictaluridae	
Ictalurus melus	brown bullhead
Percidae	
Perca flavescens	yellow perch
Petromyzontidae	
Lampetra spp.	lamprey
Salmonidae	
Oncorhynchus clarki	cutthroat trout
*Oncorhynchus kisutch**	coho salmon
Oncorhynchus mykiss	rainbow trout
Oncorhynchus nerka	kokanee salmon

*Coho salmon have been periodically stocked in Triangle Lake basin, but were not an established population at the time of this study.

Table 6. Relative proportions (% of total) of fish found in the upper, middle and lower reaches of each stream in Triangle Lake basin (– = none found).

	Cottids	Cutthroat	Rainbow	Dace	Shiner	Lamprey
<u>Upper Reaches</u>						
Congdon	81.0	14.0	4.0	–	–	1.0
Lake	51.8	19.9	28.2	–	–	<0.1
Swartz	52.0	47.0	–	–	–	1.0
<u>Middle Reaches</u>						
Congdon	86.0	9.0	0.9	1.1	–	3.0
Lake	81.0	3.0	8.0	–	–	8.0
Pontius	66.0	18.0	–	–	–	16.0
Swamp	70.0	24.0	–	–	–	6.0
Swartz	50.0	34.0	–	–	–	16.0
<u>Lower Reaches</u>						
Congdon	89.0	4.0	0.4	1.6	–	5.0
Lake*	40.0	2.0	–	10.0	23.0	24.0
Pontius	51.0	20.0	–	19.0	–	10.0
Swamp	76.0	7.0	–	2.0	–	15.0
Swartz	56.0	6.0	–	–	2.0	36.0
Little Lake*	71.0	13.0	–	–	–	15.0

* Bluegill, largemouth bass, brown bullheads, and largescale suckers were found in these reaches, but represent less than 1% of the total catch.

site on Lake Creek near the inlet to Triangle Lake. Two bluegills and one brown bullhead (Ictalarus melus) were captured at the lowest site on Little Lake Creek (about 0.16 km from its confluence with Triangle Lake).

Relative proportions of salmonids were highest in the upper reaches (**Table 6**), where they ranged from over 48% of the fish fauna in Upper Lake Creek to 18% in the upper reach of Congdon Creek. Relative proportions of salmonids were lowest in the lower reaches. For example, salmonids comprised only 2% of the fish fauna in the lower reach of Lake Creek (all cutthroats). Pontius Creek was an exception, with a slightly higher relative proportion of salmonids occurring in the lower reach than in the middle reach.

Blackside dace (Rhinichthys osculus), red-side shiner (Richardsonius balteatus), and lamprey (Lampetra spp.) were largely restricted to the lower and middle reaches in all streams. Small numbers of lamprey (both amoecoetes and eyed adults) were found in the upper reaches of Congdon, Swartz, and Lake Creeks (1% or less). The highest relative proportion of lamprey was found in lower Swartz Creek (36%). Very silty substrates prevailed for the streambed in this reach.

Analysis of Habitat Inventory Data

Estimates of channel unit area within the study reaches differed in regard to the % error of the estimations (**Table 7**). Error ranged from 10-50% with some of the largest estimation error occurring in lower reach habitats. No consistent pattern was seen in estimation error among channel unit types. For example, pools and glides had

Table 7. Estimates of channel unit area (m^2 ± % error) for the study reaches of Triangle Lake basin (UP=Upper, MD=Middle, LW=Lower). (- = none occurring)

Stream	Reach	Pool	Glide	Riffle	Rapid	Cascade
Lake						
	UP	4,252 ± 26%	472 ± 26%	2,435 ± 30%	11,594 ± 30%	332 ± 33%
	MD	2,185 ± 19%	149 ± 50%	3,529 ± 47%	-	-
	LW	112,710 ± 50%	15,795 ± 35%	47,580 ± 28%	-	-
Swartz						
	UP	194 ± 10%	-	623 ± 28%	231 ± 30%	-
	MD	1,664 ± 36%	54 ± 22%	487 ± 50%	-	-
	LW	5,893 ± 30%	501 ± 35%	1,259 ± 25%	-	-
Pontius						
	MD	90 ± 25%	-	107 ± 40%	-	-
	LW	996 ± 48%	47 ± 40%	215 ± 22%	-	-
Swamp						
	MD	774 ± 17%	91 ± 28%	811 ± 21%	-	-
	LW	5,831 ± 26%	208 ± 27%	2,104 ± 18%	-	-
Little Lake						
	LW	964 ± 27%	31 ± 21%	112 ± 23%	-	-
Congdon						
	UP	1,790 ± 14%	738 ± 28%	1,794 ± 20%	1,077 ± 26%	292 ± 37%
	MD	3,350 ± 23%	1,301 ± 14%	1,971 ± 21%	-	-
	LW	6,197 ± 20%	839 ± 10%	2,158 ± 40%	-	-

estimation error ranging from 10-50%. In general, rapids and cascades had the least estimation error.

Differences existed in habitat characteristics among the study reaches (**Table 8**). Upper reaches tended to be dominated by habitats other than pools and glides (55% - 84% higher gradient units), whereas middle and lower reaches had high proportions of pool and glide habitat (40% - 83%). Streambeds of lower and middle reaches were dominated by medium and fine substrate, whereas upper reaches were dominated by coarse substrates. In lower and middle reaches, stream gradients were generally less than 2.5%, whereas in upper reaches, gradients exceeded 4.7%. Upper reaches tended to be constrained, as ratios of valley floor to channel width were less than 7 (Lamberti et al. 1989). For middle and lower reaches, the valley floor width index was greater than 12. While none of the upper reaches were constrained, valley floor widths in the upper reaches were substantially narrower than in the other reaches.

Substantial differences in habitat were seen among reach types (**Table 9**). Analysis of variance (ANOVA) revealed significant differences for all variables across reach types ($p<0.02$). In general, lower reaches of Triangle Lake basin were low gradient, dominated by pools with fine substrates, and occupied a broad valley floor. In contrast, upper reaches had higher gradient, much non-pool habitat with coarse substrates, and a narrow valley floor. Middle reaches were intermediate in these characteristics, having moderate gradient, about 50% pool/glide habitat, and medium substrates.

To establish reach type groupings for analysis of the fish population and size data, a cluster analysis was

Table 8. Summary of habitat inventory data for the study reaches of Triangle Lake basin (UP=Upper, MD=Middle, LW=Lower).

Stream	Reach	% Pool + Glide	% Mean Gradient	Valley Floor Width Index	% Fine Substrate (<2.5 cm)	% Medium Substrate (2.5-6 cm)	% Coarse Substrate (> 6 cm)
Lake							
	UP	26.4	7.4	3.4	8.0	15.0	77.0
	MD	40.0	1.7	12.5	26.6	51.8	21.6
	LW	69.0	0.6	123.2	76.2	22.0	1.8
Swartz							
	UP	16.0	5.7	7.0	15.0	42.0	43.0
	MD	73.9	1.9	15.1	73.6	24.8	1.6
	LW	83.0	0.5	92.57	77.0	23.0	0.0
Pontius							
	MD	46.0	2.5	20.1	23.4	73.3	3.4
	LW	82.0	0.9	173.8	84.0	15.0	1.0
Swamp							
	MD	49.0	3.8	23.2	22.0	71.0	7.0
	LW	76.0	1.1	71.3	66.7	31.8	1.5
Little Lake							
	LW	69.0	0.6	123.2	76.2	22.0	1.8
Congdon							
	UP	45.0	4.7	6.1	16.0	23.0	61.0
	MD	70.0	2.8	15.9	28.0	69.0	3.0
	LW	79.0	1.9	71.5	51.6	49.0	0.0

Table 9. Summary of habitat variables ($\bar{X}$±SE) used in cluster analysis.

	Reach Type		
	Lower	Middle	Upper
% Gradient	1.0 (±0.2)	2.7 (±0.4)	5.9 (±0.8)
Valley Floor Width Index	86.8 (±16.0)	17.9 (±1.9)	5.5 (±1.1)
% Pool + Glide	79.8 (±2.5)	51.3 (±6.8)	29.1 (±8.5)
% Fine Substrate (particles < 2.5 cm)	74.9 (±4.7)	25.0 (±9.8)	13.0 (±2.5)
% Medium Substrate (particles 2.5-6 cm)	24.2 (±4.9)	66.3 (±9.1)	26.7 (±8.0)
% Coarse Substrate (particles > 6 cm)	0.8 (±0.4)	8.8 (±3.7)	60.3 (±9.8)

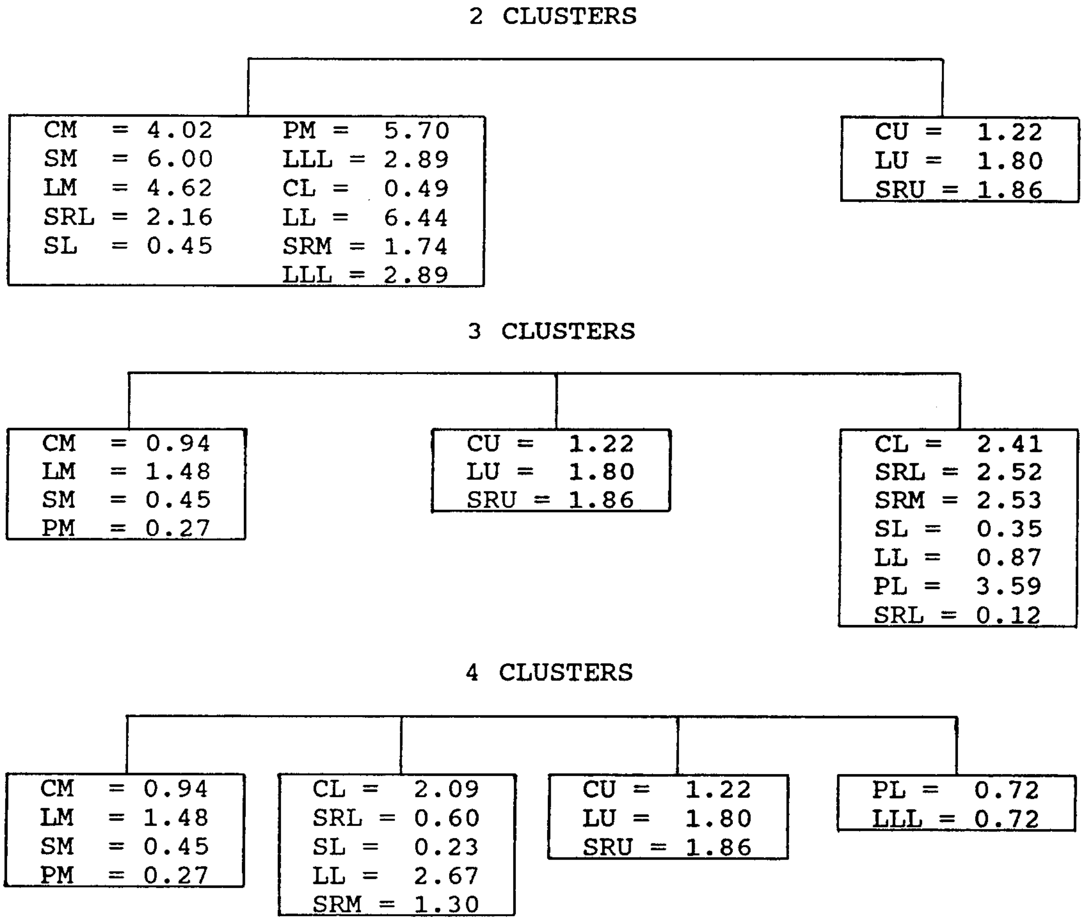
performed on the habitat inventory data using two, three, and four cluster groupings (**Figure 6**). Initially, the three upper reaches were separated from the remainder of the reaches, indicating that the middle and lower reaches were more similar to each other than to the upper reaches. With three clusters, the lower reaches were segregated from the middle reaches, with the exception of the Swartz Creek middle reach, which was grouped with the lower reaches. With four clusters, the Pontius Creek and Little Lake Creek lower reaches were separated from the other lower reaches. The results of the three cluster groupings were used to analyze fish population and size data. Based on the cluster analysis, the Swartz Creek middle reach was redesignated as a lower reach.

The abundance and type of pools varied with reach type (**Figure 7**). Lower reaches had mostly scour and dammed pools, whereas the upper reaches were dominated by plunge pools. Middle reaches typically contained scour pools.

Salmonid Size in Relation to Reach

A frequency distribution of cutthroat trout size in Triangle Lake basin indicated a bimodal distribution (**Figure 8**). Most cutthroat (58%) were less than 8 cm in forklength, probably representing 0+ fish. Some very small (<4 cm) cutthroat were found during summer sampling, and these may represent fish spawned in April or May. In general, few cutthroat were larger than 16 cm. For this study, cutthroat 8 cm and smaller were considered 0+, and cutthroat larger than 8 cm were considered 1+.

Different size distributions of cutthroat were seen among lower, middle, and upper reaches (**Figure 9**). Lower reaches had high numbers of 0+ cutthroat (75%) but few 1+



CL = Congdon Creek lower reach
LL = Lake Creek lower reach
LLL = Little Lake Creek lower reach
PL = Pontius Creek lower reach
SL = Swamp Creek lower reach
SRL = Swartz Creek lower reach
LM = Lake Creek middle reach
PM = Pontius Creek middle reach
SM = Swamp Creek middle reach
SRM = Swartz Creek middle reach
CM = Congdon Creek middle reach
CU = Congdon Creek upper reach
LU = Lake Creek upper reach
SRU = Swartz Creek upper reach

Figure 6. Cluster analysis of habitat inventory data using 2, 3, and 4 clusters. The number with each reach refers to the distance of each sample from the cluster centroid.

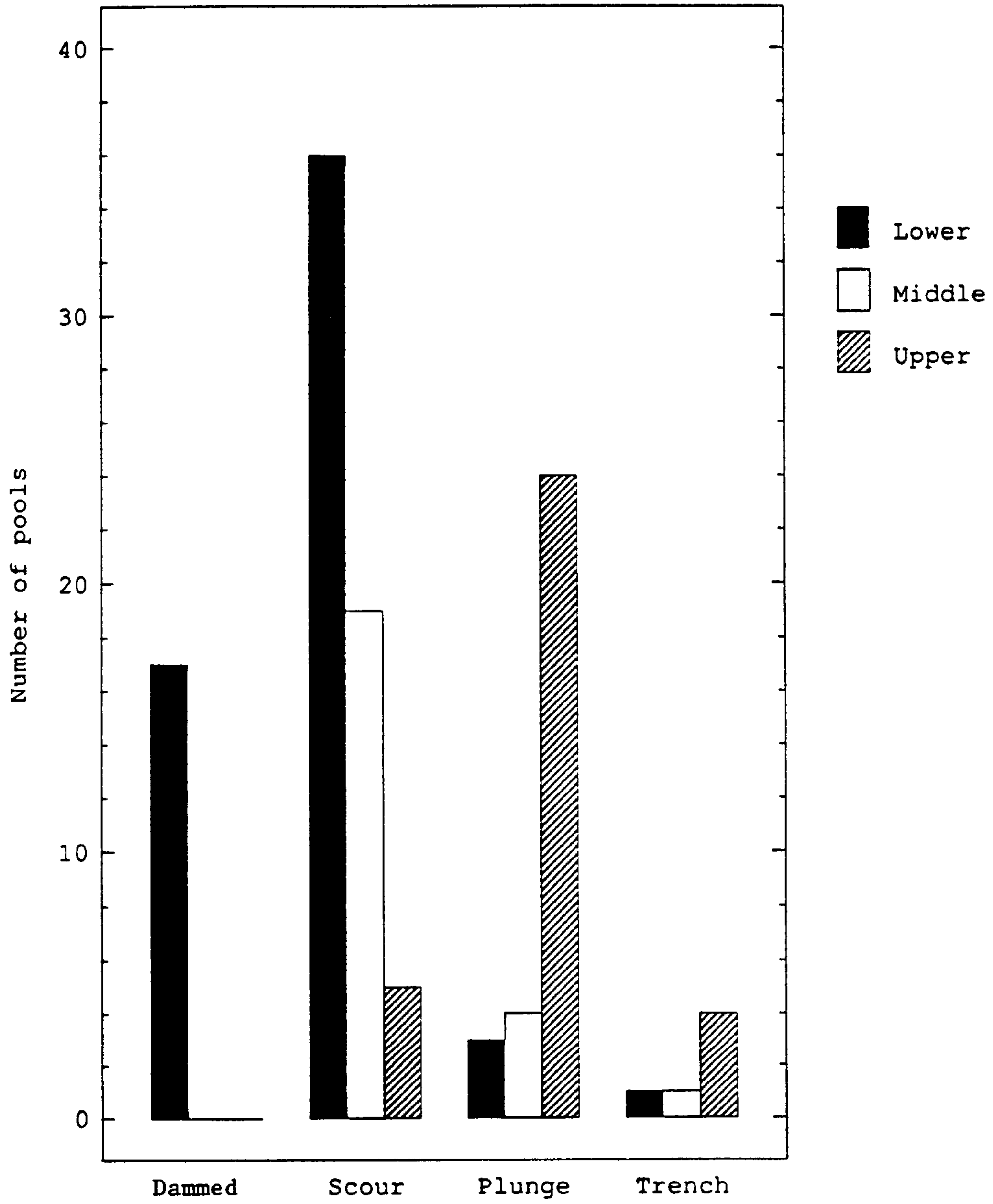


Figure 7. Pool type distribution by reach in Triangle Lake basin.

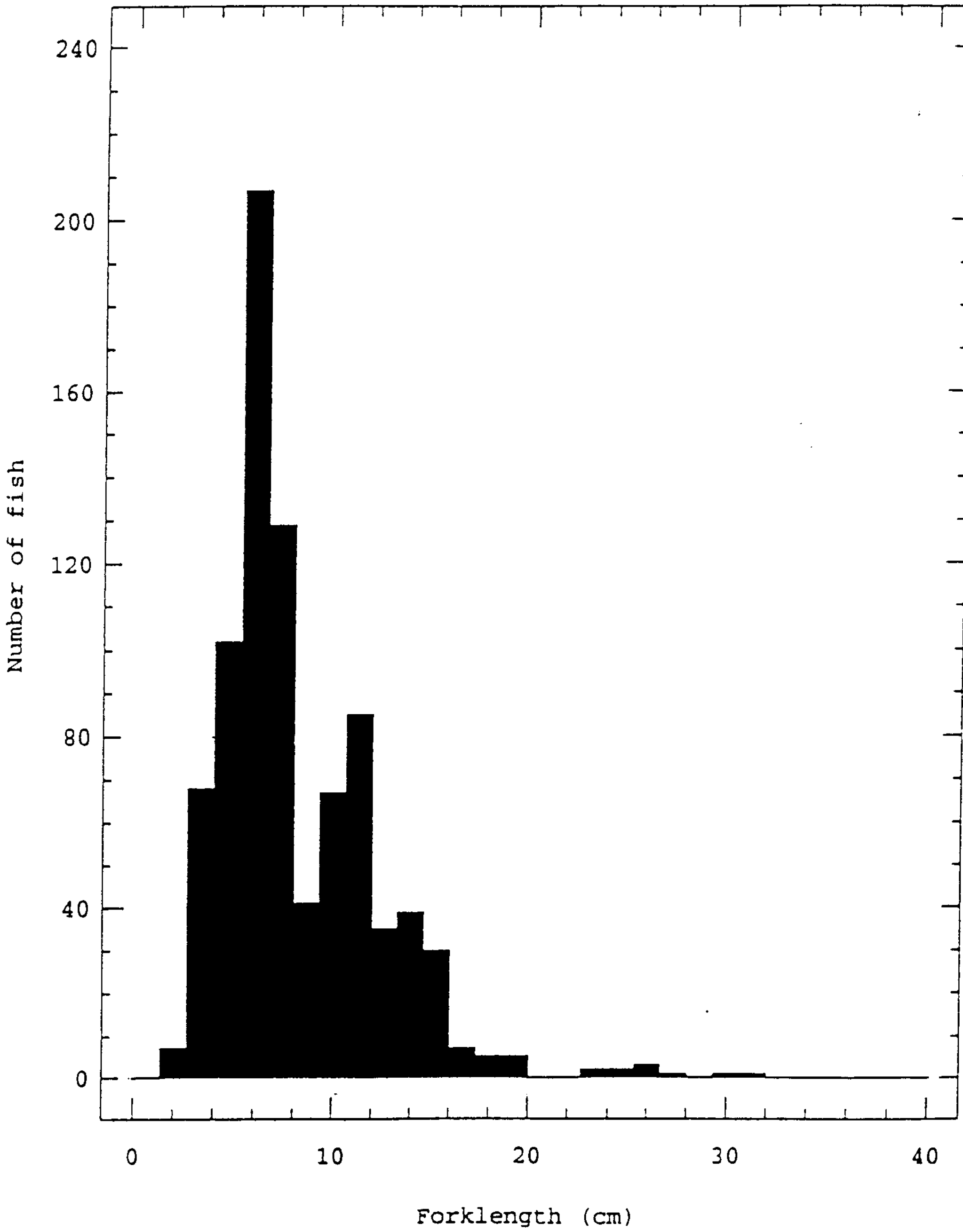


Figure 8. Frequency histogram of forklengths of all cutthroat trout collected in Triangle Lake basin.

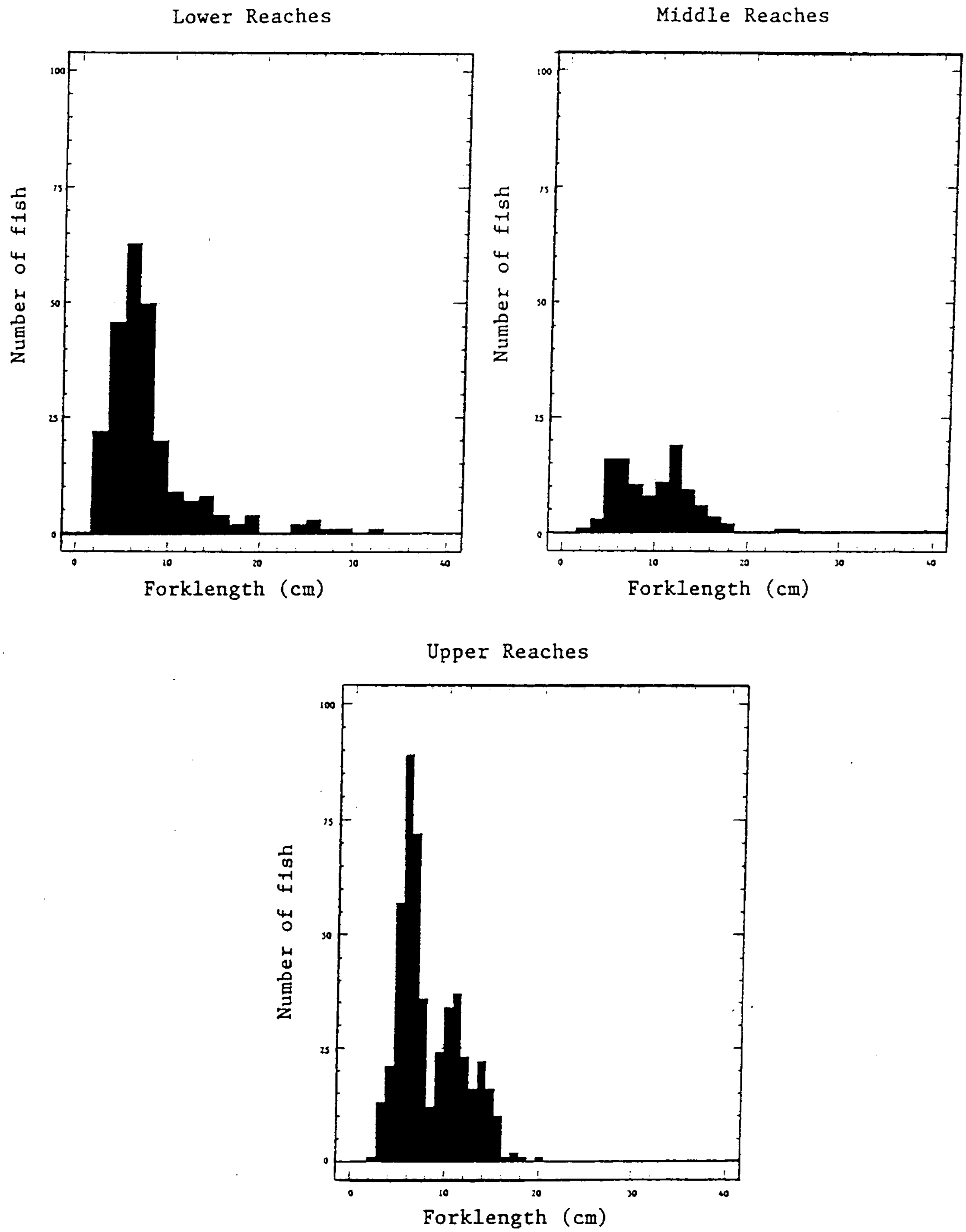


Figure 9. Frequency histogram of forklengths of cutthroat trout in lower, middle, and upper reaches of Triangle Lake basin.

cutthroat (28%). However, the lower reaches had the largest cutthroat, with several individuals over 24 cm. The middle reaches had the highest proportion of 1+ fish (61%), as well as several trout over 23 cm (probably 2+ or 3+ fish). The upper reaches had a high frequency of 0+ fish (55%) and also a large 1+ cohort (45%). No individuals in the upper reaches were larger than 20 cm.

Analysis of variance of the log-transformed size data revealed significant differences in the average size of 1+ cutthroat trout among reach types ($p<0.01$) (**Figure 10**). Subsequent multiple contrast analyses (Tukey's Test; $\alpha=0.05$) showed that lower and upper reaches were significantly different in average 1+ trout size. 1+ cutthroats were largest in the lower reaches (13.5 ± 0.7 cm; $\overline{X}\pm SE$) and smallest in the upper reaches (11.5 ± 0.2 cm; $\overline{X}\pm SE$). 1+ cutthroat trout in the middle reaches were intermediate in size between the other two reach types (12.5 ± 0.3 cm; $\overline{X}\pm SE$). 0+ cutthroat trout average size was not significantly different between reach types ($p=.166$).

A bimodal distribution of rainbow trout sizes was observed in the basin, with one peak at about 6 cm and another peak at about 12 cm (**Figure 11**). These probably represented two cohorts: 0+ and 1+ age classes. It is likely that these fish leave the basin as steelhead smolts. Only one rainbow over 20 cm was found, which may be a resident fish from the planted steelhead fry.

Differences in size distribution of cutthroat trout were seen among the six study streams (**Figure 12**), which may be related to the distribution of reach types in each stream (see below). For example, cutthroats over 20 cm were found only in Congdon, Lake, and Swartz Creeks. Swamp, Pontius,

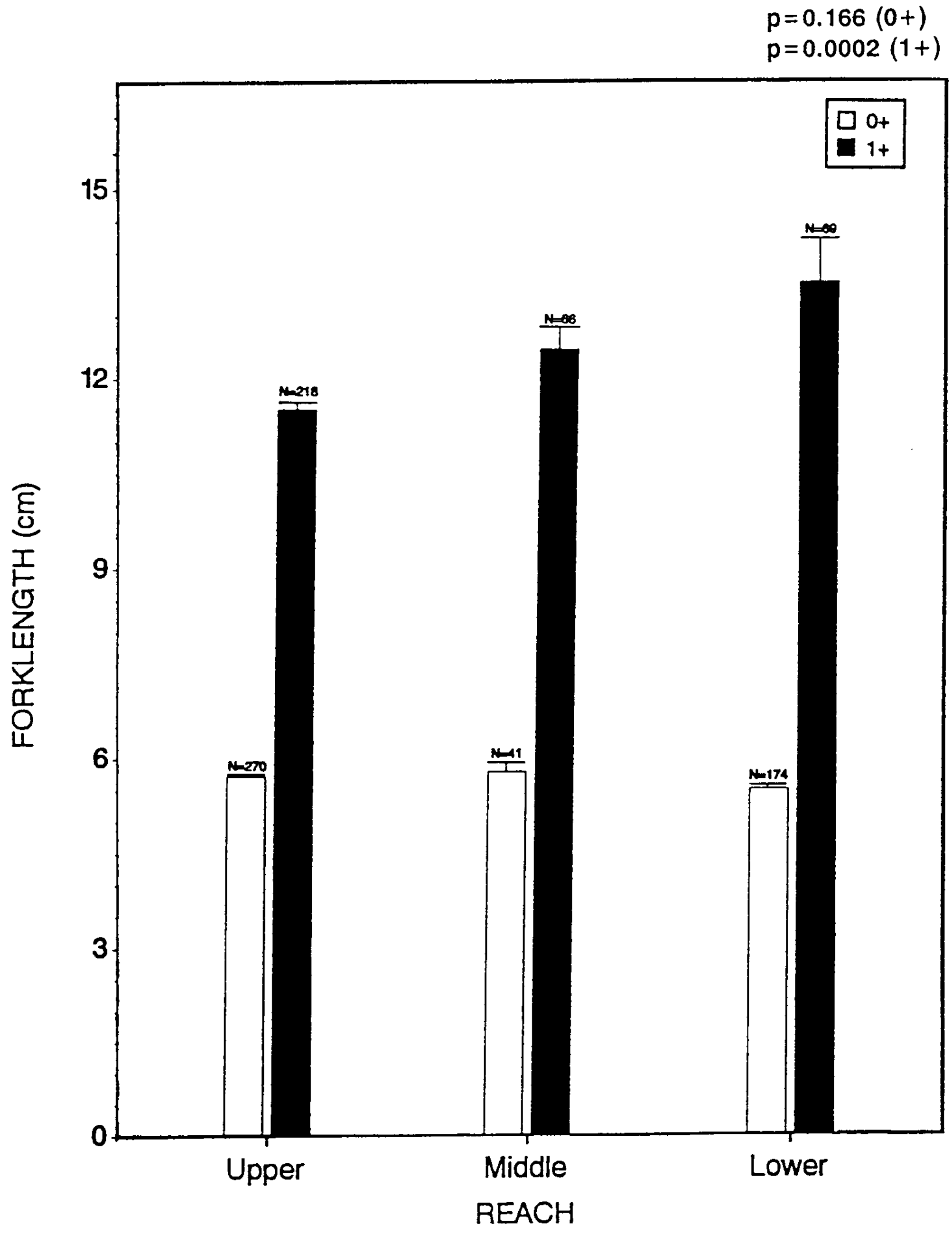


Figure 10. Size of cutthroat trout ($\overline{X}$+SE) by reach in Triangle Lake basin.

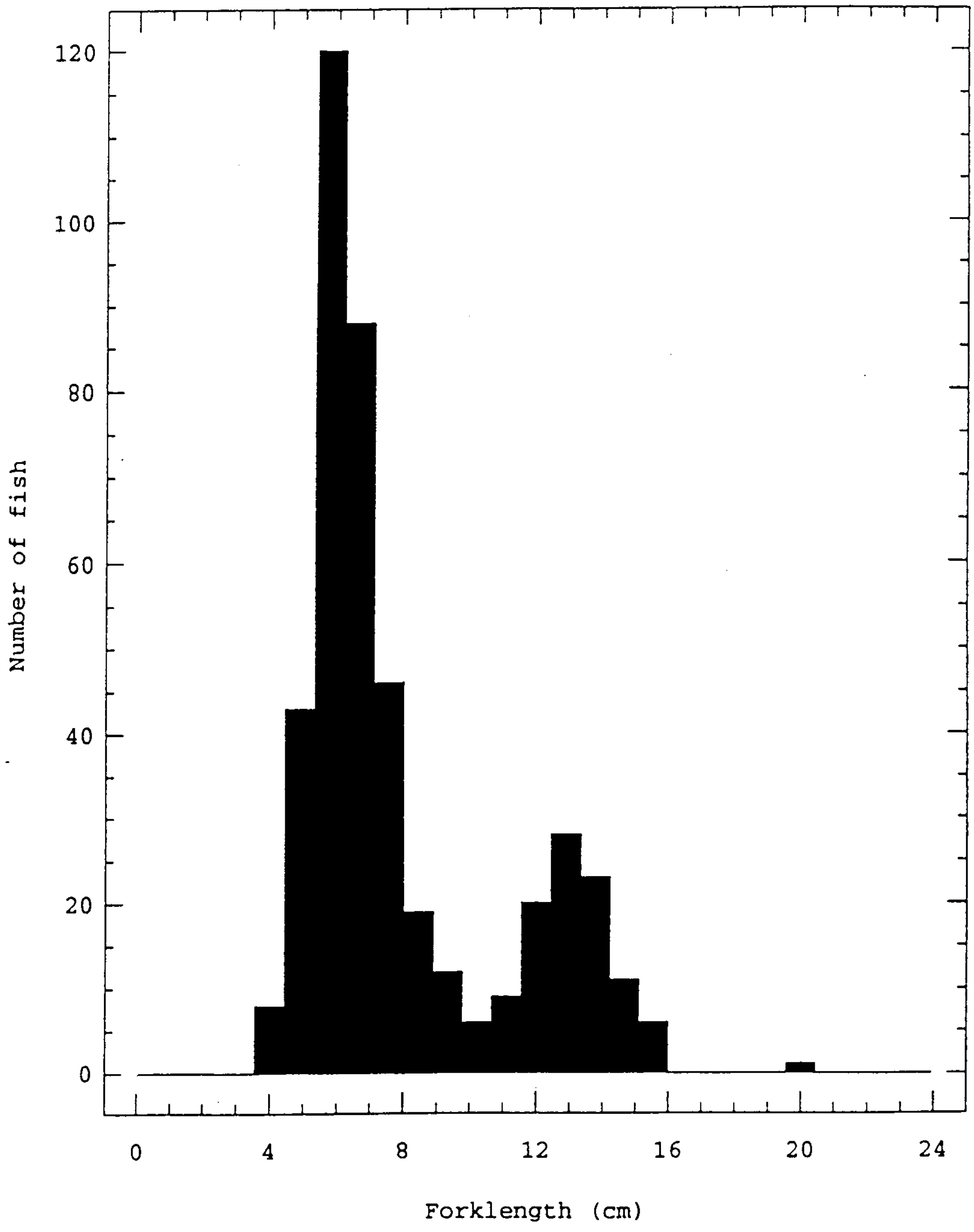


Figure 11. Frequency histogram of forklengths of rainbow trout in Triangle Lake basin.

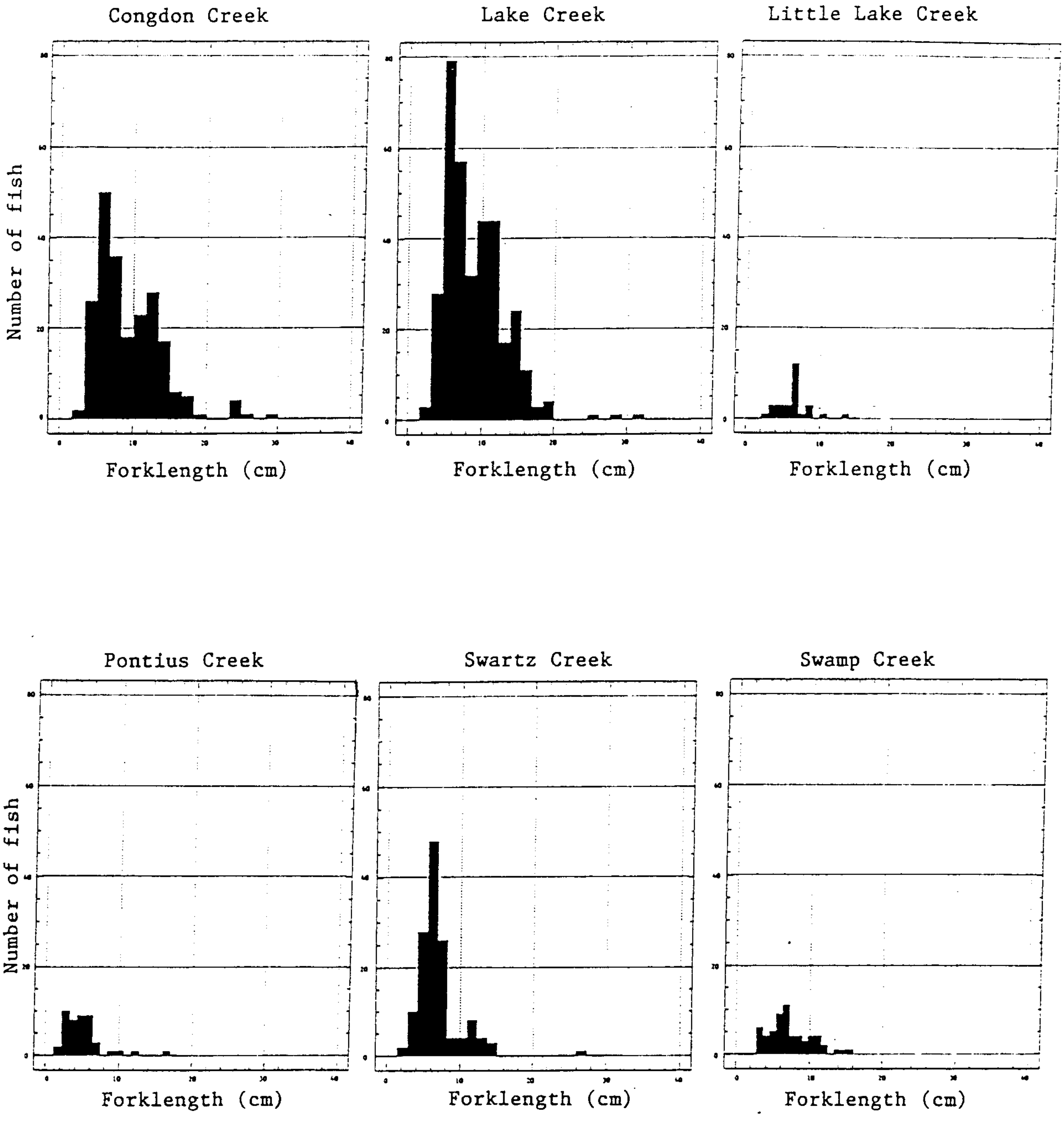


Figure 12. Frequency histograms of forklengths of cutthroat trout for the six study streams in Triangle Lake basin.

and Little Lake Creeks had higher proportions of fry than did the other streams. Pontius Creek, in particular, had a very high proportion of 0+ fish.

Analysis of variance of the log-transformed data showed significant differences in cutthroat trout size distribution among streams ($p<0.0001$). Multiple contrasts (Tukey's Test; $\alpha=0.05$) revealed three stream groupings: (1) Lake and Congdon Creeks were not significantly different in cutthroat size, (2) Little Lake, Swartz, and Swamp Creeks had similar sized cutthroats, and (3) Pontius Creek, with the smallest cutthroats, was different from all other streams.

Cutthroat Size in Relation to Channel Unit Type

Because the mean size of cutthroat trout differed significantly among reach types, the data were stratified by reach type prior to analyzing the size distribution among channel unit types. The mean size of cutthroat trout did not differ significantly (ANOVA $p=0.14$) among channel unit types in the lower reaches (**Figure 13**). However, because only three cutthroats were collected from glides in lower reaches, conclusions about size distribution in glides cannot be drawn.

In middle reaches, the mean size of cutthroat trout was significantly different among channel unit types (ANOVA $p<0.002$) (**Figure 14**). Multiple contrasts (Tukey) indicated that pools had significantly larger fish than did glides or riffles, which were not significantly different. However, the sample size for glides was small, which makes conclusions about glides difficult.

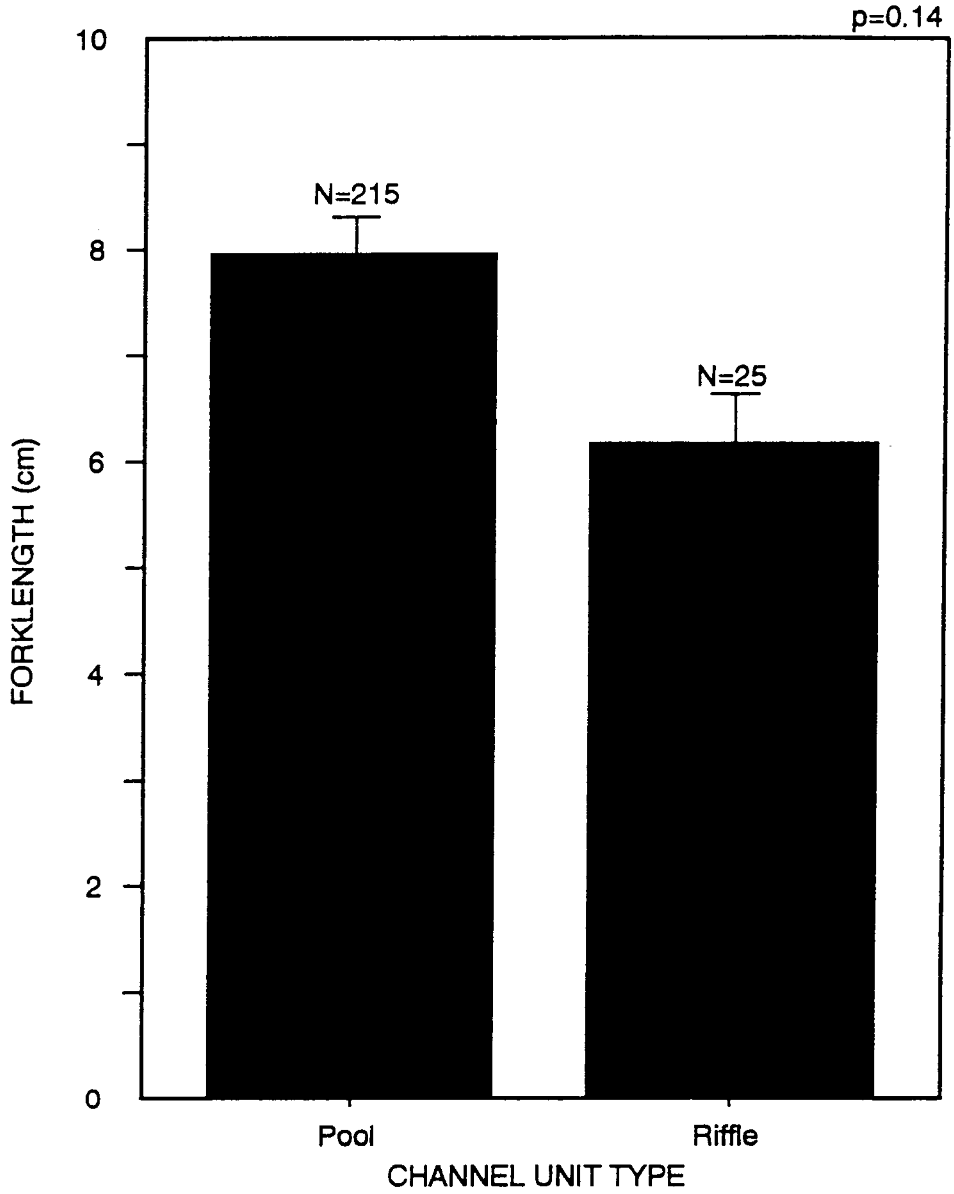


Figure 13. Size of cutthroat trout ($\bar{X}$+SE) in pools and riffles for the lower reaches of Triangle Lake basin.

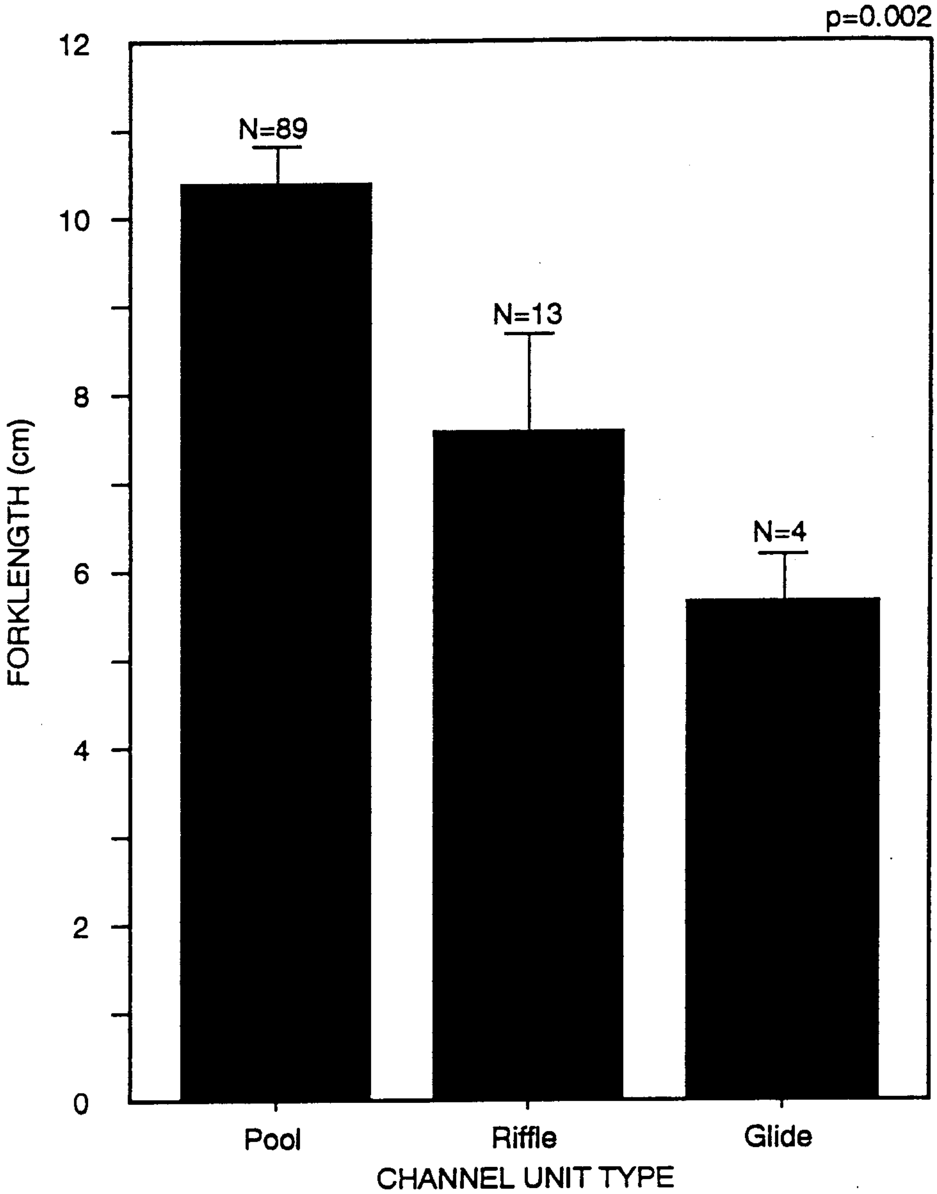


Figure 14. Size of cutthroat trout ($\bar{X}$+SE) in pools, riffles, and glides for the middle reaches of Triangle Lake basin.

Significant differences in mean cutthroat size (ANOVA p=0.01) existed among channel unit types in upper reaches (**Figure 15**). However, multiple contrasts (Tukey) were unable to precisely identify where differences resided. In general, pools and rapids contained the largest fish in the upper reaches.

Cutthroat Density in Relation to Reach

A significant difference in the mean density of cutthroat trout was found among reach types (**Figure 16**) as indicated by the Kruskal-Wallis (K-W) test (p<0.02). Overall, cutthroat trout were most abundant in the upper reaches and least abundant in the lower reaches.

Different patterns of cutthroat age-class distribution were observed in the density of 0+ and 1+ cutthroat trout. 1+ cutthroat trout were most abundant in upper and middle reaches and least abundant in lower reaches (K-W p<0.01) (**Figure 17**). 0+ cutthroat trout density was not significantly different among reaches (K-W p=0.25) (**Figure 18**).

Cutthroat Density in Relation to Channel Unit Type

A significant difference in the mean density of cutthroat trout was found among channel unit types in the upper reaches (K-W p=0.03) (**Figure 19**). Overall densities of cutthroat trout were highest in pools and rapids. The mean density of 0+ cutthroat trout did not differ significantly among channel unit types in the upper reaches (K-W p=0.73) (**Figure 20**). However, pools had higher average densities than the other channel unit types. 1+ cutthroat

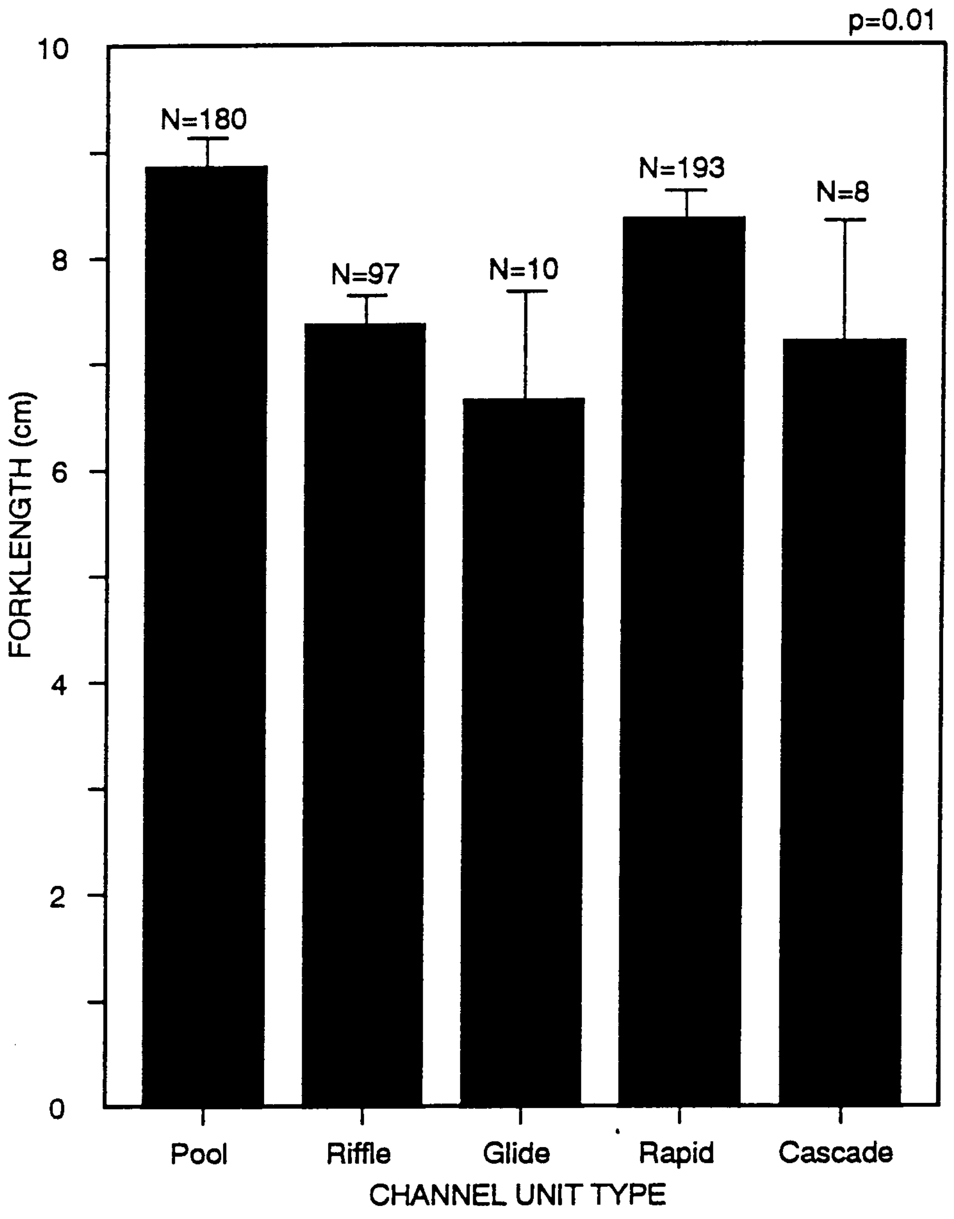


Figure 15. Size of cutthroat trout ($\bar{X}$+SE) by channel unit type for the upper reaches of Triangle Lake basin.

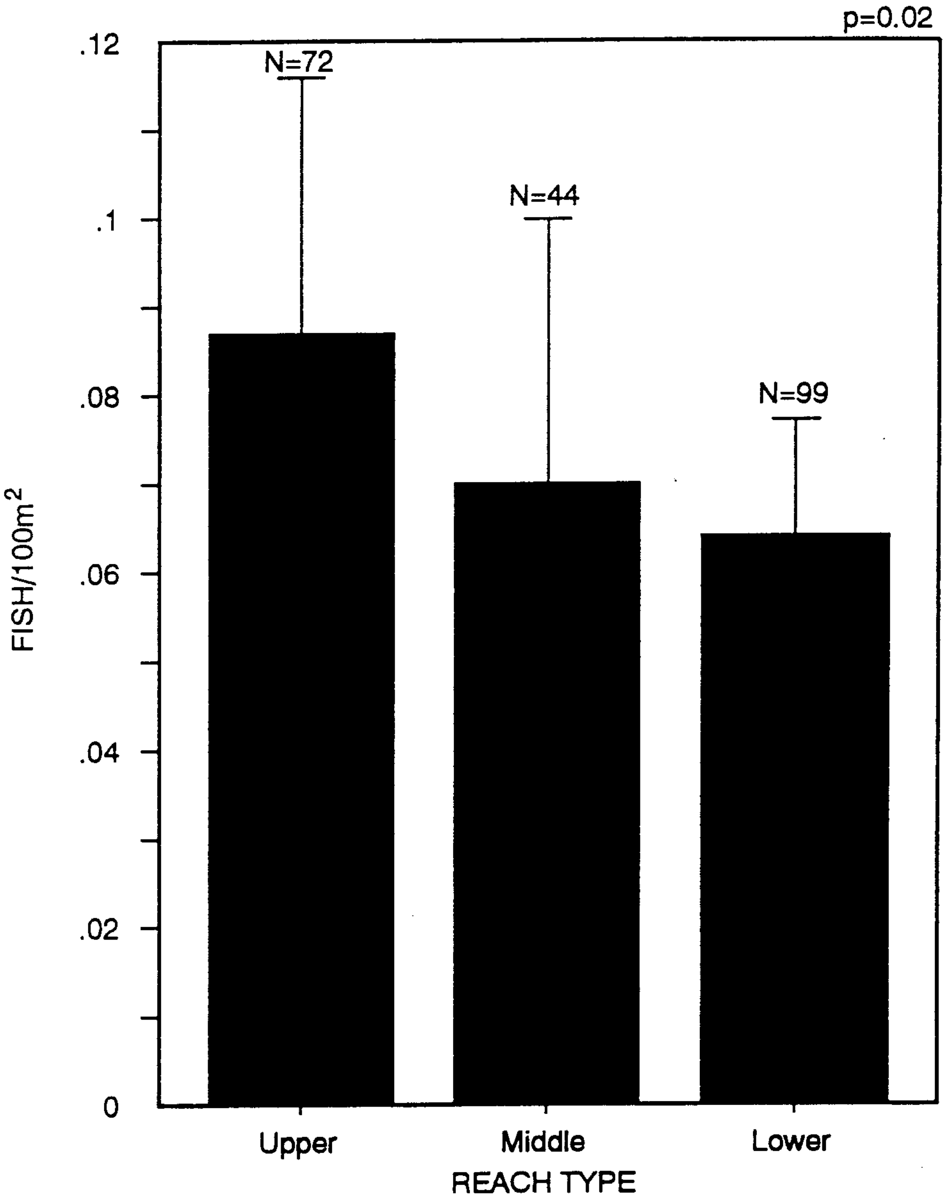


Figure 16. Mean cutthroat trout density ($\bar{X}$+SE) for the three reach types in Triangle Lake basin.

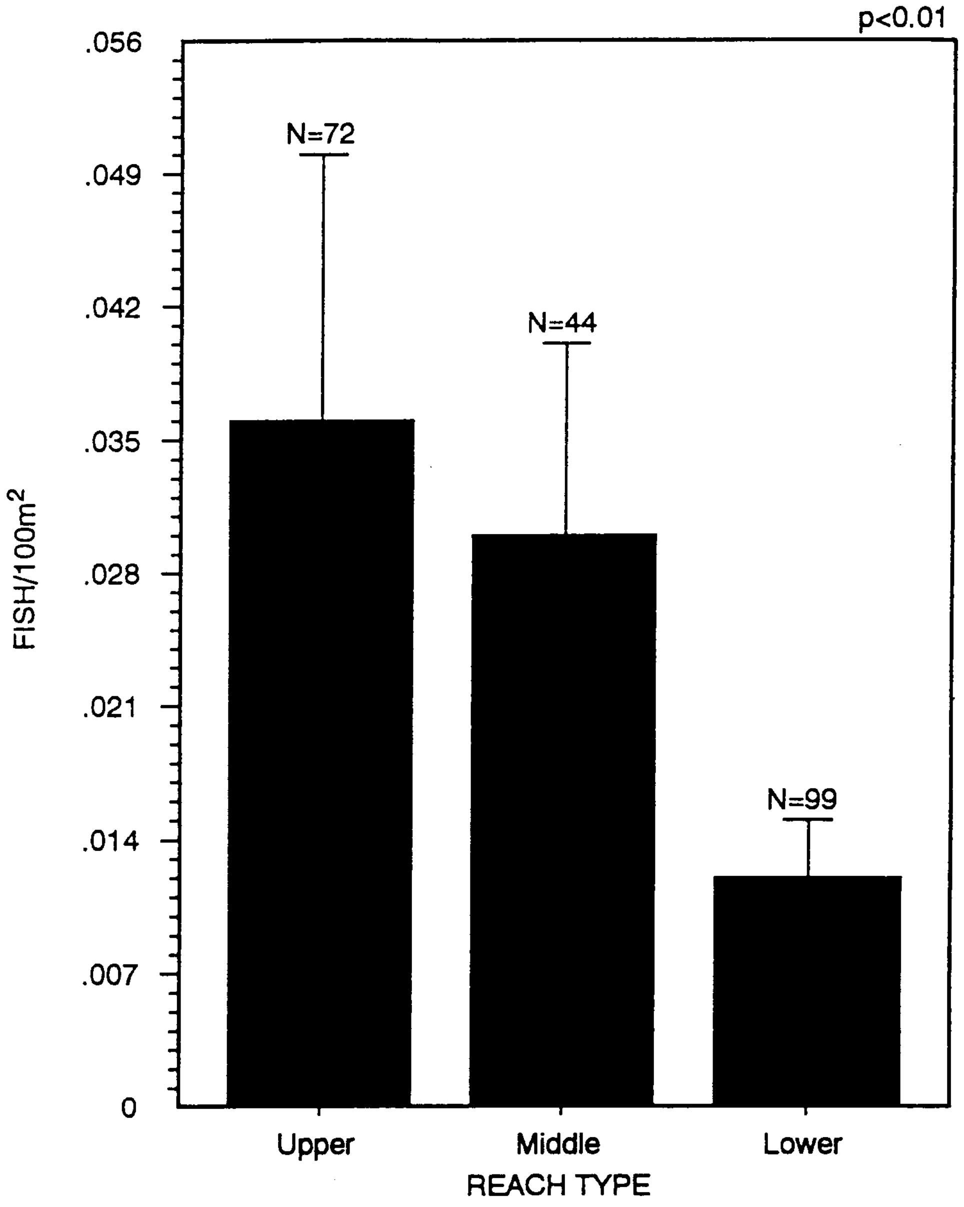


Figure 17. Mean density of 1+ cutthroat trout ($\bar{X}$+SE) by reach in Triangle Lake basin.

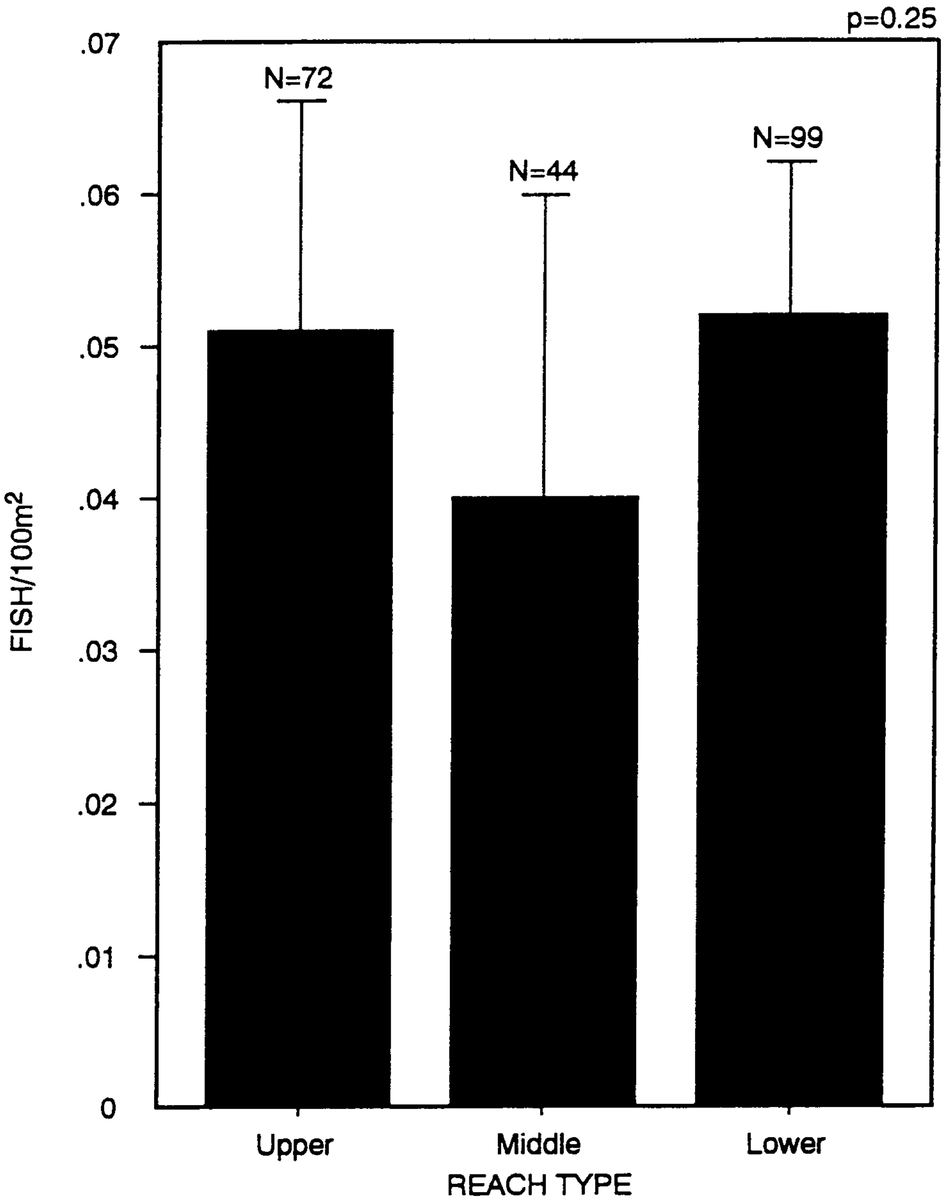


Figure 18. Mean density of 0+ cutthroat trout ($\overline{X}$+SE) by reach in Triangle Lake basin.

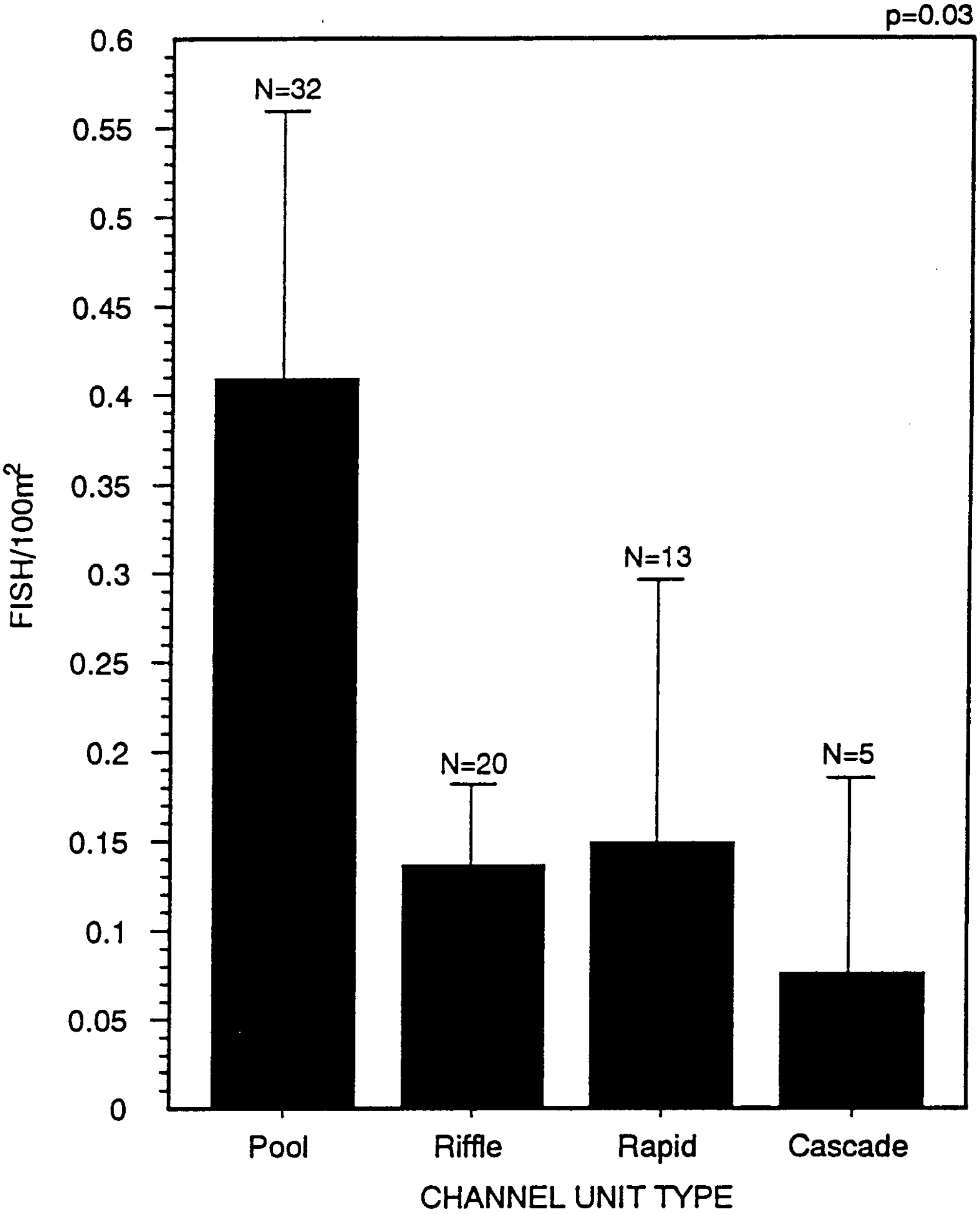


Figure 19. Mean density of cutthroat trout ($\bar{X}$+SE) by channel unit type for the upper reaches of Triangle Lake basin.

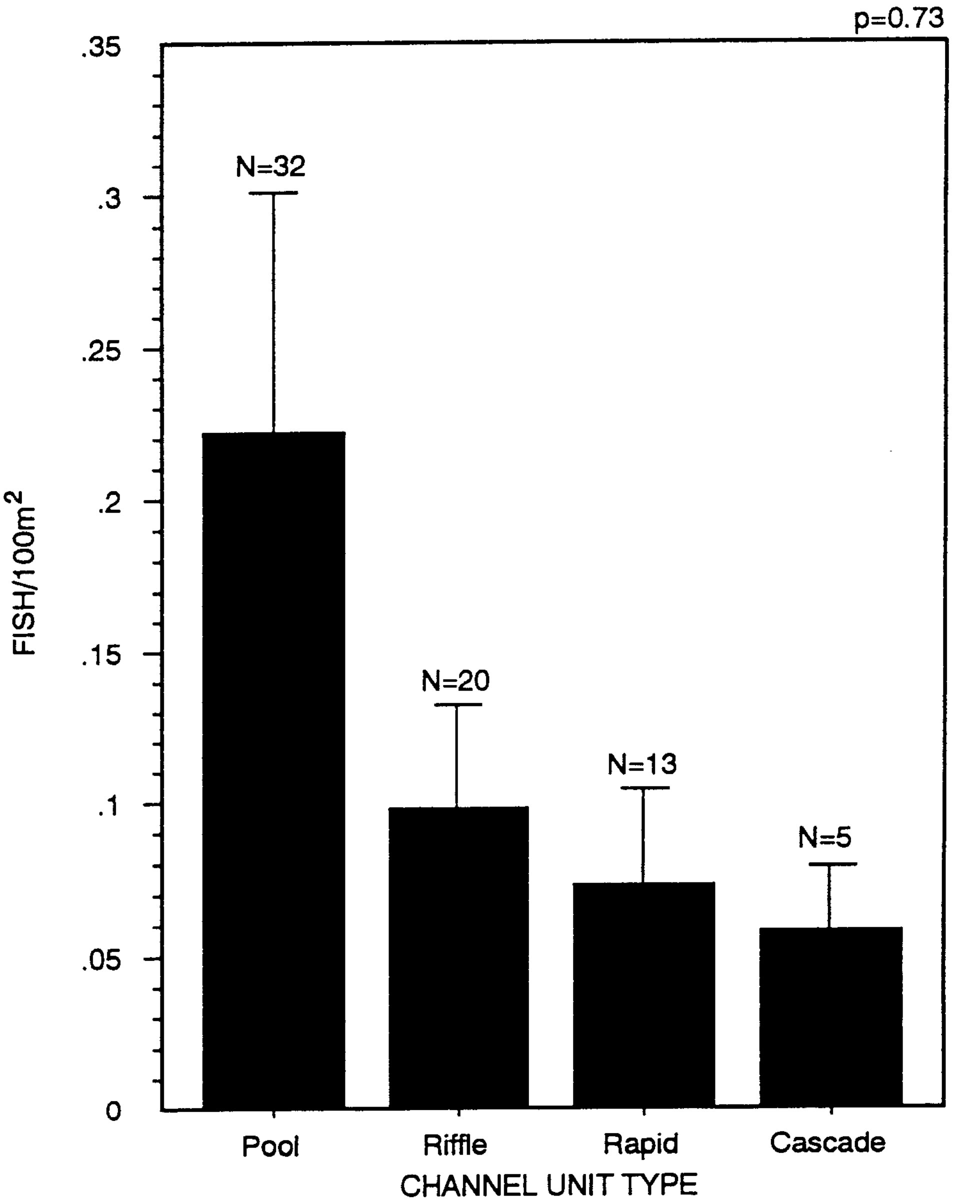


Figure 20. Mean density of 0+ cutthroat trout ($\bar{X}$+SE) by channel unit type for the upper reaches of Triangle Lake basin.

were most abundant in pools and rapids, and least abundant in riffles and cascades in the upper reaches (K-W p=0.006) (**Figure 21**). Only two glides were sampled in the upper reaches of Triangle Lake basin, and no conclusive statements concerning cutthroat density in glides can be made.

In the middle reaches of Triangle Lake basin, overall densities of cutthroat trout were higher in pools than in riffles (K-S p=0.003) (**Figure 22**), as were densities of both 0+ cutthroat trout (**Figure 23**) and 1+ cutthroat trout (**Figure 24**) (K-S p<0.02). As only one glide was sampled in the middle reaches, statistical analysis of this channel unit type was not possible.

Overall densities of cutthroat trout were significantly different among channel unit types in the lower reaches of Triangle Lake basin (K-W p=0.0001) (**Figure 25**). The highest densities of cutthroat trout were found in pools. 0+ cutthroat were most abundant in pools and less abundant in riffles and glides (K-W p=0.002) (**Figure 26**). Densities of 1+ cutthroat trout in the lower reaches were significantly higher in pools than in riffles (K-S p=0.001) (**Figure 27**). No 1+ cutthroat were found in glides in the lower reaches of Triangle Lake basin.

Salmonid Density in the Study Streams

Extrapolations of salmonid density to entire reaches using the physical habitat inventory were conducted for each reach in the five study streams. An estimate of salmonid density, and its 95% confidence interval, for each study reach is presented here.

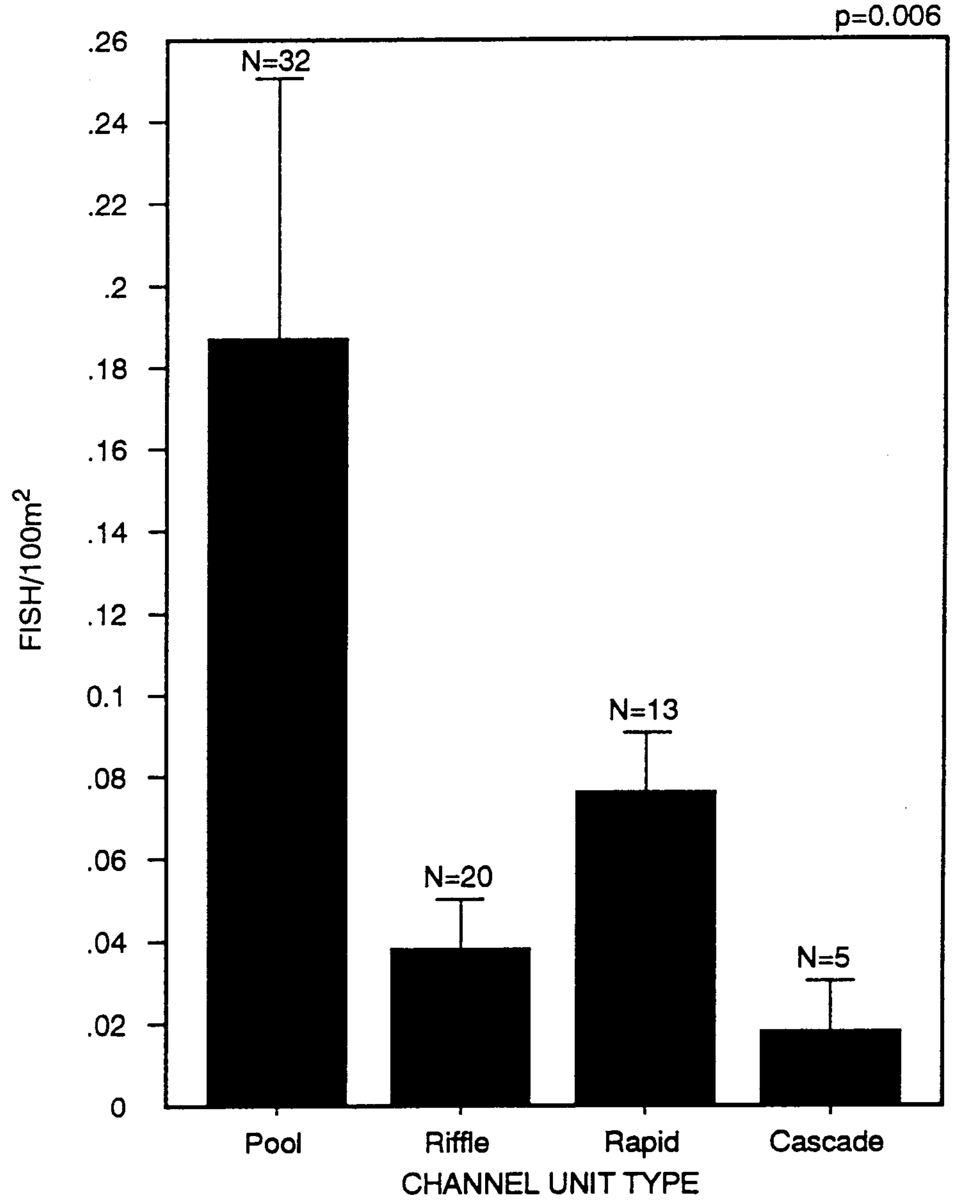


Figure 21. Mean density of 1+ cutthroat trout ($\bar{X}$+SE) by channel unit type for the upper reaches of Triangle Lake basin.

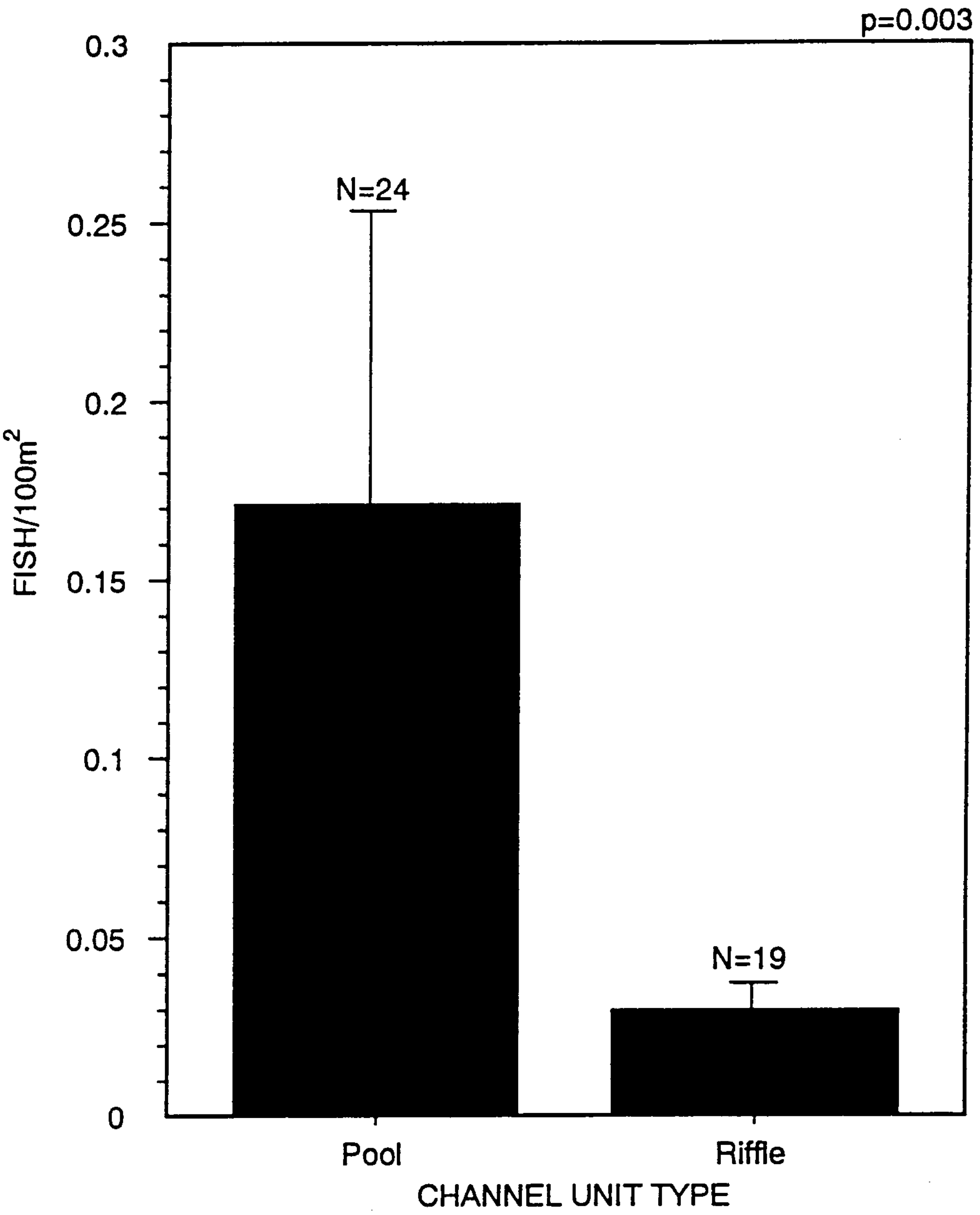


Figure 22. Mean density of cutthroat trout ($\bar{X}$+SE) in pools and riffles for the middle reaches of Triangle Lake basin.

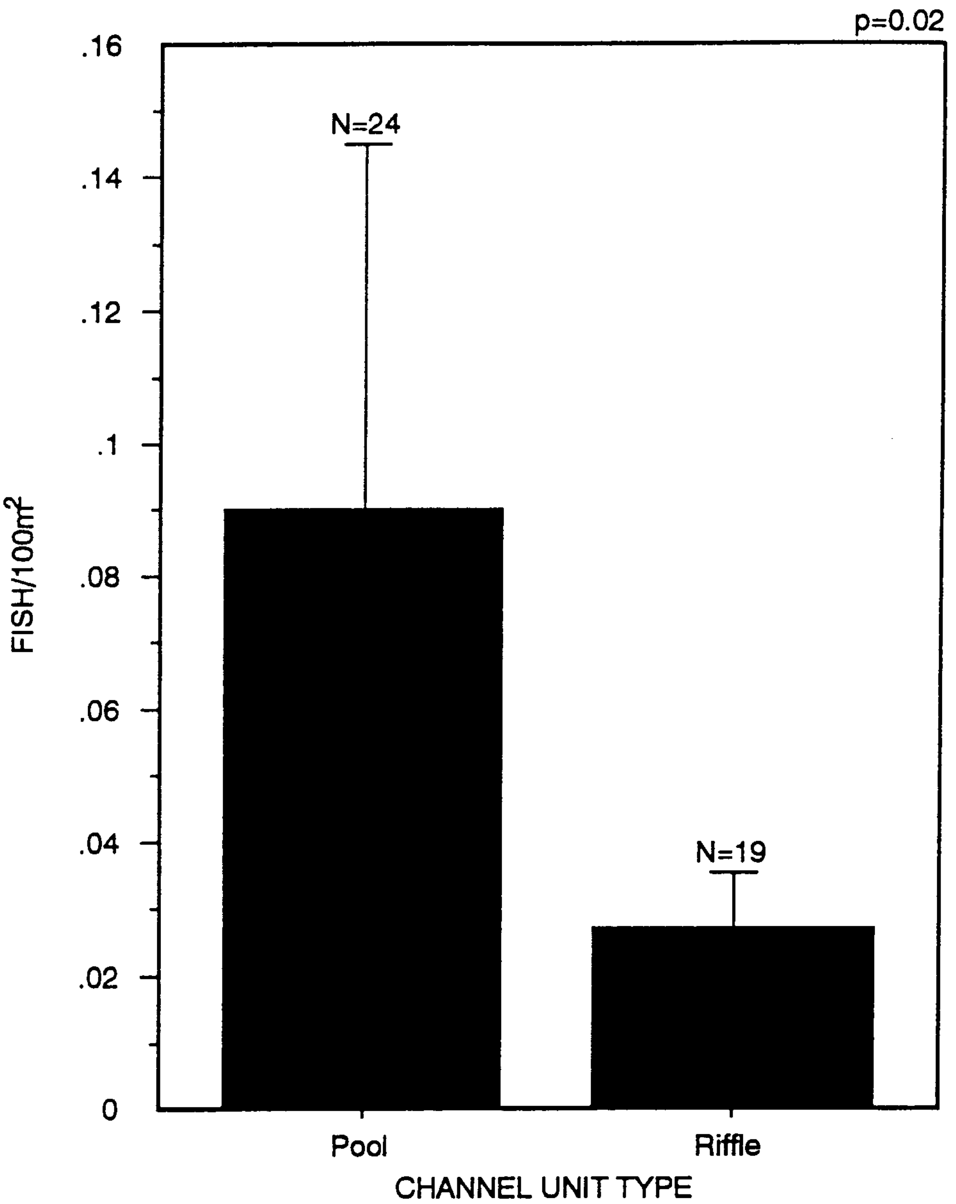


Figure 23. Mean density of 0+ cutthroat trout ($\bar{X}$+SE) in pools and riffles for the middle reaches of Triangle Lake basin.

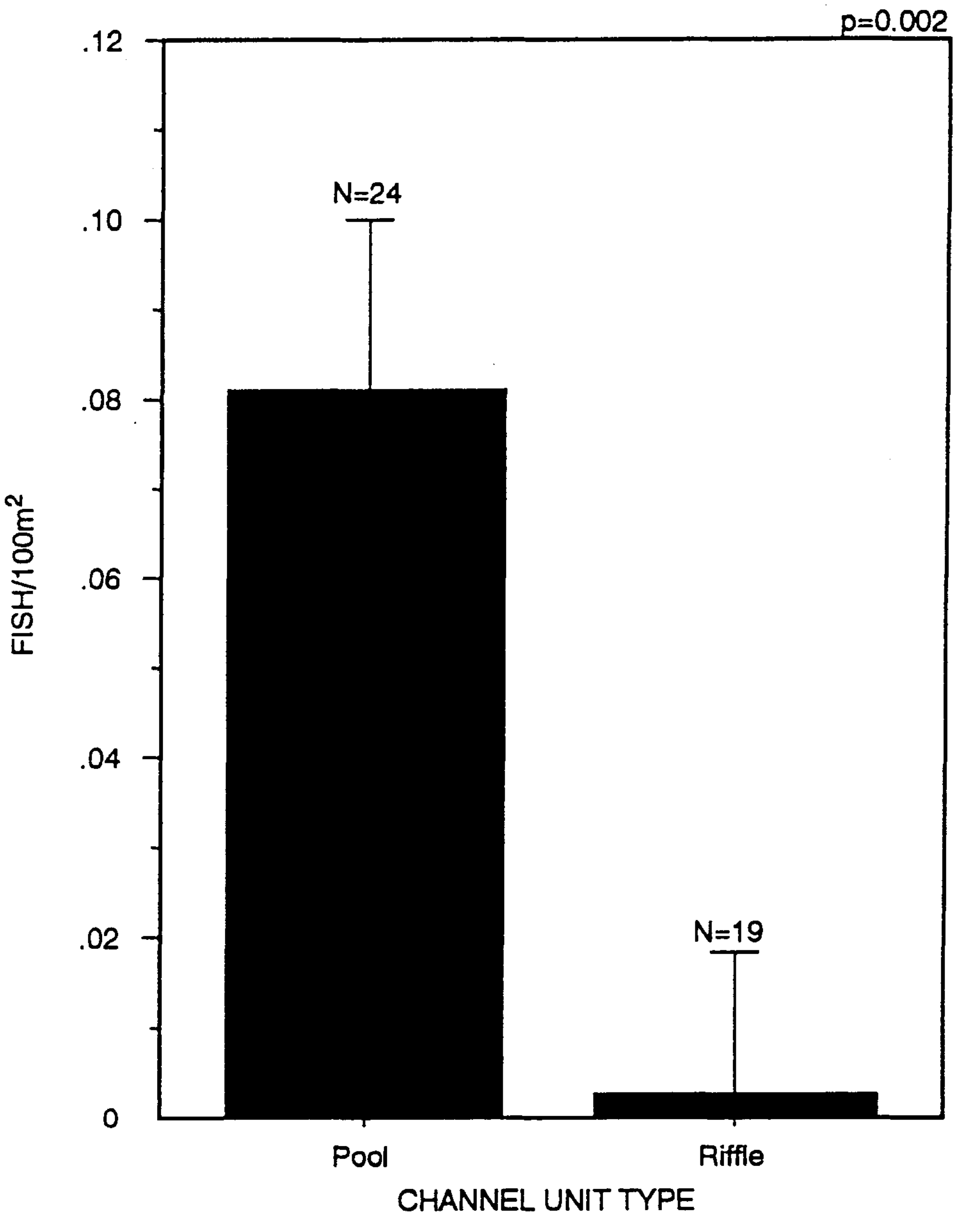


Figure 24. Mean density of 1+ cutthroat trout ($\bar{X}$+SE) in pools and riffles for the middle reaches of Triangle Lake basin.

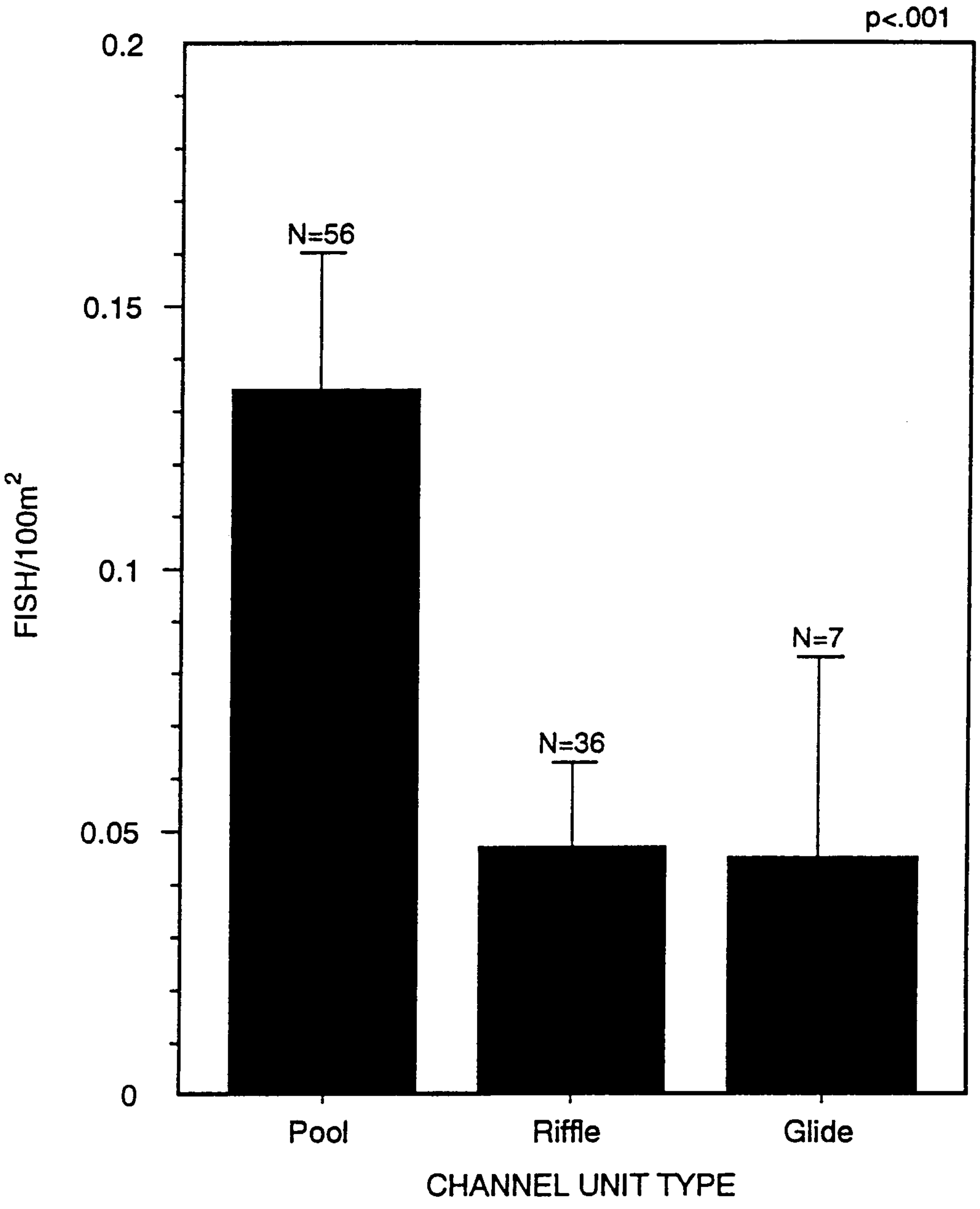


Figure 25. Mean density of cutthroat trout ($\bar{X}$+SE) in pools, riffles, and glides for the lower reaches of Triangle Lake basin.

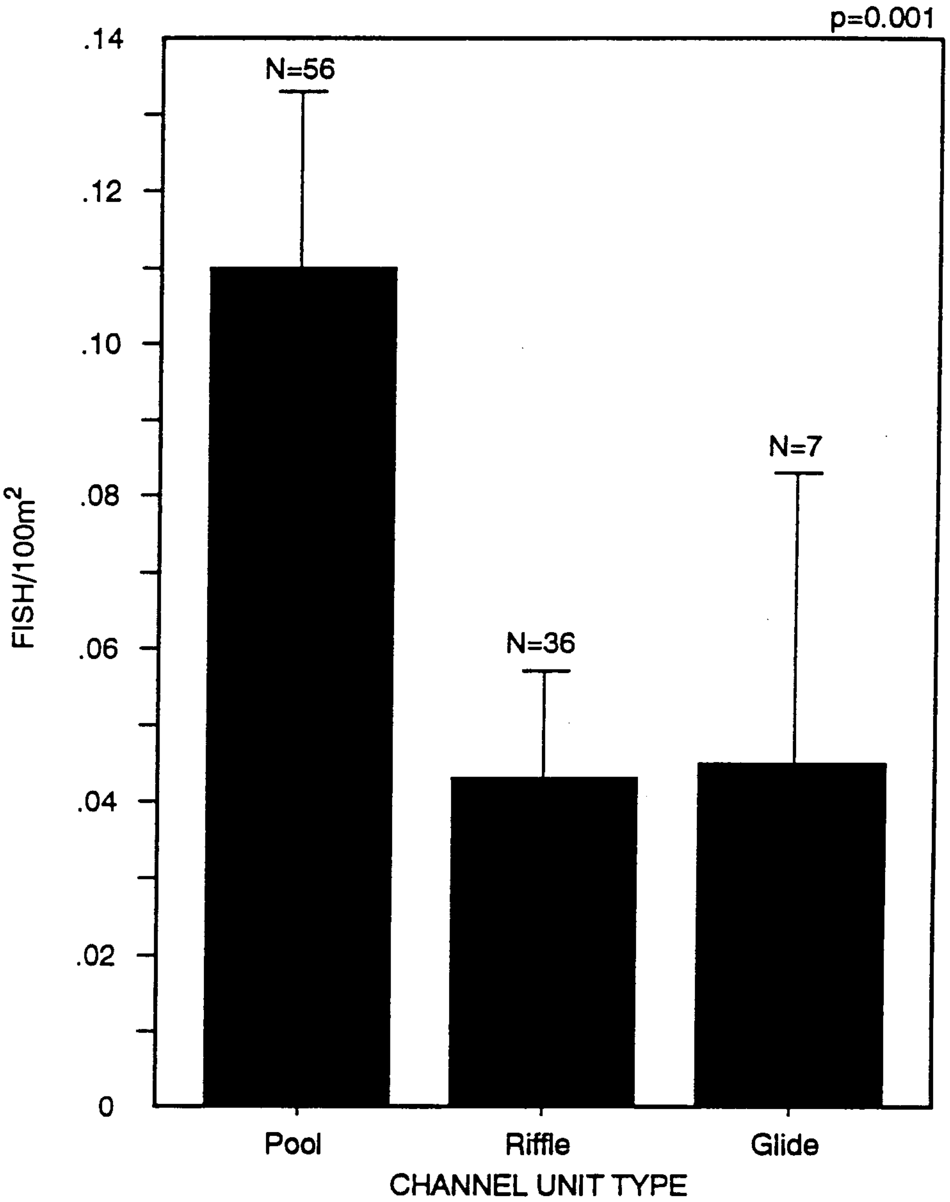


Figure 26. Mean density of 0+ cutthroat trout ($\bar{X}$+SE) in pools, riffles, and glides for the lower reaches of Triangle Lake basin.

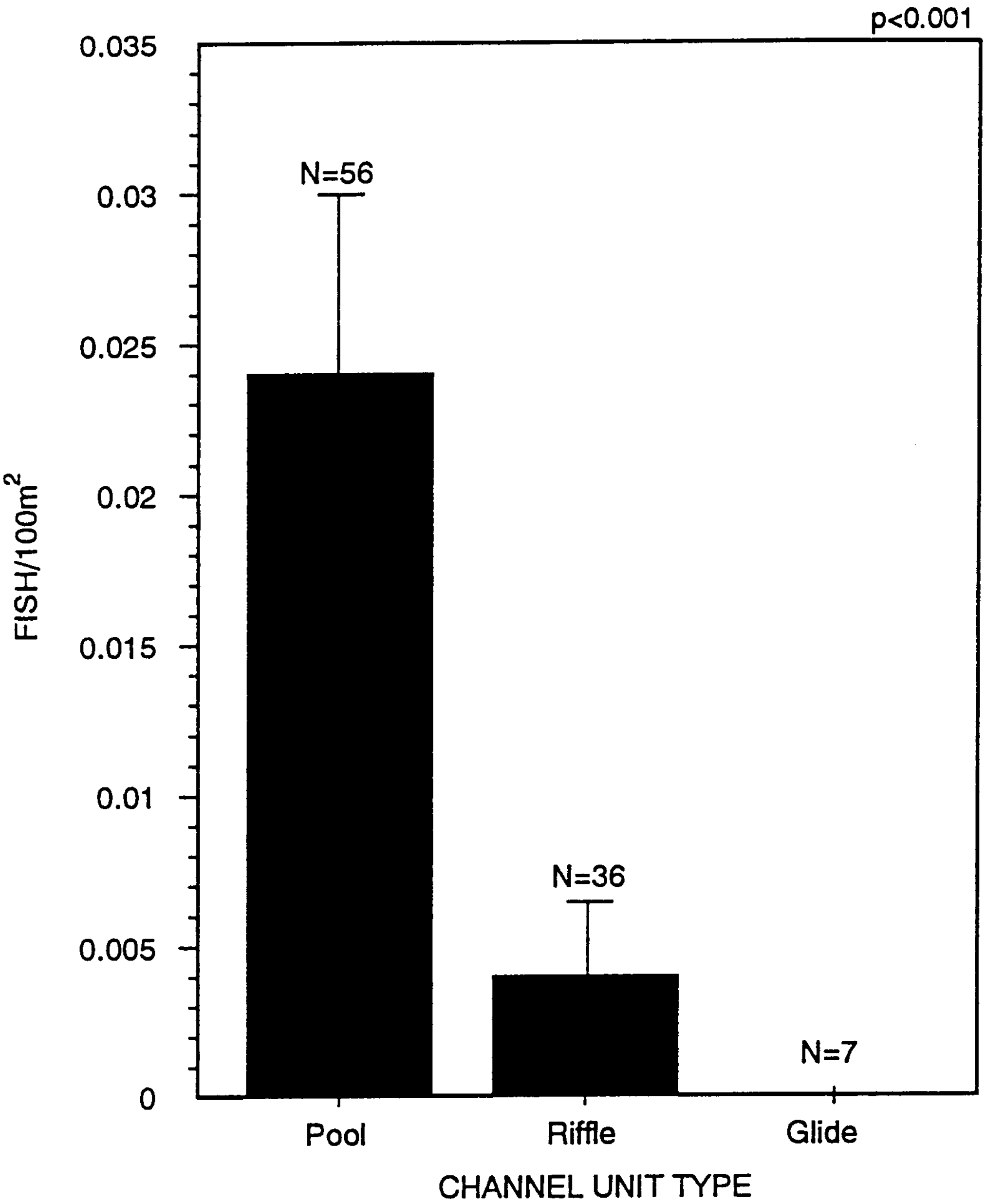


Figure 27. Mean density of 1+ cutthroat trout ($\bar{X}$+SE) in pools, riffles, and glides for the lower reaches of Triangle Lake basin.

Rainbow trout were found only in Lake and Congdon Creeks. The highest density of rainbow trout was found in the upper reach of Lake Creek (**Figure 28**). Rainbow trout were also found in the middle reaches of Congdon and Lake Creeks, but at lower densities than in the upper reaches. Very low densities of rainbow trout were found in the lower reach of Congdon Creek.

The upper reach of Congdon Creek had a higher density of 1+ cutthroat than the upper reaches of Swartz Creek and Lake Creek (**Figure 29**). In contrast, 0+ cutthroat were most abundant in the upper reach of Lake Creek and considerably less abundant in the upper reaches of Swartz and Congdon Creeks.

In general, 1+ cutthroat trout were slightly more abundant in the middle reaches than in the upper reaches, with the exception of Lake Creek, where no 1+ cutthroat trout were found (**Figure 30**). Estimated 0+ densities in the middle reaches were lower than 0+ densities in the upper reaches, with the exception of Swartz Creek, which had a higher 0+ density in the middle reaches.

The lowest cutthroat trout densities occurred in the lower reaches of Triangle Lake basin (**Figure 31**). The lower reach of Lake Creek had the lowest densities of both 0+ and 1+ cutthroat trout. Among lower reaches, the highest density of 1+ cutthroat trout was found in Pontius Creek. Densities of 1+ cutthroat trout were similar in Swamp and Little Lake Creeks. Congdon and Swartz Creeks also had similar 1+ cutthroat trout densities. 0+ cutthroat densities were much higher in the lower reach of Pontius Creek than in the other five streams.

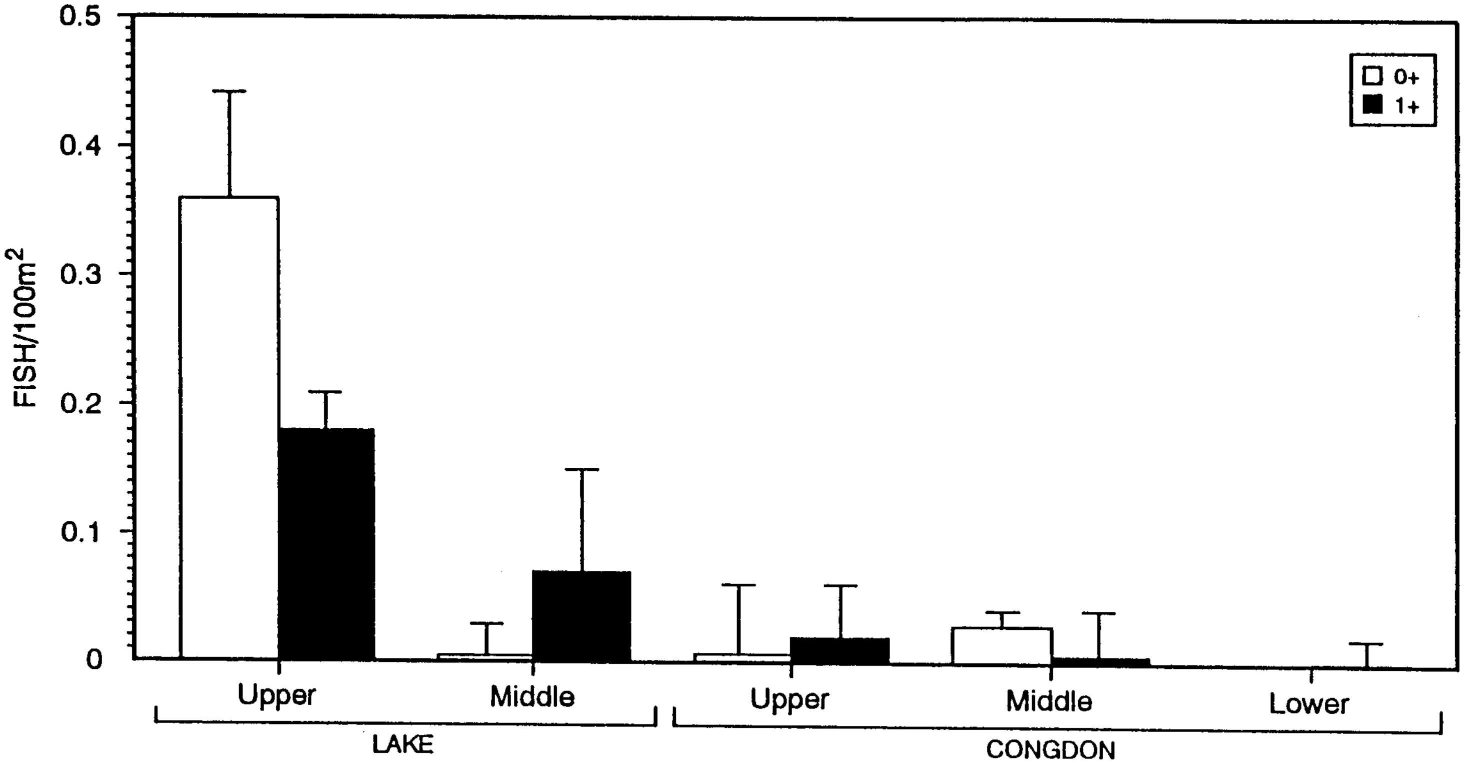


Figure 28. Density extrapolations to habitat for rainbow trout in Lake and Congdon Creeks (estimate + 95% confidence interval).

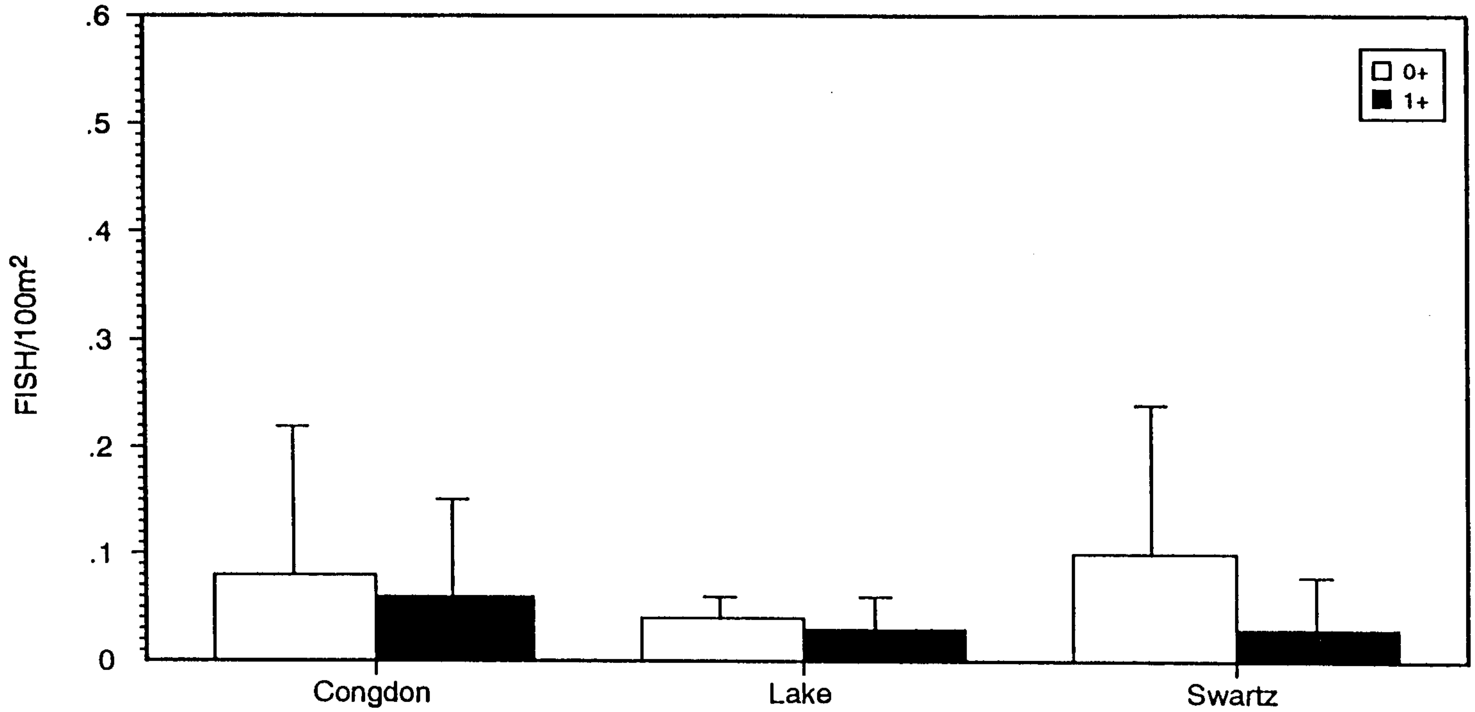


Figure 29. Density extrapolations to habitat for cutthroat trout in the upper reaches of Triangle Lake basin (estimate + 95% confidence interval).

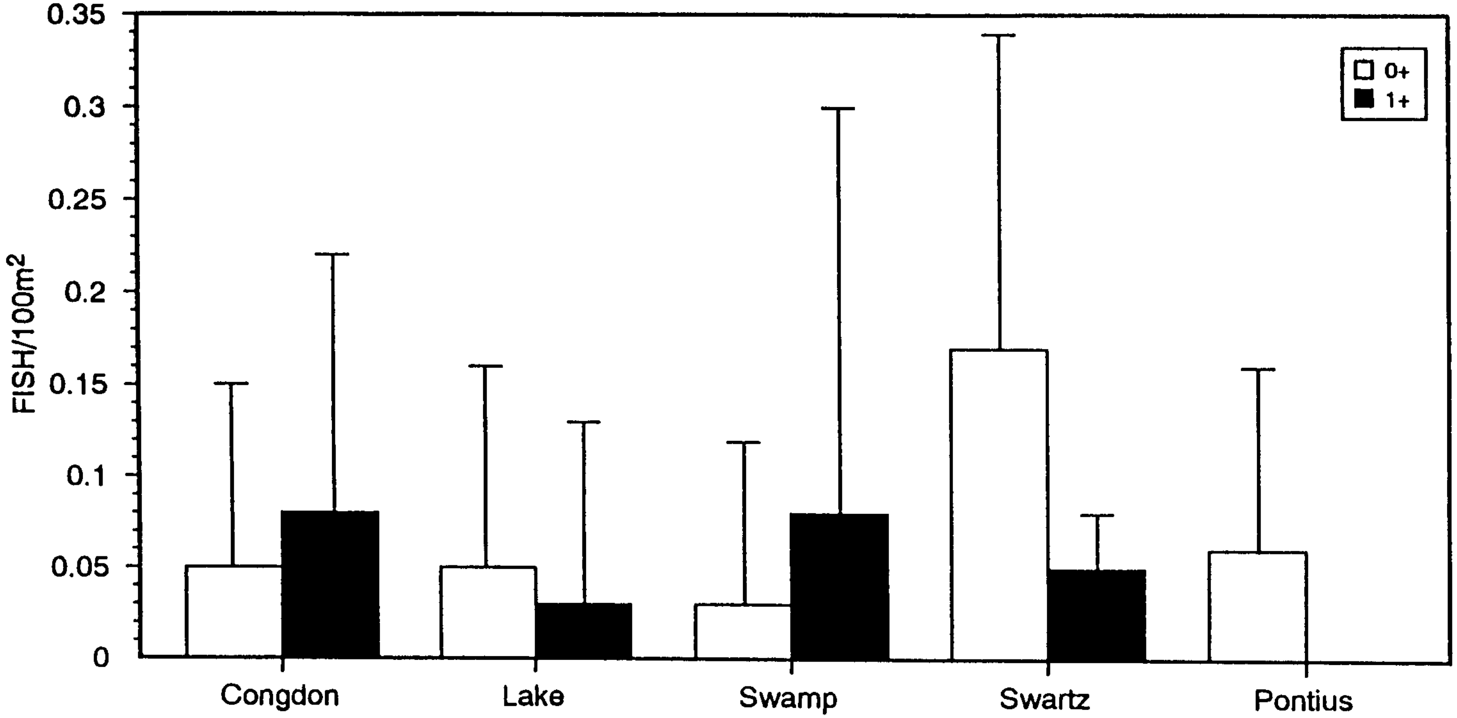


Figure 30. Density extrapolations to habitat for cutthroat trout in the middle reaches of Triangle Lake basin (estimate + 95% confidence interval).

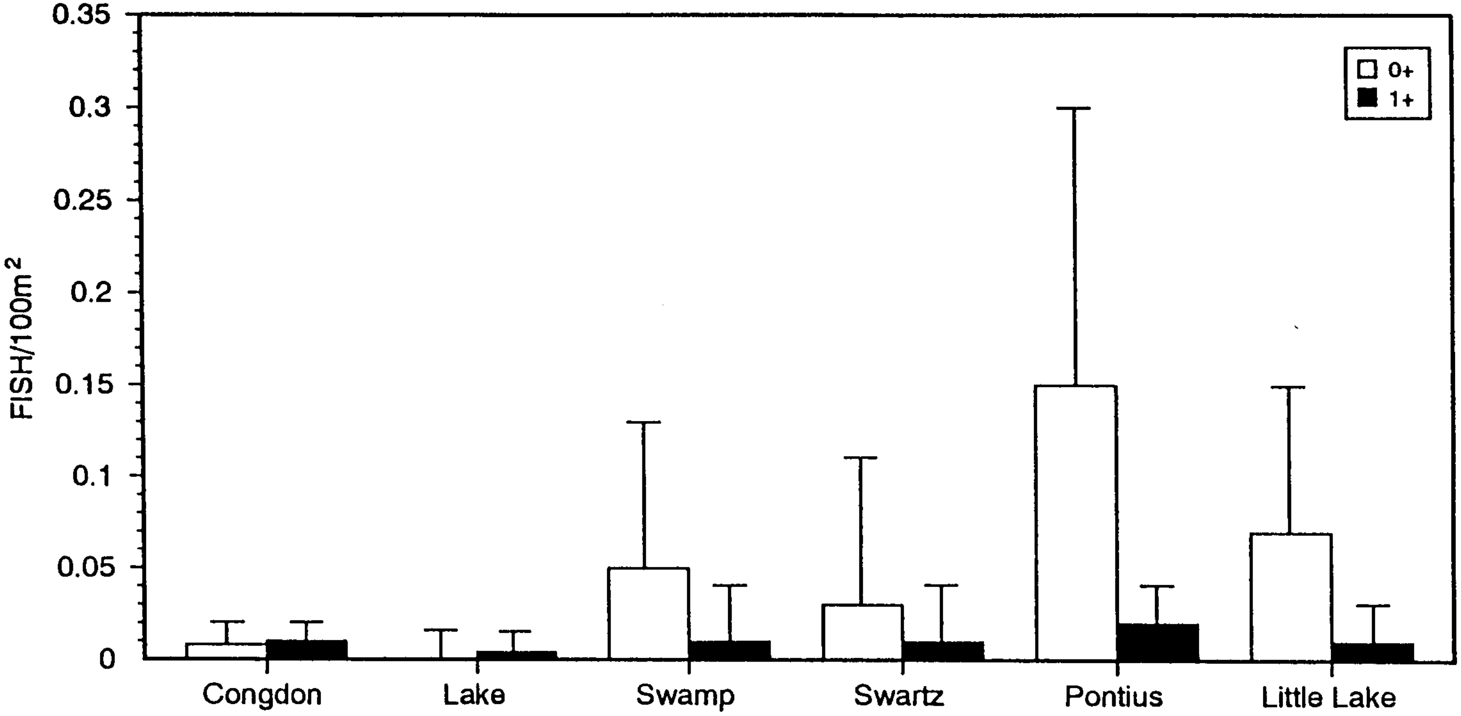


Figure 31. Density extrapolation to habitat for cutthroat trout in the lower reaches of Triangle Lake basin (estimate + 95% confidence interval).

An effect of basin position on overall cutthroat density was seen in Triangle Lake basin (**Table 10**). Higher densities of cutthroat trout were found with increasing distance upstream of the mouth of Lake, Congdon and Swartz Creek. This is particularly evident on Lake Creek; densities were much higher upstream of Rkm 14.4 than below this point.

Correlation Analysis of Habitat Variables

Cutthroat size, density, and the multiple pass estimates were analyzed for correlations with nine to eleven habitat variables. There were no strong correlations between the size of cutthroat trout and habitat variables (**Table 11**). However, several of the positive correlations were statistically significant ($p<0.05$). The highest positive correlations were between cutthroat trout size and average depth and maximum depth (0.345 and 0.340, respectively). There were no significant negative correlations.

Cutthroat trout density also was not strongly correlated with any specific habitat variables (**Table 12**), although some correlations were significant ($p<0.05$). The highest negative correlations were between 0+ cutthroat density and habitat size ($r=-0.15$) and between the density of 0+ cutthroat and habitat length ($r=-0.15$). No definitive conclusions about the relationship between cutthroat density and habitat variables can be drawn from these analyses.

Relationships between the multiple pass estimate and habitat variables also are inconclusive (**Table 13**). Many correlations were significant ($p<.05$) but the r value was

Table 10. Overall cutthroat trout density estimates by Rkm for Lake, Congdon, and Swartz Creeks.

Stream Reach*	Overall Cutthroat Trout Density (Fish/100m^2)
Lake	
0-11.2 Rkm**	0.01
14.4-15.6 Rkm	0.08
15.6 - 19.2 Rkm	0.07
Congdon	
0-1.6 Rkm	0.02
1.6-3.2 Rkm	0.13
3.2-4.8 Rkm	0.14
Swartz	
0-3.2 Rkm	0.04
3.2-4.8 Rkm	0.22
4.8-5.6 Rkm	0.13

*Distances correspond to lower, middle, and upper reaches.

**Hult Reservoir begins at 11.2 Rkm.

Table 11. Pearson product-moment correlation coefficients for cutthroat trout size (forklength) and nine habitat variables.

	Cutthroat Size	
	r	*p* value
Average Depth	0.345	<0.001
Maximum Depth	0.340	<0.001
Overhanging Vegetation	−0.005	0.912
Woody Debris	0.116	0.009
Large Woody Edge	0.221	<0.001
Boulder Edge	0.077	0.300
Turbulence	0.047	0.183
Undercut Bank	0.091	0.010
Total Cover	0.097	0.006

Table 12. Pearson product-moment correlation coefficients for cutthroat trout density and 11 habitat variables.

	Density 0+ Cutthroat		Density 1+ Cutthroat		Total Cutthroat Density	
	r	*p* value	r	*p* value	r	*p* value
Habitat Size	-0.155	0.027	-0.099	0.157	-0.117	0.095
Habitat Length	-0.150	0.032	-0.112	0.109	-0.122	0.082
Average Depth	-0.049	0.483	0.140	0.045	0.023	0.745
Maximum Depth	-0.036	0.605	0.152	0.029	0.022	0.752
Overhanging Veg.	0.106	0.123	-0.020	0.767	0.130	0.056
Woody Debris	0.084	0.218	-0.016	0.817	0.117	0.087
Large Woody Edge	-0.079	0.269	0.119	0.081	-0.026	0.710
Boulder Edge	0.179	0.009	0.252	<0.001	0.230	0.001
Turbulence	-0.086	0.208	0.162	0.018	-0.023	0.739
Undercut Bank	0.010	0.883	0.104	0.129	0.104	0.131
Total Cover	0.131	0.055	0.202	0.003	0.131	0.057

Table 13. Pearson product-moment correlation coefficients for the multiple pass estimates ($\hat{N}$) and 11 habitat variables

	$\hat{N}$ 0+ Cutthroat		$\hat{N}$ 1+ Cutthroat		$\hat{N}$ Total Cutthroat	
	r	*p* value	r	*p* value	r	*p* value
Habitat Size	0.141	0.039	0.262	<0.001	0.209	0.002
Habitat Length	0.192	0.005	0.270	<0.001	0.249	<0.001
Average Depth	0.101	0.139	0.282	<0.001	0.188	0.006
Maximum Depth	0.074	0.284	0.282	<0.001	0.168	0.014
Overhanging Veg.	0.006	0.931	−0.076	0.269	−0.022	0.747
Woody Debris	0.027	0.691	0.028	0.681	0.029	0.673
Large Woody Edge	−0.015	0.832	0.176	0.010	0.061	0.374
Boulder Edge	0.197	0.004	0.243	<0.001	0.243	<0.001
Turbulence	0.119	0.082	0.280	<0.001	0.204	0.003
Undercut Bank	0.027	0.694	0.097	0.158	0.058	0.399
Total Cover	0.197	0.004	0.392	<0.001	0.302	<0.001

low. The highest positive correlation was between 1+ cutthroat trout density and total cover ($r=0.39$).

Cutthroat Size in Relation to Pool Type

Significant differences in the mean size of cutthroat trout were detected among different pool types (ANOVA $p<0.01$) (**Figure 32**). On average, cutthroat trout were largest in dammed pools and smallest in trench pools. Multiple contrasts (Tukey's Test; $\alpha=0.05$) showed that trench pools were significantly different from both plunge pools and dammed pools.

Cutthroat Density in Relation to Pool Type

Overall, total cutthroat densities differed among pool types (K-W $p=.0005$) (**Figure 33**). The highest cutthroat density occurred in trench pools (0.75 fish/100m^2), whereas the lowest density of cutthroat occurred in dammed pools (0.05 fish/100m^2).

Differences in the density of 1+ cutthroat were marginally significant among pool types (K-W $p=.06$) (**Figure 34**). Trench and plunge pools had the highest density of 1+ cutthroat (0.16 fish/100m^2 and 0.15 fish/100m^2, respectively). Dammed pools had the lowest average density of 1+ cutthroat.

Mean density of 0+ cutthroat trout was not statistically different among pool types (K-W $p=0.15$) (**Figure 35**). However, trench pools had much higher densities than other pool types.

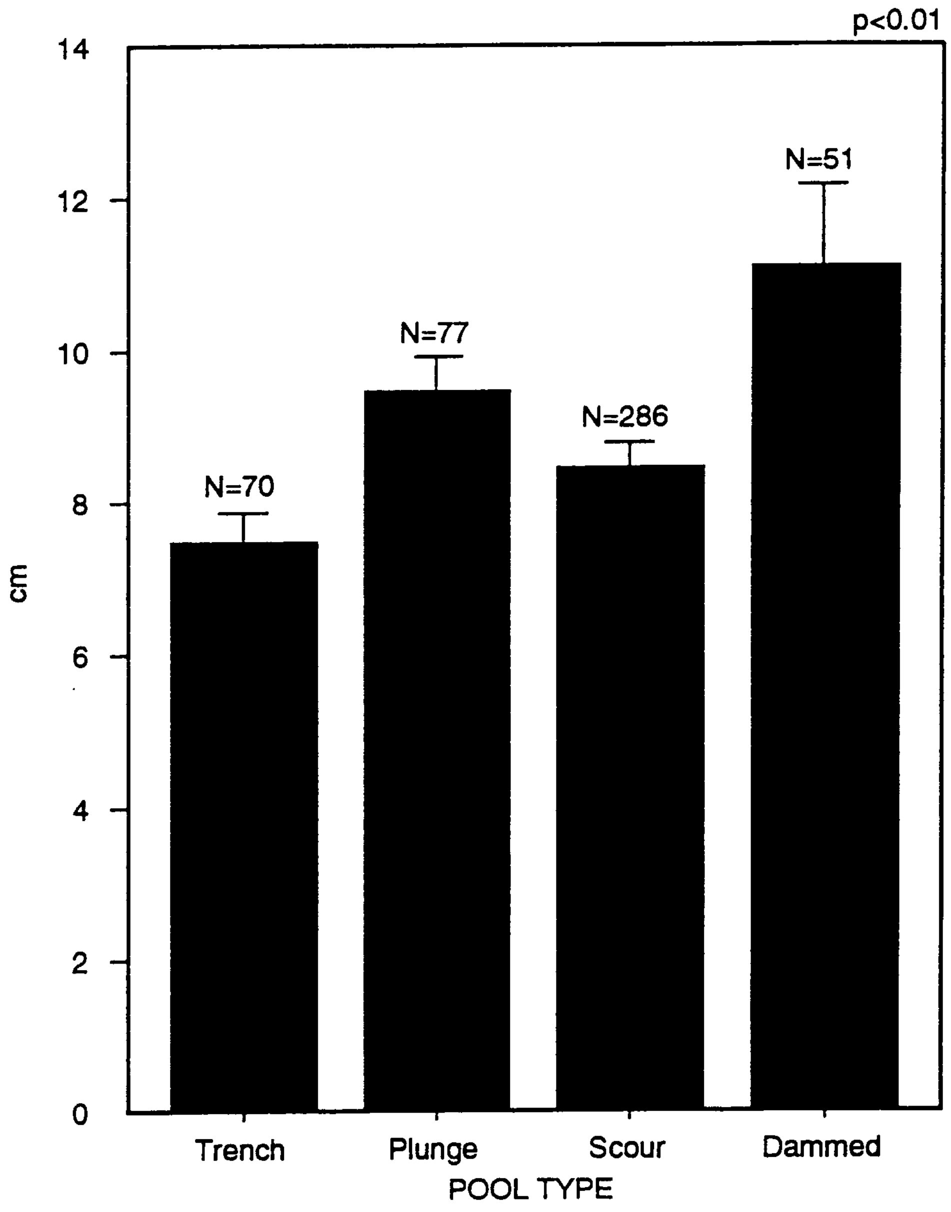


Figure 32. Size of cutthroat trout ($\bar{X}$+SE) by pool type in Triangle Lake basin.

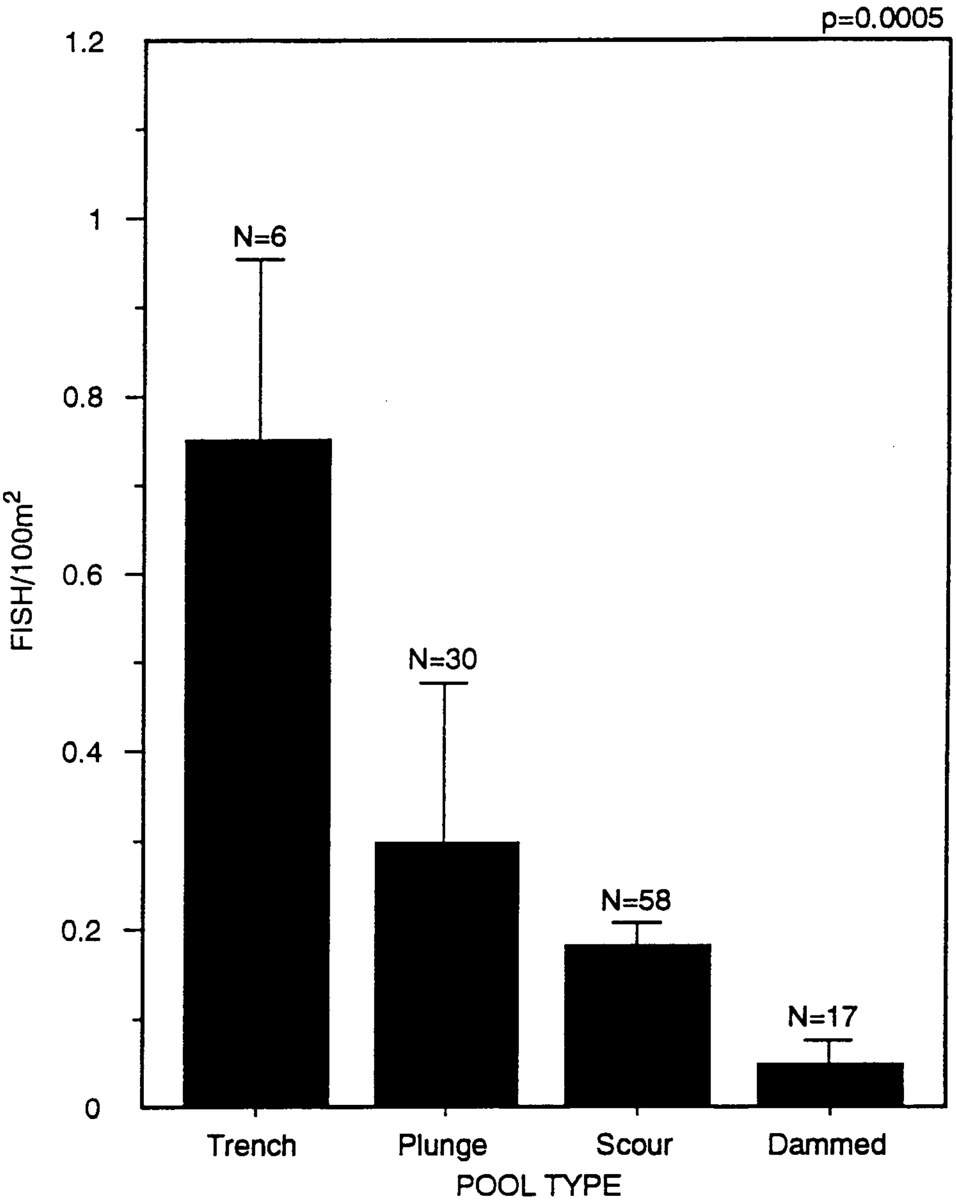


Figure 33. Density of cutthroat trout ($\bar{X}$+SE) by pool type in Triangle Lake basin.

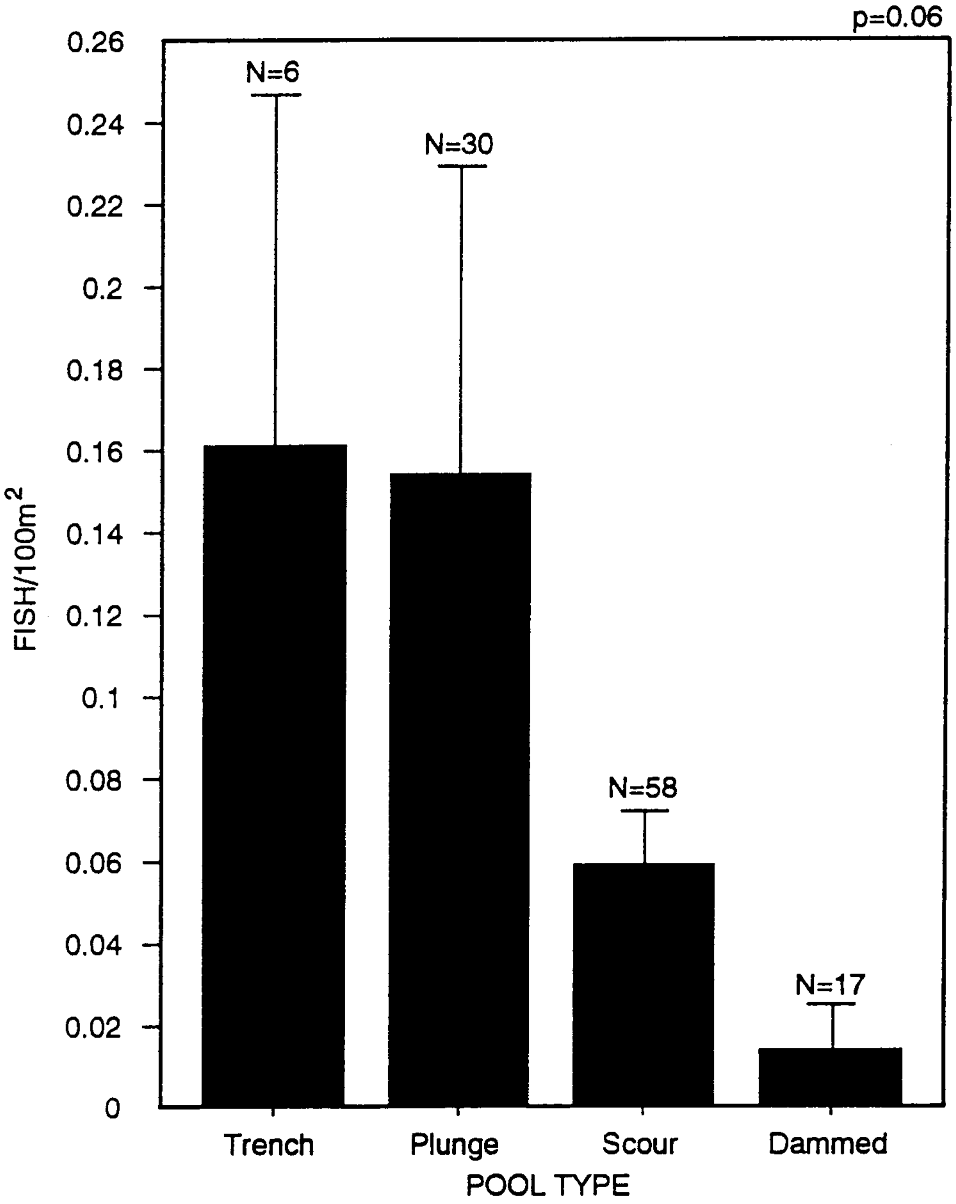


Figure 34. Density of 1+ cutthroat trout ($\overline{X}$+SE) by pool type in Triangle Lake basin.

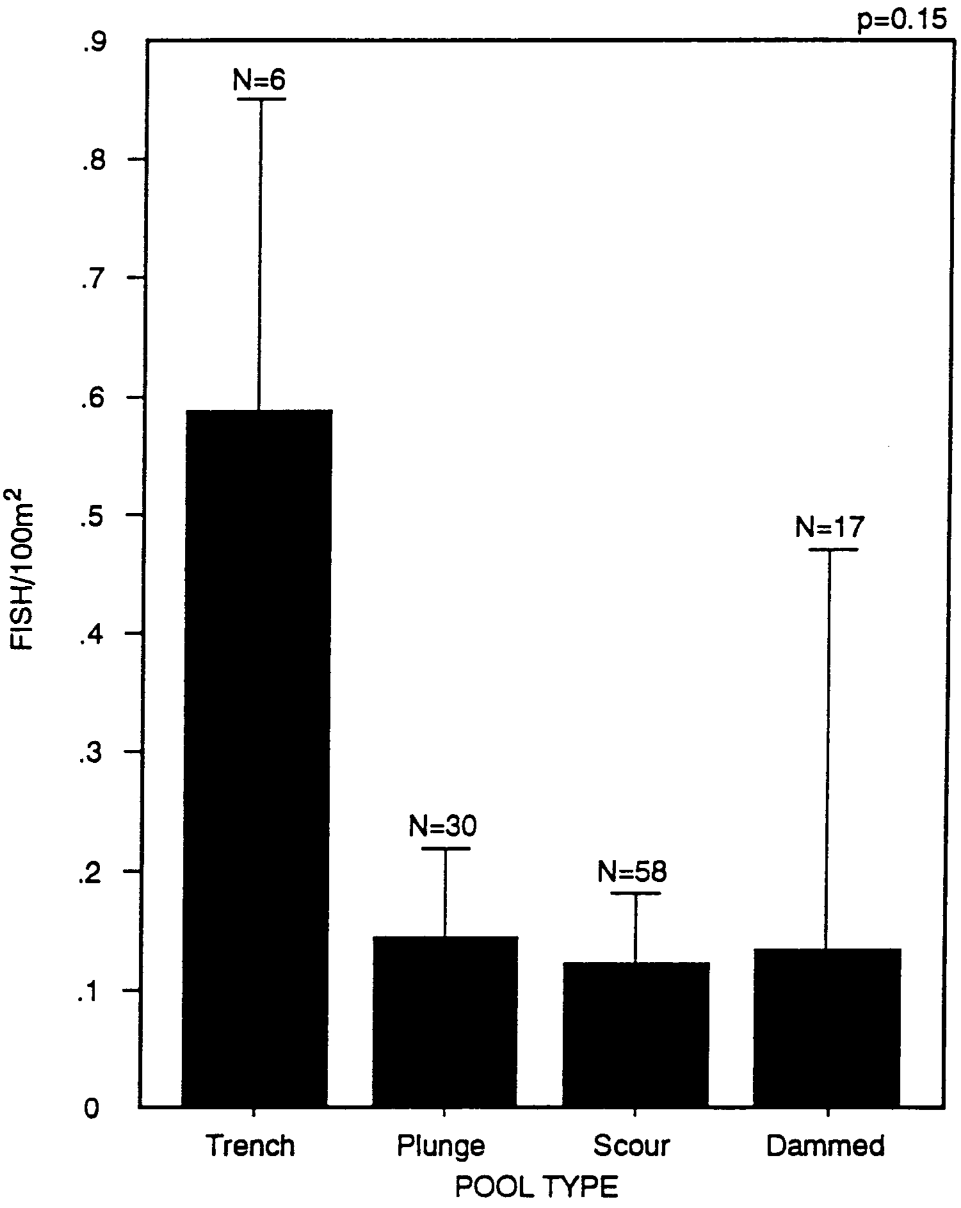


Figure 35. Density of 0+ cutthroat trout ($\bar{X}$+SE) by pool type in Triangle Lake basin.

DISCUSSION

Warmwater fish species (e.g. Centrarchidae) were a minor component of the fish fauna in the streams of Triangle Lake basin. The few warmwater fish found in the lower parts of Lake and Little Lake Creeks probably were temporary residents that moved up from Triangle Lake as stream water temperatures increased in the summer. The introduction of warmwater fish to Triangle Lake apparently has not substantially altered the community structure of native fish in the streams of this basin.

Salmonids reached their highest relative abundance in the upper reaches of the basin, and their lowest relative abundance in the lower reaches of the basin. Overall, sculpin were the most numerous fish in all reaches. Lampreys (both amoecoetes and eyed adults) were found in very high numbers in the silty streambeds of the lower reaches. Dace and shiners were found almost exclusively in the lower reaches.

This pattern of fish distribution reflects some tenets of the river continuum concept (Vannote et al., 1980). In many river systems, fish populations show a shift from coolwater species low in diversity in headwater streams, to a more diverse warmwater community in larger streams. In Triangle Lake basin, a more diverse fish fauna, and fewer salmonids, was found in the lower reaches.

In Triangle Lake basin, the low numbers of salmonids in the lower reaches may be due to unsuitable habitat conditions (high water temperature, heavy sedimentation) that favor non-salmonids. When water temperatures become warmer, trout distribution can be influenced by the presence of non-salmonids (Reeves et al., 1987). A similar pattern may be occurring in Triangle Lake basin. The lower reaches are impacted by agriculture, particularly cattle grazing. Shading is low or absent in many reaches. Salmonids may have been more numerous in the lower reaches before agricultural development and logging in the Triangle Lake basin. Past studies show that agricultural activities have been known to reduce cutthroat habitat (Chapman and Knudsen, 1980). Clearcut logging without buffers has been attributed to declines in coastal Oregon cutthroat populations (Mooring and Lantz, 1975). However, because quantitative data are not available on the original fish of Triangle Lake basin, definitive conclusions about impacts on the fish community cannot be reached.

There has been some question as to whether the native cutthroat in the Triangle Lake basin constitute a genetically distinct strain different from other Oregon coastal basins. Late spring spawning was thought to be a trait unique to the cutthroat trout of Triangle Lake basin. Some spawning was observed in late May and June, but peak spawning occurred from late December to March. Cutthroat redds were scattered in space and time, and a concentrated run was not observed in this basin. While most planted rainbow trout leave the basin as outgoing steelhead smolts, a few larger rainbow remain resident. In all likelihood, some hybridization with the native cutthroat has occurred, as supported by genetic analysis (Sharpe, 1987).

A remnant population of genetically unique lake dwelling cutthroat trout may still exist in Triangle Lake basin. This population may be isolated from cross-breeding and hybridization with a stream dwelling cutthroat trout population due to its late spring spawning cycle. This pattern was observed with kokanee salmon in Odell Lake (Behnke, 1979). If a genetically distinct lake dwelling population of cutthroat trout exists in the Triangle basin, its numbers probably are small.

A difference in the size distribution of cutthroat trout among reach types was observed in Triangle Lake basin. 0+ trout had a higher relative abundance in the upper and lower reaches, whereas 1+ trout were most numerous in the middle reaches. The lower reaches were dominated by fry, had few 1+ fish, but also contained a number of larger fish over two years old. Overall cutthroat density was highest in the upper reaches and lowest in the lower reaches. 1+ cutthroat trout were found in the highest densities in the upper and middle reaches, whereas 0+ cutthroat trout were found at similar densities in all reach types.

The age-class dominance of 0+ cutthroat trout in headwater reaches has been observed in other basins (Ely, 1979). The interesting aspect about the Triangle Lake basin is the presence of both fry and larger trout in the lower reaches. Most of the trout fry were found in the lower reach of Pontius Creek, which probably skewed the distribution of lower reaches somewhat. It is conceivable that trout fry in the lower reaches were from a different spawning population than those in the upper reaches, possibly late spring spawners that would have to spawn lower in the basin due to low flow barriers to upstream movement. The lower reach of Pontius Creek provides the best spawning habitat close to Triangle Lake. Although no definitive conclusions can be reached, it is possible that these fry are progeny of lake dwelling adults rather than stream dwelling adults.

The pattern of distribution of cutthroat trout in Triangle Lake basin may reflect water quality and/or interspecific competition. Cutthroat trout are known to be affected by water temperatures, substrate type, and interspecific interactions (Hickman and Raleigh, 1982). The low overall density of salmonids in the lower reaches may be related to reduced water quality, such as increased siltation and high water temperatures. Although this study did not include population estimates of non-salmonids, the large numbers of non-salmonids collected suggest that their densities are high in the lower reaches. The warmer, siltier conditions may favor non-salmonids, such as lamprey, dace, and shiners. Higher temperatures may restrict salmonids to the deeper pools in late summer.

The high frequency of 1+ cutthroat trout in the middle reaches probably was due to the abundance of high quality pool habitat. In general, pool area was greater than 50% of the total stream area in the middle reaches. Non-pool habitats in middle reaches were shallow, low-cover riffles and glides that provided a less optimal environment for larger fish. High water temperature and silt were less problematic in the middle reaches than in the lower reaches. Cutthroat fry were probably excluded from these middle reaches by larger fish, which occupied the preferred habitat.

Cutthroat trout were larger in middle and lower reach pools than in other channel units (as reflected in the mean size of cutthroat trout by channel unit type). Density of 1+ cutthroat trout were highest in pools in all reaches, whereas 0+ cutthroat trout densities were highest only in middle and lower reach pools. In upper reaches, 0+ cutthroat trout densities were not statistically different between channel unit types.

The greater abundance of salmonids in pools than in other habitats has been found in other studies (Bowlby and

Roff, 1986; Murphy et al., 1984; Wetherbee, 1982; Hicks, 1989). This is probably due to the greater volume of water and cover and cooler temperatures found in pools than in shallower habitats such as riffles. Riffles in the lower and middle reaches of Triangle Lake basin were typically shallow and provided very little living space for trout. Larger salmonids have been known to occupy riffle habitat if sufficient depth is present (Dambacher, 1991). Non-pool habitats in the upper reaches, such as rapids and cascades, typically had pocket pools that provided depth and cover. This allowed all age classes of trout to use non-pool habitats to a greater degree than in middle and lower reaches.

Cutthroat size, density, and numbers were not strongly correlated with specific habitat variables, such as depth or cover, in this study. At a basin level, reach and channel unit type were more important determinants of cutthroat distribution. This is inconsistent with other studies of salmonid populations (Murphy et al., 1984; Bowlby and Roff, 1986; Wetherbee, 1982; Johnson, 1985; Salo et al., 1981; Duke, 1980), where variables such as depth, cover, and velocity were found to most highly influence fish distribution. Salmonids may respond to such variables at a local scale in Triangle Lake basin; however, no consistent patterns were seen at a basin-wide scale.

In this study, the size distribution and density of cutthroat trout in four pool types were determined. These different pool types had different hydraulic conditions, such as velocity and thalweg pattern, which provided different environmental conditions for fish. Past research indicate that cutthroat trout prefer habitat of intermediate velocity. Coho prefer the lowest velocity habitats, while steelhead prefer the highest velocity habitats (Bissen et al., 1988). Significant differences in the size distribution of cutthroat trout were observed among pool types. Dammed and plunge pools supported the largest trout, whereas trench pools contained the smallest trout.

Dammed pools tended to be restricted to the slower moving lower reaches. Although lower reaches had the smallest average size cutthroat overall, these reaches also had the largest individuals, with several fish over 24 cm. These large fish were mostly restricted to dammed pools during summer low flows, which may account for the large mean size of cutthroat in dammed pools. The smaller mean size of cutthroat trout in trench pools might have been related to the dominance of trench pools in upper reaches, compared to middle or lower reaches. The upper reaches of Triangle Lake basin tended to have the highest proportion of 0+ fish.

Differences in the size distribution of cutthroat among pool types was most likely due to the varying abundance of each pool type in the different reaches rather than to differences in the environment among pool types. The size of this data base did not allow closer analysis of pool type by stratifying the data by reach. Pool type may affect cutthroat trout use on a local scale, but there is little evidence to indicate that it does so on a basin scale.

Cutthroat trout density also differed among pool types. As with size distribution, differences in trout density were probably related to the different distributions of pool types in the various reach types, rather than to a preference for a given pool type by trout. Trench and plunge pools were the dominant pool type in upper reaches, which had the highest densities of trout. Dammed and scour pools were found mostly in the slower moving middle and lower reaches, which tended to have lower trout densities.

This study has some implications for fisheries management of coastal cutthroat trout. In Triangle Lake basin, reach type was a major factor influencing cutthroat trout density. Habitat improvement projects in coastal basins designed to enhance cutthroat trout habitat should take basin position into consideration. Restructuring streams or addition of woody debris may not increase trout numbers because other factors may be more significant in determining cutthroat trout density (eg., interactions with non-salmonids, water temperature, sediment composition).

CONCLUSIONS

1. In Triangle Lake basin, spawning of cutthroat trout peaked in March, but occurred from late December through May. Spawning was scattered widely over space and time and no concentrated run was observed. Late spring spawning of lake-dwelling adults may restrict spawning to lower reaches of the basin due to lower flows and barriers that restrict upstream migration. This pattern may serve to isolate lake-dwelling spawners from stream-dwelling spawners.

2. From a basin-wide perspective, reach type was the major factor influencing size distribution and density of cutthroat trout in Triangle Lake basin. Proportionally, 0+ trout dominated the lower reaches (72%), whereas 1+ trout dominated the middle reaches (61%). Overall areal densities of cutthroat trout were highest in the upper reaches (0.087 fish/100m^2) and lowest in lower reaches (0.064 fish/100m^2). 1+ cutthroat were found in the highest densities in the upper reaches (0.036 fish/100m^2), whereas 0+ trout were equally abundant in all reaches (from 0.052-0.066 fish/100m^2). This pattern of density and size distribution was probably related to spawning patterns, water temperature and siltation, and both intra- and interspecific interactions.

3. Within reaches, size distribution and density of cutthroat trout differed among channel unit types. The highest densities of 1+ cutthroat trout occurred in pools (from 0.024-0.187 fish/100m^2), regardless of reach type, whereas significant differences in the density of 0+ cutthroat trout occurred among channel unit types only in the middle and lower reaches. In middle and upper reaches, pools had higher proportions of 1+ trout than did other channel unit types resulting in a higher mean size of

cutthroat trout in pools for these reach types. No significant differences in mean size of cutthroat trout were found among channel unit types of lower reaches. This pattern of density and size distribution may be related to the greater volume of water in pools, which provided more cover and habitat than other channel units for both 0+ and 1+ cutthroat trout.

4. On a basin-wide level, there were no strong correlations between specific habitat variables (e.g., depth, cover, woody debris) and cutthroat size, density, or numbers. Overall, reach and channel unit types were more important determinants of cutthroat distribution and abundance.

5. Size distribution and density of cutthroat trout differed among pool types. Trench pools had the highest cutthroat trout densities (0.75 fish/100m^2), while dammed pools had the lowest cutthroat trout densities (0.05 fish/100m^2). This pattern probably was due to the dominance of different pool types in the lower, middle, and upper reaches rather than to preference by trout for a particular pool type.

6. In the lower agriculture reaches, fish communities in Triangle Lake basin were dominated by non-salmonids, principally dace, shiners, sculpins, and lampreys (from 80-98% of the total fish found). In the upper reaches, sculpins and trout were the two dominant fish taxa (up to 99% of the total fish found). The middle reaches represented a transition zone between these two fish assemblages (sculpins and salmonids ranged from 84-95% of the total fish found).

7. Warmwater species (e.g. Centrarchidae) were not a significant component of the stream fish communities of Triangle Lake basin (less than 1% in reaches where they occurred). A few individuals were found in locations close to Triangle Lake, but they probably were temporary residents during warmer, late-summer conditions.

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