MARCH 3, 1849

United States Department of the Interior

NATIONAL PARK SERVICE
P O Box 168
Yellowstone National Park
Wyoming 82190

IN REPLY REFER TO:

N1423(YELL)

OCT 02 1995

Mr. Bob Behnke
Department of Fish and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523

Dear Mr. Behnke:

Enclosed you will find the first fruits of all your hard work on our behalf last winter, when you participated in our workshop on the Yellowstone Lake situation we face. We want to take this opportunity to thank you again for your help. As you will see, we've made considerable progress in formulating and articulating both the challenge we face and the directions we hope to go.

Again, our thanks.

Sincerely,

M.V. Finley

Michael V. Finley
Superintendent

Enclosure

Rocky Mountain News Sun., Nov. 17, 1996

Biologists raid fish sanctuary in battle to control lake trout

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Associated Press

LIVINGSTON, Mont. — The discovery of a major spawning ground has given a big boost to the campaign to eradicate lake trout from Yellowstone National Park.

Park biologists discovered the spawning ground near Carrington Island, in the West Thumb of Yellowstone Lake, partially through large fish tagged with transmitters, biologist Jeffrey Lutch said.

The discovery allowed biologists to net large numbers of the predatory fish, including the larger, more voracious specimens that prey heavily on the native cutthroat trout. Biologists say lake trout could wipe out the cutthroat, a major element of the food chain in the park.

Catching large lake trout also "changed a lot of what we originally thought, that they were introduced five to 10 years ago," Lutch said.

Instead, some of the lake trout were 20 years old, indicating the species may have been introduced in the mid- to late-1960s.

"There were a lot of theories, like lake trout were introduced during the Yellowstone Fires (in 1988). We put them to rest," Lutch said.

Lutch said the nets caught 182 mature fish, 180 from the Carrington area. It takes seven to eight years for lake trout to mature.

"Forty to 50 percent of the fish in the nets had cutthroats in their stomach," he said.

He rated the first season of the campaign against the lake trout a success.

Lake trout can out-compete the native cutthroat trout because they use the same food sources when young and because full-grown lake trout feed on cutthroats.

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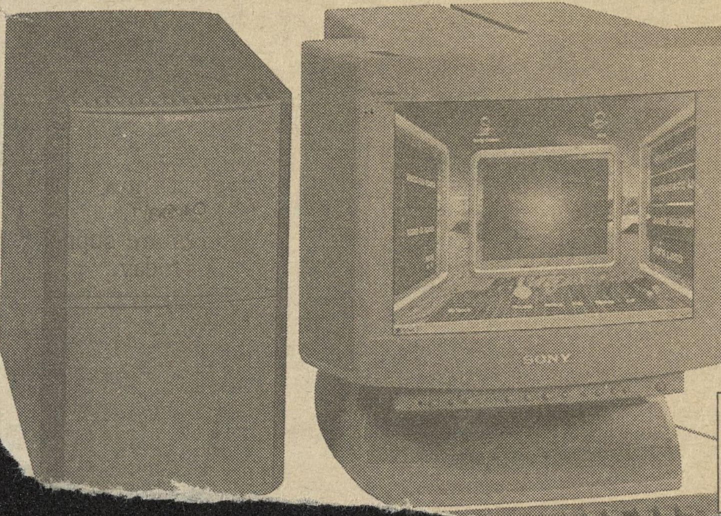

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To: Members of the lake trout advisory team

From: Jack McIntyre

Subject: Draft report on 1995 and 1996 field seasons

Date: December 6, 1996

Lynn Kaeding, Dan Mahony, and Glenn Boltz have summarized results of experimental gillnetting conducted by the Fish and Wildlife Service in 1995, and by the National Park Service in cooperation with FWS through August 1996. Their draft report does not include data obtained after an important lake trout spawning location was found near Carrington Island in the northwest corner of West Thumb. The characteristics of the lake trout removed from this spawning population will be sent to you as soon as they are summarized. In the meantime, I thought that you might like to see the summaries developed by Lynn et al. They are looking for helpful comments regarding the draft report. Please forward your comments directly to Lynn at the Bozeman address indicated on the report.

Life History and Population Characteristics of Lake Trout Recently Discovered in Yellowstone Lake

December 1996

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Life History and Population Characteristics of Lake Trout Recently Discovered in Yellowstone Lake

On 30 July 1994, lake trout *Salvelinus namaycush* were discovered in Yellowstone Lake in Yellowstone National Park, Wyoming, the core of the remaining undisturbed, natural habitat for the native Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri*. Data from the few lake trout caught that year suggested this piscivorous, nonnative fish had reproduced in the lake since at least 1989 and numbered in the thousands, perhaps tens of thousands (Kaeding et al. 1996).

Lake trout will probably thrive in Yellowstone Lake and reduce the lake's cutthroat trout stocks substantially unless preventive management actions are taken. Introduced lake trout have been implicated in the extinction of Lahontan cutthroat trout (*O. c. henshawi*) in Lake Tahoe (Cordone and Frantz 1966) and the substantial decline in native Yellowstone cutthroat trout in Jackson Lake, Wyoming (Behnke 1992). Lake trout also have been shown to eliminate native bull trout (*S. confluentus*) in lakes (Donald and Alger 1993).

A team of scientists that convened in February 1995 projected a decline of 90 percent or more in Yellowstone Lake's cutthroat trout numbers in 20-100 years if the lake trout population is not controlled (McIntyre 1995). The team concluded that mechanical removal methods, either gillnetting or some combination of gillnetting and trapping, were the management actions most likely to control lake trout. Targeting lake trout on their spawning areas and in the hypolimnion during summer, when bathymetric separation from Yellowstone cutthroat trout was anticipated, was considered especially important.

Objectives of this study were to determine lake trout distribution and population structure; lake trout sizes at the onsets of piscivory and maturity; the degree that lake trout and Yellowstone cutthroat trout are separated bathymetrically in the hypolimnion during summer; and gillnet selectivity for both species in Yellowstone Lake. On the basis of these data and the recommendations of the team of scientists, an initial control program for lake trout in Yellowstone Lake is proposed.

Study Area

Yellowstone Lake, east-central Yellowstone National Park, Wyoming, lies 2,356 m above mean sea level, has a surface area of 34,100 ha, shoreline length of 239 km, mean depth of 48.5 m, and maximum depth of 107 m (Fig. 1). A thermocline forms in July and may persist through mid-September at a depth of 10-20 m. The hypolimnion remains well-oxygenated during stratification. Phytoplankton standing crops are low and generally dominated by diatoms. Zooplankton consist primarily of *Conochilus unicornis*,

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Diaptomus shoshone, and *Daphnia schoedleri*. Summer surface temperatures rarely exceed 18°C and ice covers the lake from mid-December through May or early June (Benson 1961; Gresswell et al. 1994).

Native fishes of the lake are Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae*; longnose sucker *Catostomus catostomus*, redside shiner *Richardsonius balteatus*, lake chub *Couesius plumbeus*, and lake trout are established, nonnative species. The minnow species inhabit vegetated bays and other littoral areas; cutthroat trout, longnose sucker, and lake trout are found throughout the lake (Benson 1961; Kaeding et al. 1996).

Methods

Field procedures.--When the team of scientists met in February 1995, a member who had considerable experience with lake trout in Laurentian Lake Superior identified 12 locations on a bathymetric map of Yellowstone Lake where he believed lake trout were likely to be caught (Fig. 1). These locations, generally characterized as nearshore areas where the bathymetric gradient is especially steep, became the focus of sampling. A thirteenth sampling site (Fig. 1) was added on 19 July 1996.

Monofilament gill nets were used to capture fish between mid-June and early October 1995, and early June and early September 1996. The group of small-mesh gill nets used routinely consisted of two nets each 100 m long, 1.8 m deep, and of a single mesh size (usually 38 mm and 51 mm bar measure [used exclusively in this report]), and two nets each 76 m long and 1.8 m deep that had two series of five 7.6-m panels of 19-mm, 25-mm, 32-mm, 38-mm, and 51-mm mesh netting. Primarily in 1996, as many as four large-mesh gill nets each 76 m or 100 m long, 1.8 m deep, and made completely of 64-mm, 76-mm, 89-mm, or 102-mm mesh monofilament or multifilament netting were also set, usually at sites not sampled concurrently with small-mesh nets. When aggregations of large lake trout that might be preparing to spawn were sought in August and September 1996, some large-mesh netting was conducted at locations other than the 13 established sampling sites.

Gill nets were bottom-set approximately perpendicular to the shoreline and 150-200 m apart, almost always at depths > 15 m (i.e., below the anticipated thermocline). Sonar was used to deploy nets at desired depths and measure water depth at both net ends (the average of which was considered the mean net depth); all nets in a group were typically set with their shallow ends at similar depth. In 1995, average depth at which small-mesh nets were set was increased from 21.2 m (SE = 0.4 m) to 46.2 m (SE = 0.6 m) after the first five weeks of sampling because the catch of Yellowstone cutthroat trout (N = 628) in shallow water was unacceptably large. In 1996, average depth for small-mesh nets was 42.3 m (SE = 0.5 m) and 24.5 m (SE = 0.7 m) for large-mesh

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nets; average difference in water depth at the ends of deployed gill nets was 12.0 m (SE = 0.4 m) and did not differ between small-mesh and large-mesh nets (*T*-test, *P* = 0.29). Small-mesh nets were usually retrieved and reset on Mondays and Thursdays and soaked 3 or 4 nights at each site. Large-mesh nets were set and retrieved as time permitted and usually soaked about one week.

Gillnetting effort was not evenly distributed among sampling sites (Table 1). In 1995, four sites were randomly selected for periodic sampling with small-mesh gill nets and remaining sites were sampled as personnel resources permitted. In 1996, 12 of the 13 sites were sampled at least once. Total gillnetting effort was 24,957 linear m nights in 1995 and 99,210 linear m nights in 1996, when 87 percent was for large-mesh nets that were used exclusively after 22 July.

Lake temperatures were measured weekly at 1-5 m intervals to depths of 30-50 m at a location (Fig. 1) representative of such temperatures throughout the lake (E. Theriot, Academy of Natural Sciences, Philadelphia, personal communication). Water temperatures at the ends of deployed gill nets were estimated by comparing net depths to the lake's temperature profile for that week, then averaged to give the mean net temperature. The few net ends deeper than the temperature profile were assigned the temperature at the profile's greatest depth.

Laboratory procedures.--Fish caught in each gill net were grouped according to mesh size, individually measured to total length (TL, mm), and weighed (g); scales were taken from lake trout for age estimation and in 1995 the fish were frozen for subsequent analyses. Three to six months later, thawed lake trout were measured and weighed; otoliths were taken from a subsample of fish for age estimation; and sex was determined by gross inspection of excised gonads that were then weighed (±0.1 g) for calculation of gonadosomatic indices (gonad weight/whole-body weight [fresh] X 100). Because captured lake trout could have been in gill nets 3 days or more, detailed analyses of lake trout stomach contents were unwarranted; only the presence of fish and other food items readily identified by gross inspection was recorded, except fish were identified to species and whole fish were measured to total length in 1995. In 1996, these procedures were conducted entirely on fresh specimens in the laboratory.

Data were also taken from lake trout caught by anglers and presented to National Park Service rangers. Rangers verified that the fish were lake trout and measured most fish to total length. Anglers sometimes relinquished the lake trout for study in the manner described for fish caught in gill nets.

Catch per unit effort (CPUE) for each fish species in each gill

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net was calculated as the number of fish caught per 30.5 linear m (100 linear feet) of netting of each mesh size per net night. Because the CPUE data included a high percentage of null values and were not normally distributed, geometric means were calculated and used in some statistical analyses of CPUE (Zar 1984). Otherwise, a $\log_e$(CPUE + 1) transformation alone was used.

Multiple-regression analysis (Zar 1984) was used to explore relations between CPUE for Yellowstone cutthroat trout and lake trout and independent variables that included gillnet mesh size, water depths and temperatures at deployed nets (including mean values and differences in these variables between net ends), and day of the year of net deployment. Multivariate variable selection and all data analyses were performed using the NCSS (1992) statistical program.

Results

Lake Temperatures

The Yellowstone Lake thermocline was absent in early June 1995 and 1996, moderately developed in late June or early July 1995 and 1996, and most strongly developed in mid-September 1995 and early August 1996 at depths of 15-20 m (Fig. 2). Highest epilimnion temperatures were about 14°C in 1995 and 16°C in 1996. Although autumnal cooling was apparent the thermocline persisted on 25 September 1995 and 4 September 1996, when final measurements for those years were made and temperatures of the epilimnion were about 12°C and 14°C, respectively.

Gillnet Selectivity

. Altogether, 512 lake trout, 1,762 Yellowstone cutthroat trout, and 146 longnose suckers were caught in gill nets. Data on the mean lengths of fish caught in monofilament or multifilament nets with 64-mm, 76-mm, or 89-mm mesh netting (all 102-mm mesh nets were multifilament) were pooled within species and mesh sizes after statistical testing showed there were no differences in fish length (*T*-tests, $P = 0.28$ to 0.87) between net types.

Mean lengths of lake trout, Yellowstone cutthroat trout, and longnose suckers differed significantly among gillnet mesh sizes within species and among species within mesh sizes (ANOVAs, $P < 0.001$). Mean lengths for all three species increased with mesh size up to 64-mm netting (Scheffe's Tests, $P < 0.05$; Table 2). Among species, mean lengths of fish caught differed significantly (Scheffe's Tests, $P < 0.05$) for all mesh sizes except 32 mm, 38 mm, and 51 mm (Table 2).

There were no within-species differences (*T*-tests, $P = 0.29$ to

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0.97) between mean catch rates for fish caught in monofilament or multifilament nets with 64-mm netting, the only mesh for which sample sizes allowed such comparisons; these data were pooled within species for subsequent analyses. Geometric mean CPUE by gillnet mesh size differed significantly ($P < 0.05$) within and between species (Table 3). Overall catch rates for lake trout were highest in 25-mm and 32-mm netting, for Yellowstone cutthroat trout in 19-mm to 38-mm netting, and for longnose suckers in 32-mm and 38-mm netting.

Lake Trout Life History

Age and growth.--Range in length of the 153 lake trout caught in gill nets in 1995 was 186-527 mm (mean, 290 mm; SE = 5 mm; Fig. 3). In addition, anglers reported the capture of 43 lake trout 310-575 mm long (mean, 424 mm; SE = 10 mm; $N = 38$). In 1996, the 354 lake trout caught in nets were 173-870 mm long (mean, 476 mm; SE = 11 mm; $N = 353$; Fig. 3), whereas anglers reported the capture of 174 lake trout 330-843 mm long (mean, 470 mm; SE = 5 mm; $N = 159$). The largest angler-caught lake trout, taken at sampling site 13 on 4 July 1996, prompted initiation of large-mesh netting at that location. Among the lake trout catches reported by anglers each year, 75 percent were caught during the first 50 days of the fishing season in 1995 and the first 28 days in 1996. The fishing season opened on 15 June, closed on the first Sunday in November, and was about 145 d long.

Analyses of scale annuli for lake trout caught in gill nets and by anglers revealed the first annulus was laid down in late spring to early summer of the second growing season (Charles Bronte, U.S. Geological Survey, Great Lakes Science Center, Ashland, WI, personal communication). Lake trout lengths at capture were positively related to estimated ages from scale annuli for fish 200-600 mm long and 2-10 yr old (Fig. 4). Most lake trout > 600 mm long were estimated to be 10-20 yr old; their lengths at capture increased more slowly with scale age than did those of smaller lake trout. [A comparable analysis of ages from otoliths is being conducted.]

Gonadal development.--Gross inspection of gonads from lake trout caught in gill nets and by anglers in 1995 revealed 47 male fish (204-527 mm TL), 43 female fish (203-500 mm TL), and 63 fish (186-472 mm TL) of unknown sex. Only five (3 percent) of these fish, all male, had gonadosomatic indices > 0.5 percent (Fig. 5); the shortest was 311 mm long.

In 1996, lake trout caught in gill nets and by anglers included 206 male fish (228-870 mm TL), 127 female fish (233-864 mm TL), and 49 fish (173-419 mm TL) of unknown sex. Gonadosomatic indices commonly exceeded 0.5 percent for male fish > 375 mm long and for female fish > 600 mm (Fig. 5), and generally increased for these fish during the sampling period as the gonads developed

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seasonally in preparation for spawning.

Diet.--Stomach contents were examined for 175 lake trout caught in 1995 and 246 fish caught in 1996. Forty-eight percent of the stomachs from gillnetted fish ($N = 368$) and 43 percent from angler-caught fish ($N = 53$) were empty. The most frequently encountered food was amphipods (presumably *Gammarus* sp. and *Hyallela* sp., as per Benson [1961]), which were found in 24 percent of the stomachs, all from gillnetted fish < 410 mm long (mean, 289 mm; SE = 5.4 mm). Fish were found in 6 percent of the stomachs from gillnetted lake trout and 25 percent from angler-caught fish. The shortest lake trout with fish in its stomach was 291 mm long (mean, 514 mm; SE = 27.1 mm).

Of the 21 prey fish found in lake trout stomachs in 1995, 20 were readily identified as Yellowstone cutthroat trout. Total lengths, measurable for 8 of these prey fish, ranged from 99-146 mm. Although the species of prey fish encountered in lake trout stomachs was not routinely determined in 1996, recognizable prey fish were all Yellowstone cutthroat trout.

Fish Species' Distributions

Among sampling sites.--Comparisons of geometric mean CPUE for lake trout, Yellowstone cutthroat trout, and longnose suckers caught in small-mesh or large-mesh gill nets revealed significant differences among sampling sites within species (Fig. 6). Although lake trout were found at each of the nine sites sampled with small-mesh nets, mean CPUE was highest ($P < 0.05$) at sites 10 and 11. Mean CPUE for Yellowstone cutthroat trout in small-mesh nets was highest ($P < 0.05$) at site 5, which was sampled only once--during the first week of sampling in 1995 when netting was in shallow water.

Geometric mean lake trout CPUE in large-mesh nets did not differ significantly ($P > 0.05$) among the five sampling sites where these nets caught lake trout (i.e., sites 2, 7, 9, 11, and 13). Lake trout > 600 mm long were initially caught from location 9 during the first week of netting in 1996; thereafter, that site was sampled weekly with large-mesh nets. Altogether, 70 percent of the large-mesh netting effort was expended at sites 9 and 13 (Table 1). Only three lake trout > 600 mm long were caught in nets set at locations other than sites 9 or 13, a 772-mm fish taken at site 10 and two fish 622 mm and 710 mm long taken at site 11. Yellowstone cutthroat trout mean CPUE in large-mesh nets varied little among sampling sites, whereas longnose sucker CPUE was highest ($P < 0.05$) at site 2 (Fig. 6).

Average mean water temperature was 5.0°C (SE = 0.005°C) for small-mesh gill nets, 7.8°C (SE = 0.2°C) for large-mesh nets, and differed significantly (*T*-test, $P < 0.001$) between net types. Mean difference in water temperatures at the ends of deployed

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gill nets was 0.5°C (SE = 0.005°C) for small-mesh nets, 3.4°C (SE = 0.25°C) for large-mesh nets, and differed significantly between net types (T-test, $P < 0.001$).

Multivariate analyses of CPUE.--A multiple-regression model that included gillnet mesh size and water depth at the shallow end of the net as independent variables explained 43 percent of the variation in Yellowstone cutthroat trout CPUE in small-mesh nets ($R^2 = 0.43$, $P < 0.001$, $N = 398$). Water depth alone explained 31 percent of the variation ($r^2 = 0.31$, $P < 0.001$), whereas mesh size explained 12 percent ($r^2 = 0.12$, $P < 0.001$). Both independent variables were negatively related to Yellowstone cutthroat trout CPUE.

Only 12% of the variation in lake trout CPUE in small-mesh nets was explained by a multiple-regression model that included mesh size and water depth and temperature at the shallow end of the net as independent variables ($R^2 = 0.12$, $P < 0.001$, $N = 398$). Mesh size alone explained 7 percent of the variation ($r^2 = 0.07$, $P < 0.001$), whereas water depth and temperature each explained 4 percent ($r^2 = 0.04$, $P < 0.01$). Mesh size and water temperature were negatively related and water depth positively related to lake trout CPUE.

Regression lines for relations between CPUE for Yellowstone cutthroat trout and lake trout in small-mesh nets and gill net depth at its shallow end intercept at a depth of about 44 m (145 feet; Fig. 7). At greater depths, lake trout CPUE generally exceeds that of Yellowstone cutthroat trout.

A multiple-regression model that had day of the year of net deployment and water depth at the deep end of the net as independent variables explained 22 percent of the variation in Yellowstone cutthroat trout CPUE in large-mesh nets ($R^2 = 0.22$, $P < 0.001$, $N = 158$). Day of the year of net deployment alone explained 15 percent of the variation ($r^2 = 0.15$, $P < 0.001$), whereas net depth explained 11 percent ($r^2 = 0.11$, $P < 0.001$). Both independent variables were negatively related to Yellowstone cutthroat trout CPUE.

Nineteen percent of the variation in lake trout CPUE in large-mesh nets was explained by a multiple-regression model that had mesh size and water depth at the deep end of the net as independent variables ($R^2 = 0.19$, $P < 0.001$, $N = 158$). Net depth alone explained 14 percent of the variation ($r^2 = 0.14$, $P < 0.001$), whereas mesh size explained 4 percent ($r^2 = 0.04$, $P < 0.01$). Water depth and mesh size were negatively related to lake trout CPUE.

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Discussion

Abundant young lake trout and numerous older age-classes, including many fish estimated to be > 10 years old, show lake trout are established as a reproducing population in Yellowstone Lake. Male lake trout begin to mature in the lake when about 375 mm long and 5 years old, whereas maturing female fish are about 600 mm long and 10 years old. Thus generation time for lake trout in Yellowstone Lake is about 10 years.

Piscivory in Yellowstone Lake lake trout begins when the fish are about 291 mm long and appears wholly directed at Yellowstone cutthroat trout, at least during summer. Smaller lake trout might also be piscivorous, but rapid digestion and our cursory examination of stomach contents may have made detection of the small fish that lake trout < 291 mm long would consume unlikely.

Lake trout are not evenly distributed areally or bathymetrically in Yellowstone Lake. Highest catch rates for lake trout in small-mesh nets were from sampling sites in West Thumb, the western-most segment of the lake that is connected to the main lake by a narrow channel. The abundance of lake trout in West Thumb, particularly the exclusive occurrence there of mature female fish, suggests reproduction in that lake region.

Bathymetric separation occurs among lake trout size-classes in Yellowstone Lake during late spring and summer. Gill nets set in the hypolimnion caught primarily small lake trout, which were most abundant near the greatest depths sampled; lake trout of intermediate size were caught by anglers who mostly fished shallow waters from the lake shoreline or near the lake surface from boats between mid-June and the end of July; and most large lake trout were caught in gill nets set near the interface of the thermocline and hypolimnion.

Although the cause of this bathymetric separation among lake trout size-classes is unknown, the distribution of food and the availability of preferred water temperatures for large lake trout might be important factors. Data presented here show Yellowstone cutthroat trout, the principal fish prey of lake trout, are most abundant in summer in the hypolimnion near the thermocline--the region where large lake trout are most abundant. Temperatures of 6°C to 13°C preferred by lake trout (Martin and Olver 1980) also occur at these depths.

Small lake trout may have evolved the use of deep water where predation by large lake trout is minimized; however, in deep water in Yellowstone Lake temperatures are lower than preferred and lake trout diet appears restricted to amphipods and other invertebrates. Benson (1961) reported that *Gammarus lacustris* were abundant down to 30 m and present at 43 m in Yellowstone Lake. Lake trout of intermediate size, caught primarily from

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shallow waters by anglers, can utilize what is probably a comparatively abundant food supply consisting of both fish and invertebrates. By mid-summer, however, these shallow waters exceed 13°C, temperatures generally avoided by lake trout (Martin and Olver 1980; Coutant 1977); the angler catch of these fish declines sharply as they move to cooler waters at greater, although presently unknown, depths.

The size-classes of lake trout conspicuously missing from the gillnet data, primarily fish 400-550 mm long, revealed the inadequacy of our gillnet sampling. Although the gillnet mesh sizes used should have detected the missing size-classes, our sampling was too limited in space (i.e., sampling depth and area) and time (i.e., across seasons) to capture these fish. Achieving a definitive understanding of the size structure and distribution of the lake trout population in Yellowstone Lake will require use of the full range of gillnet mesh sizes across all lake areas, depths, and seasons.

When lake trout were first introduced to Yellowstone Lake is unknown and perhaps impossible to determine; however, when lake trout began to reproduce in the lake can be estimated on the basis of available data. The mature lake trout > 600 mm long caught in gill nets were too numerous to be explained as fish caught by anglers from a nearby source (e.g., Lewis Lake in Yellowstone National Park) and then nefariously stocked into Yellowstone Lake individually or in small groups, even over many years. Similarly, the broad ranges in lengths and estimated ages of the large lake trout, from 600 to 870 mm long and 10 to 20 years old, were not indicative of the unauthorized introduction of these fish as fingerlings (source?) about 20 years ago.

The large lake trout caught from Yellowstone Lake in 1996 can instead be explained as the first generation of lake trout produced in the lake from a founding parent stock that had been introduced illegally many years ago and perhaps numbered only a few fish. In turn, the lake trout < 600 mm long, which appear to be much more abundant than the larger fish, are second-generation lake trout. If this scenario is correct, lake trout began spawning in Yellowstone Lake about 20 years ago. Female lake trout surviving from the founding parent stock would now be at least 30 years old.

Although size of the lake trout population of Yellowstone Lake is unknown, the relative abundance of these fish in our gill net catches suggests the population is larger than the tens of thousands of fish that researchers speculated were present in 1994 (cf. Kaeding et al. 1996). Moreover, reproduction by the presumed second-generation female lake trout, the largest of which have reached sexual maturity, could lead to a rapid increase in lake trout population.

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Lake Trout Control

A two-part program that uses gill nets to remove lake trout from Yellowstone Lake is proposed. The first part, which was implemented by the National Park Service on 22 July 1996, involves extensive use of 64-mm and 76-mm-mesh gill nets, set near the interface of the thermocline and hypolimnion, to capture and remove large lake trout--particularly mature female fish--from the West Thumb region of the lake. Lake trout primarily 640-694 mm long were caught in these mesh sizes. Because the bycatch of Yellowstone cutthroat trout in these nets might be substantial, nets should be retrieved daily and captured cutthroat trout released when possible. Netting should be conducted throughout the ice-free season and particularly on spawning sites as they are discovered.

Biotelemetry of lake trout, along with ongoing analyses of gillnet catch statistics, should be routinely used to determine areal locations and lake depths at which gill nets should be set to maximize lake trout catch rates. Mature lake trout caught from the lake and implanted with pressure-sensitive ultrasonic tags could reveal favored areas and water depths used seasonally by these fish, including their spawning areas. Concurrent use of radio transmitters implanted in mature lake trout would allow tracking of tagged fish in shallow water from aircraft, which might be necessary to search the 242 km (150 miles) of lake shoreline in fall and early winter, when the lake trout probably spawn and storms can make boating hazardous.

Control program success should be measured in part by the trend in overall catch rates for mature lake trout in nets among years. Netting effort should be increased annually until a sustained decline in CPUE is evident.

Between the onsets of piscivory and vulnerability to capture in the large-mesh nets, a period of about 5 years, lake trout will be eating Yellowstone cutthroat trout. Unrestrained predation by these age-classes of lake trout, which had the highest incidence of fish in their stomachs among all lake trout examined, might significantly reduce the population of Yellowstone cutthroat trout. Thus the objective of the second part of the control program is to kill juvenile lake trout before they become piscivorous.

Gill nets with 25-mm-mesh netting should be set during summer in water ≥ 40 m, where lake trout will be caught and a low bycatch of cutthroat trout will occur. This size netting caught lake trout that averaged 260 mm long at a rate among the highest for the nine mesh sizes examined. The recommended netting should also focus initially on the West Thumb area but, like the large-mesh netting, should incorporate other lake areas as personnel and other resources permit.

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Use of professional gillnet fishermen may be a cost-effective means to control lake trout in Yellowstone Lake and should be considered. The National Park Service would closely monitor the professional gillnet catch and collect important data from lake trout caught by professional fishermen. It is unlikely that the commercial value of lake trout caught from Yellowstone Lake would be sufficient to attract and maintain professional fishermen on the lake, however; additional financial incentives may be required.

Extant knowledge of the distribution of lake trout in Yellowstone Lake is not based on comprehensive sampling and that distribution will change markedly as the lake trout population grows. Extensive, systematic monitoring of the lake trout population and analysis of resulting data must therefore be ongoing processes. To be effective in controlling lake trout, the control program must employ adaptive management strategies to adjust rapidly to changes in the lake trout population.

Acknowledgments

Funding for this study was provided primarily by the U.S. Fish and Wildlife Service and the National Park Service, Yellowstone National Park. Private donations to the Yellowstone Fisheries Fund were used to purchase gill nets and sonar equipment. Field assistance was provided by Daniel Carty, Jeffery Lutch, Shannon Troop, and numerous park staff and volunteers. Dan Reinhart cataloged much of the data from anglers. Data on lake temperatures were provided by Edward Theriot, Sue Kilham, and their coworkers. Charles Bronte kindly performed analyses of scale annuli for the large lake trout. Doug Osmundson aided statistical analyses of geometric mean CPUE. Charles Bronte and Dave Beauchamp provided useful reviews of a preceding draft of this report.

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Table 1.--Total small-mesh and large-mesh gillnet sampling effort (linear m nights) expended in each of the 13 sampling sites, Yellowstone Lake, 1995 and 1996.

Mesh	Sampling site												
	1	2	3	4	5	6	7	8	9	10	11	12	13
							1995						
Small	1061	4243	0	4596	686	0	3889	0	0	2121	5657	2475	0
Large	0	0	0	0	229	0	0	0	0	0	0	0	0
							1996[a]						
Small	1414	1414	1061	1414	0	0	1061	0	0	2829	2121	1414	0
Large	1207	1006	1408	2213	0	3621	1207	5230	37588	604	2091	604	22857

[a] An addition 6,846 linear m nights of large-mesh sampling effort were expended in other areas around Yellowstone Lake.

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Table 2.--Mean total lengths (TL; mm), 95% confidence limits (CL) of means, ranges in total length, and sample sizes for lake trout, Yellowstone cutthroat trout, and longnose suckers caught in nine gillnet mesh sizes. Means in bold type differed significantly (Scheffe's Tests, $\underline{P} < 0.05$) between species within mesh sizes (except Yellowstone cutthroat trout mean length did not differ [$\underline{P} > 0.05$] from that of longnose suckers in 76-mm mesh nets). Within species, means having a superscript letter in common did not differ significantly (Scheffe's Tests, $\underline{P} > 0.05$).

	Mesh size (mm)				
Parameter	19	25	32	38	51
			Lake trout		
TL (95% CL)	**206** (198-215)	**260** (255-265)	305 (299-311)	355^a (344-367)	376^a (348-405)
Range (N)	173-266 (27)	215-395 (126)	234-395 (78)	252-772 (90)	322-527 (17)
			Yellowstone cutthroat trout		
TL (95% CL)	**187** (184-189)	**246** (244-249)	299 (294-305)	358 (355-360)	393^a (387-399)
Range (N)	157-276 (237)	186-358 (271)	254-412 (96)	200-454 (575)	196-477 (238)
			Longnose suckers		
TL (95% CL)	191^a (0-438)	248^a (194-301)	287^a (272-302)	363^b (349-377)	400^b (364-436)
Range (N)	171-210 (2)	217-282 (4)	256-330 (10)	283-521 (60)	330-482 (11)

Table 2.--extended.

	Mesh size (mm)			
Parameter	64	76	89	102
			Lake trout	
TL (95% CL)	**664**^{b}(640-688)	**672**^{b}(649-694)	**687**^{b}(652-722)	**681**^{b}(545-817)
Range (N)	472-870 (56)	349-864 (77)	542-832 (26)	510-823 (6)
			Yellowstone cutthroat trout	
TL (95% CL)	**387**^{a,b}(378-397)	**377**^{b}(371-382)	**396**^{a,b}(374-419)	**378**^{a,b}(368-388)
Range (N)	270-485 (73)	260-479 (173)	325-440 (12)	287-465 (54)
			Longnose suckers	
TL (95% CL)	**506**^{c} (499-513)	**457**^{b,c}(146-768)		
Range (N)	450-558 (55)	316-554 (3)	(0)	(0)

Table 3.--Geometric mean CPUE (95 percent confidence limits for means in parentheses) for lake trout, Yellowstone cutthroat trout, and longnose sucker caught in nine gillnet mesh sizes. Within and between species; means with 95 percent confidence limits that do not overlap are significantly different ($P < 0.05$).

Mesh size (mm)			
19	25	32	38
Lake trout			
0.185 (0.273-0.103)	0.675 (0.947-0.441)	0.448 (0.642-0.276)	0.237 (0.326-0.156)
Yellowstone cutthroat trout			
1.568 (2.043-1.168)	1.708 (2.256-1.252)	0.570 (0.807-0.364)	1.056 (1.359-0.791)
Longnose sucker			
0.015 (0.037-0)	0.028 (0.055-0.001)	0.078 (0.125-0.032)	0.116 (0.174-0.061)

Table 3.--extended.

Mesh size (mm)			
51	64	76	89
Lake trout			
0.019 (0.040-0)	0.073 (0.123-0.024)	0.077 (0.105-0.050)	0.063 (0.102-0.026)
Yellowstone cutthroat trout			
0.337 (0.459-0.225)	0.107 (0.144-0.072)	0.151 (0.206-0.099)	0.031 (0.053-0.009)
Longnose sucker			
0.023 (0.043-0.003)	0.061 (0.019-0.006)	0.021 (0.024-0.018)	0.0

Table 3.--extended.

Mesh size (mm)
102
Lake trout
0.008 (0.016-0)
Yellowstone cutthroat trout
0.063 (0.087-0.040)
Longnose sucker
0.0

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Fig. 1.--Yellowstone Lake, sampling sites where gillnetting was conducted (numbers), and the site where water temperature profiles were measured (★).

Fig. 2.--Representative water temperature profiles for Yellowstone Lake, June-September, 1995 and 1996.

Fig. 3.--Length-frequency distributions for lake trout caught in gill nets and by anglers, 1995 and 1996.

Fig. 4.--Lake trout lengths at capture in gill nets and by anglers and estimated ages from scale annuli, 1995 and 1996.

Fig. 5.--Gonadosomatic indices (GSI) for male and female lake trout caught in gill nets and by anglers, 1995 and 1996.

Fig. 6.--Geometric mean CPUE (horizontal tick) for lake trout (L), Yellowstone cutthroat trout (C), and longnose suckers (S) caught in small-mesh gill nets (above) and large-mesh gill nets (below), by sampling site. The ends of the vertical bars are 95 percent confidence limits for means. Among species, sampling sites, and net types, means with 95 percent confidence limits that do not overlap are significantly different ($\underline{P} < 0.05$). See Fig. 1 for locations of sampling sites.

Fig. 7.--CPUE for Yellowstone cutthroat trout and lake trout in small-mesh gill nets and water depth at the shallow end of the net. Regression lines for the two relations are shown.

Fig. 1

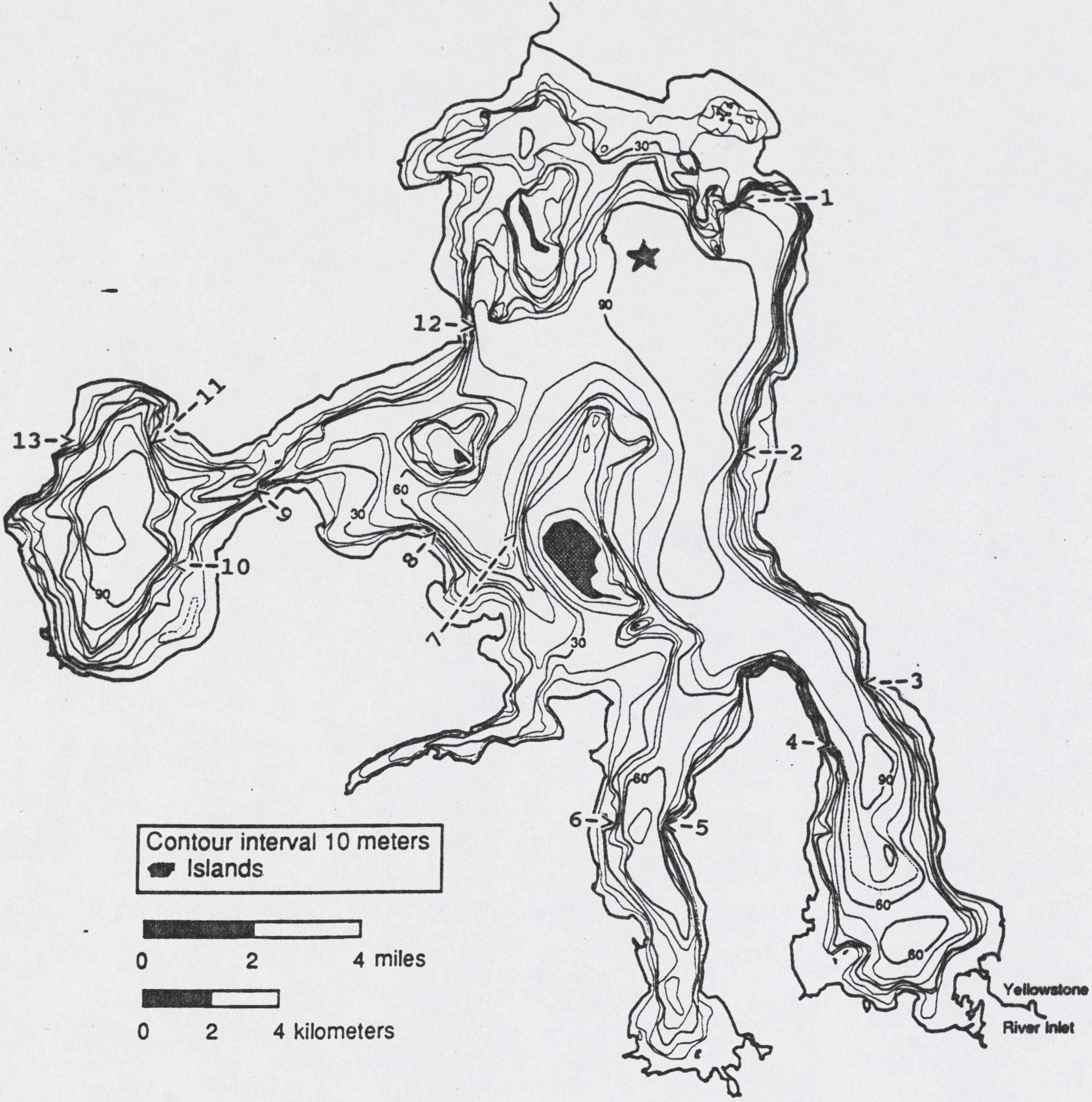

Yellowstone River Outlet
30
1
90
12
11
13
2
60
30
9
8
10
90
7
30
3
4
90
60
6
5
60
60
Contour interval 10 meters
Islands
0 2 4 miles
0 2 4 kilometers
Yellowstone River Inlet

Fig. 2

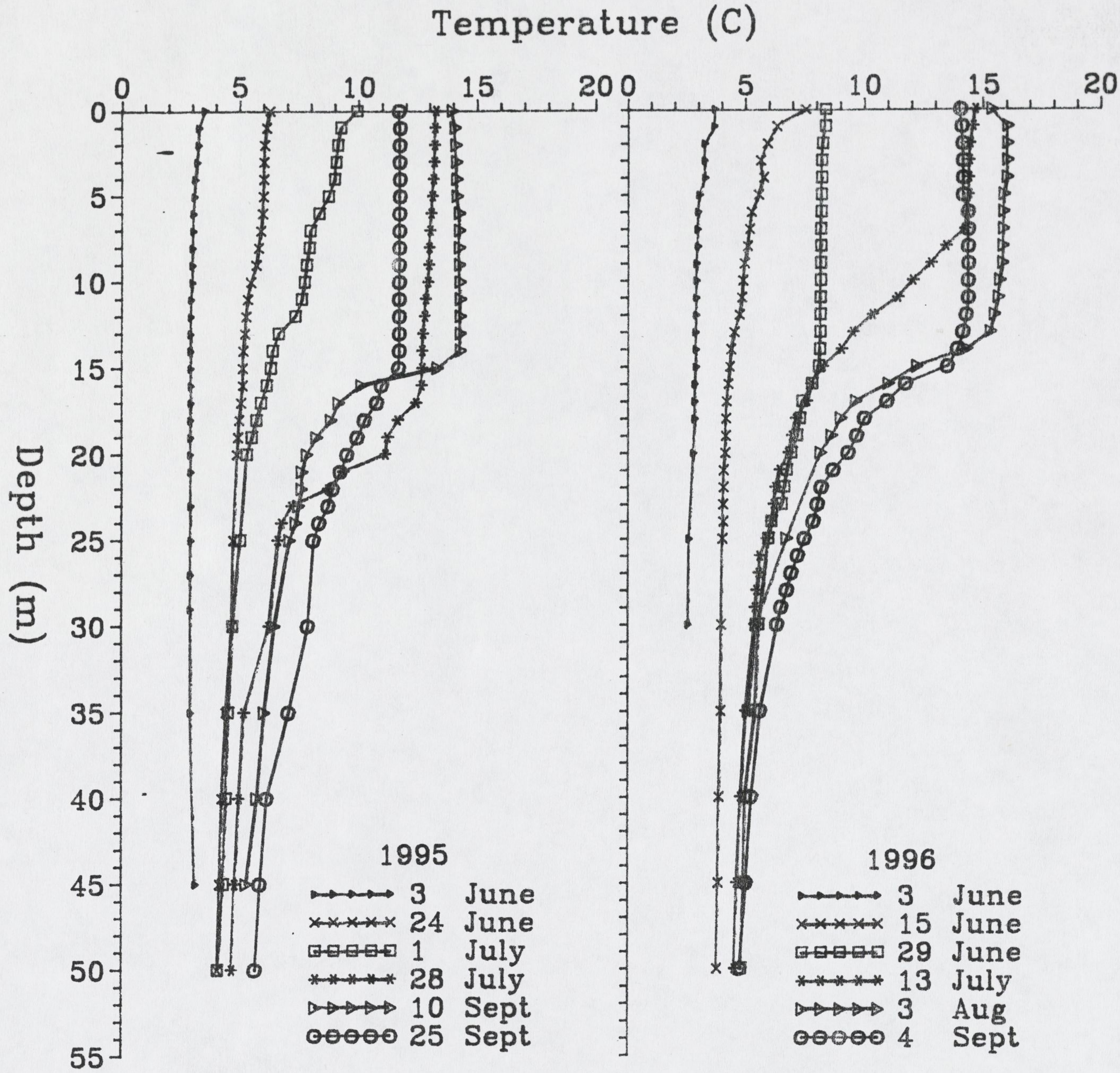
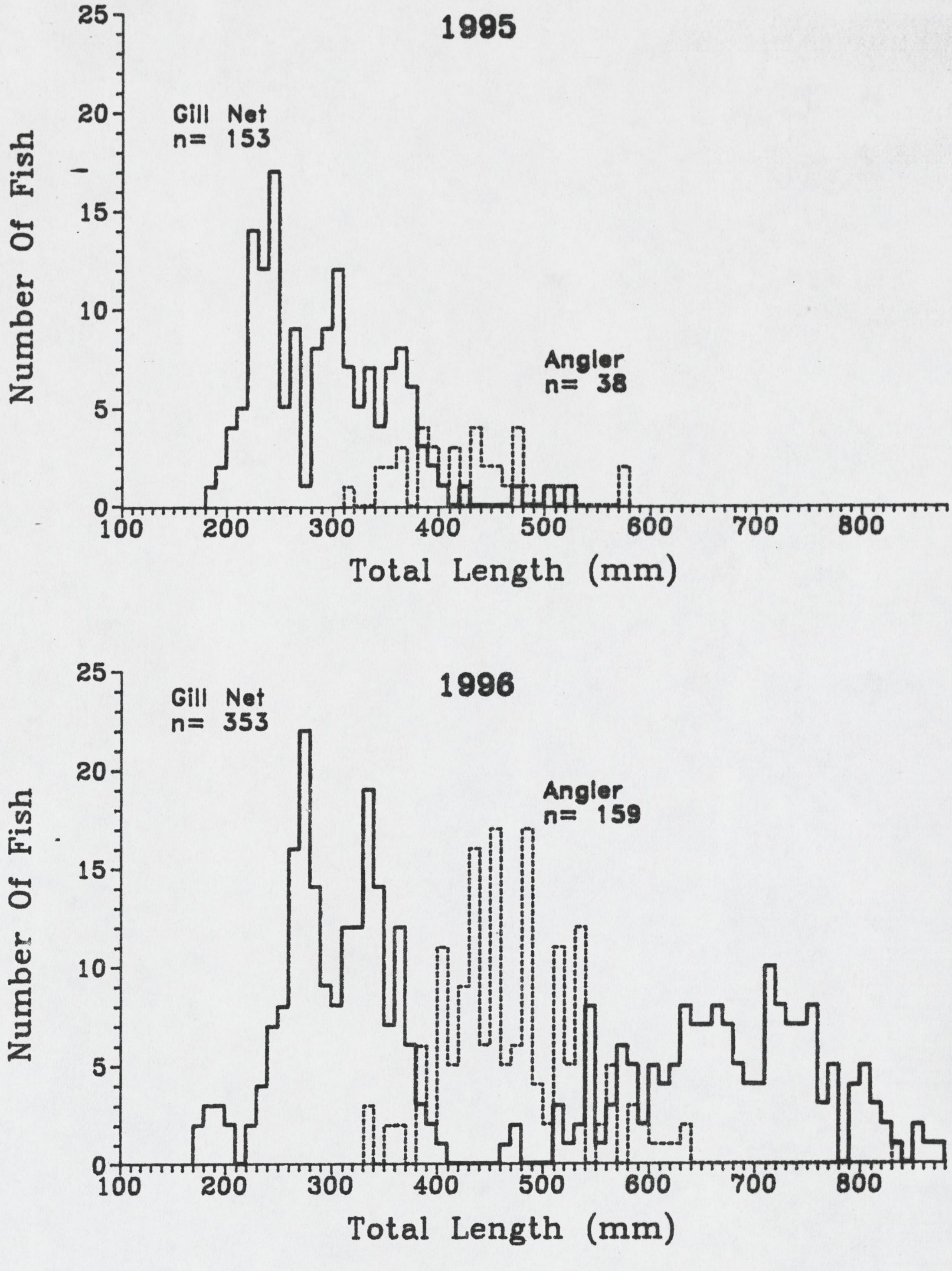
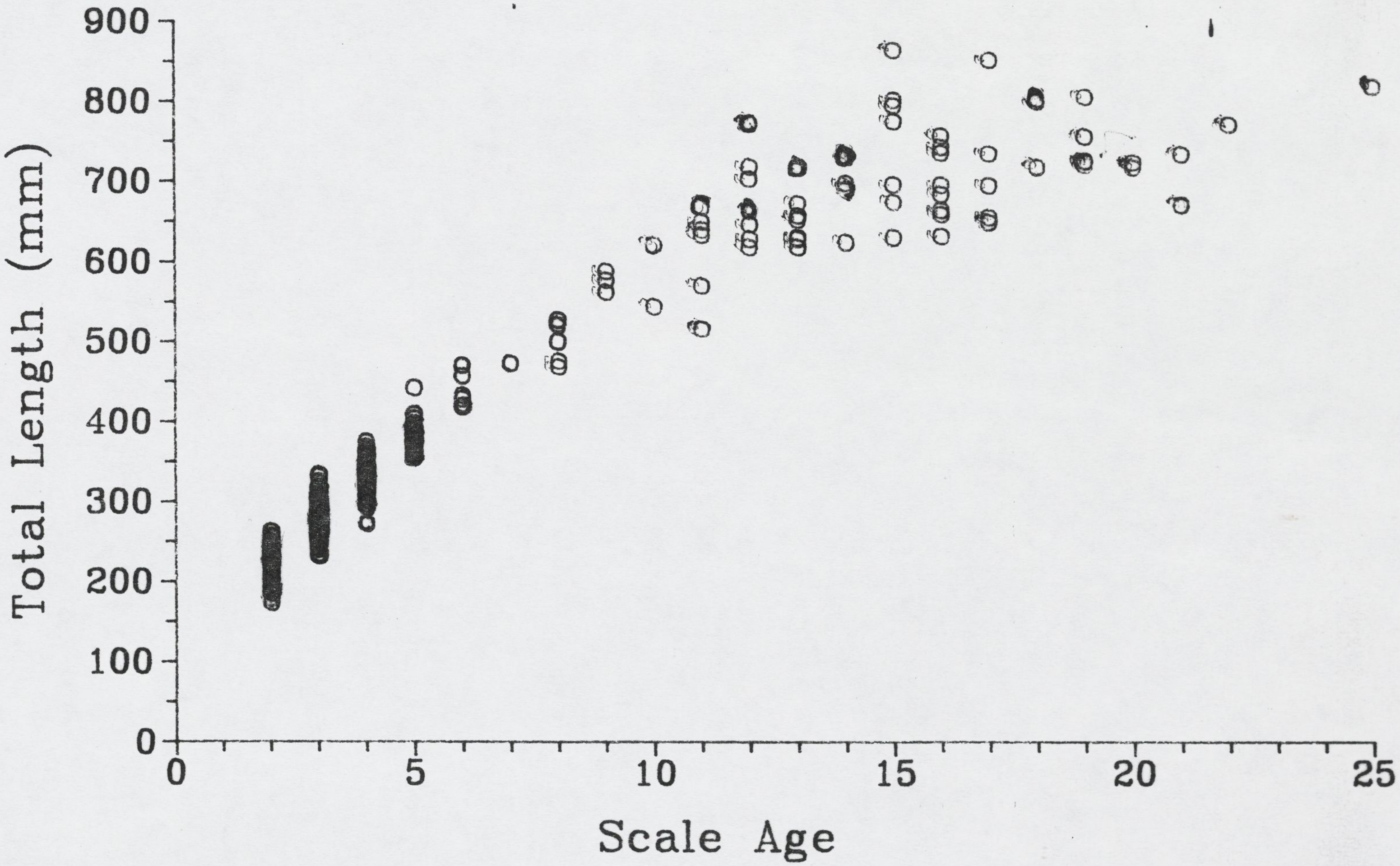

Temperature (C)
0
5
10
15
20
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
55
1995
3 June
24 June
1 July
28 July
10 Sept
25 Sept
1996
3 June
15 June
29 June
13 July
3 Aug
4 Sept

Fig. 3

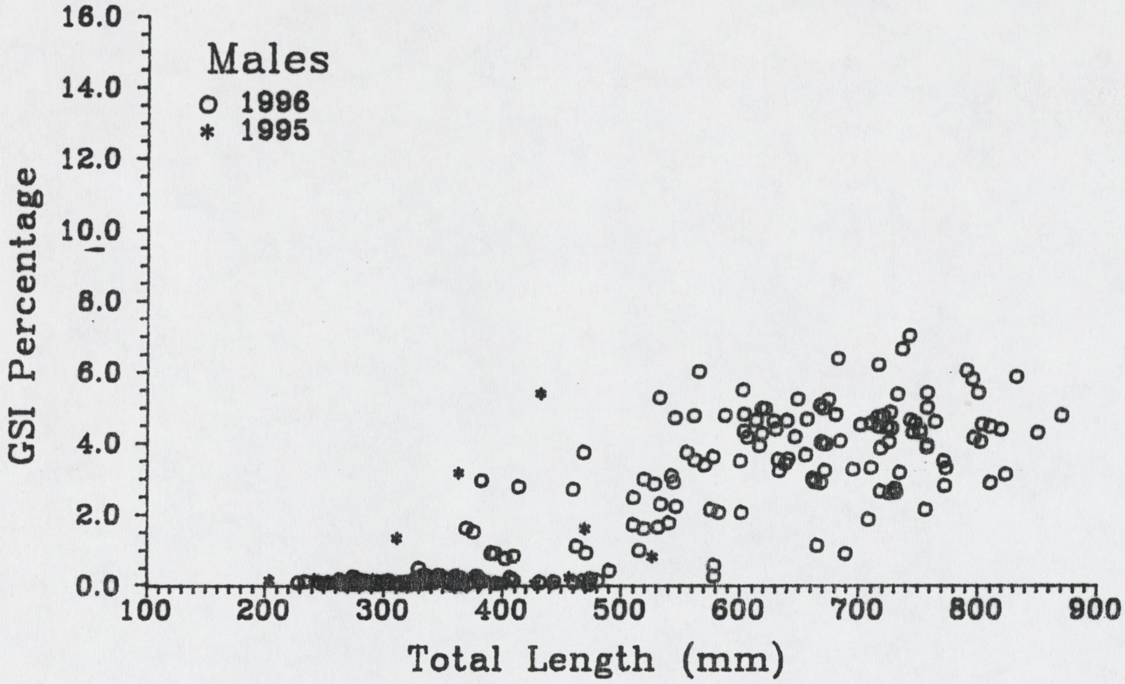

1995
Gill Net
n= 153
Angler
n= 38
Number Of Fish
0
5
10
15
20
25
100
200
300
400
500
600
700
800
Total Length (mm)
1996
Gill Net
n= 353
Angler
n= 159
Number Of Fish
0
5
10
15
20
25
100
200
300
400
500
600
700
800
Total Length (mm)



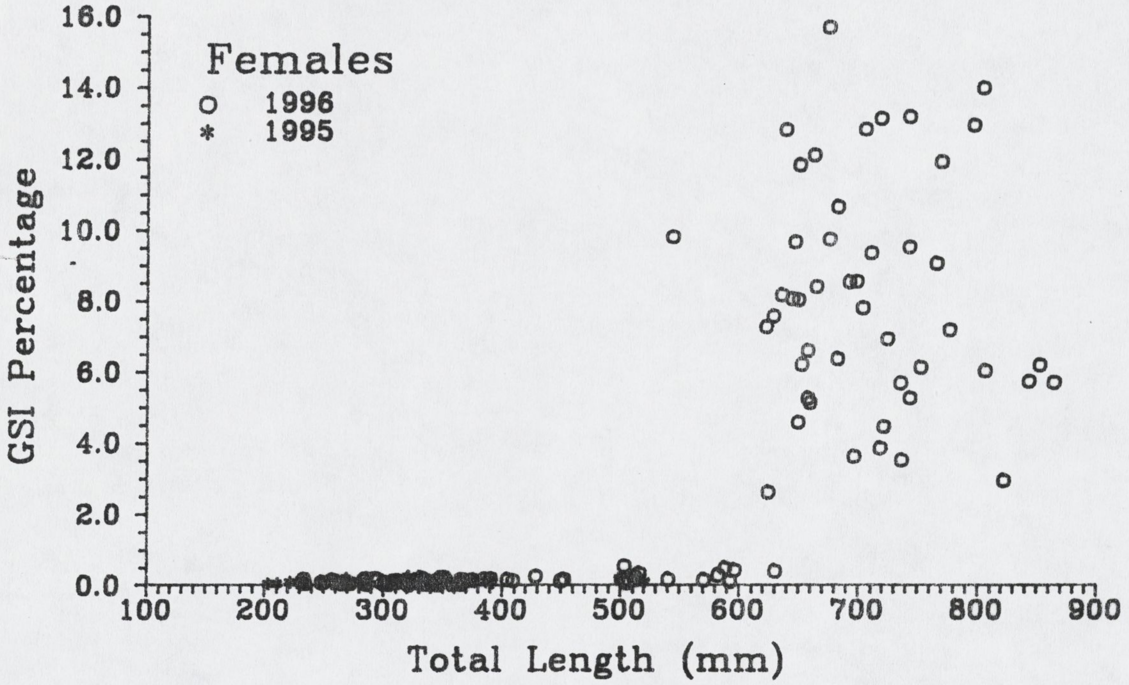
900
800
700
600
500
400
300
200
100
0
Total Length (mm)
0
5
10
15
20
25
Scale Age

Fig. 4

Fig. 5



Males
o 1996
* 1995
GSI Percentage
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
100
200
300
400
500
600
700
800
900
Total Length (mm)



Females
o 1996
* 1995
GSI Percentage
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
100
200
300
400
500
600
700
800
900
Total Length (mm)

Fig. 6

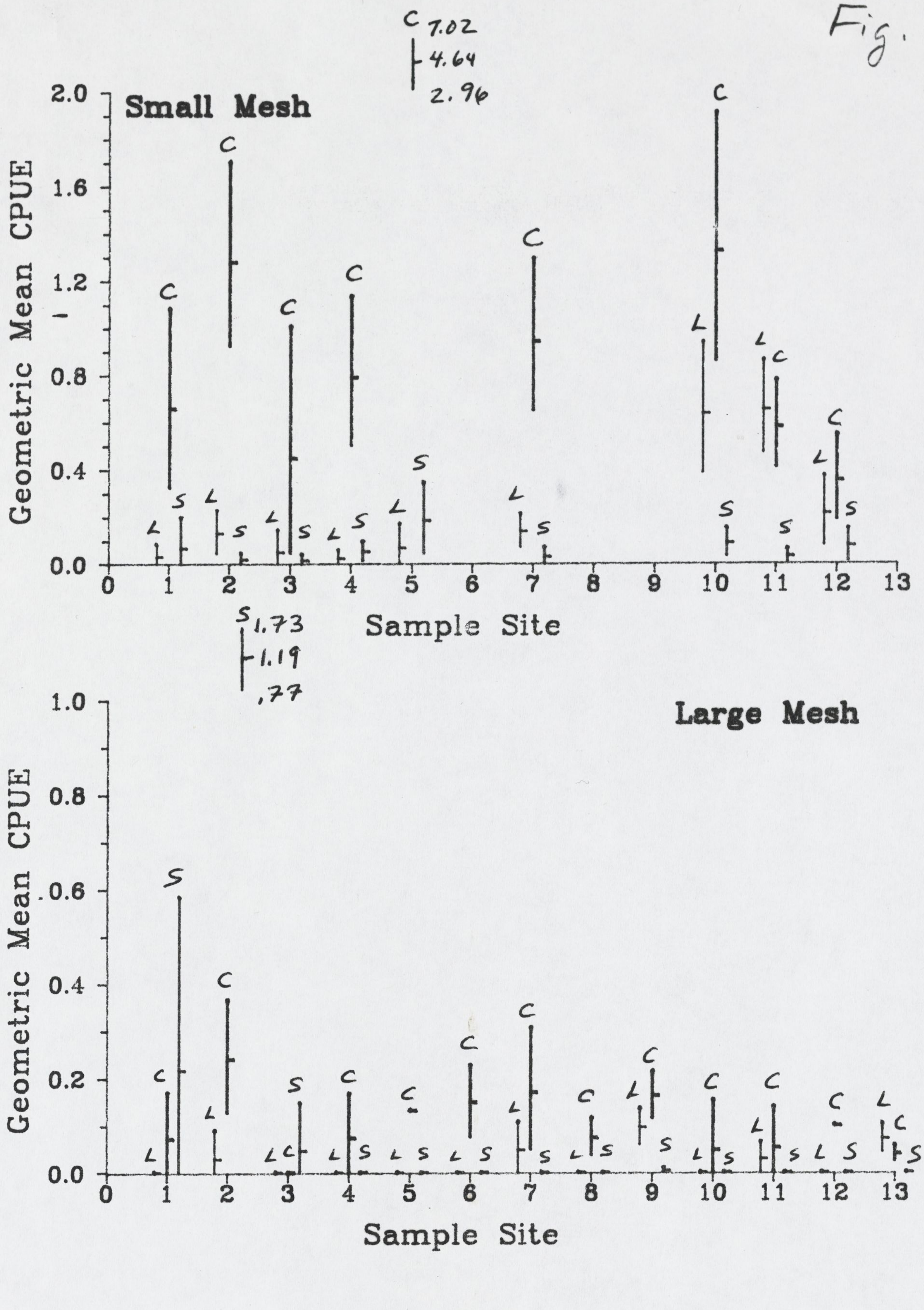
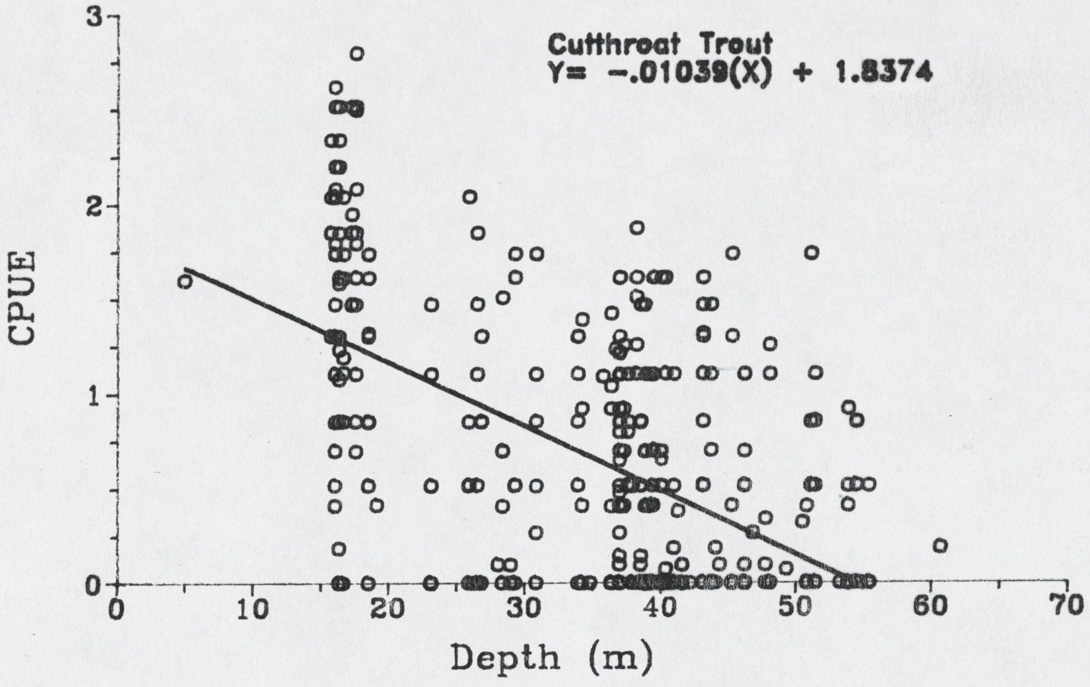
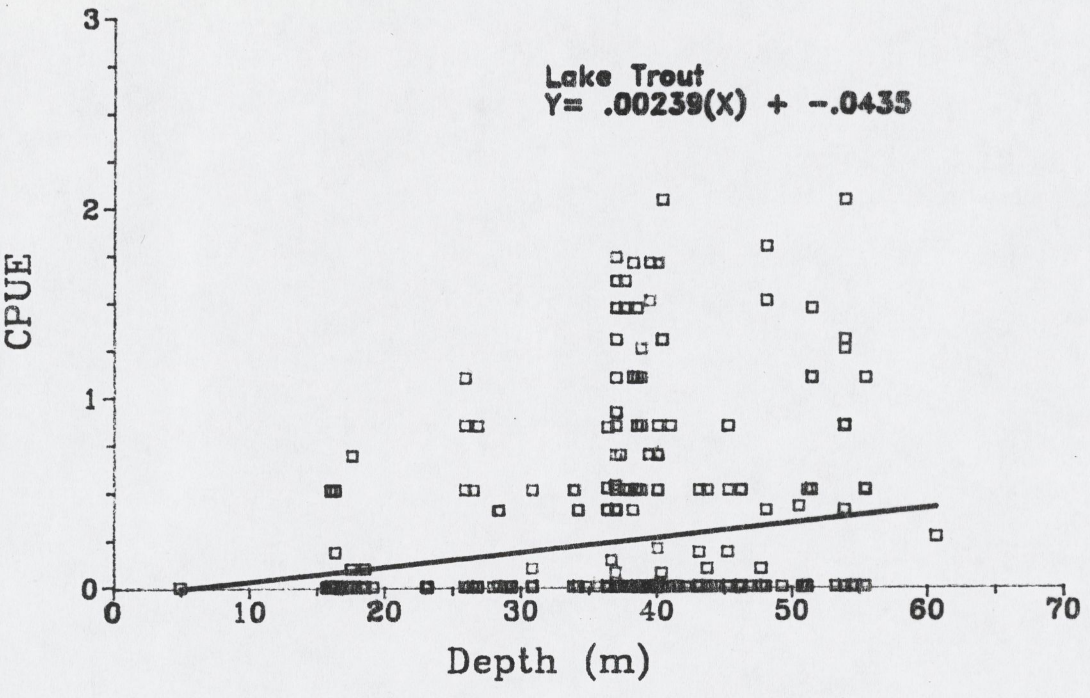

Small Mesh
C 7.02
4.64
2.96
Geometric Mean CPUE
2.0
1.6
1.2
0.8
0.4
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Sample Site
C
L
S
S 1.73
1.19
.77
Large Mesh
Geometric Mean CPUE
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Sample Site

Fig. 7



Cutthroat Trout
Y= -.01039(X) + 1.8374
CPUE
3
2
1
0
0
10
20
30
40
50
60
70
Depth (m)



Lake Trout
Y= .00239(X) + -.0435
CPUE
3
2
1
0
0
10
20
30
40
50
60
70
Depth (m)