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# TWIN LAKES STUDIES:

# A CHARACTERIZATION OF THE TWIN LAKES FISHERY VIA CREEL CENSUS WITH AN EVALUATION OF POTENTIAL EFFECTS OF PUMP—STORAGE POWER GENERATION

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16. ABSTRACT

Creel census studies were conducted at Twin Lakes, Colo. from 1972 to 1979 to characterize the fishery, and to provide a basis for the evaluation of potential impacts upon the fishery resulting from the construction and operation of the Mt. Elbert Pumped-Storage Powerplant located on the lower lake. In this report, creel census data are presented for the period December 1976 to September 1979. Creel census has resulted in characterization of the Twin Lakes fishery with a precision adequate for analyses of pumped-storage effects upon the major components of the fishery. For both lakes in the summer seasons, the best relative precision was associated with estimates of total fishermen effort and harvest, total shore fishermen effort and harvest, and total boat fishermen effort. In the winter seasons only estimates of total fishermen effort for the lower lake had an adequate precision. Because of statistically significant fluctuations in yearly estimates of fishermen effort and harvest, gradual changes in the fishery will require data gathered over longer periods before significant impacts or trends resulting from the powerplant operation can be established. Potential powerplant impacts, such as increased mortality to rainbow trout, daily and seasonal water-level fluctuations, and shoreline turbidity may have adverse effects on the Twin Lakes shore fishery for rainbow trout. Large-scale impacts probably will be necessary to demonstrate effects upon the boat fishery and the lake trout harvest due to their minor dimension in the total fishery and the lower relative precision of their estimates.

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# TWIN LAKES STUDIES: A CHARACTERIZATION OF THE TWIN LAKES FISHERY VIA CREEL CENSUS WITH AN EVALUATION OF POTENTIAL EFFECTS OF PUMPED-STORAGE POWER GENERATION

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# FOREWORD

Pumped-storage (or pump-back storage) power generation involves the use of reversible turbines to pump water to an elevated reservoir for storage during times of low energy demand. At times of peak energy demand, this water is released through the turbines, converting the potential energy of the stored water to electricity (Hauck and Edson, 1976 [1][1]). Bajura and Schwartz (1977) [2] indicate that most of the current pumped-storage operations involve a fluid exchange of 10 percent or less of the initial reservoir volume. While pumped storage is an energy-losing operation, the price differential of energy between periods of peak and low demand make the operation economical. Another favorable aspect of pumped-storage power generation is its capability for very rapid startup and loading. This permits a highly flexible system to react quickly to short-term fluctuations in energy demands. Pumped-storage units allow a more efficient and uniform operation of conventional fossil fuel and nuclear powerplants by reducing severe power load cycling. This provides a power generation system of greater reliability (Hauck and Edson, 1976 [1]).

Trends indicate pumped-storage development is moving toward larger units, averaging 975 megawatts, and toward larger-scale development projects (Hauck and Edson, 1976 [1], Riester et al., 1976 [3]). There are over 1000 potential sites for pumped-storage development in the United States (Hauck and Edson, 1976 [1]).

The major aquatic problems arising from pumped-storage operations include (1) changes in water quality or quantity, (2) entrainment and mortality of aquatic organisms, and (3) water-level fluctuation (Schoumacher, 1976 [4]). Several studies have revealed a complex interface of engineering and biological considerations when evaluating these potential impacts from pumped-storage operations. Certain specific impacts may be relevant to the operation of the Mt. Elbert Pumped-Storage Powerplant at Twin Lakes.

Disruption of thermal stratification was evident in Banks Lake, Wash. (Stober, 1976 [5] and Stober et al., 1977 [6]), and in the Salt River reservoirs in Arizona (McNatt, 1976 [7]). At Jocassee Reservoir, S. C., the annual loss of suitable trout habitat in the thermocline was a result of pumped-storage operation. This operation caused a progressive depression of the upper temperature limit that trout can tolerate toward the depth defining their lower dissolved oxygen limit in the hypolimnion (Garton, 1980 [8], Oliver and Hudson, 1980 [9]).

Entrainment and mortality of fish populations throughout their life stages have been amply documented by Boreman (1977) [10] and others. Stober et al. (1977) [6] observed kokanee salmon, rainbow trout, and lake whitefish to be more attracted to pump-back flows and entrainment than yellow perch, walleye, longnose suckers, and mountain whitefish among others. Kelso and Leslie (1979) [11] found larval white suckers were entrained in numbers much greater than their low relative abundance in Lake Huron. At the Ludington site on Lake Michigan, mortalities to entrained rainbow trout during pumping and generating modes have been estimated at 56 and 44 percent, respectively, for a combined mortality of the total population of 75 to 81 percent (Serchuk et al., 1975 [12], Liston and Tack, 1977 [13], Liston, 1979 [14]). From 1975 to 1978, an estimated 6182 lake trout were killed at Ludington during the open-water season, which amounted to 2 to 4 percent of the sport angler harvest of lake trout in the region (Liston, 1979 [14]). Brazo (1977) [15] and Anderson (1977) [16] observed a seasonal and size selective attraction of salmonid species to rock jetties (constructed as part of the tailrace of the Ludington Powerplant). This attraction was linked to the spawning season and to the attraction of the anadromous species to the powerplant flows.

The Mt. Elbert Powerplant is the first major pumped-storage development on public waters in Colorado (Hauck and Edson, 1976 [1]). Studies performed will provide insight into the potential effects of pumped-storage operation upon a coldwater, stocked rainbow trout fishery, one of the major types of reservoir fisheries found in Colorado (Nesler, 1980 [17]). Many of the State's reservoirs are in mountainous areas that provide the natural hydraulic head conditions suitable for the pumped-storage type of operation. These reservoirs are also major recreational fisheries. Unlike many of the reservoirs or lakes involved in pumped-storage development, Twin Lakes are

[1] Numbers in brackets refer to entries in the Bibliography.

a relatively small, closed system (LaBounty and Roline, 1980 [18]), and their fish populations and fisheries may experience a relatively greater impact in comparison to larger reservoir systems.

This report is one of a series of publications reporting the ecological effects of pumped storage. Described in this report are the ecological conditions in existence at Twin Lakes, Colo., prior to pumped-storage operation. Each of the reports will deal with individual aspects of the Lakes' ecology in sufficient detail to allow quantification of powerplant effects. The first of two units of the Mt. Elbert Pumped-Storage Powerplant will begin testing operation in August and full operation during October 1981. The post-operation phase of the ecological investigations at Twin Lakes will begin in August 1981.

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## FIGURES — Continued

## PURPOSE

The data contained in this report are a significant part of the baseline information on the aquatic environment of Twin Lakes, Colo. Findings during the postoperative period will be compared to the baseline data so that the impacts of the Mt. Elbert Pumped-Storage Powerplant can be more accurately determined. The information in this report will be useful to those interested in cold-water fishery management and particularly to those evaluating the impacts of powerplant operation on fisheries.

## INTRODUCTION

Twin Lakes are unique among Colorado reservoirs because of the character of their lake trout population, which has been self-sustaining and has provided trophy-size fish annually (Finnell, 1972 [19]). The fishery can be divided between the predominant summer fishery for stocked, creel-size rainbow trout *(Salmo gairdneri* Richardson), which is common to many Colorado reservoirs, and the winter fishery for lake trout *(Salvelinus namaycush* Walbaum) (Nesler, 1980 [17]). The quality of this fishery could be threatened by operation of the Mt. Elbert Powerplant through (1) potential disruption of thermal stratification, (2) increased lake turbidity by resuspension of lake sediments, (3) increased mortality to the lake trout's major food items — the opossum shrimp *(Mysis oculata relicta* Loven), and to other fish species, and (4) increased mortality to game fish species via entrainment and turbine-related injury (Finnell, 1972 [19], 1977 [20]; Bennett, 1975 [21]; Griest, 1977 [22]). The objective of this Twin Lakes study was to characterize the fishery and provide a basis for evaluating the potential impacts of the operation of the Mt. Elbert Powerplant. Creel census studies have been conducted since 1972 at Twin Lakes to accomplish this goal by characterizing fishermen effort, harvest, catch rates and catch composition. Studies from 1972 to 1975 were conducted by Larry Finnell of the Colorado Division of Wildlife (Finnell, 1977 [20]). Those from 1976 to 1979 were conducted by the author and are reported here.

## SUMMARY AND CONCLUSIONS

1. The creel census studies have resulted in estimates of seasonal fishermen effort, harvest, and catch rates with a precision suitable for use in the detection of impacts from the operation of the Mt. Elbert Pumped-Storage Powerplant.

2. The Twin Lakes summer fishery was characterized by:

   a. Percent contribution of shore, boat, weekend day, and weekday strata to seasonal estimates,

   b. Species composition of the seasonal harvest, and the percent of lake trout and rainbow trout harvested by shore and boat fishermen, and

   c. Percent returns and rate of return of marked, creel-size rainbow trout.

   These characteristics will provide a basis for describing and evaluating the impacts of the powerplant upon the fishery.

3. For the 1973-79 summer seasons, total fishermen effort estimates ranged from 66 677 to 89 820 man-hours on the lower lake and from 19 721 to 29 139 man-hours on the upper lake. Harvests ranged from 19 955 to 32 496 fish on the lower lake and from 6411 to 12 457 fish on the upper lake. Shore fishermen accounted for 84 to 86 percent of the total estimate of fishermen effort, and 89 to 91 percent of the total estimated harvest. Fifty-four to 56 percent of the fishermen effort and harvest occurred on weekends. Rainbow trout composed 94 percent or greater of the summer harvests with lake trout second in abundance. Forty-seven to 50 percent of the stocked, creel-size rainbow trout were returned in the harvest in 1977 and 1979. For a given plant of marked fish, 90 percent of the fish observed in the creel were returned in 4 weeks after stocking. Seasonal catch rates ranged from 0.25 to 0.51 fish per man-hour for shore fishermen and from 0.18 to 0.37 fish per man-hour for boat fishermen on both lakes. For the winter seasons on the lower lake from 1974 to 1979, fishermen effort estimates ranged from 3900 to 8800 man-hours and harvest estimates ranged from 400 to 1200 fish. Lake trout composed 87 percent or greater of the harvests in most winter seasons. Winter seasonal catch rates ranged from 0.07 to 0.14 fish per man-hour. The winter fishery demonstrated declines in

fishermen effort and harvests since the winter of 1976-77. The percentage of lake trout equal to or exceeding 508 mm (20 in) in length decreased significantly in the winter harvests from 26 percent to 8 percent.

4. Statistically significant changes in either seasonal fishermen effort or harvest characterized the upper and lower lake fisheries during the preoperational study period. Therefore, to determine gradual impacts of the pumped-storage operation, a data base collected over several years or more may be necessary.

5. Potential powerplant impacts via increased mortality to rainbow trout, daily and seasonal water-level fluctuations, and shoreline turbidity may have the greatest negative impact upon the Twin Lakes shore fishery for rainbow trout.

6. Because the estimates from the winter harvests, the boat fishery, and the monthly creel census for both shore and boat categories are less precise, only large-scale changes in these components will reflect statistical significance. However, these estimates may be useful to indicate long-term, consistent trends.

7. Operation of the powerplant during the weekends in the summer season with increased fishermen activity may have a relatively greater impact on fishermen effort if large-scale turbidity or fishkills are observed.

8. The future trends of the winter fishery are uncertain. The fishery is characterized by the predominance of lake trout in the harvest and is relatively minor in terms of fishermen effort and harvest. Only seasonal fishermen effort (December-March) and seasonal catch rates have a precision adequate for before-and-after impact comparisons on a statistical basis.

9. Declining lake trout harvests and the diminishing trophy aspect of this fishery are apparent from the creel census but do not necessarily indicate a decreased abundance of lake trout. Impacts to this population may not be reflected by the creel census statistics since the lake trout harvest is primarily associated with the less precise summer boat fishery and the winter fishery where large-scale changes will be required.

# STUDY AREA

Twin Lakes are two montane lakes of glacial origin, located on Lake Creek within the drainage of the Upper Arkansas River, 24 km (15 mi) south of Leadville in central Colo. (Sartoris et al., 1977 [23]). The lakes lie at an elevation of 2802 m (9193 ft) at the base of Mt. Elbert in the Sawatch Range (fig. 1). The upper lake has a maximum surface area of 263 ha (651 acres) and a maximum depth of 28 m (92 ft). The lower lake, the largest natural lake in Colo. (Pennak, 1966 [24]), has a maximum surface area of 736.5 ha (1820 acres) and a maximum depth of 27 m (89 ft) (fig. 2). The lakes are dimictic with maximum surface temperatures from 14 to 18 °C (57 to 64 °F) and maximum hypolimnetic dissolved oxygen concentrations from 8.5 to 10 mg/L (8.5 to 10 p/m). Depletion of hypolimnetic oxygen may occur during thermal stratification. An extensive amount of research has been conducted on Twin Lakes, dating back to the 1870's and is summarized by Sartoris et al. (1977) [23] and LaBounty and Roline (1980) [18]. Further details on the history, physical, and limnological characteristics of Twin Lakes, and the design characteristics of the Mt. Elbert Powerplant are provided in Sartoris et al. (1977) [23], Finnell (1977) [20] and others. In addition to the pumped-storage powerplant, an earth-filled dam was constructed 762 m (2500 ft) downstream from the existing dam, and will enlarge Twin Lakes to a combined surface area of 1269 ha (3137 acres) (Fryingpan-Arkansas Project, 1975 [25]). Maximum possible seasonal water-level fluctuation with no powerplant operation will be 12.2 m (40 ft), averaging 5.5 m (18 ft). In operation, the powerplant will cause daily water-level fluctuations from 0.15 to 0.67 m (0.49 to 2.2 ft) depending on lake level and the number of turbines operating (Fryingpan-Arkansas Project, 1975 [25]).

# METHODS

The procedures for the fishermen counts, creel census interviews, and estimation of fishermen effort and harvest at Twin Lakes used by Larry M. Finnell and Gerald Bennett, Colorado Division of Wildlife, from 1973 to 1975 (Finnell, 1977 [20]), were based on the instantaneous count method described in Neuhold and Lu (1957) [26] and applied by Powell (1975) [27].

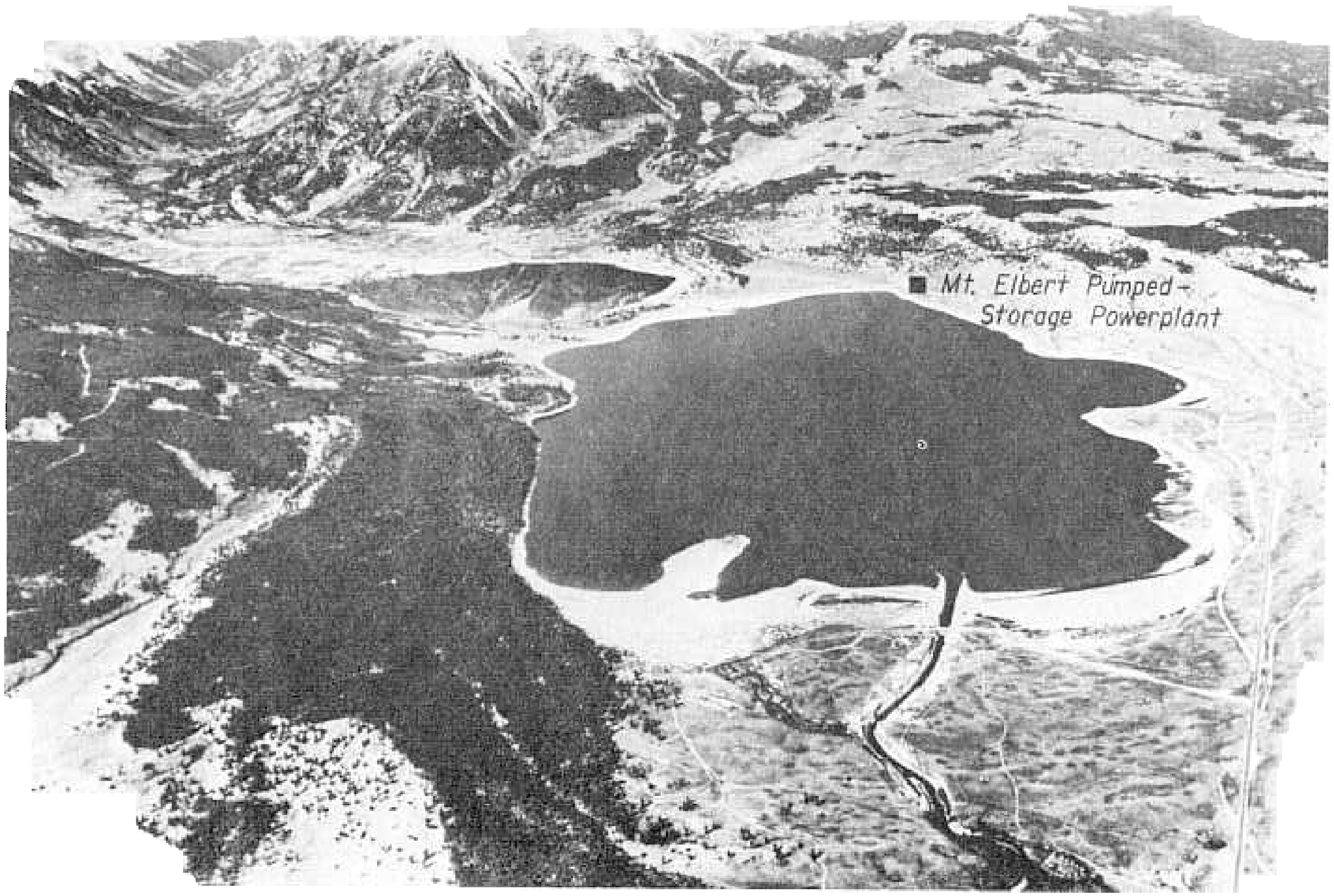


Figure 1.— Twin Lakes with Mt. Elbert in the background. Photo P915-D-79401

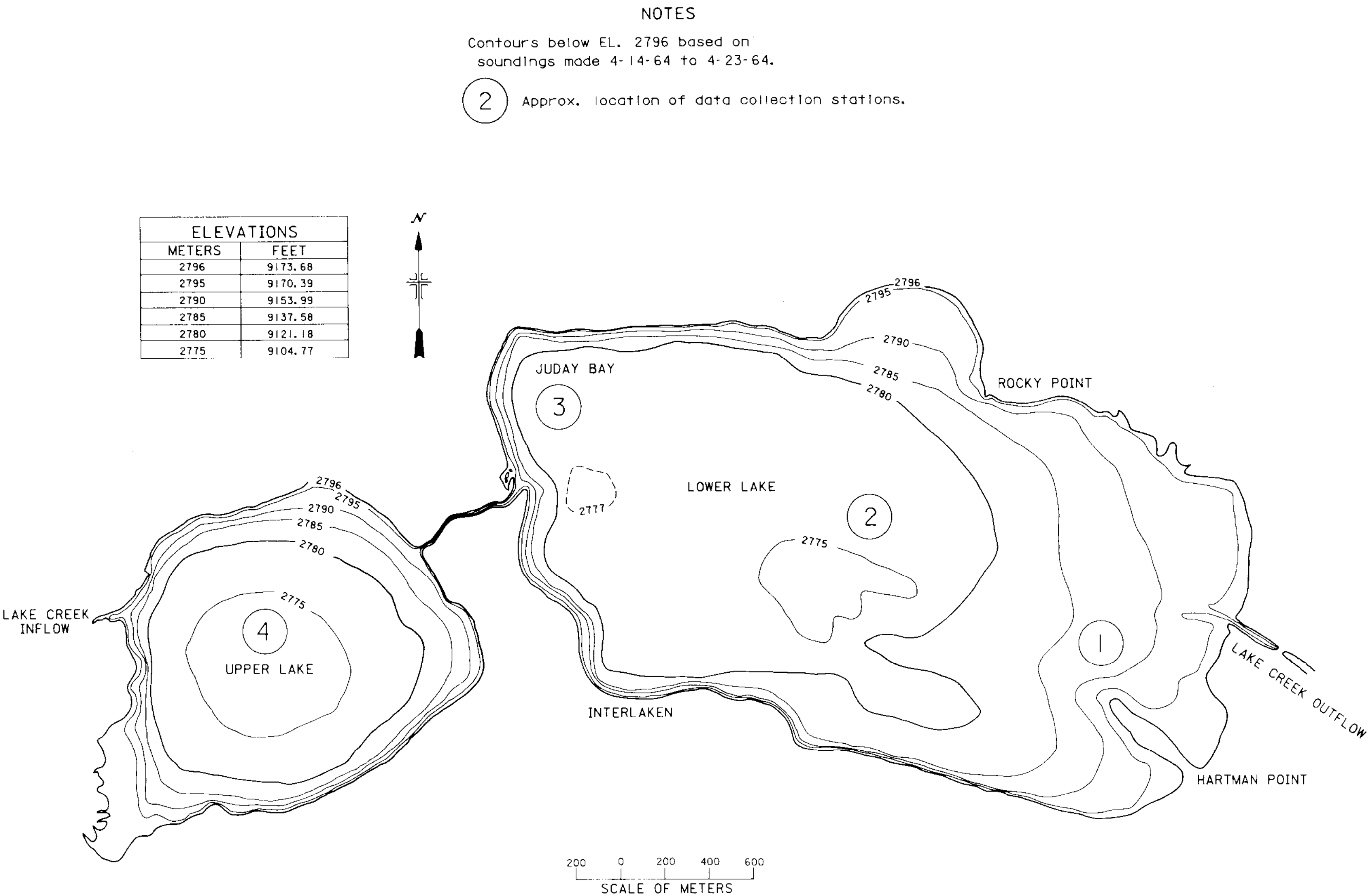


Figure 2.—Bottom topography of Twin Lakes (from USBR drawings 382-706-1325 and -1326).

From December 1976 to September 1979, a stratified-random technique of fishermen counts and creel census was again conducted at Twin Lakes. Sampling was conducted for three winter seasons on the lower lake only from December through March from 1976 to 1979 and for two summer seasons on both lakes from May through September in 1977 and 1979. Field experience from 1973 to 1976 demonstrated little fishermen activity occurred on the upper lake in the winter seasons (Finnell, 1977 [20]). Fishermen counts and creel census interviews were conducted on the same days. Further changes were made in the systematic structure of the sampling program used by Finnell and Bennett, and are described below.

### Winter Seasons

*December 18, 1976 through March 31, 1977*

Sample periods were stratified by week, weekday, and weekend days; December and January were stratified into 1-week blocks, from which 2 weekdays and 1 weekend day were selected randomly for sampling. February and March were stratified into 2-week blocks, from which 2 weekdays and 2 weekend days were selected at random. Three counts of ice fishermen were made during each sample day. The first count time was chosen at random from 12 possible 15-min periods within the period 0800-1100 hours. The remaining two count times were made at 3-hour intervals from the first count time (i.e., 0830, 1130, and 1430). The length of a fishing day was set at 10.5 hours in December (0700-1730), 11 hours in January (0700-1800), and 12 hours in February and March (0700-1900). Creel census interviews were conducted throughout the sample day according to the order in which fishermen completed their trips. Only completed trip information was taken. The number of interviews conducted was representative of the number of fishermen per area of the lake and per day. A fishermen party was used as the interview unit since members of the same ice-fishing party were likely to begin and end their fishing trip collectively. Interview information included the sample date; number of fishermen in the party; time started fishing; census time; total fishing time; number and species of game fish kept; and length, weight, and tags present on each fish.

*December 24, 1977 through March 30, 1978*

The sampling period was stratified into 2-week blocks. Two weekdays and 2 weekend days were selected randomly per block. Fishermen counts were made four times at equal time intervals throughout the sample day. The length of the fishing day was adjusted according to the same pattern in the 1976-77 season except for December, when a 10-hour day was used. The initial count time was selected in the same manner, except that the length of the first count period was determined by the length of the fishing day. This resulted in first count periods from 0700 to 0930 hours in December, 0700 to 0945 hours in January, and 0700 to 1000 hours in February and March. The three subsequent counts were made at 2½-, 2¾-, and 3-hour intervals after the first count time, respectively, for each of the three different first count periods. Creel census interviews were conducted in the same manner except that fish weight measurements were dropped.

*December 16, 1978 through March 30, 1979*

The methods described for the previous season were duplicated in this season except that scale samples were taken from most of the lake trout caught.

### Summer Seasons

Fishing activity was determined as follows:

Shore fishermen: persons attending a fishing rod, casting, or carrying fishing gear alongshore; persons in a boat physically anchored onshore attending a rod, etc.

Boats: boats stationary on the water or moving at trolling speeds.

Creel census clerks were instructed to ascertain whether or not persons at the water's edge were attending a fishing rod or merely engaged in other recreation. They were also instructed to count boats moving steadily in one direction of the lake to fish. This latter decision was qualified by the assumption that nonfishing boats would be much more random in their movements, lack trolling motors, or otherwise display power maneuvers, etc. Persons fishing the interlake stream were included in the upper or lower lake count according to their relative proximity to either lake or by the direction of their movement.

In all cases where fishermen were observed not directly engaged in line-in-the-water fishing, they were counted only if the census clerk decided that they would begin or resume fishing during the 15-min "instantaneous" count period.

*May 14 through September 30, 1977*

The sample period was stratified into 2-week blocks, weekdays, weekend days, and holidays. Two weekdays, 1 Saturday, and 1 Sunday were selected randomly per block. On 3-day holiday weekends, all 3 days were sampled. Total shore fishermen and boats were counted four times during the 13-hour fishing day (0700-2000). Initial count times for each sample day were selected randomly from 13 possible times using 15-min intervals) within the first count period (0700-1015). Three subsequent counts were made every 3¼ hours after the first count time. In September, the fishing day was reduced to 12 hours (0700-1900). Fishermen and boat counts were made from a boat circling the perimeter of both lakes.

Creel census interviews were split into four periods during the sample day: (1) early a.m. (0700-1015), (2) late a.m. (1015-1330), (3) early p.m. (1330-1645), and (4) late p.m. (1645-2000). Combinations of the four census periods were determined randomly, and provided for two census interview periods, one shore census and one boat census, in each sample day. The four periods were represented equally in each month. During a given census period, shore fishermen would be interviewed on one lake as boat fishermen were interviewed on the other lake. Complete trip information was sought whenever possible but incomplete trip information was more frequent. Interview data sought included the sample date, the number of fishermen in the party, time started fishing for each person, census time, total fishing time for the party, and number and species of game fish kept. The presence of tags or finclips were noted on all game fish. Length and weight measurements and a scale sample were taken from all lake trout. For rainbow trout, only numbers and finclips were noted. To determine fishing time, census clerks were instructed to ask what time the fishermen began fishing, and if they had been fishing continuously up to the interview time. All nonfishing time approximating half an hour or more that could be accounted for was discounted from the fisherman's time. Clerks were also instructed to interview fishermen in proportion to their relative concentrations over the lake's area.

*May 26 through September 30, 1979*

The methods used in this season duplicated the 1977 season except that the creel census interviews were split into a morning period from 0700 to 1330 hours and an afternoon period from 1330 to 2000 hours. Shore fishermen were interviewed during one period and boat fishermen during the other. Shore and boat fishermen interviews were split equally among morning and afternoon periods within a 2-week block, but the sequence of sampling the two fishermen classes in the two time periods was determined randomly.

**Estimations of Fishermen Effort and Harvest**

Fishermen count and creel census data were stratified by ice fishermen, shore fishermen, boats, weekdays, and weekend days for each month. This resulted in four strata for which fishermen-hours (effort) and harvest (catch) estimates were calculated for each month during the summer seasons. Only two strata (weekend and weekday) were used for effort and catch estimations per month during the winter seasons. Estimates of shore or boat fishermen-hours were calculated by determining the mean number of fishermen per count in a sample day and multiplying this mean by the length of the fishing day. The mean number of fishermen-hours per sample day within a given stratum (i.e., weekend-shore) was then determined and multiplied by the number of available weekdays or weekend days in that month to estimate total fishermen-hours within that stratum. The number of boat fishermen was determined by the mean number of fishermen per boat calculated from the interview data, and multiplying this mean by the respective counts of boats.

The harvest estimate was calculated by determining the catch rate as CPMH (catch per manhour) from the interview data within a stratum and multiplying by the fishermen-hours estimate for the same stratum (i.e., June shore fishermen-weekdays). Catch rates and harvests for all fish species in total, as well as individual species, were estimated for each stratum. These estimates were made using incompleted and completed trip data combined as well as completed trip data separately. The estimates for the individual strata were summed to provide monthly, seasonal, total shore or boat, or total weekday or weekend day estimates of fishermen effort and harvest. The calculations of these statistics and their standard errors were performed by computers. The details of the program may be found in Powell and Bowden (1979) [28].

Creel census interview data also provided the harvest species composition, mean length of lake trout caught, percent return to the creel of stocked, creel-size rainbow trout, and residence time in the lake of the stocked rainbow trout.

Seasonal estimates of fishermen effort and harvest were compared using the standard normal deviate, or $Z$-test, to test for significant differences. The formula for the $Z$-test is:

$$Z = \frac{X_1 - X_2}{\sqrt{(S.E.\ X_1)^2 + (S.E.\ X_2)^2}}$$

Where:

$X_1$ = larger estimates of fishermen-hours or harvest

$X_2$ = smaller estimates of fishermen-hours or harvest

$S.E.\ (X_1 \text{ or } X_2)$ = respective estimated standard errors of $X_1$ and $X_2$

### Stocking of Creel-Size Rainbow Trout

Since the summer season in 1977, approximately 70 000 creel-size rainbow trout have been stocked annually into Twin Lakes (table 1); an annual averge of nearly 24 500 fish were stocked in the upper lake and 45 500 fish in the lower lake. Each year in the lower lake, approximately 10 000 fish were stocked initially before the Memorial Day holiday weekend in late May, with seven subsequent plants of 5000 fish each made every 2 weeks thereafter up to the Labor Day holiday weekend in September. For each of these fish plants, over 80 percent of the fish were given a characteristic finclip for later identification in the creel census. Percent return of marked rainbow trout was estimated by designating these fish as a separate fish species in the computer program.

## RESULTS

### Fishermen Effort and Harvest — Summer Seasons, 1977 and 1979

Total fishermen effort at the lower lake was estimated at 66 677 man-hours in 1977 and 70 994 man-hours in 1979 (tables 2 and 3). In both years, the month of greatest fishermen effort was July, when 22 469 and 23 409 man-hours were estimated for 1977 and 1979, respectively. Greater fishermen effort was also estimated for June, August, and September in 1979 versus the same months in 1977. The estimates of total shore fishermen effort in 1977 and 1979 were 81 and 87 percent of the total fishermen effort, respectively.

Using coefficients of variation (expressed as percentages) as indices of relative precision (standard error per point estimate), the best relative precision for the 1977 and 1979 fishermen effort estimates for the lower lake was associated with total season and total shore fishermen-hours (6 to 9 pct), followed by total boat fishermen-hours (9 pct), total monthly hours (15 to 19 pct means), monthly shore fishermen-hours (15 to 20 pct means) and monthly boat fishermen-hours (22 pct means) (table 4). Coefficients of variation for monthly estimates for both years ranged from 6 to 37 percent for total hours, 5 to 39 percent for shore fishermen-hours, and 13 to 33 percent for boat fishermen-hours.

Total season harvest at the lower lake was estimated at 23 534 fish in 1977 and 25 423 fish in 1979 (tables 2 and 3). Similar to fishermen effort, the month of greatest estimated harvest was July for both years, with an estimated 6956 and 7914 fish harvested in 1977 and 1979, respectively. Harvest estimates were also greater for June, August, and September in 1979 versus the same months in 1977. The estimates of total shore fishermen harvest in 1977 and 1979 were 89 and 94 percent of the total season harvest, respectively.

Using the coefficients of variation for the lower lake in table 4, the best relative precision for the harvest estimates in both years was associated with total season and total shore fishermen harvest (8 to 12 pct), followed by monthly total harvests (19 to 25 pct means), monthly shore fishermen harvests (19 to 26 pct means), total

Table 1.—*Stocking records for Twin Lakes, Colo., from 1953 to 1979*

| Year | Size (in) | Size (mm) | Kokanee salmon | Rainbow trout Total | Rainbow trout Upper lake | Rainbow trout Lower lake | Lake trout Total | Lake trout Finclip | Other species and remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1953 | 0-2 | 0-51 | | 26 810 | | | | | |
| | 6+ | 152+ | | | | | 71 780 | | |
| 1954 | 0-2 | 0-51 | 100 440 | | | | | | |
| | 6+ | 152+ | | 63 100 | | | | | |
| 1955 | 0-2 | 0-51 | 706 112 | | | | | | |
| | 6+ | 152+ | | 40 050 | | | | | |
| 1956 | 0-2 | 0-51 | 199 680 | | | | | | |
| | 6+ | 152+ | | 50 757 | | | | | |
| 1957 | 0-2 | 0-51 | 201 824 | | | | | | |
| | 6+ | 152+ | | 68 145 | | | | | |
| 1958 | 0-2 | 0-51 | 200 000 | | | | | | |
| | 6+ | 152+ | | 53 395 | | | | | |
| 1962 | 0-2 | 0-51 | 157 050 | | | | | | 29 380 Kamloops rainbow trout 152+ (6+) stocking in May |
| | 4-6 | 102-152 | | | | | 11 480 | — | |
| | 6+ | 152+ | | 91 700 | | | | | |
| 1963 | 0-2 | 0-51 | 44 000 | | | | | | |
| | 2-4 | 51-102 | | 178 000 | | | | | |
| | 6+ | 152+ | | 60 800 | | | | | |
| 1964 | 0-2 | 0-51 | | | | | | | 13 380 Native trout |
| | 6+ | 152+ | | 72 765 | | | | | |
| 1965 | 0-2 | 0-51 | | 203 825 | | | | | |
| | 6+ | 152+ | | 67 800 | | | | | |
| 1966 | 0-2 | 0-51 | | | | | | | 25 000 Native trout |
| | 4-6 | 102-152 | | | | | 6800 | — | |
| | 6+ | 152+ | | 129 600 | | | | | |
| 1967 | 0-2 | 0-51 | | | | | 50 000 | — | 110 700 Fathead minnows |
| | 6+ | 152+ | | 106 550 | | | | | |
| 1968 | 0-2 | 0-51 | | | | | 12 250 | — | |
| | 6+ | 152+ | | 95 100 | | | | | |
| 1969 | 0-2 | 0-51 | 212 000 | | | | | | |
| | 6+ | 152+ | | 205 850 | | | | | |
| 1970 | 0-2 | 0-51 | 135 000 | 203 900 | | | 3294 | — | |
| | 6+ | 152+ | | 166 680 | 74 130 | 92 550 | | | |
| 1971 | 4-6 | 102-152 | | | | | 15 480 | Adipose | 2500 Bonneville cisco |
| | 6+ | 152+ | | 168 600 | 76 000 | 92 600 | | | |
| 1972 | 4-6 | 102-152 | | 102 100 | | | | | 100 000 American smelt as eyed eggs in upper lake inlet stream |
| | 6+ | 152+ | | 215 860 | 105 120 | 110 740 | | | |
| 1973 | 0-2 | 0-51 | 252 000 | | | | | | 3400 Bonneville cisco |
| | 3-6 | 76-152 | | | | | 35 100 | — | 100 000 American smelt as eyed eggs, same inlet |
| | 6+ | 152+ | | 208 360 | 96 340 | 112 020 | | | |
| 1974 | 0-2 | 0-51 | 353 400 | | | | | | Upper lake 21 000, 152+ (6+) May-Aug. Lower lake 43 726 rainbow 152+ (6+) April-Sept. |
| | 6+ | 152+ | | 82 375 | 28 935 | 53 440 | | | |

Table 1.—*Stocking records for Twin Lakes, Colo., from 1953 to 1979—Continued*

| Year | Size (in) | Size (mm) | Kokanee salmon | Rainbow trout Total | Rainbow trout Upper lake | Rainbow trout Lower lake | Lake trout Total | Lake trout Finclip | Other species and remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1975 | 0-2 | 0-51 | 150 800 | | | | | | Lower lake 51 679 rainbow 152+ (6+) June-Sept. |
| | 2-4 | 51-102 | | | | | 8000 | | |
| | 6+ | 152+ | | 84 664 | 28 935 | 55 729 | 9000 | R. vent. | |
| 1976 | 6+ | 152+ | | 55 005 | 19 840 | 35 165 | | | |
| 1977 | 2-4 | 51-102 | | | | | 21 000 | Red powder | 5000 lake trout w/right-vent. clip. |
| | 6+ | 152+ | | 81 700 | 35 950 | 45 750 | | | |
| 1978 | 2-4 | 51-102 | | | | | 55 632 | Red powder | |
| | 6+ | 152+ | | 63 385 | 18 360 | 45 025 | | | |
| 1979 | 6+ | 152+ | | 64 000 | 18 280 | 45 720 | | | |

boat fishermen harvest (20 to 26 pct) and monthly boat fishermen harvests (44 to 45 pct means). Coefficients of variation for monthly estimates for both years ranged from 14 to 43 percent for total harvests, 14 to 44 percent for shore fishermen harvests, and 27 to 77 percent for boat fishermen harvests.

Total fishermen effort at the upper lake was estimated at 24 743 man-hours in 1977 and 19 721 man-hours in 1979 (tables 5 and 6). These smaller estimates are only 37 and 28 percent of the same estimates for the lower lake for 1977 and 1979, respectively. Similar to the lower lake, the greatest monthly estimate of fishermen effort occurred in July for both years. In contrast to the trend exhibited by the lower lake estimates, all monthly estimates of fishermen effort in 1979 were less than the same estimates in 1977. The estimates of total shore fishermen effort was 91 percent of the total season effort in both years.

Using the coefficients of variation for the upper lake in table 4, the best relative precision for estimates of fishermen effort for both years was associated with total season and total shore fishermen-hours (6 to 9 pct), followed by total boat fishermen-hours (14 to 15 pct), monthly total hours and monthly shore fishermen-hours (16 to 22 pct means), and monthly boat fishermen-hours (28 to 34 pct means). Coefficients of variation for monthly estimates on the upper lake for both years ranged from 7 to 40 percent for total hours and shore fishermen-hours, and 16 to 60 percent for boat fishermen-hours. The precision of the upper lake estimates of fishermen effort is very similar to the lower lake estimates in both magnitude and relative order of the different strata. The exceptions occur in the total and monthly boat fishermen strata, where estimates for the upper lake are relatively less precise than the estimates for the lower lake.

Total season harvest at the upper lake was estimated at 11 240 fish in 1977 and 6411 fish in 1979 (tables 5 and 6). These estimates are 48 and 25 percent of the same estimates for the lower lake for 1977 and 1979, respectively. As in all cases above, the greatest monthly estimate of harvest for both years occurred in July, and all monthly estimates of harvest in 1979 were less than the same estimates in 1977. The estimates of total shore fishermen harvest were 93 and 94 percent of the total season harvest in 1977 and 1979, respectively.

Using the coefficients of variation for the upper lake (table 4), the best relative precision for the harvest estimates for both years was associated with total season harvest (13 pct), followed by total shore fishermen harvest (13 to 14 pct), monthly total harvest (28 to 29 pct means), monthly shore fishermen harvest (29 pct means), total boat fishermen harvest (29 to 36 pct), and monthly boat fishermen harvests (57 to 72 pct means). Coefficients of variation for monthly estimates for both years ranged from 13 to 40 percent for total harvests, 13 to 41 percent

Table 2.—*Fishermen effort and harvest estimates with estimated standard errors for the summer creel census on the lower lake, 1977*

| Strata[1] | Estimates (Standard error)[2] | | | | | |
|---|---|---|---|---|---|---|
| | Shore | | Boat | | Total | |
| | | | *Fishermen effort* | | | |
| May—WD | 536 | (36) | 322 | (72) | 858 | (197) |
| May—WE | 5 760 | (2464) | 1 524 | (590) | 7 284 | (2971) |
| Total | 6 296 | (2464) | 1 846 | (594) | 8 142 | (2973) |
| June—WD | 6 340 | (845) | 715 | (181) | 7 055 | (1009) |
| June—WE | 4 973 | (360) | 1 151 | (196) | 6 124 | (454) |
| Total | 11 313 | (918) | 1 866 | (267) | 13 179 | (1107) |
| July—WD | 7 118 | (2633) | 1 853 | (488) | 8 971 | (2677) |
| July—WE | 10 888 | (2624) | 2 610 | (499) | 13 498 | (3109) |
| Total | 18 006 | (3717) | 4 463 | (698) | 22 469 | (4103) |
| August—WD | 6 491 | (1250) | 1 483 | (446) | 7 974 | (1672) |
| August—WE | 4 674 | (931) | 1 710 | (37) | 6 384 | (932) |
| Total | 11 165 | (1558) | 3 193 | (447) | 14 358 | (1914) |
| September—WD | 2 835 | (694) | 189 | (81) | 3 024 | (699) |
| September—WE | 4 197 | (1157) | 1 308 | (473) | 5 505 | (1602) |
| Total | 7 032 | (1349) | 1 497 | (480) | 8 529 | (1748) |
| Season Total | 53 812 | (4998) | 12 865 | (1158) | 66 677 | (5798) |
| | | | *Harvest* | | | |
| May—WD | 99 | (99) | 9 | (7) | 108 | (100) |
| May—WE | 3 450 | (1545) | 172 | (90) | 3 622 | (1600) |
| Total | 3 549 | (1548) | 181 | (90) | 3 730 | (1603) |
| June—WD | 3 361 | (698) | 130 | (123) | 3 491 | (727) |
| June—WE | 1 989 | (655) | 191 | (116) | 2 180 | (668) |
| Total | 5 350 | (957) | 321 | (170) | 5 671 | (987) |
| July—WD | 3 225 | (1271) | 593 | (593) | 3 818 | (1402) |
| July—WE | 2 732 | (737) | 406 | (102) | 3 138 | (807) |
| Total | 5 957 | (1469) | 999 | (602) | 6 956 | (1618) |
| August—WD | 2 427 | (816) | 517 | (184) | 2 944 | (914) |
| August—WE | 1 388 | (393) | 170 | (39) | 1 558 | (395) |
| Total | 3 815 | (906) | 687 | (188) | 4 502 | (995) |
| September—WD | 1 171 | (321) | 59 | (37) | 1 230 | (323) |
| September—WE | 1 069 | (305) | 376 | (147) | 1 445 | (434) |
| Total | 2 240 | (443) | 435 | (151) | 2 675 | (541) |
| Season Total | 20 911 | (2547) | 2623 | (676) | 23 534 | (2728) |
| Contact[3] | 696 | | 186 | | 882 | |

[1] Months — May through September; WE = weekends, WD = weekdays.
[2] Standard error in parentheses.
[3] Number of interview contacts made (sample size).

Table 3.—*Fishermen effort and harvest estimates with estimated standard errors for the summer creel census on the lower lake, 1979*

| Strata[1] | Estimates (Standard error)[2] | | | | | |
|---|---|---|---|---|---|---|
| | Shore | | Boat | | Total | |
| | | | *Fishermen effort* | | | |
| May—WD | — | (—) | — | (—) | — | (—) |
| May—WE | 3 130 | (635) | 530 | (174) | 3 660 | (731) |
| Total | 3 130 | (635) | 530 | (174) | 3 660 | (731) |
| June—WD | 5 392 | (893) | 648 | (226) | 6 040 | (1041) |
| June—WE | 6 047 | (1074) | 1236 | (311) | 7 283 | (1232) |
| Total | 11 439 | (1396) | 1884 | (384) | 13 323 | (1612) |
| July—WD | 10 084 | (682) | 1024 | (158) | 11 108 | (770) |
| July—WE | 10 416 | (890) | 1885 | (343) | 12 301 | (1214) |
| Total | 20 500 | (1121) | 2909 | (377) | 23 409 | (1438) |
| August—WD | 9 680 | (2117) | 953 | (270) | 10 633 | (2243) |
| August—WE | 6 104 | (988) | 709 | (151) | 6 813 | (1093) |
| Total | 15 784 | (2336) | 1662 | (310) | 17 446 | (2495) |
| September—WD | 1 976 | (659) | 448 | (154) | 2 424 | (777) |
| September—WE | 9 035 | (2490) | 1701 | (498) | 10 736 | (2967) |
| Total | 11 011 | (2567) | 2149 | (521) | 13 160 | (3067) |
| Season Total | 61 864 | (3963) | 9134 | (829) | 70 998 | (4564) |
| | | | *Harvest* | | | |
| May—WD | — | (—) | — | (—) | — | (—) |
| May—WE | 1 339 | (305) | 90 | (69) | 1 429 | (324) |
| Total | 1 339 | (305) | 90 | (69) | 1 429 | (324) |
| June—WD | 2 555 | (795) | — | (—) | 2 555 | (795) |
| June—WE | 3 478 | (625) | 76 | (29) | 3 554 | (634) |
| Total | 6 033 | (1012) | 76 | (29) | 6 109 | (1017) |
| July—WD | 3 442 | (727) | 144 | (96) | 3 586 | (736) |
| July—WE | 4 026 | (746) | 302 | (94) | 4 328 | (775) |
| Total | 7 468 | (1042) | 446 | (134) | 7 914 | (1069) |
| August—WD | 2 780 | (638) | 477 | (227) | 3 257 | (726) |
| August—WE | 1 570 | (383) | 88 | (38) | 1 658 | (393) |
| Total | 4 350 | (744) | 565 | (230) | 4 915 | (825) |
| September—WD | 1 182 | (489) | 42 | (29) | 1 224 | (498) |
| September—WE | 3 419 | (1026) | 413 | (159) | 3 832 | (1138) |
| Total | 4 601 | (1137) | 455 | (161) | 5 056 | (1242) |
| Season Total | 23 791 | (2012) | 1632 | (320) | 25 423 | (2123) |
| Contact[3] | 763 | | 167 | | 930 | |

[1] Months — May through September; WE = weekends, WD = weekdays.
[2] Standard error in parentheses.
[3] Number of interview contacts made (sample size).

Table 4.—*Coefficients of variation for estimates of fishermen effort and harvest for Twin Lakes, 1977 and 1979, by lower and upper lake, and by shore, boat, and month strata*

| | Lower lake | | | | Upper lake | | | |
|---|---|---|---|---|---|---|---|---|
| | Hours | | Harvest | | Hours | | Harvest | |
| | 1977 | 1979 | 1977 | 1979 | 1977 | 1979 | 1977 | 1979 |
| | | | | *Percent* | | | | |
| *Total Season* | 9 | 6 | 12 | 8 | 9 | 6 | 13 | 13 |
| *Total Shore* | 9 | 6 | 12 | 8 | 9 | 6 | 14 | 13 |
| *Total Boat* | 9 | 9 | 26 | 20 | 14 | 15 | 36 | 29 |
| *Monthly Total* | | | | | | | | |
| May | 37 | 20 | 43 | 23 | 40 | 29 | 40 | 31 |
| June | 8 | 12 | 17 | 17 | 9 | 13 | 20 | 21 |
| July | 18 | 6 | 23 | 14 | 14 | 10 | 32 | 13 |
| August | 13 | 14 | 22 | 17 | 14 | 7 | 21 | 40 |
| September | 21 | 23 | 20 | 25 | 32 | 21 | 30 | 33 |
| Mean | 19 | 15 | 25 | 19 | 22 | 16 | 29 | 28 |
| *Monthly Shore* | | | | | | | | |
| May | 39 | 20 | 44 | 23 | 40 | 30 | 40 | 31 |
| June | 8 | 12 | 18 | 17 | 8 | 13 | 20 | 22 |
| July | 21 | 5 | 25 | 14 | 14 | 10 | 35 | 13 |
| August | 14 | 15 | 24 | 17 | 13 | 7 | 21 | 41 |
| September | 19 | 23 | 20 | 25 | 34 | 20 | 29 | 36 |
| Mean | 20 | 15 | 26 | 19 | 22 | 16 | 29 | 29 |
| *Monthly Boat* | | | | | | | | |
| May | 32 | 33 | 50 | 77 | 60 | 27 | 93 | — |
| June | 14 | 20 | 53 | 38 | 30 | 16 | 78 | 100 |
| July | 16 | 13 | 60 | 30 | 29 | 23 | 66 | 66 |
| August | 14 | 19 | 27 | 41 | 25 | 35 | 45 | 20 |
| September | 32 | 24 | 35 | 35 | 26 | 37 | 76 | 40 |
| Mean | 22 | 22 | 45 | 44 | 34 | 28 | 72 | 57 |

for shore fishermen harvests, and 20 to 100 percent for boat fishermen harvests. The precision of the upper lake harvest estimates are less than those for the lower lake for every stratum, though the relative order remained the same.

Another general pattern observed (table 4) is that the 1979 estimates had relatively greater precision for every stratum than the 1977 estimates. The exceptions occurred within the boat strata and the individual monthly estimates for total, shore, and boat strata.

The catch compositions for the summer harvests in both lakes for both years show the dominance of rainbow trout, which composed 96.3 to 99.3 percent of the total harvest (table 7). Second in occurrence was lake trout at 0.6 to 3.5 percent, with brown trout, brook trout, and kokanee salmon comprising an insignificant remainder.

## Returns of Stocked Rainbow Trout

Stocking levels for creel-size rainbow trout were reduced in 1974 and 1975 in an attempt to maximize return of these fish to the fishermen. The stocking numbers and pattern described for 1977-79 represented further attempts to maximize the return of stocked rainbow trout. In 1977, 82 percent of the rainbow trout were

Table 5.—*Fishermen effort and harvest estimates with estimated standard errors for the summer creel census on the upper lake, 1977*

| Strata[1] | Estimates (Standard error)[2] | | | | | |
|---|---|---|---|---|---|---|
| | Shore | | Boat | | Total | |
| | | | *Fishermen effort* | | | |
| May—WD | 215 | (0) | 0 | (0) | 215 | (0) |
| May—WE | 2 989 | (1275) | 164 | (99) | 3 153 | (1336) |
| Total | 3 204 | (1275) | 164 | (99) | 3 368 | (1336) |
| June—WD | 1 776 | (108) | 143 | (90) | 1 919 | (141) |
| June—WE | 1 814 | (284) | 195 | (49) | 2 009 | (309) |
| Total | 3 590 | (304) | 338 | (103) | 3 928 | (340) |
| July—WD | 2 600 | (455) | 195 | (195) | 2 795 | (495) |
| July—WE | 4 673 | (909) | 613 | (132) | 5 286 | (1004) |
| Total | 7 273 | (1016) | 808 | (235) | 8 081 | (1120) |
| August—WD | 3 426 | (568) | 274 | (96) | 3 700 | (619) |
| August—WE | 1 656 | (376) | 247 | (89) | 1 903 | (457) |
| Total | 5 082 | (682) | 521 | (130) | 5 603 | (769) |
| September—WD | 1 160 | (990) | 91 | (46) | 1 251 | (1014) |
| September—WE | 2 194 | (580) | 318 | (98) | 2 512 | (669) |
| Total | 3 354 | (1147) | 409 | (108) | 3 763 | (1215) |
| Season Total | 22 503 | (2129) | 2240 | (323) | 24 743 | (2285) |
| | | | *Harvest* | | | |
| May—WD | 191 | (16) | 0 | (0) | 191 | (16) |
| May—WE | 1 862 | (814) | 70 | (65) | 1 932 | (841) |
| Total | 2 053 | (814) | 70 | (65) | 2 123 | (841) |
| June—WD | 1 547 | (434) | — | (—) | 1 547 | (434) |
| June—WE | 760 | (177) | 9 | (7) | 769 | (177) |
| Total | 2 307 | (468) | 9 | (7) | 2 316 | (469) |
| July—WD | 1 095 | (817) | 19 | (19) | 1 114 | (817) |
| July—WE | 1 525 | (388) | 329 | (228) | 1 854 | (481) |
| Total | 2 620 | (904) | 348 | (229) | 2 968 | (948) |
| August—WD | 1 883 | (520) | — | (—) | 1 883 | (520) |
| August—WE | 633 | (148) | 183 | (82) | 816 | (213) |
| Total | 2 516 | (540) | 183 | (82) | 2 699 | (561) |
| September—WD | 39 | (39) | 30 | (30) | 69 | (54) |
| September—WE | 881 | (260) | 184 | (160) | 1 065 | (342) |
| Total | 920 | (263) | 214 | (163) | 1 134 | (346) |
| Season Total | 10 416 | (1436) | 824 | (300) | 11 240 | (1504) |
| Contact[3] | 315 | | 37 | | 352 | |

[1] Months — May through September; WE = weekends, WD = weekdays.
[2] Standard error in parentheses.
[3] Number of interview contacts made (sample size).

Table 6.—*Fishermen effort and harvest estimates with estimated standard errors for the summer creel census on the upper lake, 1979*

| Strata[1] | Estimates (Standard error)[2] | | | | | |
|---|---|---|---|---|---|---|
| | Shore | | Boat | | Total | |
| | | | *Fishermen effort* | | | |
| May—WD | — | (—) | — | (—) | — | (—) |
| May—WE | 1 147 | (339) | 104 | (28) | 1 251 | (367) |
| Total | 1 147 | (330) | 104 | (28) | 1 251 | (367) |
| June—WD | 1 519 | (143) | 137 | (—) | 1 656 | (143) |
| June—WE | 1 726 | (404) | 44 | (28) | 1 770 | (426) |
| Total | 3 245 | (428) | 181 | (28) | 3 426 | (450) |
| July—WD | 2 730 | (307) | 358 | (98) | 3 088 | (402) |
| July—WE | 3 161 | (509) | 358 | (135) | 3 519 | (526) |
| Total | 5 891 | (594) | 716 | (167) | 6 607 | (662) |
| August—WD | 2 766 | (110) | 168 | (124) | 2 934 | (165) |
| August—WE | 1 950 | (318) | 195 | (34) | 2 145 | (319) |
| Total | 4 716 | (336) | 363 | (128) | 5 079 | (360) |
| September—WD | 957 | (222) | 31 | (31) | 988 | (242) |
| September—WE | 2 084 | (570) | 286 | (113) | 2 370 | (666) |
| Total | 3 041 | (612) | 317 | (117) | 3 358 | (666) |
| Season Total | 18 040 | (1067) | 1681 | (244) | 19 721 | (1186) |
| | | | *Harvest* | | | |
| May—WD | — | (—) | — | (—) | — | (—) |
| May—WE | 389 | (119) | 0 | (0) | 389 | (119) |
| Total | 389 | (119) | 0 | (0) | 389 | (119) |
| June—WD | 560 | (135) | 25 | (25) | 585 | (138) |
| June—WE | 760 | (252) | — | (—) | 760 | (252) |
| Total | 1320 | (286) | 25 | (25) | 1345 | (287) |
| July—WD | 1251 | (209) | 31 | (42) | 1282 | (218) |
| July—WE | 722 | (155) | 56 | (40) | 778 | (160) |
| Total | 1973 | (260) | 87 | (58) | 2060 | (271) |
| August—WD | 903 | (611) | — | (—) | 903 | (611) |
| August—WE | 694 | (221) | 46 | (9) | 740 | (221) |
| Total | 1597 | (649) | 46 | (9) | 1643 | (649) |
| September—WD | 81 | (42) | 16 | (16) | 97 | (48) |
| September—WE | 651 | (257) | 226 | (95) | 877 | (318) |
| Total | 732 | (260) | 242 | (96) | 974 | (322) |
| Season Total | 6011 | (808) | 400 | (115) | 6411 | (834) |
| Contact[3] | 262 | | 44 | | 306 | |

[1] Months — May through September; WE = weekends, WD = weekdays.
[2] Standard error in parentheses.
[3] Number of interview contacts made (sample size).

Table 7.—*Catch composition for summer season harvest estimates at Twin Lakes, 1977 and 1979*

| Species | 1977 Estimate | 1977 % Total | 1979 Estimate | 1979 % Total |
|---|---|---|---|---|
| *Lower lake* | | | | |
| Rainbow trout | 22 667 | 96.3 | 24 831 | 97.7 |
| Lake trout | 830 | 3.5 | 555 | 2.2 |
| Brown trout | 26 | 0.1 | 38 | 0.1 |
| Brook trout | 4 | — | — | — |
| Kokanee salmon | 6 | — | — | — |
| *Upper lake* | | | | |
| Rainbow trout | 11 155 | 99.3 | 6 230 | 97.1 |
| Lake trout | 72 | 0.6 | 165 | 2.6 |
| Brown trout | 3 | — | 12 | 0.2 |
| Brook trout | 9 | 0.1 | — | — |
| Kokanee salmon | — | — | 6 | 0.1 |

Table 8.—*Estimated return of marked creel-size rainbow trout stocked at Twin Lakes in 1977 and 1979*

| Lake | Estimated harvest Total | Estimated harvest Marked | Estimated harvest Unmarked | Stocked Total marked | Stocked Total | % return marked |
|---|---|---|---|---|---|---|
| | | | *1977* | | | |
| Lower lake | 22 667 | 15 514 | 7 153 | 37 476 | 45 750 | 41.4 |
| Upper lake | 11 155 | 1 946 | 9 209 | | 35 950 | 5.2 |
| Total | 33 822 | 17 460 | 16 362 | 37 476 | 81 700 | 46.6 (26)[1] |
| | | | *1979* | | | |
| Lower lake | 24 831 | 18 176 | 6 655 | 38 790 | 45 720 | 46.9 |
| Upper lake | 6 230 | 1 180 | 5 050 | | 17 170 | 3.0 |
| Total | 31 061 | 19 356 | 11 705 | 38 790 | 62 890 | 49.9 (18)[1] |

[1] 95% confidence interval expressed as a percent of estimated percent return.

marked; in 1979, 85 percent were marked. The estimated return of these fish for 1977 and 1979 were 46.6 and 49.9 percent, respectively (table 8). A small percentage of the marked fish were caught in the upper lake in each year, though all marked fish were stocked in the lower lake. Finnell et al. (1975) [29] showed a 38-percent return of creel-size rainbow trout in 1974.

Assuming the movements of the marked fish were no different than the unmarked fish stocked in the lower lake, the 3 to 5 percent of the marked fish caught in the upper lake constitutes a representative estimate of rainbow trout movement from the lower to the upper lake. The unmarked segment of the rainbow trout harvested in the lower lake may have originated from (1) the unmarked portion of fish stocked in 1977 or 1979, (2) unmarked fish stocked in the upper lake and migrated to the lower lake, or (3) resident fish from previous years' stocking or natural reproduction. Assuming that marked and unmarked fish are caught or emigrate from the lower lake at a rate proportional to their relative abundance (maintaining marked fish at 82 and 85 percent of the stock abundance at any time), then 18 920 (or 83 pct) and 21 384 (or 86 pct) of the total rainbow trout harvested in 1977 and 1979, respectively, would have originated from fish stocked that year. The remaining 17 percent for 1977 and 14 percent for 1979 of the rainbow trout harvest either originated from upper lake stocks or from a resident population in the lower lake. During the marking of the rainbow trout, attempts were made to finclip only acceptable-size fish, thus the 18 percent for 1977 and 15 percent for 1979 of the fish not marked may have contained a majority of fish of an unacceptable size to anglers (throwbacks). Assuming that all of these fish were throwbacks and contributed nothing to the harvest, then a maximum of 32 and 27 percent of the total rainbow trout harvest in 1977 and 1979, respectively, would have originated from the upper lake or from resident populations. In unpublished records from 1974, Finnell indicated that approximately 6 percent of a group of rainbow trout stocked in the upper lake were harvested in the lower lake.

The cumulative percent return of individual plants of the marked rainbow trout observed in the creel census contacts in 1977 and 1979 in the lower lake are indicated in tables 9 and 10, respectively. A weekly mean percent return for all eight plants combined was determined using the final cumulative percent observed for each plant in each of the 5 weeks following the plant. The differences in percent return of individual plants was considerable, and was in part due to the randomization of sample days without regard to the stocking schedule. This contributed to the large confidence intervals for the estimated weekly percent returns in the first weeks after stocking. Differing intensities of fishermen effort may also have been a factor. In spite of this variability, the estimated percent returns of marked rainbow trout observed in the creel census were consistently close for both years, as were their respective confidence intervals (fig. 3). Approximately 90 percent of the marked rainbow trout that were observed in the creel census contacts were seen within 4 weeks after stocking. Finnell et al. (1975) [29] observed a similar rate of return in 1974. While the confidence intervals for the estimates constituted 31 percent of the estimate in the first week after stocking, the confidence intervals narrowed progressively to 3 percent of the estimates in the fifth week for both 1977 and 1979.

### Catch Rates

Catch rates at Twin Lakes may be influenced by fishermen effort and the numbers and pattern of stocking creel-size rainbow trout. The effect of these variables on the catch rate was examined through correlation. For each creel census day on the lower lake in 1977 and 1979, the catch rate for rainbow trout and the mean number of fishermen per count were estimated (tables 11 and 12, respectively). The census days were also described by a post-plant day number, which signified the number of days following a stocking date. Correlating catch rates with their respective post-plant day number would demonstrate the effect of stocking on the catch rate. The relationship between daily catch rates and fishermen effort was also examined by correlation. No significant correlations were found between post-plant day number, CPMH, and mean number of fishermen per count in either 1977 or 1979 (table 13). Potential bias in catch rates utilizing incomplete trip information may be detected by comparison of mean catch rates based on separate samples of incomplete and completed fishermen trips (Grosslein, 1962 [30]). Catch rates derived from incomplete and completed trip data at Twin Lakes were similar for both 1977 and 1979 (fig. 4). The coefficients of variation associated with the completed trip catch rates were generally from 2 to 4 times greater than those associated with incomplete trip catch rates, resulting in relatively wide confidence intervals. Considerable overlap of the interval estimates is evident in every comparison.

### Characterization of Twin Lakes Summer Fishery

Fishermen effort and harvest estimates for 1977 and 1979 were combined with similar data from 1972 to 1975 from Finnell and Bennett (1973, 1974) [31, 32] and Finnell (1977) [20] in order to characterize the fisheries of the upper and lower lakes. On the lower lake (fig. 5), a generally declining trend in fishermen effort was indicated until the 1979 season. The fluctuations observed are due to changes in shore fishermen effort, whose pattern closely parallels that for total season effort. Boat fishermen effort showed very small changes over the study years and generally fluctuated in the direction opposite of that for shore fishermen. For the upper lake, fishermen effort showed a generally declining trend also, with the 1979 estimate being the lowest observed over the study period (fig. 6). Similar to the lower lake, shore fishermen effort was largely responsible for the fluctuations observed in total season effort, while boat fishermen effort declined gradually.

Table 9.—*Cumulative percent return of creel-size rainbow trout marked by finclip as observed in the creel census contacts at the lower lake, 1977*

| Post plant day | Finclip[1] | | | | | | | | Avg. %/week ±95% C.I. |
|---|---|---|---|---|---|---|---|---|---|
| | Ad | RV | LV | BV | RVAd | LVAd | $Ad_2$ | $RV_2$ | |
| 1 | 21 | | | 40 | 39 | 34 | 19 | | |
| 2 | 59 | | | 69 | | 48 | 41 | | |
| 3 | 85 | | | 72 | | | | | |
| 4 | | 46 | | | | | 46 | 2 | |
| 5 | | | 41 | | | | | 9 | |
| 6 | | | 56 | | | | | | |
| 7 | | | | | 71 | | 61 | | 56±19 |
| 8 | 93 | 70 | 75 | | | 79 | | 27 | |
| 9 | 95 | 84 | 86 | 79 | | | 63 | 49 | |
| 10 | 97 | | 87 | 82 | | | | 63 | |
| 11 | | | | | | | | | |
| 12 | 98 | | | | | | | 69 | |
| 13 | | 85 | | | | | | | |
| 14 | | | | | | | | | 79± 9 |
| 15 | | | | 85 | 75 | | | 77 | |
| 16 | | | 90 | | 76 | 83 | | 82 | |
| 17 | | | 95 | | | 85 | | | |
| 18 | | | | | | | 66 | | |
| 19 | | 88 | | | | | 71 | | |
| 20 | | 90 | | | 82 | | | 86 | |
| 21 | | | | 87 | | | | | 87± 7 |
| 22 | 99 | 94 | 97 | | 84 | 94 | 80 | | |
| 23 | | 95 | | | | | 88 | | |
| 24 | | | | | | 96 | 92 | | |
| 25 | | | | | | | | | |
| 26 | | | | | | | | | |
| 27 | | | | | | | | | |
| 28 | | | | | | | | | 92± 5 |
| 29 | | | | 88 | 85 | | 95 | 87 | |
| 30 | | | | 89 | 88 | | 97 | 88 | |
| 31 | | 97 | | | | | | | |
| 32 | | | | | 89 | | | 90 | |
| 33 | | | | | | | | 100 | |
| 34 | | | | | | 97 | 97 | | |
| 35 | | | | | 90 | | | | 95± 3 |

[1] Ad — adipose
RV — right ventral
LV — left ventral
BV — both ventral
RVAd — right ventral/adipose
LVAd — left ventral/adipose
$Ad_2$, $RV_2$ — second use of finclip
C.I. — confidence interval

Table 10.—*Cumulative percent return of creel-size rainbow trout marked by finclip as observed in the creel census contacts at the lower lake, 1979*

| Post plant day | Finclip[1] Ad | RV | LV | BV | RVAd | LVAd | RO | LO | Avg. %/week ±95% C.I. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 | | | | 52 | | 33 | 36 | |
| 2 | 44 | | 38 | 19 | 75 | | | 71 | |
| 3 | 53 | | | | | | | 77 | |
| 4 | | | 60 | | | 29 | | | |
| 5 | | | | 33 | 85 | 49 | | 86 | |
| 6 | | | | 50 | | | | | |
| 7 | | | 62 | | 90 | | 47 | | 62±17 |
| 8 | 64 | 43 | | 75 | | 72 | | | |
| 9 | 72 | | | | | 86 | 57 | | |
| 10 | | | | | | | 64 | | |
| 11 | 76 | | | | | | | | |
| 12 | 81 | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | 88 | 74±13 |
| 15 | | | | 82 | | 89 | 78 | 95 | |
| 16 | | 57 | 70 | 87 | | | 88 | | |
| 17 | | | | | | | 91 | 97 | |
| 18 | | 68 | | | 93 | | | | |
| 19 | | | 75 | 90 | 93 | | 93 | | |
| 20 | | | 77 | | | | | | |
| 21 | | 71 | | 91 | | | | | 87± 8 |
| 22 | 84 | | 88 | | 95 | | | 99 | |
| 23 | | | | | 96 | 90 | | 100 | |
| 24 | | | | | | | | | |
| 25 | | | | | | | | | |
| 26 | | | | | | | | | |
| 27 | | | | | | | | | |
| 28 | | | | | | | 93 | | 89± 8 |
| 29 | | | 90 | | | 93 | 97 | | |
| 30 | 89 | 80 | 91 | | | 94 | | | |
| 31 | | | | | | 96 | 98 | | |
| 32 | 91 | | | 92 | | | | | |
| 33 | | 84 | 92 | 94 | | 96 | | | |
| 34 | | | | | | | | | |
| 35 | 92 | 85 | | | 96 | | 99 | | 93± 3 |
| 36 | | 91 | | | | | | | |

[1] Ad — adipose
RV — right ventral
LV — left ventral
BV — both ventral
RVAd — right ventral/adipose
LVAd — left ventral/adipose
RO — right opercle
LO — left opercle
C.I. — confidence interval

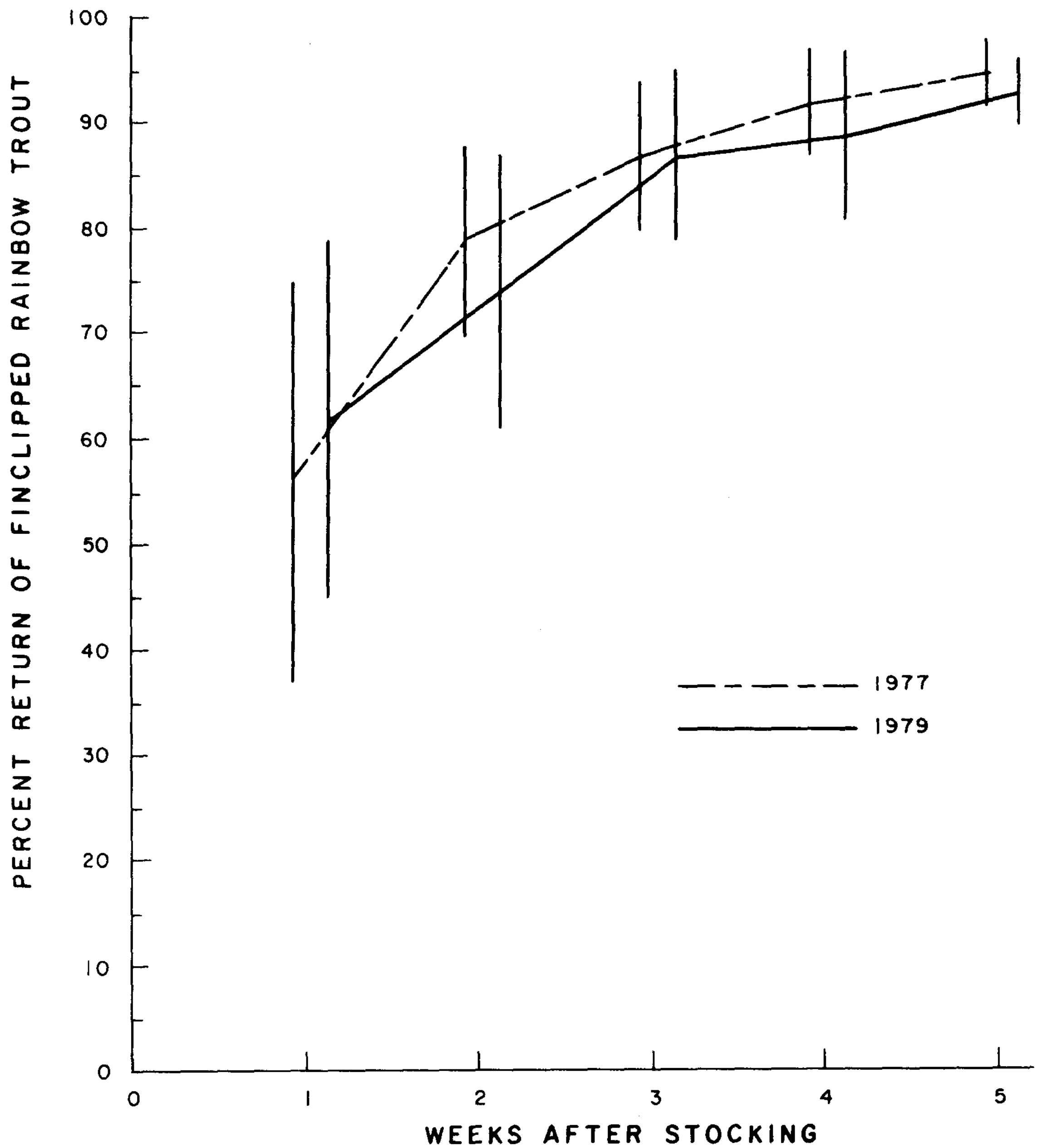


Figure 3.—Mean weekly percent returns of stocked, creel-size rainbow trout in Twin Lakes, 1977-79, with 95 percent confidence intervals.

Table 11.—*Daily catch rates and mean number of fishermen per count for shore and boat fishermen on the lower lake, 1977 (rainbow trout only)*

| Post-plant day | Date | Shore | | Boat | |
|---|---|---|---|---|---|
| | | CPMH[1] | *X* Fm[2] | CPMH | *X* Fm |
| 1 | May 28 | 0.30 | 78 | 0.05 | 30.0 |
| 2 | 29 | .54 | 160 | .08 | 27.0 |
| 3 | 30 | .86 | 53 | .13 | 15.0 |
| 8 | June 4 | 1.20 | 39 | .00 | 11.0 |
| 9 | 5 | 0.44 | 47 | .28 | 11.0 |
| 10 | 6 | .28 | 13 | .00 | 1.4 |
| 12 | 8 | .54 | 16 | .00 | 1.0 |
| 4 | 14 | .94 | 30 | .00 | 3.8 |
| 8 | 18 | .24 | 51 | .03 | 6.0 |
| 9 | 19 | .36 | 55 | .05 | 16.0 |
| 13 | 23 | .15 | 20 | .00 | 1.0 |
| 5 | 29 | .47 | 29 | .00 | 4.3 |
| 6 | 30 | .41 | 25 | .57 | 2.9 |
| 1 | July 2 | .30 | 123 | .08 | 25.0 |
| 2 | 3 | .21 | 161 | .09 | 35.0 |
| 3 | 4 | — | 58 | .12 | 16.0 |
| 9 | 10 | .31 | 20 | — | 8.0 |
| 10 | 11 | .28 | 17 | .28 | 9.0 |
| 1 | 16 | .20 | 67 | .20 | 20.0 |
| 7 | 22 | .50 | 38 | — | 5.3 |
| 1 | 30 | .42 | 56 | .14 | 11.0 |
| 2 | 31 | .17 | 48 | .15 | 12.0 |
| 6 | Aug. 4 | .63 | 27 | .44 | 8.0 |
| 7 | 5 | .00 | 34 | .50 | 10.0 |
| 8 | 6 | .24 | 71 | .13 | 16.0 |
| 1 | 13 | .28 | 35 | .08 | 16.0 |
| 2 | 14 | .64 | 42 | .20 | 17.0 |
| 4 | 16 | .16 | 24 | — | 4.6 |
| 7 | 19 | .54 | 23 | .13 | 4.0 |
| 9 | 21 | .12 | 32 | .05 | 17.0 |
| 4 | 30 | .32 | 4 | — | 0.0 |
| 5 | 31 | .51 | 20 | .09 | 3.0 |
| 8 | Sept. 3 | .27 | 63 | .28 | 21.0 |
| 9 | 4 | .26 | 86 | .36 | 28.0 |
| 10 | 5 | .39 | 46 | .15 | 23.0 |
| 12 | 7 | .32 | 18 | — | 1.5 |
| 15 | 10 | .19 | 36 | .31 | 4.0 |
| 16 | 11 | .25 | 23 | .14 | 2.5 |
| 20 | 15 | .29 | 11 | — | 0.5 |
| 29 | 24 | .00 | 9 | .00 | 2.5 |
| 30 | 25 | .07 | 10 | .08 | 2.5 |
| 32 | 27 | .53 | 5 | — | 1.5 |
| 33 | 28 | .49 | 11 | — | 0.0 |

[1] CPMH = catch per man-hour.
[2] *X* Fm = mean number of fishermen per count.

Table 12.—*Daily catch rates and mean number of fishermen per count for shore and boat fishermen on the lower lake, 1979 (rainbow trout only)*

| Post-plant day | Date | Shore | | Boat | |
|---|---|---|---|---|---|
| | | CPMH[1] | X Fm[2] | CPMH | X Fm |
| 1 | May 26 | 0.51 | 84 | 0.00 | 22.0 |
| 2 | 27 | .37 | 106 | .37 | 12.0 |
| 3 | 28 | .41 | 50 | .13 | 7.0 |
| 8 | June 2 | .62 | 36 | .03 | 5.0 |
| 9 | 3 | .45 | 41 | .02 | 5.5 |
| 11 | 5 | .36 | 13 | — | 0.5 |
| 12 | 6 | .51 | 16 | — | 2.0 |
| 8 | 16 | .58 | 77 | .03 | 16.0 |
| 2 | 24 | .58 | 53 | .03 | 6.5 |
| 4 | 26 | .68 | 28 | — | 2.5 |
| 7 | 29 | .18 | 22 | — | 4.5 |
| 2 | July 8 | .38 | 67 | .23 | 8.0 |
| 5 | 11 | .56 | 40 | — | 3.0 |
| 6 | 12 | .37 | 30 | — | 3.0 |
| 8 | 14 | .27 | 100 | .13 | 21.0 |
| 1 | 21 | .50 | 77 | .06 | 16.0 |
| 2 | 22 | .45 | 77 | .27 | 14.0 |
| 5 | 25 | .33 | 42 | — | 5.0 |
| 7 | 27 | .18 | 36 | — | 5.0 |
| 4 | Aug. 7 | .33 | 49 | .17 | 4.3 |
| 5 | 8 | .26 | 39 | .81 | 4.3 |
| 8 | 11 | .18 | 80 | .05 | 11.0 |
| 9 | 12 | .17 | 53 | .06 | 6.5 |
| 1 | 18 | .34 | 67 | .04 | 4.5 |
| 7 | 24 | .31 | 26 | — | 0.5 |
| 9 | 26 | .24 | 35 | .08 | 5.3 |
| 10 | 27 | .32 | 16 | .50 | 4.0 |
| 1 | Sept. 1 | .43 | 114 | .15 | 25.0 |
| 2 | 2 | .50 | 133 | .18 | 21.0 |
| 3 | 3 | .41 | 79 | .10 | 17.0 |
| 5 | 5 | .79 | 16 | .11 | 3.5 |
| 14 | 14 | .56 | 8 | — | 0.5 |
| 15 | 15 | .32 | 43 | .26 | 10.5 |
| 17 | 17 | — | 4 | .18 | 1.5 |
| 22 | 22 | .21 | 30 | .11 | 3.5 |
| 23 | 23 | .17 | 26 | .00 | 4.5 |
| 28 | 28 | .16 | 5 | .00 | 2.0 |
| 30 | 30 | .08 | 17 | — | 2.0 |

[1] CPMH = catch per man-hour.
[2] *X* Fm = mean number of fishermen per count.

Table 13.—*Correlation coefficients for selected catch rates versus associated parameters at the lower lake, 1977-79*

| Comparison | | $n$[1] | $r$ |
|---|---|---|---|
| | *1977* | | |
| Shore: | Post-plant day vs. CPMH | 35 | -0.090 |
| | Mean No. fishermen vs. CPMH | 35 | - .080 |
| Boat: | Post-plant day vs. CPMH | 31 | .023 |
| | Mean No. fishermen vs. CPMH | 31 | .029 |
| | *1979* | | |
| Shore: | Post-plant day vs. CPMH | 32 | - .160 |
| | Mean No. fishermen vs. CPMH | 32 | - .056 |
| Boat: | Post-plant day vs. CPMH | 22 | .009 |
| | Mean No. fishermen vs. mean CPMH | 22 | - .200 |

[1] $n$ = sample size.
CPMH = catch per man-hour.
$r$ = correlation coefficient.

The season harvest from the lower lake has ranged from 20 000 to 33 000 fish over the 1972-79 period (fig. 7). Despite stocking levels in 1972-73 exceeding 100 000 creel-size rainbow trout (table 1), harvests in these years remained within the range exhibited in 1974-79, when less than 46 000 fish were stocked during the May-September period. While some stocking of fish prior to May was conducted in 1974-75, Finnell (1977) [20] demonstrated that there was little contribution of the spring plants to the harvest. The peak harvest in 1975 was also associated with the greatest number of rainbow trout stocked during the 1974-79 period. Fluctuations in the total season harvest were influenced largely by the fluctuations in the shore fishermen harvest.

In the upper lake, season harvests ranged from 6400 to 12 500 fish over the 1972-79 period (fig. 8). Similar to the lower lake, harvests in 1972-73 were close to the range exhibited in 1974-79, despite stocking levels exceeding 95 000 fish (table 1). Relative to the magnitude of the season harvest, the 1975 stocking level appears to have been closest to optimum. While the 1973 season harvest slightly exceeds the 1975 total, over 330 percent more fish were stocked in 1973 versus 1975. The two years of lowest stocking level (1974 and 1979) were also the years of lowest estimated season harvest.

Statistical comparisons were made of the season totals of fishermen effort and harvest for both lakes for the 1973-79 period. For the lower lake, significant differences in fishermen effort were found only between 1973 (89 820 man-hours) and the 1977-79 totals (table 14). The comparisons established a generally declining trend in fishermen effort through 1977, and that fluctuations in fishermen effort between 66 677 man-hours (1977) and 79 385 man-hours (1974) were not significantly different under the current creel census sampling regime.

For the upper lake, significant differences in fishermen effort were found between the two peak seasons, 1973 and 1975 (29 036 and 29 139 man-hours, respectively) versus the two seasons of lowest fishermen effort, 1974 and 1979 (20 800 and 19 721 man-hours, respectively). The 1977 total (24 743 man-hours) represented a midrange estimate that was not significantly different from either the high or low years.

Comparisons of total season harvests for the lower lake demonstrated that the 1975 harvest of 32 496 fish was significantly greater than the estimated harvests in 1974 (19 955 fish), 1977 (23 534 fish) and 1979 (25 423 fish) (table 14). The 1973 harvest of 26 627 fish was significantly greater than the 1974 harvest only. For the upper lake, the harvests of 1973 (12 457

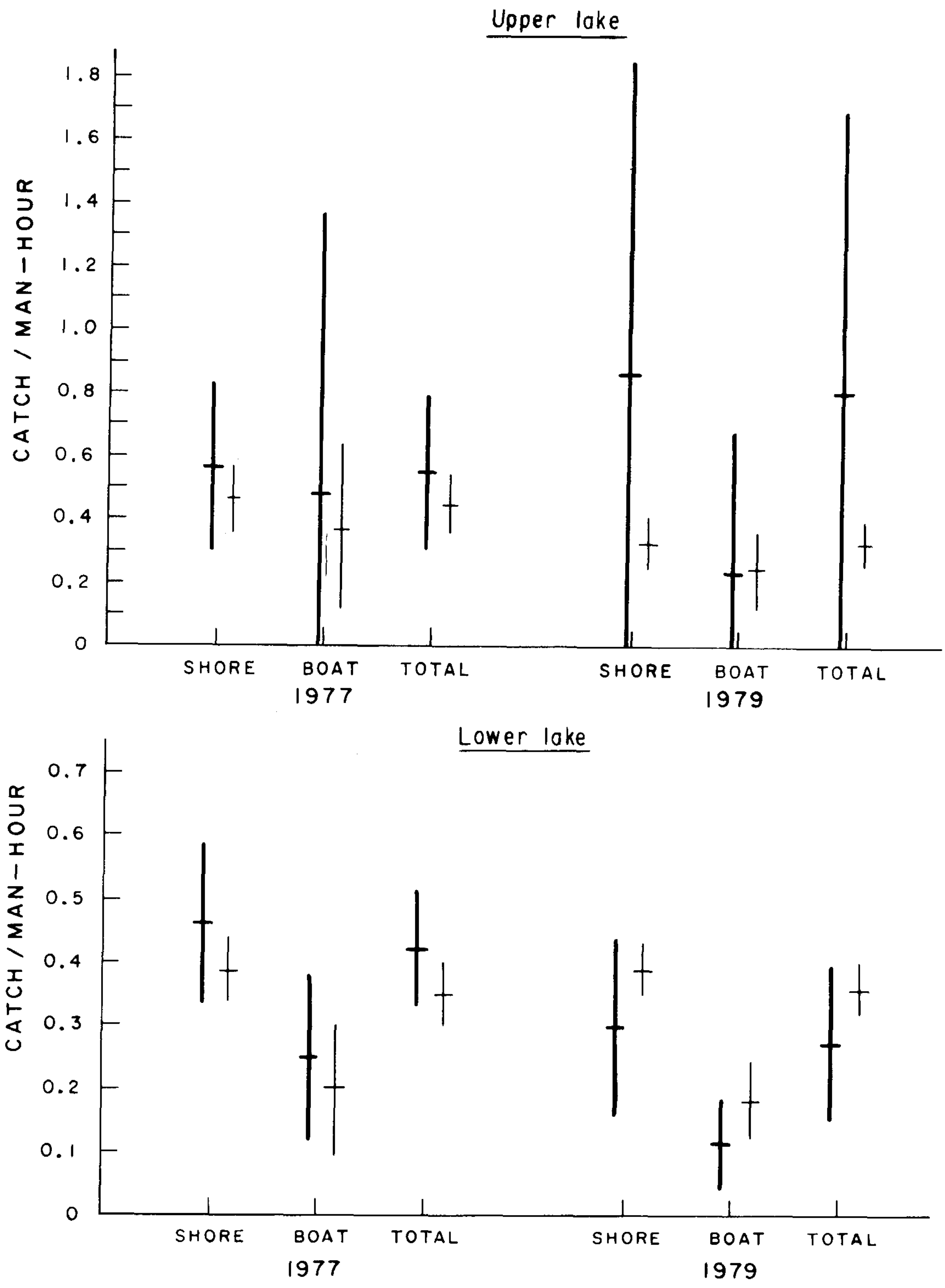


Figure 4.—Catch rates at Twin Lakes, 1977-79, based on completed and incomplete fishermen trip data. Each pairing includes a completed trip catch rate on the left and incomplete trip catch rate on the right, with 95 percent confidence intervals for each estimate.

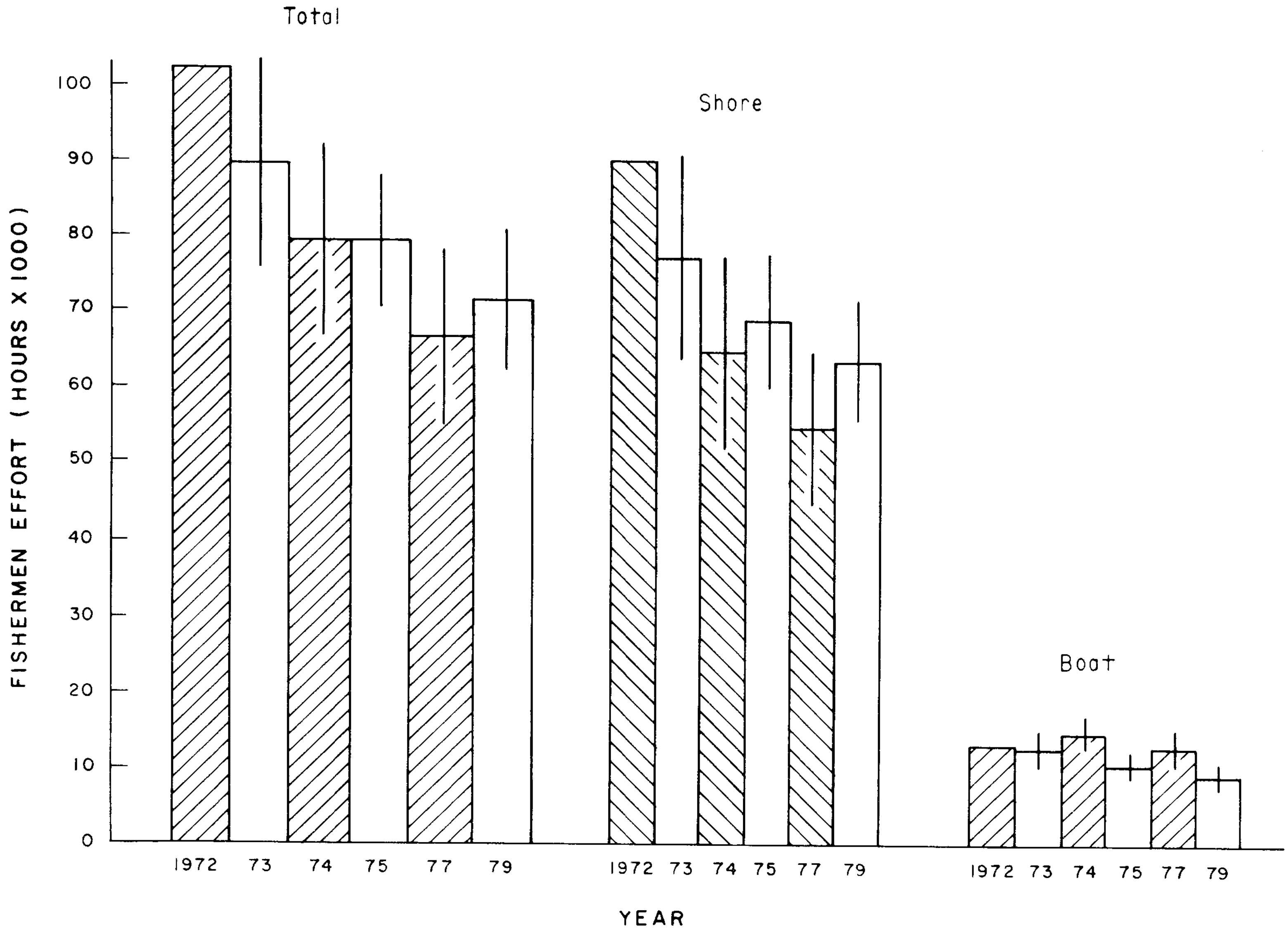


Figure 5.—Estimates of summer season fishermen effort at the lower lake, 1972-79, with 95 percent confidence intervals.

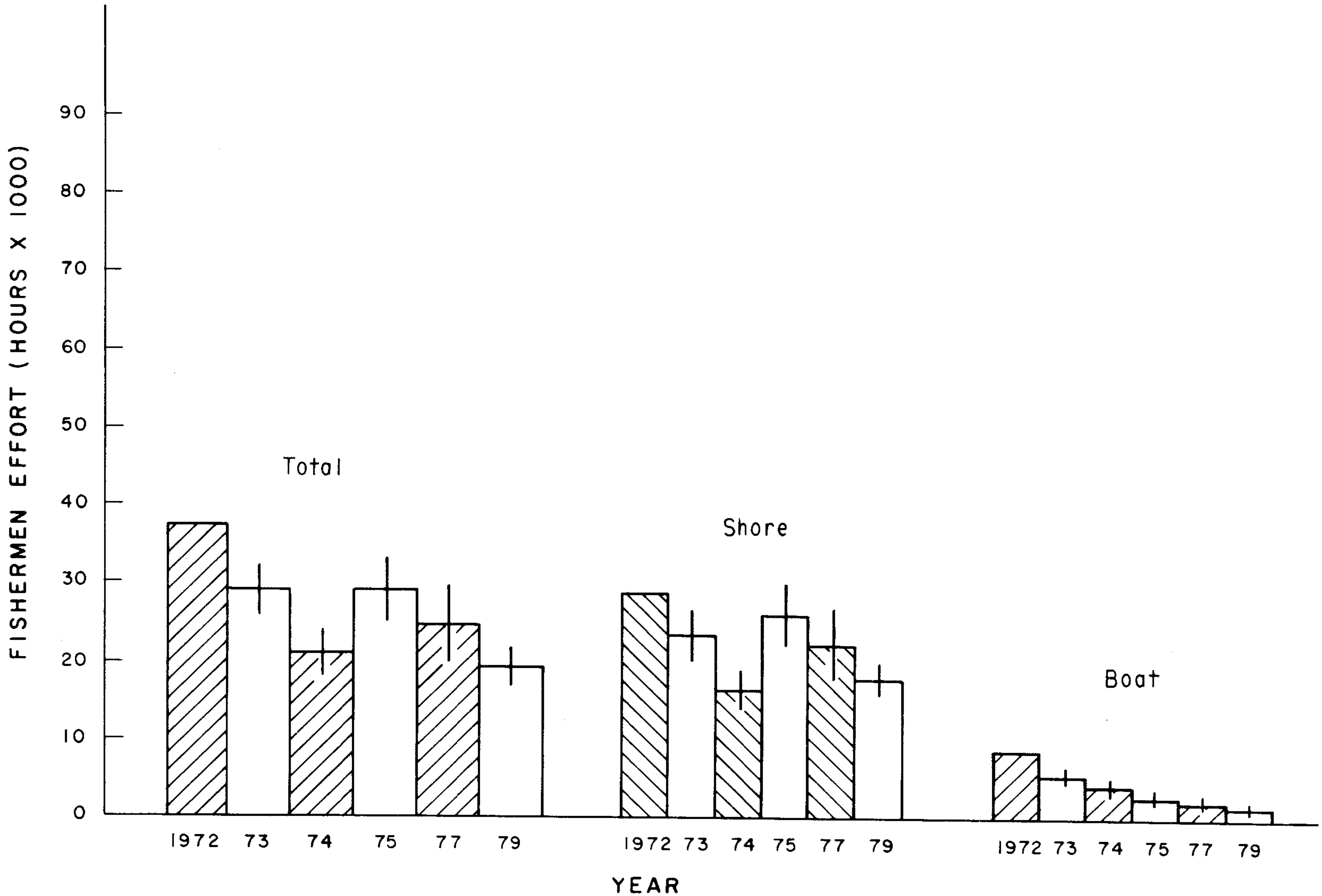


Figure 6.—Estimates of summer season fishermen effort at the upper lake, 1972-79, with 95 percent confidence intervals.

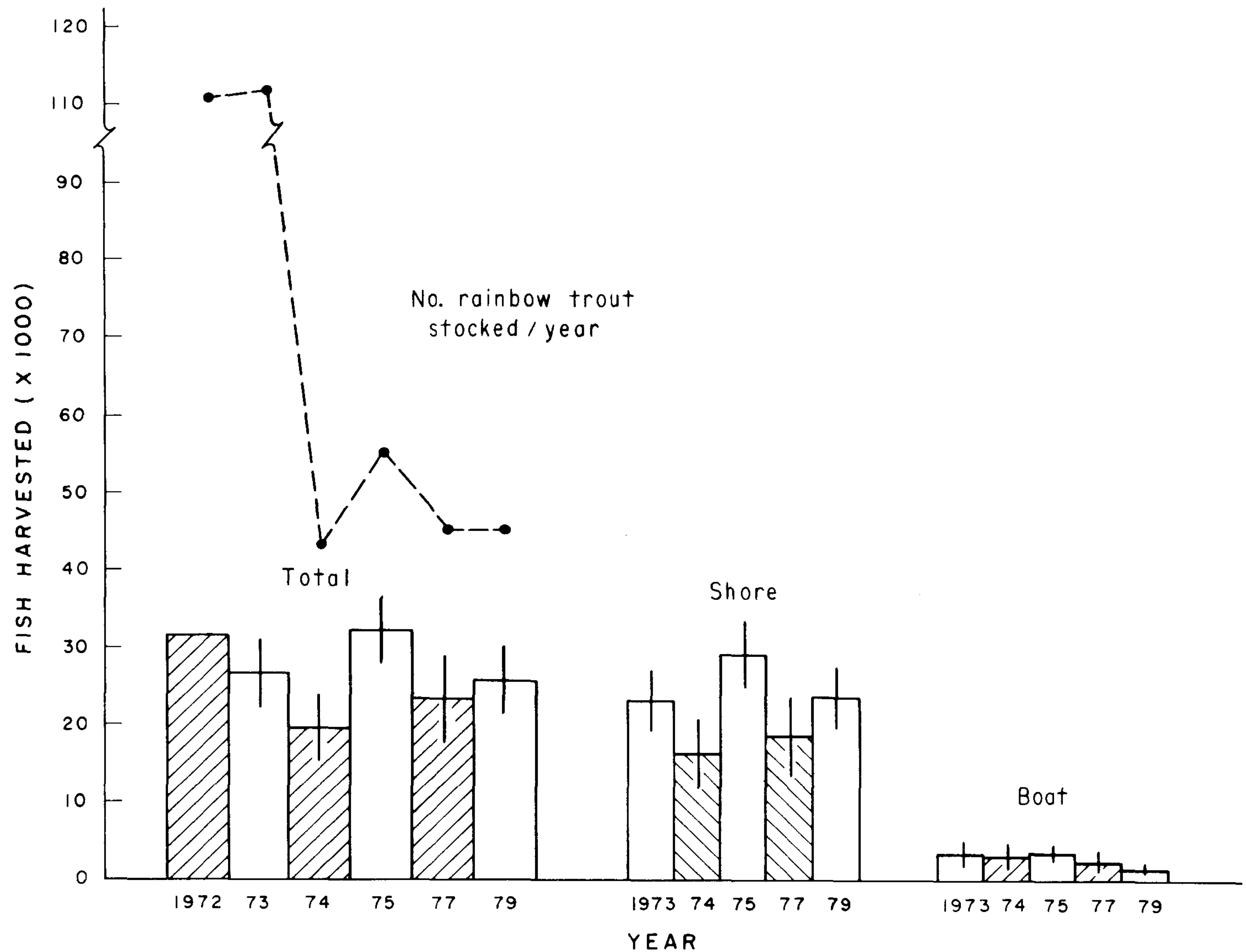


Figure 7.—Estimates of summer season harvest at the lower lake, 1972-79, with 95 percent confidence intervals.

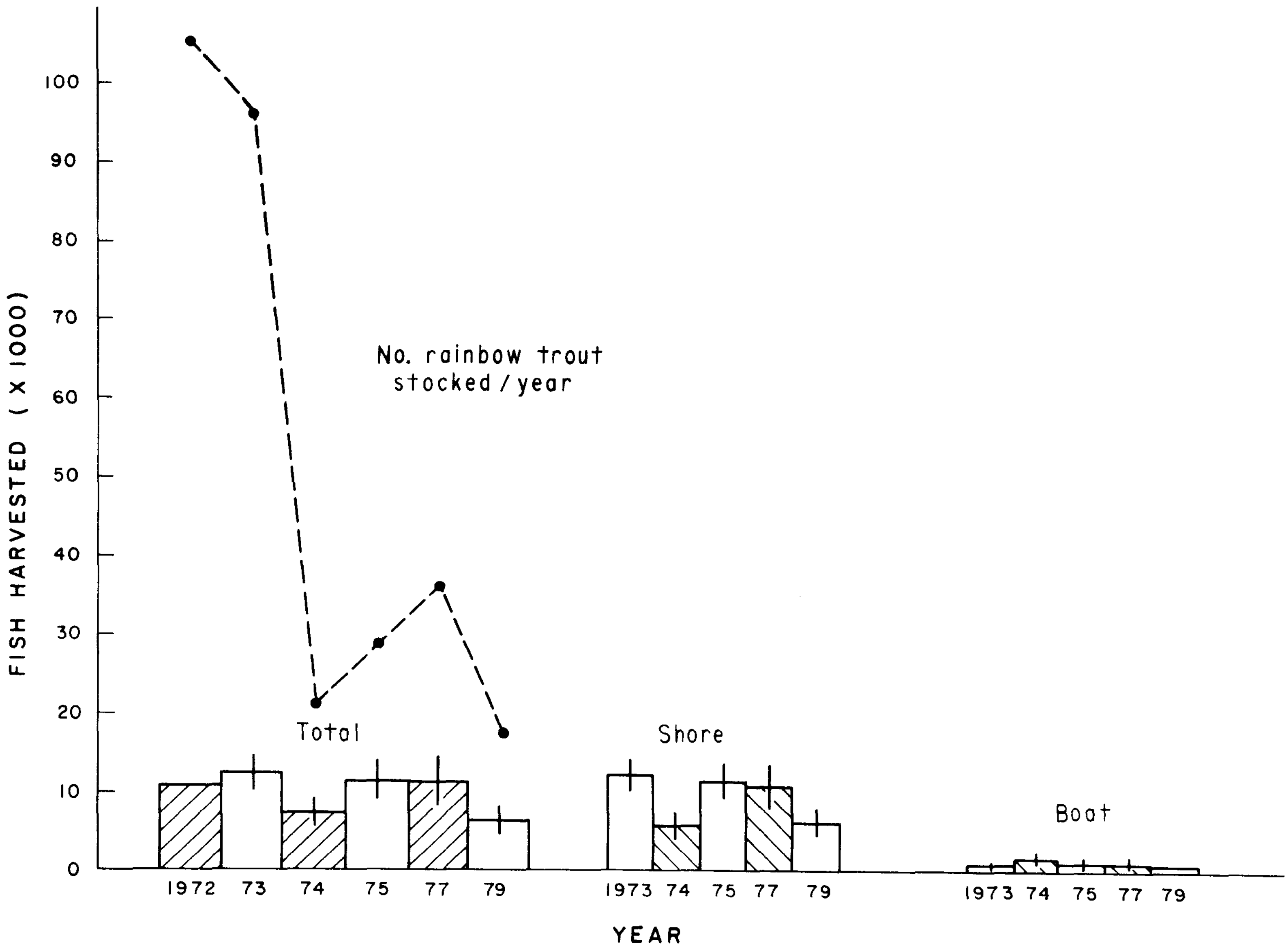


Figure 8.—Estimates of summer season harvest at the upper lake, 1972-79, with 95 percent confidence intervals.

Table 14.—*Z-test comparisons of estimated fishermen-hours and harvest for the 1973-79 summer seasons at Twin Lakes*

| | 1973 | 1974 | 1975 | 1977 | 1979 |
|---|---|---|---|---|---|
| | | | *Lower lake* | | |
| 1973 | — | | | | |
| 1974 | c[1] | — | | | |
| 1975 | | C | — | | |
| 1977 | H[1] | | c | — | |
| 1979 | h | | c | | — |
| | | | *Upper lake* | | |
| 1973 | — | | | | |
| 1974 | HC | — | | | |
| 1975 | | HC | — | | |
| 1977 | | c | | — | |
| 1979 | HC | | HC | C | — |

[1] H and C = significant differences in hours and harvest respectively at the $P = 0.01$ level; h and c = significant differences in hours and harvest respectively at the $P = 0.05$ level.

Table 15.—*Percent contribution of shore, boat, weekend, and weekday strata to estimates of fishermen-hours, and harvest at Twin Lakes, 1973-79*

| | | Lower lake | | Upper lake | | | Lower lake | | Upper lake | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | H[1] | C | H | C | | H | C | H | C |
| | | | | | *Percent* | | | | | |
| 1973 | Shore | 86 | 88 | 81 | 96 | WE | 57 | — | 57 | — |
| | Boat | 14 | 12 | 19 | 4 | WD | 43 | — | 43 | — |
| 1974 | Shore | 81 | 83 | 78 | 79 | WE | 47 | — | 49 | — |
| | Boat | 19 | 17 | 22 | 21 | WD | 53 | — | 51 | — |
| 1975 | Shore | 87 | 90 | 90 | 94 | WE | 53 | — | 48 | — |
| | Boat | 13 | 10 | 10 | 6 | WD | 47 | — | 52 | — |
| 1977 | Shore | 81 | 89 | 91 | 93 | WE | 58 | 51 | 60 | 57 |
| | Boat | 19 | 11 | 9 | 7 | WD | 42 | 49 | 40 | 43 |
| 1979 | Shore | 87 | 94 | 91 | 94 | WE | 57 | 58 | 56 | 55 |
| | Boat | 13 | 6 | 9 | 6 | WD | 43 | 42 | 44 | 45 |
| Mean 1973-1979 | Shore | 84 | 89 | 86 | 91 | WE | 54 | 55 | 54 | 56 |
| | Boat | 16 | 11 | 14 | 9 | WD | 46 | 45 | 46 | 44 |

[1] WE = weekend
WD = weekday

H = fishermen hours
C = harvest

fish), 1975 (11 761 fish), and 1977 (11 240 fish) were not significantly different from each other, and each was significantly greater than the low harvests in 1974 (7014 fish) and 1979 (6411 fish). With the exception of the 1977 harvest, significant differences in harvests corresponded with significant differences in fishermen effort in the upper lake.

The percent contribution of shore and boat fishermen to the estimates of total fishermen effort, harvest, and catch composition have remained similar throughout the study period. Snore fishermen accounted for an average of 84 and 86 percent of the total effort and an average of 89 and 91 percent of the total harvest for the summer fishery at the lower and upper lakes, respectively (table 15). An average of 54 to 56 percent of both fishermen effort and harvest occurred during the weekends. From 1973 to 1979, rainbow trout have composed 94 percent or greater of the summer season harvest at both lakes, with lake trout making up the remainder (table 16). The characteristics of the rainbow trout harvest (table 17) demonstrated that most of the rainbow trout were captured by shore fishermen.

As the second most abundant fish in the harvest, lake trout comprised an average of only 2.5 to 4 percent of the total harvest since 1974, when the size limit for lake trout was reduced from 508 mm (20 in) to 381 mm (15 in). Except for 1977, the lake trout harvest in the lower lake was generally 3.2 to 4.5 times that in the upper lake (table 18). The effect of the change in the size limit regulation may be observed in the estimated harvests of the lake trout, but coefficients of variation ranging from 22 to 263 percent on these estimates indicate their relative imprecision. The peak harvest of lake trout in the lower lake occurred in 1974 with apparent declines each year thereafter. Except for the 1974 season, 60 to 88 percent of the lake trout were caught by boat fishermen. In 1974 only, more than half the lake trout harvested were captured in May, and 82 percent of the May harvest was taken by shore fishermen (Finnell, 1977 [20]). For the upper lake, the lake trout harvest has fluctuated between shore and boat fishermen, with an average of about 50 percent of the harvest being taken by either group over the study period. For both lakes, no general monthly pattern in the lake trout harvest was apparent.

Catch rates for both lakes over the study period exhibited considerable variation from month to month, and coefficients of variation for the monthly estimates were relatively large (table 19). The best relative precision was associated with seasonal catch rates for shore fishermen, with coefficients of variation ranging from 4 to 7 percent for the lower lake and 11 to 12 percent for the upper lake. Coefficients of variation for boat fishermen catch rates ranged from 16 to 24 percent for the lower lake and 25 to 35 percent for the upper lake. On a seasonal basis, the shore catch rates for both lakes (fig. 9) appeared to correlate well with yearly stocking levels for rainbow trout. The best shore catch rates on the lower lake occurred in 1975, 1977, and 1979, following a declining trend from 1972 to 1974.

Catch rates for the upper lake shore fishermen were greatest in 1973, 1975, and 1977. Boat catch rates on the lower lake peaked in 1973 and 1975 above the 0.18 to 0.20 range exhibited in the other 4 years, while 1974 and 1977 were the best seasons for boats on the upper lake.

**Lower Lake — Fishermen Effort and Harvest — Winter Seasons, 1976-79**

Fishermen effort and harvest estimates from 1976 to 1979 demonstrate the relatively minor proportions of the ice-fishing seasons on the lower lake (tables 20-23). As a result, the relative precision of monthly fishermen effort estimates and all the harvest estimates is reduced. Fishermen effort estimates demonstrated a declining trend over most monthly and seasonal comparisons since the 1976-77 season. Harvests ranged from 400 to 600 fish with the 1978-79 total appearing noticeably less than those of the previous years. Catch rates were characteristically low, ranging from 0.03 to 0.36 fish per man-hour for weekend-weekday strata, 0.03 to 0.21 fish per man-hour for months and 0.07 to 0.11 fish per man-hour for seasons. Catch compositions were most similar for the 1977-78 and 1978-79 seasons, when lake trout made up over 90 percent of the harvests. In the 1976-77 season, lake trout comprised only 57 percent of the harvest and rainbow trout the remaining 43 percent. Lake trout harvested averaged 423 to 461 mm (17 to 18 in) in length over the three seasons.

Table 16.—*Catch composition for summer season harvest estimates at Twin Lakes, 1973-79, for lake trout and rainbow trout only*

| Species | 1973 | 1974 | 1975 | 1977 | 1979 |
|---|---|---|---|---|---|
| | | | *Percent* | | |
| *Lower lake* | | | | | |
| Rainbow trout | 99.0 | 94 | 97 | 96 | 98 |
| Lake trout | 1.0 | 6 | 3 | 4 | 2 |
| *Upper lake* | | | | | |
| Rainbow trout | 99.6 | 96 | 98 | 99 | 97 |
| Lake trout | 0.4 | 4 | 2 | 1 | 3 |

Table 17.—*Percent of rainbow trout harvest caught by shore and boat fishermen at Twin Lakes, 1973-79*

| | 1973 | 1974 | 1975 | 1977 | 1979 | Avg. |
|---|---|---|---|---|---|---|
| | | | *Percent* | | | |
| *Lower lake* | | | | | | |
| Shore | 88 | 85 | 91 | 91 | 95 | 90 |
| Boat | 12 | 15 | 9 | 9 | 5 | 10 |
| *Upper lake* | | | | | | |
| Shore | 96 | 81 | 94 | 93 | 95 | 92 |
| Boat | 4 | 19 | 6 | 7 | 5 | 8 |

**Characterization of the Lower Lake Winter Fishery, 1973-79**

The monthly and seasonal estimates for the 1976-79 seasons were combined with data from the three previous seasons included in Finnell and Bennett (1976) [33] and Finnell (1977) [20] in order to characterize the winter fishery on the lower lake. Estimates for the 1975-76 season included only the December-January period. Thus, an attempt was made to project fishermen effort and harvest estimates for the February-March period in 1976. The relationships between the December-January and February-March estimates of fishermen effort and harvest were analyzed through correlation-regression (table 24). Correlation coefficients of 0.8234 for hours and 0.9885 for harvest were found. The 1973-74 harvest estimate was excluded from the analyses on the basis of the more restrictive size limit on lake trout in effect in December 1973. This resulted in a better correlation coefficient for the harvest group. Using the regression equations (least squares) based on the greatest correlation coefficients, the results suggest that the 1975-76 season was probably the peak season for fishermen effort (8819 hours) and had one of the best harvests (1035 fish) for the December-March period.

*Z*-test comparisons of season totals for fishermen effort and harvest for the study period (table 25) showed that the increase or decrease in fishermen effort from one season to the next was statistically significant in all cases except between the peak seasons. The harvest estimates for the 1974-75 and 1975-76 seasons were significantly greater than those for the other four seasons for both the December-January and December-March periods. After reduction of the lake trout size limit in 1974, fishermen effort estimates increased to the peak of over 8800 man-hours in 1975-76 (fig. 10).

While the 1976-77 season estimate was the next highest year in terms of fishermen effort, poor fishing success occurred during this season and may have contributed to the decline in

Table 18.—*Lake trout harvest at Twin Lakes characterized by shore, boat, and monthly percentages*

| | 1973 | 1974 | 1975 | 1977 | 1979 | Avg. |
|---|---|---|---|---|---|---|
| | | | *Lower lake* | | | |
| Total estimated harvest | 174 | 1233 | 989 | 830 | 555 | — |
| (Standard error[1]) | (263) | (46) | (40) | (22) | (26) | |
| | | | *Percent* | | | |
| Shore | 31 | 58 | 40 | 32 | 12 | 35 |
| Boat | 69 | 42 | 60 | 68 | 88 | 65 |
| May | 15 | 56 | 10 | 36 | 3 | 24 |
| June | 24 | 24 | 35 | 19 | 10 | 22 |
| July | 19 | 6 | 24 | 14 | 30 | 19 |
| August | 28 | 14 | 24 | 30 | 21 | 23 |
| September | 14 | — | 7 | 2 | 36 | 12 |
| | | | *Upper lake* | | | |
| Total estimated harvest | 55 | 272 | 282 | 72 | 165 | — |
| (Standard error) | (129) | (87) | (66) | (31) | (35) | |
| | | | *Percent* | | | |
| Shore | 58 | 16 | 69 | 40 | 62 | 49 |
| Boat | 42 | 84 | 31 | 60 | 38 | 51 |
| May | — | 77 | 27 | 24 | 2 | 26 |
| June | 25 | 10 | 61 | 47 | 44 | 37 |
| July | 33 | 13 | 12 | — | 49 | 21 |
| August | 42 | — | — | — | — | 8 |
| September | — | — | — | 29 | 5 | 7 |

[1] Expressed as a percent of the harvest estimate.

the estimates of fishermen effort in subsequent seasons. Above-average snowfall in 1977-78 and 1978-79 limited fishermen access and may have also contributed to the observed decrease. The harvest estimates showed the same pattern of change as fishermen effort, with the harvest estimates increasing sharply after the reduction of the size limit for lake trout (fig. 11). The peak harvest estimates of over 1000 fish occurred in the two seasons following the size regulation change. From 1976 to 1979, the winter harvest estimates declined to the point where the December-March harvest estimates for these three seasons were less than the December-January estimates from 1974 to 1976.

Catch rates for the winter fishery were characteristically low, with the best success of 0.20 to 0.21 fish per man-hour occurring in December of 1975-76 and 1977-78 (table 26). No consistent pattern for the estimated monthly catch rates was evident. The seasonal estimates of the catch rates demonstrate the significant decrease that occurred in fishermen success in 1976-77. Following the 1976-77 season, the estimated catch rates increased significantly, but did not quite equal the estimated catch rates for the 1974-76 seasons.

Seasonal harvest compositions for the winter seasons showed that lake trout dominated the harvest with rainbow trout making up the remainder (table 27). This is directly opposite the pattern observed for the summer seasons. Excluding the 1976-77 season, lake trout normally formed 87 percent or greater of the catch composition. The 1976-77 season percentages reflect a greatly reduced number of lake trout in the harvest, and an increase in the numbers of rainbow trout caught. The consistency of the catch composition in the seasons surrounding the 1976-77 season suggests that the unusual

Table 19.—*Monthly and seasonal catch rates as catch per man-hour with coefficients of variation (in parentheses) for summer seasons at Twin Lakes, 1974, 1975, 1977, and 1979*

| | Shore | Boat | Shore | Boat |
|---|---|---|---|---|
| | | *Lower lake* | | |
| | *1974* | | *1975* | |
| May | 0.32 (24) | 0.07 (46) | 0.58 (13) | 0.28 (46) |
| June | .19 (11) | .12 (27) | .64 (10) | .17 (52) |
| July | .22 (8) | .39 (42) | .26 (8) | .34 (23) |
| Aug. | .31 (9) | .31 (20) | .51 (8) | .33 (22) |
| Sept. | .27 (17) | — | .23 (23) | — |
| Seasonal rate | .25 (4) | .19 (17) | .43 (5) | .28 (16) |
| | *1977* | | *1979* | |
| May | 0.55 (37) | 0.09 (50) | 0.43 (11) | 0.17 (74) |
| June | .47 (33) | .17 (116) | .53 (24) | .04 (45) |
| July | .33 (22) | .22 (143) | .36 (26) | .15 (66) |
| Aug. | .34 (35) | .22 (34) | .28 (55) | .34 (60) |
| Sept. | .32 (18) | .29 (56) | .42 (39) | .21 (41) |
| Seasonal rate | .39 (7) | .20 (24) | .39 (6) | .18 (17) |
| | | *Upper lake* | | |
| | *1977* | | *1979* | |
| May | 0.65 (15) | 0.43 (88) | 0.34 (9) | — |
| June | .64 (39) | .03 (137) | .41 (33) | .14 (131) |
| July | .36 (88) | .43 (84) | .34 (20) | .12 (128) |
| Aug. | .50 (25) | .35 (61) | .34 (71) | .13 (18) |
| Sept. | .27 (23) | .53 (113) | .24 (41) | .76 (69) |
| Seasonal rate | .46 (11) | .37 (35) | .33 (12) | .24 (25) |

catch rate observed does not reflect adverse changes in the lake trout population abundance in that year. From field observations in 1976-77 and subsequent winters, the low catch rate is believed to have resulted from high fishermen effort (due to relatively good fishing success in previous seasons) unsynchronized with characteristic lake trout activity at dawn and dusk. Few ice fishermen fished during the dawn period and many left the lake unsuccessful prior to the short dusk fishing period, which was observed to be the time of greatest fishermen success.

A trend in the harvests of the Twin Lakes winter fishery was evident from length frequency distributions of the lake trout harvest (fig. 12). Since the first complete season after the size limit reduction, a shift in the length frequency distribution of lake trout toward the 381- to 432-mm (15- to 17-in) size range over the five seasons were observed. Using 508 mm (20 in) or greater as an arbitrary definition of a quality-size lake trout, the percentage of lake trout in this category declined from 26 percent of the fishermen's harvest in 1974-75 to 6-8 percent in the 1977-79 seasons (table 28). Chi-square analysis of the length frequency distributions was done using category I, less than 508 mm (20 in), and category II, greater than or equal to 508 mm (20 in) (Nesler, 1979 [34]). The decline in the percent composition of category II in the fishermen's catch over the five seasons was statistically significant ($X^2$ = 24.89, $n$ = 4, $P$ = 0.05). Eighty-three percent of the contribution to the chi-square statistic came from category II for the 1974-75, 1977-78, and 1978-79 seasons.

# DISCUSSION

## Creel Census Technique

A stratified-random creel census was conducted at Twin Lakes to determine the potential impacts

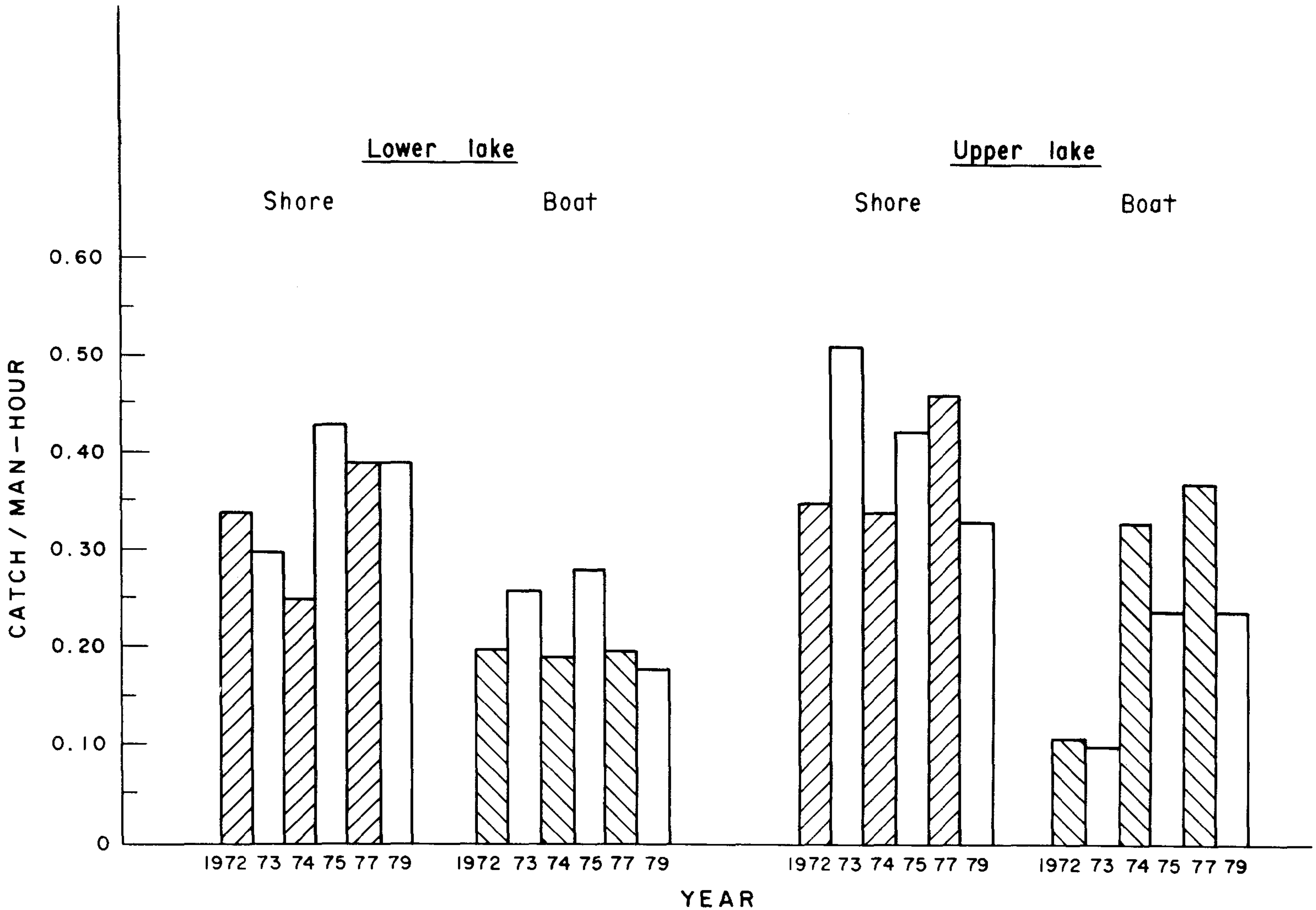


Figure 9.—Catch rates for summer seasons at Twin Lakes, 1972-79.

Table 20.—*Estimates of fishermen effort and harvest for the 1976-79 lower lake winter seasons*

| | | Dec. | Jan. | Feb. | Mar. | Dec.-Jan. | Dec.-Mar. |
|---|---|---|---|---|---|---|---|
| | | | | *Effort* | | | |
| 1978-79 | Hours | 585 | 1234 | 1183 | 897 | 1819 | 3899 |
| | %[1] | 99 | 39 | 37 | 28 | 33 | 18 |
| 1977-78 | Hours | 776 | 1869 | 2046 | 1406 | 2645 | 6097 |
| | % | 92 | 25 | 28 | 34 | 22 | 14 |
| 1976-77 | Hours | 1489 | 3091 | 2536 | 1248 | 4580 | 8364 |
| | % | 29 | 31 | 45 | 33 | 22 | 17 |
| | | | | *Harvest* | | | |
| 1978-79 | Catch | 48 | 111 | 108 | 138 | 159 | 405 |
| | % | 196 | 77 | 77 | 67 | 65 | 36 |
| 1977-78 | Catch | 116 | 200 | 233 | 48 | 316 | 597 |
| | % | 316 | 53 | 73 | 81 | 68 | 42 |
| 1976-77 | Catch | 60 | 237 | 108 | 180 | 297 | 585 |
| | % | 147 | 52 | 81 | 95 | 46 | 36 |

[1] Ninety-five percent confidence intervals are expressed as percentages (±%) of the estimates.

of the Mt. Elbert Pumped-Storage Powerplant on the sport fishery. To accomplish this successfully, biases in the counting and interviewing of fishermen had to be avoided or at least accounted for. The nature of the possible biases in creel census sampling have been examined by Grosslein (1962) [30], Neuhold and Lu (1957) [26], and Regier (1966) [35, 36].

While randomness is a prerequisite for unbiased sampling, the stratification of sampling effort over time, area, and fishermen-type may be used to improve the accuracy of the results as well as improve their precision by minimizing sampling error variances (Grosslein, 1962; Regier, 1966 [30, 35, 36]). Fishermen counts in both summer and winter seasons at Twin Lakes were of the "instantaneous" type referred to in Neuhold and Lu (1957) [26], negating the need for randomization of a starting point for fishermen counts. Grosslein (1962) [30] points out that the unit of effort used in estimating total fishing pressure must equal the unit of effort used in determining the catch rate (i.e., criteria used to determine fishing pressure and catch rates must be similiar). In the summer seasons, the overestimation of fishing effort (a positive bias) was possible since the creel census clerks may have counted some fishermen that were not directly involved in fishing, but were judged to start fishing within the 15-min instantaneous count. This bias in the Twin Lakes counts was considered negligible since fishermen generally exhibited the habit of fishing onshore in close proximity to their established camp, and boat fishermen proceeding to a distant point on the lake relative to their camp required little time to arrive at their destination and begin active fishing. This positive bias was also considered to be offset by the fishermen's tendency to overestimate their reported time spent fishing, which resulted in a negatively biased estimate of catch rate. Nonfishermen were not a problem at Twin Lakes.

The estimation of an average number of fishermen per boat from interview data was another potential source of error and bias, but was considered minimal since, generally, an adequate number of boats were sampled within a designated interview period.

During the winter, nonfishing activity was more difficult to detect since closed ice shanties were

Table 21.—*Fishermen effort and harvest estimates with standard errors for the winter creel census on the lower lake, 1976-77*

| Month | Total hours[1] | CPMH[2,3] | Total catch |
|---|---|---|---|
| December | | | |
| Weekdays | 588 (36) | 0.042 (0.017) | 28 (10) |
| Weekend days | 501 (901) | .043 (0.033) | 32 (30) |
| Total | 1089 (154) | .040 (0.017) | 60 (32) |
| January | | | |
| Weekdays | 1155 (104) | .112 (0.028) | 129 (35) |
| Weekend days | 1936 (429) | .056 (0.020) | 108 (45) |
| Total | 3091 (441) | .090 (0.017) | 237 (57) |
| February | | | |
| Weekdays | 960 (341) | .030 (0.017) | 29 (19) |
| Weekend days | 1576 (341) | .050 (0.017) | 79 (32) |
| Total | 2536 (482) | .040 (0.045) | 108 (37) |
| March | | | |
| Weekdays | 662 (142) | .194 (0.101) | 128 (71) |
| Weekend days | 586 (95) | .089 (0.022) | 52 (15) |
| Total | 1248 (171) | .130 (0.039) | 180 (73) |
| December-January | | | |
| Weekdays | 1743 (110) | .090 ( — ) | 157 (36) |
| Weekend days | 2837 (454) | .050 ( — ) | 140 (54) |
| Total | 4580 (467) | .070 (0.014) | 297 (65) |
| December-March | | | |
| Weekdays | 3365 (385) | .090 ( — ) | 314 (82) |
| Weekend days | 4999 (576) | .050 ( — ) | 271 (64) |
| Total | 8364 (693) | .070 (0.010) | 585 (104) |

[1] Standard error in parentheses.
[2] CPMH = catch per man-hour.
[3] Not additive.

commonly used. However, overestimation of fishing effort here was not considered a problem because ice fishermen using shanties were generally more serious in their approach to fishing for lake trout. They took note of the time necessary to clear ice holes, set up heaters, prepare baits, etc., as well as the actual time they started fishing and break times. Corrections in the fishermen counts could thus be made from interview data. Most ice fishermen were also aware of the creel census studies and became conditioned to noting their fishing time whether the creel census was operating that day or not.

The creel census methods used in 1972 and 1973 differed substantially from the method used in later years, thus some reservation is required in comparative analyses. Raw data for fishermen counts in 1972 showed that the horizontal or daily method of determining mean number of fishermen per count each sample day was used, but the number of daily counts varied from only one to three. The count method also appeared inconsistent for weekend and weekday strata, and from month to month. Variance estimates and confidence intervals were not published for the 1972 estimates and incomplete records prevented their calculation. In 1973, daily counts also varied from one to three, but the vertical or stratum-total method of deter-

Table 22.—*Fishermen effort and harvest estimates with standard errors for the winter creel census on the lower lake, 1977-78*

| Month | Total hours[1] | CPMH[2,3] | Total catch |
|---|---|---|---|
| December | | | |
| Weekdays | 588 (588) | 0.095 (0.134) | 56 (78) |
| Weekend days | 188 (112) | .320 (0.100) | 60 (39) |
| Total | 776 (165) | .210 (0.065) | 116 (87) |
| January | | | |
| Weekdays | 761 (76) | .090 (0.032) | 69 (29) |
| Weekend days | 1108 (190) | .118 (0.027) | 131 (37) |
| *Total* | 1869 (205) | .110 (0.022) | 200 (47) |
| February | | | |
| Weekdays | 990 (239) | .129 (0.063) | 128 (68) |
| Weekend days | 1056 (38) | .099 (0.022) | 105 (24) |
| Total | 2046 (242) | .110 (0.022) | 233 (72) |
| March | | | |
| Weekdays | 794 (156) | .034 (0.017) | 27 (14) |
| Weekend days | 612 (132) | .034 (0.010) | 21 (7) |
| Total | 1406 (204) | .030 (0.010) | 48 (16) |
| December-January | | | |
| Weekdays | 1349 (143) | .090 ( — ) | 125 (83) |
| Weekend days | 1296 (221) | .150 ( — ) | 191 (53) |
| Total | 2645 (263) | .140 (0.022) | 316 (99) |
| December-March | | | |
| Weekdays | 3133 (319) | .090 ( — ) | 280 (109) |
| Weekend days | 2964 (261) | .110 ( — ) | 317 (59) |
| Total | 6097 (412) | .110 (0.014) | 597 (123) |

[1] Standard error in parentheses.
[2] CPMH = catch per man-hour.
[3] Not additive.

mining mean number of fishermen per count each sample day was used. Count methods from month to month over weekend and weekday strata appeared more consistent. The count methods for 1972 and 1973 were subject to these inconsistencies resulting from the large-scale creel census sampling program being conducted with limited manpower for five or six reservoirs and the Fryingpan River within the Fryingpan-Arkansas Project. In 1974 and 1975, creel census sampling was confined to Twin Lakes and a more consistent counting method resulted. The 1973 estimates may be positively biased due to limited count data taken during the higher use midday hours. Considering this bias, the difference between the 1973 and 1979 fishermen effort estimates may not actually be significant, and 1973 versus 1977 may only be significant at the $P = 0.05$ level. Computing error in the estimation of the catch rates for the lower lake during the 1973 season resulted in a mistakenly high estimate of the harvest (Finnell, 1977 [20]). Corrections were possible and were made (Finnell, 1980 [37]) by using earlier reports.

In conducting fishermen interviews, the roving census technique was necessary at Twin Lakes during the summer season because of extensive access by fishermen. Certain errors in the catch data were avoided with direct examination of the

Table 23.—*Fishermen effort and harvest estimates with standard errors for the winter creel census on the lower lake, 1978-79*

| Month | Total hours[1] | CPMH[2,3] | Total catch |
|---|---|---|---|
| December | | | |
| Weekdays | 270 (148) | 0.120 (0.096) | 32 (28) |
| Weekend days | 315 (105) | .050 (0.027) | 16 (9) |
| Total | 585 (182) | .060 (0.027) | 48 (30) |
| January | | | |
| Weekdays | 605 (202) | .080 (0.042) | 48 (29) |
| Weekend days | 629 (58) | .100 (0.035) | 63 (22) |
| Total | 1234 (210) | .090 (0.027) | 111 (37) |
| February | | | |
| Weekdays | 347 (148) | .070 (0.062) | 24 (22) |
| Weekend days | 836 (106) | .100 (0.030) | 84 (27) |
| Total | 1183 (182) | .090 (0.027) | 108 (35) |
| March | | | |
| Weekdays | 215 (49) | .360 (0.144) | 77 (35) |
| Weekend days | 682 (95) | .090 (0.255) | 61 (19) |
| Total | 897 (107) | .120 (0.032) | 138 (40) |
| December-January | | | |
| Weekdays | 875 (250) | .090 ( — ) | 80 (40) |
| Weekend days | 944 (121) | .080 ( — ) | 79 (24) |
| Total | 1819 (278) | .080 (0.020) | 159 (47) |
| December-March | | | |
| Weekdays | 1437 (295) | .130 ( — ) | 181 (58) |
| Weekend days | 2462 (187) | .090 ( — ) | 224 (41) |
| Total | 3899 (349) | .100 (0.014) | 405 (71) |

[1] Standard error in parentheses.
[2] CPMH = catch per man-hour.
[3] Not additive.

fishermen's catch, but as Grosslein (1962) [30] indicates, other problems arise from the incomplete trip information characteristic of the roving census. As stated before, a negatively biased or underestimated catch rate was considered most likely since fishermen's accounts of nonfishing time referred mostly to major breaks such as lunch or rests, and did not include setup time, changing tackle, or minor intervals of nonfishing time within a fishing trip. This bias was considered negligible since (1) fishermen response errors concerning their starting time would tend to cancel out (Regier, 1966 [36]) and (2) bait fishing or trolling, the predominant forms of shore and boat fishing at Twin Lakes, permitted a more passive role by the fishermen and minimized the importance of nonfishing time for a more mobile or active type of fishing.

Catch rates using incomplete trip information are considered unbiased by Grosslein (1962) [30] if:

1. Early and late parts of the fishing trip are equally successful, and

2. Short-term and long-term fishermen are equally successful (i.e., catch rate is uncorrelated with total length of the trip).

Table 24.—*Regression equations for determining 1975-76 February-March hours and harvest as a function of December-January hours and harvest estimates*

I.

| | Total hours Dec.-Mar. | Hours | | Harvest | | Total hours Dec.-Mar. |
|---|---|---|---|---|---|---|
| | | *Y* Feb.-Mar. | *X* Dec.-Jan. | *Y* Feb.-Mar. | *X* Dec.-Jan. | |
| 1973-74 | 5600 | 2953 | 2647 | 364 | 326 | 690 |
| 1974-75 | 7295 | 3310 | 3985 | 352 | 693 | 1045 |
| 1976-77 | 8364 | 3774 | 4590 | 288 | 297 | 585 |
| 1977-78 | 6097 | 3452 | 2645 | 281 | 316 | 597 |
| 1978-79 | 3899 | 2080 | 1819 | 246 | 159 | 405 |
| 1975-76 | 8819[1] | 3941[1] | 4878 | 352[1] | 683 | 1035[1] |

[1] Estimated value from regression equations below.

II.

| | *Hours* | *Harvest* |
|---|---|---|
| With 1973-74 data | $r = 0.8234$ | $r = 0.6937$ |
| | $Y = 1622.4 + 0.4754X$ | $Y = 243.7 + 0.1746X$ |
| Without 1973-74 data | $r = 0.8221$ | $r = 0.9885$ |
| | $Y = 1574 + 0.4847X$ | $Y = 222 + 0.191X$ |

Table 25.—*Z-test comparisons of estimated fishermen-hours and harvest for the 1973-79 winter seasons at the lower lake*

| | 1973-74 | 1974-75 | 1975-76 | 1976-77 | 1977-78 | 1978-79 |
|---|---|---|---|---|---|---|
| | | | *December-January* | | | |
| 1973-74 | — | | | | | |
| 1974-75 | HC[1] | — | | | | |
| 1975-76 | HC | H | — | | | |
| 1976-77 | H | C | C | — | | |
| 1977-78 | [1] | HC | HC | H | — | |
| 1978-79 | hc[1] | HC | HC | H | h | — |
| | | | *December-March* | | | |
| 1974-75 | | — | | | | |
| 1976-77 | | C | | — | | |
| 1977-78 | | HC | | H | — | |
| 1978-79 | | HC | | H | H | — |

[1] H and C = significant differences in hours and harvest respectively at the $P = 0.01$ level; h and c = significant differences in hours and harvest respectively at the $P = 0.05$ level.

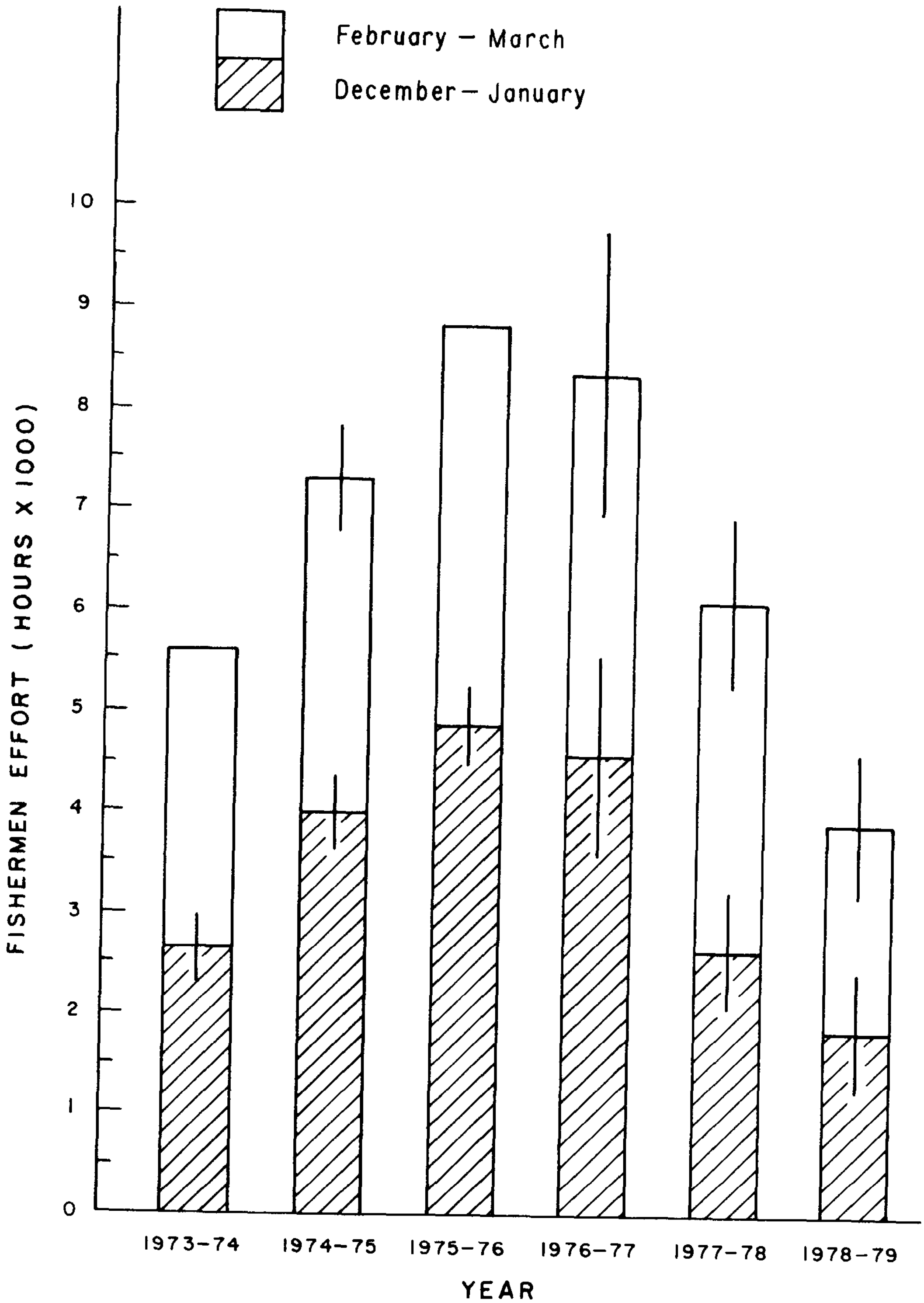


Figure 10.—Estimates of fishermen effort at the lower lake during the winter seasons, 1973-79, with 95 percent confidence intervals.

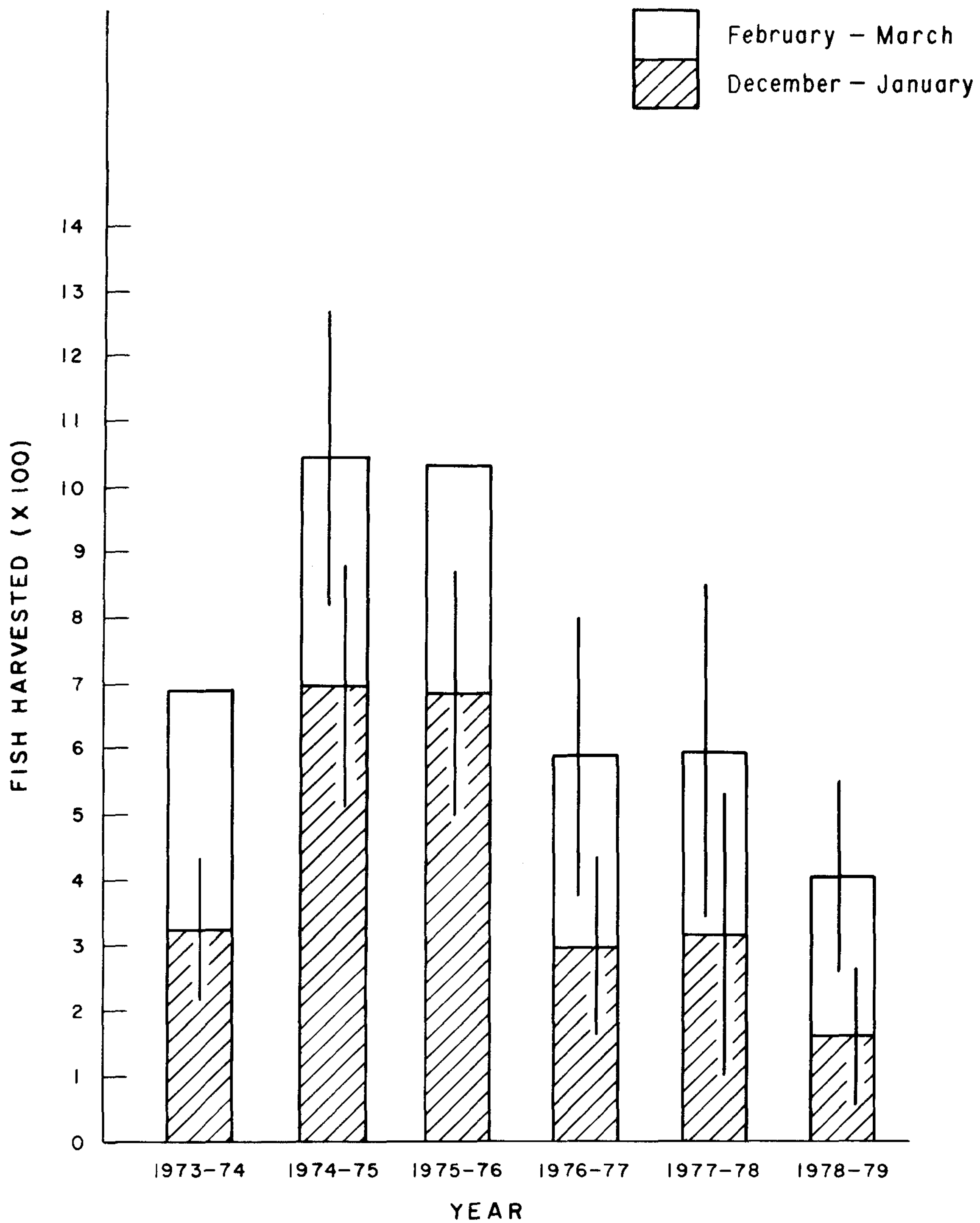


Figure 11.—Estimates of winter harvests at the lower lake, 1973-79, with 95 percent confidence intervals.

Table 26.—*Monthly and seasonal catch rates as catch per man-hour and 95 percent confidence intervals expressed as percentages of the estimates (in parentheses) for winter seasons at the lower lake, 1974-79*

| Month | 1974-75 | 1975-76 | 1976-77 | 1977-78 | 1978-79 |
|---|---|---|---|---|---|
| Dec. | 0.15 (30) | 0.20 (34) | 0.04 (82) | 0.21 (64) | 0.06 (89) |
| Jan. | .18 (30) | .10 (36) | .09 (37) | .11 (40) | .09 (59) |
| Feb. | .15 (33) | — | .04 (66) | .11 (40) | .09 (61) |
| Mar. | .05 (90) | — | .13 (62) | .03 (59) | .12 (54) |
| Dec.-Jan. | .16 (22) | .14 (24) | .07 (38) | .14 (32) | .08 (49) |
| Dec.-Mar. | .14 (18) | .12[1] | .07 (28) | .11 (23) | .10 (28) |

[1] Calculated from regression analysis estimates of hours and catch (table 24).

Table 27.—*Catch composition for winter season harvest estimates at the lower lake, 1973-79*

| | 1973-74 | 1974-75 | 1975-76 | 1976-77 | 1977-78 | 1978-79 |
|---|---|---|---|---|---|---|
| | | | *percent* | | | |
| | | | December-January | | | |
| Lake trout | 94 | 87 | 97 | 37 | 92 | 100 |
| Rainbow trout | 6 | 13 | 3 | 63 | 8 | 0 |
| | | | December-March | | | |
| Lake trout | — | 89 | — | 57 | 95 | 100 |
| Rainbow trout | — | 11 | — | 43 | 5 | 0 |

Table 28.—*Length frequency distribution of lake trout caught by ice fishermen checked during creel census on Twin Lakes, 1974-79*

| | Number of fish | | | |
|---|---|---|---|---|
| | Category | | Total | |
| Year | I (<508 mm) (<20 in) | II (≥508 mm) (≥20 in) | | % Total (≥508 mm) (≥20 in) |
| 1974-75 | 124 | 43 | 167 | 25.8 |
| 1975-76 | 115 | 25 | 140 | 17.9 |
| 1976-77 | 31 | 7 | 38 | 18.4 |
| 1977-78 | 112 | 7 | 119 | 5.9 |
| 1978-79 | 81 | 7 | 88 | 8.0 |

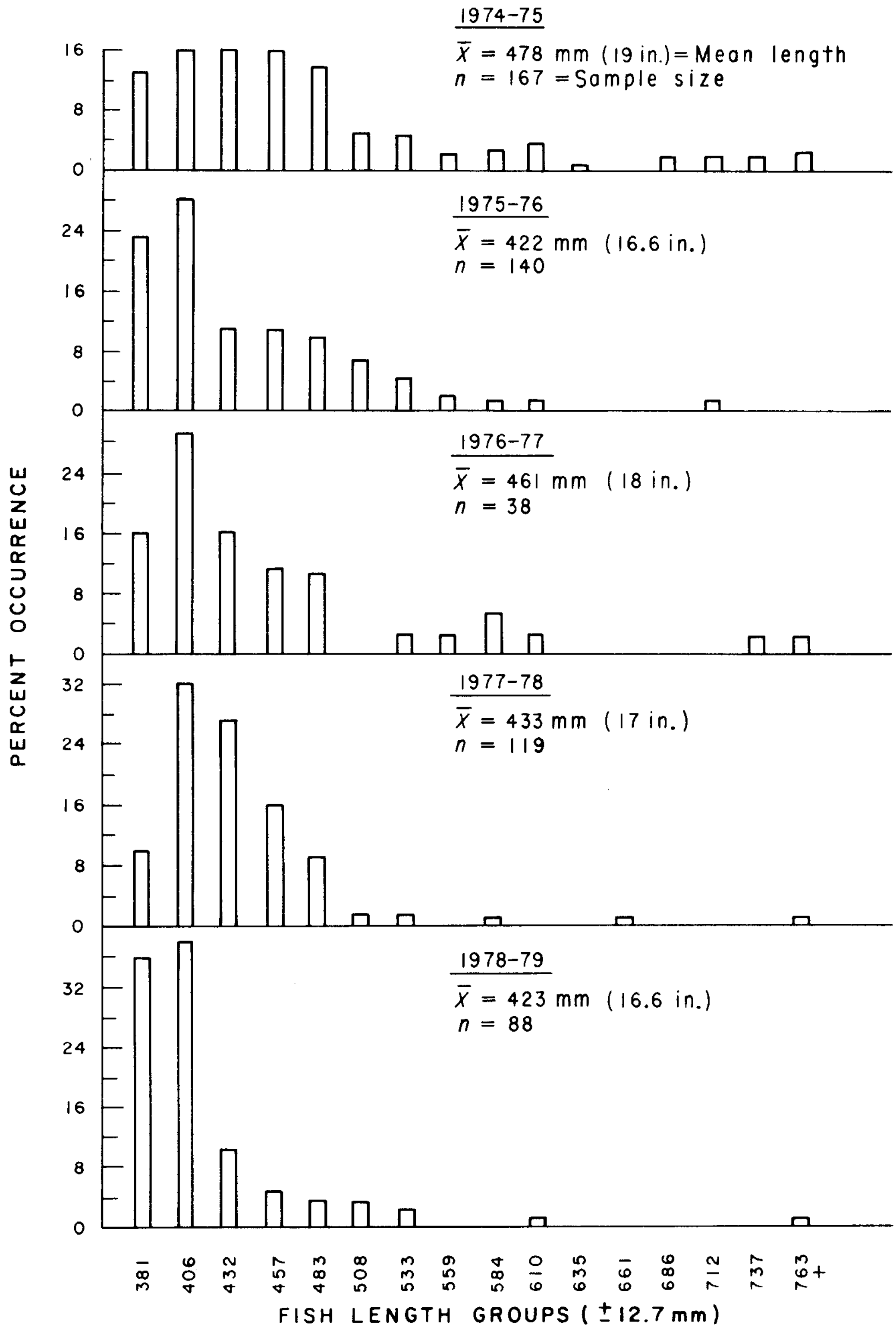


Figure 12.—Length frequency distribution of lake trout in the ice fishermen's creel at the lower lake, 1974-79.

Detection of bias in incomplete trip catch rates was possible according to Grosslein (1962) [30] by comparison of mean catch rates based on separate samples of incomplete and complete trips. Results from this study and Finnell (1977) [20] showed no significant difference between incomplete and completed trip catch rates at Twin Lakes. Grosslein (1962) [30] indicated that the variance (and thus precision) of seasonal mean catch rates were affected by systematic sampling and sample size. In a roving census, where consistent differences existed in catch rates between sections of a fishery, seasonal variance would tend to be increased; at extremely low levels of success, very large samples would be necessary to achieve a moderate level of precision. Grosslein (1962) [30] considered $\pm 10$ percent of the mean catch rate as adequate precision. By these criteria, only the seasonal estimates of shore catch rate at Twin Lakes achieved a satisfactory precision. The lower relative precision of the seasonal estimates of boat catch rate resulted from a combination of low levels of success and relatively less fishermen effort (which would equate to a smaller sample size). Both of these conditions are considered characteristic of the Twin Lakes boat fishery. The monthly estimates of both shore and boat catch rates are subject to the effect of smaller sample sizes, but variability, due to between-sample day differences in catch rates, is considered to be a natural characteristic of the Twin Lakes fishery as well.

Because of the predominance of either lake trout or rainbow trout in the seasonal harvests, winter and summer shore catch rates may be considered as species catch rates, respectively. Greater difficulty is encountered in this regard with respect to summer boat fishing, and the 1976-77 winter season. Neuhold and Lu (1957) [26] and Grosslein (1962) [30] indicate that individual species catch rates may be based on the total time spent fishing for all species, such that the sum of the individual species catch rates equals the total catch rate for all species combined, but this method may not be representative of certain species when angler preference is considered. This is considered an important criterion at Twin Lakes, since angling techniques and baits used for lake trout and rainbow trout are generally quite distinct during most times of the year. During the 1976-77 season, ice fishermen would spend most of their time using baits or terminal tackle suited for lake trout. Because of the extremely low success rate for lake trout, though, fishermen often kept tackle at hand more suited for rainbow trout. When rainbow trout were observed through the ice, fishermen would exchange tackle and attempt to catch the rainbow trout. This process usually took only a little time and would reoccur sporadically during a fishing trip. Fishermen never took note of time spent fishing with the different techniques, but it was obvious that the rainbow catch rate would have been considerably higher than a percentage of the 0.07 fish per man-hour determined for the season. Fishing for these two trout species from shore or from boats in the summer requires different baits or lures and also requires fishing at different depths or areas of the lake. The fishermen who realized these differences rarely took note of the time spent fishing for each species. An additional segment of boat fishermen used midwater trolling techniques not suitable for either the rainbow or lake trout.

### Detection of Mt. Elbert Powerplant Impacts Upon the Twin Lakes Fishery via Creel Census Statistics

Fishermen effort and harvest estimates provide an indication of the magnitude of the fishery, but the harvest estimate is tied to fishermen effort via the catch rate and the two must necessarily be considered together for the purposes of impact analyses. In the future, decreasing harvests may result from declining fishermen effort as well as loss of fish via mortality during powerplant operation. The lack of correlation of the Twin Lakes catch rate with stocking pattern or mean number of fishermen per count each sample day suggests that catch rate may be used independently as a descriptive index of the Twin Lakes fishery without including qualifications for the influence of fishermen effort or stocking patterns. Catch rates are affected by fish abundance (Grosslein, 1962 [30]), and may provide a single index of the quality of the fishery more suitable to impact analyses.

In a sport fishery like Twin Lakes, fishermen effort may also be affected by factors which are independent of the quality of fishing available at the lakes. Neuhold and Lu (1957) [26] state that weather and sky conditions, both locally at the body of water and at distant cities, could affect fishermen numbers. Water conditions, air temperature, and preceding catch rates also influenced fishermen activity. Malvestuto et al.

(1979) [38] found 83 percent of the variation in monthly creel census estimates were explained by climatic variables, especially mean daily air temperature.

For the purposes of before-and-after impact analyses, *Z*-test comparisons may be effective in pointing out changes in the Twin Lakes fishery if estimates of fishermen effort and harvest during the operational phase of the Mt. Elbert Powerplant differ significantly as a group from the preoperational fishery estimates. Because of the variability observed in the estimates of fishermen effort, harvest, and catch rates over the study period, several years may be necessary to establish a long-term, gradual change in the Twin Lakes fishery.

Impacts from pumped-storage operation may affect the Twin Lakes creel census statistics in a number of ways. Assuming that powerplant operation causes an increase in fish mortality to the point of lowering catch rates significantly, fishermen effort may decline because of dissatisfaction with lower fishing success. Another source of impact upon fishermen effort may result from a prejudiced public expectation of potential harm to the fishery and poorer fishing, regardless of the actual impacts of the powerplant on fishing success. Finnell and Bennett (1974) [32] suggest that a low catch rate in May 1974 discouraged fishermen use later in the summer. As previously stated, the poor fishing success in the 1976-77 winter season may have contributed to the decline in fishermen effort in subsequent seasons.

The creel census statistics have demonstrated the relatively constant proportions of the Twin Lakes fishery made up by shore and boat fishermen. In this regard, fishermen effort and harvest will be most affected by pumped-storage impacts on shore fishing and rainbow trout because of the greater magnitude of the shore fishermen estimates. Increased mortality to rainbow trout, daily and seasonal water-level fluctuations, and shoreline turbidity may all adversely affect the shore fishery. Rainbow trout have exhibited a greater tendency to become entrained in pumped-storage flows relative to other fish species (Stober et al., 1977 [6]), and 75 to 81 percent total mortality to entrained rainbow trout has been documented (Serchuk et al., 1975 [12]; Liston and Tack, 1977 [13]; Liston, 1979 [14]). These types of impacts should also be reflected in the seasonal estimates of percent return of rainbow trout to the fishermen's creel, and in the observed rate of return of marked rainbow trout in the creel census.

The new dam constructed at Twin Lakes will have a confounding effect on the evaluation of powerplant impacts. Currently, the powerplant may begin operating the same summer that Twin Lakes will fill to its new level. Behind the new dam, the two lakes will be combined and the surface area will increase 280 ha (692 acres) (Fryingpan-Arkansas Project, 1975 [25]). At this level, maximum exposed lake bottom resulting from water-level fluctuation will increase from 309 to 584 ha (764 to 1443 acres) with an average of 489 ha (1208 acres). Combining this with the development of recreation facilities and restricted camping areas, the nature of the Twin Lakes fishery, especially shore fishing, will be significantly altered.

The combination of the upper and lower lakes into a single body of water will also necessitate changes in the creel census sampling methods. Fishermen counts on the single lake may require half-hour intervals instead of the 15-min intervals used in this study. Creel census interviews will no longer be split into upper and lower lake groups. The preoperational fishermen counts and creel census data for the upper and lower lakes presented here and in Finnell (1977, 1980) [20, 37] will need to be combined in order to make comparisons with the data acquired on the single reservoir.

Fishermen effort during the winter seasons may be most affected by physical effects of the daily water-level fluctuation on the ice layer. Preliminary expectations are for the perimeter of the ice to slip, buckle, and shelve (Fryingpan-Arkansas Project, 1975 [25]). This condition would affect access to the lake surface via motor vehicles; use of permanent ice shanties, which are the major device used at Twin Lakes; and require extra manual effort to set up and remove portable ice shanties daily.

Increased mortality to lake trout from pumped-storage operation may not be reflected in the creel census statistics because of smaller boat and ice fishermen harvests of lake trout, the lower relative precision associated with these estimates, and the low winter catch rates. Powerplant impacts will need to be very significant or continue for some time to precipitate significant changes in the boat fishing estimates or the lake trout harvest.

Lake trout mortality may be influenced by attraction of the larger, adult fish to the riprap-lined tailrace of the powerplant during the pump mode. At the Ludington Powerplant at Lake Michigan, large lake trout were attracted to the rock jetties during the fall spawning season (Brazo, 1977 [15]; Anderson, 1977 [16]). At Twin Lakes, large lake trout were observed to be especially attracted to the outlet flow during the spring at low reservoir levels, and may be attracted to daily pump-back flows at the powerplant (Bennett, 1975 [21]).

The advantages of catch rates for determining potential impacts at Twin Lakes have been discused. In a similar situation in California, two reservoirs providing a shore and boat fishery for catchable-size rainbow trout were used in a pumped-storage development (Lambert, 1977 [39]). Catch rates of 0.41 to 0.43 were determined for these reservoirs and used as the index for mitigating fishery losses due to pumped-storage operation. The catch rates were to be maintained by stocking. Further measures involved the establishment of gravel spawning areas and eliminating the potential for stranding fish in depression pools with water-level fluctuations. Summer catch rates at Twin Lakes do not appear to be as consistent as the California case. Year-to-year fluctuations result in a mean of 0.34 fish per man-hour with a coefficient of variation of 21 percent for the study period.

The lake trout fishery is quite minor in terms of fish harvested but provides a unique form of fishing recreation. Depending upon the size-selectivity and magnitude of mortality within the lake trout population as a result of powerplant operation, replacement stocking with fingerling-size fish may not be a satisfactory means of compensation. Lake trout have a slower growth rate than rainbow trout and require 4 years to reach 381 mm (15 in) and 8 years to reach 508 mm (20 in) (Griest, 1976 [22]). Screening of the Mt. Elbert tailrace has been discouraged as an alternative for limiting fish mortality because of installation and maintenance costs (U.S. Fish and Wildlife Service, 1969 [40]). A possible solution to the lake trout problem may be to use screening in the manner of an underwater, bottom-oriented skimmer wall to block the passage of the bottom-oriented lake trout, yet minimize waterflow obstruction.

**Management Implications from the Twin Lakes Studies**

The primary objective of the creel census studies at Twin Lakes was to characterize the fishery with a precision adequate for before-and-after impact analyses concerning the development of pumped-storage power generation. In general, using the various seasonal estimates, this objective has been achieved satisfactorily. The expanding of this application to other Colorado waters appears feasible within these interrelated limitations:

1. The adaptability of creel census techniques to a given body of water to achieve a desired precision,

2. The availability of manpower and funds, and

3. The relative importance attached to a particular fishery.

To some extent, characterization of Colorado fisheries is underway via the statewide creel census program, which is providing background information on the fisheries of a large number of reservoirs and lakes. According to Powell,[2] the precision of the statistics resulting from the program is similar to that for the Twin Lakes data and would be suitable for comparative use in impact analyses. Certain bodies of water, because of their larger size or importance of the fishery, may require more intensive study on an individual basis.

It is evident from Nolting (1968) [41] that the species composition of game fish currently harvested at Twin Lakes is relatively simple in comparison to the fishermen's harvest in the late 1950's. Kokanee salmon constituted a significant portion of the harvest during Nolting's study in 1959, and may have been a result of stocking more than 700 000 salmon in 1955. No stocking level of this magnitude was attempted before or after 1955 (table 1). Adult kokanee

[2] T. G. Powell, Colo. Div. of Wildlife, Fort Collins, personal communication.

salmon should have appeared in the creel census in 1973, 1974, 1977, and 1979. It is apparent that significant reduction of the salmon occurred via escapement, lake trout predation, or unknown mortality. Additionally, the three kokanee salmon observed since 1977 have averaged approximately 305 mm (12 in) in length, demonstrating relatively poor growth under the otherwise favorable conditions of having little competition for food from other salmon. Since the introduction of *Mysis relicta,* Twin Lakes contain few large cladocerans (LaBounty et al., 1980 [42]). This lack of a suitable food source for the salmon may have contributed to their poor survival or growth. From electrofishing samples, brown trout do not appear abundant, but seem to exist in greater numbers than indicated by the fishermen's harvest in recent years. Cutthroat trout planted in 1974 were never observed in Twin Lakes during the study.

Reduction in the stocking levels of the creel-size rainbow trout had the favorable result of increasing the percent return of these fish to the fishermen. Too few years' data exist to examine the correlation between different stocking levels and catch rates, but it appears that the stocking level at the lower lake achieved the best seasonal catch rate and harvest in 1975. Assuming that 85 percent of the 1975 harvest was comprised of fish stocked that year in the lower lake (based on 1977-79 data), a 53-percent return may have resulted. For the upper lake, a stocking level somewhere between the 1975 and 1977 levels would appear to result in the best catch rate and harvest. Returns of the stocked rainbow trout varied inversely with the stocking level, thus large numbers of the creel-size rainbow trout stocked before 1974 were wasted. It may be possible to "fine tune" stocking numbers and schedules at Twin Lakes to achieve higher returns relative to fluctuating fishermen effort within a season. In this case, peak fishermen effort usually occurred in July or August. Using the 2-week stocking schedule, larger plants of fish may be made during these known periods of high effort and possibly achieve a better return. This synchronization of stocking with fishermen effort may also increase catch rates.

Inference may be made from the results of this study that the lake trout population in general and the quality-size fish in particular are in a state of decline. As stated by Grosslein (1962) [30] and Regier (1966) [35], problems occur in making reliable inferences about fish population dynamics from creel census data. This is applicable to Twin Lakes since the lake trout are a minor dimension relative to the magnitude of the summer harvests and the winter fishery estimates of fishermen effort have been declining. Reduced fishermen expertise in catching large lake trout and lower vulnerability of these fish to angling may be factors. The status of the lake trout population over the 1973-79 period will be examined in a later report.

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