AN ABSTRACT OF THE THESIS OF

DAVID THOMAS VINCENT for the M. S.
(Name of student) (Degree)

in Fisheries presented on April 29, 1968
(Major) (Date)

Title: THE INFLUENCE OF SOME ENVIRONMENTAL FACTORS ON THE DISTRIBUTION OF FISHES IN UPPER KLAMATH LAKE

Abstract approved: [redacted]
C. E. Bond

The fishes of Upper Klamath Lake appeared to distribute themselves in three general groups during the summers of 1964 and 1965: (1) the chubs--unrestricted as to distribution with slight seasonal variations; (2) rainbow trout and yellow perch--restricted to certain water conditions that exist only along the northern marsh and spring areas of the lake; (3) the brown bullhead and sculpins--and possibly suckers--partially restricted by water conditions and shoreline habitat. The limnological conditions favorable for the above distributions prevail from May until early October at which time the water temperature, nuisance algal populations and pH values are all decreasing, creating favorable conditions for all previously restricted species throughout the entire lake.

The Influence of Some Environmental Factors on the Distribution of Fishes in Upper Klamath Lake

by

David Thomas Vincent

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1968

APPROVED:

[redacted]

Professor of Fisheries
in charge of major

[redacted]

Head of Department of Fisheries and Wildlife

[redacted]

Dean of Graduate School

Date thesis is presented April 29, 1968

Typed by Opal Grossnicklaus for David Thomas Vincent

ACKNOWLEDGMENT

Sincere appreciation is expressed to my major professor, Dr. C. E. Bond, for his guidance and critical assistance during this study.

I am grateful for the dedicated assistance provided by Mr. Donald Hummel in collection of the field data, and to Mr. Charles Hazel for the many helpful suggestions he made throughout the study.

Appreciation is also expressed to Mr. Leroy Fisk of Oregon Technical Institute at Klamath Falls for providing Laboratory facilities and equipment during this study.

I am extremely indebted to my wife, Jeanie, for her patience during the study and for her assistance in the preparation of the manuscript.

I wish to thank the Water Supply and Pollution Control Program (formerly of the U. S. Public Health Service, now of the Federal Water Pollution Control Administration, Grant No. WP-00625) for providing the funds to make this study possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

THE INFLUENCE OF SOME ENVIRONMENTAL FACTORS ON THE DISTRIBUTION OF FISHES IN UPPER KLAMATH LAKE

INTRODUCTION

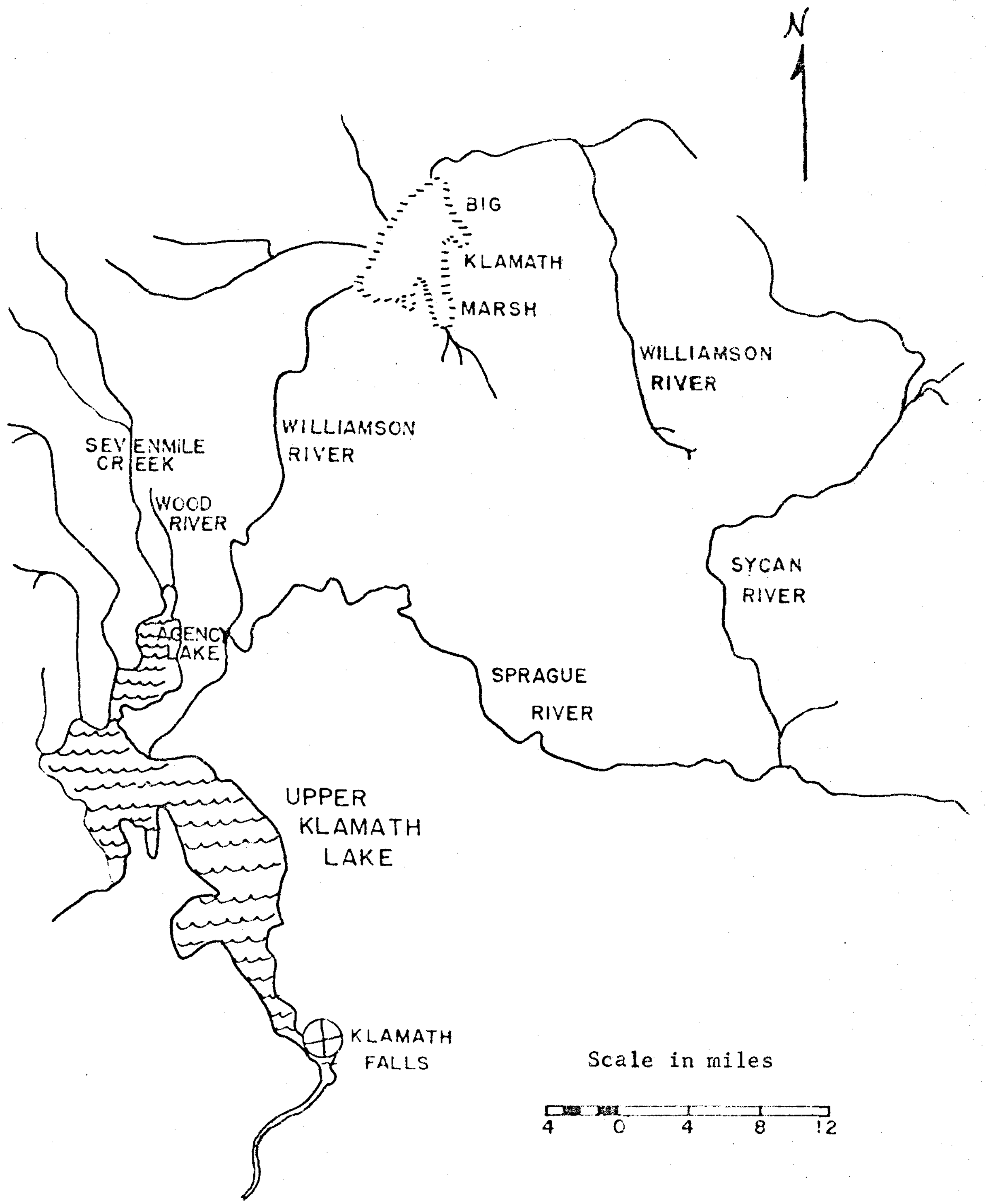
This study of Upper Klamath Lake was conducted during June 1964 to December 1965. The objectives were to determine the geographical and seasonal distribution of fish species as influenced by environmental factors. Interest was directed to the problem because of the possible relationship of abundant blue-green algae and the distribution of fishes in the lake. Support was derived from grant No. WP-00625 from the U. S. Public Health Service.

Upper Klamath Lake is in an advanced state of eutrophication essentially because of natural enrichment. Phinney and Peek (1961) reported that algal populations have been of concern for at least 60 years and that during the six month growing period (May through October of 1965) exportation through the outlet, Link River, of naturally produced organic material was estimated to be in excess of 7, 000 tons with counts of the total phytoplankton as high as 196, 360 cells per milliliter. Of the 29 species of algae in the lake, six species tend to dominate with some seasonal regularity (Phinney and Peek, 1961). Four species of Cyanophyta (*Aphanizomenon* sp., *Microcystis aeruginosa*, *Gloeotrichia echinulata*, *Anabanena circinalis*), and two species of Chrysophyta (*Asterionella formosa* and *Melosira* sp.) comprise the problem forms. *Aphanizomenon* is dominant in the summer bloom while the two species of diatoms dominate during the fall. During the summer months the lake is unsightly and has an offensive odor. Staining of skin, clothes, boats and motors, "tainting" of fish flesh, and fish kills are some of the more common effects of the nuisance blue-green algae.

Location and Physical Characteristics of Study Area

Upper Klamath Lake is located in South Central Oregon, at the base of the eastern slope of the Cascade Mountains, at an altitude of 4,139 feet, northwest of the city of Klamath Falls. The axis of the lake lies in a northwest-southeast direction in the western portion of the Upper Klamath Basin, and drains an area, mainly north and east of the lake, of approximately 3,800 square miles (Figure 1). The basin, part of the semi-arid region of the Northern Great Basin Desert, has an annual precipitation of eight to ten inches and an extremely wide daily and seasonal temperature fluctuation.

The lake lies in a transitional area typified by the vegetational differences in the eastern and western shores of the lake. The western shore is heavily forested with conifers and dense undergrowth, while the eastern shore is barren except for scattered patches of vegetation. The northern shore is mostly marshland, consisting of sedges and rushes with some diked and reclaimed farmland. The



MAP OF THE UPPER KLAMATH RIVER BASIN

Figure 1.

southern end of the lake tapers to the natural outlet, Link River, which has a mean flow of 500 cubic feet per second. Approximately one-third of this flow is diverted for hydroelectric use. The major inlet to Upper Klamath Lake is the Williamson River, however, Wood River and Seven Mile Creek and numerous smaller springs and streams enter Agency Lake which is north of Upper Klamath Lake and connected to it by the Agency Lake Straits. Consequently, all streams that enter Agency Lake can be considered as inlets to Upper Klamath Lake. The major morphometric features of Upper Klamath and Agency lakes, along with the study zones in Upper Klamath Lake are summarized in Table 1.

Upper Klamath Lake was developed into a source of irrigation water by a dam which provides an active storage capacity in Upper Klamath Lake and Agency Lake of 483,000 acre-feet, and a canal (Canal "A") that begins one-fourth mile downstream from the lake and has a mean flow of 1,000 ft^3/sec. A fish ladder at the dam is used in the late fall and early spring by some rainbow trout (*Salmo gairdneri*) and suckers (*Catostomus* sp.). Some cyprinids may also use the facility.

Biological Characteristics

Emergent aquatic vegetation ("wocus," *Nuphar polysepalum* and American Great Bullrush or "tule," *Scirpus validus*) lines most

Table 1. Major morphometric features of Upper Klamath and Agency Lakes, Oregon.

	Upper Klamath Lake	Agency Lake	Study zones in Upper Klamath Lake		
			I	II	III
Total length (miles)	22.0	6.0	6.1	11.0	5.0
Mean width (miles)	4.0	2.6	1.8	4.0	6.0
Surface area (sq. miles)	88	15.6	11.0	44.0	30
Maximum depth (feet)	58	15	17	58	20
Mean depth (feet)	9	7	8	17	7
Length of shoreline (miles)					
Rock	44.7	4.0	12.2	24.5	8.0
Marsh	12.0	9.5	1.0	3.5	7.5
Other (Levee)	10.2	5.5	1.0	5.0	4.2

of the shoreline of Upper Klamath Lake while submergent vegetation (mostly Potamogeton spp.) is confined mainly to the shallower areas of the bays and to the northern and southern ends of the lake.

Early work on benthos of Klamath Lake was done by Jewett (1938) who studied problems resulting from high midge populations in the lake. The benthic fauna is rich and varied, and is presently under study by C. R. Hazel of California Department of Fish and Game.

There is an abundant zooplankton fauna including several common genera such as Daphnia, Bosmina and Cyclops. Zooplankton collections were taken intermittently throughout the study for later analysis by Mr. C. R. Hazel and Dr. J. Tash of the Federal Water Pollution Control Administration.

A study of the phytoplankton problems of Upper Klamath Lake was initiated in 1955 (Phinney, Peek and Mclachlan, 1959, 1961), and they present a comprehensive list of the species encountered during their study.

Several early ichthyologists, Cope (1879, 1883), Gilbert (1898), Snyder (1908a and 1908b), and Evermann and Meek (1898) gave attention to the fishes of the Klamath region and described many of the species found in the basin.

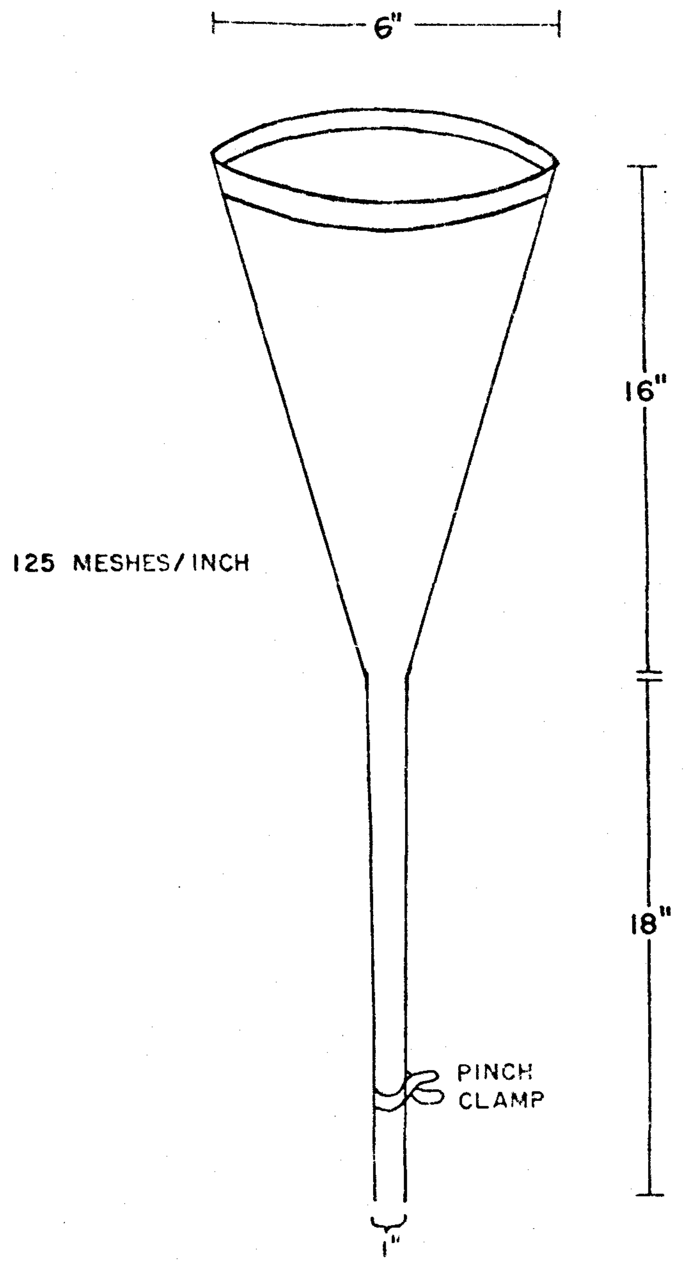
Miller (1946) stated that the fish fauna of the Klamath Basin approaches the richness and distinctness of the Columbia, Sacramento and Colorado systems. Hubbs and Miller (1948) placed great paleoichthyological and zoogeographical significance on the Klamath Basin fish fauna because of its geological history.

METHODS AND PROCEDURES

Limnology

Limnological samples were taken at the time gill-nets were placed and again when removed. Surface and bottom temperatures were recorded by the use of a transistorized or a mercury thermometer, and a Kemmerer water bottle was utilized to collect surface and bottom-water samples. The Winkler method was used to determine dissolved oxygen concentration, and a portable pH meter was used to measure pH. Total alkalinity at the surface was determined by the methyl orange indicator method.

Abundance of net plankton was determined by the use of a six-inch (diameter) cone-shaped plankton net (125 mesh/inch) with a tube of the same material, one inch in diameter sewn on the end of the net (Figure 2). The net was pulled ten feet as near vertically as possible, removed, and after draining approximately 30 to 45 seconds, the tube was laid on a flat surface so that the contents spread to about one-eighth inch in thickness. Then the length to which the plankton filled the tube was measured to the nearest one-fourth inch. Results by this method were confirmed by comparison of measured length of plankton in the tube with dry weight of that plankton. Figure 3 shows the close relationship.



PLANKTON TOW DESIGN

FOR SAMPLING ABUNDANCE OF PLANKTON

Figure 2.

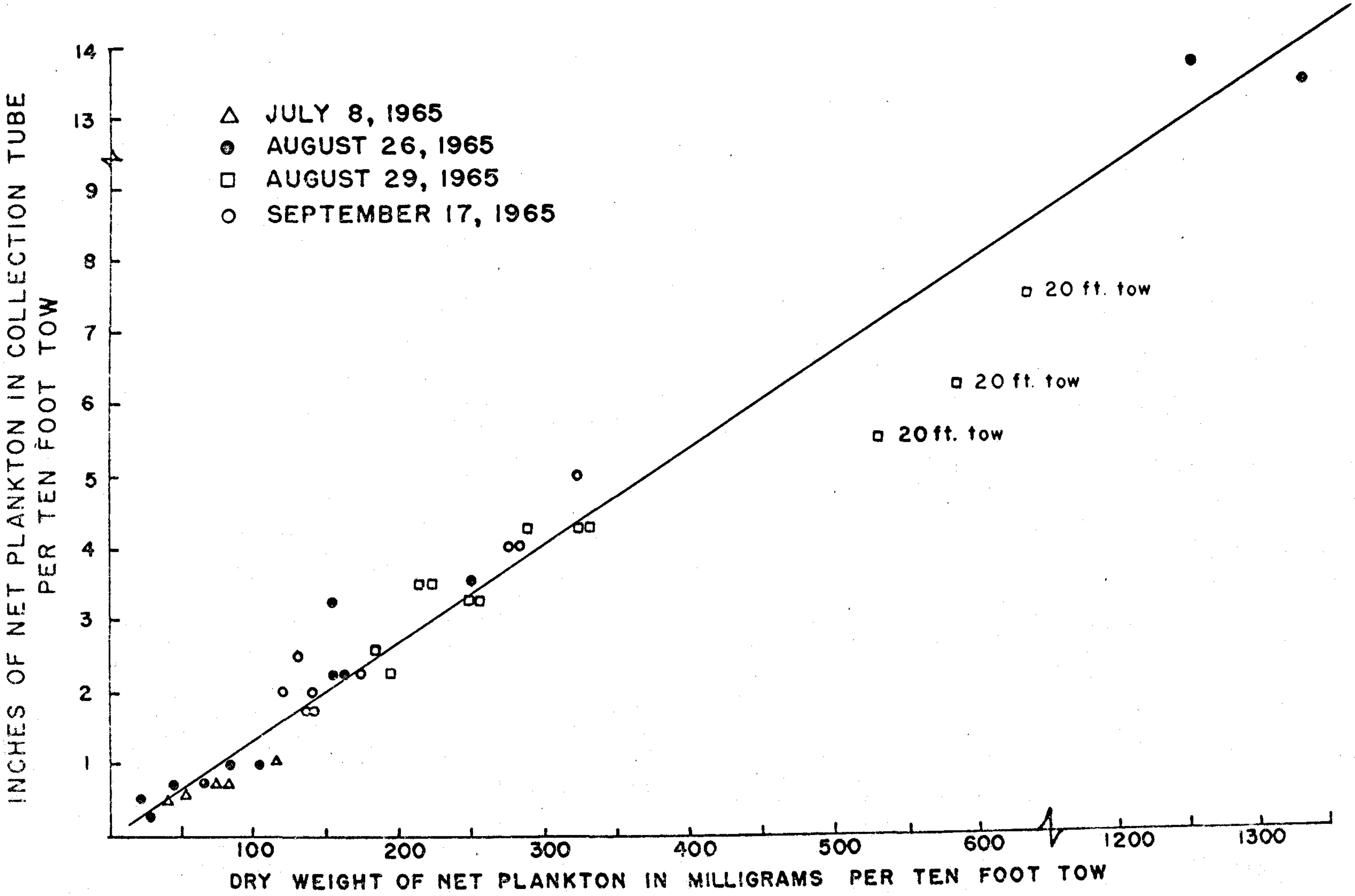


Figure 3. Calibration curve for the net plankton collection device.

On calm days, light penetration was measured at the surface and at three feet by means of a Kahl Scientific photometer. Secchi disc readings were taken routinely.

Fish Distribution

Gill nets and hoop nets were used in an exploratory survey of fish distribution in 1964. Possible seasonal and spatial differences in distribution were indicated by the preliminary investigation. Consequently, a gillnet sampling program, randomized in relation to three shoreline habitats, away from the direct influence of incoming waters, was developed for use in 1965. Fish, and basic limnological conditions, were sampled monthly (excluding October) throughout the summer and fall.

Fish sampling utilized two sets of nets, and the results of each set in a zone were added and treated as one unit for analyis. All fish were removed from the gill nets as the nets were brought into the boat. The numbers of fish in each type of net and mesh size in which they were caught were recorded. In order to compare magnitudes of monthly catches these data were converted to percentage of the catch for each zone during a particular month of sampling. Percentages were used in place of fish per hour for comparison among the different sampling periods in order to minimize sampling bias due to possible extraneous influences on the activity of the fish.

Each set of nets consisted of one 7 × 100-foot floating gill net; one 5 × 50-foot floating gill net; one 7 × 100-foot diving gill-net and one 5-foot circular hoop-net. Stretched mesh sizes were 1 1/4, 1 3/4, 2 1/4 and 6 inches for the five-panel diving gill nets.

To minimize sampling error a definite pattern was followed for placement of nets (Figure 4). The 50-foot floating gill net (net #1) was set parallel to and 10 and 15 yards offshore; the 100-foot floating gill net (net #2) was set perpendicular to the shore beginning not more than five yards from the water's edge; the 100-foot diving gill net (net #3) was set perpendicular to shore in line with net #2. The hoop-net was set parallel to and in most cases within ten yards of the shoreline. The above pattern was followed regardless of the shoreline habitat sampled.

<u>Rocky Shoreline</u>

Using information obtained during the preliminary investigations in 1964 as a basis, the lake was divided into three sampling zones: (I--south end; II--middle; III--north end). By dividing each zone into three parts and then drawing an imaginary line northwest to southeast through the middle of the lake, each zone was divided into six near-equal areas. A number (one through six) was assigned to each area (odd numbers on the westerly areas) beginning at the south end of each zone. Each of the six areas was subdivided again

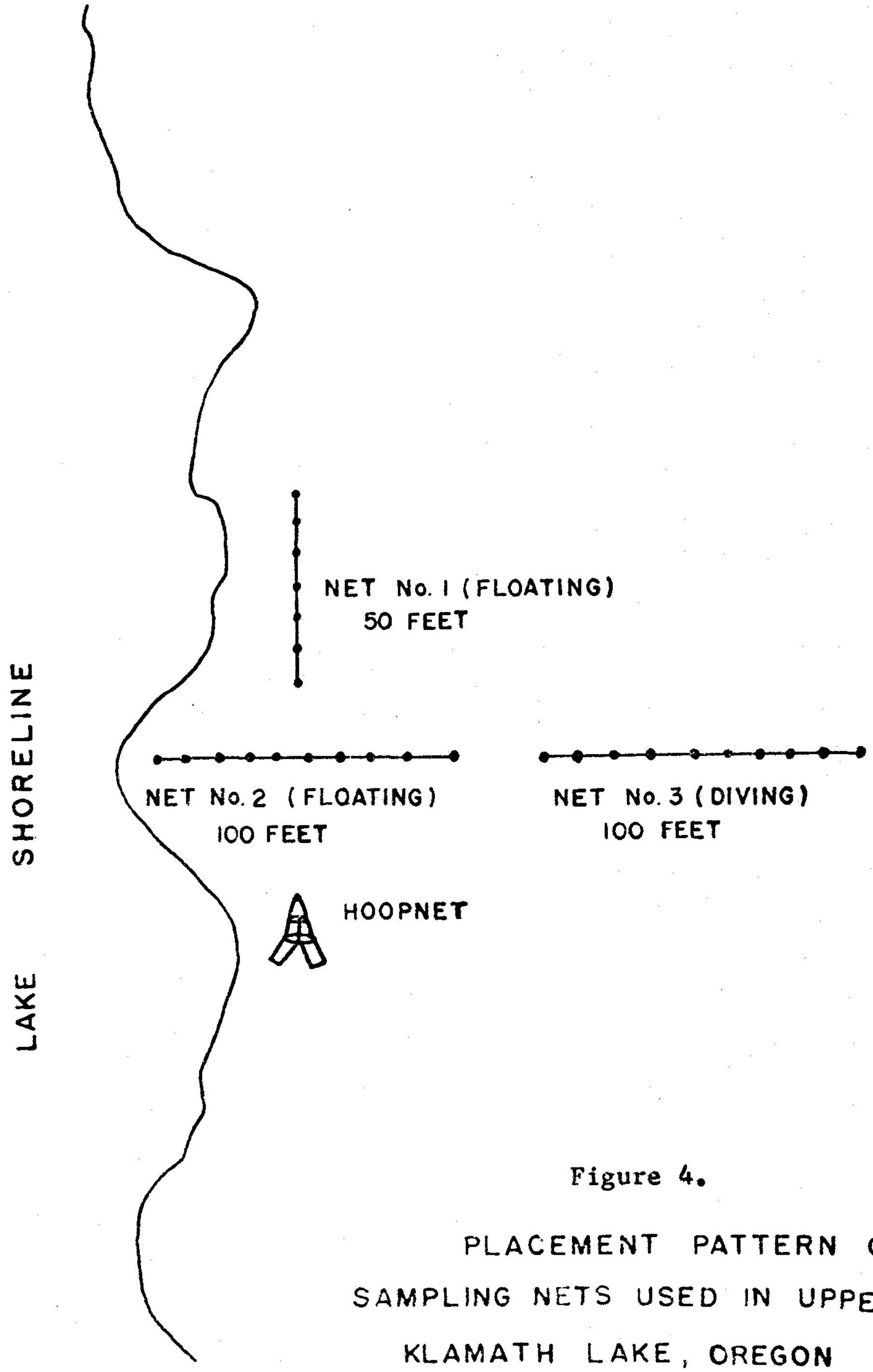


Figure 4.

PLACEMENT PATTERN OF SAMPLING NETS USED IN UPPER KLAMATH LAKE, OREGON into three sections of equal length, in relation to shoreline length, and assigned the letter a, b, or c starting at the south end of each zone and proceeding northwesterly along each shoreline (Figure 5).

To determine where the two sets of nets would be placed in each zone during the sampling period, a die was rolled twice for the placement of each set; the first number determined the area (one through six); the second established the section (numbers on the die were assigned so they could be interpreted as a, b, or c; e.g. one or two as a; three or four as b; five or six as c). After the die was rolled twice an example of the result or the area and section placement of the set would be as follows: I - (zone), 4 - (area), c - (section). If the number on the die duplicated a section or indicated an area not having a rocky shoreline, the number was rejected and the die rolled again. Sampling started in Zone I and proceeded to Zones II and III and then returned to Zone I. In this manner three cycles of samples were established for each nine-day sampling period.

Marsh Shoreline

Four marsh shoreline areas were selected for sampling in July, September and November of 1965 (Figure 6). The procedure was virtually the same in determining placement of the two sets of nets as for the rocky shoreline. The marsh areas were divided

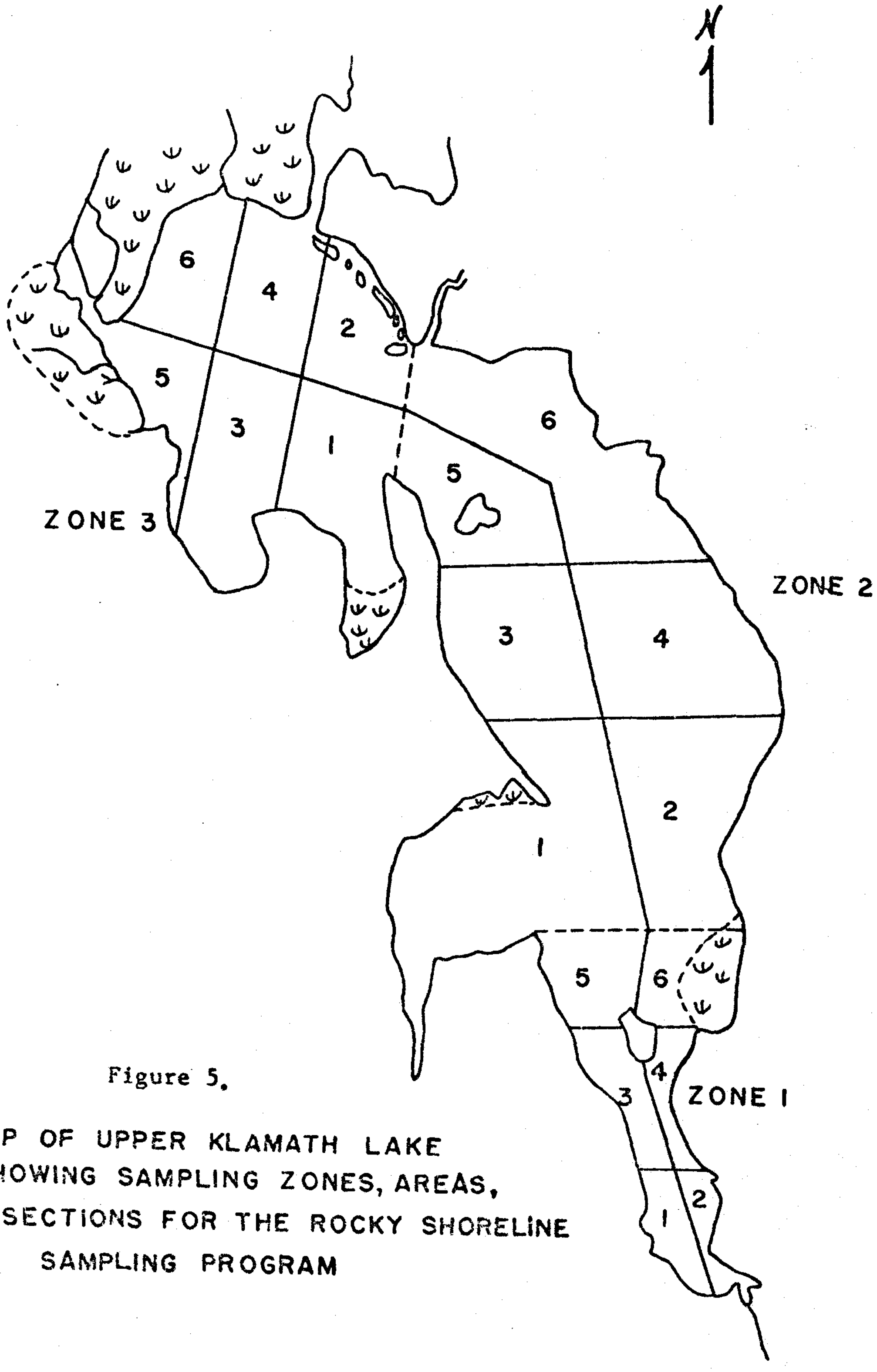


Figure 5.

MAP OF UPPER KLAMATH LAKE SHOWING SAMPLING ZONES, AREAS, SECTIONS FOR THE ROCKY SHORELINE SAMPLING PROGRAM

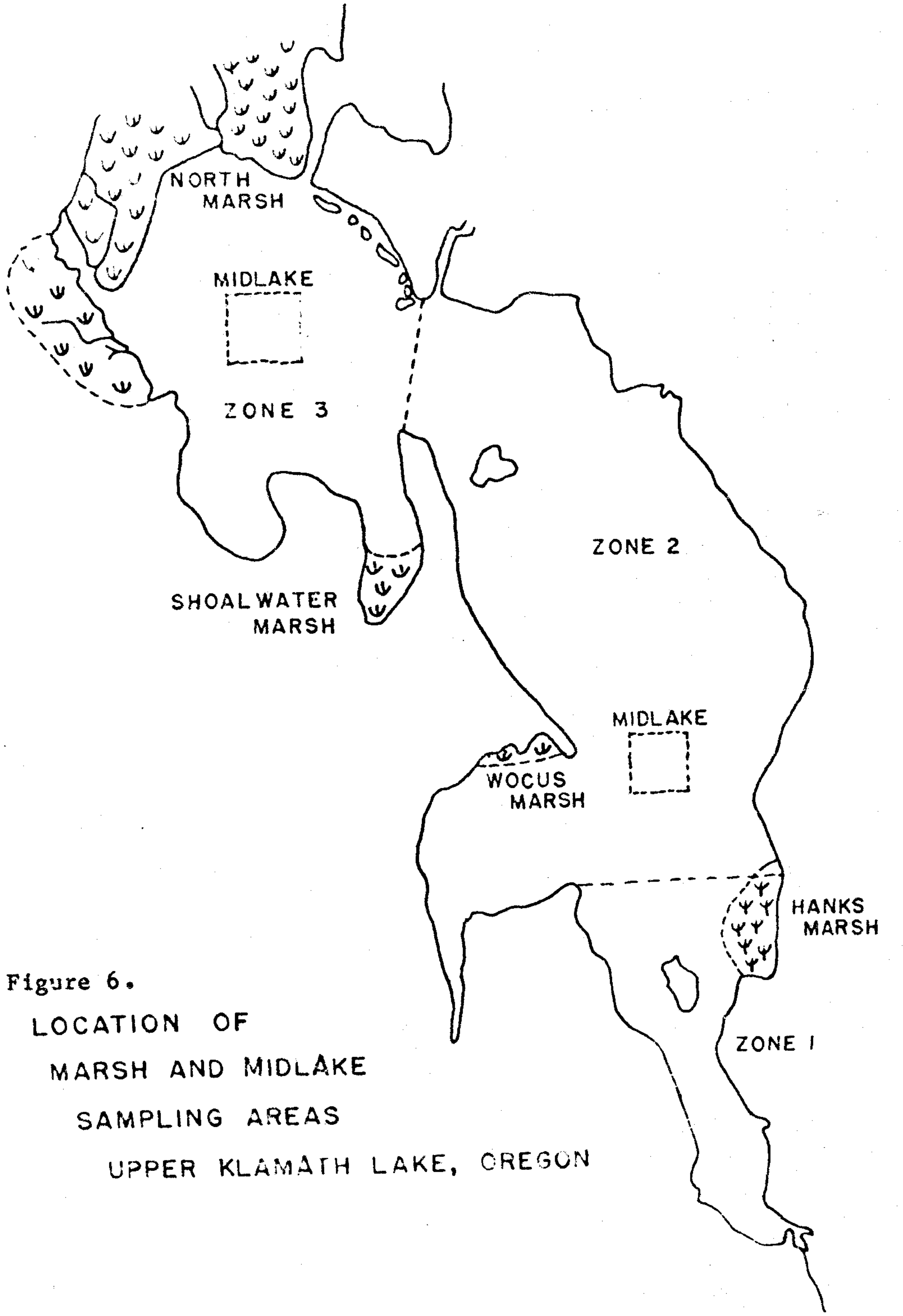


Figure 6.
LOCATION OF
MARSH AND MIDLAKE
SAMPLING AREAS
UPPER KLAMATH LAKE, OREGON

in half, in relation to shoreline length, and each half was designated a or b. In order to randomize the sampling, numbers on the die were assigned to be interpreted as a or b and the die was rolled only once to determine in which section the nets would be placed. On the first and third days of the four day sampling period, one set of nets was placed in each of the southern marsh areas (Hanks and Wocus marshes); then on the second and fourth days the nets were moved to the sections of the two northern marshes (Shoalwater and North marshes) as determined by the roll of the die.

Midlake

Areas in the middle of the lake within Zones II and III (Figure 6) were selected for sampling of fish away from the influence of the shoreline. One set of nets was placed in each area simultaneously. Nets were fished and replaced each day for the four-day sampling period in August and the two-day sampling period in September. The lake surface froze early in December before another sample could be taken.

Statistical Procedures

Environmental factors were measured when the nets were placed into the water and again when they were removed. Consequently, two sets of data required analysis in order to determine any possible effect on the distribution of fishes.

A correlation matrix, utilizing 31 variables, was designed to run on an IBM 1410 computer. Results indicated that still further elimination of variables was necessary, consequently a step-wise regression analysis was utilized to narrow the number of variables to about ten.

A step-wise regression analysis is an extension of the correlated variation principle as discussed by Overton and Florshutz (1962) in which they state:

> It is then a simple extension of these ideas (correlated variation) to examine the variability left in Y after accounting for that associated with X_1 (variable one), to see if any of this remaining variation can be associated with a second variable, X_2.

In this manner all measured variables were taken into analysis according to its contribution to the variation of Y (F value). The results were then printed in a ranked descending order of contributing variables.

RESULTS

Limnology

Limnological data gathered during this study indicates that distinct water masses undoubtedly exist in this large eutrophic lake as a result of wind action and currents involved with incoming waters through the North Marsh area and the Williamson River. Surface temperatures, plotted by zone for each month sampled, indicate the "trapping" of water in the shallow northern end (Zone III) of the lake and its subsequent warming during August and September (Figure 7). In November, however, temperatures in Zone III were slightly cooler than in Zones I and II probably because of warming as the water moves toward Zone I and the outlet. The extreme temperature variation during the July sampling period as well as the wide variation in total alkalinity and pH values indicate (1) varying degrees of bloom development throughout the lake, and (2) the possible movement of water masses through the lake. Surface pH values up to 10.0 were recorded during August, 1965, reflecting a high rate of photosynthetic activity. Figures 8, 9, and 10 geographically summarize these data along with total alkalinity and dissolved oxygen for a particular zone for each month sampled.

Net plankton tow results, as shown in Figure 11, indicate a definite increase in the abundance of net plankton as the season

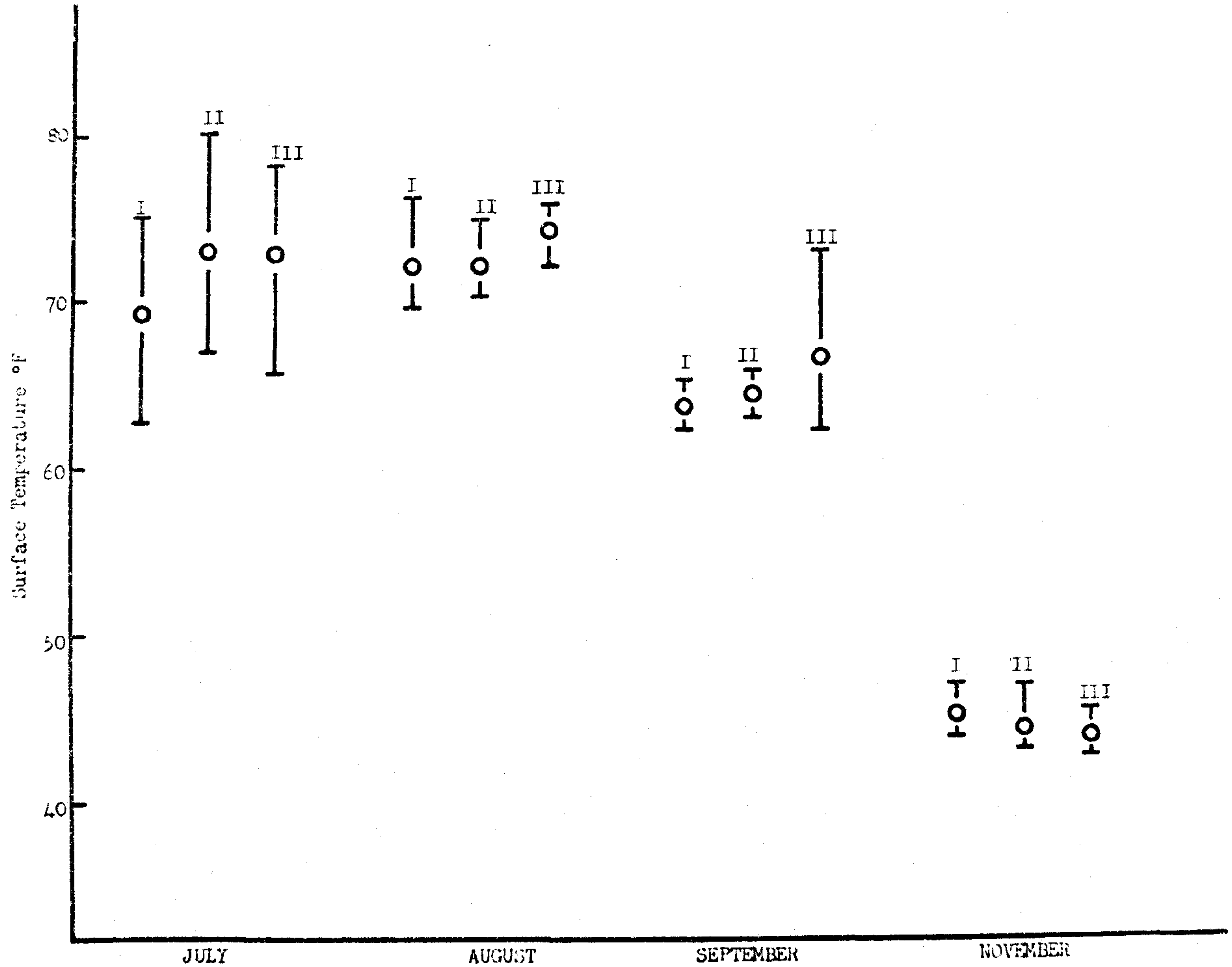


Figure 7. Range and mean surface temperatures, by zone, for July, August, September and November, 1965, Upper Klamath Lake, Oregon.

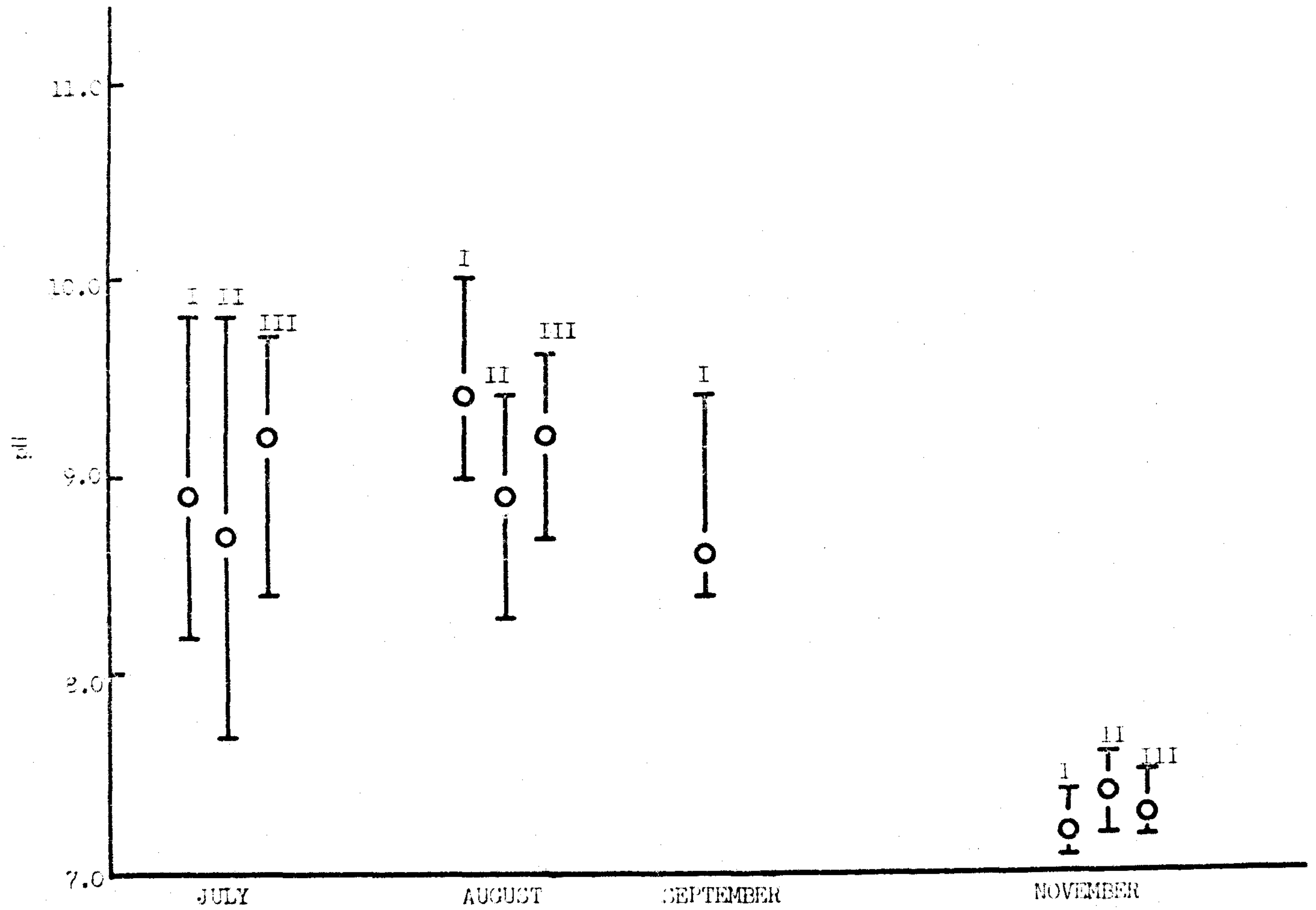


Figure 8. Range and mean pH values, by zone, for July, August, September and November, 1965, Upper Klamath Lake, Oregon.

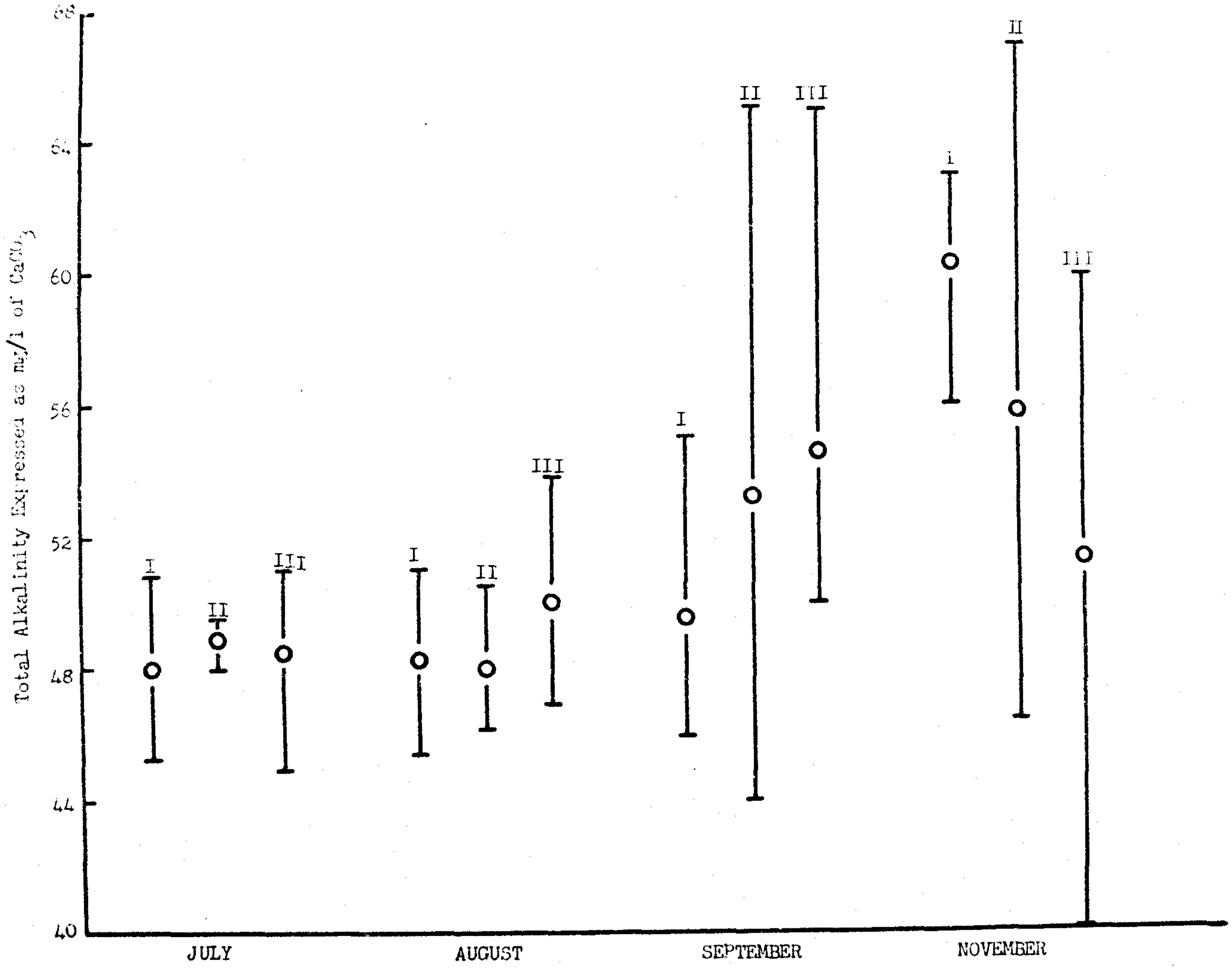


Figure 9. The range and mean of total alkalinity expressed as mg/l of $CaCO_3$, by zone, for the months of July, August, September, and November 1965, Upper Klamath Lake, Oregon.

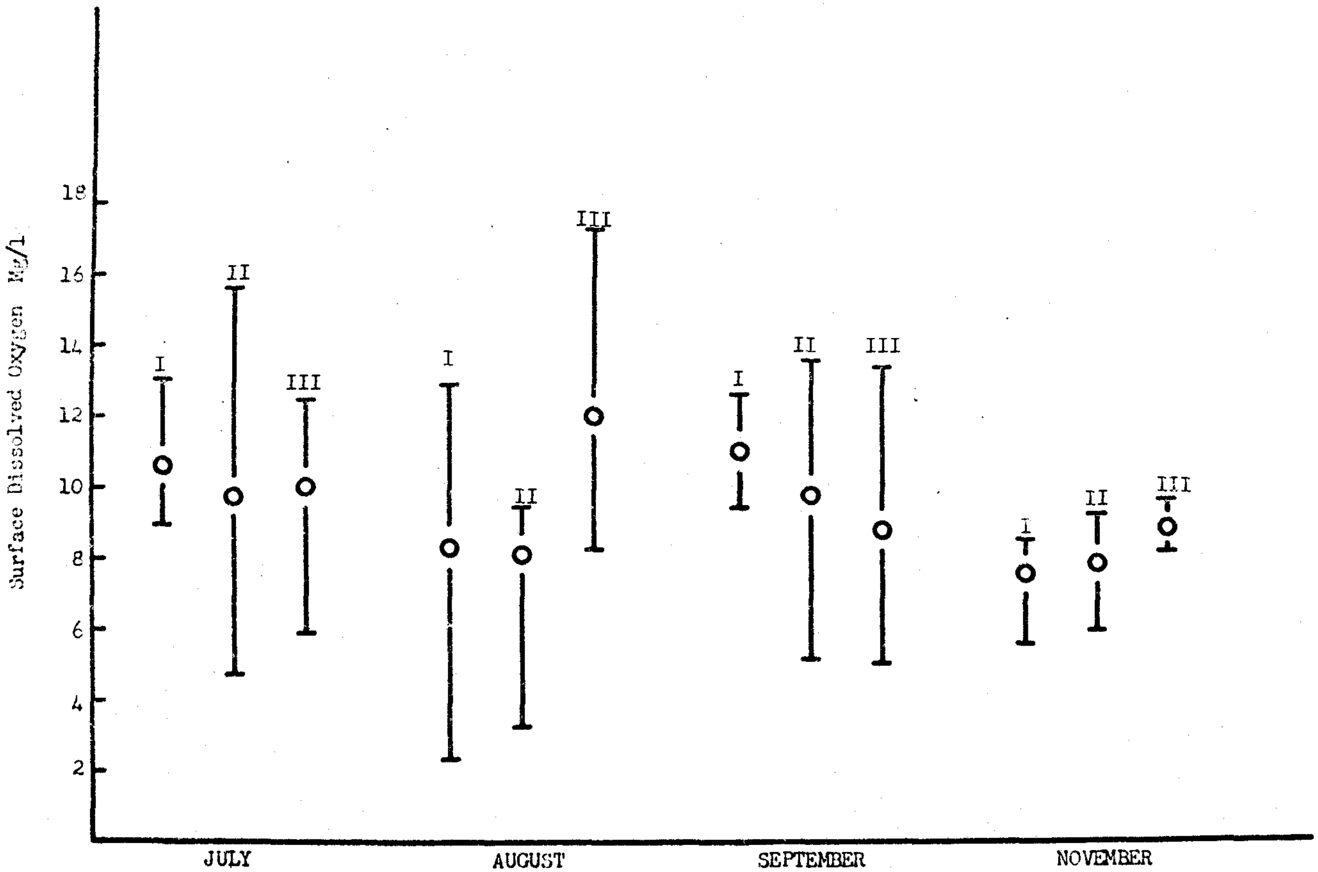


Figure 10. Range and mean surface dissolved oxygen concentrations, by zone, for July, August, September and November 1965, Upper Klamath Lake, Oregon.

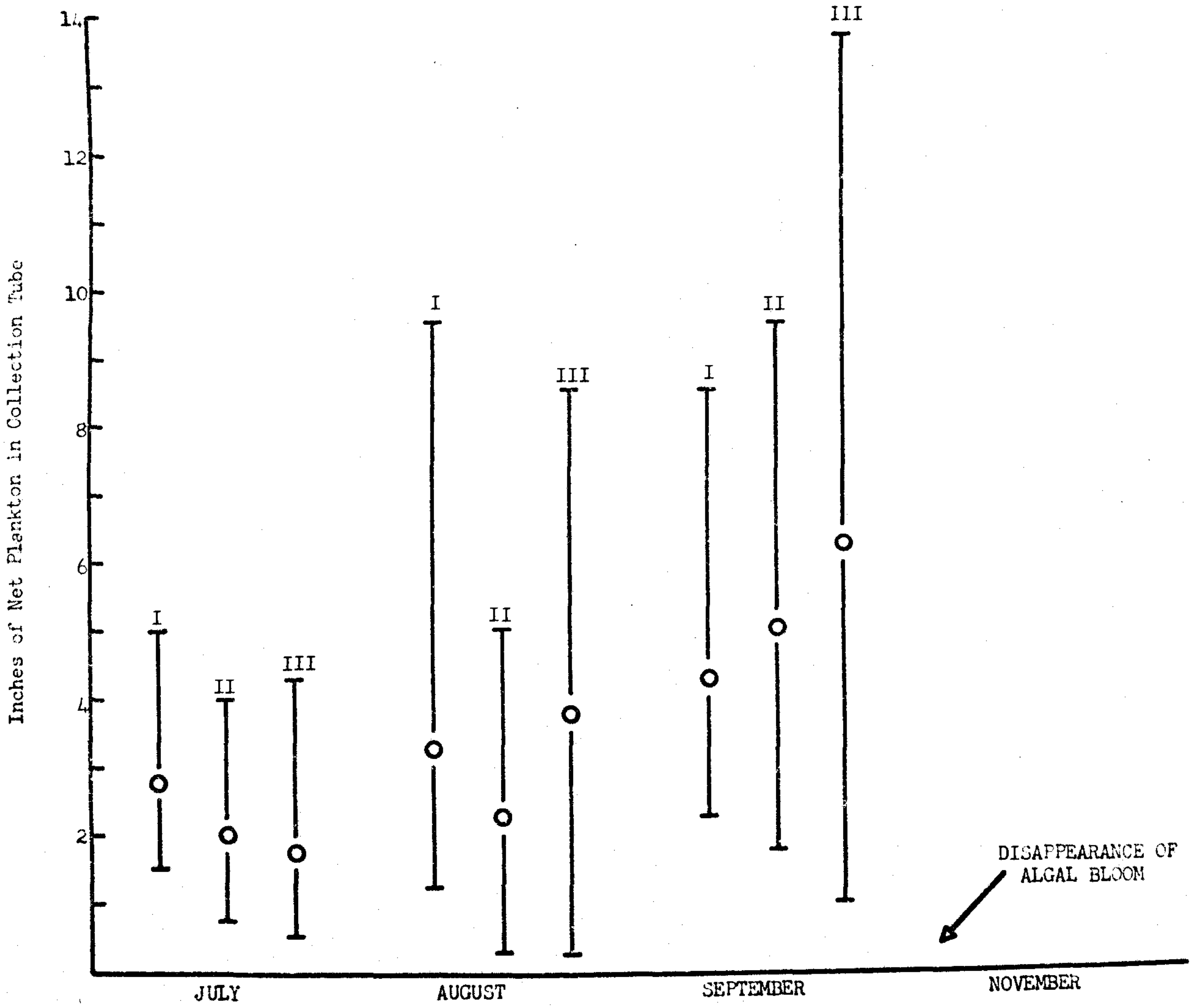


Figure 11. The range and mean inches of net plankton in the collection tube, by zone, for July, August, September and November 1965, Upper Klamath Lake.

progresses until die-off of the bluegreens in November. After this time plankton was not measurable by the aforementioned methods of collection; consequently, net plankton was considered as zero and no further measurements were taken.

Temperatures fluctuate seasonally from 32° F with ice cover in mid-December to 80° F during the summer, with an average of 72° F during July and August (Figure 7). Thermal stratification does not occur in Upper Klamath Lake for any extended periods of time because of prevailing northwest winds and its shallow depth. Stratification possibly occurs on windless days but is quickly broken down by wind action.

Periodic diel measurements of dissolved oxygen indicated that oxygen never dropped below five mg/l, at least in the areas measured; however, Wocus Bay and the Shoalwater Marsh area were anoxic for two months during the summer of 1965 because of decaying organic matter. In these areas the water was brownish red and had a stench similar to "pig pen-rotten egg" odors. Over the main body of the lake, however, only two sets were made in areas of less than four mg/l of dissolved oxygen while the remainder were set in saturated or supersaturated water up to 17 mg/l.

Light penetration measurements were taken as weather permitted and the data are plotted in Figure 12 against the abundance of net plankton. The graph shows indirect relationship between net

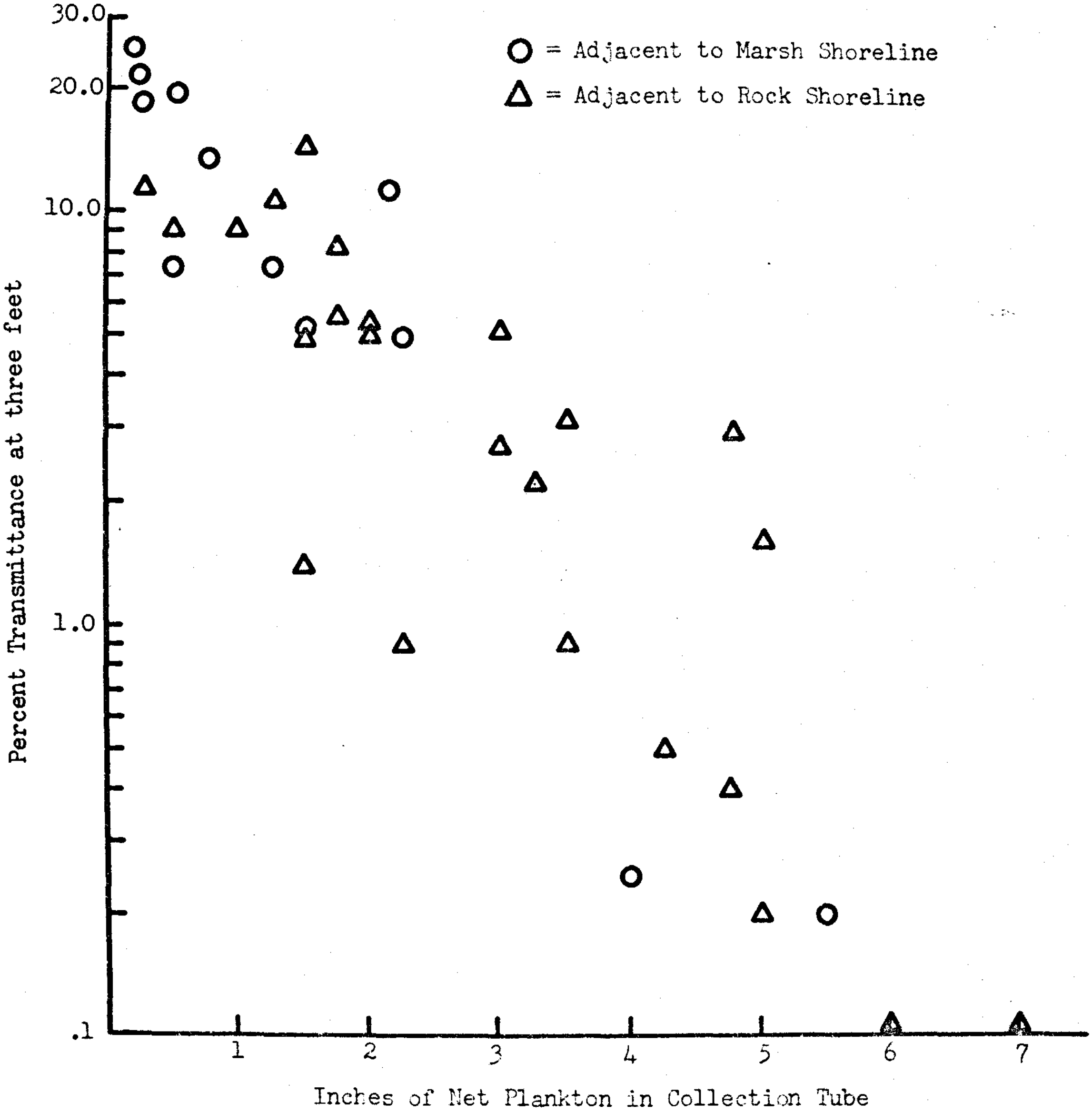


Figure 12. The relationship of light penetration at three feet and inches of net plankton in the collection tube.

plankton abundance and the percentage of light transmitted to three feet.

Fish Distribution

Species Composition

During the exploratory survey of 1964 (July 9 through December 27) 9,561 fish were caught in 392 individual net sets (average 22 hours per set for a total of 8,624 hours) on 60 fishing days. The major results obtained from this preliminary investgation were: (1) seasonal movements of rainbow trout (Salmo gairdneri), yellow perch (Perca flavescens), and brown bullheads (Ictalurus nebulosus) existed (Table 2); (2) that incoming waters from springs and streams might influence the distribution of fishes (Table 3); (3) that some fishes such as the tui chub (Siphatetes bicolor) and brown bullhead "preferred" bays to the open lake (Table 4); (4) that a differential picture of relative distribution and abundance of fishes of Klamath Lake could be produced (Figure 13).

During the comprehensive study from June 30, 1965 to December 12, 1965, 446 individual nets fished a total of 9,668 hours (average 20 hours per set) on 58 different days. A total of 24,440 fish was caught including 15 recognizable species in eight different families (Table 5). Several intergrades of the three species of suckers

Table 2. Fish per net set by zones (north, middle, south) and months, Upper Klamath Lake 1964.

	July			August			September		
	North # sets 13	Middle # sets 15	South # sets 4	North # sets 26	Middle # sets 33	South # sets 19	North # sets 28	Middle # sets 20	South # sets 8
	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set
Blue chub	16.2	17.6	14.7	10.4	31.4	10.1	5.0	30.1	8.0
Tui chub	11.2	18.0	14.0	5.1	11.5	9.2	2.8	4.2	6.1
Brown bullhead	2.8	0	0	13.4	0	0	1.9	0.1	0
Yellow perch	0.4	0.3	0	1.7	0	*	0.3	0	0
Sculpins	*	0.1	0.7	0.2	*	0.2	0.1	0.1	0
Trout	0.1	0	0	0	*	0	*	0	0
Lamprey	0	0	0	0	*	0	0	0	0
Pumpkinseed	*	0	0	0.1	*	0	0	0	0
Suckers	0	0	0	0.1	0	*	*	*	0

*less than 0.1
**one brown trout

Table 2. Continued

	October			November			December		
	North # sets 48	Middle # sets 35	South # sets none	North # sets 8	Middle # sets 24	South # sets 24	North # sets 8	Middle # sets 24	South # sets 47
	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set	Avg/ set
Blue chub	8.5	34.8	--	2.6	13.1	8.4	1.0	23.7	9.5
Tui chub	6.3	18.5	--	1.0	7.4	3.6	1.0	4.9	1.8
Brown bullhead	1.3	0.1	--	*	0.1	0	0	0	*
Yellow perch	1.1	1.9	--	0.8	1.0	*	0	*	0
Sculpins	0.1	0.2	--	0.3	0.3	*	0	0.1	0
Trout	*	*	--	0	0.2	0	0**	0.1	0.2
Lamprey	*	0	--	0	0.2	0	0	0	0
Pumpkinseed	0	0	--	0	0.1	0	0	0	*
Suckers	*	0.2	--	0	0.3	0	0.2	*	0

Table 3. Fish captured and number of fish per set in areas under the influence of incoming water and in other areas, Upper Klamath Lake, 1964.

	Incoming water influence (# sets 156)		Other (# sets 141)	
	Avg/set	# Fish	Avg/set	# Fish
Blue chub	14.3	2228	13.8	1952
Tui chub	9.7	1510	6.0	835
Brown bullhead	0.9	142	2.7	377
Yellow perch	1.2	192	0.1	14
Trout	0.2	27	0	0
Sculpins	0.2	25	0.1	17
Pumpkinseed	--	4	--	3
Lamprey	--	3	--	1
Suckers	0.1	23	00	3

Table 4. Fish captured and number of fish per set, open lake compared with bays, Upper Klamath Lake, 1964.

	Open Lake (# sets - 155)		Bay (# sets - 94)	
	Avg/set	# Fish	Avg/set	# Fish
Blue chub	17.8	2614	17.9	1681
Tui chub	5.9	920	12.1	1137
Brown bullhead	0.7	113	4.2	395
Yellow perch	0.2	24	1.5	142
Trout	0.2	23	0.1	15
Sculpins	--	9	0.1	14
Pumpkinseed	0	0	--	6
Lamprey	--	--	--	1
Suckers	0	0	0.1	14

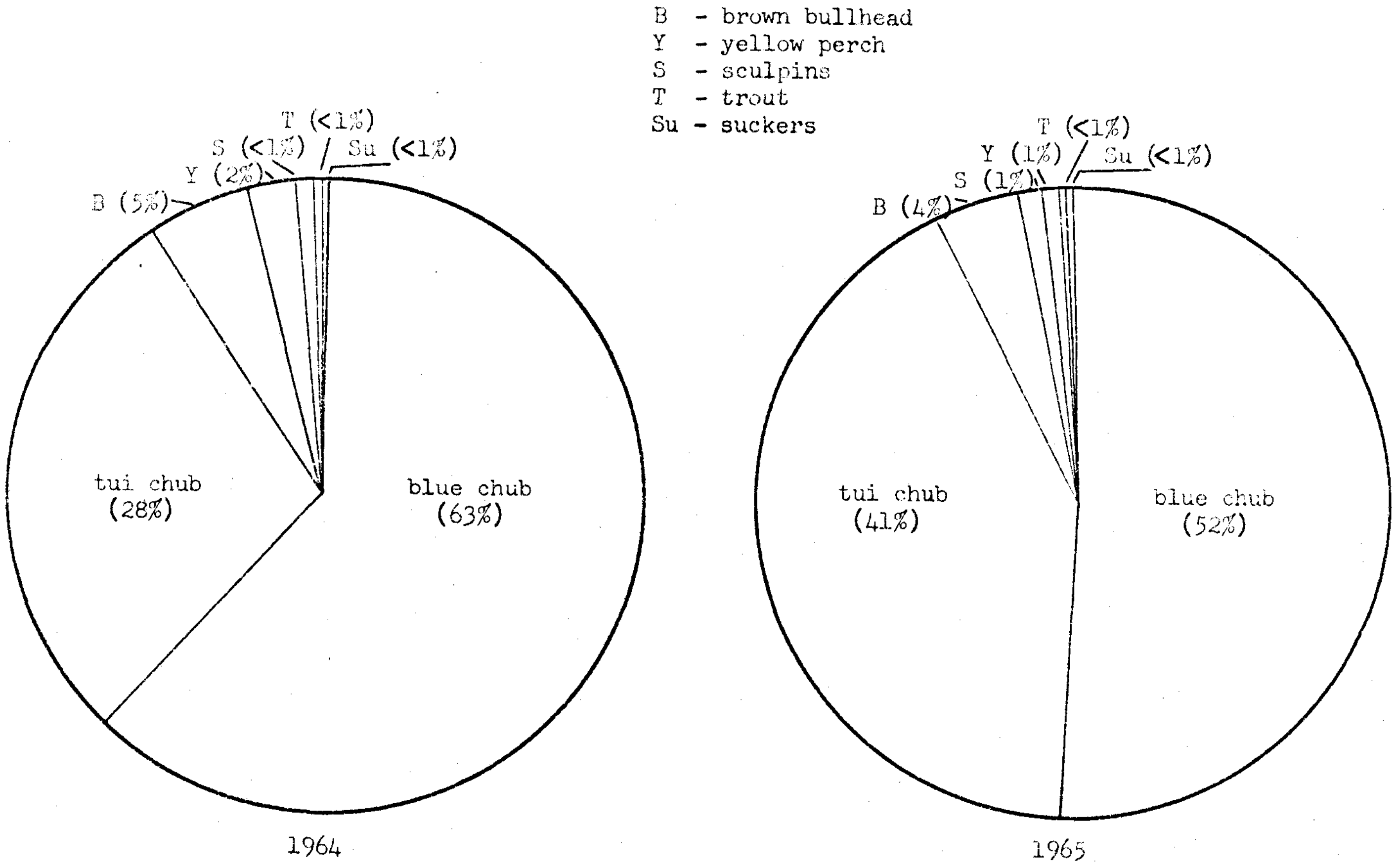


Figure 13: The relative abundance of fishes in Upper Klamath Lake, Oregon, illustrated by percentages by total number of fish caught in 392 net sets in 1964 and 446 net sets in 1965.

Table 5. List of the fishes of Upper Klamath Lake, Oregon caught during the study.[1,2]

Petromyzontidae	
Klamath brook lamprey	*Lampetra* sp.
Pacific lamprey	*Lampetra tridentata* (Gairdner)
Salmonidae	
Rainbow trout	*Salmo gairdneri* Richarson
Brown trout	*Salmo trutta* Linnaeus
Cyprinidae	
Blue chub	*Gila bicolor* (Girard)
Tui chub	*Siphateles bicolor* (Girard)
Catostomidae	
Lost River sucker	*Catostomus luxatus* (Cope)
Klamath largescale sucker	*Catostomus snyderi* Gilber
Ictaluridae	
Brown bullhead	*Ictalurus nebulosus* (LeSueur)
Centrarchidae	
Pumpkinseed	*Lepomis gibbosus* (Linnaeus)
Percidae	
Yellow perch	*Perca flavescens* (Mitchill)
Cottidae	
Marbled sculpin	*Cottus klamathensis* Gilbert
Klamath Lake sculpin	*Cottus princeps* Gilbert
Slender sculpin	*Cottus tenuis* (Evermann and Meek)
Cottus sp.	

---

[1] Shortnose sucker, *Chasmistes brevirostris* Cope, formerly numerous in Upper Klamath Lake (Jordan and Evermann, 1922) was not taken during this study.

[2] Common and scientific names obtained from American Fisheries Society (1960).

were observed along with a possible hybrid sculpin resembling *Cottus princeps*.

The relative abundance of each species or families, was similar to that of 1964 except for the yellow perch and sculpins which reversed positions in 1965 (Figure 13). The blue chub (*Gila bicolor*) and tui chub comprised 93% of the total catch while the other 13 species contributed only 7%.

As the 1964 data implied, the rainbow trout (Figures 14 and 15) displayed a seasonally or spatially regular distribution. To a lesser extent, the brown bullhead (Figures 16 and 17) and the yellow perch (Figures 18 and 19) shows this regularity.

Seasonal distribution is difficult to determine by gillnet data because activity (movement) is required of the fish before it is vulnerable to the nets. If temperature determines the activity of a fish, then the fish would be caught at a different rate each month even though the distribution of the population may not have changed.

Consequently, to compare monthly catches throughout the sampling period a conversion to percentages seemed necessary in order to minimize the bias of activity patterns on fish distribution. Thus, if we let all fish caught in the entire season equal 100%, then by dividing the total fish per hour per month by the total season's catch in fish per hour, the percentage contribution of each month's catch to the total catch is obtained. Likewise the percentage

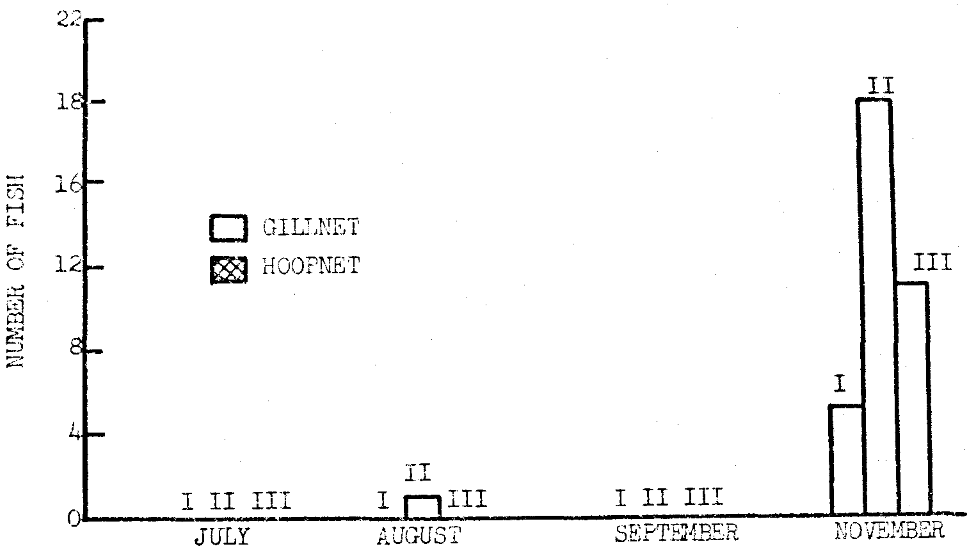


Figure 14. Catch of rainbow trout, Salmo gairdneri, along rock shoreline, Upper Klamath Lake, Oregon, 1965

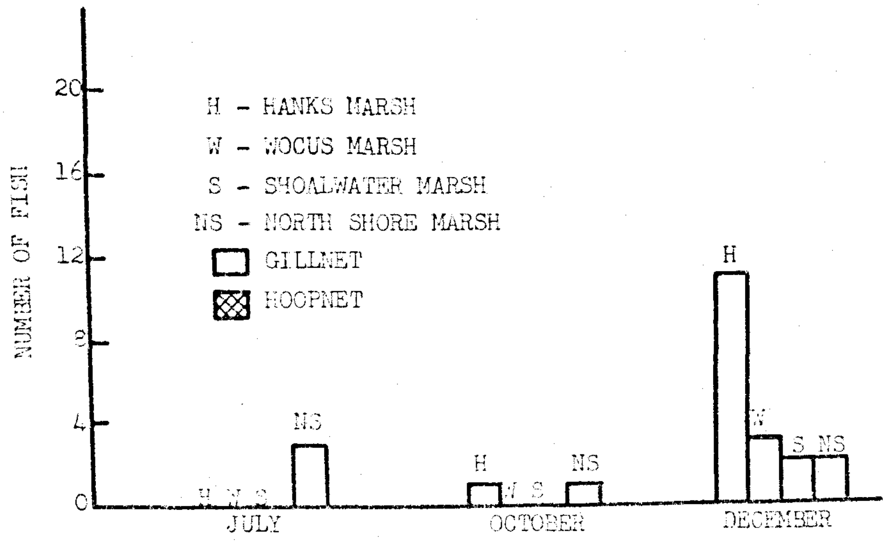


Figure 15. Catch of rainbow trout, Salmo gairdneri, along marsh shoreline, Upper Klamath Lake, Oregon, 1965.

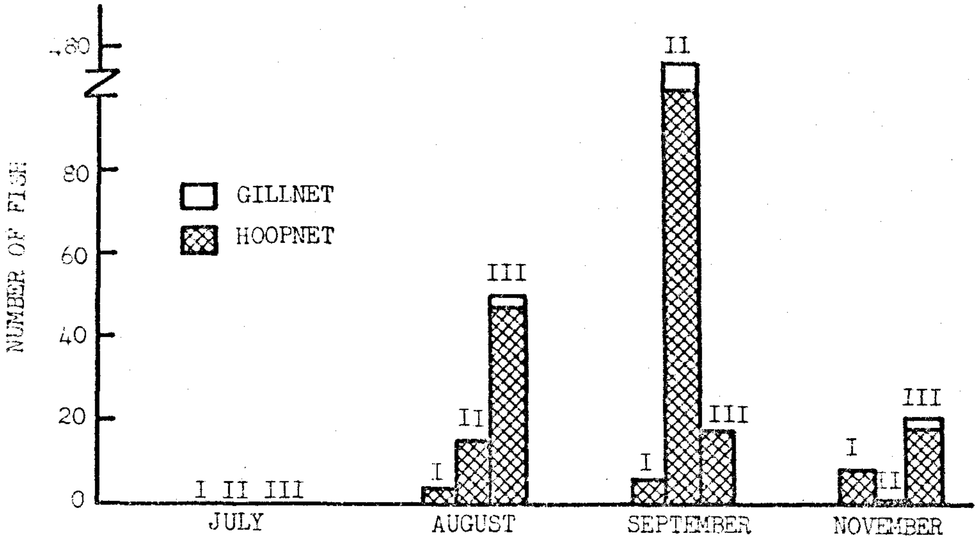


Figure 16. Catch of brown bullheads, Ictalurus nebulosus, along rock shoreline, Upper Klamath Lake, 1965.

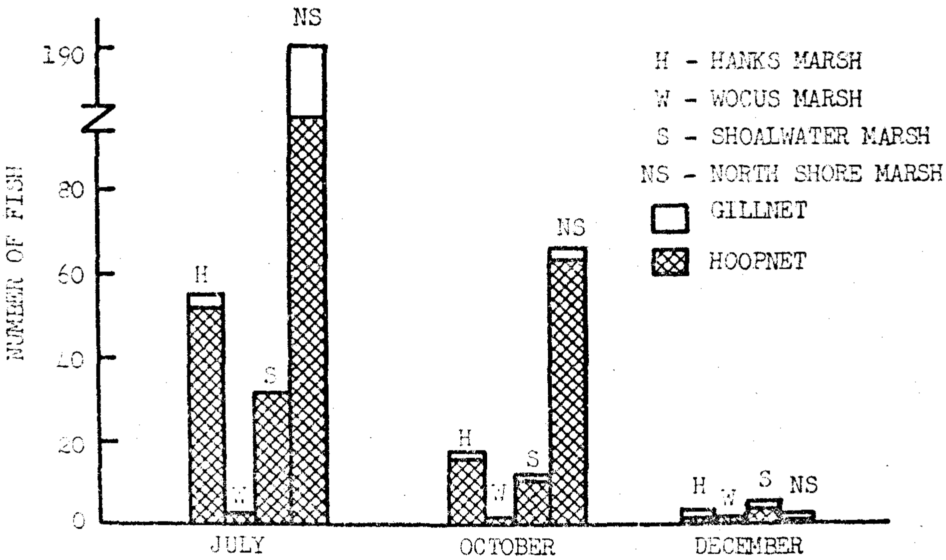


Figure 17. Catch of brown bullheads, Ictalurus nebulosus, Upper Klamath Lake, Oregon, 1965

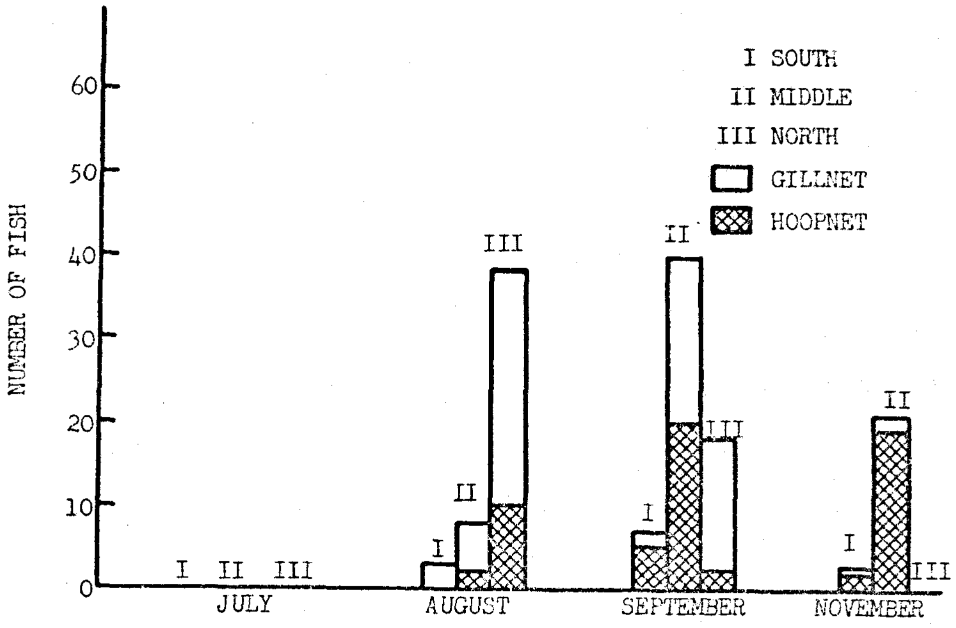


Figure 18: Catch of yellow perch, _Perca flavescens_, Upper Klamath Lake Oregon, 1965

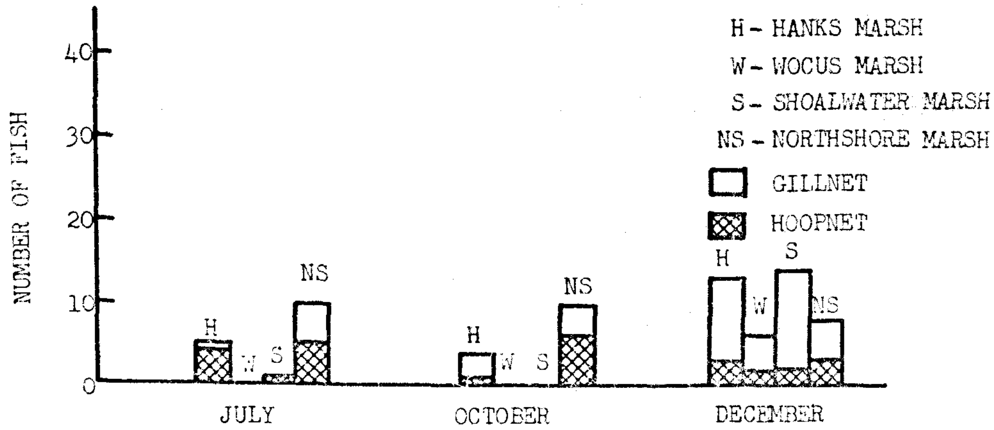


Figure 19: Catch of yellow perch, _Perca flavescens_, Upper Klamath Lake Oregon, 1965

contribution of a zone for the season can be found by dividing the total catch of a particular zone for the season by the total season's catch. Also, if the total monthly catch is interpreted to be equal to 100%, by dividing the total catch per hour of a zone by the total monthly catch, in fish per hour, the percentage contribution of each zone per month is obtained. Tables 6 and 7 summarizes these data for the tui chub and the blue chub.

Size Composition

The average percentage contribution of each of the four mesh sizes for the rock-shoreline catch is shown in Tables 8 and 9 for the tui chub and blue chub and the size range of the two species that were taken in each of the four mesh sizes is shown in Figures 20 and 21. Size overlap in the range of catch occurred only between the 2 1/4 and 3-inch meshes. The overlap is probably significant enough that the two mesh sizes could be added together and considered as one mesh size, however, for this analysis they will be considered individually.

The size composition of the seasons catch of tui chubs along the rock shoreline for the four sizes of mesh (stretched measure) utilized in sampling was: 28.3% (3-inch); 12.4% (2 1/4-inch); 29.2% (1 3/4-inch) and 30.1% (1 1/4-inch), which indicates an almost equal abundance of sizes at least on a seasonal basis (Only 40 feet of

Table 6. The percentage contribution of each zone to the monthly and total catches of tui chubs (*Siphateles bicolor*) Upper Klamath Lake, Oregon 1965.

	SAMPLING PERIOD				
Zone	July	August	September	December	Percentage of catch by zone
I	24.0	43.5	36.6	28.7	38.3
II	23.6	8.7	27.6	47.5	19.8
III	52.4	47.8	35.8	23.8	43.7
Percentage of season's catch by month	21.5	47.8	19.6	11.1	

Table 7. The percentage contribution of each zone to the monthly and total catches of blue chubs (*Gila bicolor*) Upper Klamath Lake, Oregon 1965.

	SAMPLING PERIOD				
Zone	July	August	September	December	Percentage of catch by zone
I	41.6	46.7	32.5	24.8	37.8
II	31.4	20.4	31.9	56.4	32.4
III	27.0	32.8	35.6	18.8	29.8
Percentage of season's catch by month	34.8	20.5	32.3	12.4	

Table 8. Monthly contribution of each mesh to the season's catch of tui chub (Siphateles bicolor) along rock shorelines in Upper Klamath Lake, 1965.

	Stretch mesh size (inches)			
Month	3	2 1/4	1 3/4	1 1/4
July	26.3	43.1	15.0	26.7
August	18.4	23.3	16.2	40.3
September	22.9	19.4	33.0	20.6
November	32.4	14.2	35.8	12.4
Total Percentage	100.0	100.0	100.0	100.0

Table 9. Monthly contribution of each mesh to the season's catch of blue chub (Gila bicolor) along rock shorelines in Upper Klamath Lake, 1965.

	Stretch mesh size (inches)			
Month	3	2 1/4	1 3/4	1 1/4
July	26.8	31.3	27.9	12.9
August	24.5	30.0	24.2	23.2
September	21.9	25.0	26.6	30.0
November	26.8	13.7	21.3	33.9
Total Percentage	100.0	100.0	100.0	100.0

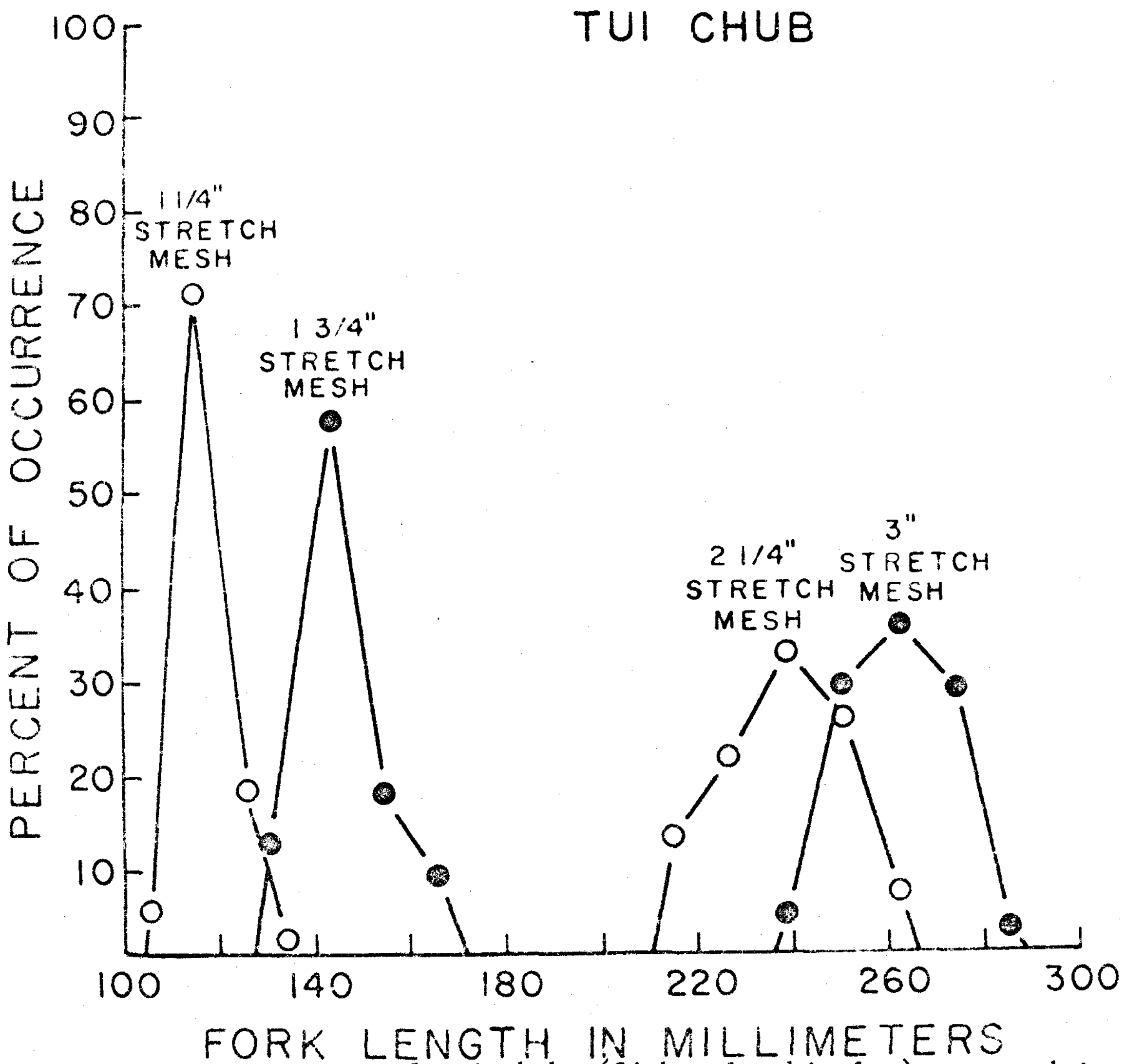


Figure 20. Size ranges of tui chubs (Siphateles bicolor) captured in experimental gillnets, Upper Klamath Lake, Oregon, 1965.

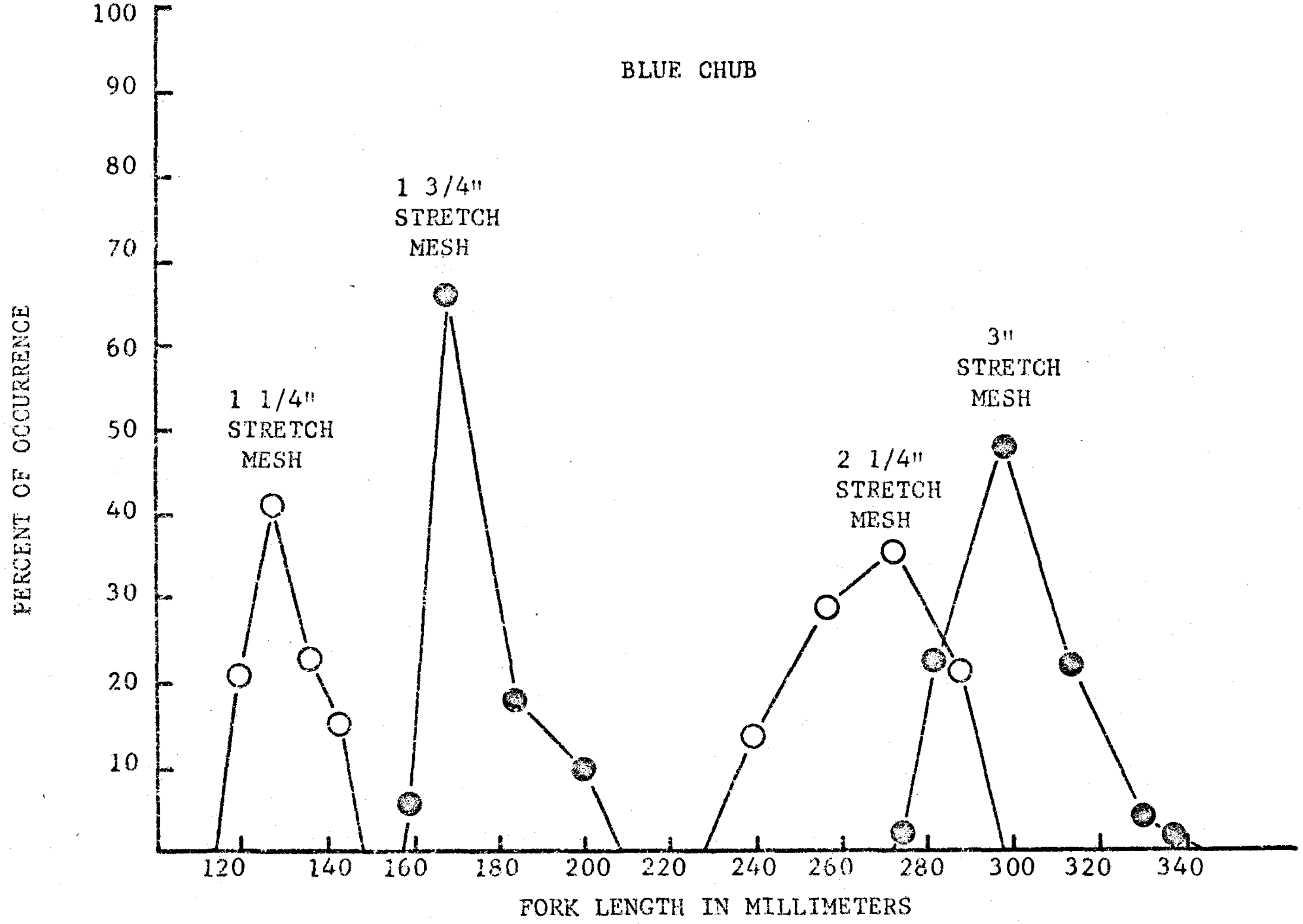


Figure 21. Size range of blue chubs (Gila bicolor) captured in experimental gillnets, Upper Klamath Lake, Oregon, 1965.

2 1/4-inch mesh was used which results in its low contribution to the catch as compared with 170 feet for each of the other mesh sizes) (Table 10).

A slight discrimination among zones was observed by the four size groups of tui chubs sampled. The larger fish were found mainly in Zone I (44.9% in 3-inch mesh and 45.4% in 2 1/4-inch mesh) while the medium size group was found mainly in Zone II (43.4%), and the smallest fish almost equally in all three Zones (I-28.0%); II-34.0%; III-38.0%) (Table 11).

The monthly distribution data (Table 12) show evidence of recruitment into certain mesh sizes, with the 1 1/4-inch showing a substantial increase in August and a decrease in September and November, while the catch in the 1 3/4-inch mesh showed substantial increase from August to September.

Seasonally the size composition of the rock-shoreline catch of blue chubs shows that 45.2% of the fish were taken in the large 3-inch mesh of the experimental gillnets while each of the three other meshes, 2 1/4, 1 3/4 and 1 1/4, contributed only 16.3%, 20.3% and 18.2% respectively to the catch (Table 13).

Spatially the various sizes of blue chubs did not appear to discriminate among zones except possibly the fish taken in the 1 1/4-inch mesh which appeared more frequently in the Zone II (43.1%) catch than in the catch of the other two zones (Table 14). The

Table 10. The percentage contribution of each mesh size to the catch by zones of tui chubs (Siphateles bicolor) along rock shorelines, Upper Klamath Lake, 1965.

Zone	Stretch mesh size (inches)				Total
	3	2 1/4	1 3/4	1 1/4	Percentage
I	38.2	16.9	19.6	25.3	100.0
II	21.2	10.1	38.0	30.7	100.0
III	25.6	10.2	29.9	34.3	100.0
Avg/mesh	28.3	12.4	29.2	30.1	

Table 11. The percentage contribution of each zone to the season's catch of tui chubs (Siphateles bicolor) for each mesh zone in Upper Klamath Lake, 1965.

Zone	Stretch mesh size (inches)			
	3	2 1/4	1 3/4	1 1/4
I	44.9	45.4	22.4	28.0
II	24.9	27.1	43.4	34.0
III	30.2	27.5	34.2	38.0
Total Percentage	100.0	100.0	100.0	100.0

Table 12. Percentage contribution of each mesh size to the monthly catch of tui chubs (Siphateles bicolor) along rock shorelines in Upper Klamath Lake, 1965.

	Stretch mesh size (inches)				
Month	3	2 1/4	1 3/4	1 1/4	Total Percentage
July	28.8	21.1	17.8	32.7	100.0
August	20.2	11.4	19.2	49.3	100.0
September	25.0	9.5	39.2	25.2	100.0
November	35.3	6.9	42.5	15.0	100.0

Table 13. The percentage composition by mesh size of the season's catch of blue chubs (Gila bicolor) for each zone in Upper Klamath Lake, 1965.

	Stretch mesh size (inches)				
Zone	3	2 1/4	1 3/4	1 1/4	Total Percentage
I	48.1	15.3	22.0	14.6	100.0
II	40.9	15.2	20.3	23.6	100.0
III	46.6	18.5	18.3	16.6	100.0
Avg/mesh	45.2	16.3	20.2	18.3	

Table 14. The percentage contribution of each zone to the season's catch of blue chubs (*Gila bicolor*) for each mesh size in Upper Klamath Lake, 1965.

	Stretch mesh size (inches)			
Zone	3	2 1/4	1 3/4	1 1/4
I	35.4	31.2	36.3	26.6
II	30.1	31.2	33.5	43.1
III	35.5	37.6	30.2	30.3
Total Percentage	100.0	100.0	100.0	100.0

Table 15. Percentage contribution of each mesh size to the monthly catch of blue chubs (*Gila bicolor*) in Upper Klamath Lake, 1965.

	Stretch mesh size (inches)				
Month	3	2 1/4	1 3/4	1 1/4	Total Percentage
July	46.3	19.3	23.8	10.3	100.0
August	42.3	18.5	20.7	18.4	100.0
September	37.8	15.4	22.7	23.8	100.0
November	46.0	8.4	18.1	26.8	100.0

monthly contribution of each mesh size to the season's catch remained virtually the same for the 3 and 3/4-inch mesh through the four months of sampling, while the 2 1/4-inch mesh contributed less as the season progressed. The 1 1/4-inch mesh was the only mesh size to increase its monthly contribution to the season's catch from July (12.9%) to November (33.9%) indicating recruitment into this mesh size. Monthly recruitment is indicated also in the 1 1/4-inch mesh by Table 15 which shows as the season progresses a larger portion of the monthly catch is of smaller fish.

Species Distribution

Distribution According to Type of Shoreline

Data gathered for the entire season on the shoreline distribution of fishes are summarized in Table 16. "Preferences" for certain habitats are indicated by most of the fishes. Table 16 shows 4.4% and 7.1% of the total catch of brown bullheads and yellow perch were taken in the midlake areas, indicating that these species remain relatively close to the shore. Trout were caught only along the northern marsh area during the summer months but failed to show a shoreline "preference" for the season. The uniformity of trout distribution indicates that other factors are involved in determining their distribution.

Table 16. Shoreline habitat preference of fishes caught in Upper Klamath Lake, Oregon 1965, shown by percentage of catch in each habitat.

Shoreline habitat	blue chub	tui chub	brown bullhead	Species yellow perch	sculpins	trout	suckers
Rock	43.1	42.4	39.3	42.9	62.3	33.3	57.8
Marsh	13.8	28.8	56.3	50.0	11.1	39.0	21.1
Midlake	43.1	28.8	4.4	7.1	26.6	27.7	21.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Probably factors such as water quality and food availability exerted more influence on the distribution of trout than the type of shoreline.

Suckers were not taken in a large enough quantity to indicate a "preference" for a shoreline habitat, although beach seine hauls over rock (gravel) bottom areas caught many small suckers (2-6 inches).

The blue chub and sculpins show an apparent avoidance of the marsh shoreline as only 13.8% of the blue chub catch and 11.1% of the sculpin catch were caught there. Brown bullhead and yellow perch, however, were caught more frequently along the marsh shoreline than along the rock shoreline or in the midlake area.

Distribution of Tui Chub by Habitat

The percentage of the rocky shoreline catch in fish per hour of the tui chubs increased from 21.5% in July to 47.8% in August and then decreased in September to 19.6% and to 11.1% in November, indicating a seasonal change in activity.

Spatially, Zone I, II, and III produced 38.3, 19.8 and 43.7% of the rocky shoreline catch respectively. Zone II contributed substantially to the catch only in November (47.5% of the monthly catch) while Zone I and III contributed almost equally in all months except July when Zone III had more than twice the catch of Zones I and II (Figure 22).

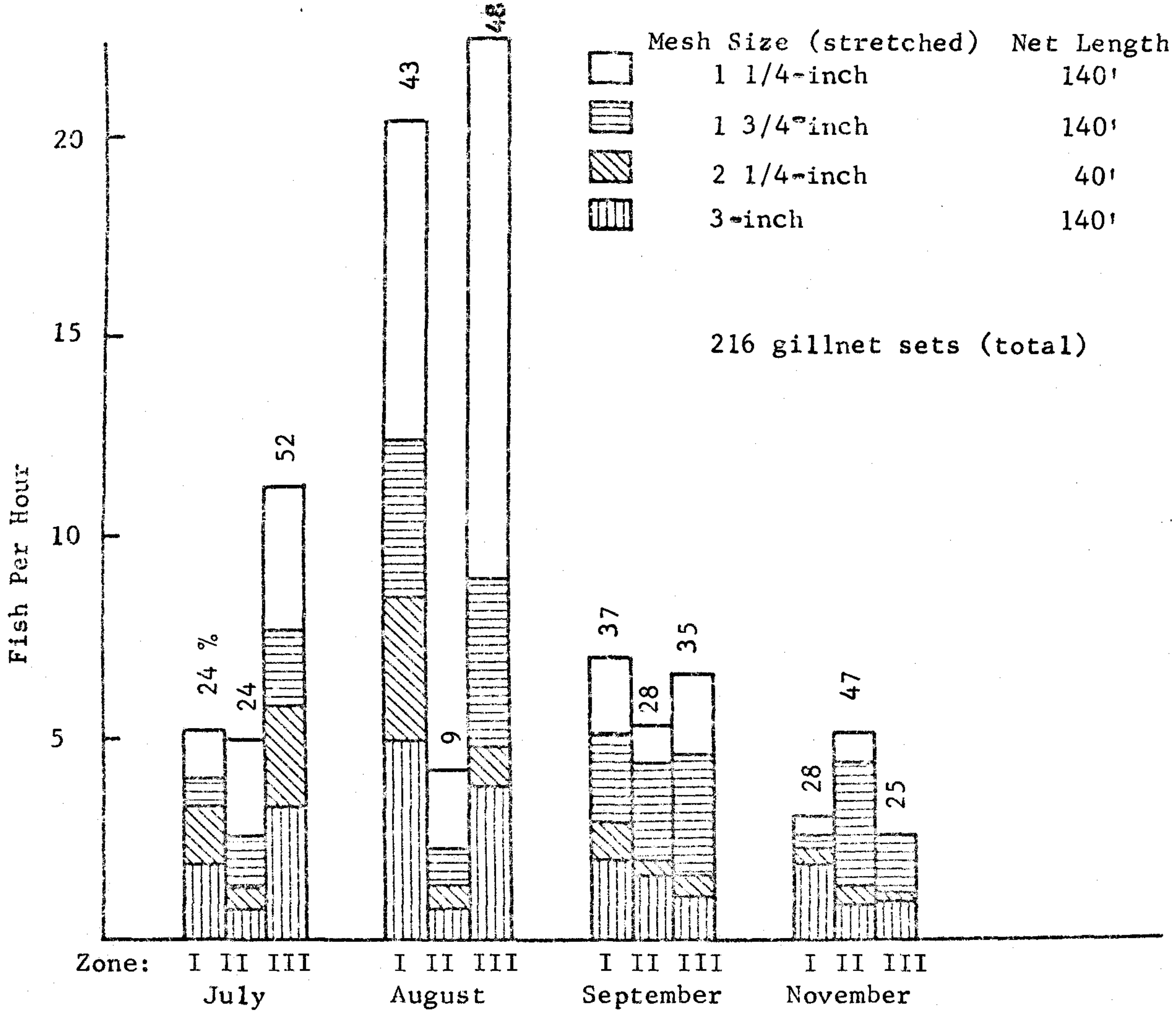


Figure 22. The distribution of tui chubs (Siphateles bicolor) along the rock shoreline by contribution of each gillnet mesh size. (Numbers show percent of monthly catch per zone). Upper Klamath Lake, Oregon, 1965.

If the percentage of the monthly catch is taken in each zone an idea of a possible geographical distribution of the species is obtained. The catch in Zone III showed a steady decline (52.4% in July to 23.8% in November) throughout the season in its percentage contribution to the monthly catch, while the catch in Zone II showed a decrease only in August to 8.7% and then increased substantially through September and November and provided almost one-half of the November catch. Zone I nearly doubled its contribution of July by November. Only in September did the fish seem to be nearly equally distributed, 36.7, 27.6 and 35.8% respectively (Figure 22).

The seasonal catch of tui chubs from the four different marshes indicate that the population of tui chubs along the marsh shoreline did not change much throughout the year except for a noticeable decline as measured by percentage of the catch from July to October (42.4% in July; 24.2% in October; and 33.4% in December). The larger percentage in July was due possibly to fast growth that recruited fish into the small meshes and to large mature fish moving from spawning grounds. The marshes located within bays seem to be "preferred" by the tui chub as indicated by the consistency of catch for the three sampling months. Wocus Marsh was the most consistent producer with Shoalwater, North Shore and Hanks marshes following in that order, except during the month of October, when Shoalwater produced only 0.3 fish per hour which was well below the almost five per hour in July and December.

During the August sampling period more tui chubs were caught in the midlake area of Zone II than Zone III. However, during the September sampling period there was little evidence of a zonal preference.(Table 17). This could be a possible indication of movement by the tui chub to the midlake area (under certain conditions, such as high winds) from the "preferred" shoreline areas.

Distribution of Blue Chub by Habitat

Two-thirds of the catch was taken along rocky shorelines in the months of July (34.8%) and September (32.3%) while the remaining one-third was divided between August (20.5%) and November (12.4%) (Table 7).

The percentage contribution of Zone II to the monthly catch decreased by 11% from July (31.4%) to August (20.4%) but increased again in September (31.9%) and almost doubled in November (56.4%). Catches in Zone I and III did not follow a pattern similar to those of the tui chub. Zone I contributed 41.6% in July, 46.7% in August and then decreased in September (32.5%) and November (24.8%) while the Zone III catch increased through September (27.0% July; 32.8% August; 35.6% September) and fell off substantially in November to 18.8%. September was the only month in which fish were nearly evenly distributed over all three zones, the other months

Table 17. Midlake catch composition for August and September 1965 (12 sets of four gillnets, fished 306 hours) Upper Klamath Lake, Oregon.

Date	No. net sets	Zone	Species: rainbow trout	yellow perch	brown bullhead	sculpins	tui chub	blue chub
Aug. 10-13	4	II	0	0	0	2	627	737
	4	III	4	0	14	4	185	403
Sept. 15-17	2	II	1	1	0	0	107	553
	2	III	2	4	0	12	83	228

over all three zones, the other months were all weighted to one zone or another (Figure 23).

Essentially there was no difference in the geographical distribution of the blue chub during the 1965 sampling season. Zone I (37.8%) was only slightly favored over Zone II (32.4%) and Zone III (29.8%).

Almost 90% of the blue chubs caught along a marsh shoreline were taken in the months of July (46.5%) and October (43.2%). A definite decrease in the activity, as in November along the rocky shoreline, was also shown in December when only 10.3% of the total season's catch was taken.

Individual marshes seemed to contribute according to their association with the lake proper. The pattern is almost the reverse of that of tui chub. In the case of the blue chub more fish were taken along marsh areas connected to the main lake (Hanks Marsh and North Shore Marsh) than the other two areas combined. Hanks Marsh contributed more than 45% of the total marsh shoreline catch.

Blue chubs appear to be as plentiful in the middle of the lake as along the shoreline with the Zone II area off Squaw Point producing more fish than the northern Zone III area during both the August and September sampling periods (Table 17).

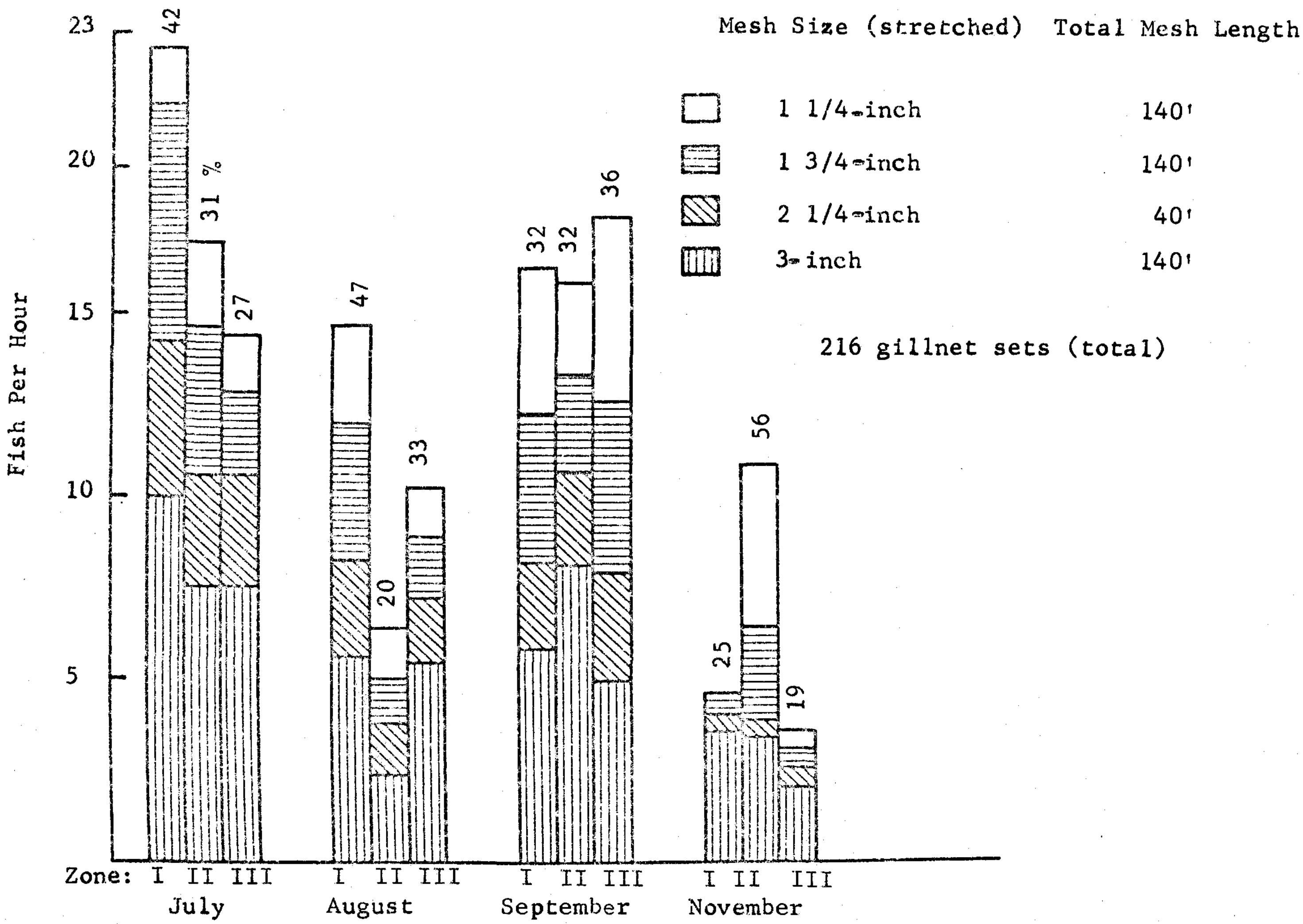


Figure 23. The distribution of blue chub (Gila bicolor) along the rock shoreline by contribution of each gillnet mesh size (numbers indicate percent of monthly catch per zone). Upper Klamath Lake, Oregon, 1965.

Distribution of Rainbow Trout by Habitat

Only one rainbow trout was taken during the summer months (July, August and September) outside of Zone III (Figure 14) and that fish was taken in a spring area along the eastern shore of Zone II. However, along the northern marshy shoreline of Zone III (North Marsh area), fishermen troll lures throughout the summer months. According to Gerlach (1964 and 1965), fishermen caught 1.4 and 0.9 trout per angler in this area during the summers of 1964 and 1965 respectively. My colleagues and I also caught fish in this area by trolling, and with gillnets set in the shallow (four to five feet deep) water. Trolling and 108 net sets in the other two zones failed to catch any trout during these summer months. But, by the middle of October trout began to appear in nets and sport catch of other zones. Angling at this time is done almost entirely from the banks and fishermen first appear along the eastern shore (Barclay Springs area). By the middle of November trout were taken in all three zones, including Wocus Bay. Trout are available to fishermen from the banks until about May of the following spring then seem to disappear from all zones except Zone III.

The pattern of distribution of rainbow trout along the marshy shoreline follows closely the pattern observed in Figure 14 for the rocky shoreline except that trout did not appear in the Zone III rock shoreline net catch until November. The North Marsh area was the only area to produce trout during the July sampling season and as previously mentioned is the only area in which they are available to fishermen through the summer. The December catch data show that trout were scattered throughout the lake with most fish taken along Hanks Marsh (Figure 15).

Limited numbers of fish caught prevent the drawing of definite conclusions about the rainbow trout caught in the midlake region, however, in Zone III six trout were caught for the two sampling periods (four in August) compared with one for Zone II. Indicating again, as in the marsh and rock shoreline data, that trout are found in the northern end of the lake during the summer (Table 17).

Distribution of Yellow Perch by Habitat

Absence of yellow perch from the July sampling period (Figure 18) is probably related to the fact that hoop nets were not utilized for sampling until the beginning of the second sampling period. Yellow perch apparently spend the early spring in the marsh area of the northern part of the lake and are first susceptible to sampling in Zone III. They then move south into Zone II with relatively few yellow perch ever reaching Zone I, the few caught in this area were all small (4-6"). Data show the yellow perch taken by nets in Zone II in all months were taken along the eastern shore in areas two and four of that zone.

Yellow perch are taken by fishermen mainly in Zone III, in Pelican Bay and the marsh creeks: Crystal, Recreation and Odessa. Occasionally they are taken from the "canals" around the edge of Hanks Marsh in Zone II. The yellow perch are taken at these places from about the middle of July through September and usually have left these areas by the middle of October, according to fishermen and resort owners.

The marsh shoreline distribution of yellow perch tends to indicate a possible movement to the marsh area in the late fall. Figure 19 shows that 57.7% of the three month's catch was taken in December and that North Shore and Hanks marshes contribute 70.4% of the season's catch.

Yellow perch were not taken in the month of August in either midlake sampling zone; however, during the September sampling period five individuals were caught; four of these in Zone III. Yellow perch appear to favor the shoreline areas and possibly, even though the lake is shallow, do not venture far from shore.

Distribution of Brown Bullheads by Habitat

The spatial distribution of the brown bullhead (Figures 16, 17) show that 67.7% of the marsh shoreline catch was taken in the North Shore Marsh area, 19.3% in Hanks Marsh, 12.6% in

Shoalwater Marsh and 0.4% in Wocus Marsh. Thus, most of the catch seems to be associated with the size of marsh area sampled. The lengths of the marsh shorelines are as follows: North Marsh, five miles; Hanks Marsh, four miles; Wocus and Shoalwater, two miles each. The latter two were characterized by "foul" water conditions which prevailed into late September.

Although brown bullheads were caught in the midlake area in Zone III during the month of August, most evidence shows that the brown bullhead may prefer the shoreline. The set of nets in August may have intercepted a school of fish "passing through" the area.

Distribution of Sculpins by Habitat

The sculpins seem to be rather evenly distributed throughout the season except for Zone I in November when the catch was almost triple that of the other two zones (Figure 24). The July catch should not be considered as a representative sample of the sculpin population because hoopnets were not employed during that time, and more than 90% of the sculpins were captured in hoopnets.

Only 19 sculpins were caught along the marsh shoreline with Hanks Marsh contributing ten of these fish in the last two sampling periods. A possible reflection on the water quality is indicated by the fact that sculpins were not caught in Wocus Bay (Figure 25).

Sculpins were caught almost equally in both midlake sampling

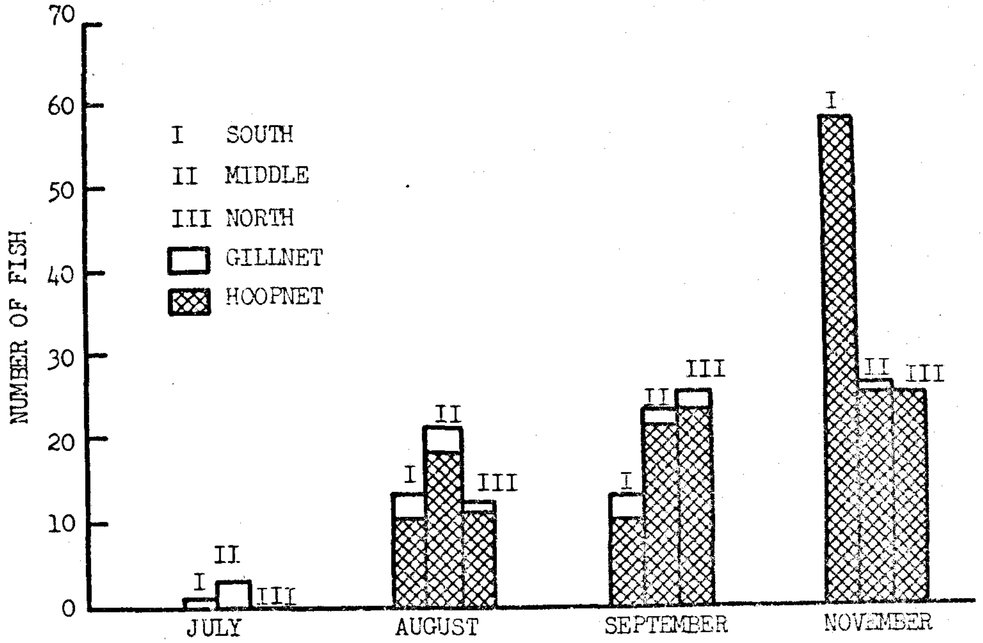


Figure 24. The rock shoreline distribution of sculpins (<u>Cottus</u> sp.) Upper Klamath Lake, Ore. 1965.

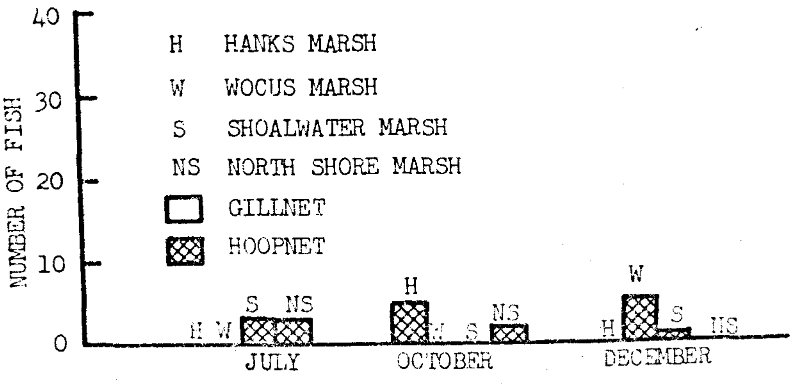


Figure 25. The marsh shoreline distribution of sculpins (<u>Cottus</u> sp.) Upper Klamath Lake, Ore. 1965

areas of Zone II and Zone III in the month of August.(Table 17). However, sculpins were taken only in Zone III during the September sampling period.

DISCUSSION

The apparent wide ecological tolerance of cyprinids is substantiated by data from Klamath Lake. A significant correlation was not found between the numbers of chubs caught and the environmental factors measured. Only nearly complete lack of dissolved oxygen appeared to prevent blue and tui chubs from occupying all sections of the lake. These species were taken even in areas where dissolved oxygen was as low as 0.1 mg/l and a scum of decaying algae existed. Capture of tui chubs under such dissolved oxygen conditions is reported by Kimsey (1954) from Eagle Lake, California. In Klamath Lake only a single series of six nets, set in the anoxic waters of Wocus Bay, failed to catch a single cyprinid. Decaying organic matter, predominately algae, was responsible for these extreme conditions in certain areas of the lake.

Geographically, the blue chub was found equally in all three zones indicating that the whole lake was utilized equally and that "optimum regions" did not exist. This is also illustrated by the size composition data. Except for fish caught in the 1 1/4-inch mesh in Zone II no preference was indicated by any of the size groups for a particular zone.

The blue chub spawns over rocks along the shoreline at water temperatures of approximately 60-63° F during the months of May

June in contrast to the tui chub which broadcasts eggs over submerged aquatic vegetation. The differences in spawning habits and morphological features probably explain the reason for the smaller amount of fluctuation in blue chub catch as compared with the tui chub. Because of morophological differences between species, growth in girth is slower in the slimmer blue chub; therefore, the blue chub would not grow into and out of vulnerability to the different mesh sizes as rapidly as the tui chub.

The size composition data of the rock shoreline catch shows a gradual increase in the small 1 1/4-mesh through the season indicating recruitment into this mesh size throughout the year while the 1 3/4-inch mesh remained almost the same.

The percentage contribution of each mesh size of the blue chub rock shoreline catch is extremely unusual because a greater percentage of the catch consisted of large rather than small fish. In every zone and month sampled, except Zone II in November, the greatest portion of the catch consisted of fish taken in the 3-inch mesh. This could be due to any combination of the following suggested causes: (1) a discrete schooling behavior or segregation of the fishes into length classes so that mainly large fish were sampled; (2) gear selectivity such as the "spilling-over" effect as described by Regier and Robson, (1966), wherein the fish actually moves along the net seeking a hole large enough to go through, which again results in more larger fish being taken; (3) existence of a single strong year-class which was vulnerable to the nets during this study; (4) differential gear activity, which results in a smaller range of lengths being taken by the small mesh than by the larger, so that more age classes are available to the large mesh. This increases the number of fish taken in the large mesh beyond the amount available to the more selective small mesh. Round haul seine data (Figure 26) suggests that the latter (4) is possible and the most likely explanation for the size composition of the blue chub catch.

The seasonal distributional pattern of the tui chub shows that almost 50% of the season's rock shoreline catch was taken during the month of August. Examination of the size composition of the catch showed that 49.3% of that month's catch was composed of smaller fish taken in 1 1/4-inch mesh of the experimental gillnets. This indicates a definite recruitment into this mesh size of yearling fish. Figure 20 shows the length distribution taken by the 1 1/4-inch mesh and a spread of only 32mm (102 mm-134 mm) exists. According to Kimsey (1954), 1, 2, and 3-year old tui chubs of Eagle Lake, California had standard lengths of 66, 112 and 167 mm respectively. This would indicate, then, if growth is comparable, during July the fish of age-class II would be entering the range of the small 1 1/4-inch mesh. (In July almost one-third of the catch was composed of the smaller fish). By August these fish are well within the limits of

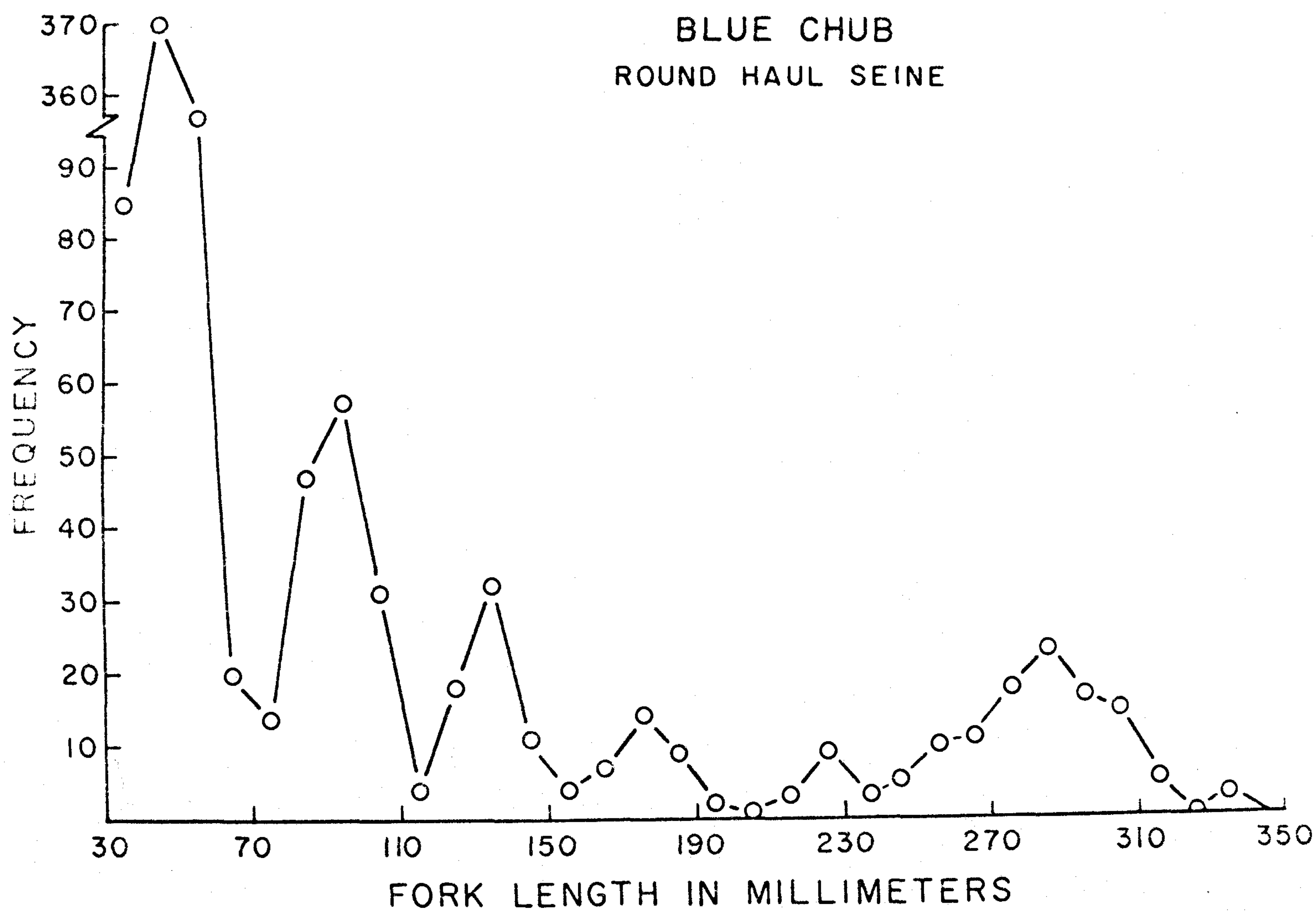


Figure 26. Size composition of blue chub (*Gila bicolor*) population in Upper Klamath Lake, Oregon, 1965.

the 1 1/4-inch mesh and by September have grown out of the small mesh and possibly into the 1 3/4-inch mesh which the data suggest (Table 12). A substantial increase is noted in the catch of the 1 3/4-inch mesh from August (19.2%) to September (39.2%) and again in November to 42.5%. During the latter months the percentage of fish taken in the small mesh decreased from 49.3% in August to 25.2% in September and to 15.0% in November. Thus, two-year-old fish grow through one mesh size completely and partially through another in less than six months.

That the catch does not stay at a certain level throughout the year can be partially explained by natural mortality and gear selectivity. Because of the rapid growth and the type of gear used, the fish grow in and out of mesh sizes quickly, causing fluctuations in the catch.

The significant decrease shown by the tui chub in the percentage of season's catch during the month of September could be associated with an avoidance to the abundance of net plankton (algae) during that month. The blue chub catch, however, increased by 12% during the same period indicating greater tolerance to the condition created by the abundance of net plankton (algae).

Other possible explanations for the decrease in the September catch are that the fish were not vulnerable to the nets during this period of time being "between mesh sizes" or falling temperatures could have affected the activity of the fish.

The November catch fell off substantially from the other months, possibly as a result of inactivity on the part of the fish. Water temperatures at this time were approximately 45° F. The November catch also indicates a possible migration into Zone II especially by fish of the 1 3/4-inch mesh size. Kimsey (1954) observed that the Eagle Lake tui chubs moved into deeper water to spend the winter. This is probably the same reason for movement into Zone II of Klamath Lake in November where the deepest water of the lake is located. A similar winter migration by cyprinids into deep water was noted by Crossman (1959).

In an effort to determine the possible effects of the many variables encountered, a step-wise regression analysis was instituted to eliminate variables of probable insignificance. All 31 factors measured do influence fish distribution to some degree but this computer analysis indicated that out of the 31 variables, the linear combination of the first ten entering variables[1] could have the greatest influence on the catch of blue chubs (Table 18). The other 21 were either masked or nonsignificant in their contribution.

The data for tui chubs show that only the first seven variables were above the cut-off of ±2.00 for the Student's T (Table 19).

---

[1] On the basis of a cut-off of an entering Student's T value of ±2.00 as suggested by Dr. Scott Overton.

Table 18. Ranked list of variables as they entered the step-wise regression analysis ("Order of Importance") for blue chub (*Gila bicolor*) in Upper Klamath Lake, 1965.

Variable	Entering F level	Entering Student's T	Correlation coefficient
Diver Gill net	183.90	13.56	.54
Marsh shoreline	43.10	-6.56	-.25
Floating gill net	42.83	6.54	.04
Dissolved oxygen "In"* surface	22.82	4.78	.21
Methyl Orange Alkalinity "In"*	9.36	3.06	-.15
Zone II	9.57	3.09	.05
Net Plankton "Out"**	8.68	2.95	.15
Methyl Orange Alkalinity "Out"	5.81	2.41	.03
Time	5.6	2.37	-.02

*measurements taken when nets were placed into the water (mean time 1000 hrs)

**measurements taken when nets were removed from the water (mean time 1430 hrs)

Table 19. Ranked list of variables as they entered the step-wise regression analysis ("Order of Importance") for tui chub (Siphateles bicolor) in Upper Klamath Lake, 1965.

Variable	Entering F level	Entering Student's T	Correlation coefficient
Net plankton "In"*	230.65	15.19	.58
Net plankton "Out"**	41.58	-6.45	-.05
Diver gill net	39.55	6.29	.22
Methyl orange alkalinity "Out"**	18.48	-4.30	-.46
Dissolved Oxgen Surface "In"*	5.01	-2.24	-.12
Zone II	4.81	-2.19	-.10
Floating gill net	3.91	2.00	-.01

*measurements taken when nets were placed into the water (mean time 1000 hrs)

**measurements taken when nets were removed from the water (mean time 1430 hrs)

Many of the same variables entered in both cases; however, the order of appearance was not the same.

These data indicate that the diver gill net accounted for the greatest variation in the blue chub catch, while the net plankton accounted for the greatest variation in the tui chub. This would then help substantiate a previously made statement that the decrease in the September tui chub catch could be due to avoidance to an abundance of net plankton (algae) that was present during that sampling period.

This statistical analysis emphasizes the difficulty of correlating distribution of fishes with environmental factors. Many factors, environmental or otherwise, operating singly or in combination, including the ones measured and others are apparently involved in influencing cyprinid distribution in Klamath Lake.

CONCLUSIONS

Limnology

1. Limnological data showed a wide seasonal fluctuation in all factors measured, e.g., temperature, pH, alkalinity, etc.
2. Bloom conditions of the blue-green alga Aphanizomenon sp. prevailed from June through September with die-off occurring in October.
3. Shallow depths and prevailing northwest winds prevent thermal stratification for any extended period of time.
4. Decaying organic material (algae) caused portions of Wocus Bay and Shoalwater Marsh to become anoxic for two months during the summer of 1965.

Fish Distribution (1965)

1. Blue chubs and tui chubs comprised 93% of the total catch while 13 species contributed to the remaining 7%.
2. Only complete lack of dissolved oxygen prevented the blue chub and tui chub of all age classes from occupying all sections of the lake.
3. Seasonal "migration patterns" were indicated by rainbow trout, yellow perch and brown bullheads.

4. Tui chub catch showed a seasonal pattern of activity with the peak catch of fish occurring in August and with only 11% of the season's catch taken in November.
5. Rainbow trout were not caught during the summer months in areas with a heavy "bloom" of Aphanizomenon, and did not indicate a shoreline preference.
6. Tui chub catch decreased with an increase in net plankton (algae).
7. Brown bullheads and yellow perch were taken more frequently along the marsh shoreline than along the rock shorelines and mid-lake areas.
8. Blue chub showed no zonal discrimination, and were evenly distributed except smaller fish in Southern Zone I.
9. Blue chub catch was composed mainly of larger fish.
10. Blue chub recruitment into the small gill-net meshes was obvious as the summer progressed.
11. Blue chub and sculpins showed an apparent avoidance of marsh shorelines.

Fish Distribution (1964)

1. Seasonal movements were indicated by rainbow trout, yellow perch, and brown bullheads.
2. Incoming waters from springs and streams influenced fish

distribution.

3. The brown bullhead and tui chub "preferred" bays to the open lake.

BIBLIOGRAPHY

American Fisheries Society. 1960. A list of the common and scientific names of fishes from the United States and Canada. McLean, Virginia. 102 p. (Special Publication no. 2)

Cope, Edward D. 1879. The fishes of Klamath Lake, Oregon. American Naturalist 13:784-785.

__________ 1883. On the fishes of the Recent and Pliocene lakes of the western part of the Great Basin and of the Idaho Pliocene lake. Proceedings of the Academy of Natural Sciences, 1883, p. 134-166.

Crossman, E. J. 1959. Distribution and movements of a predator, the rainbow trout, and its prey, the redside shiner, in Paul Lake, British Columbia. Journal of the Fisheries Research Board of Canada 16:247-267.

Evermann, Warren and S. E. Meek. 1898. A report upon salmon investigations in the Columbia River Basin and elsewhere on the Pacific Coast in 1896. Bulletin of the United States Fish Commission 17:15-84.

Gerlach, Arthur H. 1964. Klamath District. In: Annual report of the Fishery Division of the Oregon State Game Commission, ed. by C. J. Campbell and F. E. Locke. Salem. 1. 177-194.

__________ 1965. Klamath District. In: Annual report of the Fishery Division of the Oregon State Game Commission, ed. by C. J. Campbell and F. E. Locke. Salem. p. 45.

Gilbert, Charles H. 1898. The fishes of the Klamath River basin. Bulletin of the United States Fish Commission 17:1-13.

Hubbs, Carl L. and R. R. Miller. 1948. The Great Basin, with emphasis on glacial and post-glacial times. II. The zoological evidence. Bulletin of the University of Utah 38(20):17-166.

Jewett, Stanley G. 1938. Unpublished research report on the Klamath midge project. Corvallis, Oregon, Agricultural Experiment Station, Dept. of Fish and Game Management.

Jordan, D. S. and B. W. Evermann. 1922. American food and game fishes. New York, Doubleday, Page and Company. 572 p.

Kimsey, J. B. 1954. The life history of the tui chub (Siphateles bicolor) from Eagle Lake, California. California Fish and Game 40: 395-410.

Miller, R. R. 1946. The need for ichthyological surveys of the major rivers of Western North America. Science 104: 517-519.

Overton, W. S. and O. Florschutz. 1962. Use of path analysis in analyzing and interpreting observational data, with reference to the analysis of goose kill around Lake Mattamuskeet, North Carolina, 1960-61. Paper presented at the Sixteenth Annual Conference of the Southeastern Association of Game and Fish Commissioners, Charleston, South Carolina, October, 1962.

Phinney, Harry K., C. A. Peek and J. L. Mclachlan. 1959. Unpublished research on a survey of the phytoplankton problems in Klamath Lake. Corvallis, Oregon, Dept. of Botany.

Phinney, Harry K. and Chester A. Peek. 1961. Klamath Lake, and instance of natural enrichment. In: Algae and metropolitan wastes. Washington, D.C. p. 22-27. (U.S. Dept. of Health, Education, and Welfare. TR W61-3)

Regier, H.A. and D.S. Robson. 1966. Selectivity of gill nets, especially to lake whitefish. Journal of the Fisheries Research Board of Canada 23: 423-454.

Snyder, J.O. 1908a. The fishes of the coastal streams of Oregon and Northern California. Bulletin of the United States Bureau of Fisheries 27: 153-189.

________________ 1908b. Relationships of the fish fauna of the lakes of Southeastern Oregon. Bulletin of the United States Bureau of Fisheries 27: 69-102.