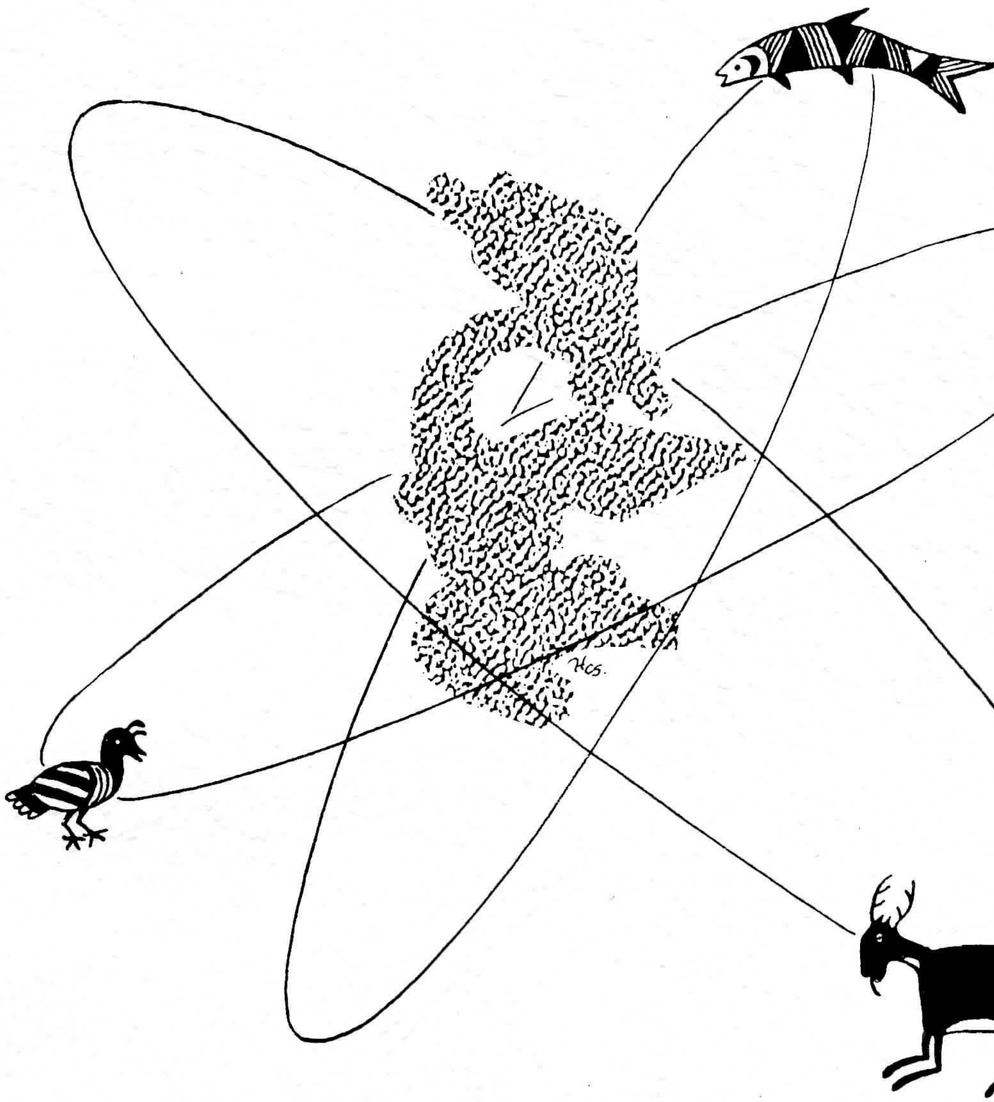
FISHERY RESEARCH REPORT NUMBER 3



RESEARCH DIVISION

Oregon State Game Commission

Federal Aid Project
F-71-R-2
Kokanee

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OREGON STATE GAME COMMISSION

Portland Oregon

STUDIES OF THE ECOLOGY OF KOKANEE

IN

ODELL LAKE, OREGON

by

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Research Division

Oregon Game Commission

FEDERAL AID TO FISH RESTORATION

Progress Report

Kokanee ecology

F-71-R-2

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TABLE OF CONTENTS

List of tables

List of Figures

List of figures (continued)

Studies of the ecology of kokanee salmon in Odell Lake, Oregon

Introduction

Studies of the ecology of the kokanee, Oncorhynchus nerka (Walbaum), were initiated by the Oregon Game Commission in 1962. These studies were designed to gain information for the improved management and utilization of this important sport fish. Earlier, Chapman and Fortune (1963) discussed the ecology of kokanee in several Oregon lakes. Fortune (1964) reported on the distribution of kokanee fingerlings in Odell Lake, and Campbell (1965) presented a preliminary report on the ecology of kokanee in the same lake.

Odell Lake lies at an elevation of 4,788 feet in the central Cascade Mountains (Figure 1) and is oligotrophic. The lake covers 3,593 surface acres, has a maximum depth of 282 feet, and is approximately 5 miles long and 1 mile wide. Thermal stratification is present from late spring until late fall. Crystal and Trapper creeks are the main tributaries. The outlet, Odell Creek, enters Davis Lake at a distance of 13 stream miles. Fortune (1964) presented data showing that in general the minimum discharge of Odell Lake took place in September at 3,100 acre-feet. The maximum discharge was in June at 9,000 acre-feet.

In past years Odell Lake has been stocked with kokanee from Flathead Lake, Montana and from Kootenay Lake, British Columbia. At the present time it is one of the most popular kokanee lakes in Oregon. The lake also contains rainbow trout, Salmo gairdneri (Richardson), Dolly Varden trout, Salvelinus malma (Walbaum), brook trout, Salvelinus fontinalis (Mitchell), and lake trout, Salvelinus namaycush (Walbaum).

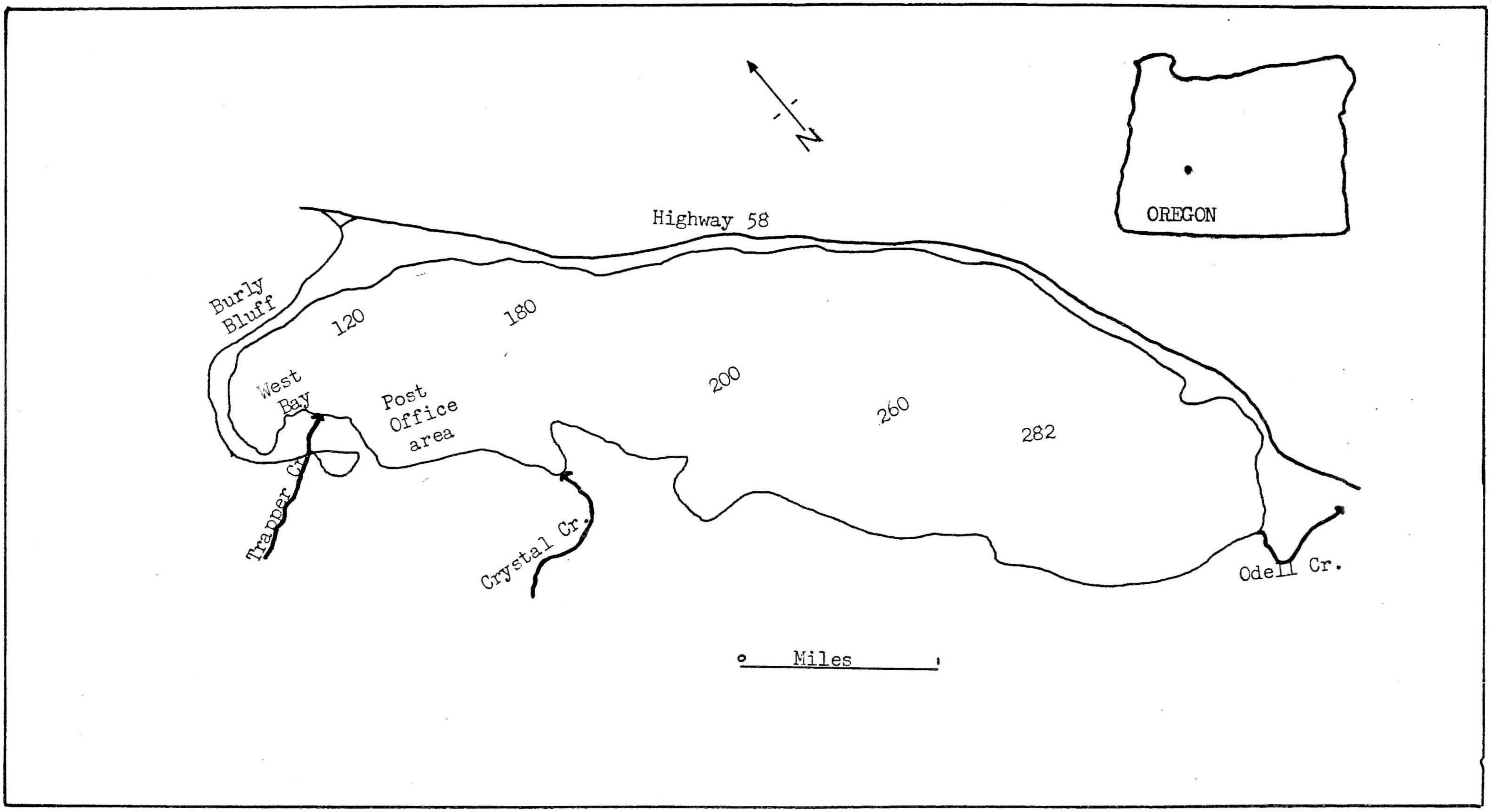

Figure 1. Odell Lake showing location of spawning areas and selected depths.

Campbell (op.cit.) found that 87 percent of the anglers interviewed in 1964 were fishing for kokanee. The percentage increased to 95 in 1965. Resort owners have found it necessary to expand facilities to accomodate increased numbers of kokanee anglers.

The lake is well suited to the study of kokanee. Large numbers of fish are present, the open water allows easy trawling for young kokanee, and its summer stratification affords an opportunity to study the influence of temperature on distribution. The presence of inlet and outlet streams and gravel-shore areas provide a variety of sites for the study of spawning habits.

Objectives

The current objectives of the Odell Lake study are to:

1. Determine total angler harvest and the contribution of hatchery kokanee to the creel.
2. Determine the survival and growth of hatchery and wild kokanee and their spatial distribution in the lake.
3. Determine the location and magnitude of the spawning runs, length and age at maturity, fecundity and spawning success of kokanee.
4. Separate groups of kokanee on the spawning areas.

Additional objectives as the project continues will be to:

1. Determine methods of evaluating year of maturity by early-life gonad inspection.
2. Evaluate the relationship between length, weight, and egg numbers in mature kokanee.
3. Evaluate the relationship of stocking time to survival of hatchery-reared kokanee.
4. Determine the effect of environmental changes on kokanee populations.

Methods and equipment

Creel census

A creel census was initiated at the beginning of the angling season on April 24, and continued until September 18, 1965. Although the season did not terminate until October 31, there were essentially no anglers after mid-September.

Anglers were interviewed at boat landings when catches were brought ashore. An angler trip was considered complete at this time. The following information was obtained from angler interviews.

1. Number of anglers in boat party.
2. Number of hours boat party had fished.
3. Species of fish anglers were seeking.
4. Number and species of fish landed.
5. Size of kokanee in catch.

Whenever possible, fork length measurements of kokanee were made to the nearest millimeter to provide information on the seasonal changes in length frequency of the catch. Scale samples were collected from kokanee of various sizes throughout the season.

Beginning in 1963, twenty percent of the fish stocked were marked by removing either the right ventral (RV), left ventral (LV), or both ventral (BV) fins. The rate of stocking and marks are shown in Table 1. The source of eggs was Kootenay Lake (Meadow Creek), British Columbia.

Because angling pressure is likely to exhibit less variation within similar time periods, the angling season was divided into three strata. These were:

Stratum I	Weekdays (n=101)
Stratum II	Weekend days (n=35)
Stratum III	Opening day and weekend days with associated holidays (n=11)

Table 1

Kokanee stocking record, Odell Lake 1963-1965

Year	Date of release	No. released[1]	Total pounds	No. per pound	No. marked	Mark
1963	15 May	150,246	757	198	30,326	LV
1963	17 June	149,607	1,336	112	30,040	RV
1964	22 May	150,083	1,129	133	30,000	BV
1965	7-8 June	125,410	765	164	25,082	LV
1965	8-9 July	124,293	1,361	91	25,859	RV

1/ Based upon subsample of fish-per-pound.

To estimate angling pressure on the lake, instantaneous boat counts were made at two-hour intervals from 8 A. M. until 6 P. M. on randomly selected days in each stratum. These counts provided data for estimating total pressure. On all other census days, a 10 A. M. and 6 P. M. boat count was made. Boat counts were made from Burly Bluff, a high rocky ledge on the west end of the lake. A 7 by 50 binocular was used to locate distant boats.

The area under the total pressure curve for a given stratum was computed by the trapezoidal formula:

$$\text{Area} = h\ (1/2(yo + yn) + y_1 + y_2 = \ldots.yn\text{-}1)$$

Where: h = 2 and y = number of boats counted for the given two-hour interval.

The area under the pressure curve (P) was then divided by the 10 A. M. plus 6 P. M. boat counts (p) for the same stratum. The quotient is an index ratio (I) of total boat counts to the combined 10 A. M. and 6 P. M. boat counts.

Algebraically the estimates were obtained as follows:

$$\frac{(P)}{(p)} = I \ :\ (I)\ (C) = A \ :\ \frac{(A)}{(B)}\quad (X) = E\ :\ \frac{E}{n} = \bar{E}\ :\ (\bar{E})\ (N) = TE$$

Where: P = area under total pressure curve for a given stratum

p = 10 A. M. plus 6 P. M. boat counts for a given stratum

I = index count

C = combined 10 A. M. and 6 P. M. boat counts for a given census day

A = total estimated boat hours for a given census day

B = total boat hours obtained from angler interviews for a given census day

X = variable expanded, such as angler hours, number of kokanee, etc.

E = estimate of X variable for a given day i.e. expanded X

$\frac{E}{n}$ = mean E computed for days censused in a given stratum (i.e. $\bar{E}$)

n = total days sampled in a given stratum

N = total number of days in a given stratum

TE = total estimate of variable X for a given stratum

A 95 percent confidence interval was computed for the total kokanee catch. The sample variance for the total catch for all strata combined (S^2) was first computed in the usual manner. This was multiplied by the quotient of $(\frac{N^2}{n})$, the product being the expanded total variance Vi. By formula: $(\frac{N^2}{n})(S^2) = Vi$.

Where N = total days in season

n = total days of season sampled

S^2 = sample variance of kokanee catch for all strata

Vi = estimated total variance for all days in the season

The confidence interval was then computed by the formula

$$CI = TE \pm t.05 \left| \frac{Vi}{n} \right|^{1/2}$$

A final expansion was to multiply the estimated number of marked kokanee in the catch by 5 (the ratio of marked to unmarked hatchery kokanee) to find the total estimated number of hatchery kokanee in the catch.

Collection of kokanee

The collection of young-of-the-year kokanee was made at night with a midwater trawl as described by Fortune (1964) and Campbell (1965). In 1965, trawling was confined primarily to the west end of the lake. Ten minute trawls were made at the surface, at 20 feet and greater than 60 feet in depth. Trawling speed was determined by placing two buoys 400 feet apart in mid-lake. The trawl was towed past the buoys and the time recorded. The surface trawl speed was 4 feet per second (2.7 mph) while the sub-surface trawls were 3.6 feet per second (2.4 mph).

A monofilament "curtain" gill net 50 feet wide and 100 feet in depth (Campbell, 1965) was also employed to capture kokanee in a study of vertical distribution. It is divided into four 25 by 50 foot panels with stretched mesh sizes ranging from 0.75 to 2.5 inches. Nylon experimental gill nets measuring 100 by 6 feet were set along the shoreline for two days in late August to capture maturing kokanee.

Mature kokanee on their spawning run were captured in Trapper Creek with a wire-mesh trap supported by steel posts. Fish were inspected for marks, sex, and except in a few cases when caudal fin tissue was missing they were measured to the nearest millimeter (fork length). Weights were taken from as many kokanee as time would allow. Eggs were collected from a sample of females for fecundity studies.

Kokanee spawning along the lakeshore were collected by gill net and seine. They were inspected for marks and a representative sample weighed. In Odell Creek the measurement of spawning kokanee was a special problem because of rapid caudal fin decomposition. Consequently, surveys in the stream were made only to examine dead or spent kokanee for marks.

Temperature

A vertical temperature series, at five-foot intervals, was taken at selected times from May 28 to November 3 with a thermistor. In Trapper and Odell creeks the temperature was taken almost daily with a pocket thermometer from late August until early November.

Scale collection

In order to assist with future age and growth studies, the length at which young kokanee first form scales and the area on the fish where scales should preferably be collected were determined from kokanee captured in the trawl and gill net. Scales were differentially stained from the surrounding tissue with Alizarin Red. A binocular dissecting scope was used to locate scales and count circuli.

Length and weight

Length-weight relationships were computed separately for immature and mature kokanee. Immature kokanee were arbitrarily considered to be less than 20 centimeters in fork length. For them a logarithmic regression was computed.

In 1965 there were two discrete spawning groups of kokanee in Odell Lake. One was primarily of hatchery origin from the 1963 and 1964 liberations and the other was unmarked. Analyses of variance and covariance were used to compare them.

Results

Creel census

Of the 3,394 anglers interviewed, 95 percent (3,224) were fishing for kokanee. The remaining 5 percent were seeking either lake or rainbow trout. A few Dolly Varden trout were observed in the catch, but they were taken incidently by kokanee or lake trout anglers. The results of the 1965 creel census are summarized in Table 2. In the season's catch of 63,353 kokanee, a total of 14,412 (22.7 percent) was of hatchery origin. Fish from the liberation of June 17, 1963 (RV mark) constituted 75 percent of the total catch of hatchery fish. The group stocked May 15, 1963 (LV mark) contributed 17 percent, and the group liberated May 22, 1964 (BV mark) comprised only 8 percent of the catch. The 1964 group (BV mark) did not enter the fishery until about mid-June of 1965. Kokanee from the 1963 liberations (RV and LV marks) were in the fishery at the beginning of the 1965 season. The only known differences between the two 1963 liberations were size and time of stocking (see Table 1). It is concluded that the two factors had an effect upon survival, since the two groups appeared in the catch at a ratio of 4.3 RV to 1 LV.

The 95 percent confidence interval of the total catch (58,519 to 68,187) is within 7.6 percent of the estimated catch of 63,353. The creel census was conducted on 65 of the 147 days in the season.

The mean pressure curve for each stratum is shown in Figure 2. Thirty percent of the total angling pressure was exerted during Stratum III (holidays) which comprised only 7.5 percent of the total angling season. The abrupt drop in angling pressure during the afternoon period was due to wind action which made boating hazardous. The greatest angling pressure for Strata I (weekdays) and III was exerted at 10 A.M. For Stratum II (weekends) the greatest angling pressure was at 12 noon, although the pressure at this time was not greatly different from that of 10 A.M.

Table 2

Summary of creel census results, Odell Lake, 1965

	I Weekdays	II Weekends	III Holidays	Total
Total angler hours	33,546	48,320	34,892	116,758
Total boat hours	15,118	18,760	12,366	46,244
Total anglers	10,507	11,683	8,888	31,078
Proportion angling for kokanee	0.93	0.95	0.96	0.95
Total boat parties	4,580	4,659	3,207	12,446
		Kokanee statistics		
Total catch of kokanee	17,454	27,089	18,810	63,353
95 percent confidence interval of kokanee			58,519 to 68,187	
Hatchery kokanee				
May 17, 1963 release(LV)	645	1,253	613	2,511
June 15, 1963 release(RV)	2,490	5,198	3,067	10,755
May 15, 1964 release(BV)	389	429	328	1,146
Total hatchery kokanee in catch				14,412
Percent hatchery kokanee in catch				22.7
Angler hours	31,319	45,682	33,434	110,435
Boat hours	14,114	17,735	11,849	43,698
Anglers	9,809	11,045	8,516	29,370
Boat parties	4,276	4,405	3,032	11,713
Length of angler trip(hours)				3.76
No. of anglers per boat				2.51
No. of kokanee per angler				2.15
No. of kokanee per hour				0.57

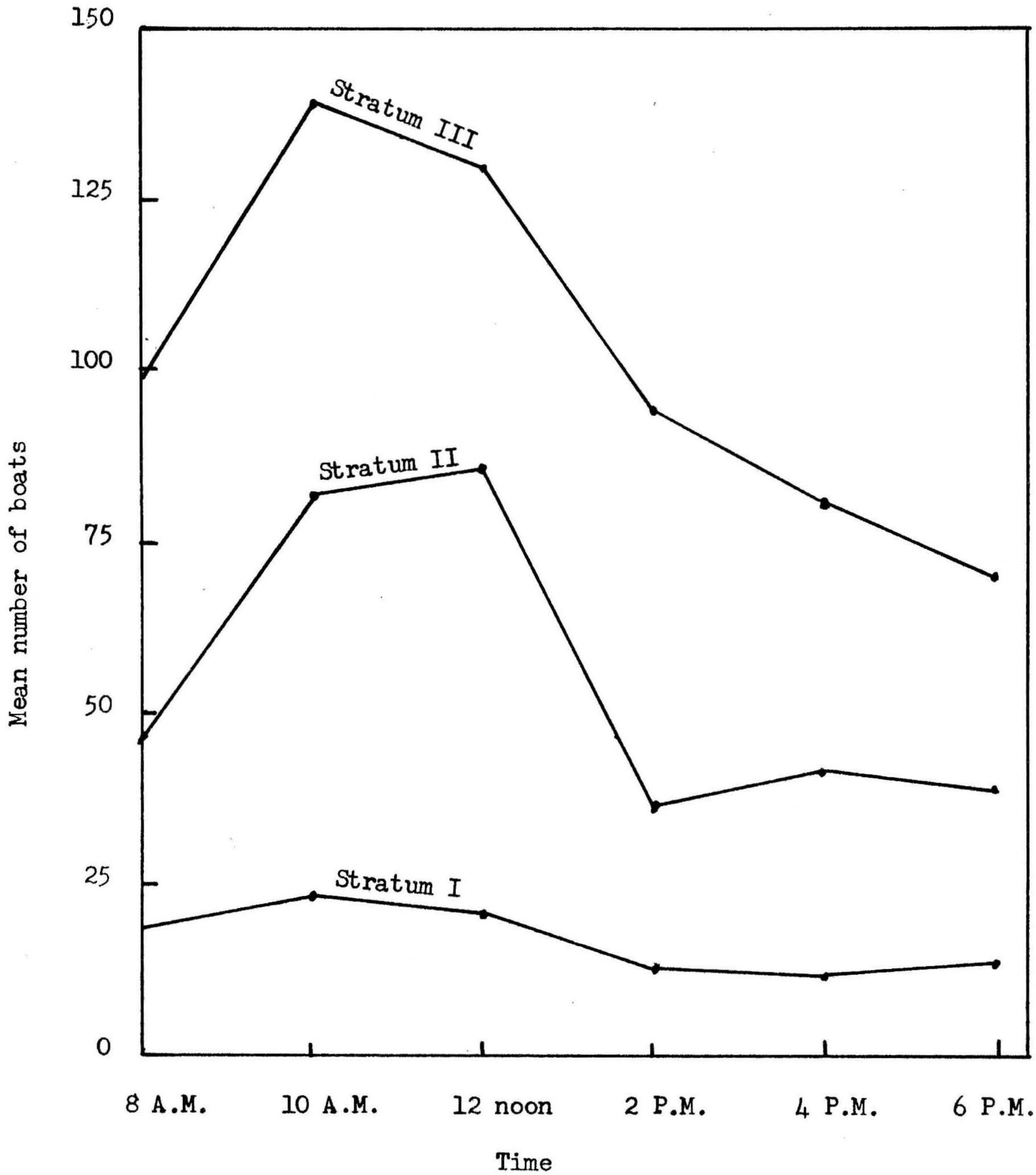

Figure 2. Mean pressure curves for the three strata of the Odell Lake creel census (1965).

Length frequency of angler catch

A downward shift in the length-frequency of the angler catch occurred in 1965. As the season progressed the length-frequency of kokanee became bimodal and a major shift in the catch to kokanee of smaller lengths was apparent. Figure 3 shows a sample of the length-frequency of the angler catch divided into four-week periods.

Weight-length relationships of immature kokanee.

It was not possible to examine gonads for maturity on all kokanee and, even if it were, no criteria have been developed for predicting year of maturity in immature fish. Therefore, in computing the regression of weight on length for immature kokanee it was necessary to make an arbitrary decision concerning the upper length boundary. For this report immature kokanee are considered to be those fish 20 centimeters or less in fork length. A sample of 464 kokanee was grouped into 0.5-centimeter length intervals and the mean weight and length of each interval used to calculate the regression line. When less than two kokanee were available for a given interval, the data were omitted.

The regression line was computed to be: log weight = (8.00768 -10) +3.0010 log length. Figure 4 shows the calculated regression line plotted on log-log paper, with the relationship of the points to this line.

Early scale development

Based on a sample of 14 fish it was found that Odell Lake kokanee form scales at a fork length of 35 millimeters. Scales first appear immediately above and below the lateral line between the insertion of the dorsal fin and origin of the adipose fin. Scale development is complete at about 43 millimeters.

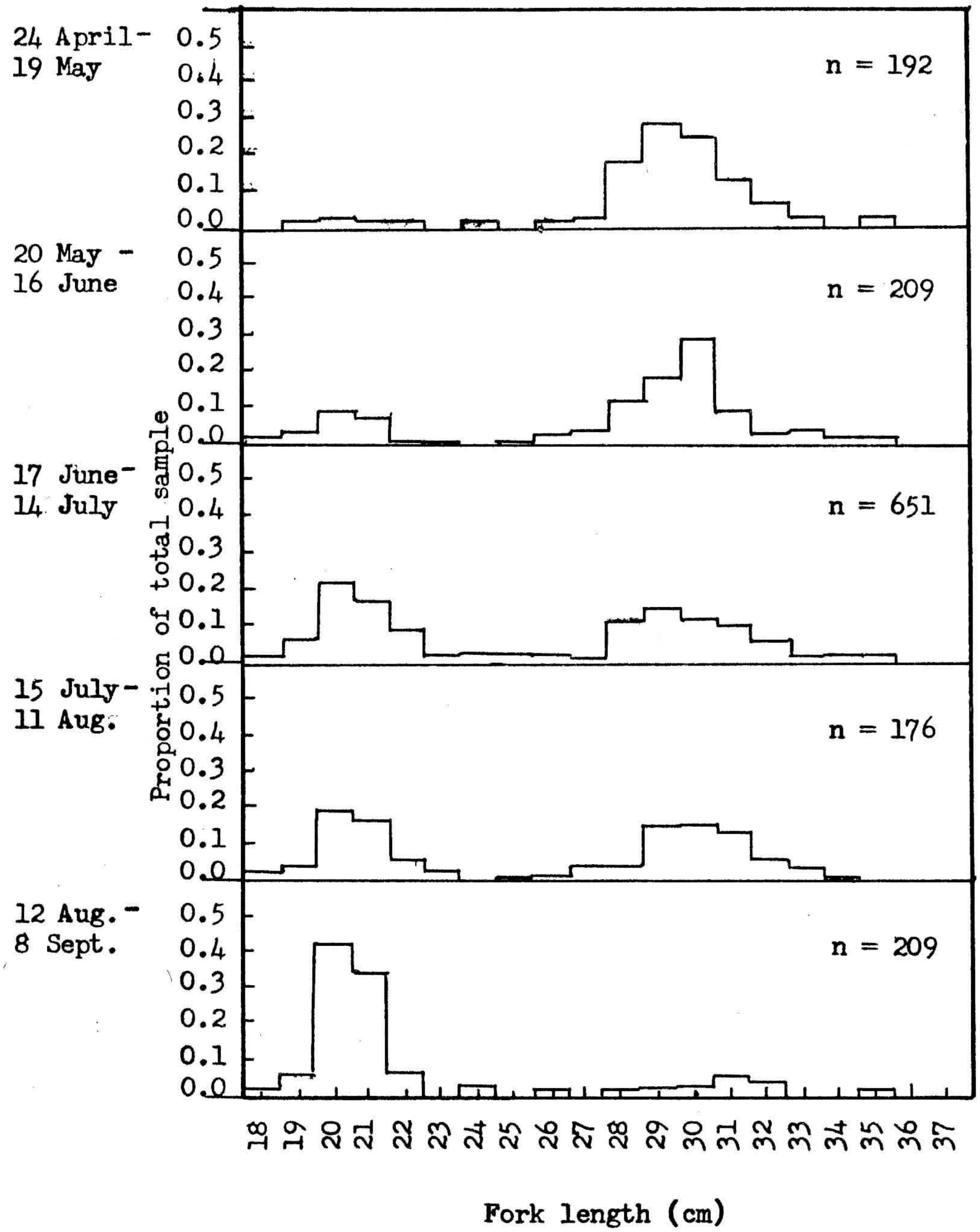

Figure 3. Length frequency of angler catch by proportion for five time periods. Odell Lake, 1965. N = 1437

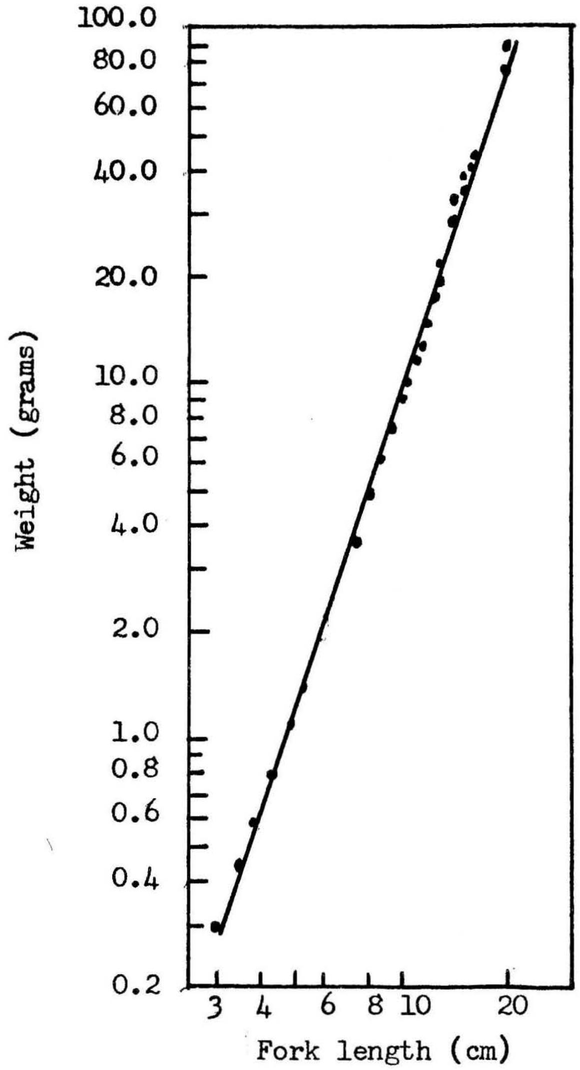

Figure 4. Weight-length relationship of 464 immature kokanee, Odell Lake, 1965 expressed by the formula
$\log W = (8.00768 - 10) + 3.0010 \log L$

Scales from the left side of two kokanee (105 and 113 mm F.L.) were examined to substantiate scale pattern determinations on young-of-the-year kokanee. The circuli on every fourth scale in a quadrilateral were counted, and the mean number of circuli computed. The results are shown in Figure 5. Because scales used for age and growth analysis should be the most mature scales on the fish, the following criteria were developed.

(1) Scales should be collected within the first four rows either above or below the lateral line in the area immediately posterior to the dorsal fin. For uniformity, they should be collected from the left side.

(2) When using the direct proportion method to back-calculate length at a given annulus, the correction factor should be 35 mm.

Growth of first year wild kokanee

The summer growth of wild 0-age kokanee is shown in Figure 6. The data presented are from surface trawls only. Trawl catches from below the surface were not analyzed in 1965 because they were not consistent. On some dates it was possible to catch fish at all depths, on others it was not. Campbell (1965) has shown an apparent difference in mean length between first-year kokanee caught at the surface and those caught at greater depths. When additional samples are available, a statistical comparison between mean length of fish caught at various depths will be possible.

Vertical distribution of kokanee

Limited studies on the vertical distribution of kokanee were made in 1965. The present data are not conclusive, and additional samples are needed.

The curtain gill net was set 10 times in 6 locations from July 1 to November 2. The net was moved about in the lake in an effort to find

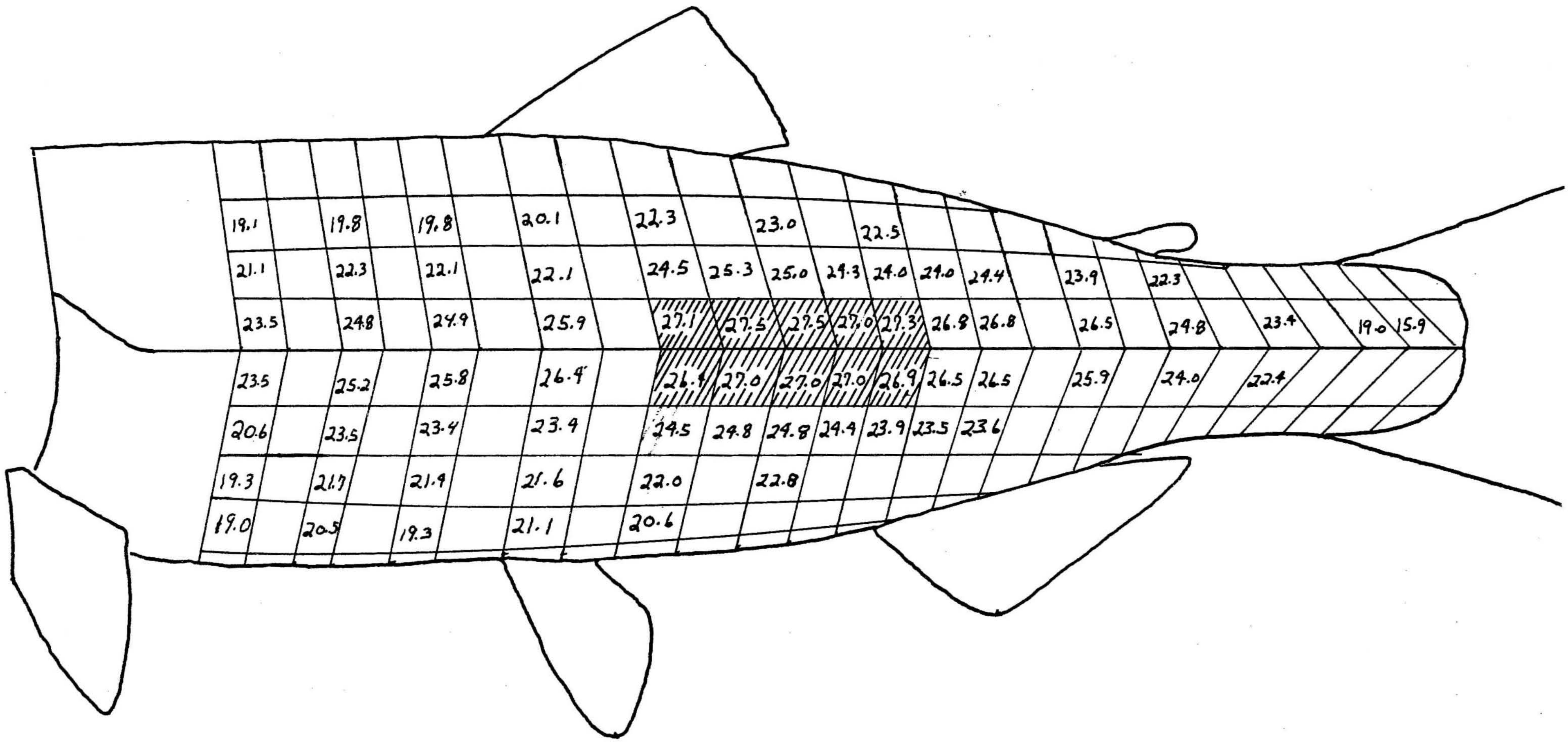

Figure 5. Schematic drawing showing mean number of circuli on every fourth scale in a quadrilateral from two kokanee (105 and 113 mm F.L.). The area darkened by oblique lines shows where scales should be collected.

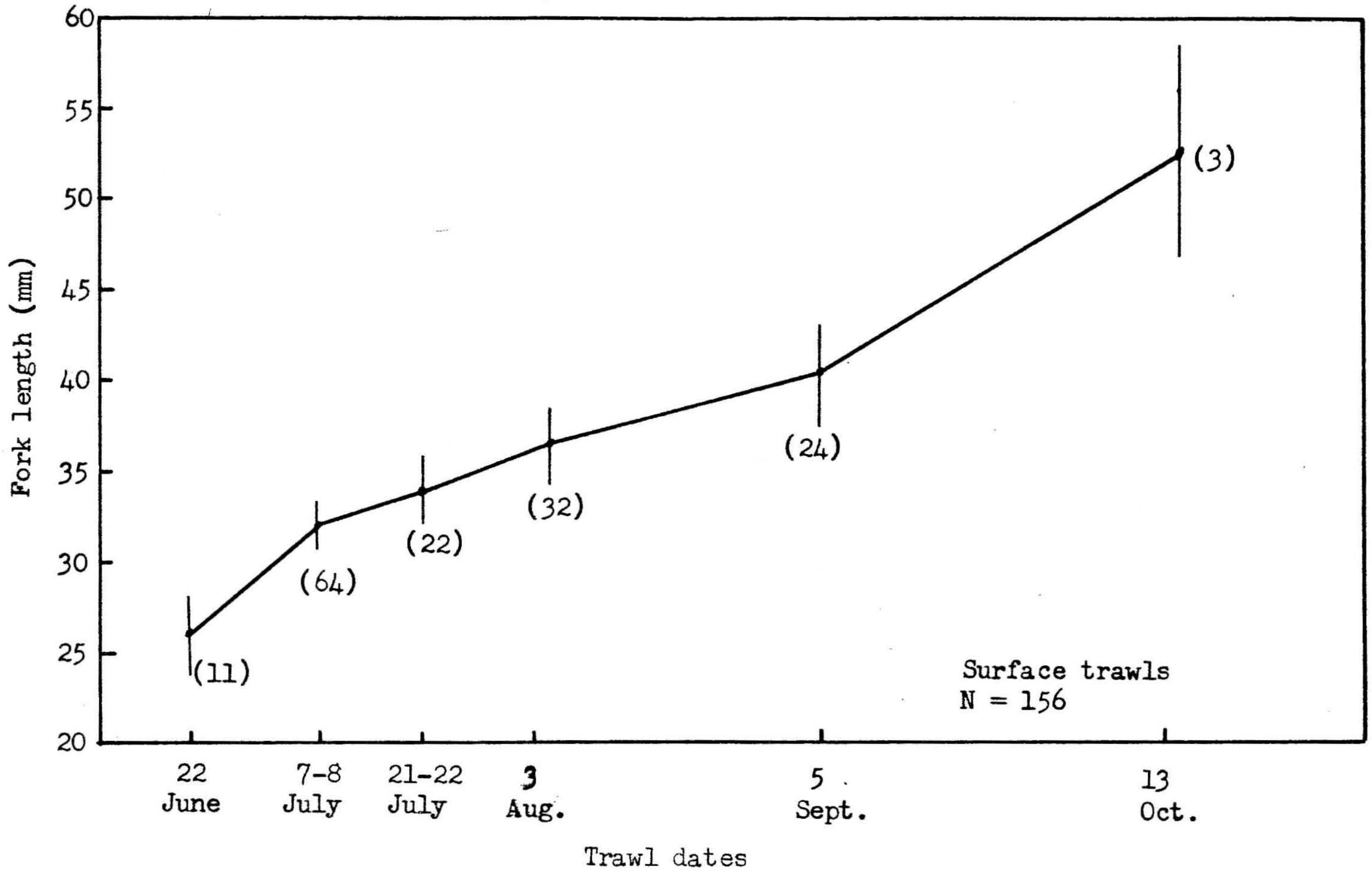

Figure 6. Mean length of first year wild kokanee captured by surface trawl, Odell Lake, 1965. Vertical line is 95 percent confidence interval. Number in parenthesis is sample size.

concentrations of kokanee. Figure 7 shows the length-frequency of kokanee taken in each 25-foot panel. The data are too meager for statistical treatment. It is interesting to note the paucity of kokanee in the length range of 13 to 23 cm. The normal set with the curtain gill net is from the surface to 100 feet in depth. On August 10, the net was set from 50 to 150 feet in depth. Kokanee were taken only in the upper two panels between 60 and 100 feet from the surface.

Of the 246 kokanee captured in the net, only seven were marked. One was from the 1963 release (RV) and the remaining six had been stocked in 1965.

Forty-seven individual trawls ranging from 7 to 20 minutes each were made in 1965 and 538 kokanee captured. Trawling was principally confined to the western third of the lake. The prevailing winds at Odell Lake are from the west, and often the eastern half of the lake is too rough for the operation of trawl gear.

Fortune (1964) and Campbell (1965) captured more fry on the surface on moonlight nights than on dark nights. For the 1965 data no comparison is made because the data were too meager for meaningful conclusions. The factors concerning fry distribution with light are discussed in another section.

Only three kokanee of the 538 captured in the trawl were marked. The ratio is not surprising, as trawl catches usually consisted of wild 0-age fish. In 1965, 420 of the 538 fish captured in the trawl were fish of this age group. Although there were 0-age hatchery kokanee in the lake after July 8, none were captured with the trawl, probably because of the greater size of 0-age hatchery fish and their consequent probable avoidance ability.

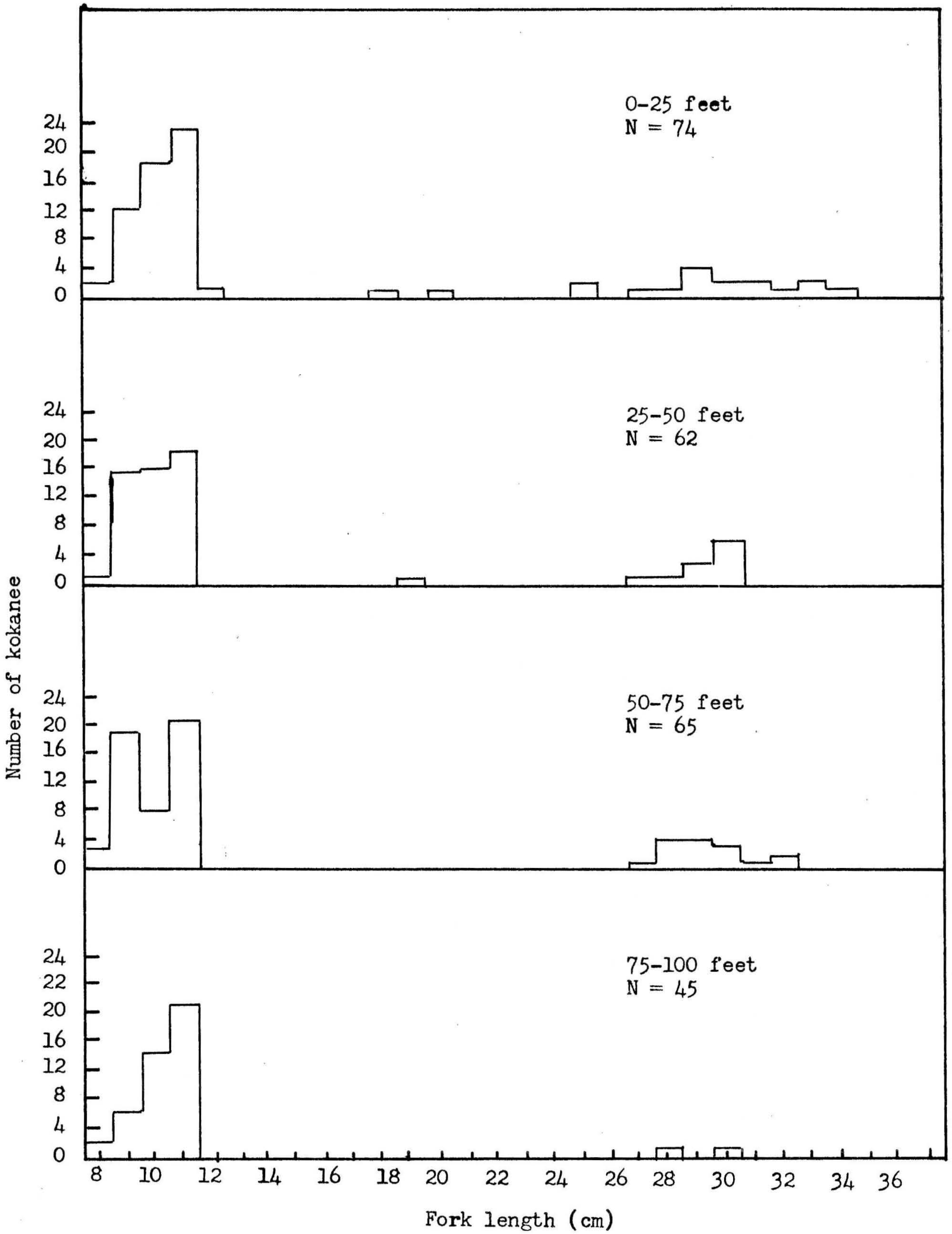

Figure 7. Length frequency of kokanee caught in 25-foot sections of curtain gill net, Odell Lake, 1965 (data from nine sets).

Temperature

Temperature profiles of Odell Lake were taken from the surface through the thermocline on selected dates from May 28 until November 3. Figure 8 shows seven profiles taken 300 yards offshore from Burly Bluff. Fortune (1964) found a 24-hour variation in thermocline position which he attributed to wind action. A similar phenomenon was found in 1965. The temperature profiles reported here were taken at mid-day to eliminate the variable. Although surface and thermocline temperatures varied widely with the season, water temperature at 100 feet in depth or greater did not vary more than 2.4°F. The position of the thermocline is shown in Figure 9. The greatest thermocline width was on July 28. As the season progressed, the thermocline became narrower and exhibited a downward shift.

Water temperatures were taken between 9 A.M. and 12 Noon on Odell and Trapper creeks from September 1 to November 2 (Figure 10). A wide temperature difference is apparent between the two streams and is attributed to their water sources. Odell Creek flows directly from Odell Lake, whereas Trapper Creek receives snow melt from higher elevations. Since kokanee spawned in the streams, temperature data are important.

Mature kokanee

There were two distinct groups of spawning kokanee in Odell Lake in 1965. They are here designated as Group I and Group II. They were separated by the presence or lack of hatchery marks, and the time of spawning. In addition, Group I spawned in two streams and a lakeshore area. Group II spawned only in the lakeshore area. To further define the two groups, parameters were computed around their mean lengths and weights. The parameters were mean length with 95 percent confidence interval and analysis of variance tests

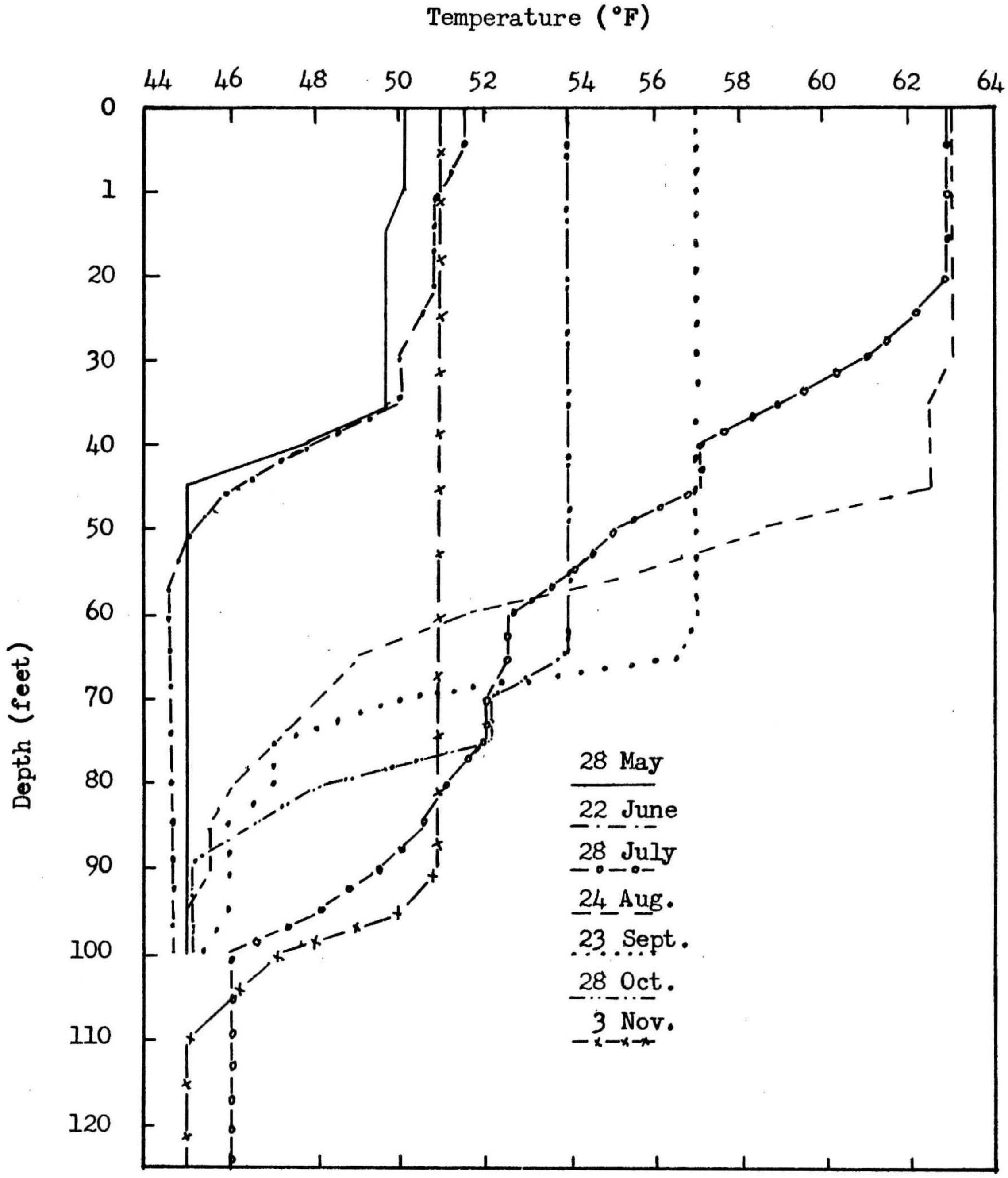

Figure 8. Selected temperature profiles of Odell Lake 1965. Data collected near Burly Bluff.

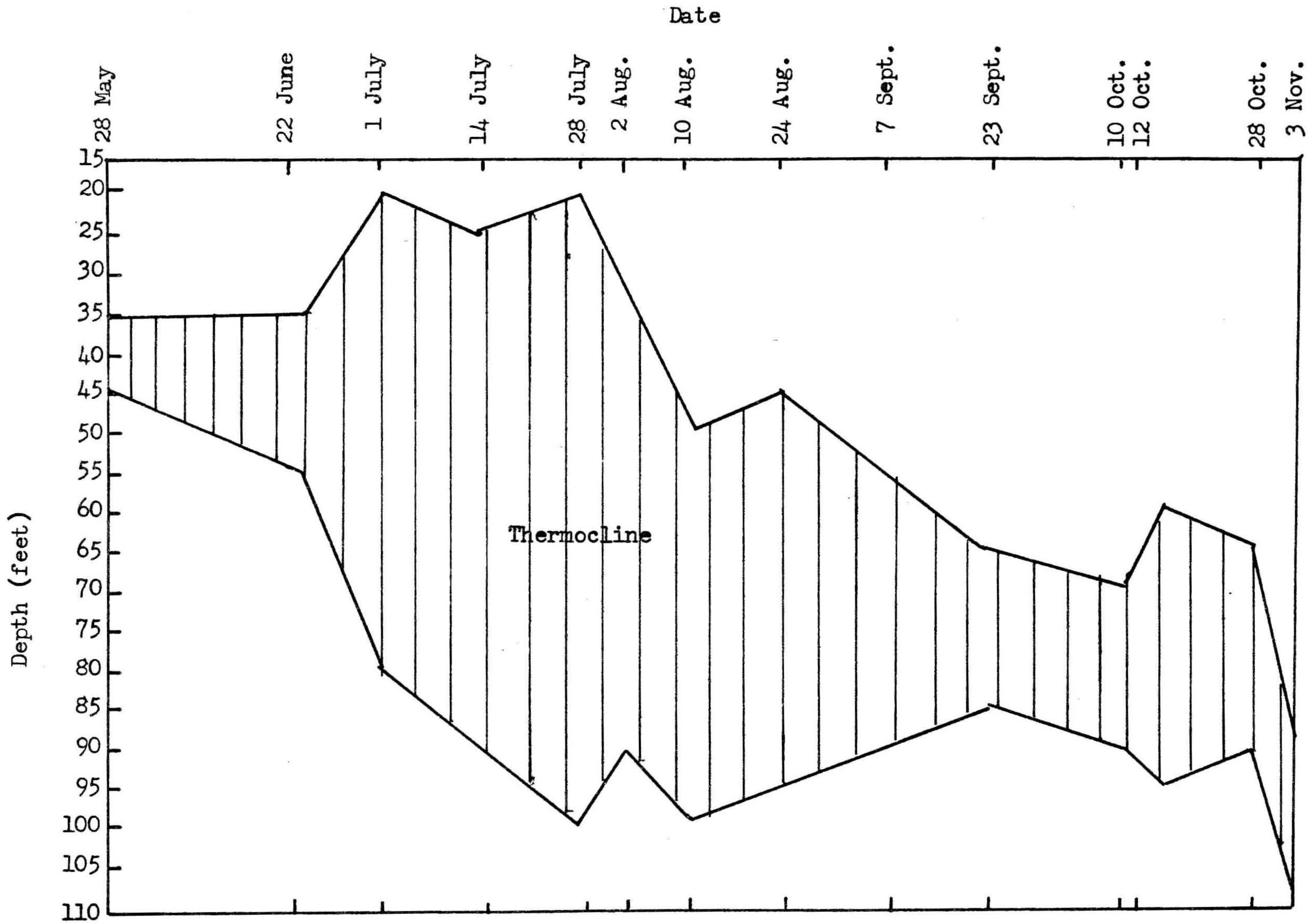

Figure 9. Thermocline position from 28 May to 3 November. Odell Lake, 1965.
Data collected near Burly Bluff.

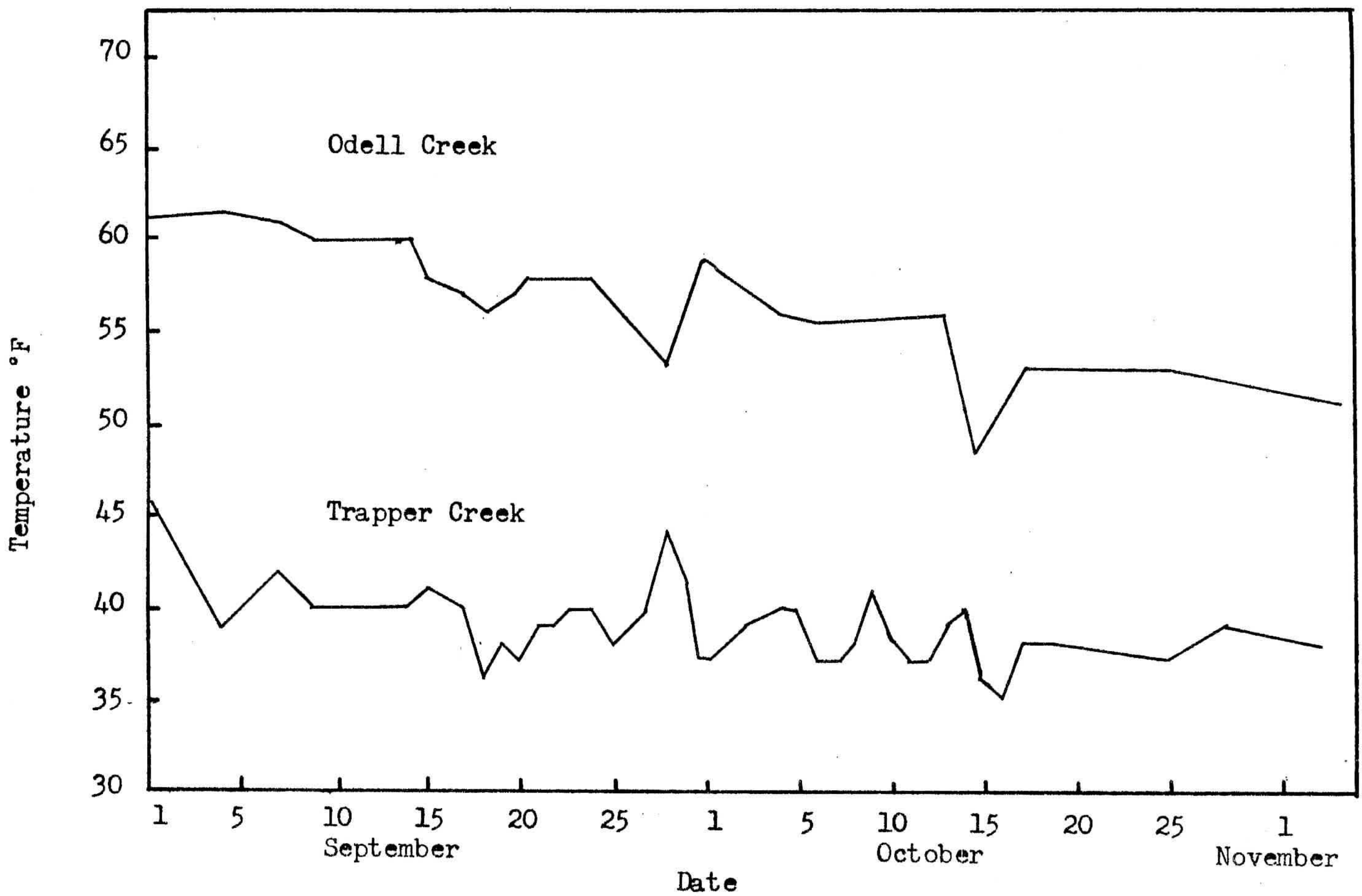

Figure 10. Fall temperatures of Odell and Trapper creeks, Odell Lake, 1965. Temperatures taken between 9 A.M. and 12-Noon.

between the mean lengths of males and females within each group. In addition, a regression of weight on length was computed. This permitted analysis of covariance tests to compare males and females of each group and males and females of the separate groups. All tests were made at the 0.05 probability level. The two hypotheses tested with analysis of covariance were:

(1) Hypothesis A (H_A): There is no significant difference between the regressions of weight on length for the two sexes and the data will fit a common regression line. By formula: $E(Y_{ij}/X_{kj}) = \alpha + \beta (X_{ij} - \bar{X}_{..})$.

(2) Hypothesis B (H_B): There is a significant difference between the regressions of weight on length for the two sexes but the regression lines are parallel. By formula: $E(Y_{ij}/X_{ij}) = \alpha i + \beta_i (X_{ij} - \bar{X}_{i.})$. This of course refers to equal slopes, $\beta_I = \beta_2 = \cdots \beta_n$.

Each group will be discussed separately and then a comparison will be made between them.

Group I

Kokanee of Group I spawned from mid-September to early November. Of 1,265 examined, 1,025 or 81 percent were estimated to be from the 1963 and 1964 hatchery liberations. Fry from these liberations were from parent stock of Kootenay Lake (Meadow Creek), British Columbia.

The first indication of maturity for Group I occurred on August 10 when three red kokanee were captured in the curtain gill net. Later, on August 22, approximately 30 maturing kokanee were observed in Odell Creek near the lake outlet.

On the nights of August 25 and 26 eight experimental shoreline gill net sets captured 385 kokanee. With few exceptions, all were red. Expanding the number of marked kokanee in the net catch (x5) it was estimated that 340 of 385 fish (88 percent) were of hatchery origin. The gill nets were set in 3 to 30 feet of water with one end in contact with the lakeshore.

Two important factors were revealed by these kokanee. First, although displaying color, they were not immediately ready to spawn. Eggs were still held firmly by the ovarian membrane and sperm from the males could not be expressed. Second, they had left the fishery and were moving about the shoreline of the lake, possibly seeking a spawning area.

Group I kokanee spawned in three areas: Odell Creek; Post Office shoreline (hereafter called Post Office area); and Trapper Creek. In 1964 many spawning kokanee were observed in Crystal Creek (Campbell, 1965) but there were none observed there in 1965. The number of hatchery-reared kokanee in the spawning runs was estimated by multiplying the number of marked kokanee observed by a factor of 5.

Group I kokanee were actively spawning in Odell Creek by mid-September. Surveys made on September 28 and October 6, 10, 13 and 14 revealed them to be dispersed the entire length of the stream (13 miles). Of 215 examined for marks, 170 (79 percent) were estimated to be of hatchery origin. Sixty-five of these 215 were collected near Davis Lake (mouth of Odell Creek). The presence of marks revealed that 55 of the 65 kokanee were of hatchery origin. The greatest spawning concentrations appeared to be in the upper two miles of the stream near Odell Lake. Preferred spawning areas were the slower flowing riffles near the stream edge. No measurements of stream velocity were made. Spawning in Odell Creek was virtually complete by mid-October. A survey on October 28 revealed no live kokanee in the stream.

While some kokanee from Group I were spawning in Odell Creek, others of the same group were spawning at the Post Office area.

Collections in this area were limited to dead kokanee which had washed towards shore. Of 45 dead kokanee examined, 9 possessed the hatchery mark. Expanding this figure (x5) would theoretically indicate that all were of hatchery origin. This might not be realistic because of the small sample size. It is indicative that a high percentage of the kokanee spawning in this area were of hatchery origin. The spawning of Group I kokanee at the Post Office area was complete by November 10 when there were less than 25 spent kokanee present. Redd excavation was limited to an area of approximately 200 feet along the shoreline and 50 feet into the lake. A small stream (less than 0.25 cfs) enters the lake here. It is not known that the stream water attracts spawning kokanee, or if a series of underwater springs are present.

The third spawning area used by Group I kokanee was Trapper Creek. A wire mesh trap was installed 150 feet above the mouth of the stream on September 15, and maintained until November 15 (61 days). A total of 620 kokanee entered the trap of which 470 (76 percent) were estimated to be of hatchery origin. The trap was checked daily from September 16 until October 20. Thereafter, owing to declining fish movement, it was checked every 3 to 5 days. Kokanee first entered the trap on September 15 and none entered after November 1.

Kokanee usually entered Trapper Creek in the first hour of darkness. Movement into the stream for any one evening was often complete by 10 P.M.

The sex ratio was 1.1 females to 1.0 males or 326 females and 294 males. Figure 11 shows the number of kokanee entering the trap between September 15 and October 20, the period when the trap was emptied daily.

Approximately 0.75 mile above the mouth of Trapper Creek is an impassable falls limiting the area available to spawning kokanee. The greatest

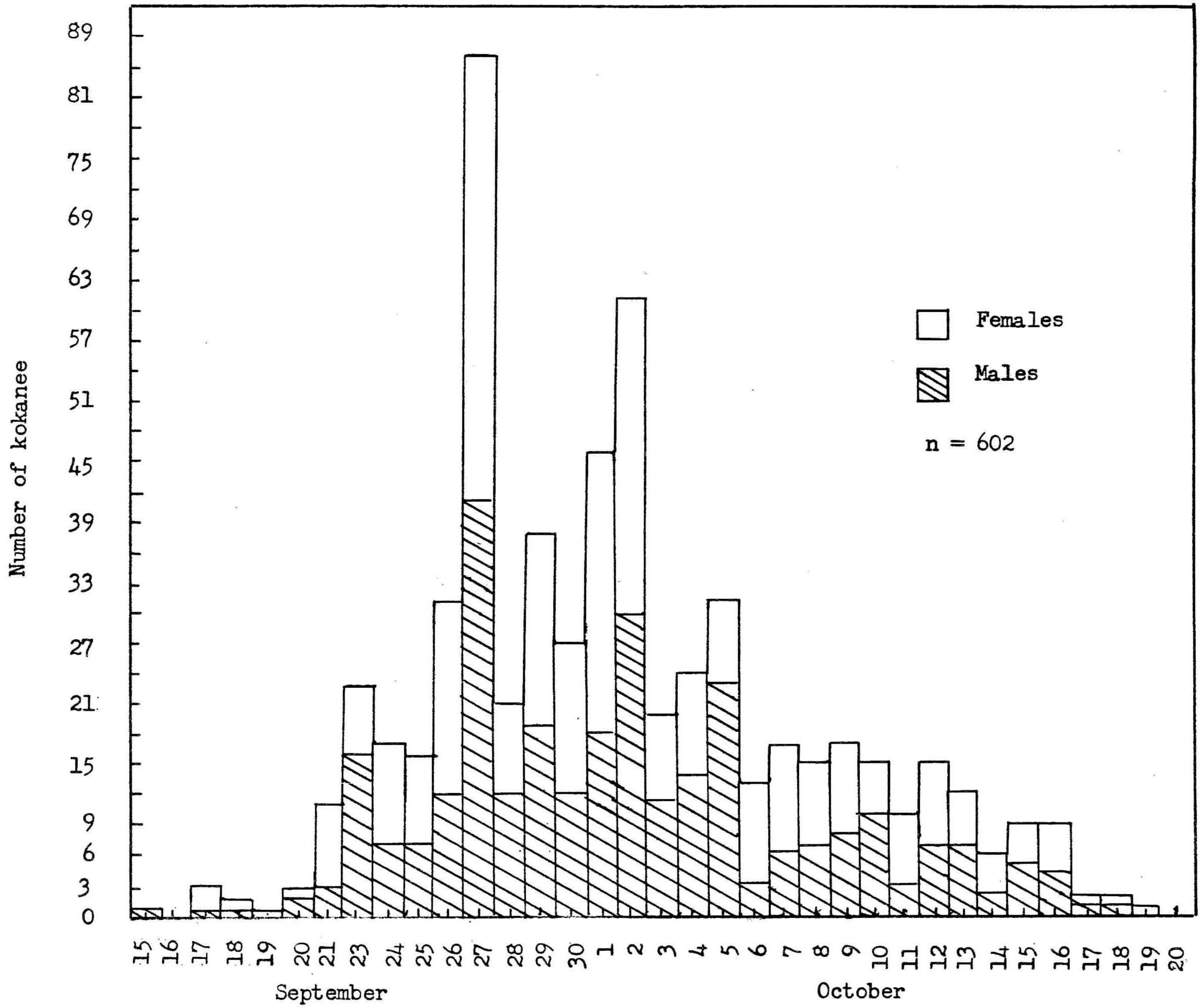

Figure 11. Frequency of kokanee entering Trapper Creek between September 15 and October 20, Odell Lake, 1965.

concentration of spawning kokanee was in the first riffle which is located about 300 feet above the mouth. The trap was located between the riffle and the lake.

A survey of Trapper Creek on October 16 revealed approximately 195 live kokanee in the stream. On November 10, none could be found.

A summary of the collections and marked kokanee for Group I is shown on Table 3.

Table 3.

Number of Group I kokanee observed in Odell Lake and tributaries, 1965

Area	Collection dates	No. observed	Marked fish observed			Expanded mark total	Percent of No. observed
			LV	RV	BV		
Shoreline net sets	August 25-26	385	21	47	0	340	88
Odell Creek	Sept. 28-Oct. 14	215	9	25	0	170	79
Post Office shoreline	October 15-25	45	3	4	2	45	100
Trapper Creek	Sept. 16-Nov. 2	620	18	69	7	470	76
Totals		1,265	51	145	9	1,025	

It should be noted that the 620 kokanee observed in Trapper Creek constitutes all the kokanee that spawned in the stream. In Odell Creek and the Post Office area the number of kokanee observed refers to a sample of the total number.

The greatest spawning concentrations of Group I kokanee were estimated to be in Odell Creek. Trapper Creek was next, followed by the Post Office area.

Although Group I kokanee spawned in three areas, measurements were made only on those fish which ascended Trapper Creek. A total of 620 kokanee entered the stream. The lengths of 597 were measured and 312 were weighed. Length frequency histograms of the combined and separate sexes are shown in Figure 12. The

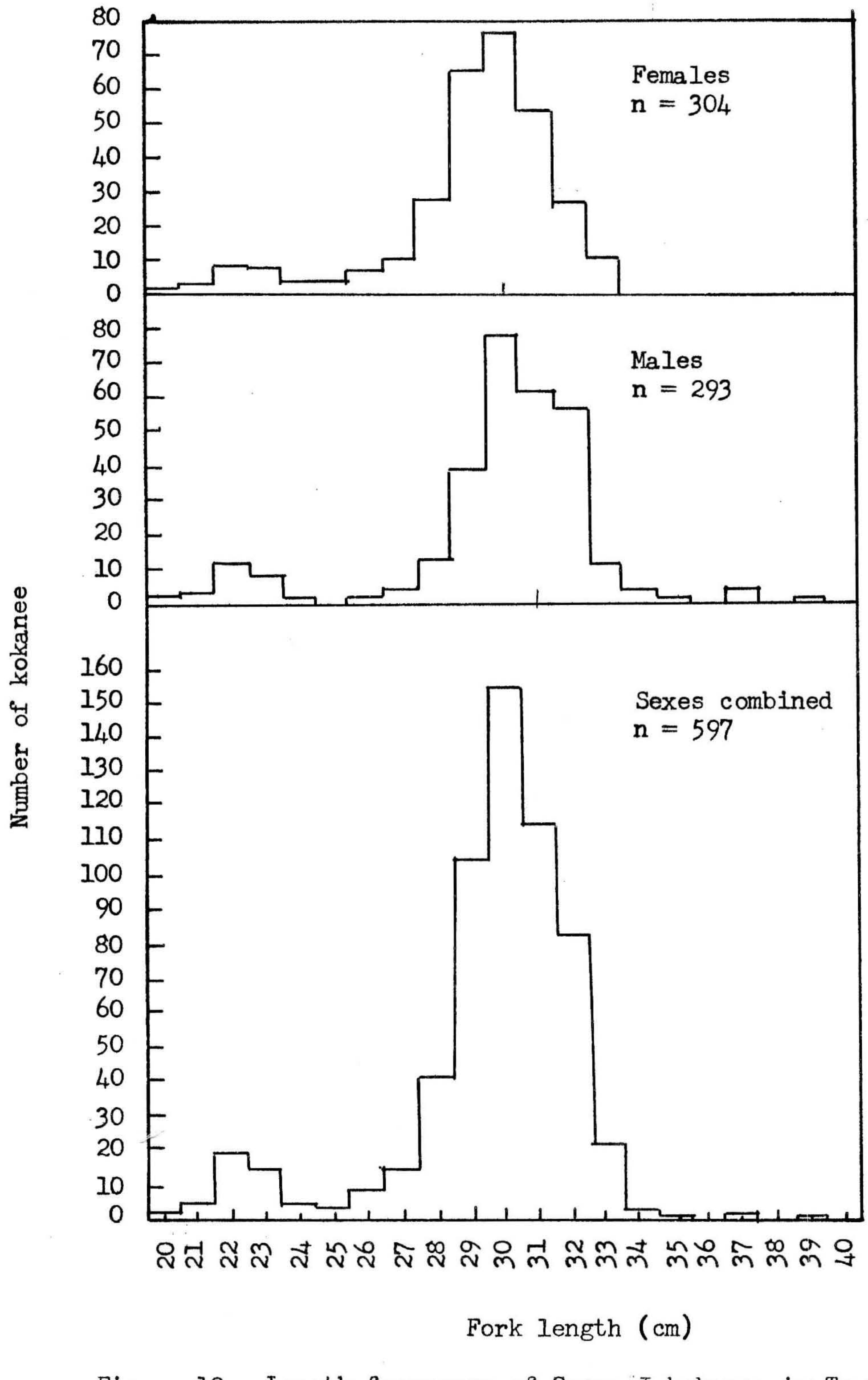

Figure 12. Length frequency of Group I kokanee in Trapper Creek, Odell Lake, 1965.

histograms have a bimodal appearance which reflects the presence of hatchery kokanee from the 1963 and 1964 liberations. The bimodal appearance is further illustrated by Figure 13 which compares the length frequency of the measured marked kokanee to that of the total kokanee. The 1964 fish were in their second year of life (Age Group I +) while the 1963 fish were in their third year (Age Group II +).

Because of the bimodal nature of Figure 12 it seemed appropriate to compute a mean length for each age group. The division between age groups was made at 25 centimeters. Kokanee greater or equal to 25.0 centimeters were considered to be in their third year of life (II+). Those less than 25.0 centimeters were considered to be in their second year (I+). That the division is not entirely arbitrary can be seen from the center and top graphs of Figure 13. Kokanee marked LV and RV had a length range from 25 to 34 centimeters. Those marked BV had a range from 20 to 23 centimeters.

Males of Age Group I+ had a mean length of 22.8 centimeters, while females had a mean length of 22.9 centimeters. The analysis of variance test between mean lengths for the age group showed no significant difference ($F = 0.1585$ with 1,43 d.f.). Male kokanee of Age Group II+ had a mean length of 31.1 centimeters. Females of the age group had a mean length of 30.2 centimeters. The analysis of variance test showed a significant difference between the two mean lengths ($F=47.21$ with 1,550 d.f.).

Figures 14 and 15 show the regression of weight on length for male and female kokanee of Group I respectively, along with the 95 percent confidence interval. In computing the regression no division for separate analysis was made between age groups.

The result of the analysis of covariance tests of H_A and H_B (common and parallel regression lines) show that the regression of weight on length for the

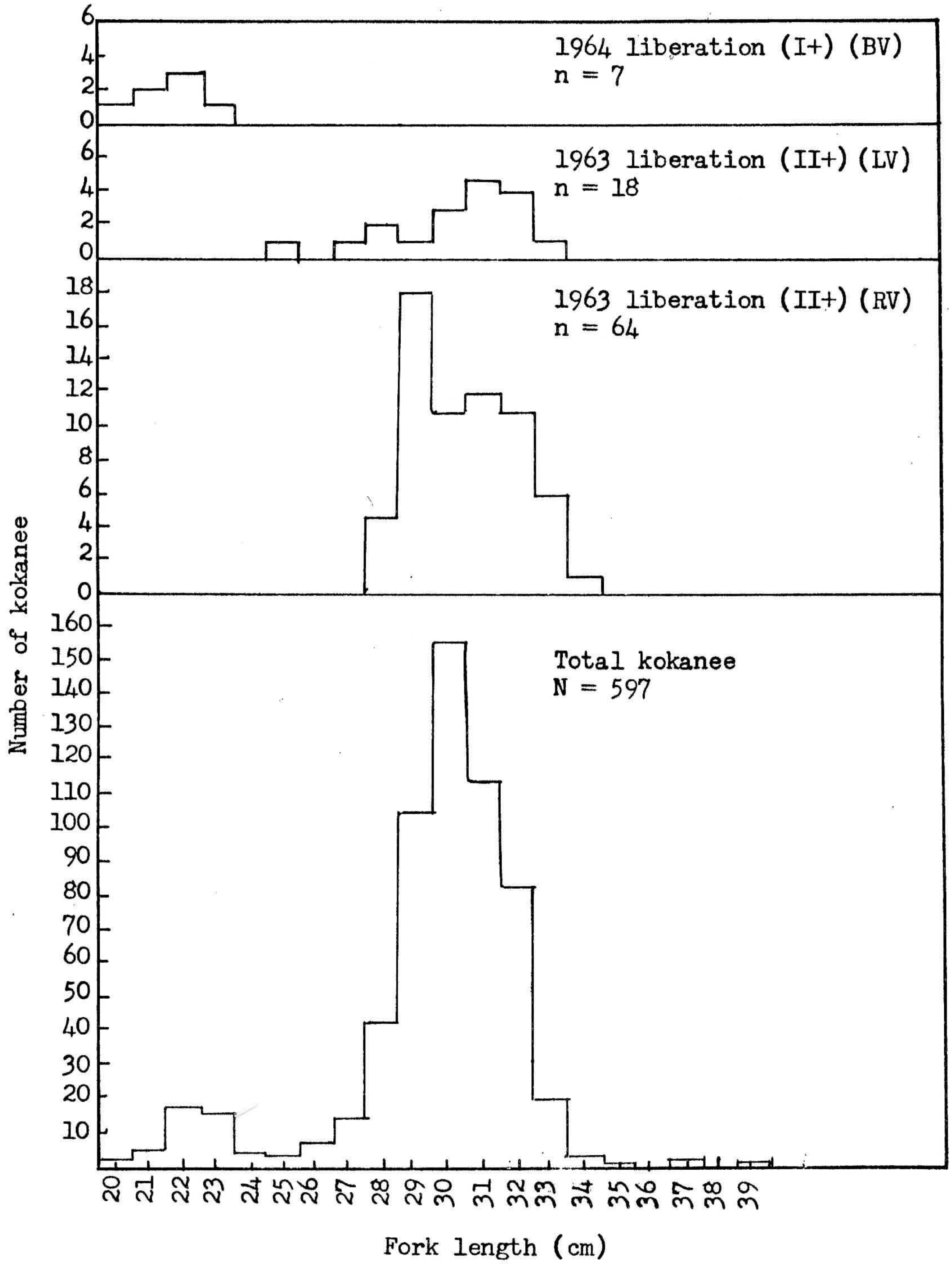

Figure 13. Length frequency of measured mature kokanee captured in Trapper Creek. Bottom graph includes all fish measured. Upper three graphs include marked fish measured.

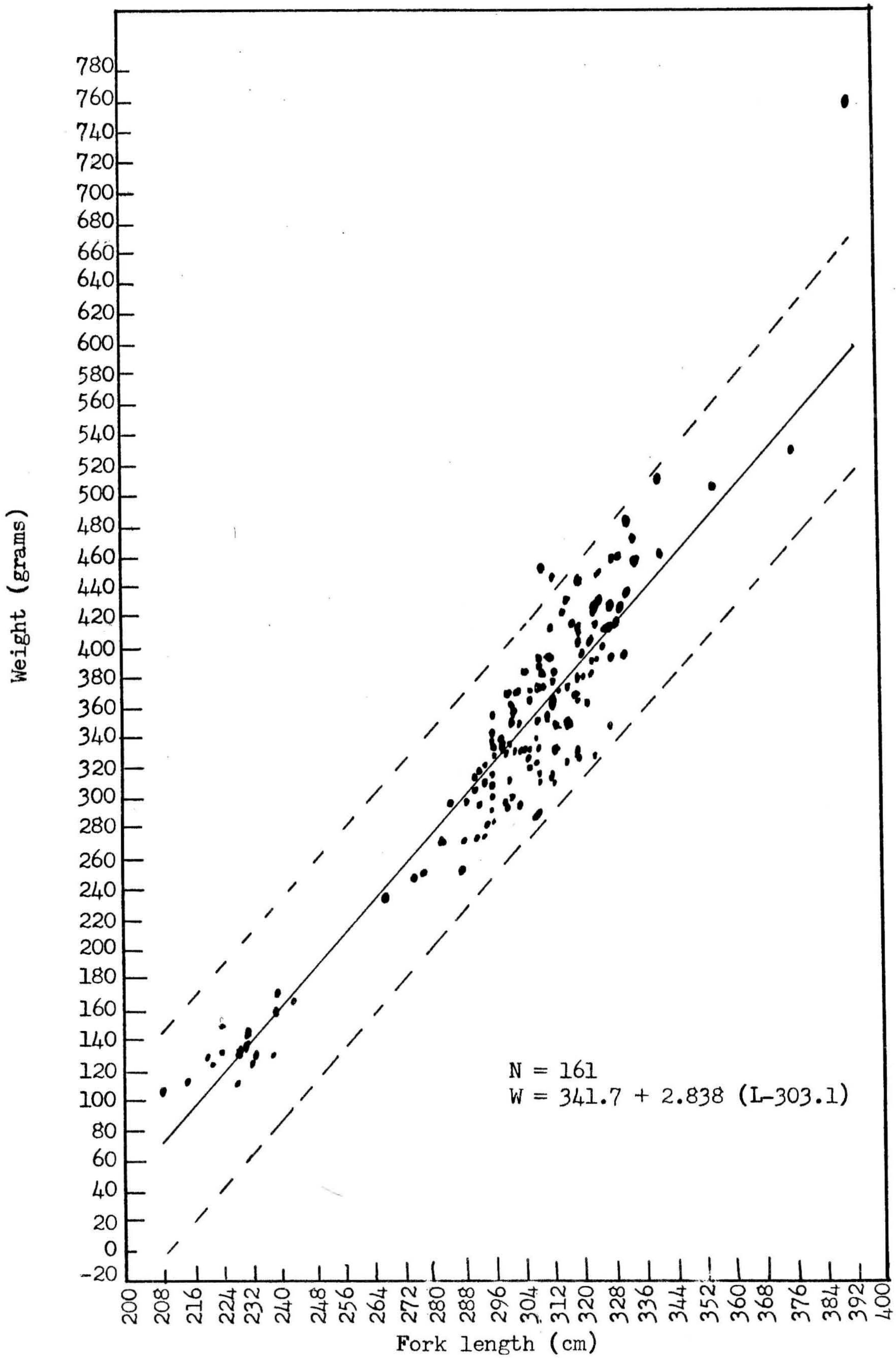

Figure 14. Regression of weight on length for Group I males, Odell Lake, 1965. Broken line is 95 percent confidence interval.

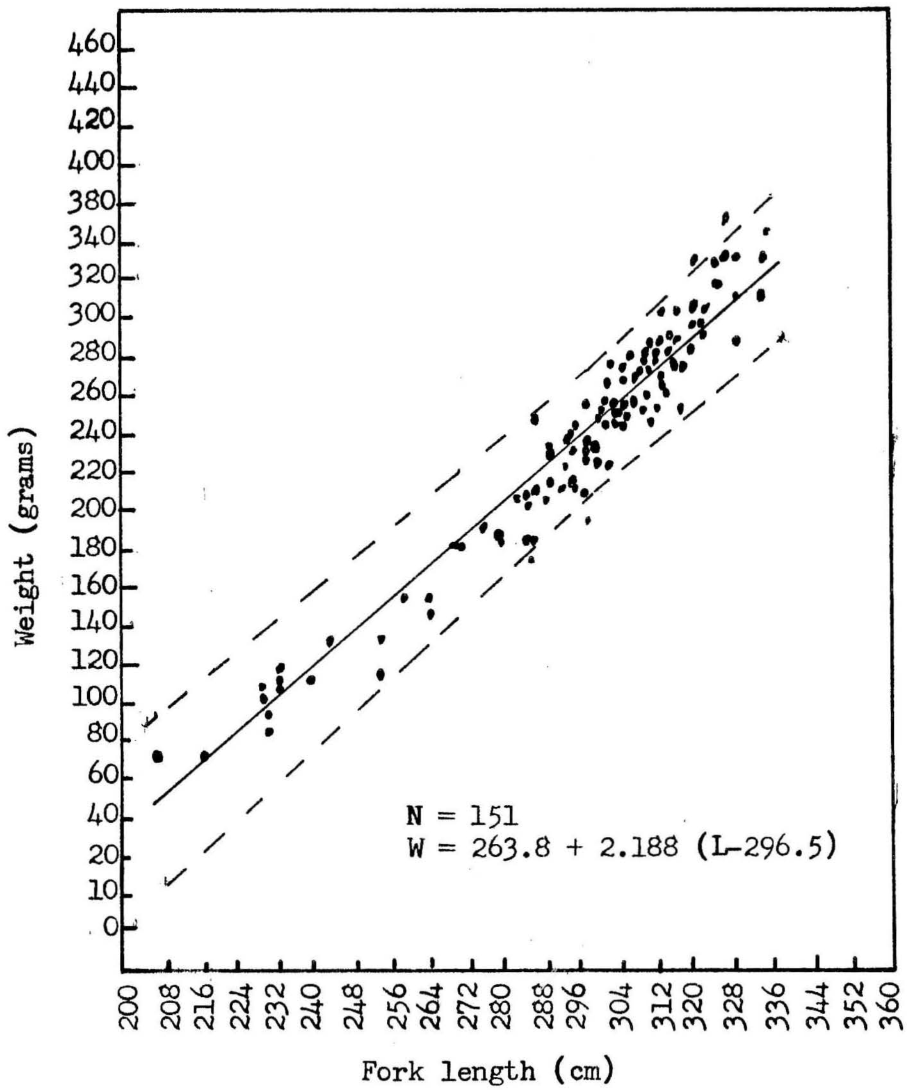

Figure 15. Regression of weight on length for Group I females, Odell Lake, 1965. Broken line is 95 percent confidence interval.

two sexes cannot be fitted by a common regression line, nor are the regression lines parallel (for H_A F=292.29 with 2,308 d.f. and for H_B F=30.73 with 1,308 d.f.). Males had a significantly greater mean weight and length than females. As the males increase in length their weight increases at a significantly greater proportion than that of females.

Group II

For a number of years kokanee have been observed spawning at the Post Office area but only since 1962 has it been possible to separate wild from marked hatchery fish on the spawning grounds.

Mature kokanee of Group II were first observed near the Post Office area on October 28 in a dense school 80 to 100 feet from the lakeshore. They were 30 to 50 feet from the area where Group I had spawned and where a few members of this group were still present. The two groups were distinguishable since the few fish on the spawning redds all had worn caudal fins, appeared spent, and were extremely docile. They were the remaining members of Group I which had its peak spawning period here earlier in October. Kokanee of Group II were not (as previously mentioned) on the spawning redds. Many of the 315 fish captured were ripe, but their caudal fins showed no sign of wear from redd excavation.

A monofilament gill net and a 6 by 200-foot seine were employed to capture a sample of 315 Group II kokanee. Each fish was given an upper caudal lobe clip before it was returned to the lake to insure that the same fish would not be measured or weighed twice. Captures were made on October 28, November 2, 3, and 8 but three seine hauls on November 10 failed to take any Group II fish. A survey by boat in the adjacent offshore area failed to locate the school, and it was concluded they had moved to a different area of the lake.

It was not until December 6 that kokanee of Group II returned to the Post Office area to spawn. At this time they moved into the same spawning area that had been occupied by Group I fish some 26 days earlier. Spawning activity on December 6 was profuse. The caudal clip was observed on at least seven kokanee over the spawning redds, indicating that this was the same group from which an earlier sample had been collected.

None of the 315 fish captured in Group II possessed the hatchery mark. Consequently it can be assumed that they represent fish from natural reproduction. Here, then, is the first indication that the stocking of small fish might have drastic and possibly beneficial effects producing a fish which spawns late, stays in the seasonal fishery longer, and is larger in the year of maturity. Group II did not spawn in any of the inlet streams or Odell Creek. The only spawning activity observed for this group was at the Post Office area.

The 315 Group II kokanee captured were measured, and 193 (113 males and 80 females) were weighed. Males had a mean length of 33.6 centimeters, while females had a mean length of 32.1 centimeters. The analysis of variance test showed a significant difference between the mean lengths ($F=41.61$ with 1,313 d.f.).

Figure 16 is a histogram comparing length frequency of males and females with the total sample of Group II kokanee. The age groups are presently unknown. Scales were obtained from only three females and they were so highly reabsorbed that it was impossible to determine age accurately from them. Otoliths were collected from a number of Group II fish, but have not been analyzed for age determination.

Figures 17 and 18 present the regression of weight on length for male and female Group II kokanee respectively, along with the 95 percent confidence interval.

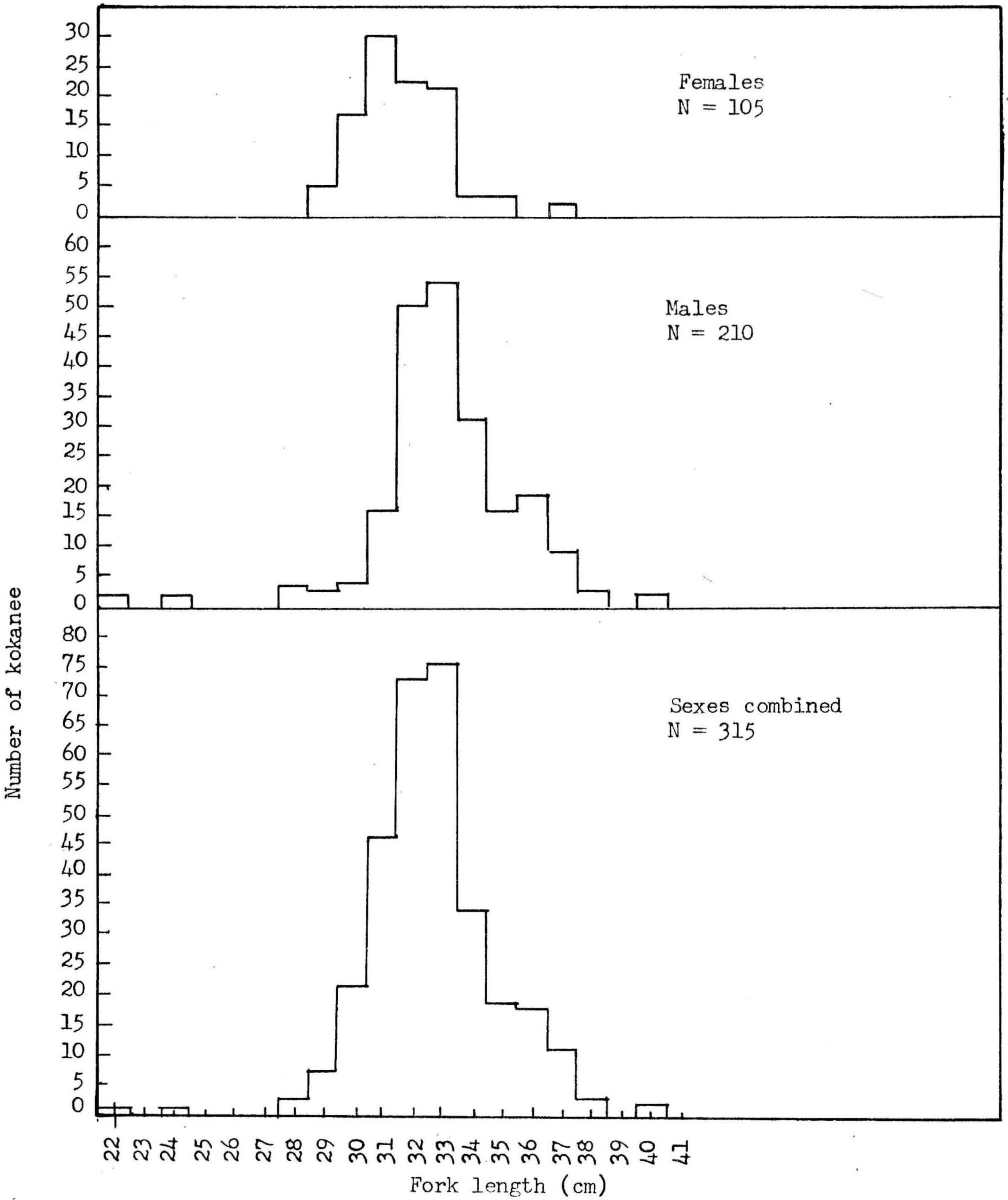

Figure 16. Length frequency of Group II kokanee. Odell Lake, 1965.

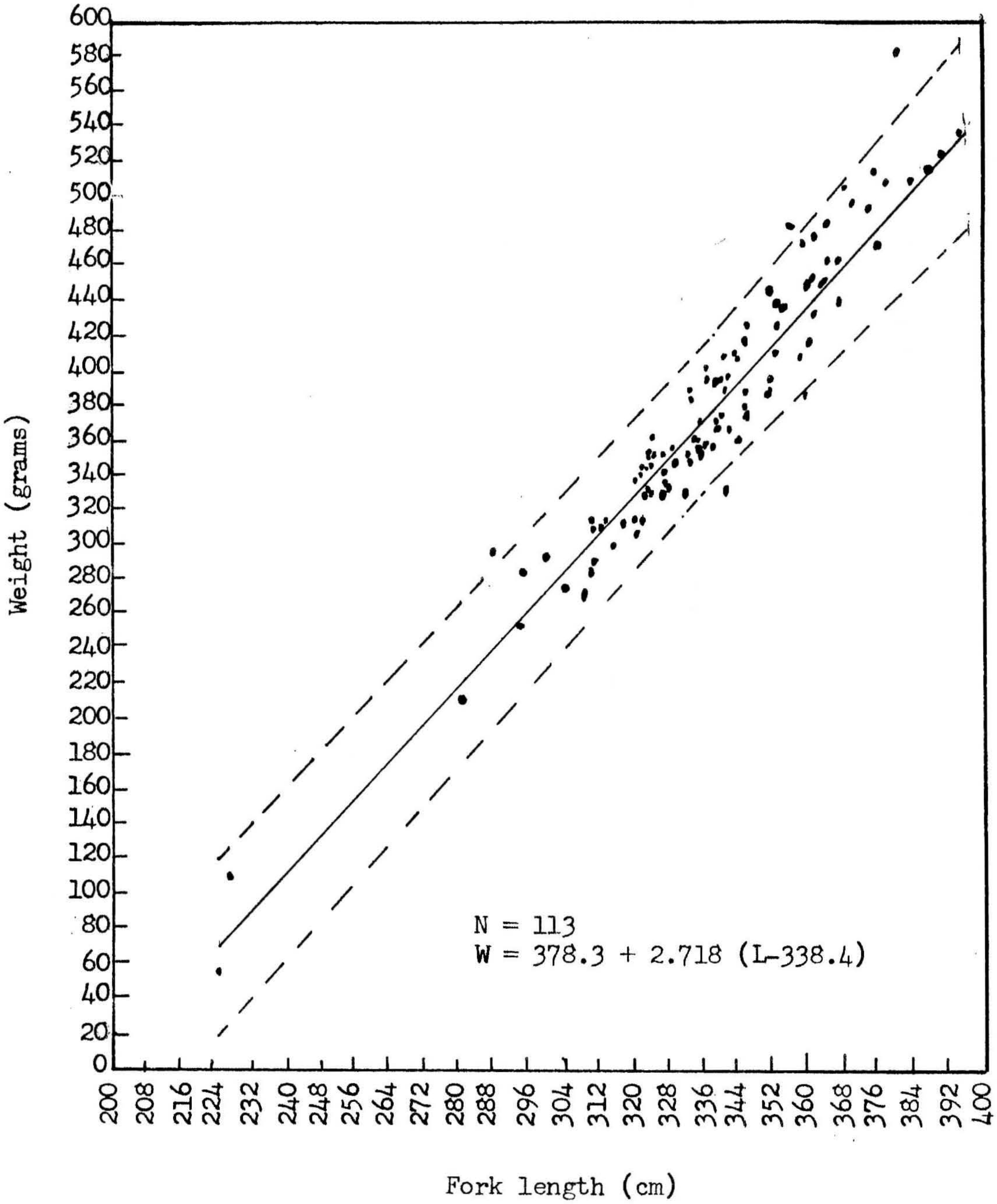

Figure 17. Regression of weight on length for Group II males, Odell Lake, 1965. Broken line is 95 percent confidence interval.

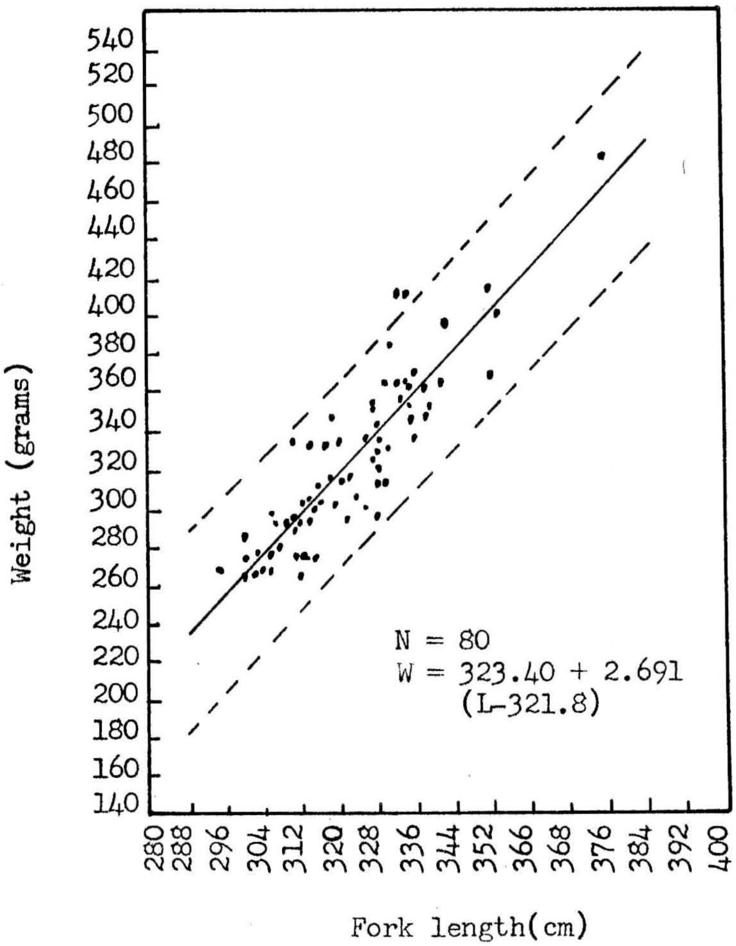

Figure 18. Regression of weight on length for Group II females. Odell Lake, 1965. Broken line is 95 percent confidence interval.

The analysis of covariance tests of H_A and H_B (common and parallel regression lines) shows that no common regression of weight on length can be fitted for males and females but the regressions of weight on length for the two sexes are parallel (for H_A F=3.828 with 2,189 d.f; for H_B F=0.0285 with 1,189 d.f.).

Comparison between Group I and Group II

Some distinct differences were noted between kokanee of Group I and Group II. Some of these differences are summarized in Table 4. There is no overlap at the 95 percent level between mean lengths of the two groups. Although both groups used the Post Office area for spawning, they did so at different times. Group I also spawned in Odell and Trapper creeks.

Of great importance in separating the two groups was the high number of hatchery marks (fin clips) on Group I kokanee. An estimated 81 percent of the fish observed in this group were of hatchery origin. In contrast, none of the Group II kokanee observed were marked.

The analysis of covariance tests of H_A and H_B between sexes of the two groups show that in each case the data will not fit a common regression line, nor are the regression lines parallel (for male F=89.73 with 2,270 d.f., for H_A and 5.1320 with 1,270 d.f. for H_B. For females F=5.40 with 2,227 d.f. for H_A and 10.26 with 1,227 d.f. for H_B).

Table 4

Comparisons between kokanee of Group I and Group II.

Mean length and 95 percent confidence interval of the mean (cm)

Age	Group I I+	II+	Group II unknown
Males	22.8 ± 0.4	31.1 ± 0.1	33.6 ± 0.3
Females	22.9 ± 0.3	30.2 ± 0.2	32.1 ± 0.3

Spawning areas and period of spawning

Area	Spawning period* Group I	Group II
Odell Creek	Aug. 22 - Oct. 28	
Trapper Creek	Sept. 15 - Nov. 10	
Post Office	mid-Sept. - Nov. 10	Dec. 6 - mid-January

*Refers to the period when fish were in the area. Peak spawning was within period listed.

Considering the four regression lines:

Group I Males: Weight = 341.7 + 2.838 (length -303.1)

Group II Males: Weight = 378.3 + 2.718 (length -338.4)

Group I Females: Weight = 263.8 + 2.188 (length -296.5)

Group II Females: Weight = 323.4 + 2.691 (length -321.8)

it is clear that Group II males have a greater mean weight and length than Group I males but the increase in weight for a given increase in length for Group II males is less than with Group I males. Group II females have a mean weight and length greater than Group I females. As Group II females increase in length, their weight increases at a faster rate than does that of Group I females.

Discussion

The data presented here represent the first complete year of study of the kokanee in Odell Lake. The results will be more meaningful with subsequent studies.

The fact that 95 percent of the anglers fishing Odell Lake were seeking kokanee is of significance in the management of Oregon's lake fisheries. Kokanee were originally introduced into Odell Lake to provide forage for lake trout. Through continued stocking or increased survival of natural fry they have become the dominant species. Bjornn (1961) reported similar findings in Priest Lakes, Idaho. The ease by which kokanee are caught, and their excellent food quality has made them a highly sought-after fish. The expenditure of 110,435 hours by 29,370 anglers on Odell Lake during the 1965 season attests to their popularity.

Some workers have supported the introduction of kokanee into trout lakes for the purpose of maintaining a mid-summer fishery. Seeley and McCammon (1963) mention that the idea was successful in Pardee Reservoir, California, but not so in other California waters. The work of Bjornn (op.cit.) implies that caution should be placed on the introduction of kokanee to new waters until more is known about their competition with other species. This is especially true in waters that presently maintain a trout fishery.

The decline in the length frequency of angler-caught kokanee as the season progressed can presently be attributed to two events. Many anglers failed to change their fishing habits as the season progressed. In early spring when temperatures are low, large kokanee are easily caught by trolling on the surface. These larger kokanee may move into deeper water during mid-summer, and unless anglers troll deeper they may fail to catch them. In Odell Lake hatchery and wild kokanee first enter the fishery during mid-summer when they are between

18 and 22 centimeters fork length. Hatchery kokanee are in their second year of life, and it is expected that wild kokanee are the same age. Apparently kokanee of this length range are more easily taken by anglers trolling at the surface. Group I kokanee spawned early and consequently left the fishery in late summer. This event could have had some effect upon the downward shift of the length frequency in the catch. It is not the only explanation since most of the fish were from the 1963 liberation and comprised only 21 percent of the total catch.

We still know too little about the spatial distribution of kokanee in lakes. The data presented here are too meager for meaningful conclusions. Horak and Tanner (1964) found that kokanee occupied the deeper water of Horsetooth Reservoir (Colorado) during the summer; the majority being found in the thermocline. Campbell (1965) presented the results of 12 overnight curtain gill net sets in Odell Lake. He found that the number of kokanee from 20 to 36 centimeters exceeded the 10 to 20 centimeter length group only at the 50 to 75 foot level and hypothesized that the larger kokanee were seeking the thermocline. This hypothesis is logical and is supported by several findings. First, trawl data for August, 1965 show that only 0-age kokanee were captured at the surface when the water temperature reached 60°F. At the same trawling periods larger kokanee were taken only at depths of 60 to 80 feet where the temperature ranged from 45 to 51°F. Kokanee other than 0-age class are not commonly taken by the trawl. When they are taken it is suspected that they are in relative abundance.

The second reason supporting the hypothesis of Campbell (1965) has been discussed. That is, anglers often do not troll in the deeper waters during mid and late summer, and thus may fail to catch larger kokanee. Vertical distribution might be influenced by the location of preferred foods. Northcote and Lorz (1966) found in Nicola Lake, British Columbia that maturing kokanee often seek chironomid (Tendipedidae) larvae and pupae. Thus, larger kokanee might be closely associated with the lake bottom during summer owing to a diet change. Chironomid larvae are found in the bottom material of Odell Lake.

A study of the diel distribution of kokanee in Nicola Lake was reported by Northcote, et al. (1964). In August, 1959 they found that kokanee were near the bottom at night but in the upper 7.5 meters during the day. In August, 1961 an opposite diel movement was found. Some of the differences noted in 1961 were warmer surface layers at night, increased oxygen depletion in lower layers, greater light penetration, and a marked increase in the size of kokanee. Thus, the habits of kokanee can be rapidly altered by changes in the environment.

Fortune (1964) and Campbell (1965) studied the vertical distribution of 0-age kokanee with light. More kokanee were captured at the surface on moonlight nights than on dark nights. Fortune postulated that young kokanee are attracted to the surface during light nights to feed, possibly silhouetting their prey against the light background. Fields, et al. (1963) studied the effect of light on downstream migrant salmonids above McNary Dam on the Columbia River. Using the same type of trawl employed at Odell Lake they found that 10 times as many salmonids were captured at the surface when the mercury vapor lights on the powerhouse deck were on, than when off. The study is meaningful, for the lights controlled the source and strength of illumination.

When moonlight is the sole source of illumination, a number of other variables must be considered in relating fry distribution to light. These include moving cloud cover and the duration of moonlight for a given night. In addition, the same assumptions (i.e. movement to the surface during bright moonlight) might not be as valid in early spring as in late summer. Such variables as temperature, zooplankton abundance and increased size of the fry as the season progresses could have additional effects. Johnson (1961) used an echo sounder to show that young sockeye are transported horizontally to the downwind end of the Nilkitkwa Lake, British Columbia. He mentions that they are passively concentrated there by maintaining their preferred depth in spite of the downward current caused by wind action. Future use of an echo sounder plus more intensive gill net sampling should assist in determining the distribution of kokanee in Odell Lake. At the present time it seems important to expend more effort towards locating larger kokanee that could enter the sport fishery. A method for enumerating fry would provide information on potential year-class strength. In terms of general studies, the work of Northcote et al. (1964) shows that a knowledge of environmental factors is important and must be considered in any study concerned with kokanee distribution.

The differences between the two spawning groups of kokanee in Odell Lake suggest that they are two races[1/]. In past years, kokanee from Flathead Lake, Montana as well as from Kootenay Lake, British Columbia have been stocked in Odell Lake. Although 81 percent of the fish sampled from Group I can be attributed to hatchery liberations of 1963 and 1964 (Kootenay Lake stock) no definite knowledge is available concerning the original source of Group II fish. Even if Group II fish originally came from Kootenay Lake stock, their behavior has been altered in Odell Lake. The alteration could be solely a function of the size and age at stocking.

The term "race" deserves some discussion here. Vernon (1957) used the term in describing kokanee in Kootenay Lake, British Columbia. He examined differences between spawning kokanee in three areas of the lake. Significant among his findings was that kokanee in the south end of the lake spawned 10 to 15 days later than those of the north end. South-end fish predominately spawned at 3 years of age while those of the north end spawned at 4 years of age.

[1/] The term "race" as used here refers to a sub-population isolated in either time or space during the period of reproduction.

Straying among mature kokanee was estimated to be less than 3 percent. With hatchery-reared progeny from the three races, he found that parental differences in the number of vertebrae were transmitted to offspring. Growth rates were not transmitted. Vernon concluded that the strong tendency of kokanee to spawn in the stream of their natal origin was the principal isolating factor for the three races. The majority of Group I kokanee as described in the present report were from the north end of Kootenay Lake. Most of them spawned at three years of age in Odell Lake.

Henry (1961) separated races of Frazer River sockeye on the basis of freshwater scale circuli. Cope (1957), in discussing the races of cutthroat trout in Yellowstone Lake, Wyoming, defined the term race as "a population within the subspecies." He further described a number of racial types separated by differences in physiology, ecology, season and altitude. He suggested that Yellowstone Lake cutthroat probably fall into several of these racial categories but that races should not be divided so delicately since many are synonymous. The cutthroat have different time patterns of movement into spawning streams, significant differences in total length of fish in the different spawning runs as well as a significant difference between the number of eggs and ovary weight.

Recently Mayr (1963) suggested the abandonment of the terms variety and "biological race" calling them "...catchalls for heterogenous phenomena...". He states that all races are geographical as well as ecological.

Marr (1957) has defined some of the terms used in describing sub-populations of fishes. He preferred not to use the term race because in other fields (Ornithology for example) it is used as a synonym of subspecies. Under the heading "Race", Marr states "Although it might be desirable to standardize on this or some other set of terms, this is not essential so long as everyone defines whatever terms he does use".

The use of Odell Creek, Trapper Creek, and the Post Office area for spawning by Group I kokanee has several points for discussion. Most of them were stocked in 1963 and 1964 and had no natal spawning area in Odell Lake. Subsequently, they spawned in two distinct temperature environments and three distinct physical environments (inlet, outlet and lakeshore). Trapper Creek, the inlet stream had a mean morning temperature during the spawning period of 39°F., while Odell Creek (outlet stream) had a mean morning temperature of 57.3°F. (The Post Office shoreline temperature was very similar to that of Odell Creek). The fact that Group II kokanee spawned only along the lakeshore (Post Office area) is important. It may have been that when first introduced, kokanee of this group also spawned in Trapper and Odell creeks, but that fry survival or return to the lake was unsuccessful. The low temperatures of Trapper Creek and its apparent scouring with the spring snow melt may preclude an opportunity of fry survival. It is possible that fry hatched in Odell Creek would not possess the imprint to return to Odell Lake. Consequently, the original (introduced) parents of Group II kokanee might have spawned in other areas or streams of Odell Lake, but fry survival was successful only at the Post Office shoreline making this the natal area.

Further discussion should await results from forthcoming spawning years. A kokanee racial study by the Oregon Game Commission is now underway. The results should clarify some of the problems discussed above.

Little is known about kokanee population fluctuations. A number of workers have reported on the freshwater population dynamics of sockeye. Although sockeye and kokanee developed from common ancestors, different life history patterns are apparent. A lake must support kokanee throughout their life whereas sockeye progeny often spend but one year in freshwater. Thus, changes in the environment are likely to affect the well-being of kokanee throughout their life, and fluctuations in numbers might vary greatly between and among year classes.

Limnological studies in relation to kokanee food habits are urgently needed. In addition, more information is needed concerning the cropping of zooplankton by kokanee. In summary, we will not fully understand the dynamics of kokanee populations until we understand the environment in which they live.

One final comment needs to be made. Since 1963, one-fifth of the hatchery kokanee released into Odell Lake have been marked by fin removal. Thus, to estimate the number of hatchery fish in a given group, the number of marked fish are multiplied by a factor of 5. The validity of this assumption is unknown. In Trapper Creek for example there were 94 marked fish observed out of a total of 620. Multiplying 94 by 5 would indicate that 470 of the 620 fish observed (76 percent) were of hatchery origin. To account for all of the 620 fish being of hatchery origin one would have to multiply 94 by 6.6. Certainly it is important to know if the difference between 5.0 and 6.6 is due to a differential mortality between marked and unmarked fish.

Summary

1. At Odell Lake 29,370 anglers expended 110,435 hours to catch 63,353 kokanee between April 24 and September 18, 1965. Ninety-five percent of the anglers interviewed were seeking kokanee. The greatest angling pressure was exerted on holiday weekends.

2. A downward shift in the length frequency of kokanee in the anglers catch occurred as the season progressed. Early in the season kokanee 28 to 33 centimeters were predominant in the catch. Near the end of the season the predominant length range was 19 to 22 centimeters.

3. The weight-length relationship of immature kokanee was best described as Log W = 8.00768-10 + 3.0010 log L.

4. Young kokanee first form scales at a fork length of 35 millimeters. Scales first appear on both sides of the lateral line between the insertion of the dorsal fin and the origin of the adipose fin.

5. Most kokanee captured with the curtain gill net were between 9 and 11 centimeters although some were as large as 34 centimeters. Only three kokanee between 13 and 23 centimeters were taken in the net.

6. Trawl catches were extremely variable in 1965. No apparent relationship was found between catches made at the surface and at greater depths on moonlight nights. A discussion concerning the variables involved in such relationships is presented.

7. Temperature profiles for selected dates are presented as well as the location of the thermocline throughout the spring and summmer and early fall. Fall temperatures of the two streams used for spawning are presented.

8. Two groups of mature kokanee were found in Odell Lake. One group was comprised almost entirely of kokanee liberated in 1963 and 1964. The other group was naturally-spawned. Significant differences were found between mean lengths,and weight associated with length. One group spawned early (September and October) in a tributary stream, the outlet stream and a lakeshore area. The other group spawning in December used only the lakeshore area. The two groups are distinctly different in habits.

Literature cited

Bjornn, T. C. 1961. Harvest, age structure and growth of game fish populations from Priest and Upper Priest Lakes. Trans. Am. Fish. Soc., 90 (1):27-31.

Campbell, H. J. 1965. A preliminary investigation of the kokanee in Odell Lake, Oregon. Oregon Game Commission Research Division. Fishery Research Report No. 1, D-J Project F-71-R-1. 24 pp.

Chapman, D. W. and J. D. Fortune, Jr. 1963. Ecology of kokanee salmon. Oregon Game Commission Research Division, 1963 Annual Report, 11-42.

Cope, O. B. 1957. Races of cutthroat trout in Yellowstone Lake. In contributions to the study of subpopulations of fishes. U. S. Fish and Wildlife Service Special Scientific Report. Fisheries No. 208:74-84.

Fields, P. E., R. G. Mausolf and W. B. Carter. 1963. Illumination effect on tow net catches of young salmonids at McNary Dam. Research in Fisheries, Fisheries Research Institute, Univ. of Washington, Seattle. Contribution No. 166:29-31.

Fortune, J. D. Jr., 1964. Distribution of kokanee (<u>Oncorhynchus nerka</u>) fingerlings in summer as related to some environmental factors. M. S. Thesis. Oregon State Univ., Corvallis. 53 pp.

Henry, K. A. 1961. Racial identification of Frazer River sockeye salmon by means of scales and its application to salmon management. International Pacific Salmon Commission, Bull. XII. 97 pp.

Horak, D. L. and H. A. Tanner. 1964. The use of vertical gill nets in studying fish depth distribution, Horsetooth Reservoir, Colorado. Trans. Am. Fish. Soc., 92(2):137-145.

Johnson, W. E. 1961. Aspects of the ecology of a pelagic, zooplankton-eating fish. Verh. Internat. Verein. Limnol., XIV:727-731.

Marr, J. C. 1957. The problems of defining and recognizing subpopulations of fishes. In contributions to the study of subpopulations of fishes. U. S. Fish and Wildlife Service, Special Scientific Report. Fisheries No. 208:1-6.

Mayr, E. 1963. Animal species and evolution. The Belknap Press of Harvard Univ., Cambridge. 797 pp.

Northcote, T. C., H. W. Lorz and J. C. MacLeod. 1964. Studies on the diel vertical movement of fishes in a British Columbia lake. Verh. Internat. Verein. Limnol., XV:940-946.

Northcote, T. G. and H. W. Lorz. 1966. Seasonal and diel changes in food of adult kokanee (Oncorhynchus nerka) in Nicola Lake, British Columbia. Typewritten manuscript, 5 pp.

Seeley, C. M. and G. W. McCammon. 1963. A review of kokanee in California. The Resources Agency of Calif. Dept. of Fish and Game, Inland Fisheries Administration Report No. 63-11. 35 pp.

Vernon, E. H. 1957. Morphometric comparison of three races of kokanee (Oncorhynchus nerka) within a large British Columbia lake. Jour. Fish. Res. Bd. Canada, 14(4):573-598.

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