INVESTIGATIONS AND EXPERIMENTATION RELATIVE TO WINTER AGGREGATIONS OF FISHES IN CANTON RESERVOIR, OKLAHOMA

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INVESTIGATIONS AND EXPERIMENTATION RELATIVE TO WINTER AGGREGATIONS OF FISHES IN CANTON RESERVOIR, OKLAHOMA

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INTRODUCTION

Within a period of 69 days extending from January 10, 1950, to March 25,
50, hook and line fishermen harvested more than 426,000 legal-sized white
appie from the Boatdock Cove of Canton Reservoir, Oklahoma (Buck and Cross,
52). The harvest amounted to 22 tons of fish per surface acre for the cove,
ich is the equivalent of 27 pounds per surface acre for the entire reservoir.
e magnitude of the aggregation in so diminutive an area, scarcely more than
ree surface acres, led to a series of investigations of the causes under-
ing the phenomenon. The present report concerns two successive phases of
vestigations conducted in the winters of 1950-1951 and 1951-1952.

Since the writer was not assigned to the project until autumn of 1950,
ference is made to the observations of Buck and Cross (1952) concerning the
itial phase done in the winter of 1949-1950. As stated by them, the only
tectable difference between the Boatdock Cove wherein the aggregations
iefly occurred and others wherein none had taken place was an inflow of
epage water into the headwaters of the former cove. Limited readings of
ter temperatures indicated that the incoming ground water was warmer (in
nter) than the waters of the cove proper, and led to the conclusion that
temperature gradient of some sort probably existed, particularly when there
s a coverage of ice. Consequently, a theory was advanced that the concen-
ations had probably been caused by attraction of the fishes to the warmer
ters of the Boatdock Cove during periods of low lake temperatures.

A more accurate appraisal of the effects of the incoming water on the
ters of the cove, as well as the fishes within it, along with consideration

f other possible influences were the primary objectives undertaken by the riter in the autumn of 1950. The ultimate objective was to cause fish aggreation, if possible, in a cove wherein none had previously occurred. Condiions hypothesized to be influential on grouping reaction in the Boatdock Cove ere to be duplicated in an experimental area.

REVIEW OF LITERATURE

A review of literature indicates that although considerable research fort has been expended on investigations of factors controlling animal gregations in general, comparatively little has been directed toward those ncerning the aggregations of fishes. It also indicates that of the com-ratively few biologists concentrating their attentions on the grouping haviors of fishes, still fewer have extensively investigated contrasts in ter temperature as a causative factor. Moreover, researchers studying the fects of temperature changes on fishes in their natural environments seem be fewer in number than those confining their investigations to fishes ntained in experimental gradient tanks and aquaria. As far as can be termined, the present work introduces the first attempt to cause an aggre-tion in a given area of a lake by deliberately influencing the temperature the water.

Morrow (1948) not only summarized virtually all of the data concerning ctors conducive to the grouping behaviors of fishes to that date, but con-ibuted additional service by clearly defining the difference between the rms "school" and "aggregation." The former is described as ". . . a close-it cohesive group in which there appears to be a definite centripetal fluence existing between fish and fish"; the latter as ". . . a chance ouping of individuals brought into a given locality by some external factor factors not concerned with relationships between individuals."

Studying thermal responses of fishes in artificial habitats, experi-nters utilizing gradient tanks and aquaria have reached conclusions that

e perhaps basic to interpretation of causes underlying winter aggregations
natural waters. Shelford and Powers (1915) found that herring were remark-
ly sensitive to differences in temperature and reported observations of
od aggregation reactions with a difference of 0.6° C., and fair with a dif-
rence of 0.5° C. They further observed that herring were apparently able
detect gradients as small as 0.2° C. Bowen (1931) found that young black
llhead catfish, *Ameiurus melas* (Rafinesque), gave evidence of positive
sponse to highly conditioned water to which they had become adapted when
e conditioned water was directed against unconditioned water in a gradient
nk. Doudoroff (1934) experimented principally with the marine greenfish,
rella nigricona (Ayres), in a compartmented gradient tank in which a dif-
rence of 18° C. was usually maintained between the two ends, and 2° C.
tween each of eight adjacent apartments. While warning that ". . . analogies
tween experimental gradients and those which occur in nature should be
garded with caution as the former are usually much steeper," he definitely
ncluded that selections made by the fish in the experimental tank were
dicative of the relative stimulative or detrimental effects of rapid changes
temperature and did not indicate a seeking of "optimal conditions" or
bitat preference. He further concluded that ". . . within normal ranges of
mperatures, rapid cooling is more detrimental or stimulating than a rapid
se of temperature."

These views are supported by Prosser, et al. (1950), as evidenced by the
llowing quotation from their textbook on the comparative physiology of
imals: "The temperature selected [by fishes in gradient tanks] depends on
e acclimatization and the rate of transfer from one temperature to another
the rate of rise or fall of temperature; hence the term 'optimal tempera-
re' has little meaning in gradient behavior." Re-emphasizing the observa-
ons of Shelford and Powers (1915), Doudoroff (1934) and others, they

onclude that fishes are stimulated principally by cutaneous thermal receptors o selective orientation reactions against heat and cold.

By using aquaria in place of gradient tanks, Breder and Nigrelli (1935) ere able to study reactions to total changes rather than selections of diferences in water temperatures. They observed that the yellow-bellied sunish, *Lepomis auritus* (Linnaeus), formed a clesely compacted aggregation, esting quiescently, when the temperature fell to 5° C. They further observed hat the tendency to maintain such a formation was only feebly present at ° C., and was virtually abandoned at 9° C. In addition to low temperature, t was found that the presence of light and of a slight current were equally s essential to winter aggregation. Although pointing out that several other entrarchids subjected to identical conditions had failed to exhibit similar rouping behavior, they did note that the black crappie showed a slight tendncy to form large, loose aggregates. Townsend's experiments (1916) with the mallmouth black bass, *Micropterus dolomieui* Lacepede, were cited as having roduced results remarkably in keeping with their own finding concerning the ellow-bellied sunfish. No references to investigations of white crappie nder artificial conditions were found, but it seems reasonable that Breder nd Nigrelli's observations of near relatives in the same family could be at east suggestive of some of the factors leading to the crappie concentraions in Canton Reservoir.

References to investigations in natural waters show that Wiebe (1941) nd Dendy (1945) found density currents and temperature to be highly imporant factors influencing fish distribution in deep reservoirs. The studies f Borges (1950), however, are perhaps more comparable to those here preented in that the areas of water investigated by him and by this writer conained certain characteristics in common. The relatively shallow, spring-fed iangua Arm of the Lake of the Ozarks, although much larger, compares somehat favorably with the coves--particularly the Boatdock Cove of Canton Lake. orges was able to demonstrate that the headwaters of the Niangua Arm were nfluenced by "... a cold, highly oxygenated spring-water density current" oward which fishes, particularly white bass, Morone chrysops (Rafinesque), igrated when routed from preferred deep water habitats as a result of midummer stratification and stagnation. Although basing his report primarily n records and observations made during a period from June 10 to September 6, 947, he indicated that "... oxygen and temperature conditions were uniform t all depths" during the winter and early spring of the same year.

The findings of this investigation are at variance with the opinion thus mplied, that the incoming spring-water had little or no effect on the headaters of the Niangua Arm during the winter months. It is believed that if he winter phase of this fine study had been pursued as thoroughly as was the ummer phase, the effects of the warmer spring-water would have become disernable. The foregoing conjecture is based on: (1) the relatively few three) winter and early spring visits to the experimental area; (2) the reat distance (approximately two miles) of the nearest recording station rom the spring feeding the arm; and (3) the lack of reference to ice cover t the time of the visits (unlikely present on March 29 and May 3). Notwithtanding this difference of opinion, the overall findings of the Borges eport lend support to a premise that if inflowing cooler waters could influnce midsummer migrations in one body of water, the reciprocal could possibly e a contributing factor to midwinter aggregations in another. As water ecomes progressively heavier with increasing water temperatures between ° and 4° C. (thus, sinking to the bottom), the possibility of demontrating the presence of temporary, yet effective warmer spring-water ensity currents did not seem to be too remote if the waters were sufficiently nsulated and protected from wind action by coverages of ice.

Direct references to fish densities that could be correlated with the nflow of warmer into colder waters are indeed scarce. Hansen (1951) reported bservations of white crappie in Lake Springfield, Illinois, concentrated efore a wire screen fastened to a culvert delivering a large volume of water rom an electrical power plant. The aggregation which occurred in May of 931 was of such density that the fish could be caught readily with a dip net. nfortunately, no temperature recordings were taken.

In a popular article concerning angling for burbot, *Lota lota maculosa* Le Sueur), Hutt (1951) wrote: "By fishing through ice or in areas where ater is warmed by power plants or by other means, your chances of hooking nto them are good."

Gordon L. Trembly, Chief Aquatic Biologist, Pennsylvania Fish Commission, n private correspondence with W. H. Irwin of Oklahoma Agricultural and echanical College, wrote (in 1951) of observing heavy winter concentrations f gizzard shad in a bay at Erie, Pennsylvania. His letter stated that the ennsylvania Electric Company (Erie Plant) drew water from the lake, used it o cool their condensers, and returned it to the area wherein the aggregaions were observed.

C. A. French, Executive Director, Pennsylvania Fish Commission, also nformed Dr. Irwin, by private correspondence, of the large concentrations of had in the bay at Erie, Pennsylvania. He wrote:

> here is a large electric plant on the bay which discharges warm water, and t seems that as soon as the shad leave this water, which has a much higher emperature than the bay proper, they begin dying by the thousands. Last ear we removed over three hundred tons of these fish, both living and dead; hey were given to the farmers in the neighboring areas who used them as ertilizer.

From the foregoing, a hypothesis was thus suggested that winter aggregaions of fishes influenced by inflowing warm water, whether from natural ources such as seepage or springs, or of artificial origin such as indusrial plants, are probably of common occurrence and, excepting occasional iscovery, pass unnoticed by the general public. In this respect, it is alled to mind that the initial great concentration in the Boatdock Cove of anton Reservoir was discovered entirely by accident in December of 1949.

DESCRIPTIONS OF COVES

The three coves involved in investigations subsequently to be discussed re situated generally on the western side of Canton Reservoir at distances ot far removed from the original bed of the North Canadian River (Figure 1). ll are characterized by steep, rapidly eroding banks of exposed Permian reded formation and scarcities of marginal vegetation, the combined effects of hich result in rapid siltation and ever increasing shallowness of the coves.

Boatdock Cove

Boatdock Cove, in which the first great aggregation was discovered, is ocated approximately one mile northwest of the main dam and stems along a outh-southwesterly axis from a larger body of water known as the Cantonement reek Arm. The cove's mouth, opening to the north, is approximately 100 ards from the main body of the lake. The "draw" embracing this cove also ontains, at its head, a spring-fed pond of between three and four surface cres known as Cantonement Pond. An earthen dam (Permian redbed) constructed t a point approximately 1200 feet from the foot of the draw impounds the ond and maintains its surface at an elevation considerably higher than that f the cove (Figure 2). Waters that have apparently seeped from the pond hrough the dam have two principal sites of emergence at its base--one on ach side--at places conforming with the juncture of the dam and the steeply loping natural sides of the "draw." In addition to these main "springs," he first hundred feet below the impoundment contains many other points of ngress from which the inflow ranges between brisk trickles and slow oozings

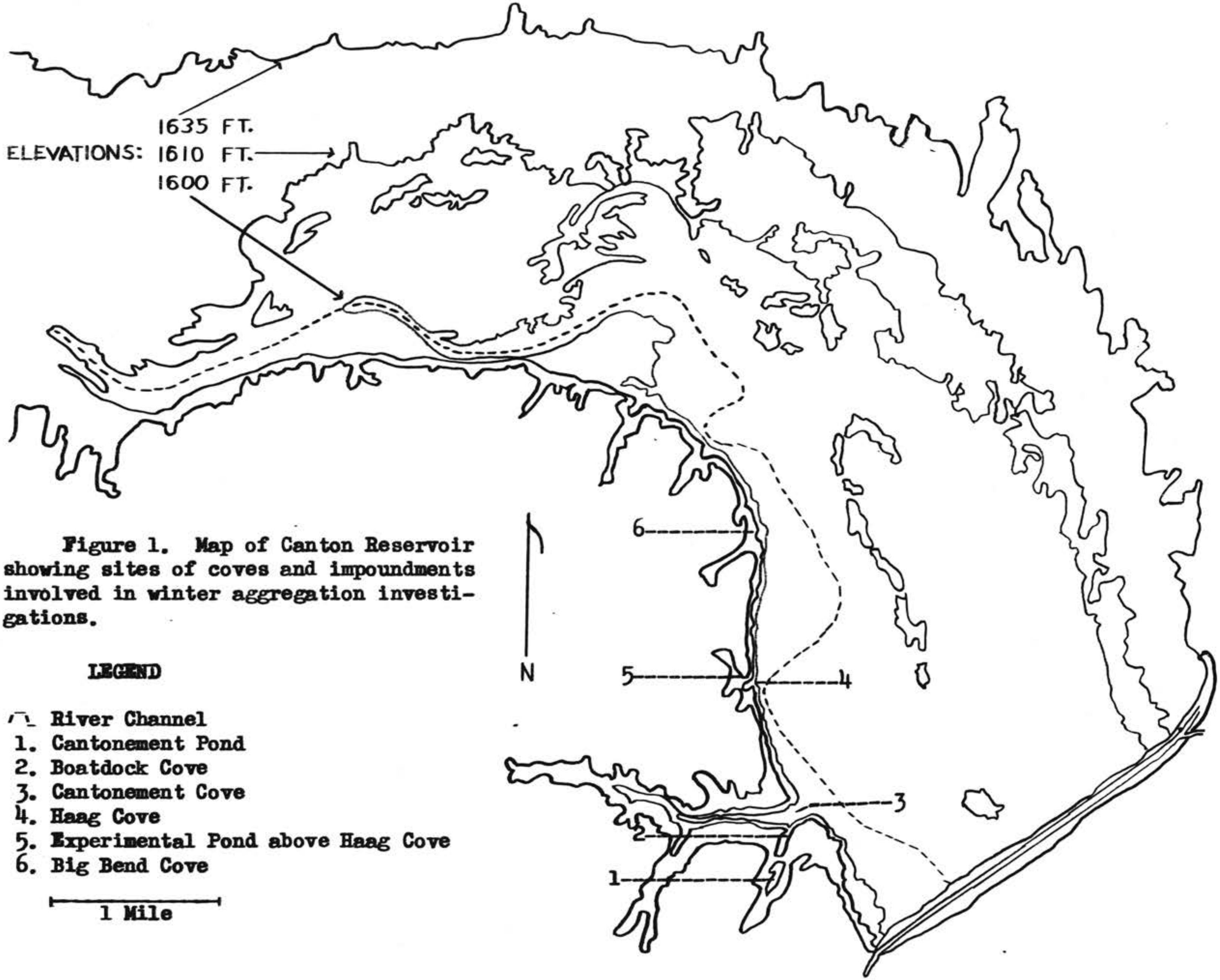


Figure 1. Map of Canton Reservoir showing sites of coves and impoundments involved in winter aggregation investigations.

LEGEND

⌒ River Channel
1. Cantonement Pond
2. Boatdock Cove
3. Cantonement Cove
4. Haag Cove
5. Experimental Pond above Haag Cove
6. Big Bend Cove

1 Mile

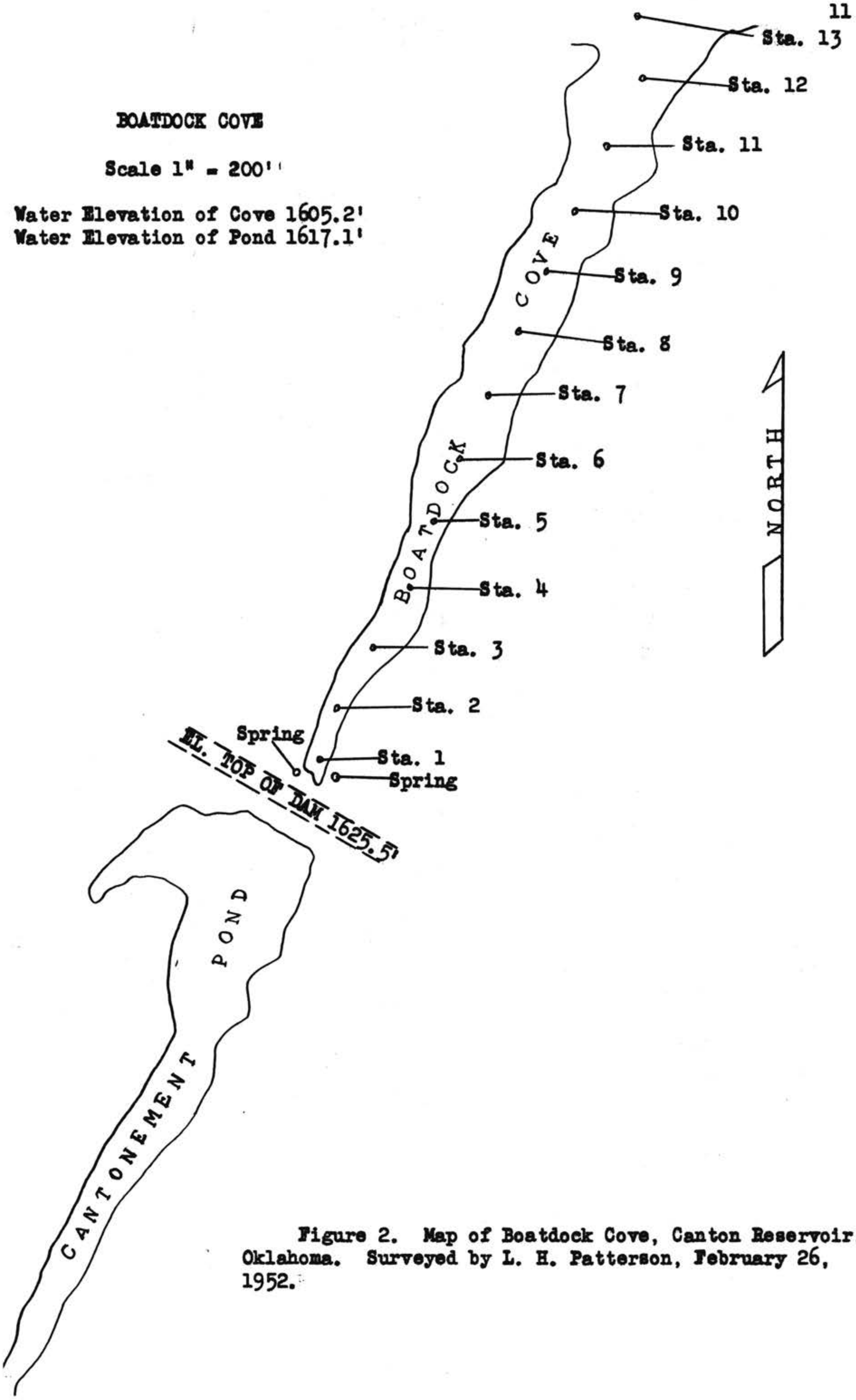


Figure 2. Map of Boatdock Cove, Canton Reservoir, Oklahoma. Surveyed by L. H. Patterson, February 26, 1952.

rom highly saturated soil. Waters from these sources converge into a shalow, swiftly flowing stream, which courses over a mucky sandy bed until erging with the standing water of the cove proper.

As the pool elevation varied between 1602 and 1603 feet (above sea evel) throughout most of the three winter periods of investigation, the istance traversed by this stream between the dam and the head of the cove roper fluctuated between 125 and 160 feet. A deliberate raising of the lake evel to 1605 feet during January of the third winter brought the upper imits of the cove to within ten feet of the two "springs" at the foot of the am. When the lake elevation stands at 1603 feet, the cove attains a length f approximately 1000 feet and averages 73 feet in width. Its depth, ranging rom less than a foot at the upper shallows to 13.5 feet at the mouth, verages 6.8 feet throughout. The bottom inclines gradually but successively, and is covered with constantly increasing deposits of silt.

Big Bend Cove

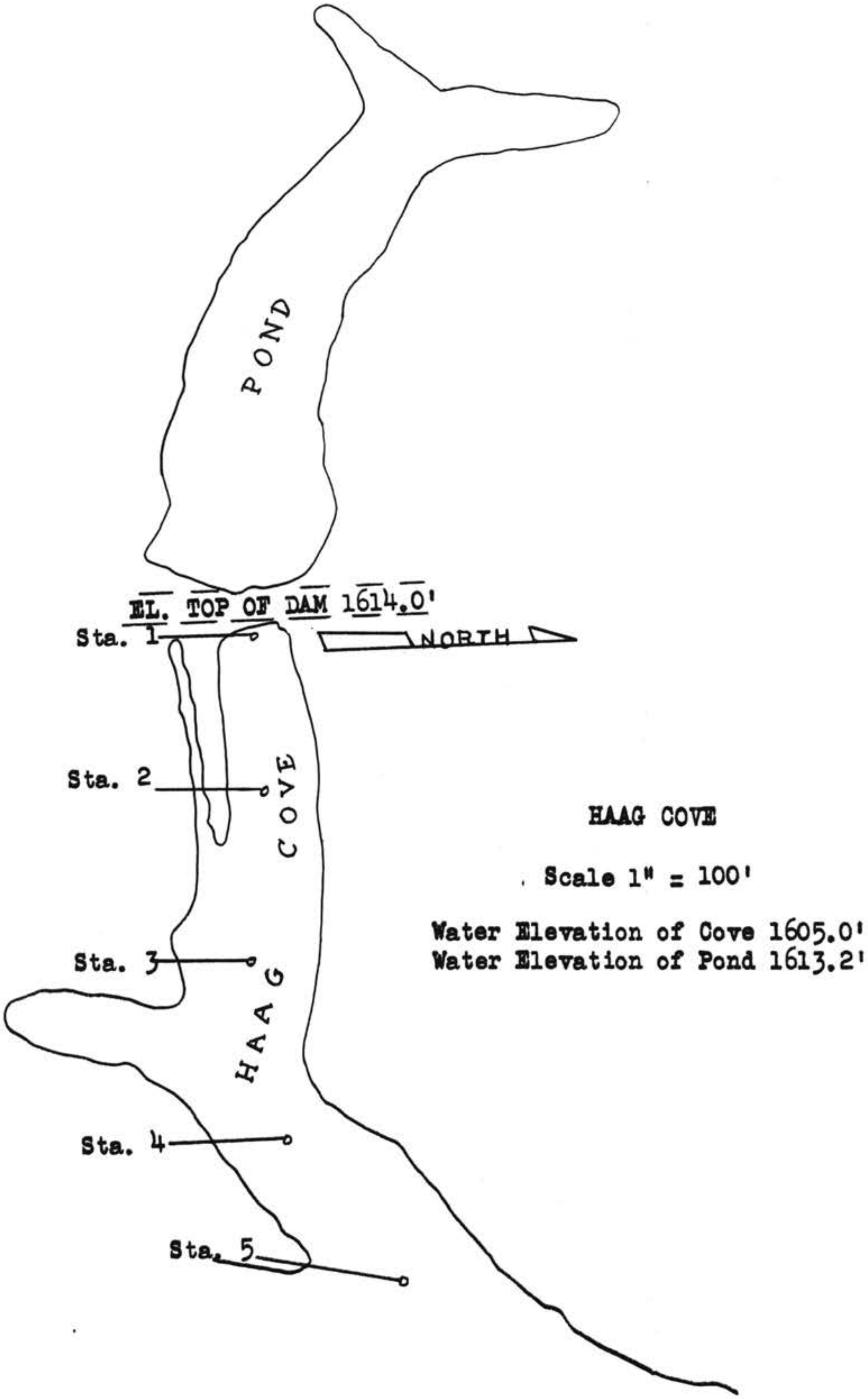
Big Bend Cove (Figure 1) was used as a control because its directional lignment corresponded generally to that of the Boatdock Cove, and because ittle or no seepage or spring water flowed into it. Its value as a control as further enhanced by its accessibility to fishermen. Located in one of e recreational areas, easily reached by a good road, it was fished witht success by anglers "crowded out" from the Boatdock Cove at the height the "crappie runs" in that area.

The cove is situated approximately one and one-half miles north of the atdock Cove, and joins directly with the main body of the lake from which extends along a general south-southwesterly axis. At a lake elevation of

603 feet, the total length of the cove is 450 feet. The bottom inclines ery gently over the first 300 feet from the upper limits and drops abruptly o a 5.5-foot depth at the point of juncture with the main body of the lake. he average depth is 3.1 feet, and the average width is 57 feet. It is felt hat shallowness did not greatly impair the value of the Big Bend Cove as a ontrol medium, because thousands of fish had been observed and caught at epths of less than two feet in the Boatdock Cove.

Haag Cove

Haag Cove (Figure 3), situated approximately half way between the Boatock and Big Bend Coves, was utilized as an experimental area during the ast winter of the investigations. It extends from the main body of the ake along a westerly axis and lies in a deep gully-like draw incased by bruptly rising sides of Permian redbed supporting little vegetation other an stunted juniper trees. The mouth is marked by a deep gap in the "red luffs" characterizing the western side of the reservoir, and by almost irect contact with the old channel of the North Canadian River (Figure 1). t a lake elevation of 1605 feet, the cove averages 8 feet in depth, 80 feet n width, and attains approximately 400 feet in length. The bottom slopes rogressively from a depth of five feet at the head to 14 feet at the mouth ith the exception of a hump caused by the washing out of an old dam contructed by civilian conservation corpsmen before the impoundment of the eservoir. As will subsequently be discussed, the dam was repaired during e last phase of the investigation, and a centrifugal pump was used to pound a one and one-half acre pond behind it.



HAAG COVE

Scale 1" = 100'

Water Elevation of Cove 1605.0'
Water Elevation of Pond 1613.2'

Figure 3. Map of Haag Cove, Canton Reservoir, Oklahoma. Surveyed by L. H. Patterson, March 26, 1952.

WINTER PHASE OF 1950-1951

Methods and Materials

The initial series of water temperature recordings taken on December 9, 950, was obtained at stations determined by measurements from one position o the next. Data were procured thereafter from permanent stations. Begin-ing at the principal area of seepage, thirteen temperature stations were stablished at 100-foot intervals by setting stakes along the margins of oatdock Cove. Stations were established at the Big Bend Cove in the same anner beginning at the upper limit. Readings were taken at each station y lowering the thermistor of a Whitney underwater thermometer, generally rough ice, and recording the registrations at one-foot depth intervals.

Information regarding angling successes was obtained by general obser-ation during the first two visits to the reservoir and by random inter-iews and spot-check creel censuses thereafter.

The data composing each series were tabulated and averaged in the man-er illustrated in Table 1. Both linear and curvilinear regression methods statistical analyses were applied in pursuance of precise interpretations the influence of inflowing ground water on the colder waters of the coves.

Calculated linear regression lines expressing the formula $T = a \pm bD$ nsistently exhibited fidelity to plotted empirical data points. The thod was the simplest and most convenient method of all considered and is, erefore, the one most frequently used in evaluations throughout the report. lculations involved in the method are demonstrated and explained in Table 1.

TABLE 1. Demonstration of Derivation of Linear Regression Line Calculated from Data Obtained on December 9, 1950.

Station Number	Distance in Hundreds of Feet from Sta. 3	Average Temperatures at Each Station	Deviations from the Mean		Squares of Deviations		Product of Deviations	Calculated Temperatures
	d	t	d	t	d^2	t^2	d x t	T = a ± bD
4	1	2.3	-3.75	+0.25	14.06	0.06	-0.94	2.38
5	2	2.2	-2.75	+0.15	7.56	0.02	-0.41	2.29
6	3	2.2	-1.75	+0.15	3.06	0.02	-0.26	2.21
7	4	2.1	-0.75	+0.05	0.56	-	-0.04	2.11
8	5	2.1	+0.25	+0.05	0.06	-	+0.01	2.03
9	6	2.0	+1.25	-0.05	1.56	-	-0.06	1.94
10	7	1.9	+2.25	-0.15	5.06	0.02	-0.34	1.85
13	10	1.6	+5.25	-0.45	27.56	0.30	-2.36	1.58
Sums	38	16.4	0.0	0.0	49.48		-4.40	
Averages	4.75	2.05						

$$T = \text{av. } t + \frac{\text{sum } d \times t}{\text{sum } d^2}(D - \text{av. } d)$$

$$= 2.05 + \frac{-4.40}{49.48}(D - 4.75)$$

$$= 2.05 - .089D + .42$$

$$= 2.47 - .089D \text{ (2.47 expressing intercept a and .089 expressing slope b)}$$

$$\therefore T = a \pm bD$$

where T = calculated temperature in degrees Centigrade

and D = distance in hundreds of feet from point where influence of incoming water becomes effective (Sta. 3)

and a (intercept) and b (slope) are constants derived by foregoing procedure.

Linear regression has been described by Snedecor (1946) as a kind of oving average passing among the data points specified by the hypothesis set p. He demonstrated that estimates, so expressed, tend to be more accurate han the sample values themselves and, at the same time, tend to equalize he influences of non-uniform conditions encountered along the line. On uch basis, influences other than the inflowing ground water are measurable o some extent by failure of data points representing counterinfluenced reas to conform with the estimated trend. For example, rapid meltage of ce within a shallow area of water would be depicted by the vertical distance rom the regression line to representative empirical data points. As melting ce takes heat from surrounding media, the data points would lie below the ine, and the vertical distance would express negative deviation. By the same oken, data points representative of shallow areas exposed to sustained sun-ight would lie above the regression line, and the vertical distances between ould be demonstrative of positive deviations.

Another attribute of the method is that the components of the formula, specially the regression factor or slope, may be effectively used as indices a comparisons of data.

The curvilinear regression method of analysis was applied to the data a several occasions in efforts to establish distance-water temperature elationships originating at the source of the ground water rather than at he juncture of the stream with the headwaters of the cove. In view of the act that heat gained by water in passage through earth was obviously iven off more rapidly with increased distance in the stream than in the cove, t was apparent that a simple straight line relationship could never be stablished.

Snedecor (1946) exemplified the application of curvilinear regression to ata of variable nature by demonstrating the conformity of chick embryo growth henomena with the exponential law. He refers to the law as homologous with he law of compound interest in that the weight increase of the embryos at ny moment is proportional to gains already attained. Conformance of a series f water temperature recordings to the law would simply mean that the decline n average water temperature at any distance from the seepage area would be roportional to declines already experienced; or, an explanation still more ignificant to the objectives of the present problem could be stated as fol-ows: a fish swimming up the cove would, at any point, encounter an increase n average water temperature proportional to increases already encountered.

Curvilinear regression lines expressing the equation $T = \frac{c}{D^n}$ were fitted o empirical data points. In logarithmic form, which is most convenient, he equation is expressed $T = \log c \pm n \log D$, where T = temperature in egrees Centigrade, D = distance in hundreds of feet from the seepage area, nd c and n are constants to be derived. A demonstration of calculations nvolved in the curvilinear method is presented in Table 2.

Air temperature and lake elevation data were obtained from files main-ained in the Canton Dam Project office, Corps of Engineers, United States epartment of the Army. Supplemental data were procured from Oklahoma limatological Data released by the United States Department of Commerce, eather Bureau (1949-1952), Kansas City, Missouri.

Procedure

Although a sudden and severe drop in air temperature (Appendix B) ccurred between December 4 and December 5, 1950, the reservoir could not

TABLE 2.* Demonstration of Derivation of Curvilinear Regression Line Calculated from Data Obtained on January 30, 1951.

D	log D	T (X 100)	log T (X 100)	log D X log T	(log D)^2	Calc. log T	Calc. T (÷ 100)
100	2.0000	310	2.4914	4.9828	4.0000	2.5294	3.38
200	2.3010	230	2.3617	5.4343	5.2946	2.3007	2.00
300	2.4771	140	2.1461	5.3161	6.1360	2.1669	1.47
400	2.6021	120	2.0792	5.4103	6.7709	2.0719	1.18
500	2.6990	98	1.9912	5.3742	7.2846	1.9983	1.00
600	2.7782	87	1.9395	5.3883	7.7184	1.9381	.87
700	2.8451	82	1.9138	5.4450	8.0946	1.8873	.77
800	2.9031	68	1.8325	5.3199	8.4280	1.8432	.70
900	2.9542	69	1.8389	5.4325	8.7273	1.8044	.64
1000	3.0000	55	1.7404	5.2212	9.0000	1.7696	.59
1100	3.0414	51	1.7076	5.1935	9.2501	1.7381	.55
1200	3.0792	52	1.7160	5.2839	9.4815	1.7094	.51
	32.6804 (1068.0085)		23.7583	63.8020	90.1860		

$$T = \frac{c}{D^n}$$

* In logarithmic form, which is most convenient, the equation is stated:

$$\text{Log } T = \log c \pm n \log D$$

where T is the temperature in degrees Centigrade (station averages), D is distance in feet from seepage area, and c and n are constants derived as follows:

$$(1) \quad \log c = \frac{\text{sum log T} \cdot \text{sum(log D)}^2 - \text{sum log D} \cdot \text{sum(log D} \cdot \text{log T)}}{\text{number of groups} \cdot \text{sum(log D)}^2 - (\text{sum log D})^2}$$

$$= \frac{23.7583 \cdot 90.1860 - 32.6804 \cdot 63.8020}{12 \cdot 90.1860 - 1068.0085}$$

$$= \frac{2142.6660 - 2085.0749}{1082.2320 - 1068.0085} = \frac{57.5911}{14.2235}$$

$$= 4.0490$$

$$(2) \quad n = \frac{\text{sum log T} - (\text{number of groups} \cdot \log c)}{\text{sum log D}}$$

$$= \frac{23.7583 - (12 \cdot 4.0490)}{32.6804}$$

$$= \frac{23.7583 - 48.5880}{32.6804} = \frac{-24.8297}{32.6804}$$

$$= -.7598$$

$$\therefore \log T = 4.0490 - .7598 \log D$$

e visited until early morning of the 9th, when the first series of tempera-
ure recordings was initiated. By then, it was generally conceded by anglers
at the winter "crappie run" had begun the preceding afternoon.

Virtually all but the shallower areas at the upper limit of the cove
ere under an ice coverage of sufficient strength to bear the weight of
umans, although the 400-foot area nearest the mouth was less thickly covered
d became progressively more dangerous throughout the day. The distance
etween the principal area of seepage and the head of the cove proper
pproximately 140 feet) was entirely free of ice. Rectangular holes chopped
the ice by anglers during the afternoon of December 8 had frozen over
ring the night affording comparatively clear "windows" in the otherwise
paque ice. In the more shallow areas, Deward Whetstone, Reservoir Manager,
d the writer were thus able to observe numerous white crappie, headed up-
tream but otherwise quiescent, just above the bottom at depths of two to
ree feet. The fish would, however, quickly disperse at the passing of a
adow across the "windows." After the early arrival of numerous anglers,
opening the holes and chopping new ones, no further such observations
re made although several fishermen later reported seeing sizeable "schools"
ss under the holes through which they were angling. The ice began melting
pidly as the day became progressively warmer, but anglers remained at their
ishing holes," often standing ankle-deep in water spreading ominously
ound them. Angling successes continued to be unusually high throughout the
y, becoming even better in the late afternoon. Crappies were frequently
ught two at a time by anglers using multi-hooked lines, and one fisherman
ported having caught five fish with a single minnow. It was noted that the
appies caused only slight motions of the bobbers when taking bait, and all
re lightly hooked, frequently falling off, when lifted from the water.

Beginning with the "springs" at the base of impoundment toward the head f the draw, water temperatures were taken at 10-foot intervals in the shalow running water between that area and the ice-covered standing water of he cove proper. Thereafter, recordings were effected at 20-foot intervals ntil rapid ice meltage created conditions considered too hazardous for coninuance of procedure beyond Station 10. Recordings at Station 13 were btained after breaking ice, by boat, to a position at the center of the uth of the cove. Data procured at 100-foot intervals (designated as staions) are tabulated and averaged in Table 2.

Comparatively few water temperatures were taken on December 10, as most f the day was given to boring into the dam separating Boatdock Cove and antonement Pond (Figure 2). For the same reason, observations of angling ccesses were limited but were generally considered to be comparable with hose of the previous day. A drop in air temperature during the night to a inimum of 25° F. had re-covered all open areas of the cove with ice, and glers were seen chopping new "fishing holes" as early as 7:30 a.m. By dafternoon the air temperature had risen to 57° F., and approximately 300 ople were fishing with no apparent decline in seccesses.

A ground auger, 3 inches in diameter and equipped with 4-foot extenons, was used in boring a hole from the top of the dam to a depth of 16 eet in an effort to more fully determine the source of the springs near e base. Moist earth, encountered at a depth of 4 feet, became progresvely more saturated until, at 10 feet, the contents of the auger could actically be poured when evacuated at the surface. Rapid water accumution followed further penetration to the maximum depth.

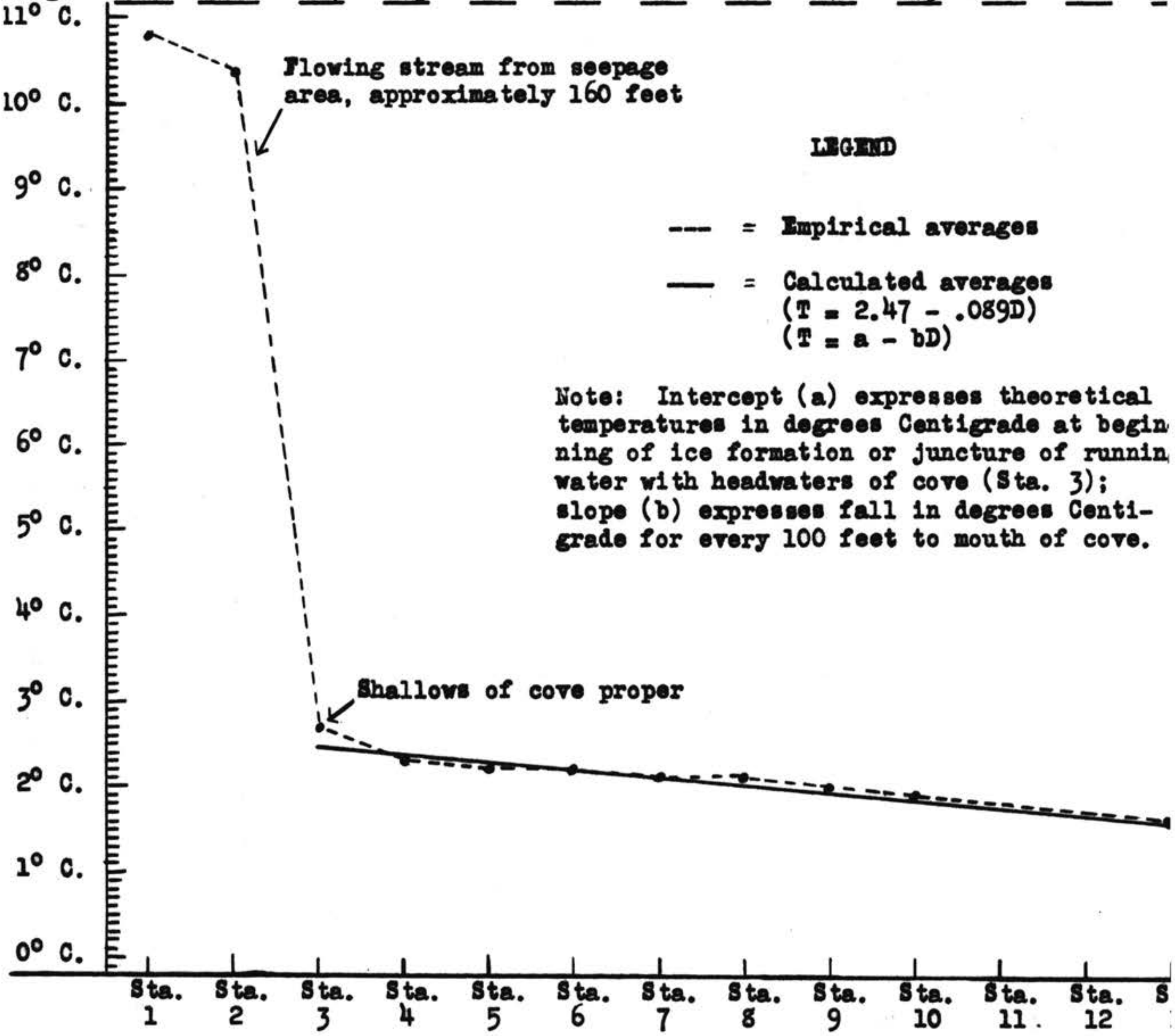
As the diameter of the thermistor of the Whitney underwater thermometer xceeded the dimension of the hole, substitution was effected by lowering a lass thermometer, graduated in degrees Farhenheit, to varying depths within he dam. Readings at 10 and 11 feet were 50.2° F. (10.1° C.) and 51.8° F. 11.0° C.) respectively. The thermometer registered 57.2° F. (14.0° C.) at he 16-foot depth after a period of 3 minutes, but registered only 52.7° F. 11.5° C.) when relowered to the same depth and allowed to remain 30 minutes. y comparison, spring number 1 registered 10.8° C. and spring number 2 regisered 11.6° C. when tested with the Whitney thermometer a short time later.

The accuracies of temperature readings taken from the holes within the am may have been slightly impaired for two reasons: first, the mercury olumn of the substituted thermometer could have receded in the interim etween emergence from ground water and interpretation at the surface in pite of a felt covering fitted over the bulb and maximum haste exercised in aising the instrument; and, secondly, the open water in the hole would tend o be rearranged with the colder and heavier water settling. Additional ime was lost at each reading by the necessity of removing muddy water from he graduated areas of the thermometer before registrations could be observed. hese difficulties and probable sources of error led to the formulation of a lan, later successfully executed, to sink a 16-foot length of 3-inch pipe ith a well point attached to the distal end and threaded for a tight-fitting ap at the surface. Nevertheless, the procedure appeared to have adequately emonstrated that a considerable volume of water, warmed by passage through arth, was seeping through the dam between the pond and the cove and merging in the principal areas of seepage near the lakeward base. A brief urvey of Cantonement Pond verified the presence of two springs feeding that ody of water near the upper limit.

Subsequent perusal of tabulated data indicated that a very gentle tem-erature gradient probably existed in the cove between 9:00 a.m. and 5:15 p.m. n December 9, 1950. Inasmuch as water density increases from temperatures f 0° to 4° C., it is again emphasized that a density gradient existed. It as noted that, at some stations, slightly warmer and consequently slightly eavier waters were recorded at the highest levels. This was probably due to hanging densities resulting from rapid ice meltage at the time the stations ere visited in midafternoon. Significantly, the air temperature had returned near freezing by the time the last two stations were processed (Table 3). t was apparent that the greatest amount of heat was lost from the ground ater in the last 60 feet of the stream and in the open or thinly covered tanding shallows at the immediate head of the cove; however, this could have een a temporary condition due to heat taken by ice meltage. Slightness of he differences between recordings taken in the principal area of seepage, at he base of the impoundment, and those taken over the initial hundred feet of unning water seemed to indicate that considerable subterranean flow entered he stream in addition to waters from visible sources. Occurrences of higher ttom recordings at stations farther removed from sources of inflowing water ere perplexing, to say the least, and led to a conjecture that the recorder d probably failed to consistently follow the maximum course of the density urrent, if such existed. Warmth taken from the earth at the bottom of the ve was also given consideration, but the effectiveness of the factor was parently minimized by failure of all bottom readings to register approxi-tely the same temperature. Bottom readings were omitted entirely from the alyses of several subsequent data series without nullification of gradient pression.

TABLE 3. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 9:00 A.M. to 5:15 P.M., December 9, 1950.

epth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
rface	10.8	10.4	2.2	Ice	Ice	Ice	Ice	Ice	Ice	Ice			I
ft.			3.2	2.1	2.0	2.0	2.1	2.2	2.0	1.0			1
ft.				2.2	2.0	2.0	2.0	2.0	2.0	1.9			1
ft.				2.6	2.2	2.3	2.0	2.0	1.9	1.9			1
ft.					2.4	2.2	2.0	2.0	1.9	1.9			1
ft.						2.5	2.0	2.0	1.9	1.9			1
ft.							2.7	2.0	1.9	1.9			1
ft.								2.3	2.0	1.9			1
ft.									1.9	1.9			1
ft.									2.0	1.9			1
ft.									2.4	1.9			1
ft.										1.9			1
ft.										2.8			2
erage	10.8	10.4	2.7	2.3	2.2	2.2	2.1	2.1	2.0	1.9	---	---	1



Note: Intercept (a) expresses theoretical temperatures in degrees Centigrade at beginning of ice formation or juncture of runnin water with headwaters of cove (Sta. 3); slope (b) expresses fall in degrees Centigrade for every 100 feet to mouth of cove.

Figure 4. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, December 9, 1950, expressed in graphic form.

It was felt that a more concise expression of the apparently delicate nfluence of inflowing water was needed, and, to that end, the data were sub- ected to a number of graphic arrangements and statistical analyses. Nearest greement between calculated and existent average temperatures was met rough application of the linear regression method (Figure 4). The regres- ion line, expressing the formula $T = a - bD$, fitted the plotted empirical ata sufficiently close to support a reasonable assumption that a relation- ip existed between the average temperature of a given station and the istance of that station from the effective source of warmer water. Pro- edure involved in application of the method is exemplified in Table 1.

The negative value of the constant b (regression factor), expressing the lope of the regression line, was taken to indicate a theoretical decline of 089° C. over each hundred feet of distance between the effective source of ncoming water and the mouth of the cove. Conversely, a positive value would ave indicated a corresponding progressive rise in water temperature over the ame distance and would, therefore, have mathematically excluded the seepage ater from consideration as an influential warming agent.

The constant a, expressing the intercept of the regression line, was aken to denote a theoretical water temperature of 2.47° C. at a point Station 3) where the inflowing water exerted initial effectiveness. Since e weight of water changes correspondingly with temperature changes, a istance-density relationship could have been demonstrated by substitution f average water densities at each station in place of average temperatures.

It would be virtually impossible to demonstrate the effectiveness of ncoming warmer water exclusive of such other influences as ice formation, e peculiar behavior of water densities at temperatures between 4° C. and e point of freezing, and warmth gained from earth at the bottom of the ve. As previously commented, the effects of these factors are distributed calculations expressed by regression lines.

Potentialities inherent in ice coverage are paradoxically both construc- ive and destructive to the expression of temperature gradients induced by e seepage water. When air temperatures remain below 32° F., the cover not ly insulates the underlying water of the cove but becalms and shields it gainst the disturbing influences of wind and wave. At higher temperatures e ice melts and, in contrast to the usual law of expansion by heat, the eltage water sinks until attaining a maximum density at 39.2° F. or 4° C. ters warmed above this temperature again exhibit lighter densities and scend in conformance with the physical law. It is recalled that the energy ecessary for transformation from the solid to the liquid state is taken om all surrounding media--underlying water as well as from the atmosphere. t can, therefore, readily be seen that changing water densities caused by e melting over the entire cove would not be in phase with changes origi- ting and spreading progressively lakeward from mingling cove and seepage ters at the upper limit, and that the counter-influence could gradually quickly, according to climatic conditions, obliterate gradient expres- ion altogether.

The influence of heat absorption from sunlight must be considered with owledge that a bright sun, even on a comparatively cold day, is capable of ating water to a higher temperature than that of the surrounding atmos- ere (Ide, 1935). Observations of daily changes in water temperatures in e Big Bend Cove, wherein no inflow was evident, clearly showed that the solar fluence was effective through ice coverage when air temperatures remained elow 32° F. Similar influence of sunlight through ice covering farm ponds as reported by Wallen (1951). In the course of subsequent surveys, it was oted, on several occasions, that a shallow area of water registering low emperatures attributable to ice meltage would, when revisited after a few ours of sustained sunshine, register temperatures above the influence of ncoming water.

It follows that data most expressive of the unadulterated influence of he seepage water should be obtained at times when other factors are nearest o neutral. Sub-freezing pre-dawn hours, or at least the early morning hours f cold, cloudy mornings following nights of below-freezing air temperature hould, therefore, yield data of maximum interpretive value. As it was ealized it would often be impracticable or impossible to obtain data under uch climatic conditions, it was conceded, from the beginning, that data, enerally taken, would generally reflect a conglomeration of abetting and onflicting influences. It could be demonstrated, however, that as long as he influence of the inflowing ground water was the predominant one, the ffectiveness of other influences could be detected by the degree of positive negative regression from a line representing the warm-water influence. or example, the calculated trend expressed by the straight regression line n Figure 4 indicates that a significant temperature gradient existed at the ime the data were taken, while positive regression, chargeable to sunlight bsorption, at Station 3, and negative regression, chargeable to ice meltage, t Stations 4, 5 and 6, indicate that other influences were beginning to bear n gradient expression caused from inflowing ground water.

The above diagnosis appears reasonable in view of the fact that ecember 9, 1950, following a sub-freezing night, was a bright sunny day ring which air temperatures rose well above 32° F. before midmorning when

e upper regions of the cove were tested. As large numbers of white crappies
re present, it was assumed that the prevailing gradient was, or recently
d been, of sufficient steepness to promote aggregation.

The status of bottom warming as a contributing factor to the overall
adient expression remained the most difficult to demonstrate in that such
fluence, uniformly emitted, was not tetectable by deviation from regres-
on; nor could its effectiveness be isolated, as there were no practicable
cilities available for discontinuing or diverting the flow of water from
e seepage area.

Although a relationship, induced by ground-heated water, seemed to have
en demonstrated between the water temperature at any given site and the
stance of the site from the head of the cove, the fact remained that
plicability was confined almost entirely to waters within the cove proper.
e relationship did not assume accountability for water temperatures above
e merger of the cove and the stream. It was felt that such a relationship,
monstrable in both the cove and the running stream, would provide a more
finite link between the springs at the base of the dam and the cove's
per limit, and thus even more conclusively point to the inflowing water
the dominant influence behind gradient expression in the Boatdock Cove.

In view of the greater rate of heat loss in the running stream as com-
red to that in the cove, it appeared evident that the establishment of
ch a relationship would have to be based on mathematical procedures capable
expressing calculated trends in conformance with non-linear data points.
thematical procedures followed are exemplified in Table 2.

Application of the described procedure to data procured on December 9,
50, resulted in poor agreement between the curvilinear regression line and
otted empirical data, although a correlation was indicated (Figure 5). The

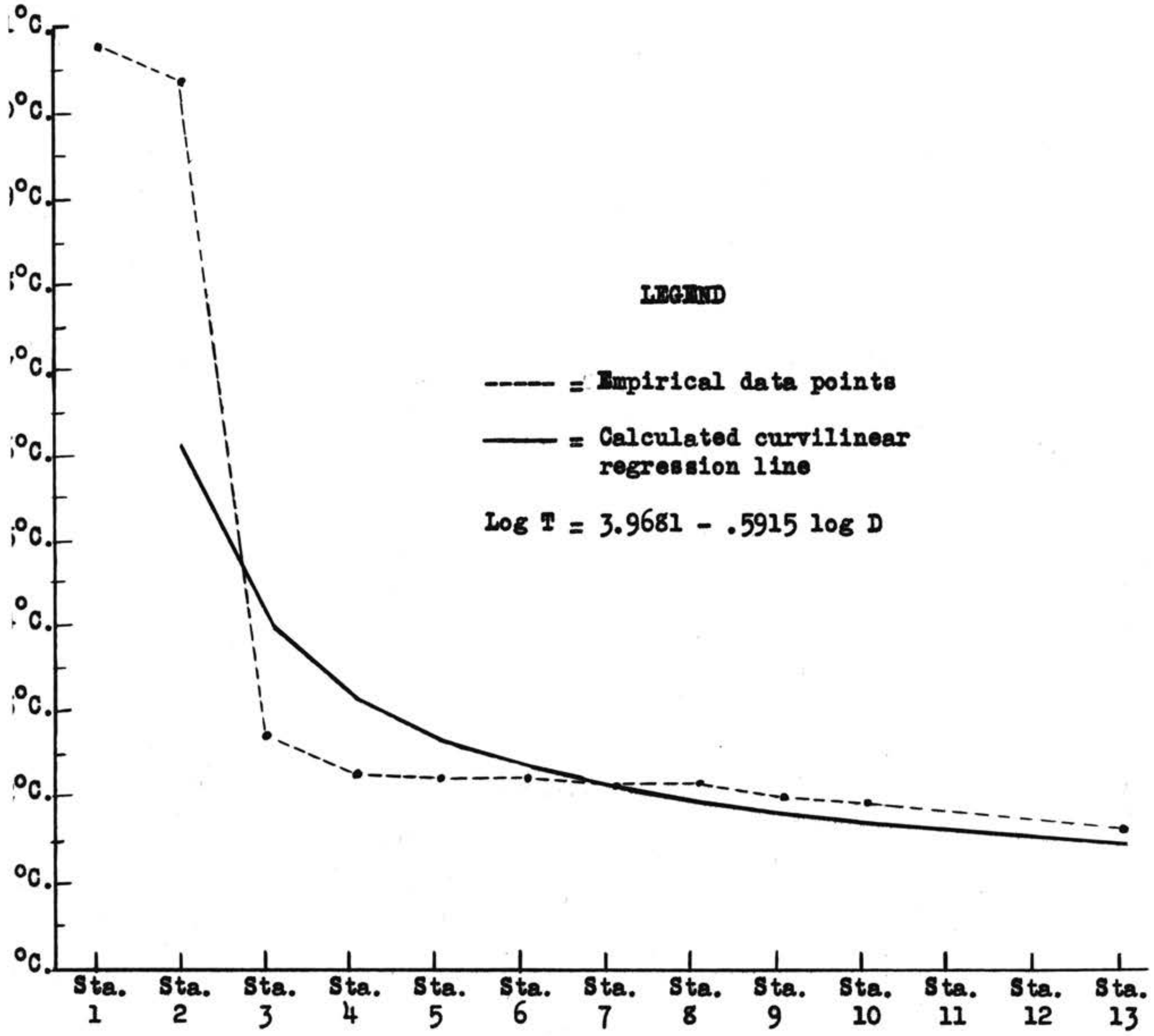


Figure 5. Distance-water temperature relationship, expressed by curvilinear regression, of water between seepage area and mouth of Boatdock Cove of Canton Reservoir, December 9, 1950. Maximum air temperature, 59° F.; minimum, 24° F. (Linear regression relationship shown in Figure 4; tabulated data in Table 3.)

or agreement, it was felt, could be attributed to influences counteractive that of the incoming water. Consequently, a series of temperature cordings procured on January 30, 1951--a day when all influences other than ose of the incoming ground water should have been virtually neutral--was bjected to the same procedure. The resultant parabola, as shown in gure 6, not only fitted the data points with unusual fidelity throughout e cove but continued to display reasonable harmony up the running stream within 100 feet of the seepage area. Data of that date were deliberately lected because the day had followed three consecutive 24-hour periods of b-freezing air temperatures and was further characterized by general haze d cloudiness, although brief periods of sunshine occurred intermittently the afternoon. The minimum air temperature recorded during the preceding ght was 5° F., and the maximum reached during the day was 15° F. Although w fishermen were out in the severe weather, possession of 260 white crappie ten anglers, interviewed at random, was considered to be indicative of sh aggregation.

Attention is here invited to a comparison of parabolas representative of ta on January 30, 1951, and December 24, 1951--almost a year later--as esented in Figures 6 and 7. Weather conditions occurring for these dates re similar in that a thick cover of ice lay over the cove on both days d both had followed sustained periods of extreme cold weather initiated severe drops in air temperature. Differences were that some ice meltage curred on December 24, as air temperatures ranged between 17° and 44° F., d that the ice was not as thick nor the day as cloudy as on the preceding nuary date. Significantly, the agreement between parabola and data points, though generally satisfactory, was not as close as the fit exhibited on

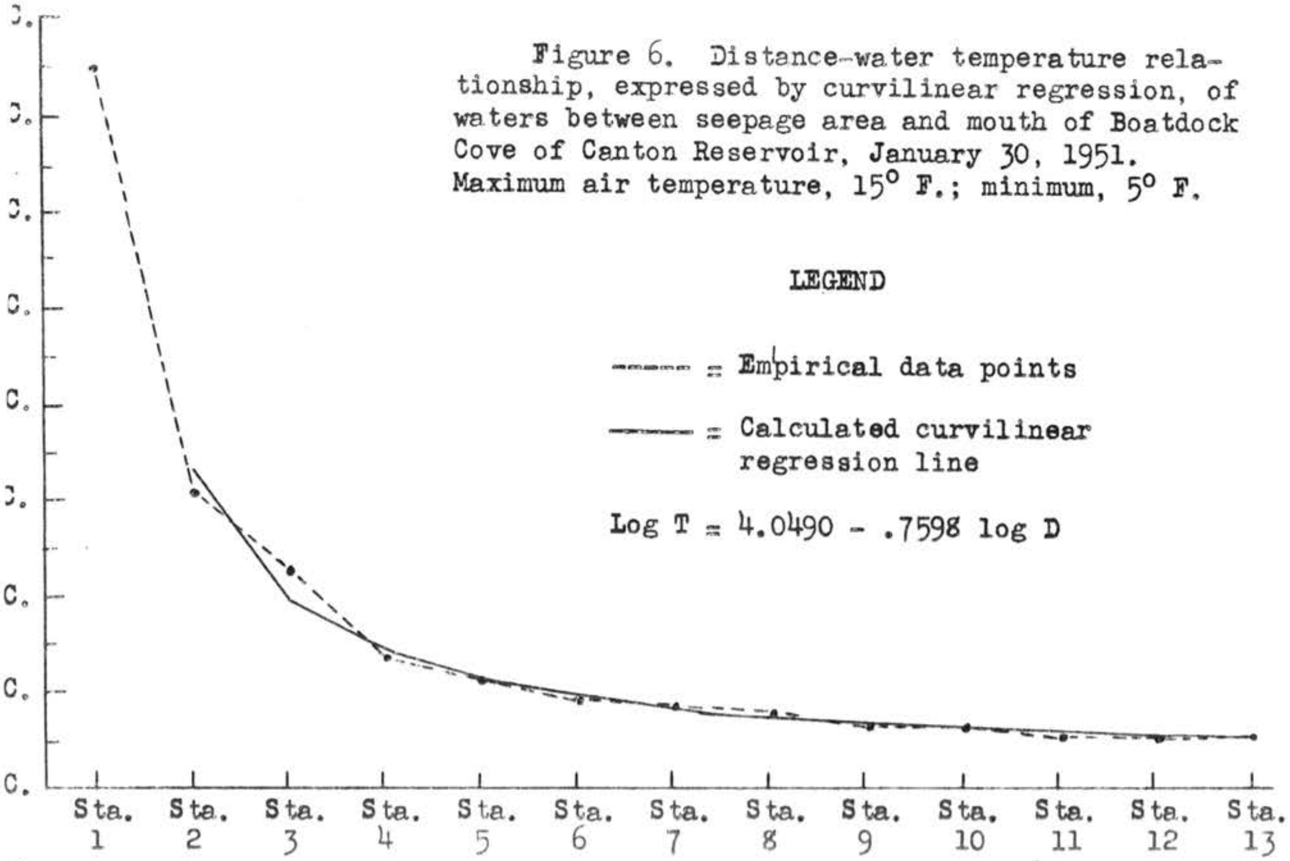


Figure 6. Distance-water temperature relationship, expressed by curvilinear regression, of waters between seepage area and mouth of Boatdock Cove of Canton Reservoir, January 30, 1951. Maximum air temperature, 15° F.; minimum, 5° F.

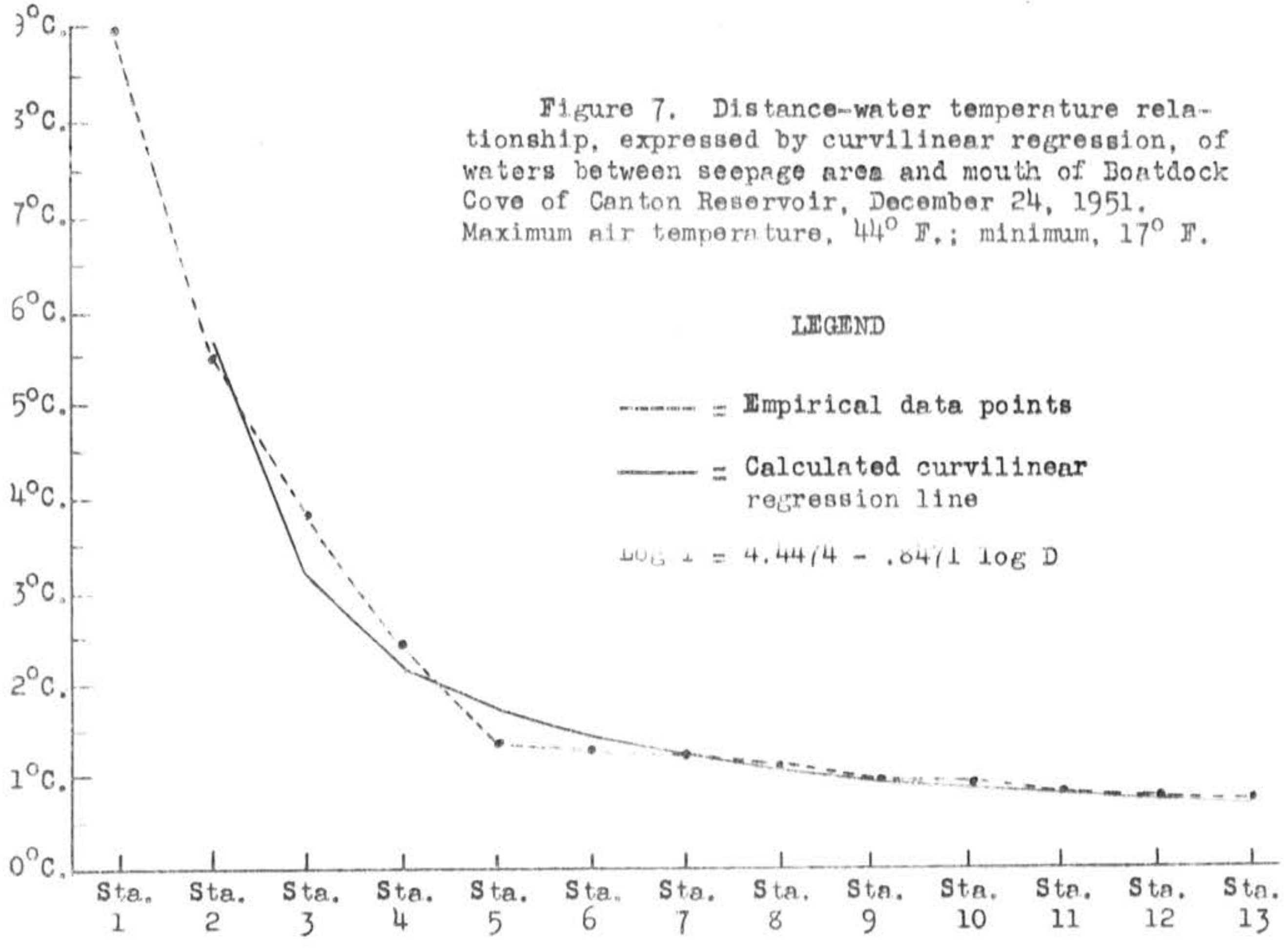


Figure 7. Distance-water temperature relationship, expressed by curvilinear regression, of waters between seepage area and mouth of Boatdock Cove of Canton Reservoir, December 24, 1951. Maximum air temperature, 44° F.; minimum, 17° F.

nuary 30. In view of the similarity of the regression factors derived 'om solved equations and of the graphically expressed parabolas, it appears asonably evident that, under specific weather conditions, the distribution ' average water temperatures between the seepage area and the mouth of the ve tended to conform with the exponential law.

Calculations involved in the determination of non-linear relationships e much more time consuming than those leading to linear expression and e sparingly used. The simpler method is substituted, because it is not ly more expedient but adequately expresses the gradient trends in the shable depths of the cove proper.

The weather moderated soon after the first visit to the reservoir and mained reasonably mild until the night of December 27, when another sudden op in air temperature occurred. The reservoir was visited a second time on e following morning. Ice had formed over most of the Boatdock Cove during e night but was too thin to bear one's weight, thus preventing the procurement of data in the usual manner. Since readings were taken at shallow offore depths at each station rather than in the center of the cove, limited nfidence is held in the calculated trend expressed in Figure 8. The graph presented principally to demonstrate that, by the linear regression method analysis, information of limited general value may be derived even from data imperfectly taken. It can be seen that a temperature gradient of slight eepness (.06° C. per 100 feet) generally indicated over the 600 feet nearest e cove's mouth was disrupted over the remaining distance to the upper limit. e negative regression exhibited over this shallow region is in keeping with e fact that the day warmed rapidly, with appreciable ice meltage apparent early as 9:00 a.m. Significantly, fishing was generally poor throughout

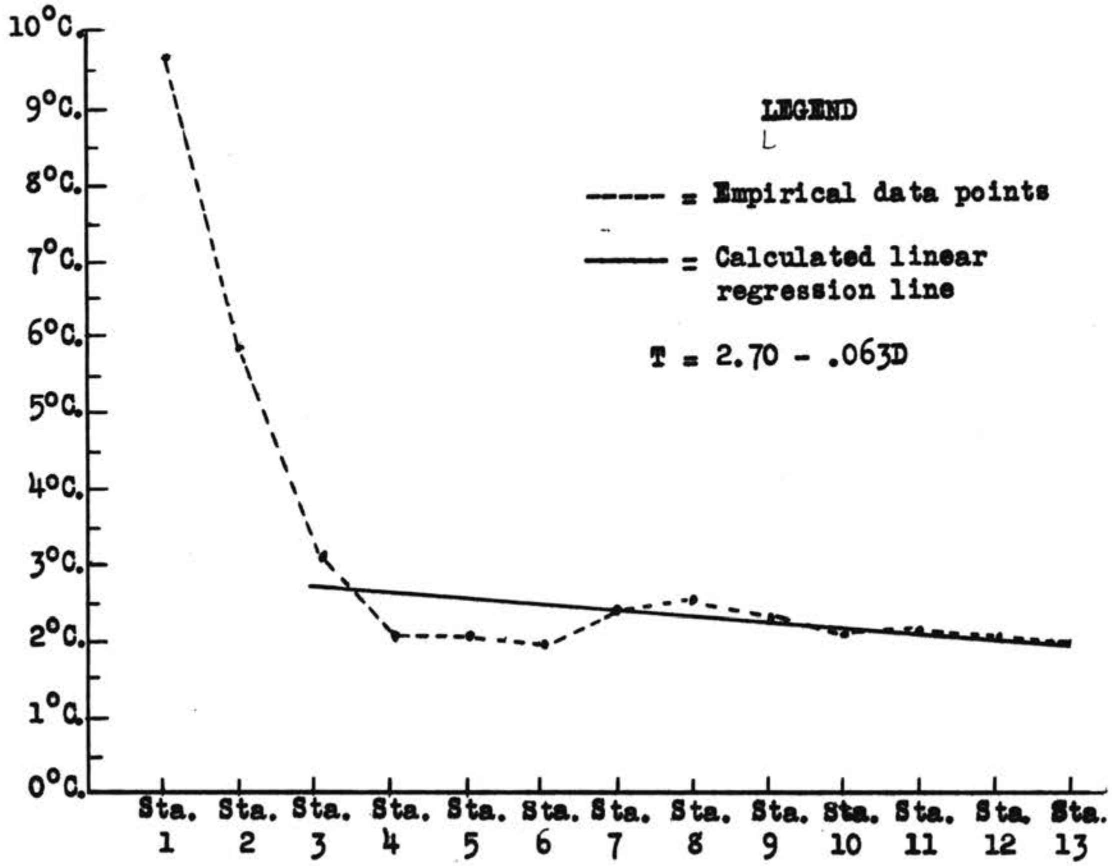


Figure 8. Empirical and calculated average temperatures for December 28, 1950, expressed in graphic form. Maximum air temperature, 50° F.; minimum, 5° F.

e cove, but anglers on the boat docks anchored at the mouth were fairly suc- essful. Far greater successes were enjoyed by fishermen in boats out in the ch larger Cantonement Cove.

The month of January, 1951, was, in general, unseasonably mild and dry til the night of the 27th when a severe cold wave suddenly overspread the tate. Air temperatures fell abruptly (Appendix B) and remained below reezing over a period of five consecutive days. The third visit to Canton eservoir began on the morning of January 28 and extended through February 4. nuary 28 was characterized by a sustained northerly gale, intermittent ow, and severely cold air temperatures (minimum, 7° F.; maximum, 22° F.). gh waves were forced from the lake directly into Boatdock Cove throughout e day, causing a rise in the water level that was particularly noticeable the upper limits. No water temperatures were taken as the cove did not eeze over during the day, and the turbulence of water prohibited the use of boat. Large areas of the lake froze over during the night, and on the rning of the 29th the cove could be safely walked upon throughout its tire length. Hundreds of fish, predominantly gizzard shad, could be seen bedded in the rough mosaic-patterned ice.

Water temperatures were taken daily over a one-week period (January 29 February 4, inclusive) in both Boatdock and Big Bend Coves by procedures eviously described. Each daily series of temperature recordings taken in atdock Cove during the one-week survey are presented in tabular, graphic, d statistical forms in the following tables and figures. Also depicted are ily comparisons of average water temperatures at each station with those of e preceding day.

<u>January 29, 1951</u>. Data of January 29 (Table 4 and Figure 9) show tremely low water temperatures in Boatdock Cove with no indication of a

mperature gradient. Weather of such severity prevailed (maximu, 14° F.; inimum, 0° F.) that only two fishermen were seen throughout the entire day.

January 30, 1951. Data of January 30 (Table 5 and Figure 10) demon- trate the apparent manifestation of a temperature gradient in Boatdock Cove ince the recordings of the preceding day. Comparisons of average water emperatures at each station, as presented in Table 6, clearly show rises in ater temperatures throughout the cove in spite of continued severe weather maximum, 15° F.; minimum, 5° F.). Attention is directed to the general pat- ern of the rises in average water temperatures (Figure 11) which is also in e form of a gradient. Very few anglers braved the extremely inclement eather, but those who did experienced high success during short periods of ime—most fished less than half an hour. Ice covering the cove measured irteen inches in thickness.

January 31, 1951. Water temperatures failed to rise appreciably, but e temperature gradient persisted throughout January 31, as evidenced by ata presented in Tables 7 and 8 and Figures 12 and 13. Cold northerly winds d low air temperatures (maximum, 7° F.; minimum, 6° F.) characterized the y, but more fishermen appeared than had been present on the previous day. man and wife interviewed during a spot-check of creels had harvested 84 sh in approximately three hours, and several catches of over 100 white rappie were reported by the concessioner. Creel limits had been removed y the Oklahoma Game and Fish Department.

February 1, 1951. February 1 was the fifth day of continuous sub- reezing air temperatures (maximum, 19° F.; minimum, 7° F.). Data presented n Tables 9 and 10 and Figures 14 and 15 indicate the continued presence of temperature gradient and a general rise in water temperatures throughout e cove. The number of fishermen increased considerably despite continued

TABLE 4. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 9:45-11:45 A.M., January 29, 1951.

Depth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
urface	7.2	0.2*	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
1 ft.			0.1	0.05	0.1	0.1	0.1	0.10	0.10	0.1	0.25	0.2	0
2 ft.			0.2	0.10	0.2	0.1	0.3	0.25	0.10	0.1	0.25	0.2	0
3 ft.				0.05	0.3	0.1	0.3	0.30	0.10	0.1	0.25	0.2	0
4 ft.					0.4	0.2	0.4	0.35	0.10	0.1	0.25	0.2	0
5 ft.					1.1	0.3	0.4	0.40	0.10	0.1	0.25	0.2	0
6 ft.						0.8	0.4	0.40	0.10	0.1	0.25	0.2	0
7 ft.								0.40	0.10	0.1	0.25	0.2	0
8 ft.								0.75	0.10	0.1	0.30	0.2	0
9 ft.									0.10	0.1	0.30	0.2	0
0 ft.									0.10	0.1	0.30	0.2	
1 ft.									0.15	0.1	0.30	0.2	
2 ft.									0.50	0.1	0.30	0.2	
3 ft.										0.5	0.30	0.2	
4 ft.											0.30	0.2	
verage in ice	7.2	0.2	0.15	0.07	0.42	0.27	0.32	0.37	0.14	0.13	0.28	0.2	0

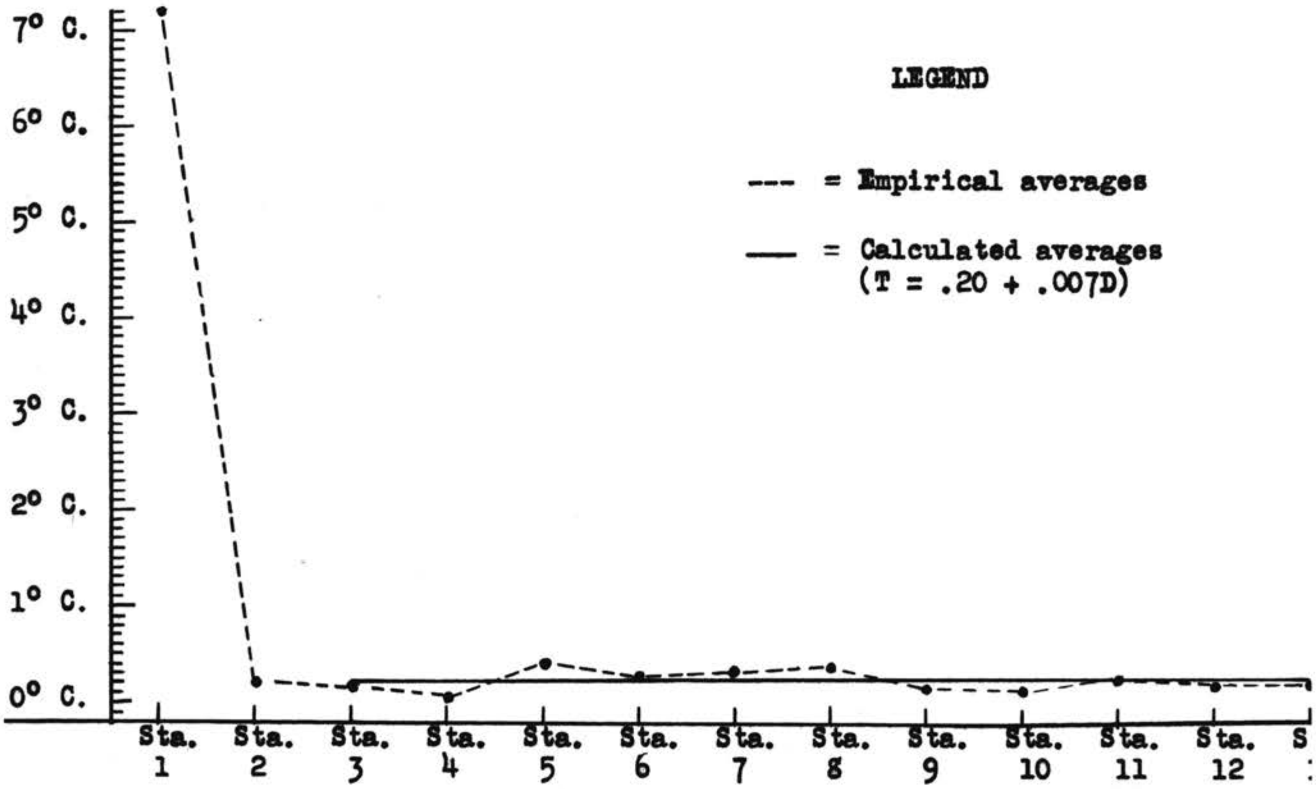


Figure 9. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, January 29, 1951, expressed in graphic form.

TABLE 5. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 1:00-4:00 P.M., January 30, 1951.

Depth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
urface	7.5	3.1*	2.0*	1.2*	1.1*	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
1 ft.			2.6	1.4	1.1	0.9	0.9	0.8	0.6	0.6	0.5	0.5	0
2 ft.				1.6	1.1	0.9	0.9	0.8	0.6	0.6	0.5	0.5	0
3 ft.					1.1	1.0	0.8	0.8	0.6	0.6	0.5	0.5	0
4 ft.					1.2	1.0	0.8	0.8	0.7	0.6	0.5	0.5	0
5 ft.					1.6	1.0	0.8	0.8	0.7	0.7	0.5	0.5	0
6 ft.						1.1	0.8	0.9	0.9	0.7	0.5	0.5	0
7 ft.							1.1			0.7	0.6	0.5	0
8 ft.										0.7	0.6	0.5	0
9 ft.										0.7	0.6	0.5	0
0 ft.										0.7	0.6	0.5	
1 ft.										0.7	0.6	0.5	
2 ft.										1.0	0.6	0.5	
3 ft.											0.8	0.5	
4 ft.												0.6	
verage	7.5	3.1	2.3	1.4	1.2	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0

ery thin ice

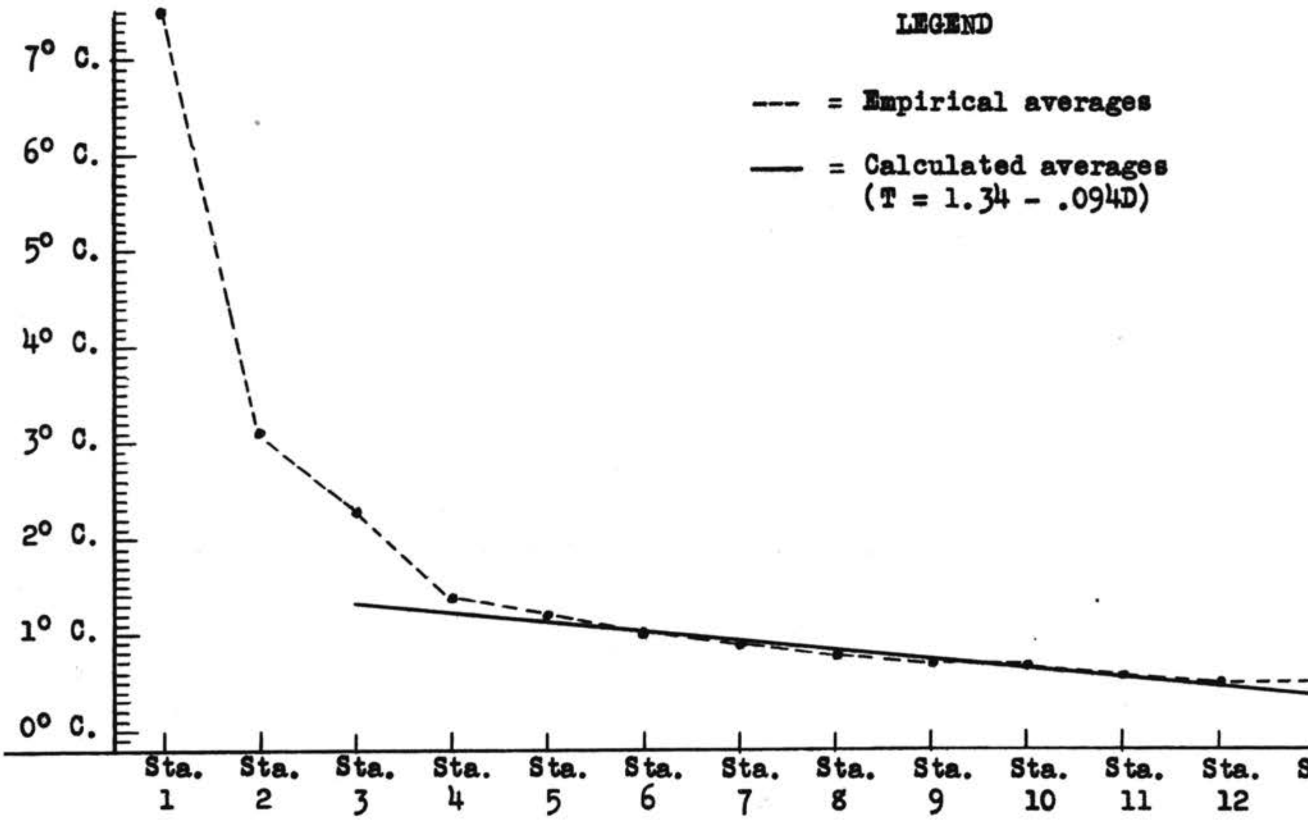


Figure 10. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, January 30, 1951, expressed in graphic form.

TABLE 6. Comparison of Average Water Temperatures at Each Station in Boatdock Cove on January 30 with Corresponding Averages on January 29, 1951.

Date	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
uary 29	7.2	0.2	0.2	0.1	0.4	0.3	0.3	0.4	0.1	0.3	0.3	0.2	0
uary 30	7.5	3.1	2.3	1.4	1.2	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0
ference	+0.3	+2.9	+2.1	+1.3	+0.8	+0.7	+0.6	+0.4	+0.6	+0.4	+0.3	+0.3	+0

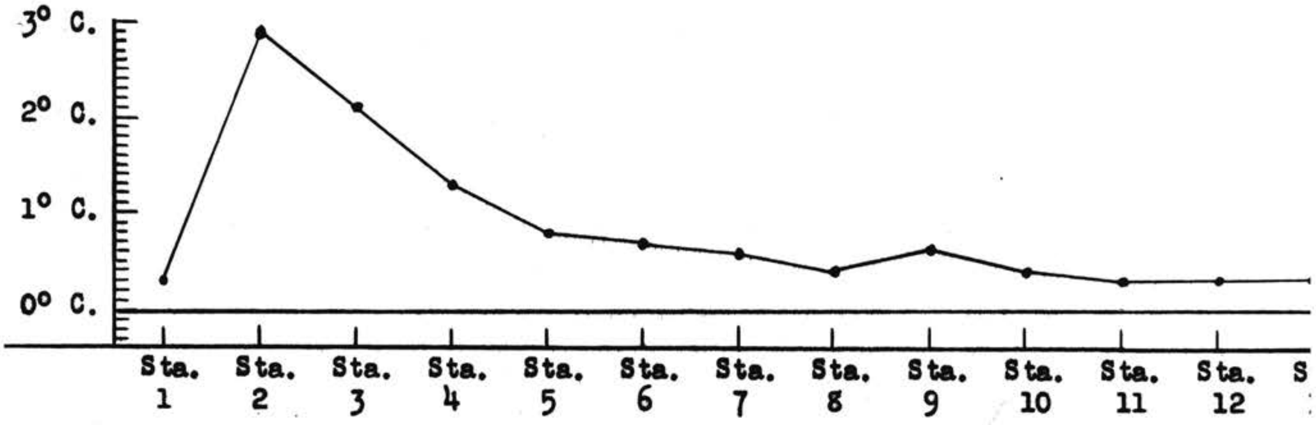


Figure 11. Differences in average water temperatures at each station in Boatdock Cove on January 30 and corresponding averages on January 29, 1951, expressed in graphic form.

TABLE 7. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 1:00–4:00 P.M., January 31, 1951.

epth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
rface	6.1	3.4	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
ft.			2.3	1.1	0.8	0.8	0.60	0.5	0.40	0.50	0.40	0.30	0
ft.				1.1	0.9	0.8	0.60	0.5	0.40	0.50	0.40	0.40	0
ft.				1.5	1.0	0.9	0.60	0.6	0.50	0.60	0.45	0.50	0
ft.					1.0	0.9	0.65	0.6	0.60	0.60	0.50	0.55	0
ft.					1.3	1.4	0.70	0.6	0.60	0.60	0.55	0.60	0
ft.							1.00	0.6	0.60	0.60	0.60	0.60	0
ft.								0.6	0.60	0.60	0.60	0.60	0
ft.								0.8	0.65	0.60	0.60	0.60	0
ft.								1.2	0.65	0.65	0.60	0.60	0
ft.									0.65	0.65	0.60	0.60	0
ft.									1.00	0.70	0.60	0.60	
ft.										0.90	0.60	0.60	
ft.											0.90	0.60	
ft.												0.70	
erage	6.1	3.4	2.3	1.2	1.0	0.96	0.69	0.67	0.60	0.63	0.57	0.56	0

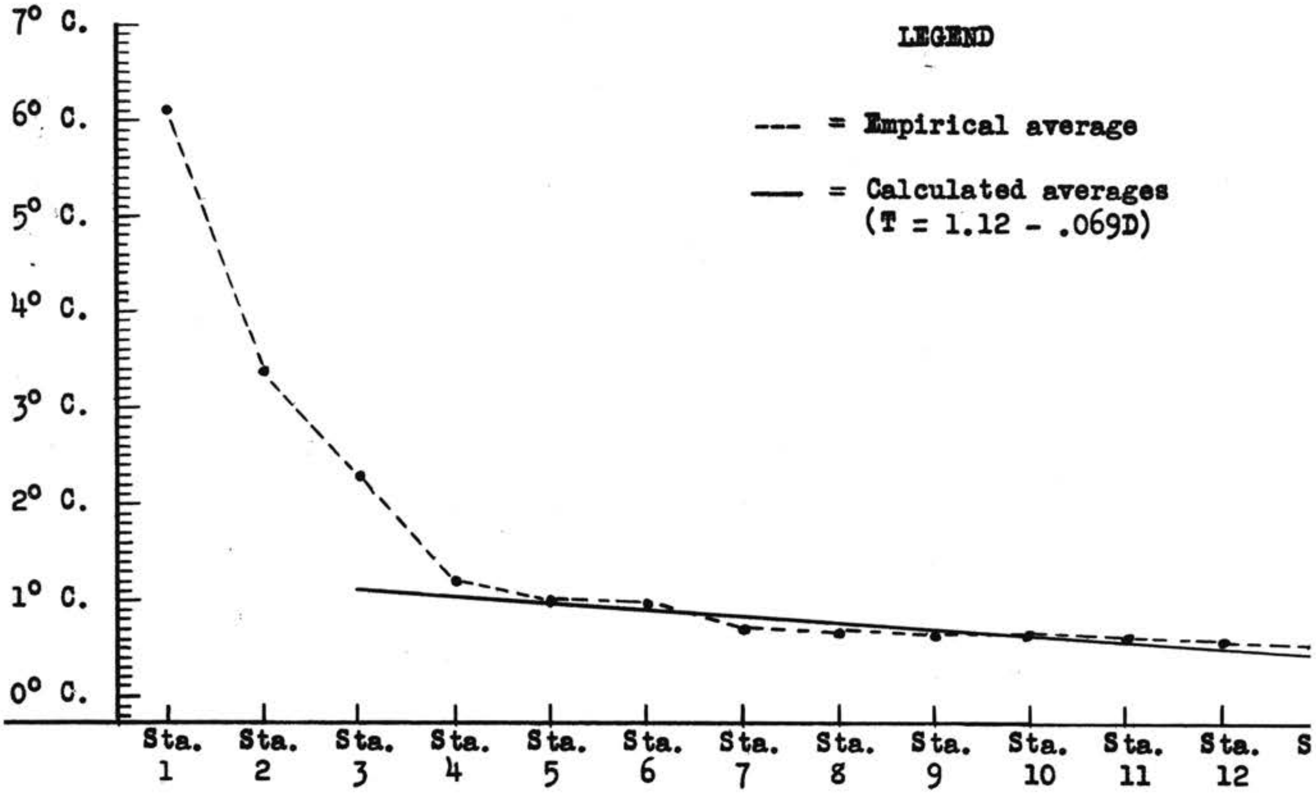


Figure 12. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, January 31, 1951, expressed in graphic form.

TABLE 8. Comparison of Average Water Temperatures at Each Station in Boatdock Cove on January 31 with Corresponding Averages on January 30, 1951.

Date	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
uary 30	7.5	3.1	2.3	1.4	1.2	1.00	0.90	0.80	0.70	0.70	0.60	0.50	0
uary 31	6.1	3.4	2.3	1.2	1.0	0.96	0.69	0.67	0.60	0.63	0.57	0.56	0
ference	-1.4	+0.3	---	-0.2	-0.2	-0.04	-0.21	-0.13	-0.10	-0.07	-0.03	+0.06	+0

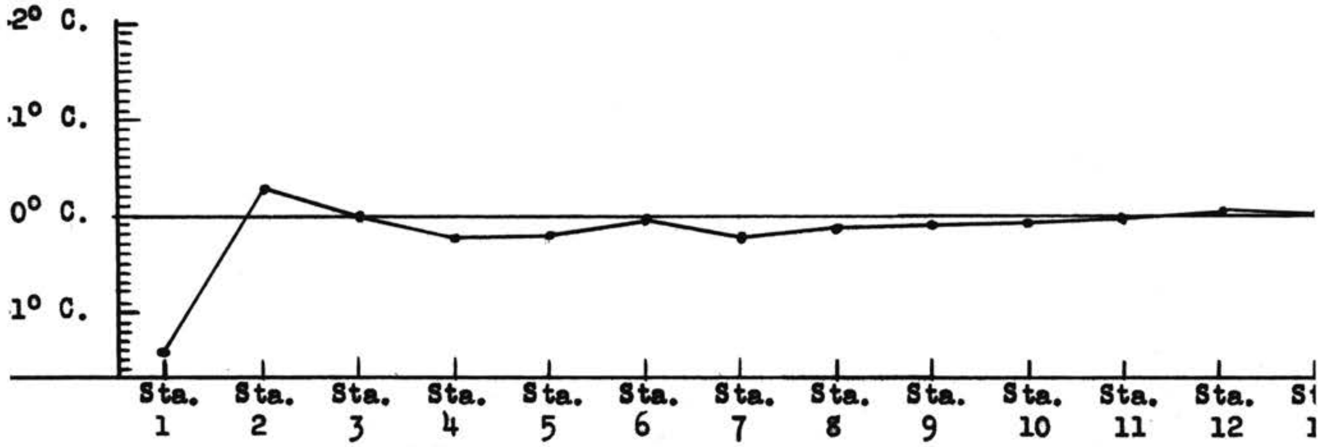


Figure 13. Differences in average water temperatures at each station in Boatdock Cove on January 31 and corresponding averages on January 30, 1951, expressed in graphic form.

TABLE 9. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 11:45 A.M.-1:45 P.M., February 1, 1951.

epth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
rface	6.3	3.2	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
ft.			2.2	1.1	0.8	0.9	0.9	0.70	0.70	0.8	0.6	0.60	0
ft.				1.3	1.0	1.0	0.9	0.70	0.70	0.8	0.6	0.60	0
ft.				2.6	1.0	1.1	0.9	0.80	0.70	0.8	0.6	0.60	0
ft.					1.4		0.9	0.85	0.75	0.8	0.7	0.60	0
ft.							1.2	0.85	0.75	0.8	0.7	0.60	0
ft.								0.85	0.75	0.8	0.7	0.60	0
ft.								0.90	0.75	0.8	0.7	0.60	0
ft.								1.10	0.80	0.8	0.7	0.60	0
ft.									0.80	0.8	0.7	0.60	0
ft.									0.80	0.8	0.7	0.60	1
ft.									1.10	0.8	0.7	0.60	
ft.										1.0	0.7	0.60	
ft.											0.7	0.60	
ft.											0.8	0.65	
erage	6.3	3.2	2.2	1.7	1.3	1.0	0.96	0.84	0.74	0.82	0.69	0.60	0

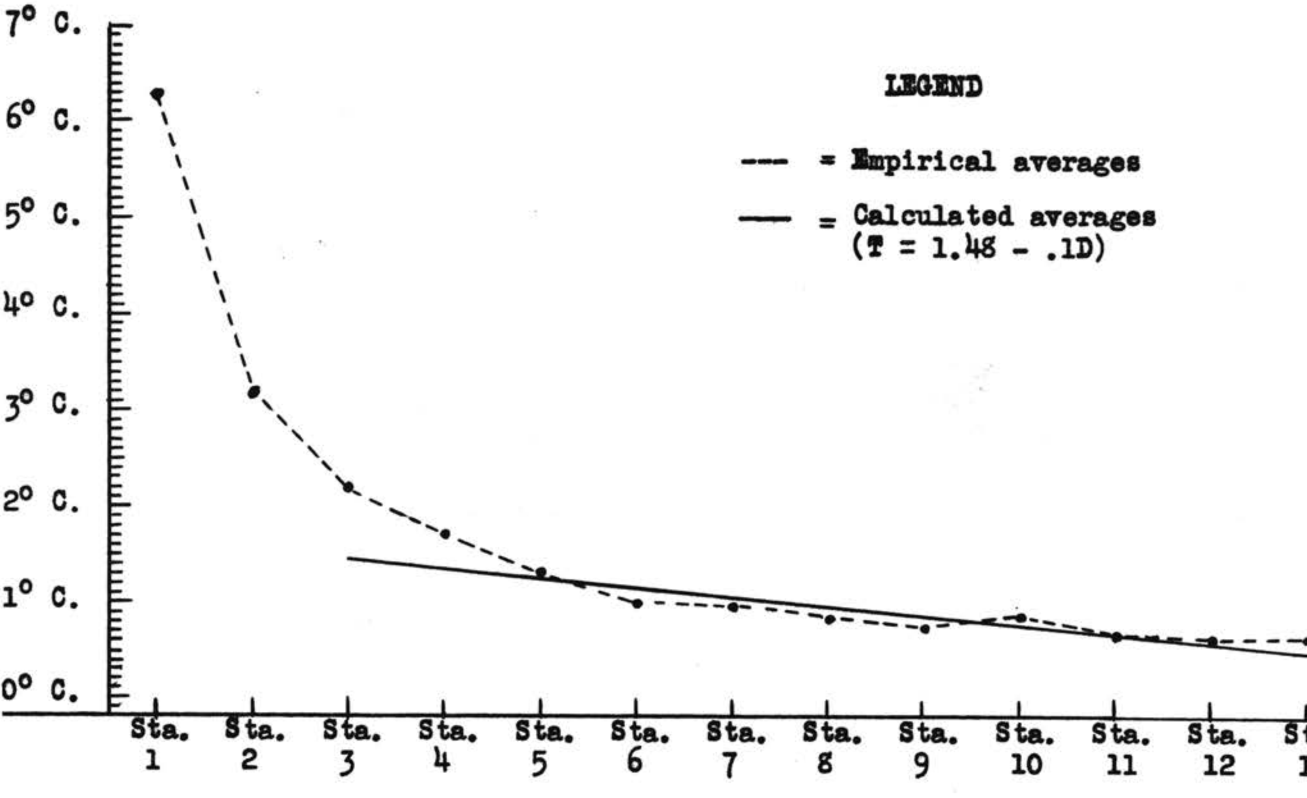


Figure 14. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, February 1, 1951, expressed in graphic form.

TABLE 10. Comparison of Average Water Temperatures at Each Station in Boatdock Cove on February 1 with Corresponding Averages on January 31, 1951.

Date	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
uary 31	6.1	3.4	2.3	1.2	1.0	0.96	0.69	0.67	0.60	0.63	0.57	0.56	0
ruary 1	6.3	3.2	2.2	1.7	1.3	1.00	0.96	0.84	0.74	0.82	0.69	0.60	0
ference	+0.2	-0.2	-0.1	+0.5	+0.3	+0.04	+0.27	+0.17	+0.14	+0.19	+0.12	+0.04	+0

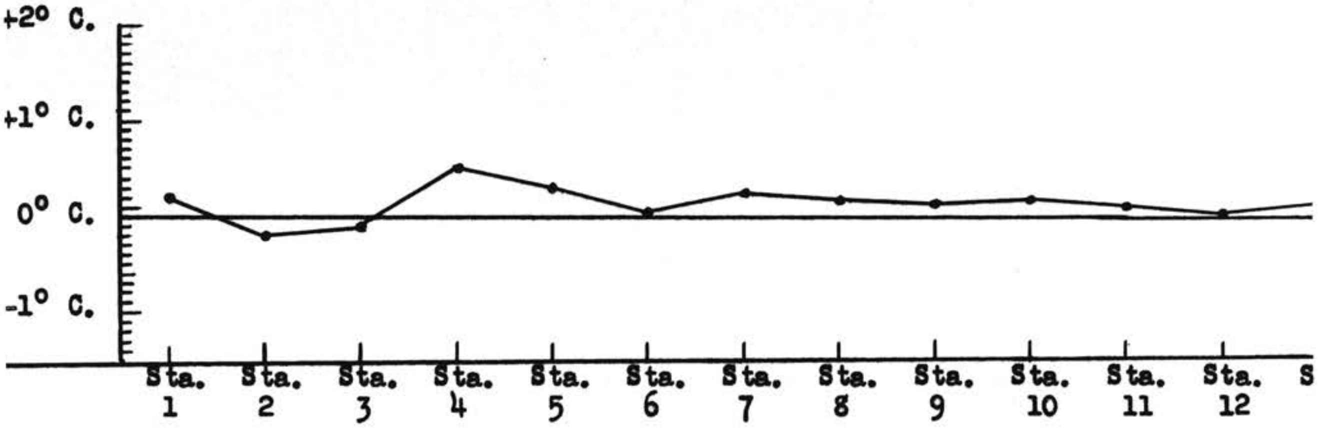


Figure 15. Differences in average water temperatures at each station in Boatdock Cove on February 1 and corresponding averages on January 31, 1951.

TABLE 11. Water Temperatures in Degrees Centigrade Recorded in One-Foot Depths and Averaged for the Stations in Boatdock Cove, 9:30-11:30 A.M., February 2, 1951.

epth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
rface	6.3	3.0	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
ft.			1.8	0.7	0.8	0.55	0.55	0.55	0.60	0.55	0.8	0.6	0
ft.				0.8	0.8	0.55	0.70	0.60	0.60	0.55	0.8	0.8	0
ft.				1.9	0.9	0.60	0.70	0.70	0.85	0.55	0.8	0.8	0
ft.					0.9	1.00	0.80	0.80	0.90	0.80	0.9	0.9	0
ft.					1.2		1.30	0.80	0.90	0.80	1.0	0.9	0
ft.								0.80	0.90	1.00	1.0	0.9	0
ft.								0.90	1.00	1.00	1.0	0.9	0
ft.								0.90	1.00	1.00	1.0	0.9	0
ft.								1.30	1.00	1.00	1.0	0.9	0
ft.									1.00	1.00	1.0	0.9	1
ft.									1.30	1.00	1.0	0.9	
ft.										1.30	1.0	0.9	
ft.											1.0	0.9	
ft.											1.1	1.0	
erage	6.3	3.0	1.8	1.13	0.92	0.68	0.81	0.82	0.91	0.88	0.96	0.87	0

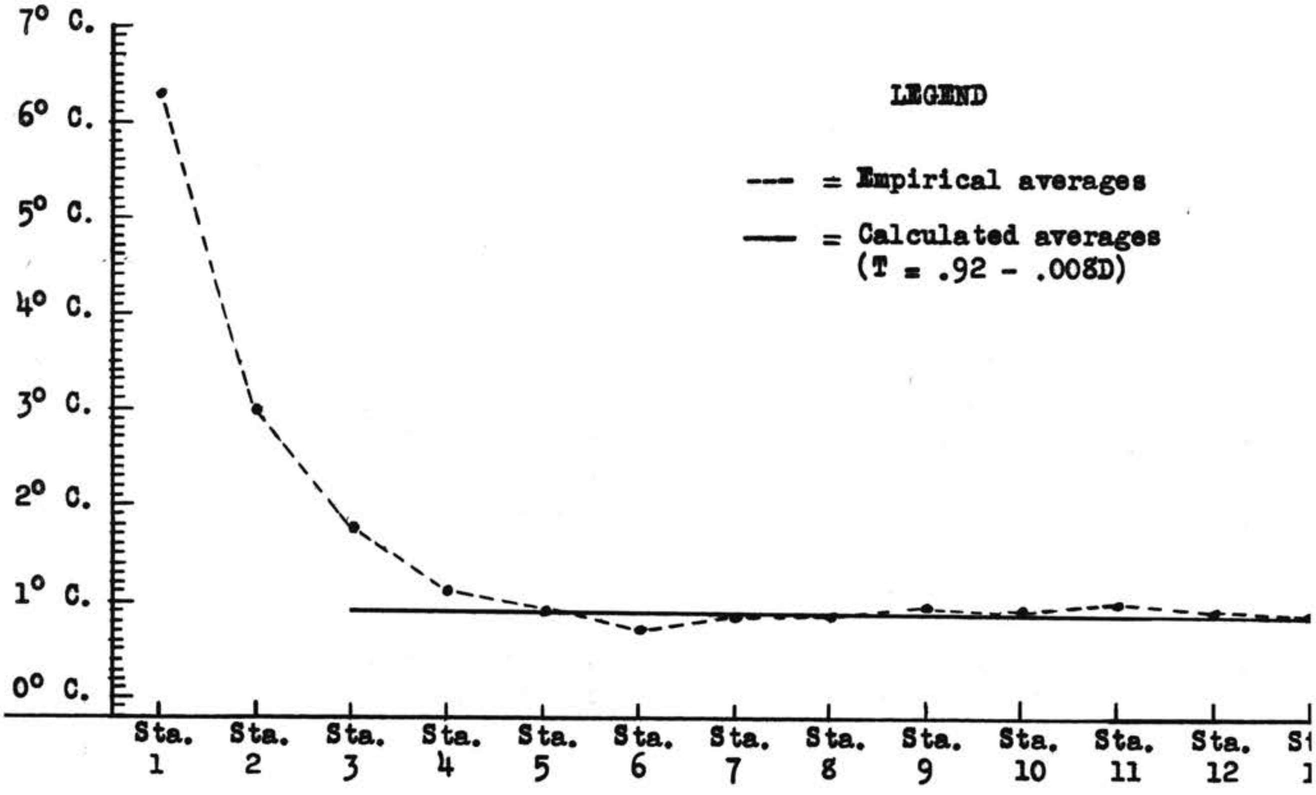


Figure 16. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, February 2, 1951, expressed in graphic form.

TABLE 12. Comparison of Average Water Temperatures at Each Station in Boatdock Cove on February 2 with Corresponding Averages on February 1, 1951.

Date	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
ruary 1	6.3	3.2	2.2	1.70	1.30	1.00	0.96	0.84	0.74	0.82	0.69	0.60	0
ruary 2	6.3	3.0	1.8	1.13	0.92	0.68	0.81	0.82	0.91	0.88	0.96	0.87	0
ference	---	-0.2	-0.4	-0.57	-0.38	-0.32	-0.15	-0.02	+0.17	+0.06	+0.27	+0.27	+0

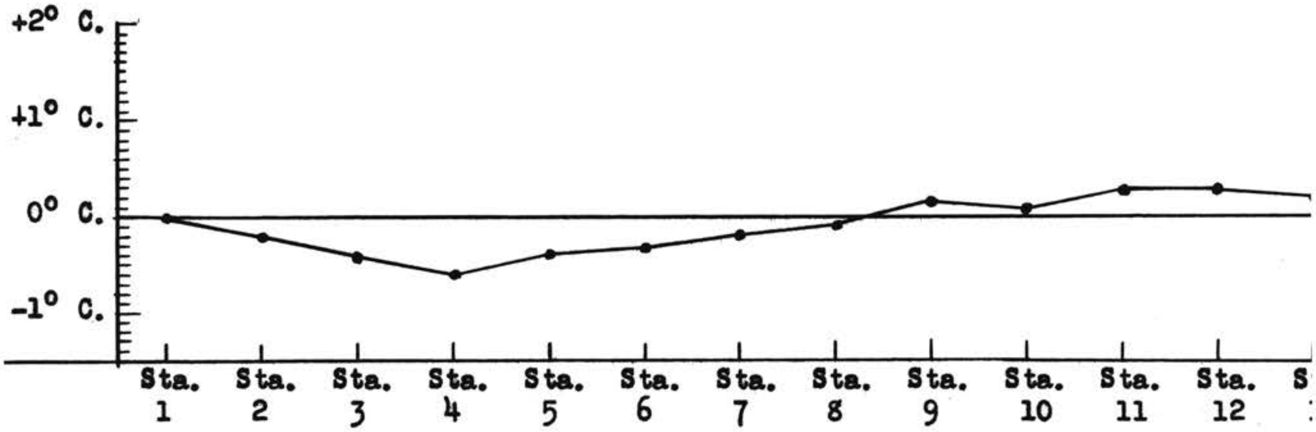


Figure 17. Differences in average water temperatures at each station in Boatdock Cove on February 2 and corresponding averages on February 1, 1951, expressed in graphic form.

TABLE 13. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 1:15-3:30 P.M., February 3, 1951.

epth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
rface	6.3	4.7	1.7	1.9	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
ft.			2.0	1.9	1.0	1.0	0.8	0.8	1.0	0.9	0.80	0.8	0
ft.				1.9	1.0	1.0	1.0	0.9	1.0	1.0	0.90	1.0	0
ft.				2.0	1.0	1.0	1.0	0.9	1.0	1.0	1.00	1.0	0
ft.					1.2	1.0	1.0	0.9	1.0	1.0	1.00	1.0	1
ft.					1.4	1.1	1.0	0.9	1.0	1.0	1.00	1.0	1
ft.						1.3	1.6	0.9	1.0	1.0	1.00	1.0	1
ft.								1.0	1.0	1.0	1.00	1.0	1
ft.								1.3	1.0	1.0	1.00	1.0	1
ft.										1.0	1.00	1.0	1
ft.										1.0	1.00	1.0	1
ft.										1.0	1.00	1.0	
ft.										1.0	1.15	1.1	
ft.										1.4	1.30	1.2	
ft.											1.40	1.3	
erage	6.3	4.7	1.85	1.92	1.12	1.07	1.07	0.95	1.00	1.02	1.04	1.03	0

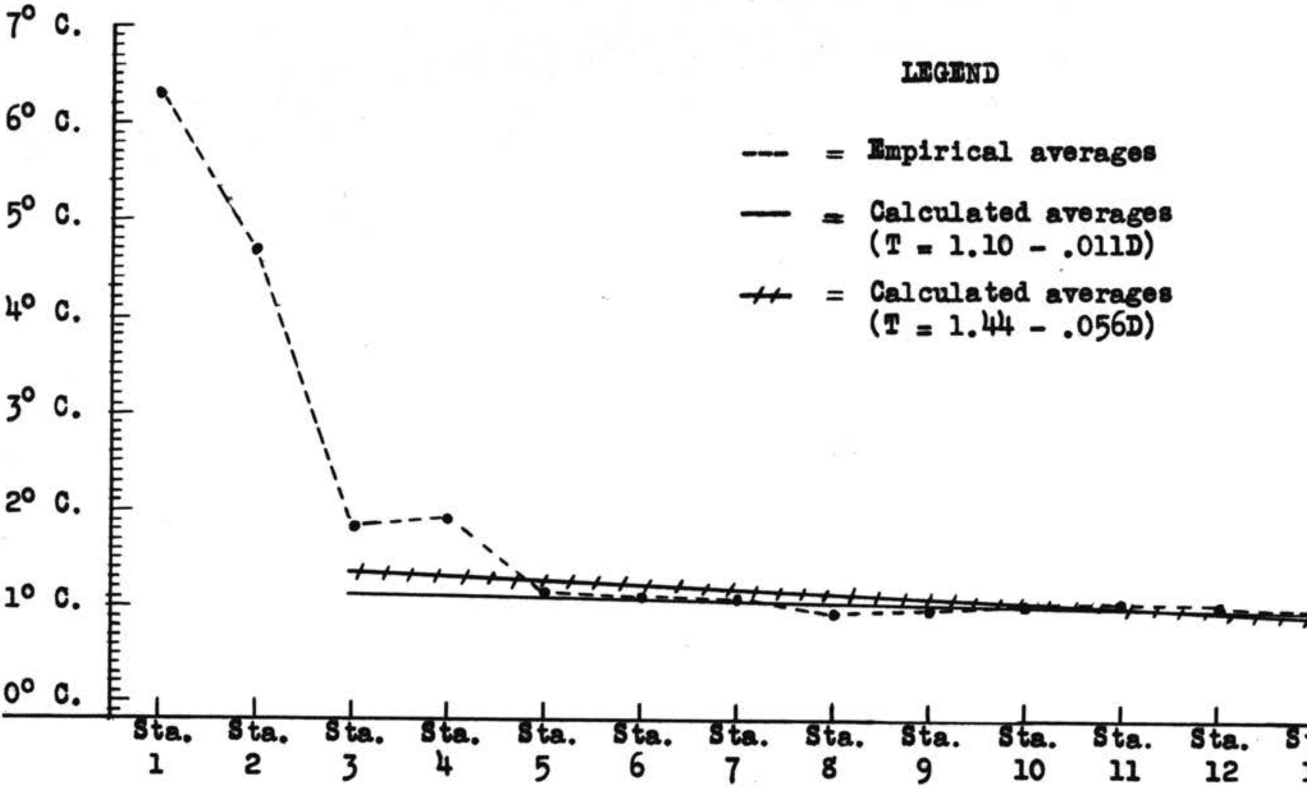


Figure 18. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, February 3, 1951, expressed in graphic form.

TABLE 14. Comparison of Average Water Temperatures at Each Station in Boatdock Cove on February 3 with Corresponding Averages on February 2, 1951.

Date	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
ruary 2	6.3	3.0	1.80	1.13	0.92	0.68	0.81	0.82	0.91	0.88	0.96	0.87	0
ruary 3	6.3	4.7	1.85	1.92	1.12	1.07	1.07	0.95	1.00	1.02	1.04	1.03	0
ference	---	+1.7	+0.05	+0.79	+0.20	+0.39	+0.76	+0.13	+0.09	+0.14	+0.08	+0.16	+0

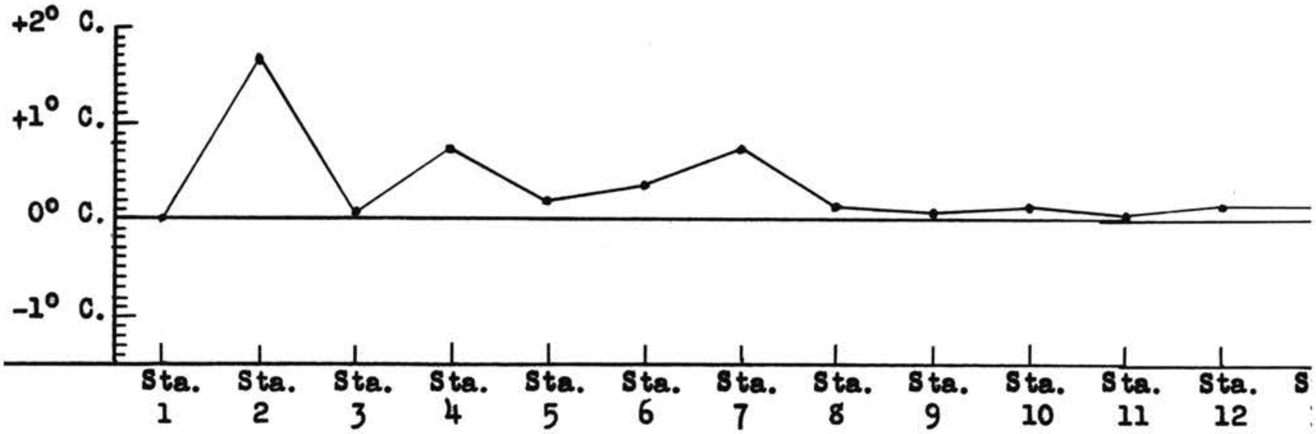


Figure 19. Differences in average water temperatures at each station in Boatdock Cove on February 3 and corresponding averages on February 2, 1951, expressed in graphic form.

TABLE 15. Water Temperatures in Degrees Centigrade Recorded at One-Foot Depths and Averaged for the Stations in Boatdock Cove, 10:00 A.M.-12:15 P.M., February 4, 1951.

epth	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
rface	6.8	6.5	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	Ice	I
ft.			3.1	2.0	1.1	1.0	1.0	0.80	0.80	0.70	0.7	0.5	0
ft.			3.4	2.4	1.2	1.1	1.0	1.00	1.00	0.90	1.0	1.1	1
ft.				2.6	1.3	1.2	1.1	1.10	1.10	1.10	1.1	1.1	1
ft.					1.4	1.9	1.1	1.10	1.10	1.10	1.1	1.2	1
ft.					1.6		1.3	1.20	1.15	1.15	1.2	1.2	1
ft.								1.20	1.15	1.20	1.2	1.2	1
ft.								1.20	1.20	1.20	1.2	1.2	1
ft.								1.35	1.20	1.20	1.2	1.2	1
ft.								1.70	1.20	1.20	1.2	1.2	1
ft.									1.30	1.20	1.2	1.3	1
ft.									1.40	1.30	1.3	1.3	
ft.									1.70	1.80	1.4	1.3	
ft.											1.7	1.3	
ft.												1.4	
erage	6.8	6.5	3.25	2.33	1.32	1.30	1.10	1.22	1.19	1.17	1.19	1.18	1

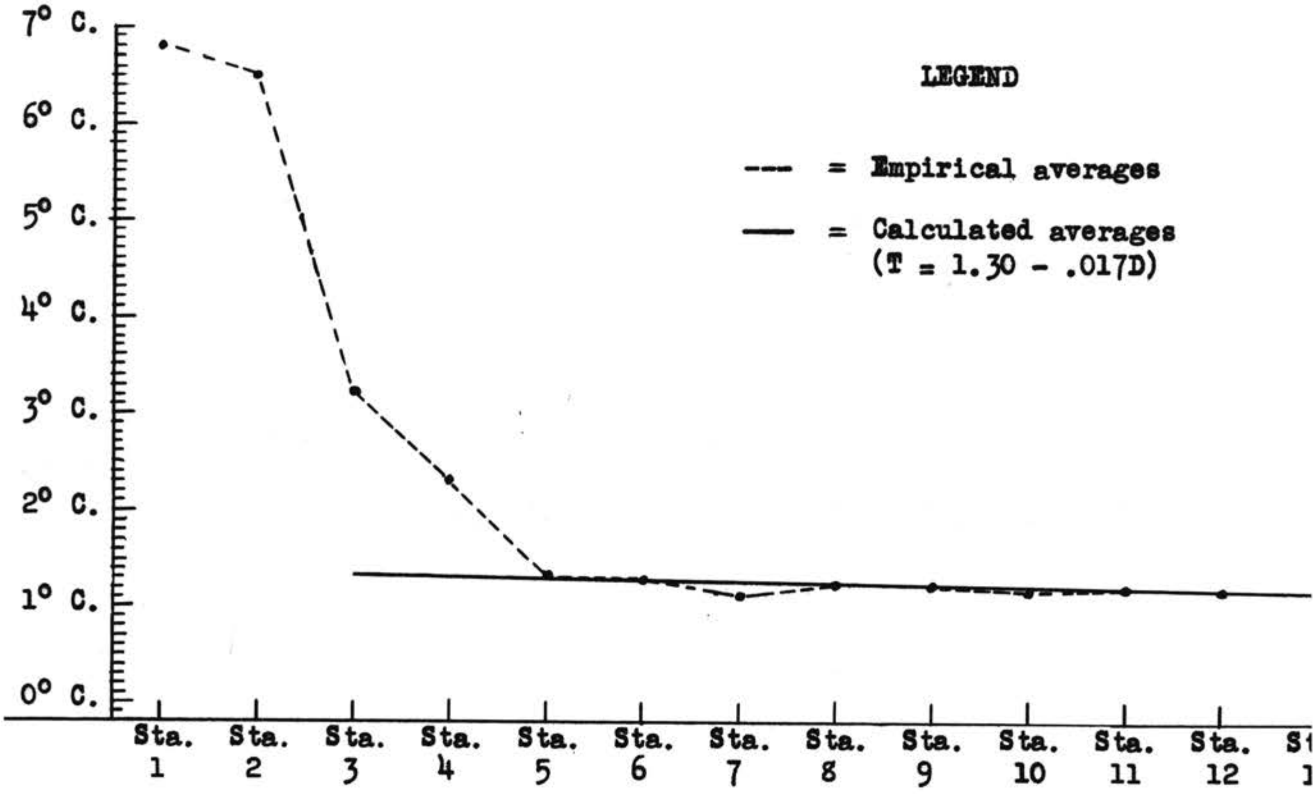


Figure 20. Empirical and calculated average water temperatures in degrees Centigrade recorded at one-foot depths and averaged for the stations in Boatdock Cove, February 4, 1951, expressed in graphic form.

TABLE 16. Comparison of Average Water Temperatures at Each Station in Boatdock Cove on February 4 with Corresponding Averages on February 3, 1951.

Date	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	S
ruary 3	6.3	4.7	1.85	1.92	1.12	1.07	1.07	0.95	1.00	1.02	1.04	1.03	0
ruary 4	6.8	6.5	3.25	2.33	1.32	1.30	1.10	1.22	1.19	1.17	1.19	1.18	1
ference	+0.5	+1.8	+1.40	+0.41	+0.20	+0.23	+0.03	+0.27	+0.19	+0.15	+0.15	+0.15	+0

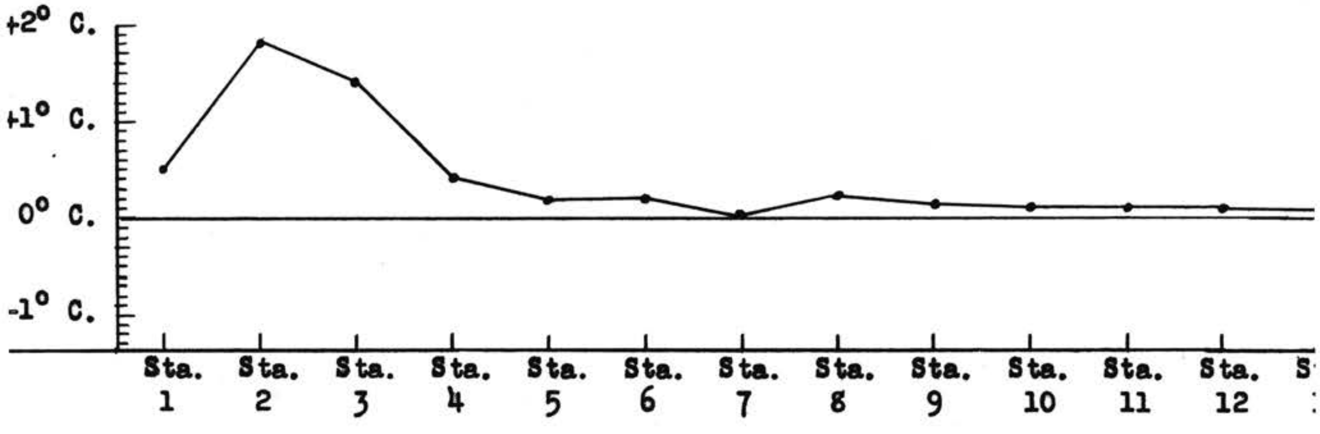


Figure 21. Differences in average water temperatures at each station in Boatdock Cove on February 4 and corresponding averages on February 3, 1951, expressed in graphic form.

lverse weather conditions, and there was no appreciable decline in angling ıccess.

February 2, 1951. The air temperatures rose above freezing in the late rning of February 2. Anglers appeared to have more than doubled in number, t individual catches were obviously well below those of the previous three ys. For the first time during the week-long series of surveys more crappie re caught toward the mouth than toward the headwaters of the cove. Data esented in Table 11 and Figure 16 show that the water temperature gradient s not as steep on the morning of the 2nd. Moreover, comparisons of station mperature averages (Table 12 and Figure 17) show substantial falls in water mperatures over the upper region of the cove. This was in keeping with the ct that the ice over the center of this region had caved-in during the preding night leaving that area in the form of a V, with both sides slanting ther steeply toward open water in the center. Quite probably the cave-in s caused by recession of water forced into the cove by the high northerly nds prevailing during the first days of the cold wave. The drops in water mperatures within this area seem to attest to the insulative value of ice verage. In view of the subsequent drastic decline in angling successes, it pears probable that this sudden loss of heat in the headwaters not only rtually obliterated the temperature gradient but drove the bulk of the fish gregation from the cove. Previous observation had suggested that milder d more gradual losses in water temperatures were accompanied by a more adual dispersal of the concentrations. The maximum air temperature for the y was 41° F.; the minimum, 7° F. Bright sunshine appeared intermittently roughout the day, and considerable ice meltage occurred in the late morning d early afternoon.

February 3, 1951. February 3 was clear and sunny, with air temperatures cending from 21° F. to a maximum of 51° F. by midafternoon. Rapid ice ltage occurring during most of the daylight hours did not deter constantly cumulating numbers of fishermen from chopping increasing numbers of "fishing les" in the deteriorating ice. Creel counts, however, were drastically low those of the previous day. Data contained in Table 13 and Figure 18 monstrate that only a semblance remained of the temperature-density gradient at had persisted in the January 30-February 2 series of water temperature cordings. Attention is directed to the fact that the data were subjected two statistical analyses (linear regressions), graphically expressed in gure 18. One analysis included Station 3, the uncovered, shallow depth of ich appeared to be influenced more by sunlight than by seepage water; the cond analysis merely excluded Station 3. The latter was in nearer agree- nt with the empirical averages of the majority of stations still under ice d was thus considered to be more indicative of the situation. Data pre- nted in Table 14 and Figure 19 indicate that, in general, greater gains in ter temperatures occurred in areas wherein the greater losses had been in idence on the preceding day.

February 4, 1951. Data of February 4 concluded the seven-day series of ter temperature recordings. Since February 4 was a Sunday and the second nsecutive day of bright sunny weather, hundreds of anglers swarmed over th Boatdock and Cantonement Creek Coves in spite of rapidly melting ice verage (air temperatures rose to 53° F. early in the day). Although the owd was by far the largest, catches were the most meager of the seven-day rvey. Analyses of data as presented in Tables 15 and 16 and Figures 20 d 21 indicate that, although small increases in water temperatures probably curred in the fishable depths within the preceding 24 hours, no more than negligible temperature-density gradient remained in evidence throughout e cove.

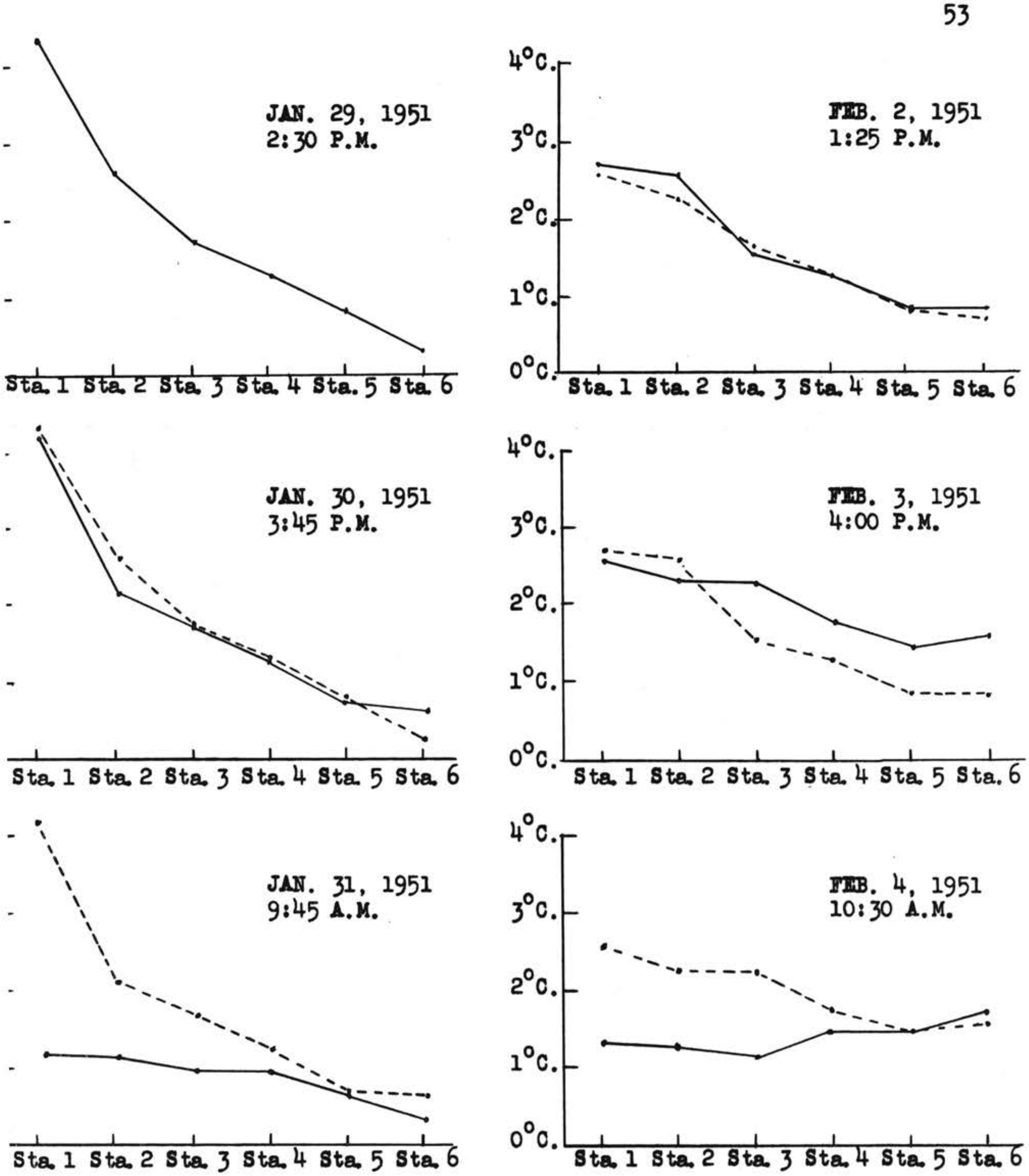
TABLE 17. Comparison of the Magnitude of the Constant b (Slope) With Angling Successes as Determined by Random Interviews Over a One-Week Period.

Date	Slope	Anglers Interviewed	Total Fish Caught	Average Catch Per Angler	Remarks
an. 29 1951	+.007	2	2	1.0	Severe weather. Only two anglers seen all day. Max. air temp., -10.0° C.; min., -17.8° C.
an. 30 1951	-.094	10	246	24.6	Severe weather continued. Few anglers. Ice 13" thick. Max. air temp., -9.5° C.; min., -15.0° C.
an. 31 1951	-.069	3	78	26.0	Severe weather continued. Few anglers—some watched bobbers from heated cars. Max. air temp., -8.4° C.; min., -14.5° C.
b. 1 1951	-.100	27	666	20.9	5th day of continuous sub-freezing weather. Max. air temp., -7.2° C.; min., -13.9° C.
b. 2 1951	-.008	62	707	11.4	Slightly warmer weather. Air temp. rose above freezing. Max. air temp., 5.0° C.; min., -13.9° C.
b. 3 1951	-.011	73	243	3.3	Much warmer weather. Rapid ice meltage. Max. air temp., 10.6° C.; min., -6.1° C.
b. 4 1951	-.017	98	162	1.7	Bright and sunny. Rapid ice meltage. Hundreds of anglers present. Max. air temp., 13.9° C.; min., -2.2° C.

Results of the seven-day survey of the Boatdock Cove are summarized in ble 17. Attention is again directed to consideration of the constant b, or ope, which is derived by statistical analyses (linear regression) and notes the theoretical rise and fall of water temperatures in degrees Centiade per hundred feet between the headwaters and mouth of the cove.

Appraisal of the foregoing indices recalls to mind that Doudoroff (1934) rned against conclusions based on analogies between gradients produced in perimental tanks and gentler ones occurring in natural waters. The dices presented herein, and others not shown, strongly suggest that fective water temperature gradients more delicate than any exhibited in perimental tanks and aquaria had been demonstrated in the Boatdock Cove at nton Reservoir. Further indicated is the apparent necessity of the co- istence of at least four other contributing factors subsequently to be dis- ssed.

Water temperature averages (empirical) for the stations in the Big Bend ve between January 29 and February 4, inclusive, are graphically expressed Figure 22. The graphs show that relatively steep temperature gradients isted on all but the last day, and that daily fluctuations of station water mperature averages were more drastic than in the Boatdock Cove. Fishermen gled in the cove repeatedly throughout the seven-day survey, but no fish re known to have been caught. This naturally poses the question of how the adients could become manifest in sub-freezing weather when there was no idence of inflowing warmer water. In a report on investigations of solar diation in inland lakes, Birge and Juday (1931) demonstrated that a lake uld gain heat steadily during periods of ice cover. They found that about e-fourth of the heat gain in Lake Mendota, Wisconsin, came from the bottom, d the major part of the remaining three-fourths came from the sun through e ice, with a small part possibly coming from inflowing water. Welch (1935) ated that the greater part of the heat from the sun is absorbed within the rst meter of water depth. As the Big Bend Cove averaged slightly less than e meter in depth and as water temperatures recorded during morning hours re always lower than those taken in the afternoon, it appears evident that



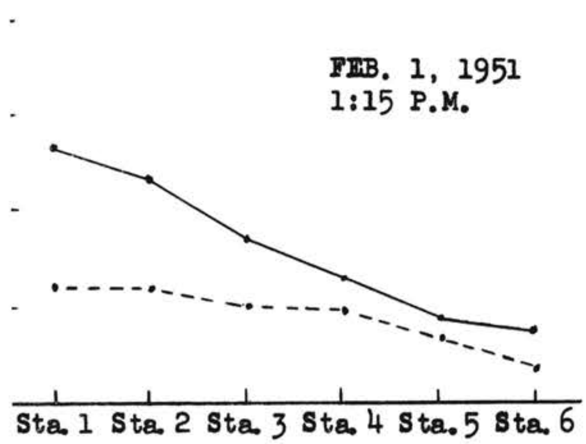


Figure 22. Empirical average temperatures at each station in the Big Bend Cove over a one-week period, January 29-February 4, 1951 (dotted lines connect temperature averages of preceding day).

rtually all the heat gained came from solar radiation and basin warming. would thus appear that the failure of fishes to concentrate in conformance th seemingly optimum temperature gradients lends significant support to the ndings of Breder and Nigrelli (1935) who concluded that the presence of a rrent of water, however slight, was essential to winter aggregation of the ntrarchid species studied by them.

Discussion

It appears from the foregoing data that the winter aggregations resulted om a concurrent combination of conditions that could be termed as follows.

1. *The presence of an adequate population of fish characteristically clined to aggregate in winter under certain conditions.* The Buck and Cross port (1952) showed that the white crappie—predominantly the 1948 Year-ass—represented 33 percent of their total catch of 21,633 fish of all ecies captured between October 1948 and October 1950. Observations clearly owed that some other species, abundant in the lake, did not aggregate as tensively as did the white crappie.

2. *The rapid cooling of lake waters to temperatures below 4° C. (39.2° F.) used by sudden and severe weather changes.* Water possesses maximum density 4° C. and becomes progressively less dense (lighter) as it approaches the eezing point. Thus, when temperatures range between 4° and 0° C., the rmer water in undisturbed situations is nearest the bottom. The initial gregations of both winter seasons in the Boatdock Cove could be clearly sociated with abrupt drops in air temperatures. It seemed to become creasingly apparent in the course of the investigations that a general pat-rn of angling successes which progressed down the cove, into the much larger

ntonement Cove, on into the lake proper, and back (more quickly) into the
atdock Cove, was in phase with undulating rises and sudden falls in air
mperatures. Observations on the highly accelerated angling successes fol-
wing severe weather changes suggested a possibility that the fish might
ve begun the formation of aggregations as water temperatures approached
C. and thus entered the cove in groups, rather than straggled individually,
en stimulated by sudden additional drops in the water temperature. At any
te, the temperature gradients seemed to influence the direction taken by
st numbers of fish thus stimulated.

3. *The formation of ice cover.* The insulative and becalming qualities
ice cover have been demonstrated. Attention is again directed to data of
bruary 2, when the cover temporarily and suddenly disintegrated from a
rtion of the Boatdock Cove.

4. *The inflow of warmer water.* Contributions of seepage water appeared
be two-fold in that it induced and distributed the temperature (and
nsity) gradients throughout the cove, and probably provided water movement
ich Breder and Nigrelli (1934) demonstrated to be essential to aggregation
the yellowbellied sunfish.

5. *The manifestation of temperature (and density) gradients.* It was
tablished that temperature gradients periodically existed in both the Boat-
ck and the Big Bend Coves, but remained more stable over longer periods of
me in the former. Doubtlessly, both coves received similar amounts of heat
r unit area from basin heating and solar radiation and likewise dissipated
oportionate amounts of heat at night. It is, therefore, evident that the
re persistent gradient found in the Boatdock Cove was maintained by an
ditional source of heat--ground-heated seepage water.

WINTER PHASE OF 1951-1952

Methods and Materials

The final phase of the investigations was devoted to testing the fore-
ing hypothesis. The Haag Cove (Figures 1 and 3) was selected as the
perimental area, but observations and procurements of data were continued
both the Boatdock and Big Bend Coves. No aggregations were known to have
curred in the Haag Cove during preceding winter seasons. Methods and
terials employed in the preceding winter phase were maintained throughout
e final phase with the exception of three additional features. (1) Wire
aps, six feet in length and two and one-half feet in diameter, were used
an attempt to determine movements of fish in and out of the coves and to
gment angling successes as indicators of the magnitude of the aggregations.
2) White wooden floats anchored to heavy stones were placed at 100-foot
tervals throughout the coves in further establishment of permanent tempera-
re stations, as anglers often tampered with stakes driven along the cove
rgins. (3) By cooperation of the Corps of Engineers, the water elevation
the lake was deliberately raised three feet, toward the end of the experi-
nt, in order to bring the headwaters of the Boatdock Cove nearer to the
prings" and thus decrease the heat loss in the running stream.

Procedure

Inasmuch as no other coves of Canton Reservoir were fed by any visible
flow of water, the initial procedure was to determine the amount of ground

ter entering the Boatdock Cove in order to calculate the amount needed for e experimental area. To this end, the inflowing water was impounded by conructing a dam of sand bags immediately above the standing headwaters of the ve. The dam was penetrated with 6-inch tile piping and the outflow measured, 'ter three days of impoundment, by repeatedly timing the filling of a 9-quart ntainer by stop-watch. An average of ten "fillings" showed that 12 gallons ' water per minute (720 gallons per hour) were flowing through the tile pipe to Boatdock Cove. Allowing for additional subterranean flow beneath the m, it was estimated that approximately 1000 gallons of ground water per ur entered the Boatdock Cove, and it was decided that a comparable volume ould be directed, if possible, into the experimental area of water.

The original plan of pumping ground water from a well bored at the upper mit of the experimental area was abandoned after professional drillers, ing rotary drill equipment, failed to encounter sufficient water sources in e vicinity of either the Haag or the Big Bend Coves. This was the prerred plan because the inflow could have been controlled, thus permitting portunities at will to: (1) demonstrate the effects of inflowing warmer ter at varying rates of flow, and (2) further isolate the influences of sin warming and solar radiation from that of the inflowing warmer water in 'adient expression.

The failure to effect an adequate source of ground-heated water by 'illing led to the enactment of an alternative plan--that of duplicating the tuation in the Boatdock Cove by impounding water above the upper limit of e Haag Cove. This procedure precluded opportunities to gauge or control e inflow effectively, and, due to its late adoption, there was no assurance at incoming seepage water, so induced, would attain an adequate rate of ow in time to concur with the other contributing factors.

A washed-out dam at the upper limit of the Haag Cove was repaired and a e and one-half acre pond formed behind it (Figure 3). The dam had been nstructed by Civilian Conservation Corps personnel in the 1930's and had en virtually destroyed soon after the impoundment of Canton Reservoir. A soline powered Pratt and Whitney centrifugal pump (capable of pumping ,000 gallons of water per hour) was utilized in hoisting water from the ve into the experimental pond.

Six of the one inch mesh chicken wire traps were altered in a manner at permitted fish to enter from only one direction. Small boat docks were chored at the mouths of the three coves, and two traps, with entrances cing opposite directions, were suspended from each. Traps capable of cap- ring only incoming fish are hereafter referred to as "in" traps and those stricted to outgoing fish as "out" traps.

Two traps with inleading throats at both ends (hereafter referred to as wo-entrance" traps) were later placed in the upper region of the Haag Cove; e at the extreme end, the other, one hundred feet nearer the mouth.

The experimental pond was still in the process of filling when the first vere cold wave of the 1951-1952 winter season occurred on December 14 ppendix C). The Haag Cove was covered with substantial ice by the fol- wing morning, but trap yields remained insignificant, and no appreciable ter temperature gradients were in evidence throughout the following six ys. Temperature recordings taken from the bottom at each station failed present indications of inflowing warmer water during the same period.

Attention is here directed to the fact that the Haag Cove was completely rrounded by privately owned land. Although the owner was in sympathy with e project, anglers, unable to reach the cove by boat during periods of ice verage, were obliged to obtain a key to a locked gate in order to gain cess to the area. Consequently, fishermen were few and trapping constituted rtually the only consistent means of gauging fish densities. This was the in reason for the placement of two additional traps (totaling four) in the perimental cove, whereas only two one-way traps were stationed at entrances the other coves.

The Haag Cove, as depicted by Figure 3, ended abruptly at the base of e reconstructed dam. It was apparent, therefore, that a great part of the epage water from the experimental pond would emerge at depths of more than ve feet and would not be subject to observation as was possible in the atdock Cove. For this reason, profiles of bottom temperature recordings re considered carefully for indications of incoming warmer water.

In comparison with Haag Cove, trap yields from Boatdock Cove increased derately on the 17th and 19th, and significant water temperature gradients re exhibited from the 16th through the 18th. Air temperatures, rising to ximums of 54° F. on both the 19th and 20th, appeared to have disrupted the velopment of aggregation. This concurred with observations of preceding nter seasons, which had indicated that appreciable aggregations in the atdock Cove generally followed severe weather changes and ice coverages three days, and persisted in proportion to the duration of sustained low r temperatures.

The experimental pond became filled after pumping water continuously om December 10 to December 18, inclusive. Water elevation on the latter te was marked on a previously implanted stake, and pumping was resumed termittently to maintain the level thereafter at near the original mark.

Malfunction of the resistance-type thermometer prevented the procurement bottom and water temperatures between December 19 and December 23. How- ver, a supposition that seepage water from the experimental pond began an rer increasing ingress into the Haag Cove within this period of time was ipported by the following observations. (1) "Sand boils" appeared at and ear the junctures of the dam and the natural sides of the "draw." These rickles of incoming water at visible depths below the water surface suggested the probable presence of numerous others that could not be observed. 2) More rapid ice meltage (after December 21) was evident in the vicinity f the "sand boils" than in any other area of the cove. (3) Holes bored nto the dam midway between the experimental pond and cove rapidly filled ith water. (4) Trap yields appeared to have increased significantly after severe cold wave accompanied by complete ice coverage occurred on the night f December 20-21.

The drop in air temperature on the night of December 20-21 was so drasic that, on the following morning, no open water could be seen anywhere on anton Reservoir. Increases in trap returns followed in the coves associated ith inflowing water, but it appeared obvious that acceleration occurred ooner in the Haag Cove. In this respect, it should be recalled that the ength of the Boatdock Cove was approximately twice that of the experimental ove. Angling successes, although not sensational, increased in the Boatock Cove, while trap and angling yields remained insignificant in the Big end Cove.

When bottom and water temperature recordings were resumed on December 24, profile of readings from the bottom at each station in the Haag Cove preented strong evidence of warmer water entering the upper limit of the cove. ottom temperature profiles taken intermittently between December 24 and ecember 30 are graphically expressed in Figure 23; empirical and calculated ater temperature averages at each station on the same dates are graphically resented in Figure 24. From this evidence, it seemed apparent that an

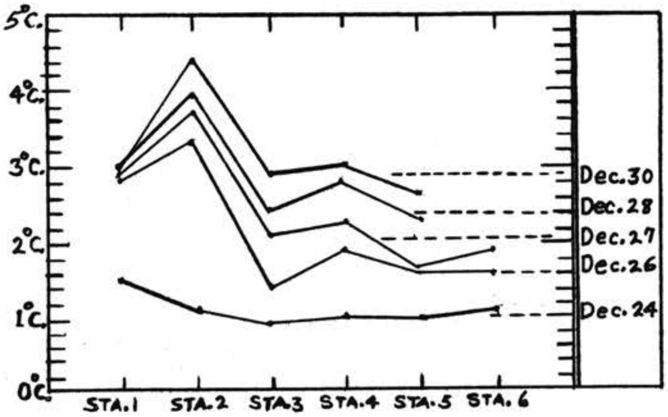
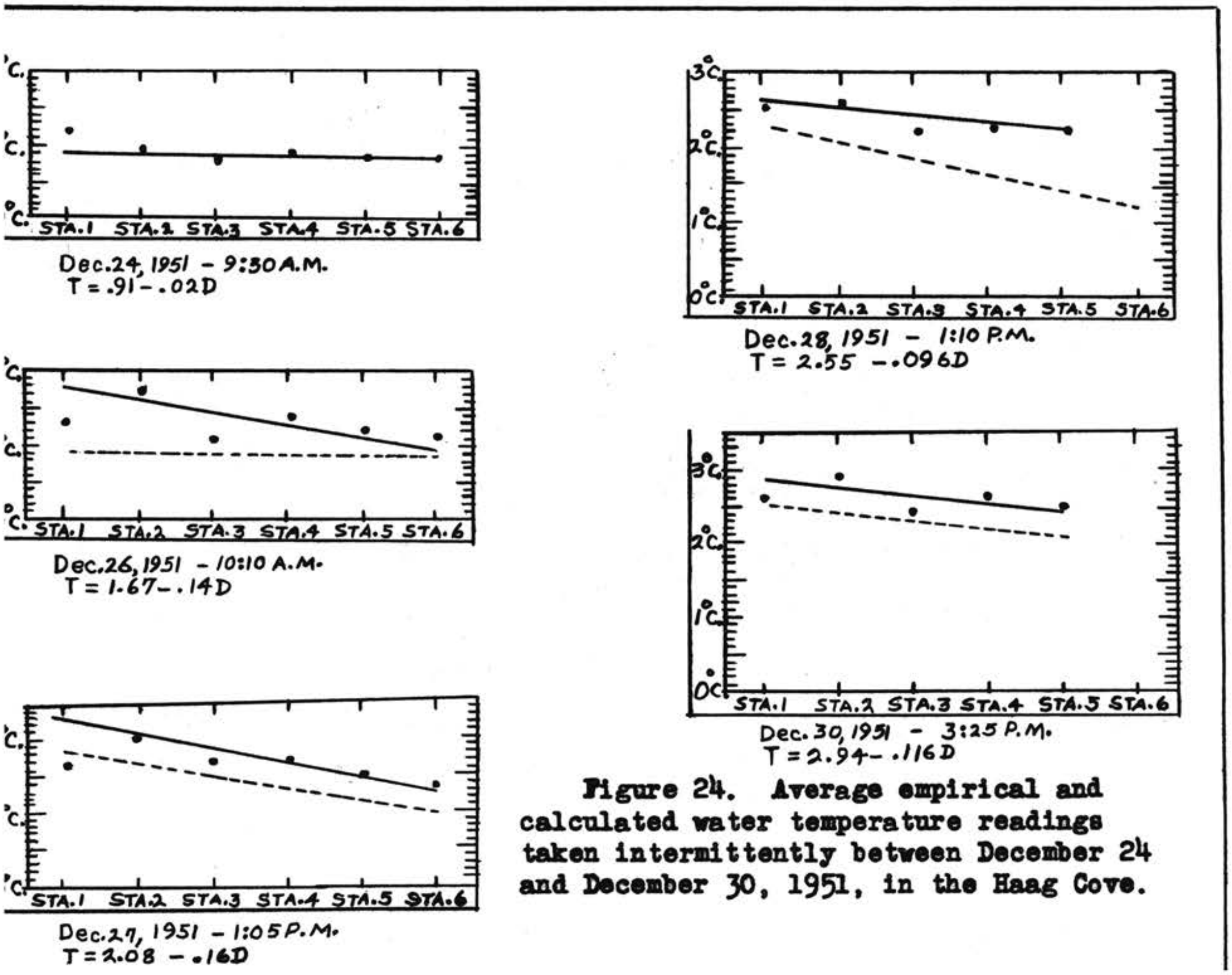


Figure 23. Profiles of bottom temperature readings taken intermittently between December 24 and December 30, 1951, in the Haag Cove.



Dec.24, 1951 - 9:30 A.M.
T = .91 - .02D

Dec.26, 1951 - 10:10 A.M.
T = 1.67 - .14D

Dec.27, 1951 - 1:05 P.M.
T = 2.08 - .16D

Dec.28, 1951 - 1:10 P.M.
T = 2.55 - .096D

Dec.30, 1951 - 3:25 P.M.
T = 2.94 - .116D

Figure 24. Average empirical and calculated water temperature readings taken intermittently between December 24 and December 30, 1951, in the Haag Cove.

flow of warmer seepage water was increasing in volume daily and was, in all obability, exerting a definite influence on gradient expression throughout e cove. The graphs also indicate that the majority of the seepage water s emerging in the vicinity of Station 2, 100 feet from the upper limit of e cove. This was in line with two facts that were known before repairment the original dam: (1) the distal end of an overflow pipe, in the original nd, terminated in the vicinity of Station 2; (2) when drilling for water the bed of the original pond, a layer of impervious clay was encountered a depth of approximately 15 feet. Assuming that this layer paralleled rata of an identical nature distinctly exposed in the sides of the draw, it obably emerged on the cove bottom in the vicinity of Station 2.

Attention is here directed to the peculiar bottom and average water mperatures at Station 3, as depicted in Figures 23 and 24. The water at is point was shallow because of a great "hump" extending completely across e bottom of the cove. Residents stated that no such topography existed fore impoundment of the reservoir and that the "hump," in all probability, s material washed from the original dam and deposited farther down the ve. It appeared evident, from comparison of a long series of bottom and ter temperature recordings, that warmer water was passing through this und on the cove bottom, although it could not be probed with the thermistor the thermometer.

The severe weather change of December 20-21 persisted until the 27th. tween 1:30 and 4:00 p.m. on the afternoon of the 26th, a sudden rise in gling successes moderately resembling the "crappie circuses" of the two eceding winter seasons occurred in the Boatdock Cove. White crappie were rvested steadily during that period of time but ceased abruptly in the late ternoon. Analysis of scale samples taken from creels showed that the

appie, averaging a pound, were of the 1948 Year Class--the same age-group
at had provided the previous harvests.

On December 27, the air temperatures began a rise which culminated on
cember 31 with the warmest day of that date on record. Unseasonably warm
ather appeared to have disrupted--for a second time--the formation of a
jor aggregation, for trap yields in both the Haag and Boatdock Coves gener-
ly increased and decreased with the fall and rise of air temperatures, as
aphically expressed in Figures 25 and 26. No such correlation was evident
yields from the Big Bend Cove.

The balmy weather characterizing the last days of December ended with
e abrupt occurrence of a severe weather change on January 1, 1952
igures 25 and 26).

By the end of the following ten days, the four traps in the Haag Cove
d captured 2,308 fish, of which 1,412 (61 percent) were white crappie and
9 (26 percent) were white bass. From these highly accelerated trap
turns, it appeared evident that an appreciable inflow of ground-heated
ter had been attained and that the objective of the second phase of the
vestigations--that of causing fish aggregation in an area wherein none
s known to have previously occurred--had been effected.

Trap yields from December 25, 1951, to January 19, 1952, inclusive, are
esented in Table 18. It is here emphasized that the 1,817 crappie trapped
thin the 26-day period in the Haag Cove were more than double the number
21) of crappie caught during the three-month period of intensive netting
d trapping activities between August 6 and November 9, 1951. These activi-
es embraced the entire lake, utilizing gill nets and hoop nets, as well as
re traps. Moreover, the 1,817 crappie were caught in 103 settings (24-hour
riods) of wire traps, whereas 433 settings of the same type of gear yielded

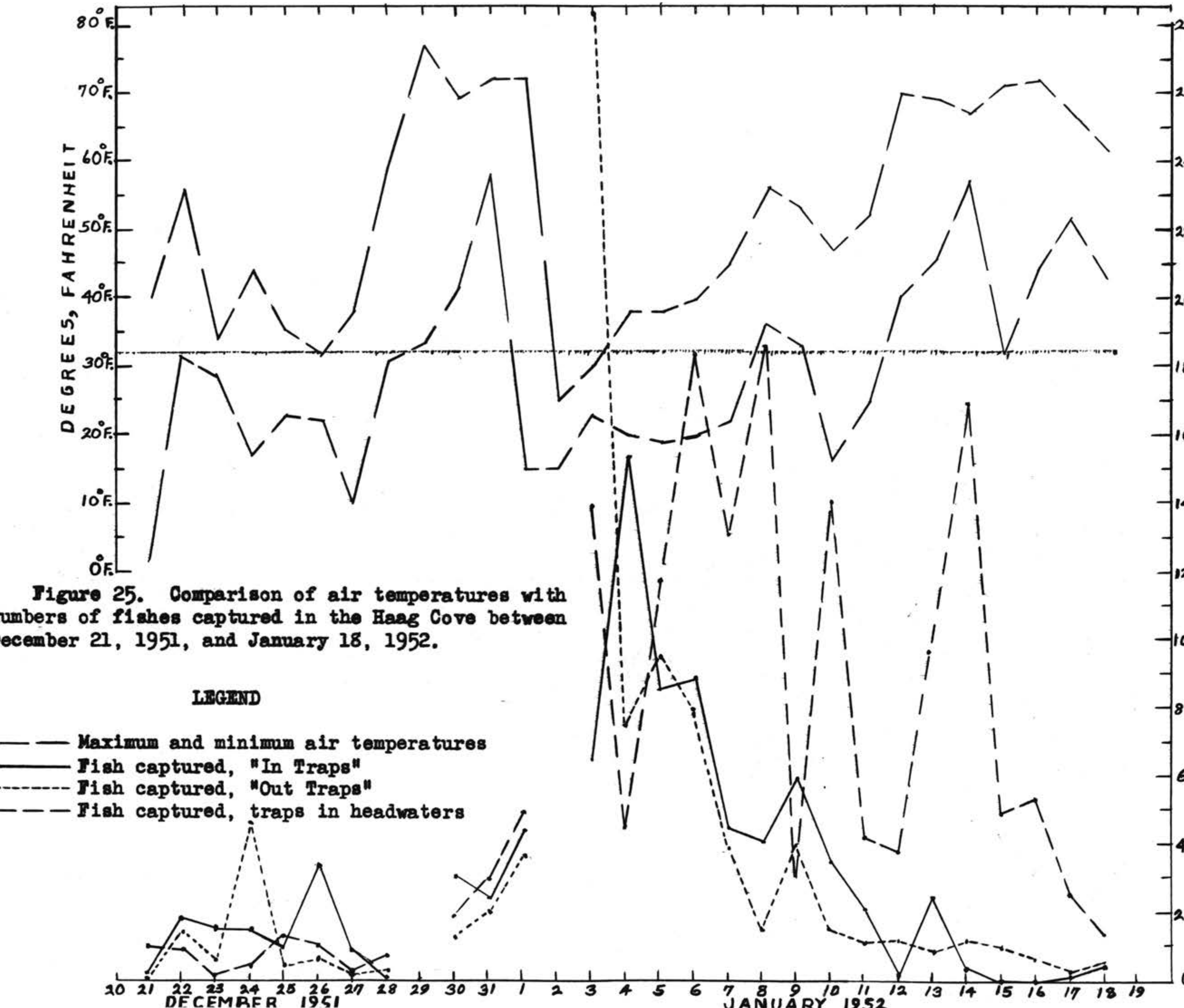


Figure 25. Comparison of air temperatures with umbers of fishes captured in the Haag Cove between ecember 21, 1951, and January 18, 1952.

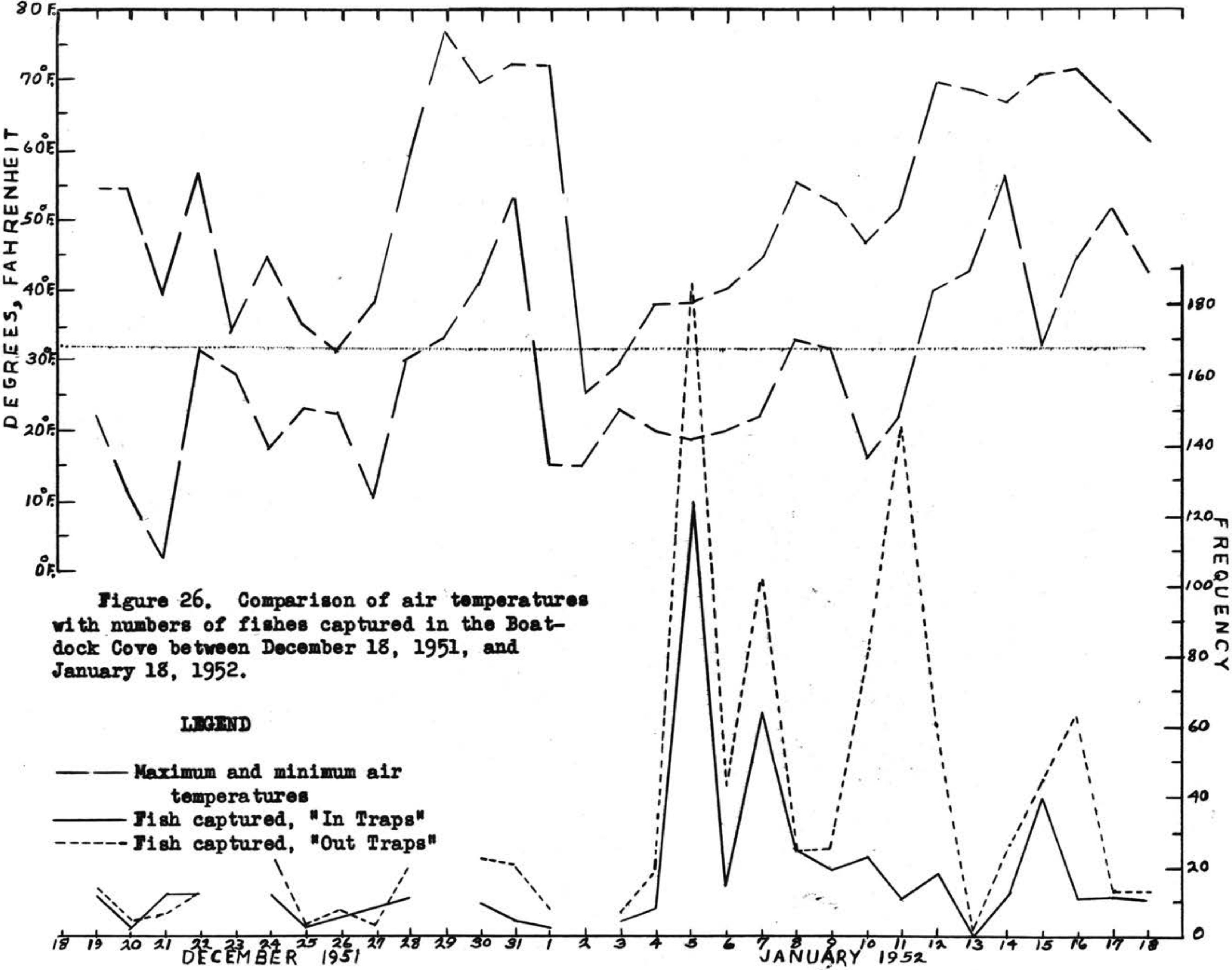


Figure 26. Comparison of air temperatures with numbers of fishes captured in the Boatdock Cove between December 18, 1951, and January 18, 1952.

TABLE 18. Total Number of Fish Trapped in the Experimental Cove, December 25, 1951–January 19, 1952 (26-Day Period).

Date	Total Fish	Crappie	White Bass	Black Bullhead	Blue-gill	Gizzard Shad	Carp	Drum	Carp-sucker	Black Bass	Yellow Pikeperch
51											
ecember 25*	26	8		13	4	1					
ecember 26	50	10		31	8	1					
ecember 27**	13	5		5	3						
ecember 28	10	2		3	4					1	
ecember 30	62	25		29	5		1		1	1	
ecember 31	74	34	28		7		2		1	2	
52											
nuary 1	140	46	36	10	33	7	3		2	3	
nuary 3	489	322	55	35	25	3	11	15	23		
nuary 4	269	97	113	6	4	11	17	11	9	1	
nuary 5	300	166	111	2	6	5		9		1	
nuary 6	352	277	55	3	7	6	1	1		2	
nuary 7	214	179	15	2	9		2	1		6	
nuary 8	233	119	100	2	4	1	1	2	2	2	
nuary 9	131	53	69	2		2	2	2			
nuary 10	195	153	30	1		1	2	3	1	1	3
nuary 11	74	48	20			2		2	1		1
nuary 12	52	36	11	1	1	2					1
nuary 13	134	46	77			6	1	1	2		1
nuary 14	185	73	96	1	2	6	3	1	1		2
nuary 15	66	35	12	14	3		2				
nuary 16	59	42	11		2						4
nuary 17	29	21	5		2		1				
nuary 18	23	6	1	12	2		2				
nuary 19	18	14	1		1		2				
Totals	3,198	1,817	846	172	132	54	53	49	43	20	12

3 Traps

4 Traps

ly 212 crappie during the preceding three-month period. Overall yields of e opposing single-entrance traps (2) at the cove's mouth, as well as of the o-entrance traps (2) in the upper limits between December 18, 1951, and bruary 12, 1952, are tabulated in Appendix D.

The large numbers of white bass present in the yields indicated that is species was also responsive to influences leading to crappie aggregation. rthermore, the substantial representation appeared to have corroborated the rly conjecture that a winter reciprocal of the findings of Borges (1950) ght possibly be demonstrated.

Because of limited accessibility, very few anglers could be persuaded to sit the experimental cove during the periods of highest trapping yields. wever, on January 11, twenty-five anglers--probably belatedly influenced by ports of the trap returns--fished in the cove to good advantage. Although bstantial catches of white crappie and several largemouth black bass were served, the vast majority of the total catch were white bass.

Within ten days after the cold wave of January 1, the two one-way traps the mouth of the Boatdock Cove had captured 752 fish. Of this number, 3 (35 percent) were white crappie and 433 (58 percent) were white bass.

The white bass population had "exploded" from numerical insignificance species dominance in the reservoir during the year of 1951. Buck and oss (1952) captured only 22 specimens between October 1948 and October 1950, d none were observed or reported during the winter harvests of 1949-1950 d 1950-1951. A detailed tabulation of trap returns by species and direction of movement is presented in Appendix E. The data clearly indicate that eater numbers of white bass than of white crappie entered and left the cove ring the 1951-1952 winter phase. Moreover, observations of angling ccesses as well as of trap returns strongly suggested that white bass aggretions, although tardier in manifestation, were more persistent than were appie aggregations. Evidence of greater persistence was demonstrated by a ntinuous harvest by anglers (mostly women) of vast numbers of small white ss over a considerable period of time after crappies had virtually ceased be caught. This was particularly evident in the shallow area made avail- le for fishing by deliberately raising the lake water level, extending the ve proper nearer to the "springs" previously described. The maximum sired level (involving a three-foot rise over the entire reservoir) was not tained until after January 8, 1952.

The two single-entrance traps at the mouth of the Big Bend Cove yielded 9 fish, including 28 white crappie and 58 white bass, within ten days fol- wing the drastic weather change of January 1. Although a moderate accelera- on of movements into and out of the cove was thus reflected (Appendix F), ere was no evidence of an aggregation comparable to those in the other ves. Yields from the Big Bend area were, in general, numerically inferior the extent that the traps were not lifted as often as those in the other o coves. Moreover, not a single catch by fishermen was observed or reported roughout the entire 1951-1952 winter season. Few anglers were actually en in the area, although evidence of their efforts in the form of "fishing les" in the ice were common.

With the exception of prolonged white bass angling activities in the mediate headwaters of the Boatdock Cove, the period of accelerated trapping d angling yields ended somewhat abruptly with rising air temperatures and sintegrating ice coverage after January 12. The final severe weather ange of the 1951-1952 winter season (January 20-24) was of brief duration d failed to stimulate appreciably either trapping or angling returns. eld activities at Canton Reservoir were terminated on February 14, 1952.

Additional Observations Concerning Fish Movements

Information depicted in Figures 25 and 26 show that fish movements into
d out of the coves characterized by inflowing ground water were in phase with
scending and ascending air temperatures coupled with formation and disinte-
ation of ice coverages. Furthermore, it appeared evident that a more or less
pid series of temperature changes was more influential to fish movement than
sustained period of low air temperatures yielding slowly to gradual warming.
is strongly suggested that the fish tended to become acclimated to pro-
nged low water temperatures and appeared to substantiate the conclusions of
urdoroff (1934) and others that selections made by fish were determined by
lative stimulative or detrimental effects of rapid changes of temperature,
d that rapid cooling was more stimulating than rapid rises.

In general, more fish were captured while departing than while entering
e Haag and Boatdock Coves. The reverse was true of captures in the Big
nd Cove. Data presented in Appendix D indicate that 27 percent of all
sh trapped in the Haag Cove were caught in the "out" trap, 24 percent in
e "in" trap, and 49 percent in the two double-entrance traps in the head-
ters. Data contained in Appendix E show that 64 percent of all specimens
ptured in the Boatdock Cove were taken by the "out" trap and 36 percent by
e "in" trap. In the Big Bend Cove (Appendix F), 58 percent of the specimens
re taken by the "in" and 42 percent by the "out" traps. Traps were not
ployed in the upper limits of the Big Bend or in the headwaters of the
atdock Coves because of the extreme shallowness of the former and inter-
rence with angling in the latter. As the traps rested on the bottoms of
e cove entrances, it appears evident that the majority of fishes entered
levels greater than two and one-half feet from the basins. The original
an of suspending the traps at varying depths from rafts anchored at the

ve entrances was abandoned due to constant turning of the rafts by wind and ve action. For that reason, it is suggested that compartmented trapping vices extending from basin to surface be employed in future research of is nature.

Data depicted in Figure 25 further demonstrate that the number of fish scaping both traps at the Haag Cove entrance generally increased progres- vely with rising air and water temperatures. Moreover, continuation of gh trap yields in the upper region despite declining returns at the trance strongly suggested a probability that the inflowing ground water t only attracted but tended to detain fish in the headwaters of the perimental area.

From analyses of trap returns, it is postulated that the rhythmic pat- rns of entrances and departures of fish, as graphically depicted in Figures 5 and 26, are probably attributable to the following sequences of contrasting imuli and responses. (1) Fish are stimulated by rapid cooling of lake ters caused by the initial cold waves of winter. (2) Warm water-induced mperature gradients extending through and beyond the coves influence the rection taken by large numbers of fish thus stimulated. (3) Despite con- nuous entrances and departures by some, fish continue to accumulate, adually or rapidly in accordance with intensities of the stimuli, until unterinfluences leading to dispersal begin to exert effectiveness. (Such unterinfluences are probably acclimatization, overcrowding, gradient nul- fication by ice meltage, and accruing quantities of organic wastes.)) Fish disperse toward the lake gradually or rapidly in accordance with e intensities of the dispersal influences. (5) On return to the lake, ey are again stimulated by comparatively colder waters still prevailing recurring cold waves, and respond by following temperature gradients back to the coves. (6) The cycle is repeated in varying extents through the nter months. It remains for further research to further test the validity the hypothesis.

Pursuant to an investigation of the differences, if any, between night d day catch rates, the single-entrance traps in the mouth of the Boatdock ve were checked twice daily on 8 intermittent days between December 19, 51, and January 12, 1952. Results contained in Table 19 show that 72 per- nt of the total of catches (401 fish) were taken between the approximate urs of 5 p.m. and 9 a.m. and 28 percent between 9 a.m. and 5 p.m. Con- dering the white crappie exclusively, the data indicate that 8 "day" sets 8-hour duration and 8 "day-night" sets of 16-hour duration yielded 203 sh in 192 hours—an average of 1.06 fish per hour. A ratio of 2:1 between e 5 p.m.-9 a.m. and 9 a.m.-5 p.m. yields should, therefore, be expected if correlation between catch rate and the hours of daylight and darkness isted. The empirical ratio was approximately 4.2:1.0 between the "day-night" d "day" settings, which seemed to bear evidence that a substantial majority the white crappie were captured during hours of darkness. Conversely, the ite bass exhibited a darkness-daylight ratio of only 1.5:1.0 compared to an pected ratio of 2:1. Other species were of insufficient numbers to merit rious evaluation.

Hansen (1951) discussed a hoop-net experiment conducted by Dr. David H. ompson (results unpublished) at Meredosia Bay, Illinois. Dr. Thompson ised, emptied, and reset his hoop-nets twice daily at the approximate urs of 6 a.m. and 5 p.m. on 25 different days between June 24 and August 17, 31, inclusive. Hansen stated: "The experiment showed that, except on a few tes, both species [white and black crappies] entered the nets in larger mbers between the hours of 5 p.m. and 6 a.m. than in the remaining hours

TABLE 19. Catches of White Crappie in Twice-Daily Lifts of Single-Entrance Traps in the Mouth of the Boatdock Cove on December 19, 20, 24, 27, and 28, 1951, and January 7, 8, and 12, 1952.

Species	Total Fish Trapped Day and Night	Fish Trapped by Night 5 P.M. - 9 A.M.			Fish Trapped by Day 9 A.M. - 5 P.M.		
		Total Fish Trapped by Night	"In" Traps	"Out" Traps	Total Fish Trapped by Day	"In" Traps	"Out" Traps
ite Crappie	203	164	59	105	39	16	23
ite Bass	124	74	25	49	50	15	35
lack Bullhead	15	13	7	6	2	2	-
luegill	14	7	4	3	7	-	7
arpsucker	14	11	2	9	3	1	2
izzard Shad	12	10	6	4	2	1	1
arp	10	4	1	3	6	5	1
rum	6	4	2	2	2	1	1
lack Bass	2	2	2	-	-	-	-
ellow Pikeperch	1	1	-	1	-	-	-
ll Species	401	290 (72%)	108 (37%)	182 (63%)	111 (28%)	41 (37%)	70 (63%)

he ratio of white to black crappie during the entire winter survey was approximately 75:1. None of the latter were represented in catches on these particular days.

the day." Along with other probable explanations, Hansen suggested that ie fish were possibly less able to avoid the nets or, once captured, to see ieir way to escape during the hours of darkness. He further stated that it is not believed that the longer night period could fully account for the ifferences observed.

Discussion

The magnitudes of crappie aggregations during the winter of 1951-1952 ere inferior to those of the preceding two winter seasons. The following re submitted as partial explanation.

1. With the exception of December, the 1951-1952 winter months were, in eneral, unseasonably mild and dry. Climatological data for the State of lahoma, issued by the U. S. Department of Commerce Weather Bureau, Kansas ity, Missouri, indicated that January of 1952 was the third warmest January i record and the warmest since 1933. The month of February, according to ie data, was also mild, exhibiting a state average of 46.6° F., which was .9° above normal. As previously mentioned, the formation of aggregations ollowing severe weather changes appeared to have been abruptly disrupted on everal occasions simultaneously with occurrences of unseasonably mild eather.

2. The 1948 Year-Class which had largely composed the white crappie ggregations of 1949-1950 and 1950-1951 had declined from 88 percent of the appie samples in late 1950 to 8 percent by November of 1951. The 1949 lass was unsuccessful, and the 1950 age-group, although generally of a size ttractive to anglers, was not nearly as abundant as was the 1948 class when corresponding size and age in the winter of 1949-1950.

As the final phase of the investigations progressed, it became increas-
gly apparent from accelerated trap returns--especially from those situated
the headwaters of the experimental cove--that substantial numbers of both
ite crappie and white bass were recurrently accumulating in the coves
ceiving ground-heated water. Moreover, analyses of accruing catch-rate data
peared to verify further the thesis that the aggregates were directly asso-
ated with recurrences of clearly defined--albeit gentle--water temperature
adients and severe changes of weather.

By the close of the series of investigations (mid-February 1952), there
emed to remain little doubt that significant concentrations of white crappie
d white bass, resulting from causes hypothesized during the previous winter
rvey, had occurred in both the Haag and Boatdock Coves (Table 20; Appendices
and E. These data also indicate that some species, such as channel cat-
sh, black buffalofish and spotted gar, were apparently unaffected by the
mperature gradients. Other species, such as black bullhead, gizzard shad,
uegill, carp, river carpsucker, drum, and perhaps largemouth bass and wall-
e, were responsive to the gradients in varying degrees. Consideration of
e fact that catch rates of species less frequently captured were not neces-
rily in phase with one another, or with the two species most frequently
ken, points to a need for future research. In the interest of future man-
ement procedure, it would be highly advantageous to know if temperature
adients specific to the aggregation of different species could be engendered
will within a situation subject to controlled volumes of warmer water than
s possible from the limited inflows in Canton Reservoir.

The advantages to be gained by causing desired species of fish to aggre-
te in large numbers, in order to increase winter harvest, were implied in
nclusions expressed by Eschmeyer (1944). His conclusions, based on studies

TABLE 20. Comparison of Numbers of Fishes Captured in Coves of Canton Reservoir During December 1951 and January 1952 with Those Captured from the Entire Lake Between August 6 and November 9, 1951.

Kinds of Fish	Haag Cove Dec. 18, 1951- Feb. 1, 1952 4 Wire Traps 170 Sets* 44 Days	Boatdock Cove Dec. 19, 1951- Feb. 1, 1952 2 Wire Traps 86 Sets 43 Days	Big Bend Cove Dec. 27, 1951- Jan. 29, 1952 2 Wire Traps 62 Sets 35 Days	All Coves Dec. 18, 1951- Feb. 1, 1952 8 Wire Traps 318 Sets 44 Days	Entire Lake Aug. 6, 1951- Nov. 9, 1951 All Gear 756 Sets 96 Days
White Crappie	1,894	552	57	2,503	821
White Bass	859	801	111	1,771	1,593
Black Bullhead	219	54	21	294	816
Gizzard Shad	163	66	4	233	884
Bluegill	134	30	4	168	267
Carp	56	144	8	208	293
Carpsucker	55	45	7	107	413
Drum	51	24	2	77	148
Largemouth Bass	24	7	2	33	106
Black Crappie	24	7	4	35	41
Yellow Pikeperch	14	30	4	48	51
Channel Catfish	-	-	-	-	165
Black Buffalofish	-	-	-	-	54
Spotted Gar	-	-	-	-	14
Longear Sunfish	-	-	-	-	3
Orangespotted Sunfish	-	-	-	-	2
Green Sunfish	-	-	-	-	2
Totals	3,493	1,760	224	5,477	5,673

*Set = 24-hour period.

nducted at Norris Lake, Tennessee, were that angling returns decline dras-
cally after the first cold spell of December and generally remain poor
roughout the months of January, February and March, and that, during this
me, "Where fish are not highly concentrated, the chances are small of
nding a hungry one." In explanation, he wrote:

> e fish is a cold-blooded animal and its rate of digestion, as well as its
> her body processes, slows down as the water cools. In a study made by the
> S. Bureau of Fisheries some years ago, it was found that in water under
> degrees Centigrade (50 degrees Fahrenheit) the larger young-of-the-year
> ss would take no food. In water 4 degrees Centigrade (39.2 degrees Fahren-
> it) the fish required over 350 hours to completely digest a minnow once it
> d been placed in the stomach. During the summer that same minnow would
> ve been digested in several hours. If a fish in Norris Reservoir which
> gests a minnow in several hours in summer needs about two weeks to do the
> me job in winter, provided it feeds at all in winter, a plug will very
> ldom be attractive enough to the fish to cause it to strike. Winter
> shing may be fair where fish are highly concentrated, as in the case of
> uger or white bass in the tailwaters, because a small percentage of the
> rge number of fish present might be ready for another supply of food.

chmeyer's account substantiates a conjecture often held that anglers,
ile bemoaning their ill fortune of arriving after aggregations had
parted the area, were often standing (on ice) above myriads of non-feeding
sh and probably explains the feeble and languid manner in which even the
rgest crappie took bait during periods of extremely cold weather.

The practicability of enticing large numbers of harvestable fish during
nter--a season when angling is ordinarily at its lowest ebb--has been
monstrated by fishermen themselves at Canton Reservoir. Anglers not only
ceived recreational and dietary benefit from thousands of prime fish that
uld otherwise have expired of natural causes but contributed to the growth
tential of remaining young and forthcoming generations by relieving the
essures of competition and predation. This was particularly true of the
rvests of 1948 Year-Class white crappie during the winter of 1950-1951 when

ll restrictions were removed, as evidenced by accelerated growth rates xhibited by the 1950 and 1951 age-groups during the following year.

On the basis of evidence resulting from the present research, a new and ersatile management technique applicable to the improvement of winter haresting of fish has, by test and demonstration, proved worthy of further evelopment and practical exploitation.

RECOMMENDATIONS

Intensive long-term investigations conducted by biologists of the Tenessee Valley Authority (Anonymous, 1950) and by others have unfailingly led o the same conclusions---useless waste due to inadequate harvesting. Such esearch has repeatedly demonstrated that more than two or three percent of arvestable fish are rarely taken by angling effort and that the remainder xpire from other causes. The surveys have shown that among the majority f food and game fishes, large populations retard and suppress the growth f current and oncoming generations by competition and overpopulation, and hat stunting and progressively poorer angling invariably follow. Eschmeyer 1949), Miller (1951), Jenkins, Leonard and Hall (1952), and many others, ave been virtually unanimous in proposing the promotion and application of aximum harvesting methods as remedial measures, except in aberrant situaions proved by investigation to require other treatment.

From increased winter angling and trapping yields, clearly associated uring these investigations with natural and deliberate deliveries of warmer nto colder waters, it appears evident that the induced temperature-density radient principle has qualified as a feasible fishery management technique otentially directable to the enhancement of winter fish harvesting in reas of low water temperatures. The following recommendations and sugestions pertinent to the potentialities and future utilization of the rinciple are submitted for the consideration of the Council and other intersted agencies.

1. As both the Boatdock and Haag Coves are becoming progressively shal- wer, it is recommended that these areas be preserved for future fishery by e prevention or drastic curtailment of further siltation through applica- on of erosion controls. If at all practicable, these coves should be redged to their original depths before enactment of anti-erosion measures.

2. Areas in other impoundments, particularly coves and small bays, that re known to be fed by waters that would be warmer in winter than the average ater temperatures of the impoundments proper should be marked and made known the angling public. As previously discussed, observations contained in is and other reports appear to justify a reasonable suspicion that unde- ected winter aggregations occur more commonly than has been realized in icinities of springs, seepage areas, and outlets of heated water from indus- ial plants.

3. Additional areas of water could be made conducive to aggregations uring winter months by applications of the warm versus cold water technique. ggested sources and methods are (a) wells deliberately drilled near the adwaters of coves or apexes of small bays, (b) seepage areas engendered by rategically constructed impoundments as demonstrated at the head of the ag Cove, and (c) water heated specifically for the purpose by artificial thods. It remains for future research to determine whether warmer water troduced into unconfined areas, and thus susceptible to spreading in all rections, could compare favorably with water introduced into the heads d apexes of coves and bays wherein the flow is diverted in a single neral direction.

4. The Council could promote the combination of the temperature gra- ent principle with other techniques and devices designed for the better- nt of angling wherever possible. It appears likely that the effectiveness,

ring winter months, of such year around inducements as fishing docks and
ers, brush shelters, submerged cedar (juniper) boughs, baited fishing areas,
erwater and underwater lighting devices, and combinations of these, could
substantially enhanced and greater harvests achieved by strategic deliveries
warm water currents.

5. Further research could be planned with less restricted warm water
urces than those prevailing at Canton Reservoir. Despite apparent success
tained in demonstrating the effectiveness of the temperature gradient
inciple on white crappie and white bass grouping behavior, other poten-
alities suggestive of promise remained unfathomed because of limited warm
ter sources and complete lack of control over them. Experiments, such as
e following, carried out within situations subject to controlled injections
warmer water at varying temperatures and rates of flow should lead to con-
usions of definite managerial value.

a. Further experimentation with introduced water at varying rates of flow, and, where possible, of varying temperatures, should more decisively determine whether or not certain species or groups of species tend to aggregate in greatest number within particular water temperature and density gradient ranges, that is, whether different kinds of fish react specifically to different gradients.

b. Continued research of this nature should demonstrate whether or not fish aggregations could be consistently maintained at maximum densities during winter months by strategic manipulations of the inflow rate. It seems reasonable that contrasting stimulative influences thus exerted could be counteractive to dispersal tendencies due to gradual acclimatization to sustained low water temperatures.

c. Experiments involving far greater volumes of heated water than were attainable at Canton Reservoir should ascertain the feasibility of prolonging the duration of fish concentrations beyond advents of such other dispersing influences as rising water and air temperatures and disintegrating ice coverage by progressively increasing the flow rate of incoming water. In this respect, it is recalled that Hansen (1951), as late in the season as May, described a white crappie aggregation before a culvert delivering a large volume of water from a power plant.

d. It would be a relatively simple matter in the course of such experimentation to demonstrate further isolation of the abetive influences of basin warming and solar radiation from that of inflowing warmer water.

e. It does not appear inconceivable that further investigation could possibly lead to determinations of practical formulae expressive of amounts of inflowing water needed to advantageously influence areas of specified dimensions in conformance with anticipated weather conditions.

f. It is suggested that a system of stationary thermistors be utilized in future research of this nature. Such procedure would not only expedite data procurement by enabling water temperature recordings to be taken from shore, but would considerably alleviate discomforts (and sometimes dangers) such as characterized these investigations.

6. It is recommended that the Council advocate general removal of creel d size limits except in special situations requisite of such restrictions. consensus of opinion common to virtually all fishery biologists is that the

ok and line is at best a very inadequate harvesting implement, and that shing regulations generally tend to detract further from its efficiency. rtinent statements of Eschmeyer (1946) are particularly articulate in this spect:

> cause the fish belong to the public and because it is admittedly desirable at the fish be used, any regulation which is imposed should be supported definite evidence that the regulation is needed, and by proof that it is rving its desired purpose. Where the regulations are arbitrarily made, as st of them have necessarily been, the violator, in too many instances, has en arrested for practicing good conservation, instead of doing harm.

further commented that, in general, the trend is properly tending toward wer fishing regulations and that, in big and moderately fished waters, few gulations are needed.

SUMMARY

1. Investigations of causes surrounding winter aggregations of fishes, rticularly of white crappie, in certain coves of Canton Reservoir, Okla- ma, were conducted in two successive phases during the winters of 1950-1951 d 1951-1952.

2. Research activities during the 1950-1951 phase were confined to the atdock and Big Bend Coves of the reservoir. The Boatdock Cove, charac- rized by inflowing seepage water, contained the initial major aggregation ported by Buck and Cross (1952) during the winter of 1949-1950. The Big nd Cove, utilized as a control area, received no detectable inflow of water d did not exhibit fish aggregations.

3. Appraisal of the effects of the inflowing water on the colder waters the Boatdock Cove and investigations of other influences possibly bearing the grouping behavior of fishes were the objectives of the 1950-1951 phase research.

4. It was established that water entering the upper limit of the Boat- ck Cove was warmed by earth while seeping through an earthen dam separating e cove and an impounded pond of considerably higher elevation.

5. Temporary manifestations of gentle, yet comparatively stable water mperature and water density gradients were mathematically demonstrated by bjecting data procured in the Boatdock Cove to statistical analyses. sultant linear and curvilinear regression lines strongly indicated that the flowing ground-heated water was a major contributive factor to gradient pression and stabilization throughout the cove.

6. Analyses of data further indicated that concurrencies of additional
ctors, including the inflowing warmer water, were essential to gradient
pression and, consequently, to aggregation in the Boatdock Cove. The addi-
ional factors appeared to be: (a) sudden and severe weather changes,
) cooling of lake waters to temperatures below 4° C., and (c) occurrences
comparatively persistent ice coverage.

7. Data involving recurring coincidences of increased angling returns
d gradient manifestations in the Boatdock Cove denote that an apparent
rrelation persisted between densities of winter aggregations and the steep-
ss of gradient expression.

8. It appeared equally evident that changing water densities resulting
om ice meltage tended to disrupt and obliterate gradient expression and
adually or rapidly, according to the rate of meltage, to effect dispersal
fish aggregations.

9. Comparatively unstable water temperature gradients, steepening pro-
essively by day and declining drastically at night, were demonstrated in
e shallower Big Bend Cove.

10. Evidence supporting the effectiveness of inflowing warmer water on
e persistence of gradient expression was afforded by comparisons of gra-
ent stabilities within the two coves. It thus appeared evident that most
the heat gained by day from solar radiation and basin warming in the Big
nd Cove was dissipated at night without replenishment, except continued
ble contributions from the latter source, while corresponding heat loss
om the Boatdock Cove was more substantially replenished by continuously
flowing warmer water.

11. No aggregations of fish were detectable in the Big Bend Cove during
winter of 1950-1951.

12. From evidence obtained during the 1950-1951 phase of research, it s hypothesized that winter aggregations of white crappie in the Boatdock ve of Canton Reservoir were governed by a composite of the following con- tions and eventualities: (1) existence in the reservoir of an adequate pulation of fish sensitive to contrasting water temperatures in winter; 2) consistent ingress of ground-heated water into the cove; (3) rapid oling of reservoir waters to temperatures below 4° C. by sudden and severe ather change; (4) formation of persistent ice coverage; and (5) manifesta- on of a stable, albeit gentle, water temperature gradient throughout the ve.

13. The 1951-1952 phase of research was confined to testing the pothesis advanced by investigations of the preceding winter (1950-1951) d to continued procurement of data from the Boatdock and Big Bend Coves.

14. The cardinal objective of the final phase was to demonstrate induced nter aggregation in an area of water wherein none had previously occurred. this end, the Haag Cove was selected as an experimental area wherein the ctors hypothesized to have influenced gradient expression and crappie gregation in the Boatdock Cove were to be duplicated as closely as possible.

15. A washed-out dam immediately above the head of the Haag Cove was paired and a pond impounded behind it. Emergence of appreciable amounts of ound-heated seepage water, gradient manifestations, and increased trap elds were evidenced within two weeks after repairment of the dam--six days ter complete filling of the pond.

16. By the close of the 1951-1952 phase of research, little doubt mained that significant concentrations of white crappie and white bass had, several occasions, occurred in both the Haag and the Boatdock Coves, and at the hypothesis of the preceding winter had been validated. No aggrega- on was apparent in the Big Bend Cove.

17. Achievement of induced winter aggregation and, thereby, accomplish-ent of the cardinal objective, was evidenced by the magnitude of trapping ields from the experimental Haag Cove. A total of 1,894 white crappie were aptured by 170 sets of wire traps within a period of 44 days in the Haag ove compared with a total of 212 captured by 433 previous sets in 96 days rom the entire reservoir. Only 821 crappie were taken with all gear ncluding wire traps, hoop nets and gill nets (756 sets) during the 96-day eriod.

18. It was clearly established that young-of-the-year white bass were ighly responsive to the same factors apparently leading to the grouping eactions of white crappie. Further indications were that white bass aggre-ations accumulated more slowly but, once formed, were generally more per-istent than those of white crappie.

19. The data indicated that while some species, such as channel catfish, lack buffalofish and spotted gar, were apparently unaffected by conditions pparently influential on white crappie and white bass, other species, such s the black bullhead, gizzard shad, bluegill, carp, river carpsucker, drum, nd probably largemouth bass and yellow pikeperch, were responsive to arying extents.

20. Trapping yields from the coves receiving warmer water exhibited pat-erns which clearly associated increasing and decreasing yields with ecreasing and increasing air and water temperatures respectively.

21. The data further showed that more fish were generally captured while eparting than while entering the Boatdock and Haag Coves, while the reverse as generally true of fish in the Big Bend Cove.

22. Results of trapping activities at the mouth of the Boatdock Cove ndicated that more fish were captured during hours of darkness than at any ther time.

23. Trapping data from the Haag Cove strongly suggested that fish ntered and departed the cove at increasingly higher levels in keeping with ising air and water temperatures.

24. On the basis of evidence exposed by research herein described, it s contended that a new and versatile fishery management technique--the nduced water temperature-density gradient principle---has been proved, by est and demonstration, to be worthy of application toward the enlargement f winter fish harvests and of further improvement.

25. Recommendations and suggestions pertaining to the utilization and uture development of the technique are presented.

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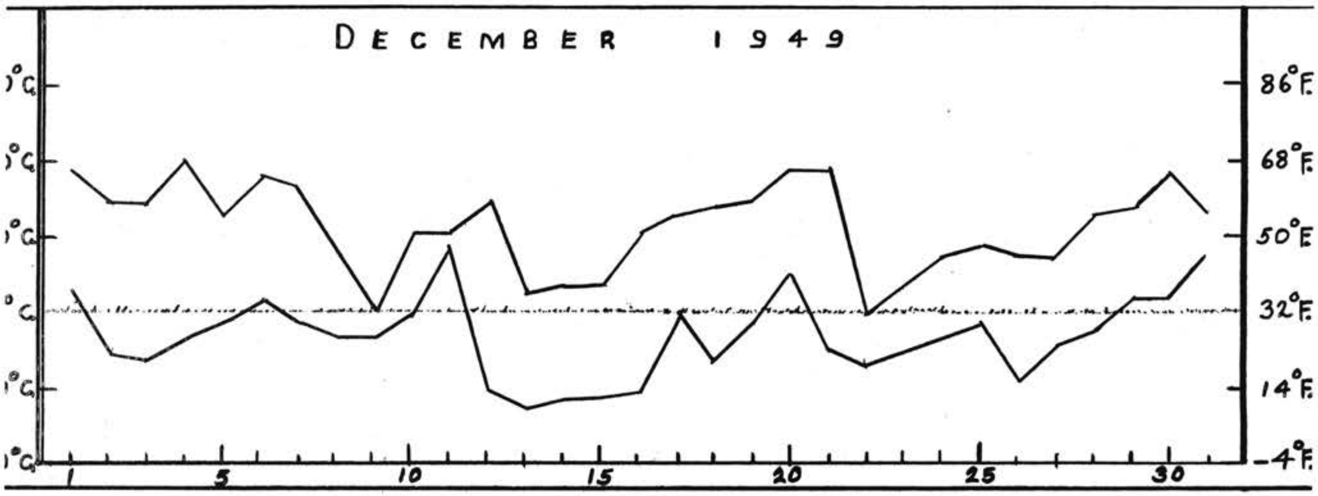
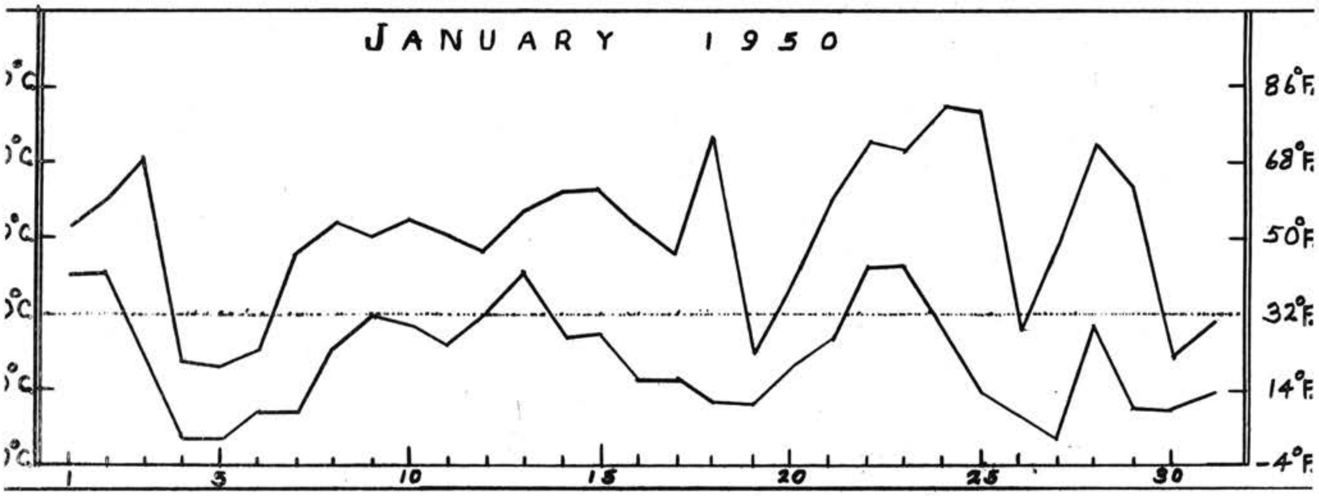
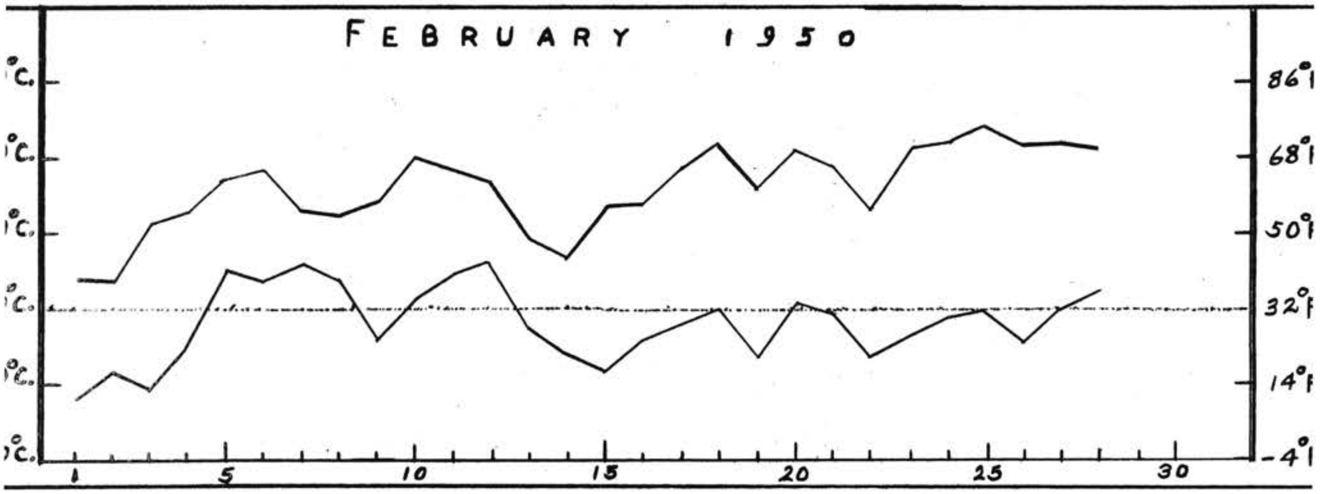
APPENDIX A

Daily Maximum and Minimum Air Temperatures for the Winter Months of 1949-1950 Graphically Expressed.

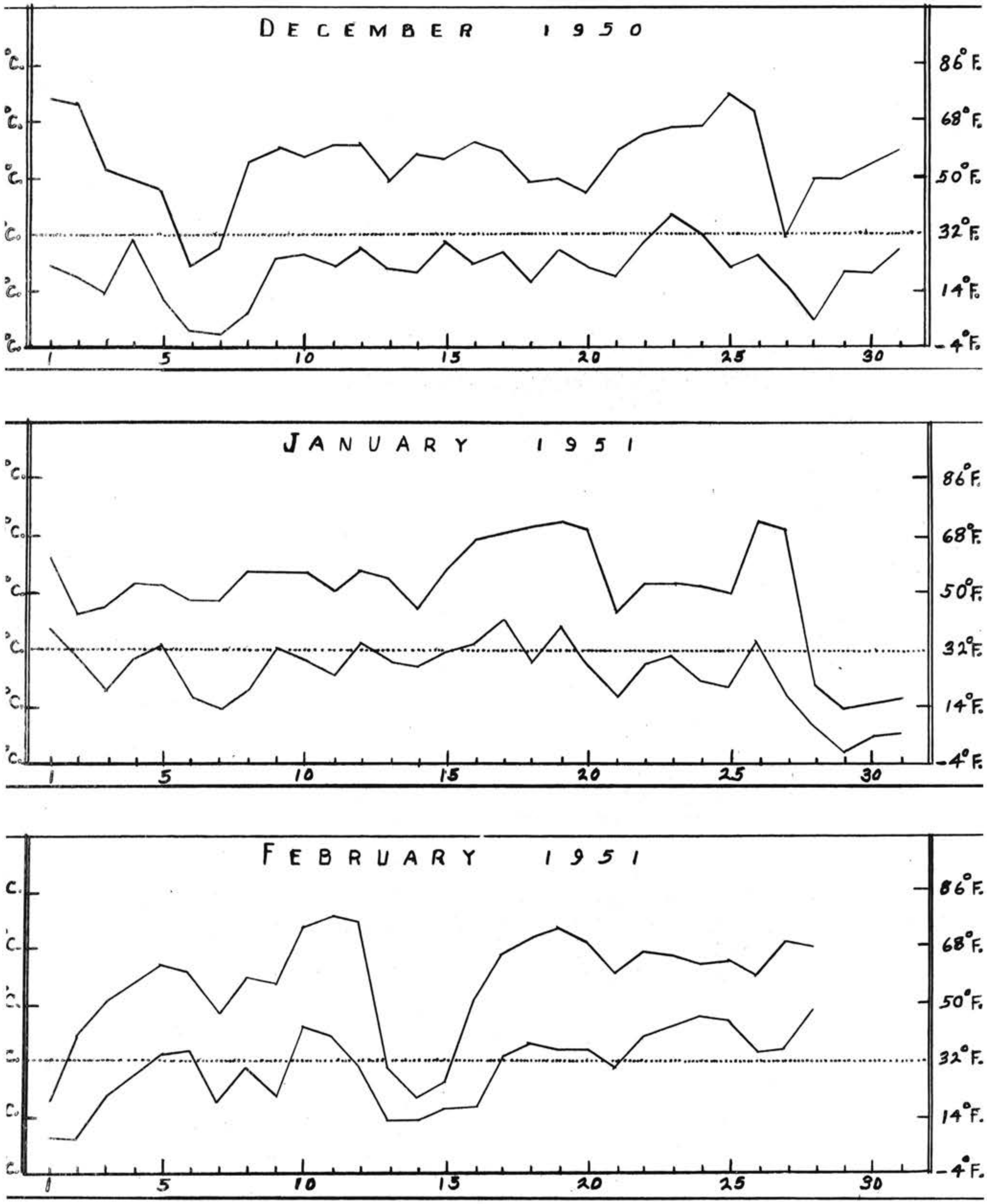






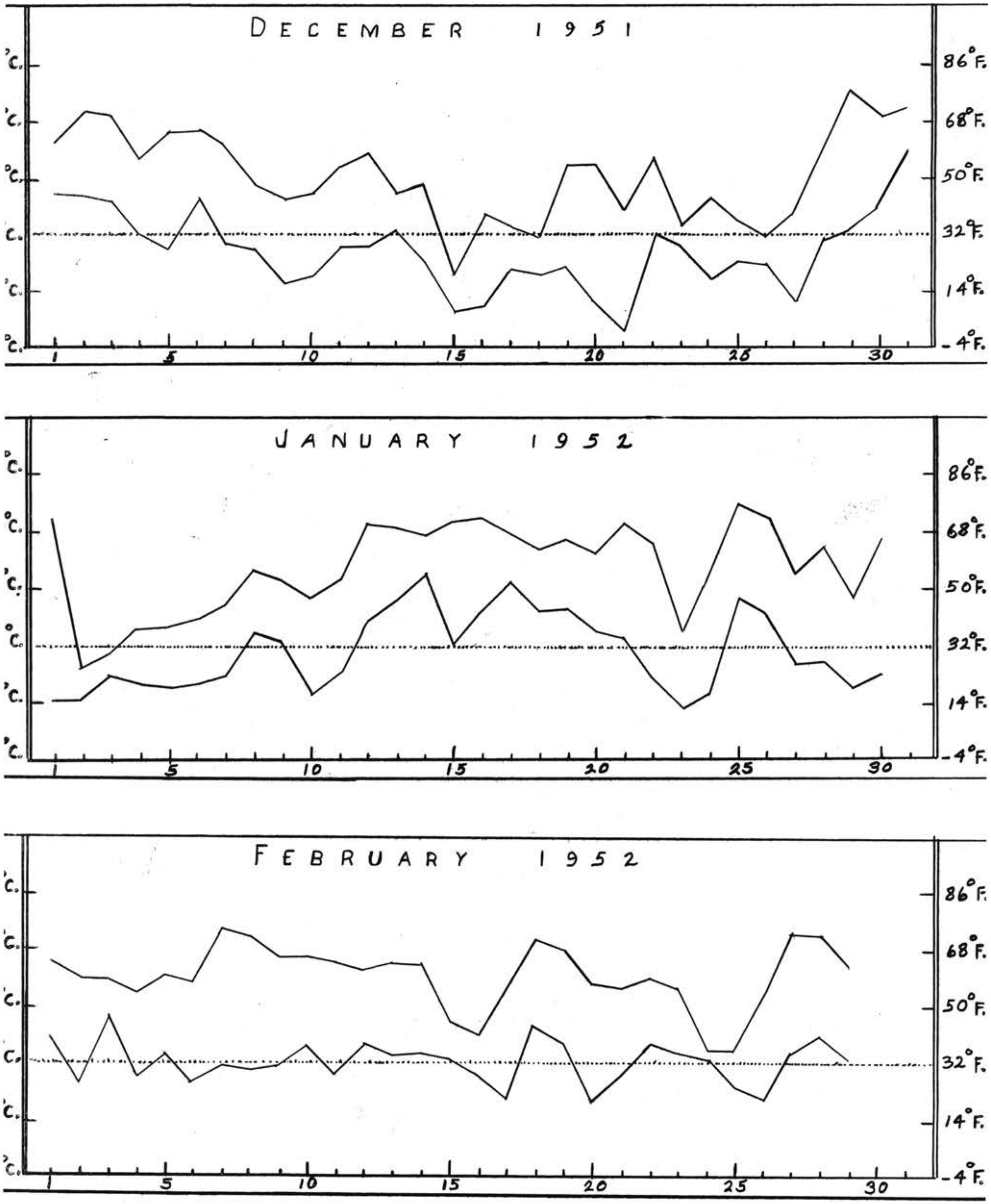
APPENDIX B

Daily Maximum and Minimum Air Temperatures for the Winter Months of 1950-1951 Graphically Expressed.



APPENDIX C

Daily Maximum and Minimum Air Temperatures for the Winter Months of 1951-1952 Graphically Expressed.



APPENDIX D

Total Catch Record of Two Single-Entrance Traps at the Mouth and Two Double-Entrance Traps in the Headwaters of the Haag Cove During the Winter Investigation of 1951-1952.

Date	All Species				White & Black Crappie				White Bass			
	In	Out	H*	T*	In	Out	H*	T*	In	Out	H*	T*
Dec. 18			18	18			9	9			2	2
Dec. 19			15	15			12	12				
Dec. 20			29	29			6	6			4	4
Dec. 21	2	1	10	13	1	1	2	4				
Dec. 22	18	14	9	41	3	2	5	10				
Dec. 23	15	6	1	22	1	1		2				
Dec. 24	15	47	4	66	2			2	2			2
Dec. 25	9	4	13	26	1	1	6	8				
Dec. 26	34	6	10	50	3		7	10				
Dec. 27	9	1	3	13	2	1	2	5				
Dec. 28		3	7	10			2	2				
Dec. 30	30	13	19	62	5	5	15	25				
Dec. 31	24	20	30	74	7	4	23	34	13	15		28
Jan. 1	44	37	49	130	16	11	19	46	19	12	5	36
Jan. 3	64	286	139	489	26	178	118	322	12	39	4	55
Jan. 4	153	74	42	269	46	43	8	97	91	13	9	113
Jan. 5	85	95	120	300	37	47	82	166	46	43	22	111
Jan. 6	89	80	183	352	66	58	153	277	16	20	19	55
Jan. 7	45	39	130	214	40	32	107	179	2	6	7	15
Jan. 8	41	15	177	233	9	5	105	119	30	6	64	100
Jan. 9	60	40	31	131	12	16	25	53	46	20	3	69
Jan. 10	35	15	140	190	13	10	130	153	19		6	25
Jan. 11	21	11	42	74	4	7	37	48	15	2	3	20
Jan. 12	2	12	38	52	1	3	32	36	1	8	2	11
Jan. 13	25	9	100	134	1	1	44	46	22	5	50	77
Jan. 14	4	12	169	185	4	6	63	73		4	92	96
Jan. 15		10	49	59		1	34	35			5	5
Jan. 16		6	53	59		1	41	42		1	10	11
Jan. 17	1	3	25	29	1	2	18	21			5	5
Jan. 18	4	5	14	23		1	5	6			1	1
Jan. 22		5	25	30		2	21	23		1	1	2
Jan. 24		8	9	17		6	8	14			1	1
Jan. 25	5	2	4	11	3	2	3	8	2			2
Jan. 26	5	6	5	16	3	2	3	8	1	2		3
Jan. 28	7	15	2	24	4	4		8	1	4		5
Jan. 29	3	16	3	22	1	3	1	5			1	1
Feb. 1	2	6	3	11	1	1	2	4	1	3		4
Feb. 12	1	3	8	12					1		2	3
Totals	852	925	1728	3505	313	457	1148	1918	340	204	318	862
% In-Out	48%	52%			41%	59%			63%	37%		
Total In-Out	1777				770				544			
% Grand Total								55%				25%

*H = Traps in Headwaters; T = Total.

APPENDIX D (Continued)

Date	Black Bullhead				Bluegill				Gizzard Shad			
	In	Out	H*	T*	In	Out	H*	T*	In	Out	H*	T*
Dec. 18			4	4							1	1
Dec. 19							2	2			1	1
Dec. 20			6	6			3	3			10	10
Dec. 21	1		2	3							6	6
Dec. 22	5	1	3	9					10	11	1	22
Dec. 23	5			5					9	5	1	15
Dec. 24	4	3	1	8	2		2	4	5	44	1	50
Dec. 25	6	2	5	13	2	1	1	4			1	1
Dec. 26	27	2	2	31	3	4	1	8	1			1
Dec. 27	4		1	5	3			3				
Dec. 28			3	3		3	1	4				
Dec. 30	22	7		29	2		3	5				
Dec. 31					2		5	7				
Jan. 1		7	3	10	3	4	16	23	4	3		7
Jan. 3	10	25		35	3	14	8	25			3	3
Jan. 4	4	1	1	6		2	2	4	2	2	7	11
Jan. 5		1	1	2		3	3	6	1		4	5
Jan. 6	1		2	3	1	1	5	7	4		2	6
Jan. 7	1		1	2	1		8	9				
Jan. 8		2		2	1		3	4			1	1
Jan. 9	1		1	2							2	2
Jan. 10		1		1							1	1
Jan. 11											1	1
Jan. 12			2	2							2	2
Jan. 13									1		5	6
Jan. 14			1	1			2	2			6	6
Jan. 15		6	8	14		1	2	3				
Jan. 16							2	2				
Jan. 17							2	2				
Jan. 18	3	3	6	12			2	2				
Jan. 22		2	2	4			1	1				
Jan. 24		1		1		1		1				
Jan. 25							1	1				
Jan. 26			2	2	1			1				
Jan. 28		1	2	3						1		1
Jan. 29			1	1						4		4
Feb. 1							1	1				
Feb. 12		3	5	8			1	1				
Totals	94	68	65	227	24	34	77	135	37	70	56	163
% In-Out	58%	42%			41%	59%			35%	65%		
Total In-Out		162			58				107			
% Grand Total				7%				4%				5%

H = Traps in Headwaters; T = Totals.

APPENDIX D (Continued)

Date	Carp				Drum				Carpsucker			
	In	Out	H*	T*	In	Out	H*	T*	In	Out	H*	T*
Dec. 18												
Dec. 19												
Dec. 20												
Dec. 21												
Dec. 22												
Dec. 23												
Dec. 24												
Dec. 25												
Dec. 26												
Dec. 27												
Dec. 28												
Dec. 30		1		1					1			1
Dec. 31	1	1		2					1			1
Jan. 1	1		2	3					1		1	2
Jan. 3	9	1	1	11	4	8	3	15		21	2	23
Jan. 4	4	13		17	1		10	11	4		5	9
Jan. 5					1	1	7	9				
Jan. 6	1			1		1		1				
Jan. 7	1	1		2			1	1				
Jan. 8		1		1	1		1	2		1	1	2
Jan. 9	1	1		2		3		3				
Jan. 10	1	1		2	2	1		3		1		1
Jan. 11			1	1	1	1		2		1		1
Jan. 12												
Jan. 13		1		1			1	1	1	1		2
Jan. 14			3	3			1	1			1	1
Jan. 15		2		2								
Jan. 16												
Jan. 17		1		1								
Jan. 18	1	1		2								
Jan. 22												
Jan. 24												
Jan. 25												
Jan. 26		1		1						1		1
Jan. 28	1	1		2	1			1		1		1
Jan. 29					1			1	1	8		9
Feb. 1		1		1						1		1
Feb. 12												
Totals	21	28	7	56	12	15	24	51	9	36	10	55
% In-Out	43%	57%			44%	56%			20%	80%		
Total In-Out		49				27				45		
% Grand Total				2%				1%				1%

*H = Traps in Headwaters; T = Totals.

APPENDIX D (Continued)

Date	Largemouth Bass				Yellow Pikeperch			
	In	Out	H*	T*	In	Out	H*	T*
Dec. 18			2	2				
Dec. 19								
Dec. 20								
Dec. 21								
Dec. 22								
Dec. 23								
Dec. 24								
Dec. 25								
Dec. 26								
Dec. 27								
Dec. 28			1	1				
Dec. 30			1	1				
Dec. 31			2	2				
Jan. 1			3	3				
Jan. 3	1			1				
Jan. 5			1	1				
Jan. 6			2	2				
Jan. 7			6	6				
Jan. 8			2	2				
Jan. 9								
Jan. 10			1	1		1	2	3
Jan. 11					1			1
Jan. 12						1		1
Jan. 13						1		1
Jan. 14						2		2
Jan. 15								
Jan. 16						4		4
Jan. 17								
Jan. 18								
Jan. 22								
Jan. 24								
Jan. 25								
Jan. 26								
Jan. 27								
Jan. 28		2		2		1		1
Jan. 29						1		1
Feb. 1								
Feb. 12								
Totals	1	2	21	24	1	11	2	14
% In-Out	33%	67%			8%	92%		
Total In-Out		3			12			
% Grand Total				--%				--%

*H = Traps in Headwaters; T = Totals.

APPENDIX E

Total Catch Record of Two Single-Entrance Traps at the Mouth of the Boatdock Cove During the Winter Investigation of 1951-1952.

Date	All Species			White & Black Crappie			White Bass			Black Bullhead		
	In	Out	T*	In	Out	T*	In	Out	T*	In	Out	T*
ec. 19	11	14	25	3	6	9				2		2
ec. 20	1	4	5									
ec. 21	12	6	18							1		1
ec. 22	13	12	25		4	4	1	1	2	3	2	5
ec. 24	12	25	37	7	18	25	3	6	9	2		2
ec. 25	2	3	5	1	3	4						
ec. 26	6	7	13	3	2	5	1	2	3	1	1	2
ec. 27	8	3	11	2	3	5	3		3			
ec. 28	11	20	31	5	8	13				3	5	8
ec. 30	9	22	31	2	13	15	4	5	9	2	2	4
ec. 31	4	20	24	1	7	8	2	6	8			
an. 1	2	7	9	1	4	5	1	2	3			
an. 3	4	6	10		1	1		1	1			
an. 4	8	9	17	1	4	5		2	2	1	1	2
an. 5	123	178	301	21	25	46	94	144	238	1		1
an. 6	13	41	54	7	13	20	5	25	30		1	1
an. 7	64	103	167	44	63	107	17	39	56	2		2
an. 8	24	26	50	11	15	26	9	5	14		1	1
an. 9	19	25	44	5		5	9	19	28	1		1
an. 10	22	78	100	8	40	48	7	34	41	2	1	3
an. 11	10	147	157	3	15	18	3	120	123			
an. 12	18	57	75	3	15	18	8	34	42			
an. 13		1	1		1	1						
an. 14	11	24	35	3	9	12	7	14	21	1		1
an. 15	39	44	83	2	2	4	17	14	31	1	8	9
an. 16	11	62	73	3	17	20	8	33	41		2	2
an. 17	11	13	24	8	5	13	2	5	7			
an. 18	10	12	22	5	1	6	1		1		3	3
an. 25	18	101	119	9	32	41	3	51	54	1	1	2
an. 26	16	15	31	6	6	12	9	7	16			
an. 28	35	27	62	17	15	32				1		1
an. 29	24	20	44	18	13	31	1	1	2			
eb. 1	40	17	57				12	4	16	1		1
eb. 6	41	11	52	1		1	17	5	22	8	1	9
eb. 12	14	23	37	7	10	17	1		1			
tals	666	1183	1849	207	370	577	245	579	824	34	29	63
In-Out	36%	64%		35%	65%		30%	70%		54%	46%	
Grand Total						31%			45%			3%

T = Total.

APPENDIX E (Continued)

Date	Bluegill			Gizzard Shad			Carp			Drum		
	In	Out	T*	In	Out	T*	In	Out	T*	In	Out	T*
ec. 19		1	1	6	4	10						
ec. 20		2	2									
ec. 21				6	6	12						
ec. 22				4	5	9						
ec. 24					1	1						
ec. 25		1	1									
ec. 26	1	1	2									
ec. 27	1		1	1		1						
ec. 28	2	7	9									
ec. 30		2	2									
ec. 31		1	1									
an. 1												
an. 3				3	3	6						
an. 4				4	1	5	1		1			
an. 5	1		1	1		1		2	2	2	3	5
an. 6				1		1		2	2			
an. 7	1		1									
an. 8										2	1	3
an. 9					1	1	1	1	2		2	2
an. 10				5	2	7						
an. 11							2	6	8			
an. 12							5	1	6	1		1
an. 13												
an. 14											1	1
an. 15				2		2	15	18	33	1	2	3
an. 16								2	2		2	2
an. 17		1	1					1	1	1		1
an. 18							3	8	11			
an. 25				1		1		15	15	1		1
an. 26		1	1				1	1	2			
an. 28	2	1	3		2	2	13	9	22	1		1
an. 29	3	1	4	1		1	1	4	5			
eb. 1				2	4	6	22	6	28	1	1	2
eb. 6				1	2	3	8		8			
eb. 12	1	1	2	1	1	2	2	10	12			
otals	13	19	32	39	32	71	75	89	164	10	14	24
In-Out	41%	59%		54%	46%		46%	54%		42%	58%	
Grand Total			2%			4%			9%			1%

T = Total.

APPENDIX E (Continued)

Date	Carpsucker			Black Bass			Yellow Pikeperch		
	In	Out	T*	In	Out	T*	In	Out	T*
Dec. 19		3	3						
Dec. 20	1	2	3						
Dec. 21	5		5						
Dec. 22	5		5						
Dec. 24									
Dec. 25									
Dec. 26					1	1			
Dec. 27				1		1			
Dec. 28				1		1			
Dec. 30	1		1						
Dec. 31		4	4		1	1	1	1	2
Jan. 1					1	1			
Jan. 3	1		1		1	1			
Jan. 4		1	1				1		1
Jan. 5	1	2	3				2	2	4
Jan. 6									
Jan. 7								1	1
Jan. 8	2	4	6						
Jan. 9	2	1	3				1	1	2
Jan. 10		1	1						
Jan. 11	2	1	3					5	5
Jan. 12		2	2						
Jan. 13									
Jan. 14									
Jan. 15							1		1
Jan. 16		2	2					4	4
Jan. 17								1	1
Jan. 18							1		1
Jan. 25	1	1	2				2	1	3
Jan. 26									
Jan. 28							1		1
Jan. 29								1	1
Feb. 1					1	1	2	1	3
Feb. 6	6	3	9						
Feb. 12	1	1	2				1		1
Totals	28	28	56	2	5	7	13	18	31
% In-Out	50%	50%		29%	71%		42%	58%	
% Grand Total			3%			--			2%

*T = Total.

APPENDIX F

Total Catch Record of Two Single-Entrance Traps at the Mouth of the Big Bend Cove During the Winter Investigation of 1951-1952.

Date	All Species			White & Black Crappie			White Bass			Black Bullhead		
	In	Out	T*	In	Out	T*	In	Out	T*	In	Out	T*
ec. 27	3	2	5				1		1	2		2
ec. 28	2	1	3							1		1
ec. 30	4	5	9				3	5	8	1		1
ec. 31	25	13	38	11		11	12	11	23			
an. 4	8	25	33	2	6	8	3	10	13	1	5	6
an. 5	12	7	19	3	2	5	9	4	13			
an. 6	3	3	6	1	3	4	1		1	1		1
an. 8	14	9	23	3	3	6	3	2	5	3	2	5
an. 11	21	17	38	3	2	5	12	14	26	1		1
an. 14	12	6	18	8	3	11	3	2	5	1		1
an. 18	15		15				14		14	1		1
an. 25	11		11	10		10	1		1			
an. 26		4	4		1	1					2	2
an. 28		2	2					1	1			
an. 29												
tals	130	94	224	41	20	61	62	49	111	12	9	21
In-Out	58%	42%		67%	33%		56%	44%		57%	43%	
Grand Total						27%			50%			9%

= Total.

APPENDIX F (Continued)

Date	Bluegill			Gizzard Shad			Carp			Drum		
	In	Out	T*	In	Out	T*	In	Out	T*	In	Out	T*
ec. 27		2	2									
ec. 28				1	1	2						
ec. 30												
ec. 31	2		2		1	1						
an. 4				1		1						
an. 5												
an. 6												
an. 8							5	2	7			
an. 11										1		1
an. 14											1	1
an. 18												
an. 25												
an. 26												
an. 28								1	1			
an. 29												
otals	2	2	4	2	2	4	5	3	8	1	1	2
In-Out	50%	50%		50%	50%		63%	37%		50%	50%	
Grand Total			2%			2%			3%			1%

T = Total.

APPENDIX F (Continued)

Date	Carpsucker			Black Bass			Yellow Pikeperch		
	In	Out	T*	In	Out	T*	In	Out	T*
Dec. 27									
Dec. 28									
Dec. 30									
Dec. 31					1	1			
Jan. 4	1	3	4					1	1
Jan. 5								1	1
Jan. 6									
Jan. 8									
Jan. 11	2	1	3				2		2
Jan. 14									
Jan. 18									
Jan. 25									
Jan. 26					1	1			
Jan. 28									
Jan. 29									
Totals	3	4	7	-	2	2	2	2	4
% In-Out	43%	57%		-	100%		50%	50%	
% Grand Total			3%			1%			2%

*T = Total.

VITA

Hunter McRae Hancock
candidate for the degree of
Doctor of Philosophy

Thesis: INVESTIGATIONS AND EXPERIMENTATION RELATIVE TO WINTER AGGREGATIONS OF FISHES IN CANTON RESERVOIR, OKLAHOMA

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Minor: Wildlife Management

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Date of Final Examination: April 1955.

THESIS TITLE: INVESTIGATIONS AND EXPERIMENTATION
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