Seasonal Abundance and Availability of Forage Fishes and their Utilization by Landlocked Atlantic Salmon and Brook Trout in Echo Lake, Mount Desert Island, Maine

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SEASONAL ABUNDANCE AND AVAILABILITY OF FORAGE FISHES AND THEIR UTILIZATION BY LANDLOCKED ATLANTIC SALMON AND BROOK TROUT IN ECHO LAKE, MOUNT DESERT ISLAND, MAINE

By

ROBERT T. LACKEY

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An Abstract of the Thesis Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science (in Zoology). August, 1968.

A study was made of landlocked salmon, brook trout, American smelt and landlocked alewives inhabiting Echo Lake. Landlocked alewives were introduced from Cayuga Lake, New York, in 1966, one year before the start of this study. Seasonal depth distribution, feeding habits, age and growth, and abundance were determined.

Salmon were found to be wide-ranging fish, but were infrequently captured in very shallow or very deep water. Brook trout were primarily an inshore species and were not often captured in water deeper than 25 feet. The majority of captured alewives were taken from shallow to mid-depths (0-40 feet) in summer and fall, and from deeper waters (maximum lake depth is 63 feet) in winter and spring. Smelts were widely distributed, but the majority were captured in water deeper than 30 feet during every month of this study.

The annual salmon diet consisted of several forage fishes (smelts, sticklebacks, alewives, and killifish) and insects. Smelts were used during the entire year, killifish and sticklebacks during summer, and alewives only during spring. Brook trout had roughly similar feeding habits except that sticklebacks were used throughout the year, and insects constituted a higher proportion of their overall diet. Brook trout fed extensively on isopods (Asellus sp.) during winter and early spring. Alewives fed extensively on plankton with insects being important food only during summer months. Smelts utilized a higher proportion of insects and isopods than did alewives, but still fed mainly on plankton.

The growth of salmon, trout, and smelt were similar to growth of these species on other Maine lakes. Echo Lake alewives grew rapidly compared to this species in other completely landlocked lakes.

It was concluded that landlocked alewives were utilized only to a limited extend by the salmon (12 to 19 inches in total length) in Echo Lake, but would likely be preyed upon more heavily by larger salmon. Similarly, alewife utilization by brook trout likely would be greater with larger trout.

Alewives and smelts were thought to compete for food and space during much of the year.

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Drs. John H. Dearborn and Kenneth W. Allen, Department of Zoology, and Dr. Harold E. Young, Department of Forestry, University of Maine, carefully reviewed the manuscript and offered many helpful suggestions.

I would like to thank my wife, Lana, for her constant encouragement, tolerance, and help during the many long hours at Echo Lake and in typing preliminary drafts of the thesis.

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INTRODUCTION

A major problem in fishery management is providing piscivorous game fish with suitable and adequate forage. The value of any particular species of potential forage fish must be measured by several criteria to determine its overall effectiveness in maintaining a given fishery at optimum levels. Most obvious, and perhaps most important of these criteria, is the ability of a particular forage species to become a significant part of the game fish diet. Unrecognized factors may illicit behavioral responses in game fish making a seemingly excellent forage fish of little benefit or perhaps detrimental to the fishery. Although factors determining feeding preference in fish are rarely, if ever, fully understood, anglers, as well as biologists, are aware that certain fishes are preferred items in the diet of piscivorous fish.

The American smelt (Osmerus mordax) is the foremost forage fish for landlocked salmon in most Maine lakes (Rupp, 1968). The potential of smelt populations to support small, as well as very large, landlocked salmon fisheries has been shown by many studies (Cooper, 1940; Fuller and Cooper, 1946; Havey and Warner, 1968 MS). However, this potential is often unrealized because of factors presently beyond the control of fishery management programs. For unknown reasons, smelt are often subject to large year to year fluctuations in abundance (Rupp, 1968). Attempts to minimize these fluctuations through management have met with little success to date. Although other forage species are often utilized by landlocked salmon, smelt, even with the problems associated with population irregularities, support the bulk of the landlocked salmon fisheries in Maine.

Because the forage value of smelt in certain Maine lakes is greatly reduced by population fluctuations, other species have been considered to supplement smelt as a forage species. Special attention has been given the landlocked alewife, Alosa pseudoharengus. The widely publicized success of landlocked alewives in supporting various game fishes in New York and, more recently, the apparent success of alewives as forage fish in Lake Michigan, has further enhanced interest in this species as a forage fish for Maine lakes.

The alewife was originally limited to the Atlantic coast of North America and probably occurred only in the anadromous form (Threinen, 1958). However, introductions and altered waterways have extended distribution into many freshwater lakes. Today there are many landlocked populations in the eastern half of the United States and Canada. Lake Ontario, as well as several of the Finger Lakes of New York, have supported landlocked alewives since the late nineteenth century (Miller, 1957). Lakes Erie, Huron, Michigan, and Superior have all acquired populations since 1930. Freshwater alewife populations were well established in New Jersey by 1850 (Gross, 1953). Several Connecticut lakes have long supported alewives (Brooks and Dodson, 1965).

Anadromous alewives, as forage for warmwater fish, have been used successfully in New York for several years (Vincent, 1960). Mature alewives are stocked prior to spawning, and the young, and possible the adults, provide immediate forage. However, both adults and young apparently fail to survive beyond late fall of the year of introduction. Foye (1956) has described a similar procedure used in several Maine lakes inhabited by salmonids.

Permanently established alewives in Cayuga Lake, New York, are heavily utilized by lake trout (Webster, Bentley, and Galligan, 1959) as well as by smallmouth bass (Webster, 1954). The utilization of landlocked alewives in New Jersey by many warmwater species, as well as by brown trout, has been reported (Gross, 1953). The coho salmon fishery of Lake Michigan apparently is dependent to a large extent on alewives.

The potential of alewives as a forage fish for landlocked salmon has never been fully evaluated. Utilization of young anadromous alewives has been reported by Havey (1952) and several other workers, but these data were obtained incidental to other research. Hutchinson (1968) and Flick (personal communication) have observed that landlocked salmon in New York ignore schools of alewives while feeding on surface insects, but quantitative data are not available on the feeding habits of these salmon.

As part of its statewide program to investigate techniques to improve salmon and trout fishing, the Maine Department of Inland Fisheries and Game decided to evaluate the potential of landlocked alewives in Maine lakes. In 1966, landlocked alewives from Cayuga Lake were introduced into three small Maine lakes, one of which contained the desired populations of forage and game fishes (landlocked salmon, brook trout, and smelt). The primary purpose of this report is to compare the landlocked alewife and smelt as forage for landlocked salmon and brook trout.

STUDY AREA

Echo Lake, located on Mount Desert Island, Hancock County, Maine, is partially in Acadia National Park. Surface area is approximately 234 acres with a maximum depth about 63 feet. The drainage area encompasses 1.5 square miles of predominantly wooded land with dense stands of conifers and patches of hardwoods. The lake is marginally oligotrophic and of glacial origin as are most of the lakes of the region.

Lurvey Brook, the only permanent tributary entering Echo Lake, originates from a spring about one mile from the southern shore. The upper reaches of the brook are fair spawning and nursery habitat for trout, but poor spawning and nursery habitat for salmon. The lower part of the stream supports a population of adult trout.

Little Echo Lake, a 10 acre artificial pond, lies directly north of Echo Lake, and is connected to the larger lake by 100 yards of stream of low gradient. Little Echo Lake is shallow and supports a dense growth of aquatic vegetation. A small concrete and rock dam, located at the north end of Little Echo Lake, creates the impoundment.

Denning Brook, the outlet of Little Echo Lake, flows for approximately one mile before reaching tidal water (Somes Sound) to the north. A second concrete dam is located on Denning Brook close to Somes Sound.

A two-year study of Echo Lake was initiated by Keith A. Havey in 1950. Work involved marked trout, stream and lake improvement, creel census, tributary trapping, growth, and parasites. Havey tentatively concluded from his study that serious competition existed between the brook trout and warm-water fishes inhabiting the lake.

Echo Lake and its fisheries was again studied for two years (1956-58) by Robert M. Davis. The lake was chemically reclaimed during his study to provide better brook trout fishing. Davis' work again emphasized brook trout and included gill netting, creel census, age and growth studies, feeding habits, and predators.

Echo Lake was selected by the Maine Department of Inland Fisheries and Game to provide a study location for determining the relative forage value of landlocked alewives and smelts for salmon and brook trout. Echo Lake was chosen because the lake is not part of a drainage in which an introduced fish species might spread. An additional reason was the existence of previous fishery research on Echo Lake. Landlocked salmon were introduced in 1965 and landlocked alewives the following year.

Physical and Chemical Environment

Hydrography

An accurate hydrographic map of Echo Lake was important not only for general background information, but as a necessity for selecting specific sampling stations. Selection of these stations is discussed in a later section (Fish

Distribution). Depths recorded with a Raytheon Recording Fathometer were used to construct the necessary map (Figure 1). Gill netting stations and sampling sites of other types are indicated on Figure 1 for future reference.

Dissolved Oxygen

Dissolved oxygen was determined at 10 foot depth intervals (Figure 2) during each sampling period if weather conditions permitted. All determinations were made at a permanently marked "water quality station" (Figure 1). The sodium azide modification of the Winkler method was used for all but June, 1967, data,when determinations were made by the Hach method. The two methods, compared over several sample periods in July, 1967, gave nearly identical readings.

Dissolved oxygen determined in August during three previous studies at Echo Lake are presented in Table 1. Determinations made in 1967 are presented for comparison. No significant differences exist between the four groups of data, and an assumption that dissolved oxygen conditions in Echo Lake, during summer, 1967, were "typical," seems valid.

Water Temperature

Water temperature data are important as a possible factor affecting fish distribution. Figure 3 illustrates this aspect of the Echo Lake physical environment during the present study. Relationships between fish distribution and water temperature are discussed in the following section.

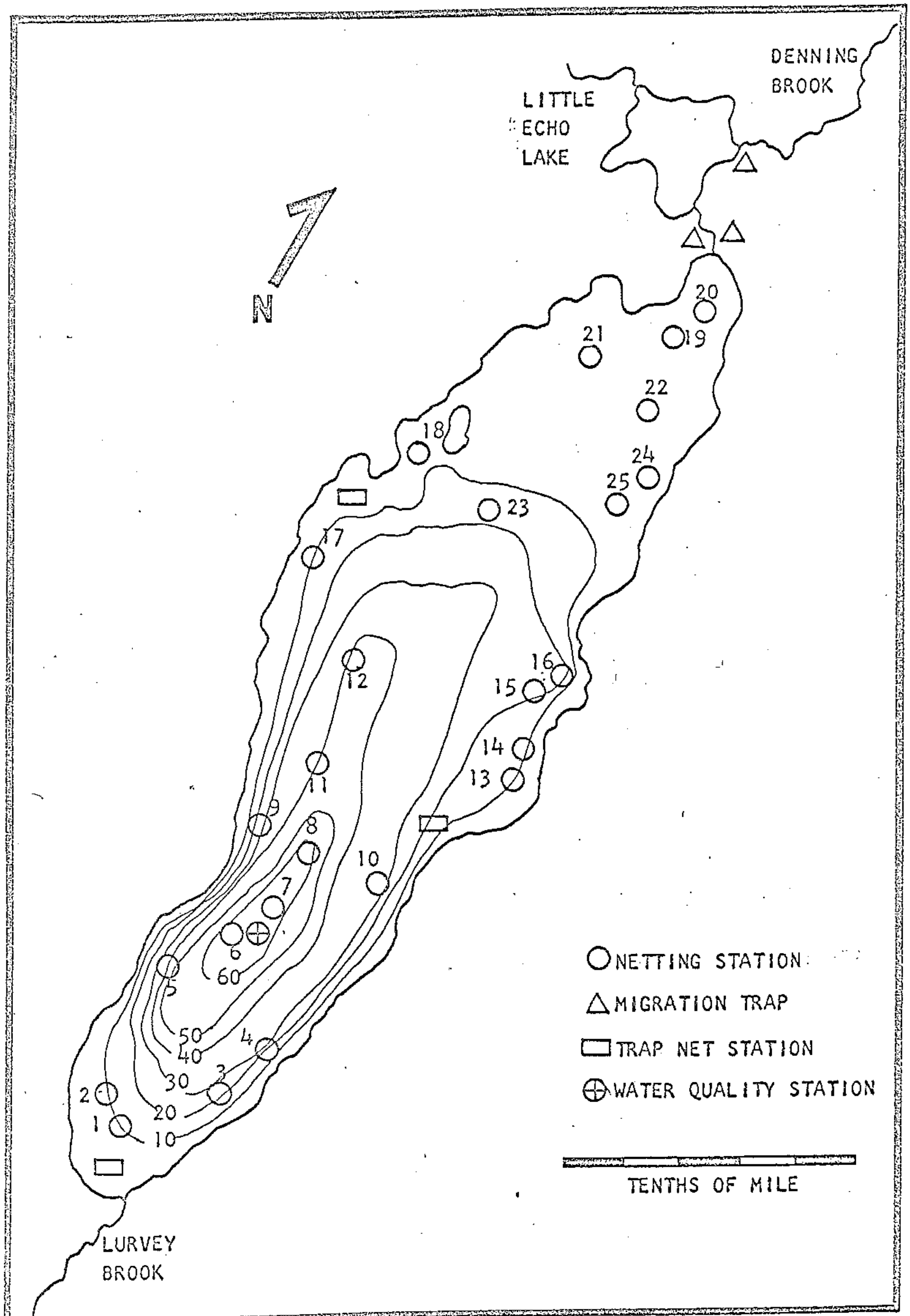


FIGURE 1.—Echo Lake showing depth contours and sampling stations.

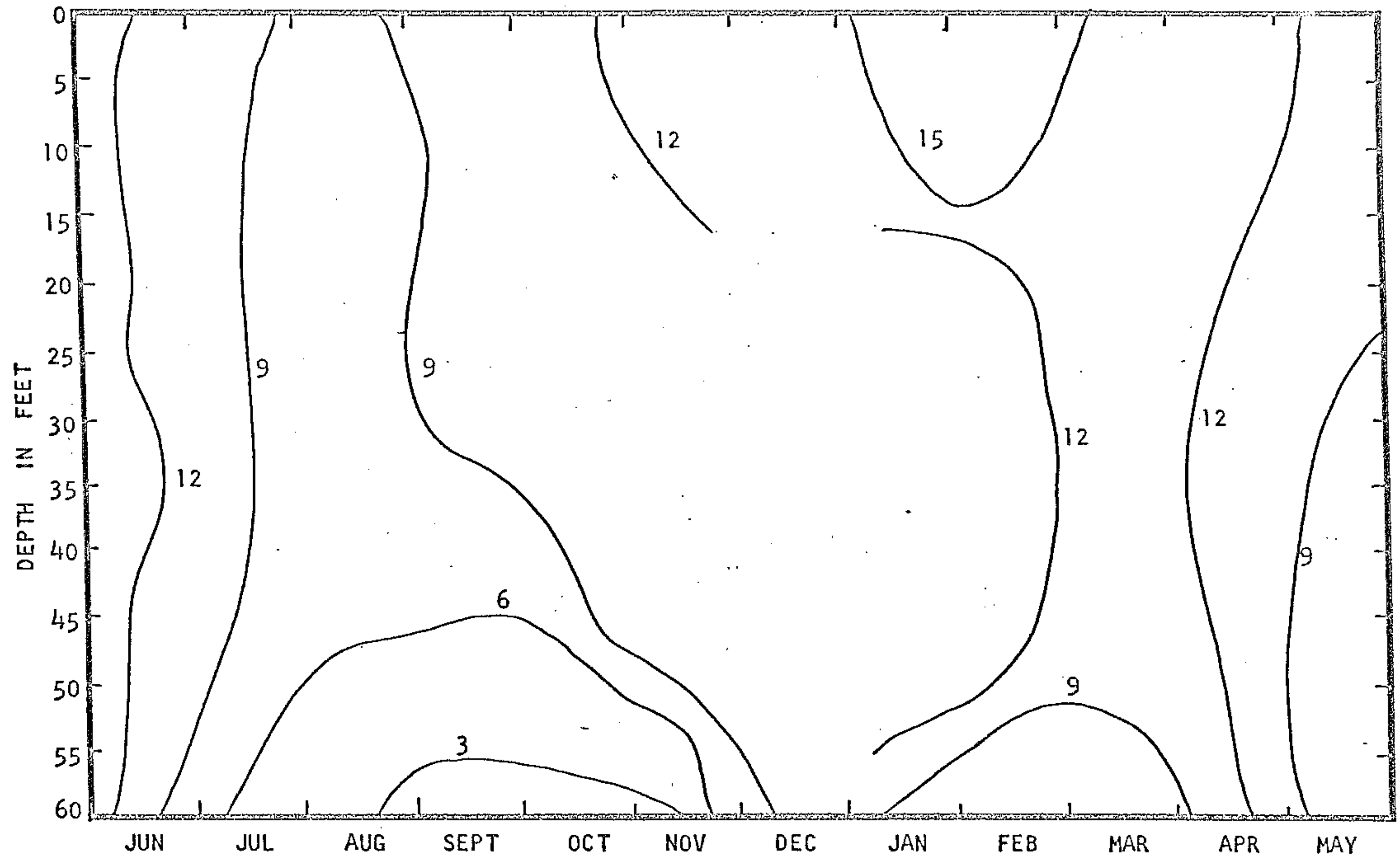


FIGURE 2.—Dissolved oxygen (parts per million) in Echo Lake from June, 1967, to May, 1968.

TABLE 1.—Dissolved oxygen (parts per million) at various depths in Echo Lake in four different years.

Depth (ft)	Sampling Date			
	27 Aug 1942[1]	20 Aug 1950[2]	11 Aug 1957[3]	18 Aug 1967
Surface	9.5	8.4	7.8	8.6
5	-	-	-	9.3
10	-	-	-	9.3
15	9.4	-	8.0	9.0
20	-	8.4	-	8.4
25	-	-	-	9.0
30	9.0	6.8	-	8.0
32	7.5	-	-	8.4
35	-	-	8.2	7.7
38	-	-	-	7.0
40	-	5.3	8.0	4.6
45	5.1	-	-	5.6
50	4.7	3.9	6.0	5.0
60	4.4	3.1	5.6	4.2

1.—Data taken from Fuller and Cooper (1946)

2.—Data taken from Havey (1952)

3.—Data taken from Davis (1958)

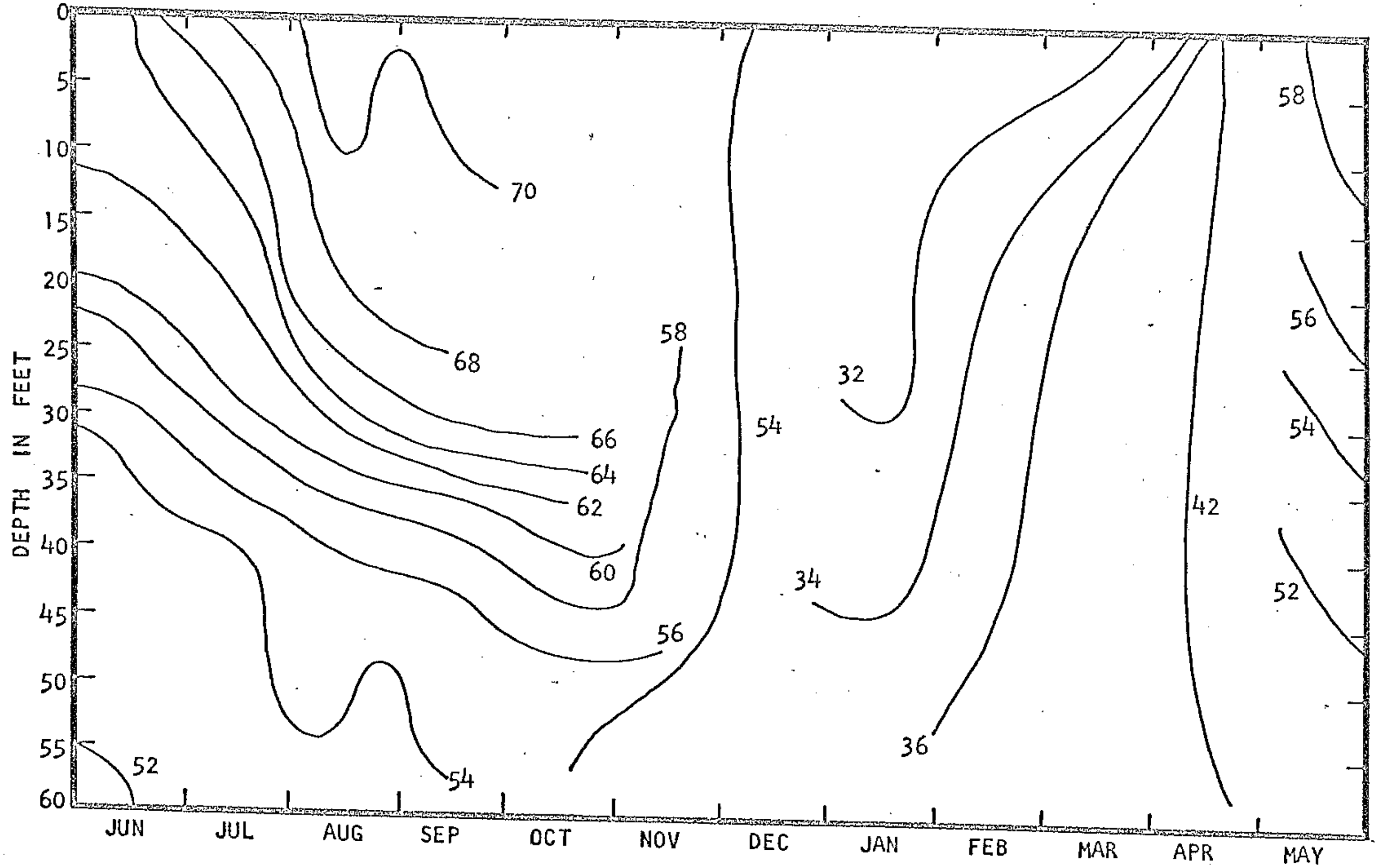


FIGURE 3.—Isotherms in Echo Lake (degrees F.) from June, 1967, to May, 1968.

Water temperatures were determined at 10 foot intervals during each sampling period with an electric resistance thermometer. All readings were taken at the same water quality station as were dissolved oxygen determinations.

Table 2 presents August temperature profiles from three previous studies and an August temperature profile taken in 1967. Water temperatures from the upper 25 feet are similar for all four profiles, but temperatures at greater depths are quite different. The 1942 and 1967 profiles show only slight stratification. The deeper water in Echo Lake was noticeably colder (5-6°F.) in the summer of 1950 and 1958 if these samples are representative of the respective summers.

Water Chemistry

An analysis of various chemical aspects of Echo Lake was made to provide additional information on the physical environment. Results are presented in Table 3. Data are similar to those for most Maine lakes. The relatively high chloride concentration is probably associated with the proximity of Echo Lake to the ocean.

Fish Fauna

All fishes reported from Echo Lake are listed in Table 4. The information from 1942 was obtained by interview with the local warden, however, the other reports are based on intensive netting (1952 and 1968) or reclamation (1956). The alewives reported in 1942 were the anadromous rather than the landlocked form currently under investigation.

TABLE 2.—Temperature (degrees F.) at various depths in Echo Lake during four different years.

Depth (ft)	Sampling Date			
	27 Aug 1942[1]	20 Aug 1950[2]	11 Aug 1957[3]	18 Aug 1967
Surface	70	70	72	71
5	70	70	72	71
10	70	70	72	70
15	70	70	70	70
20	69	70	72	70
25	69	70	71	68
30	69	70	71	68
32	68	-	69	64
35	66	66	67	60
38	59	62	65	56
40	54	61	62	55
45	54	59	59	53
50	53	59	58	53
60	52	59	58	53

1.—Data taken from Fuller and Cooper (1946)

2.—Data taken from Havey (1952)

3.—Data taken from Davis (1958)

TABLE 3.—Chemical analysis (parts per million) of Echo Lake water determined from two depths, 28 July 1967.

Item	Depth of Sample	
	Surface	30 ft
Phenolphthalein alkalinity	0.0	0.0
Total alkalinity	6.0	4.0
Total hardness (as $CaCO_3$)	12.0	13.0
Calcium	3.2	3.2
Magnesium	0.97	1.22
Total iron	0.045	0.03
Copper	0.02	0.02
Orthophosphate	0.01	<0.01
Sulfates	2.0	1.6
Ammonia nitrogen	0.025	0.125
Nitrate nitrogen	0.0	0.0
Nitrite nitrogen	0.0	0.0
Chlorides	8.5	10.0

TABLE 4.—Fishes reported from Echo Lake by Fuller and Cooper (1946), Havey (1952), Davis (1958), and in present report.

Species	Year of Study			
	1942	1952	1956	1968
Alewife *Alosa pseudoharengus*	*			*
Landlocked salmon *Salmo salar*	*			*
Brook trout *Salvelinus fontinalis*	*	*	*	*
American smelt *Osmerus mordax*	*	*	*	*
Brown bullhead *Ictalurus nebulosus*		*	*	
Golden shiner *Notemigonus crysoleucas*	?	*	*	*
Northern redbelly dace *Chrosomus eos*	?	*	*	
White sucker *Catostomus commersoni*	*	*	*	
Banded killifish *Fundulus diaphanus*	?	*	*	*
Ninespine stickleback *Pungitius pungitius*	?	*	*	*
Threespine stickleback *Gasterosteus aculeatus*	?	*	*	
American eel *Anguilla rostrata*	*	*	*	*
Smallmouth bass *Micropterus dolomieui*		*	*	
Pumpkinseed *Lepomis gibbosus*	*	*	*	
White perch *Roccus americanus*	*	*	*	

FISH DISTRIBUTION

An accurate estimate of seasonal depth distributions of major predatory and forage fish in Echo Lake was considered important in evaluating predator-prey and competition interrelationships. The purpose of this section is to compare depth distribution of the various species under investigation at monthly intervals from June, 1967, to May, 1968. Such comparisons among game fishes (salmon and trout), among forage fishes (alewife, smelt, stickleback, and banded killifish), and between game and forage species permit inferences concerning the degree of environmental overlap among and between these species. The distributions of important forage species allows an estimate of the degree of space competition within the forage population. Similarly, distribution data on salmon and trout permit an estimate of space competition between these two predatory species.

Aside from seasonal depth distributions of species within Echo Lake itself, it was desirable from a fish management standpoint to have an estimate of fish movement between Echo and Little Echo Lake, and between Little Echo Lake and Denning Brook, particularly the movement of alewives.

Methods

Vertical Gill Nets

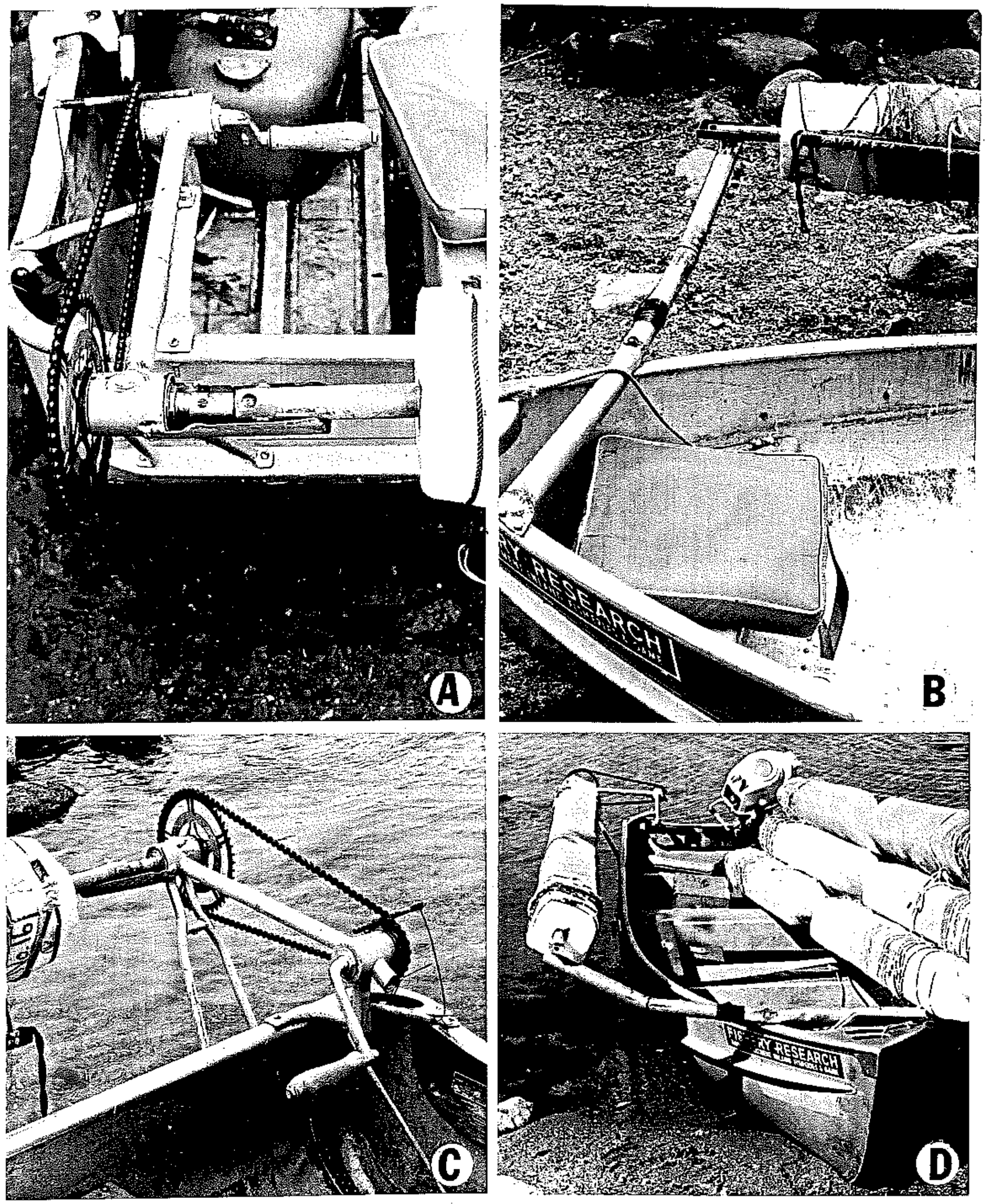
Small meshed vertical gill nets were designed and built to determine the depth distribution of landlocked alewives and smelt in Echo Lake.

Tibbles (1956) described rolling gill nets used to determine the vertical depth distribution of yellow perch in Lake Mendota, Wisconsin. Hartman (1962) used a larger gill net roller to determine diel vertical migration of peamouth chum (Mylocheilus caurinus) and kokanee (Oncorhynchus nerka) in a British Columbia lake. Gill nets hung vertically in gangs and used for studies of the vertical distribution of four fish species in Horsetooth Reservoir, Colorado, were described by Horak and Tanner (1964). Miller and Perrin (1967) described a gill net similar to Hartman's, but incorporating a work platform to facilitate handling the nets.

Description. The experimental vertical gill nets used at Echo Lake were made of 02 and 03 filament nylon with 1/4- and 1/2-inch bar mesh, respectively. All nets were 10 feet wide and were 10, 20, 30, 40, 50, or 60 feet long. The upper end of each net was attached to a styrofoam float and the lower end to a 10-foot length of 3/4-inch, thin-walled steel conduit (Figure 4). The conduit served both as a weight and a spreader, and was attached with nylon twine and plastic tape.

The float for each net consisted of two 4 1/2-foot styrofoam rollers cemented securely to an axle consisting of a 12 foot length of 1 1/4 inch thick-walled steel conduit. Each roller was 6 inches in diameter, and was positioned on the axle in such a way that the axle projected 6 inches beyond the ends of the rollers (Figure 4). Epoxy resin was used to cement the styrofoam to the steel conduit and 1/2-inch holes were drilled in the ends of the conduit to permit attachment of anchor ropes. In addition, a 1/4-inch brass

FIGURE 4.—Modified boat used during this study. A. Rear net support; B. Front net support; C. Crank; D. Net in position.


A
Y RESEARCH
B
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D

bolt was placed into one end of each float axle to form a drive pin for winding up the net. The mechanism for winding up the net is described below, and details of the float assembly are shown in Figure 4.

In addition to the spreader-weight, the 50- and 60-foot nets had spreaders attached midway between top and bottom to aid in keeping the nets open when suspended. The auxiliary spreaders consisted of 10-foot lengths of 1/2-inch, thick-walled conduit, and were held in place with plastic tape. Plastic tape of various colors was used to mark each net at 5-foot intervals, with white used at the 5-foot depth, red at 10 feet, brown at 15 feet, and so on.

To raise and lower the vertical gill nets, outrigger supports were designed and constructed on a 14-foot aluminum boat. The front support was provided by a 4-foot length of 2-inch conduit split lengthwise and welded to the outer, upper side of the front cross piece to support one end of the styrofoam float axle.

The crank for raising and lowering the nets was modified from bicycle pedals, chain, and sprockets. Both pedals and pedal shafts were removed. The large sprocket was mounted aft on the outside of the boat, while the small sprocket was mounted inboard. A wooden handle was attached to the small sprocket and a bicycle chain connected the two sprockets. The bolt fastened in one end of each styrofoam float axle and was designed to mesh with a forked rod welded to the axle of the large sprocket. This drive pin arrangement provided a solid connection for raising and lowering nets.

Sampling Stations. Using the hydrographic map of Echo Lake shown in Figure 1, the approximate percentage of the lake surface over each 10 foot contour interval was determined. The following numbers of each net length were selected as being roughly proportional to the contour area represented:

Length (feet)	1/4 inch mesh	1/2 inch mesh
10	3	3
20	3	3
30	1	1
40	1	1
50	1	1
60	1	1
TOTAL	10	10

Twenty-five sampling stations of various depths (Figure 1) were selected with depths corresponding to the six net lengths. The number of stations at each depth was roughly proportional to lake surface over that depth:

Station Depth (feet)	Station Number
10	1, 2, 13, 14, 18, 19, 20, 21, 24, and 25.
20	3, 15, 16, 17, 22, and 23.
30	9 and 10.
40	4, 5, and 12.
50	8 and 11.
60	6 and 7.

The selection of sampling stations was affected by several practical considerations, including their proximity to swimming and boating areas.

Each station was marked by two large rock anchors separated by a distance roughly equal to twice the depth (Figure 5). Periodic adjustment of

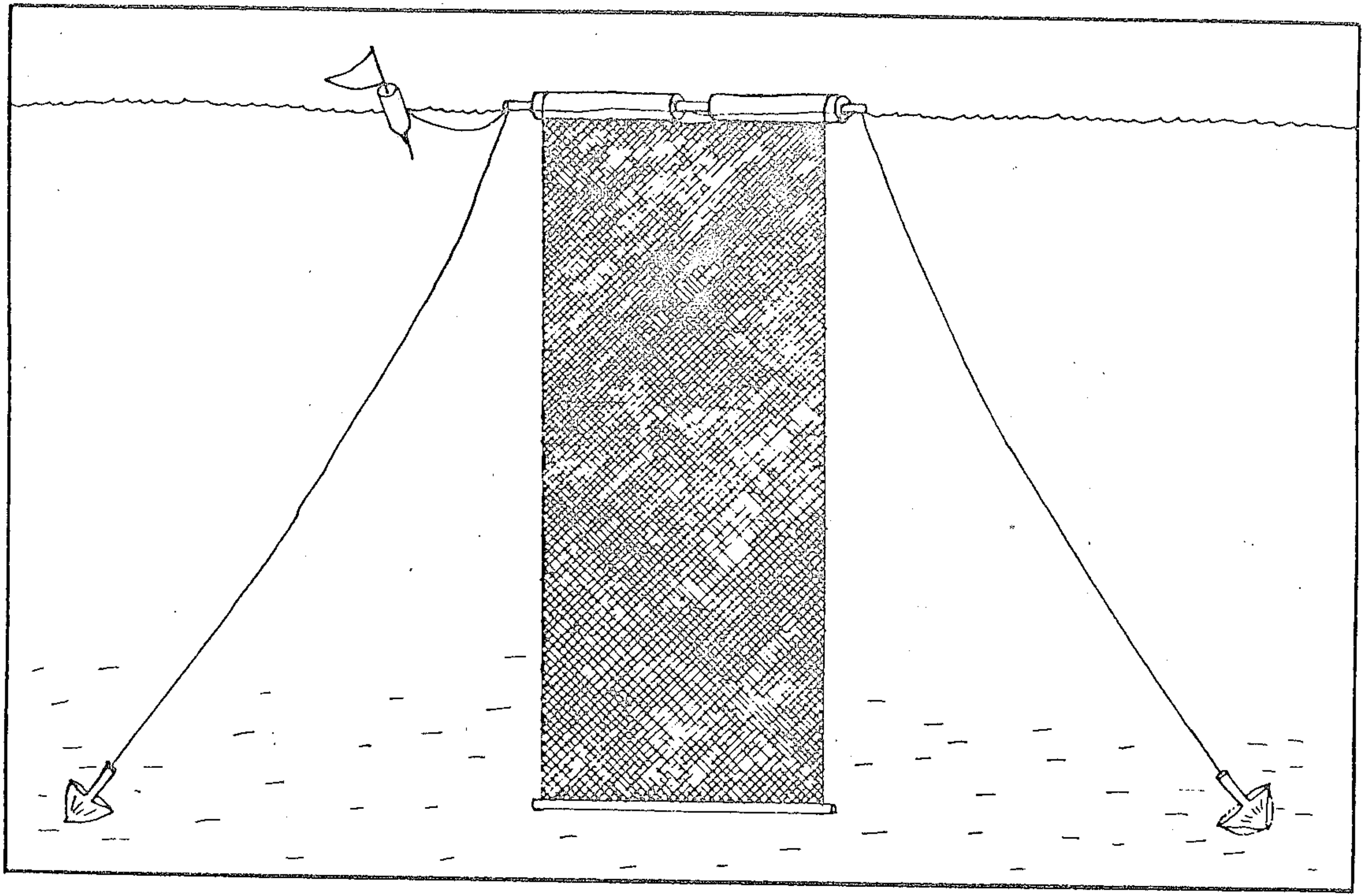


Figure 5.—Vertical gill net in sampling position. Depths are marked along sides of net.

anchors was required to maintain stations at the exact depths of water due to changes in the lake water level.

Sampling Procedure. During summer months, 14 to 19 nets were set for 48 consecutive hours each week. This number of nets could be reasonably handled with the personnel available and still permit repair of several nets during each sampling period. The selection of nets to be used was based on those in need of repair as well as other important considerations, such as proximity of certain stations to recreational areas.

Each net was cleared of fish at least every 12 hours and usually more frequently. All fish captured were recorded by species and depth of capture. The majority were preserved for stomach analysis, although a few were released in connection with population estimation studies.

During winter sampling, ice cover presented several sampling problems. Ice less than 18 inches thick could be cut with a chain saw to permit placement of a vertical net. To set a net under these conditions, a trench 1 foot by 6 feet was cut at the desired location. The styrofoam float was removed from each net. A 10 foot length of steel conduit was attached in place of the styrofoam float. This conduit was placed in the trench after the net was lowered, and supported by ropes tied to small logs laid across the trench. In this way the top of the net (conduit) was just below the bottom of the ice layer. This procedure minimized the possibility of nets freezing in the ice. Ice in Echo Lake reached a maximum thickness of about 42 inches in early March, 1968. Under such severe conditions, the only technique even partially effective was use of a gasoline powered ice auger to supplement the chain saw and ice chisel in cutting trenches. This method was extremely time consuming and resulted in relatively low netting intensity in February and March.

Horizontal Gill Nets

Although a few salmon and trout were captured in vertical gill nets, additional sampling gear was needed to make an accurate estimate of the distribution of these two species.

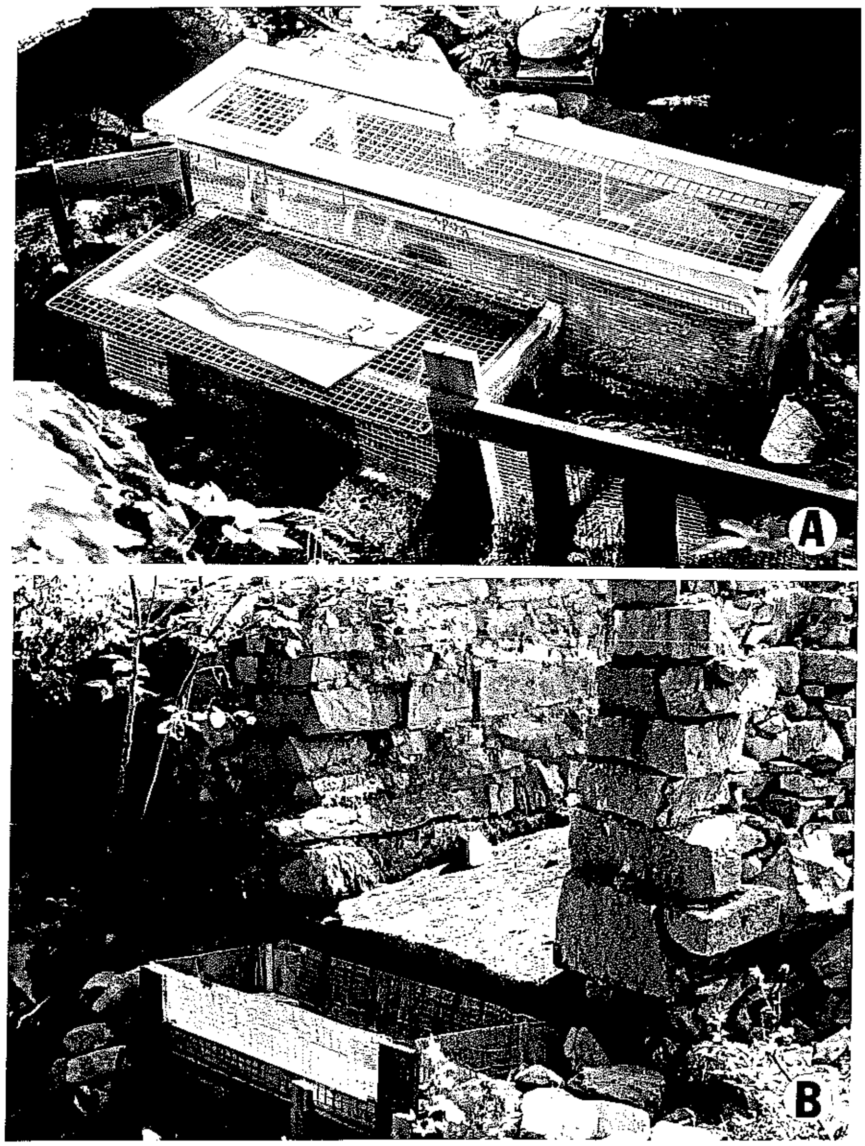
Two 500 foot gangs of horizontal gill net were used, each composed of five 100 foot sections of different mesh sizes (1 1/2-, 2-, 2 1/2-, 3-, and 4 1/2-inch stretch mesh). These nets were set concomitantly with the vertical gill nets.

In order to determine the depth of capture of fish taken with these nets, it was necessary to make sets with a fathometer or in areas of known depth. By carefully setting these nets, it was possible to sample all depths.

Migration Traps

During summer and fall, 1967, a two-way trap was maintained between Echo and Little Echo Lake. An additional trap was operated at the spillway of Little Echo Lake (Figures 1 and 6). These traps were used to detect any movements or migrations of fish between lakes or out of Little Echo Lake.

FIGURE 6.—Traps used to determine movements of fish in Echo Lake. A, trap between Echo and Little Echo Lake; B, outlet trap at Little Echo Lake.


A
B

Results

Salmon

The annual depth distribution of salmon based on captures from vertical and horizontal gill netting is presented in Figure 7. Since individual sample periods often contained only 1 or 2 captures, results were grouped in monthly periods. One cautionary point must be emphasized from the results taken during ice cover in January, February, and March. Shallow horizontal gill net sets during these months were represented to a greater degree than deeper sets. This was due to difficulty in maintaining a deep water sampling station (around station 6 or 7 on Figure 1). When ropes froze in new ice after a severe cold wave, sampling in this area had to be abandoned until some ice melted. Consequently, the deeper water was sampled only by vertical gill nets in late February and March, hence data are biased and must be interpreted with care. The other monthly samples are based on netting from all depths with approximately equal intensity.

Brook Trout

The annual depth distribution of brook trout is presented in Figure 8. As with salmon, there is a distinct increase in the depth of capture in August and perhaps another increase in April and May, although this is somewhat less pronounced. The February and March brook trout data are biased in the same manner pointed out above for salmon. In summary, however, it appears that brook trout in Echo Lake are primarily residents of the upper 30 feet of water, but are not entirely limited to this range.

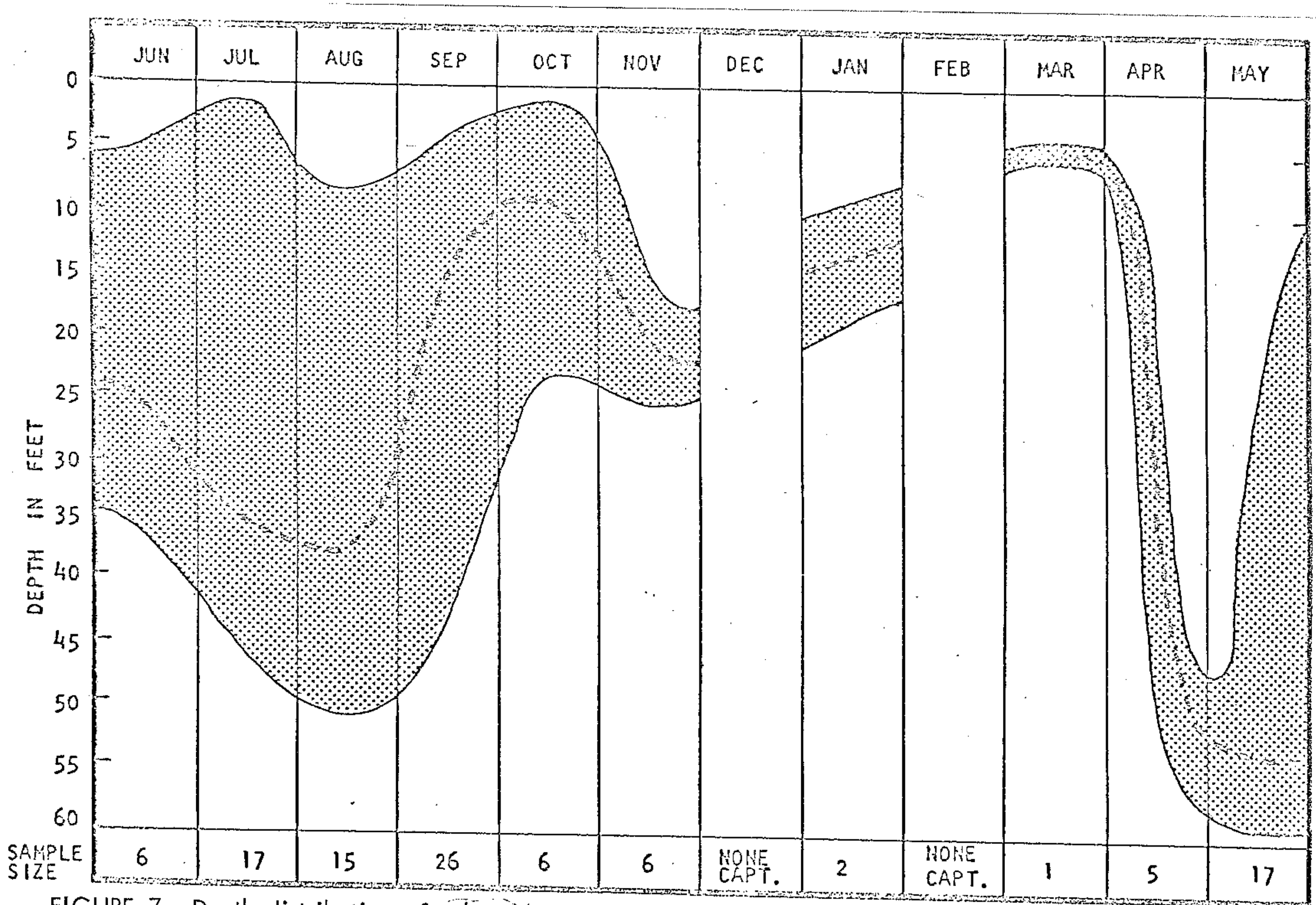


FIGURE 7.—Depth distribution of salmon based on combined vertical and horizontal gill netting in Echo Lake, 1967-68. Shaded area represents approximate depth range; dotted line represents depth of highest concentration of captured fish.

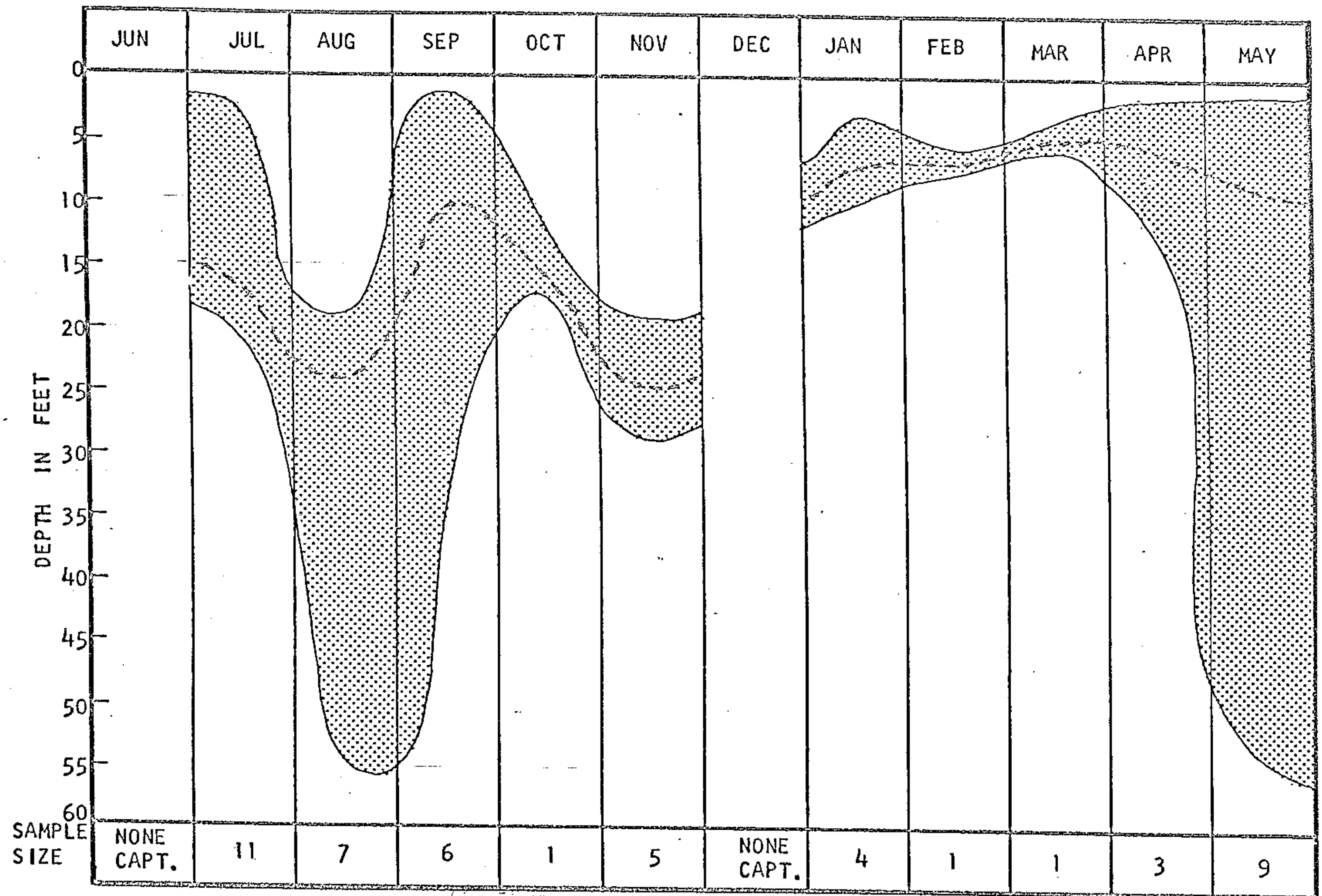


FIGURE 8.--Depth distribution of brook trout based on vertical and horizontal gill netting, 1967-68. Shaded area represents approximate depth range; dotted line represents depth of highest concentration of captured fish.

Alewives

By far the most abundant of the several alewife age classes in Echo Lake when this study was started, were the fish hatched from eggs of adults introduced from Cayuga Lake, New York, on 10 June 1966. Spawning was very successful that year and it is not unlikely that 1966 brood year alewives are more abundant than those of the 1967 brood year.

The annual depth distribution of 1966 brood year alewives is presented in Figure 9. In addition to the data presented in this figure, additional sampling information is available from preliminary studies done in May, 1967. These data show 1966 brood year alewives in 40 to 60 feet of water. This agrees closely with data from May of the following year.

The relatively shallow distribution (10 to 20 feet) of alewives from June to November appears to indicate a definite trend. With the coming of winter, the alewives moved into the lake depths.

Smelt

Throughout this study there were two smelt age classes represented in significant numbers. The more abundant class was hatched in 1966. The other age class was probably from the 1965 hatch, but these fish were relatively uncommon. All smelt captured from 3 to 5 inches in total length were presumably from the 1966 brood year and were recorded as such. The 1965 brood year fish were between 6 and 8 inches in total length. Depth distribution, as determined from vertical and horizontal gill netting, is given in Figure 10.

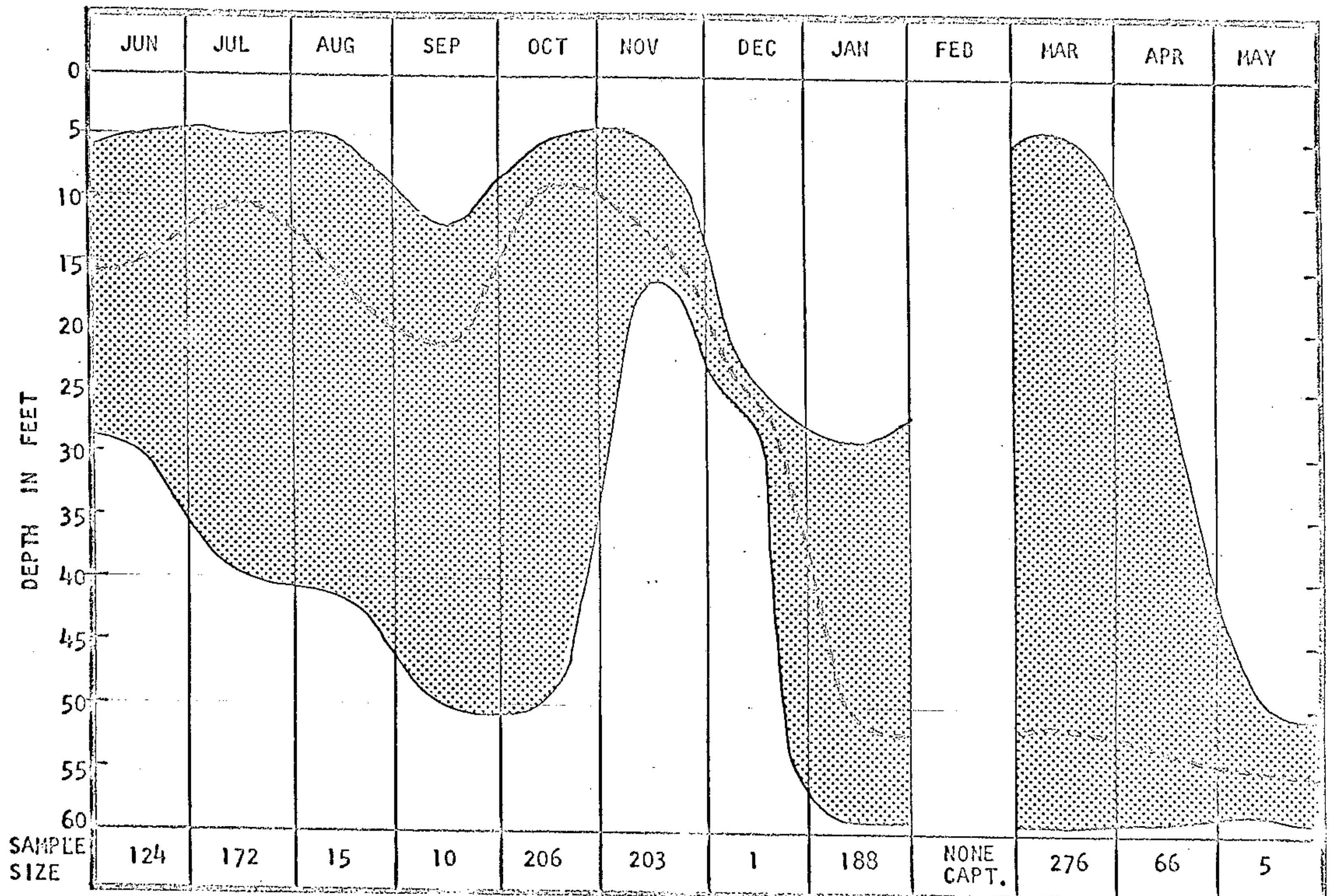


FIGURE 9.--Depth distribution of 1966 brood year landlocked alewives based on combined vertical and horizontal gill netting in Echo Lake, 1967-68. Shaded area represents depth range; dotted line represents depth of highest concentration of captured fish.

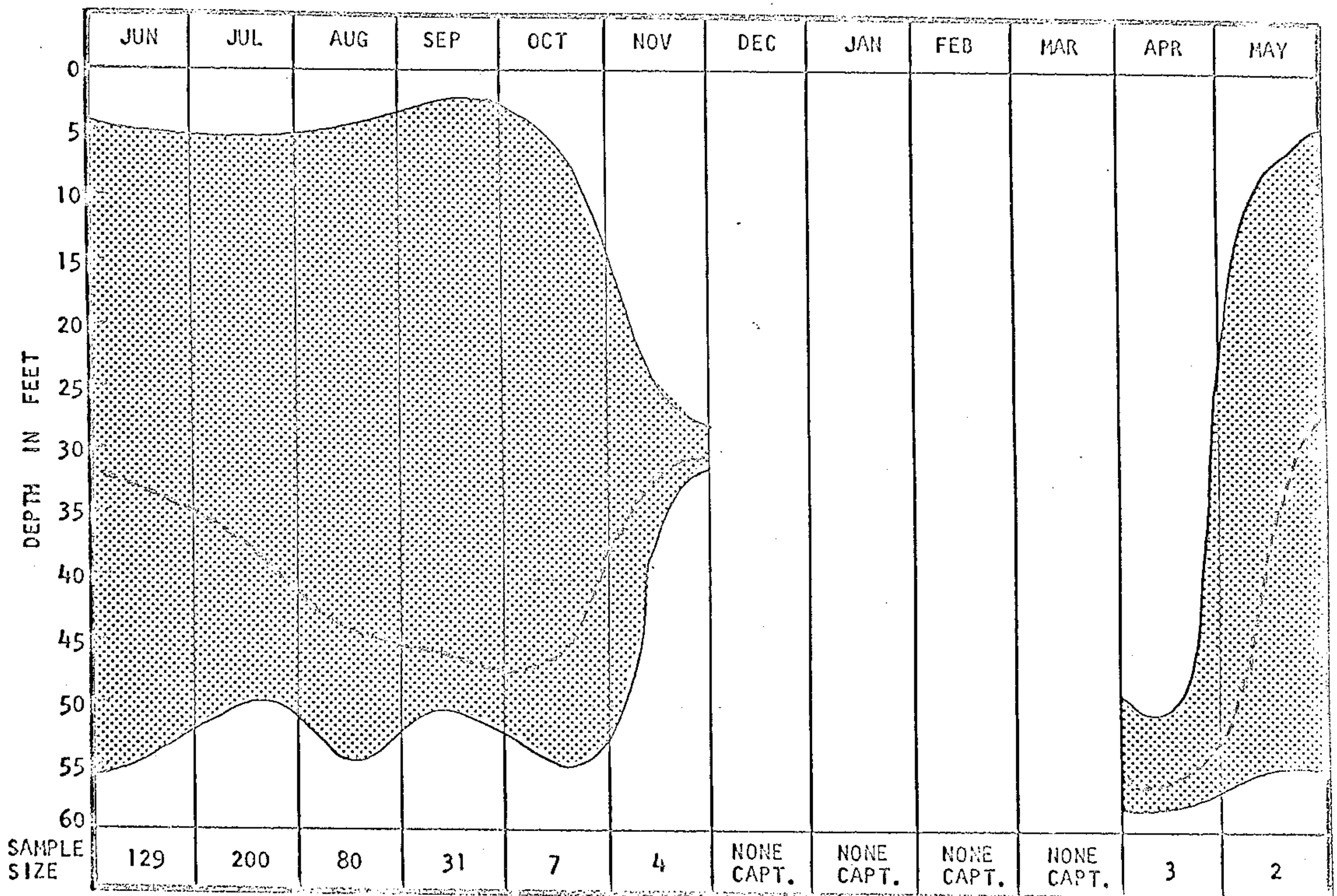


FIGURE 10.--Depth distribution of smelts (3-5 inches) based on combined vertical and horizontal gill netting in Echo Lake, 1967-68. Shaded area represents approximate depth range; dotted line represents depth of highest concentration of captured fish.

Other Species and Age Classes

Although some data were obtained on fish species other than those discussed, not enough information is available to make quantitative statements. The 1967 brood year alewives appear to follow roughly the same distribution as the 1966 brood year based on available captures. Several dozen captures were made in September, November, March, April, and May. It is not known, however, where these fish were located immediately after hatching.

Banded killifish are primarily an inshore species, but have been taken at depths of 29 feet. Golden shiners are rare in Echo Lake, but very common in Little Echo Lake. A few shiners have been taken while seining for inshore fish.

The depth distribution of eels can be estimated by inference. Eel slime rings and partially eaten fish have been observed in nets at all depths during late spring, summer, and early fall. Little is known about these wide ranging predators.

Movements and Migration

The traps between Echo and Little Echo Lake revealed no appreciable movements of any fish when in operation during summer and early fall. Periodically a few killifish were captured, but little else. The outlet trap to Little Echo Lake was operated at the same time, and showed similar results with one exception; 49 eels were caught on 8 July 1967 apparently leaving for the sea.

Discussion

The seasonal depth distribution of few fish species have been accurately determined. Hasler and Villemonte (1953), Wisby (1955), and Tibbles (1956) have studied the distribution of yellow perch in Lake Mendota, Wisconsin. Horak and Tanner (1964) reported on the results of vertical gill netting in a Colorado reservoir to determine the summer distribution of rainbow trout, kokanee salmon, white sucker, and yellow perch. The distribution of white catfish (Ictalurus catus) and rainbow trout has been reported by von Geldern (1964) for a California lake. Chapman, Campbell, and Fortune (1967) determined the distribution of rainbow trout, kokanee salmon, and brook trout in a small Oregon lake.

Webster (1954) has reported on the distribution of alewives in Cayuga Lake. Alewives exhibit a pronounced inshore movement in late June and July which was associated with the shallow water spawning habits of this species. Galligan (1951) reported that Cayuga Lake alewives move to the deeper water during late summer and fall. He further hypothesized that alewives take up a pelagic distribution in winter. Gross (1953) reported similar results for Lake Hopatcong, New Jersey.

The distribution of alewives in Echo Lake follows the general pattern reported by Webster, Galligan, and Gross, but differs in several respects. In summer and fall alewives in Echo Lake occupy the upper depths of the lake, mainly away from shore. With the onset of winter, there is a marked movement to the deeper waters where the species remains until the following summer.

Spawning alewives were not as readily observed as reported by others (Gross, 1953; Robert Foye, personal communication), but appeared to spawn over several months, with heaviest spawning in late June and in July. Spawning activity, based on captures from gill netting appeared to be concentrated in shallow areas over fairly rocky substrate. This is similar to spawning sites in Cayuga Lake and Lake Hopatcong. The appearance of at least several ripe 1966 brood year alewives in July, 1967, was noted. Thus, indications are that alewives hatched in Echo Lake will spawn as 2 year old fish (1968).

Smelt follow a depth distribution similar to that described by Rupp (1968). Although primarily deep water residents, smelt do make forays into the upper waters, perhaps in search of food.

Brook trout in Echo Lake are generally near the lake bottom when caught, a condition also reported by Flick and Webster (1962) and Chapman, Campbell, and Fortune (1967). Although found in deep water on occasion, this species is characteristically an inshore resident.

None of the four species studied showed a clear preference for any particular water temperature, although temperature preference was difficult to evaluate because of the extreme annual range. The only consistent trend was the progressively lower average depth of capture as summer progressed, then a rise in the depth of captures in early fall. This distribution is similar to that reported by Horak and Tanner (1964) for rainbow trout, kokanee salmon, and white sucker in Horsetooth Reservoir, Colorado.

FOOD STUDIES

The success of landlocked alewives in providing forage for landlocked salmon and brook trout compared with other potential forage fishes can be ascertained only by estimating utilization of these forage species by the game fish. Similarly, competition between forage species must be evaluated in light of their respective feeding habits, as well as comparative distributions.

Methods

Many of the fish collected in determining depth distribution were preserved in 10% formalin for later stomach analysis. At the beginning of the study, stomach contents were determined both numerically and volumetrically. It soon became apparent that these methods, especially the volumetric method, were not entirely satisfactory for describing contents of some stomachs.

Determination of alewife and smelt stomach contents numerically and volumetrically was time consuming and results were of questionable accuracy. Analysis of contents through careful estimation of volume of each item expressed as a percent of total stomach volume proved of comparable accuracy to actual measurement by water displacement. The amount of material found in even full alewife and smelt stomachs was always very small and a marked degree of homogeneity of diet during much of the year minimized errors associated with subjective evaluations.

Salmon and trout stomach contents were analyzed by water displacement or by making careful estimates. Generally, if food consisted of more than one item, types were separated in lots and the percentage of total volume of these various lots estimated.

Results

Salmon

Data from the stomach contents of each salmon studied were arranged in monthly periods and each food type expressed as a mean percentage occurring in fish with that item in their stomach. The mean percentage by volume of each item was then determined by considering each stomach containing food to be of equal importance regardless of the actual amount of food in each stomach. The results are summarized in Figure 11. Original data are presented in Table 5 of the Appendix.

During this study, salmon in Echo Lake were mainly from one age (1965 brood year). Another stocking of 1966 brood year salmon was made in the fall of 1967. However, all sampled fish were from the 1965 brood year. The lengths of salmon studied varied from 9 to 19 inches, but the majority were between 12 and 16 inches, total length.

Feeding habits of Echo Lake salmon showed definite seasonal variations. Fish constituted over 50% of the diet (by volume) during each month for which there are data. Alewife utilization was limited to winter and early spring. Smelt utilization was relatively constant at least during spring, summer, and

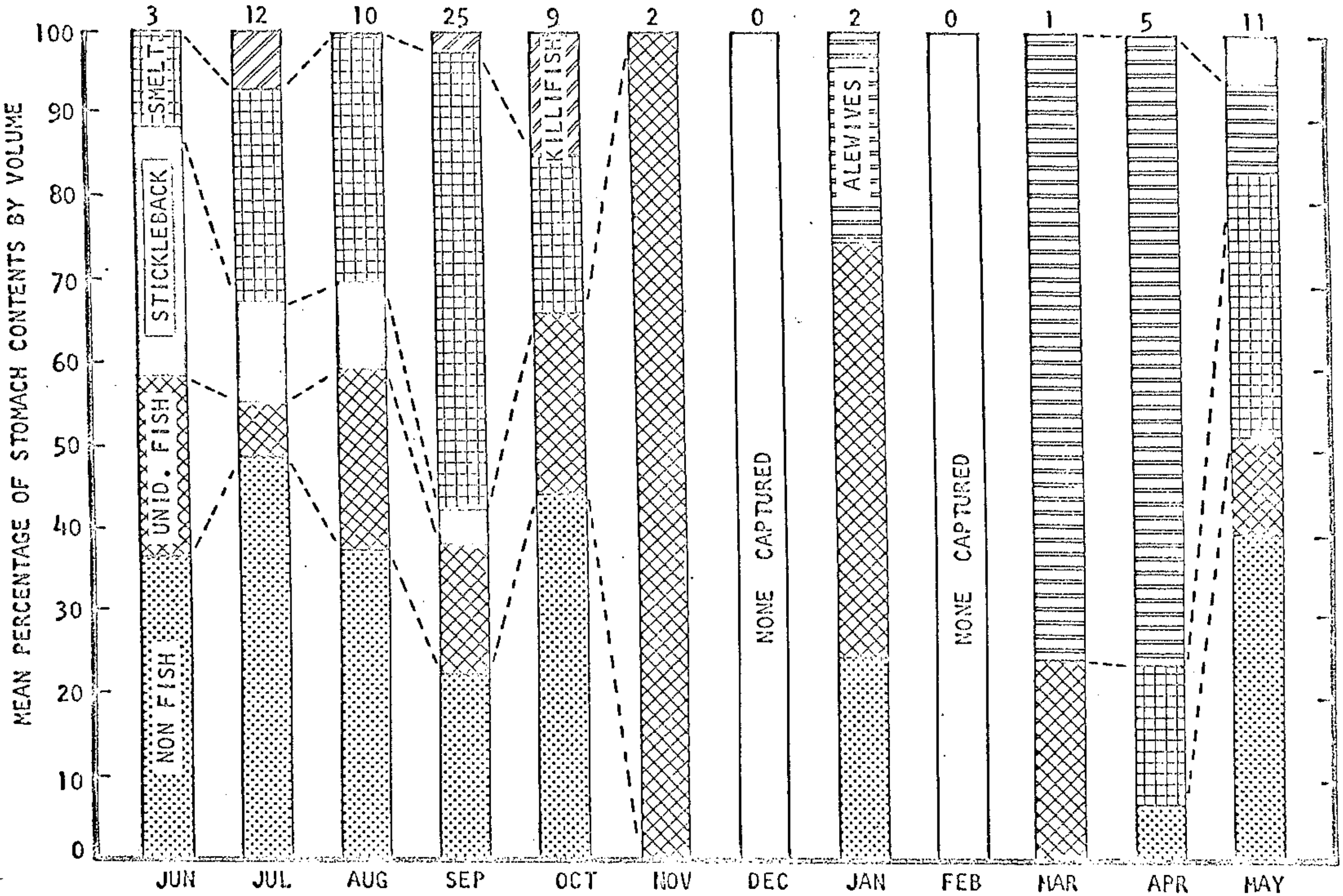


FIGURE 11.—Stomach contents of landlocked salmon collected in Echo Lake from June, 1967 to May, 1968. Number of stomachs containing food is above each bar.

fall. Unidentified fish were probably smelt since other forage fish were much easier to identify after partial digestion. Banded killifish provided some salmon forage during summer, but little or none during late fall, winter, and spring. Sticklebacks occurred quite frequently in salmon stomachs during summer, but not during the remainder of the year.

The nonfish portion of the salmon diet consisted mainly of insects and isopods (Asellus sp.). Insects were found in salmon stomachs more frequently during late spring, summer, and early fall, as would be expected. Isopod utilization was heaviest from winter to early spring.

Brook Trout

The feeding habits of brook trout collected in Echo Lake during this study are summarized in Figure 12. The original stomach analysis data are presented in Table 6 of the Appendix.

The diet of brook trout during this study averaged about 50% fish and 50% nonfish organisms. The only significant variation in these percentages occurred in fall and winter months. The high nonfish diet in the January sample reflects a high frequency of isopods in diet, and perhaps different feeding habits of the noticeably smaller trout in this sample (see Figure 15 for size difference).

Sticklebacks were used fairly consistently as forage during much of the year. Killifish, although heavily utilized in summer, were conspicuously absent during other months. Smelt provided significant, but intermittent forage. At least some alewives were utilized in late winter, although the sample is small.

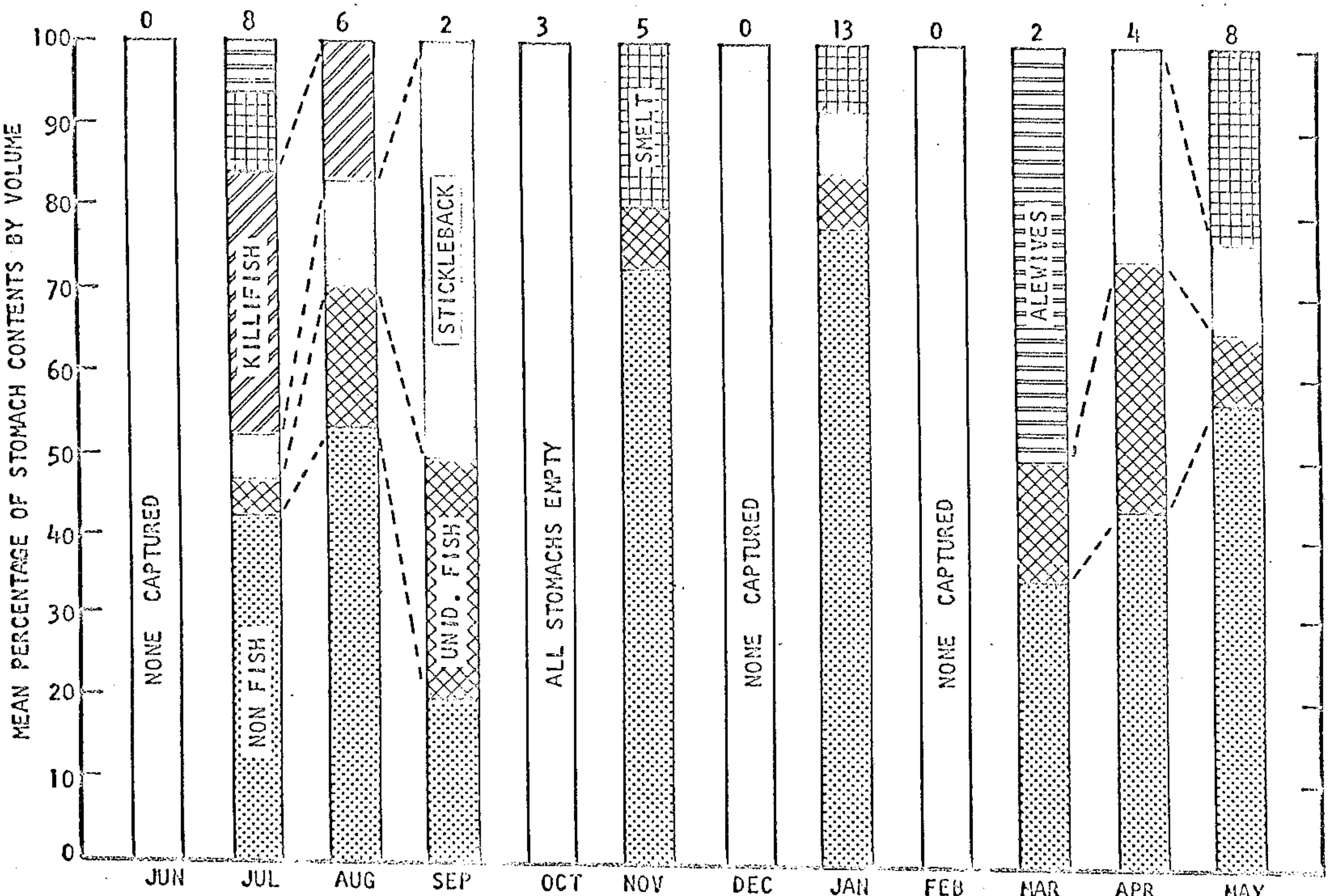


FIGURE 12.—Stomach contents of brook trout collected in Echo Lake from June, 1967 to May, 1968. Number of stomachs containing food is above each bar.

Alewives

The feeding habits of 1966 brood year alewives are summarized in Figure 13. The original data are given in Table 7 of the Appendix.

The alewife diet was exclusively planktonic animals (mainly copepods and Cladocera) during much of the year. Insects became increasingly important food during late spring and summer.

The available data on other alewife age classes indicated that older alewives utilized higher percentages of insects, but plankton is still the main food source. The 1967 brood year alewives fed almost exclusively on plankton.

Smelt

The stomach contents of 1966 brood year smelt are presented in Figure 14. Original data are presented in Table 8 of the Appendix. Obtaining adequate numbers of smelt stomachs proved difficult except during summer months. Of the small number collected during the remainder of the year, a high percentage had empty stomachs.

It is probably safe to assume that most of the material labeled "unidentified" in Figure 14 is actually plankton. Digestion proceeds rapidly on copepods, Cladocera, etc., and, consequently, positive identification of these items was often impossible.

It appears that this year class of smelt largely utilize plankton and insects during summer, with the bulk of the diet consisting of plankton. The food of smelt during the remainder of the year is difficult to evaluate with the small sample available but it is apparent that at least some plankton, insects, and isopods are eaten.

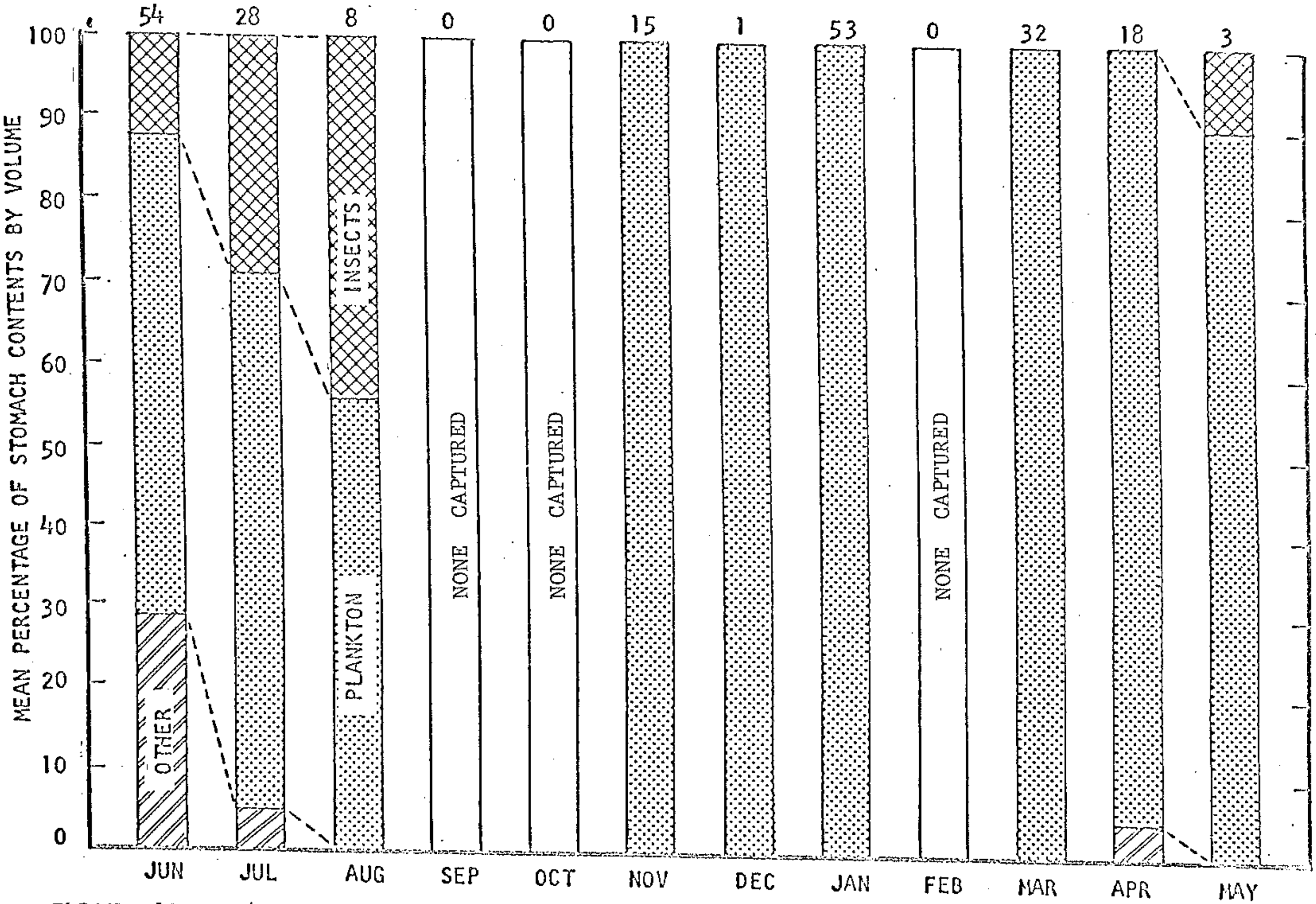


FIGURE 13.—Stomach contents of 1966 brood year alewives collected in Echo Lake from June, 1967 to May, 1968. Number of stomachs containing food is above each bar.

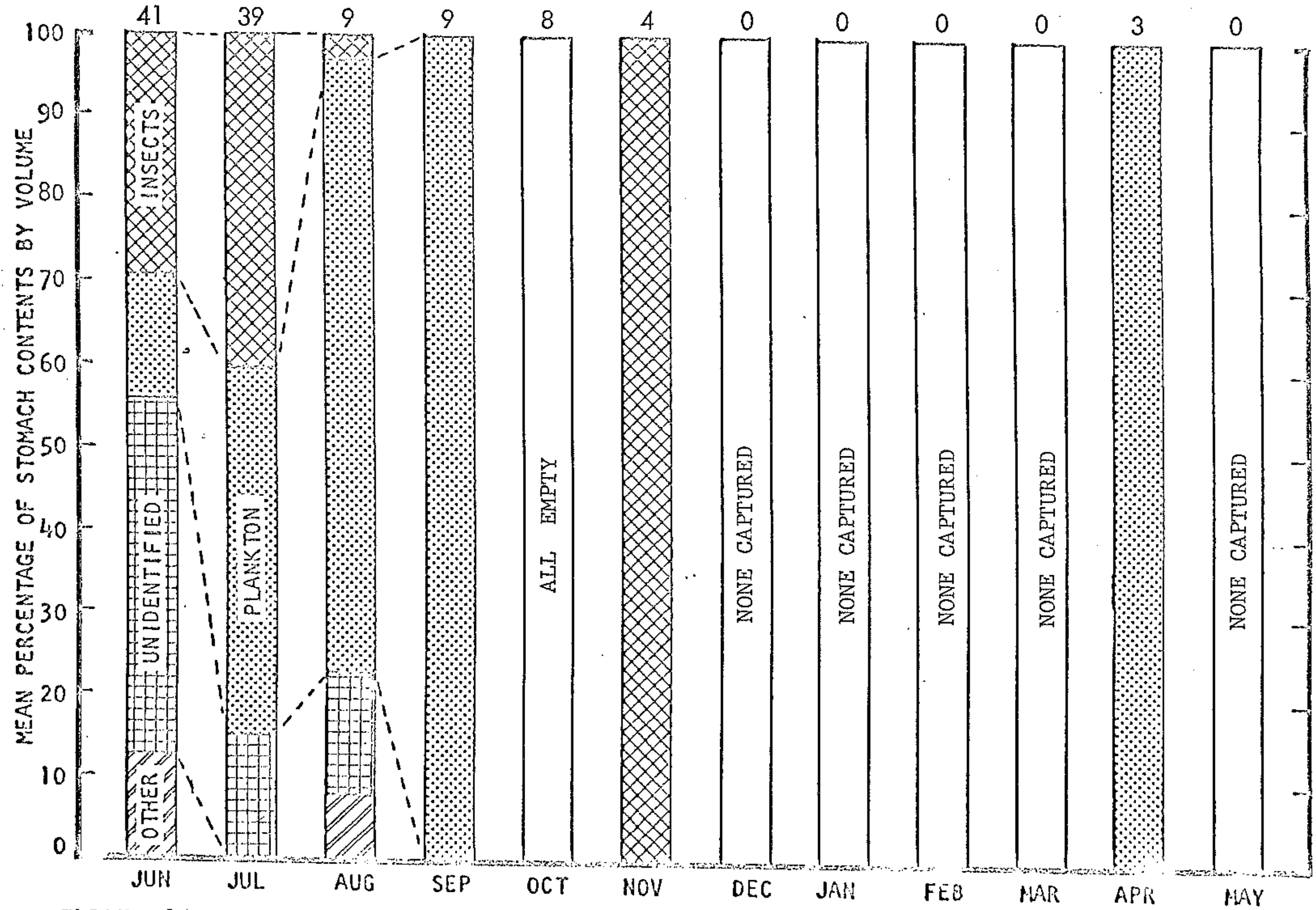


FIGURE 14.—Stomach contents of 1966 brood year smelt collected in Echo Lake from June, 1967 to May, 1968. Number of stomachs containing food is above each bar.

Discussion

It has long been known that salmon diet changes predominantly to fish, if available, after the salmon attain a certain size and depending on the size and species of forage fish available. Fuller and Cooper (1946) examined 42 landlocked salmon (12.2-23.3 inches) from lakes on Mount Desert Island and surrounding areas and found that of the 24 stomachs containing food, 97% of the diet was smelt by volume. Havey and Warner (1968 MS) state that young landlocked salmon gradually change from an insect to a fish diet after migrating to the lake from a nursery area (brook or stream). The principal forage fish are smelt, young alewives, stickleback, yellow perch, and various minnows. All available data support the widely held belief, at least in Maine lakes, that the primary forage fish of landlocked salmon, if available, is smelt.

The feeding habits of salmon in Echo Lake do differ somewhat from that observed in many Maine lakes (Havey and Warner, 1968 MS). The proportion of insects in the Echo Lake salmon diet is roughly a third of the total diet. No one fish species dominates the diet as might be expected with populations of schooling forage fish such as smelt and alewives inhabiting the lake. There are several factors which might account for the wide variety of foods eaten in Echo Lake.

The organisms eaten by salmon seem to indicate a distinct lack of a satisfactory forage fish abundant enough to supply the bulk of the dietary needs of Echo Lake salmon such as smelt provide in other lakes. After attaining legal size (14 inches), salmon feed heavily on smelt if available, but other fish are occasionally utilized (Cooper, 1940; Havey and Warner, 1968 MS). However, the smelt population in Echo Lake is thought to be low (see section on abundance), although a quantitative estimate is not possible. The 1966 brood year alewives were very abundant, but too large to be eaten by 1965 brood year salmon, most of which were between 12 and 16 inches during this study.

It is not entirely clear why salmon did not utilize 1967 brood year alewives more heavily, since this year class was apparently available in significant numbers. The utilization of killifish and sticklebacks (primarily inshore species) indicate salmon were moving into shallow water either in search of food or eating these species incidental to other movement. Netting data make it seem unlikely that these two forage species venture into deeper water.

Brook trout in Echo Lake had similar feeding habits as salmon, but did differ in several important aspects. The occurrence of killifish and sticklebacks in significant numbers is a strong indication trout were primarily inshore feeders. The occurrence of large numbers of sticklebacks and killifish in individual stomachs when they were found at all, supports this contention. Smelt usually were found in small numbers when they occurred. This fact indirectly supports the observation that the smelt population was relatively low and that, as a result, predation on this species was somewhat sporadic.

Compared to salmon, trout utilized isopods quite heavily. The most intense utilization of isopods was by trout captured near the mouth of Lurvey

Brook and in particular smaller trout captured in that area in winter and early spring. The heavy utilization of isopods by brown trout in winter and early spring was observed by Berglund (1968) in a small pond in Sweden. This seasonal variation is apparently related to the life cycle of the isopod and not to movement or changing feeding preference of the trout. Davis (1958) reported only one isopod in 89 brook trout stomachs taken from Echo Lake during the summer of 1957. Davis also collected 464 small brook trout from Lurvey Brook during reclamation in 1956 and found that isopods accounted for less than 1% of the stomach contents by volume.

Although utilization of insects was continuous throughout the year, the greatest numbers were eaten during spring and summer. This pattern of utilization contrasts sharply with the low use of isopods during summer, and may be associated with the greater availability of insects during certain times, in particular late spring and early summer.

The diet of Echo Lake alewives agrees quite closely with that determined by other workers at other lakes. Hutchinson (1968) reported that alewives in Black Pond, a small New York pond, fed primarily on zooplankton during summer, but also fed extensively on Diptera larva when available (mainly in September). Unfortunately, no data are available on fall, winter, and spring feeding habits of alewives in Black Pond. Odell (1934) found microcrustacea to constitute about 46% of the alewife diet by volume in Seneca Lake, New York. Odell also found insects and alewife eggs making up a significant part of the diet in June and July. Morsell (personal communication) reported the diet of Lake Michigan alewives to be mainly copepods and amphipods.

The diet of alewives in Echo Lake is generally similar to the above results, but differs in several respects. The utilization of Diptera larva in Echo Lake is similar to that reported by Hutchinson in Black Pond, but quite different from that reported by Morsell for Lake Michigan. This might be expected because of the greater availability of Diptera larva in a small lake. Morsell found copepods and amphipods (Pontoporeia affinis) the main food items, while midge larvae, ostracods, and hydracarina formed minor parts of the diet.

The feeding habits of smelt have been the subject of much controversy among sportsmen as well as fishery biologists. The presence of a well developed set of teeth support the commonly held belief that smelt are heavy predators on other fish, and perhaps on juvenile game fish. Many studies have shown this belief to be erroneous. Kendall (1927) showed smelt diet, at least in New England, to be highly variable, but primarily consisting of zooplankton. Creaser (1926), Greene (1930), Schneberger (1937), and Van Oosten (1940) all showed zooplankton to be the main smelt food item. Gordon (1961) showed zooplankton and insects made up about 92% of the diet of smelt in Saginaw Bay, Michigan. Rupp (1968) reported on 800 smelt stomachs collected at Branch Lake, Maine, and found the diet mainly zooplankton and insects. The stomach contents of Echo Lake smelt are virtually the same as that reported by Rupp.

Larger smelt may have a significantly different diet than those reported for the smaller smelt, however this is unlikely. The available data on large smelts collected from Echo Lake indicate a higher percentage of insects in the diet, but few fish. All of the larger smelts collected in Echo Lake were in the deepest part of the lake, and thus would not likely be in the best location for preying in juvenile game fish or the inshore species used extensively by salmon and trout.

AGE AND GROWTH

There are many factors which may affect the growth of fish in a given body of water. Certain types of growth data may be useful in making inferences about a given fishery or various populations comprising a fishery. By comparing growth rates of Echo Lake game fish before and after introduction of alewives, and by comparing growth rates of the same species in other lakes, it is possible to obtain a rough idea of the condition of the salmon and trout populations. This is one measure of the state of the fishery. Similar comparisons among forage species may also be of value in determining the general condition of these populations relative to populations in other lakes.

Methods

Since all salmon and many trout taken during this study were from hatchery stock, obtaining age and growth information was greatly simplified. Throughout this study, scales and lengths were taken from salmon, trout, alewives, and smelt. All lengths were measured in inches from the tip of the snout to the tip of the caudal fin when squeezed together (generally called total length). Scales were mounted on microscope slides and read with the aid of an overhead scale projector. Smaller or more difficult to read scales were observed under a compound microscope.

Results

Salmon and Brook Trout

The growth rates by month of salmon and trout collected in Echo Lake during this study are presented in Figure 15. Salmon lengths used to compile growth data were all from the 1965 brood year stocked in Echo Lake as fall fingerlings in 1965. Trout between 8 and 10 inches in total length are thought to be survivors from those planted as fall fingerlings in Echo Lake in 1966. The small group of trout collected from January to May, although the same year class (1966), are thought to be trout from Lurvey Brook. These fish were captured close to the mouth of Lurvey Brook and were unusually uniform in size. Further inferences about these trout are given in the discussion. Growth data collected by Davis (1958) are also presented in Figure 15 for comparison.

Alewives and Smelt

The monthly growth of 1966 brood year alewives in Echo Lake during 1967 and 1968 is presented in Figure 16. Growth of alewives in other lakes is also presented for comparison.

Figure 17 shows alewife scales taken from a sample of Cayuga Lake fish, Cayuga Lake fish after they had spent approximately one year in Echo Lake, and alewives hatched in Echo Lake. The change in growth of introduced alewives can be seen in scales C and D.

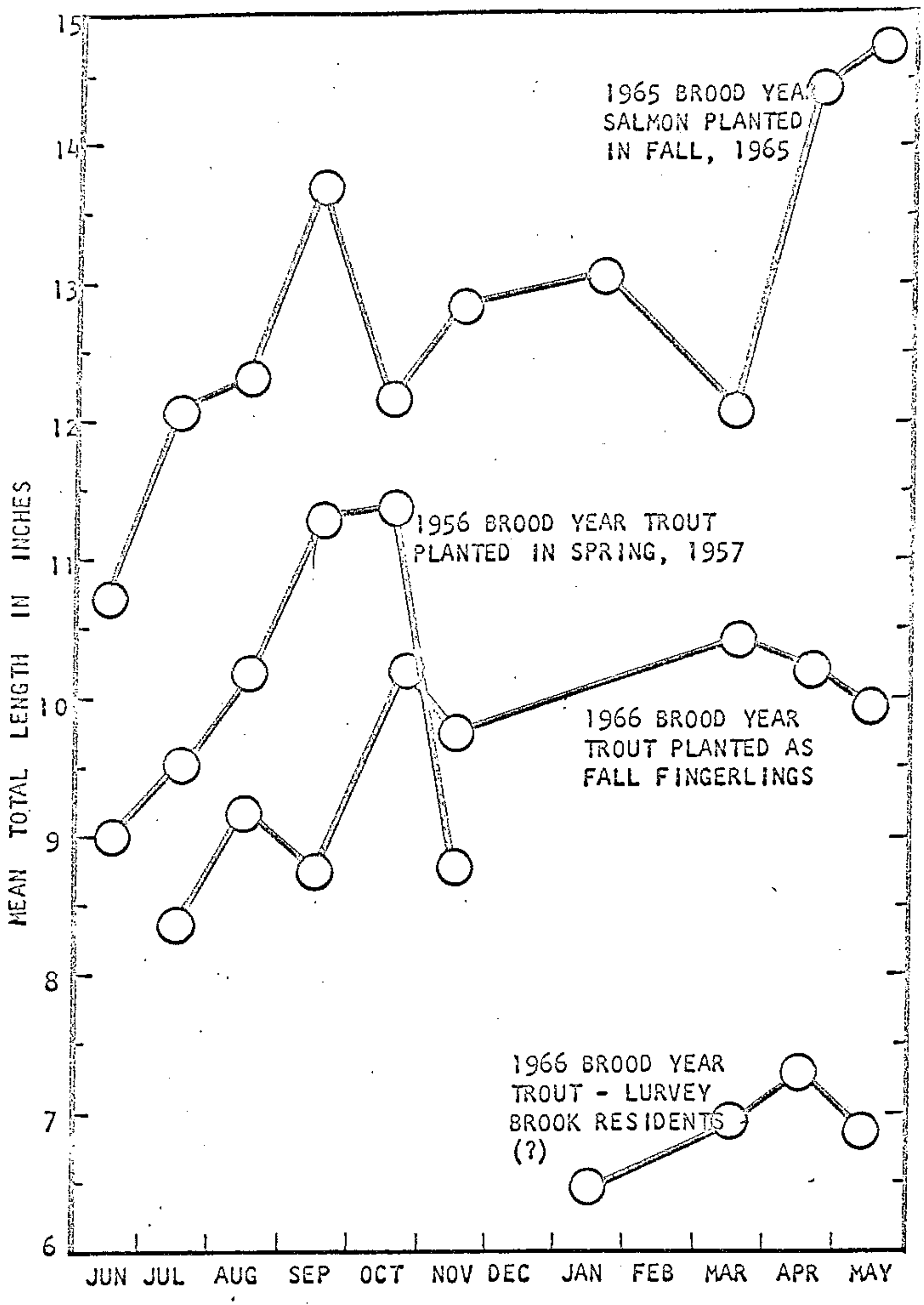


FIGURE 15.— Growth of landlocked salmon and brook trout collected in Echo Lake during this study and reported by Davis (1958).

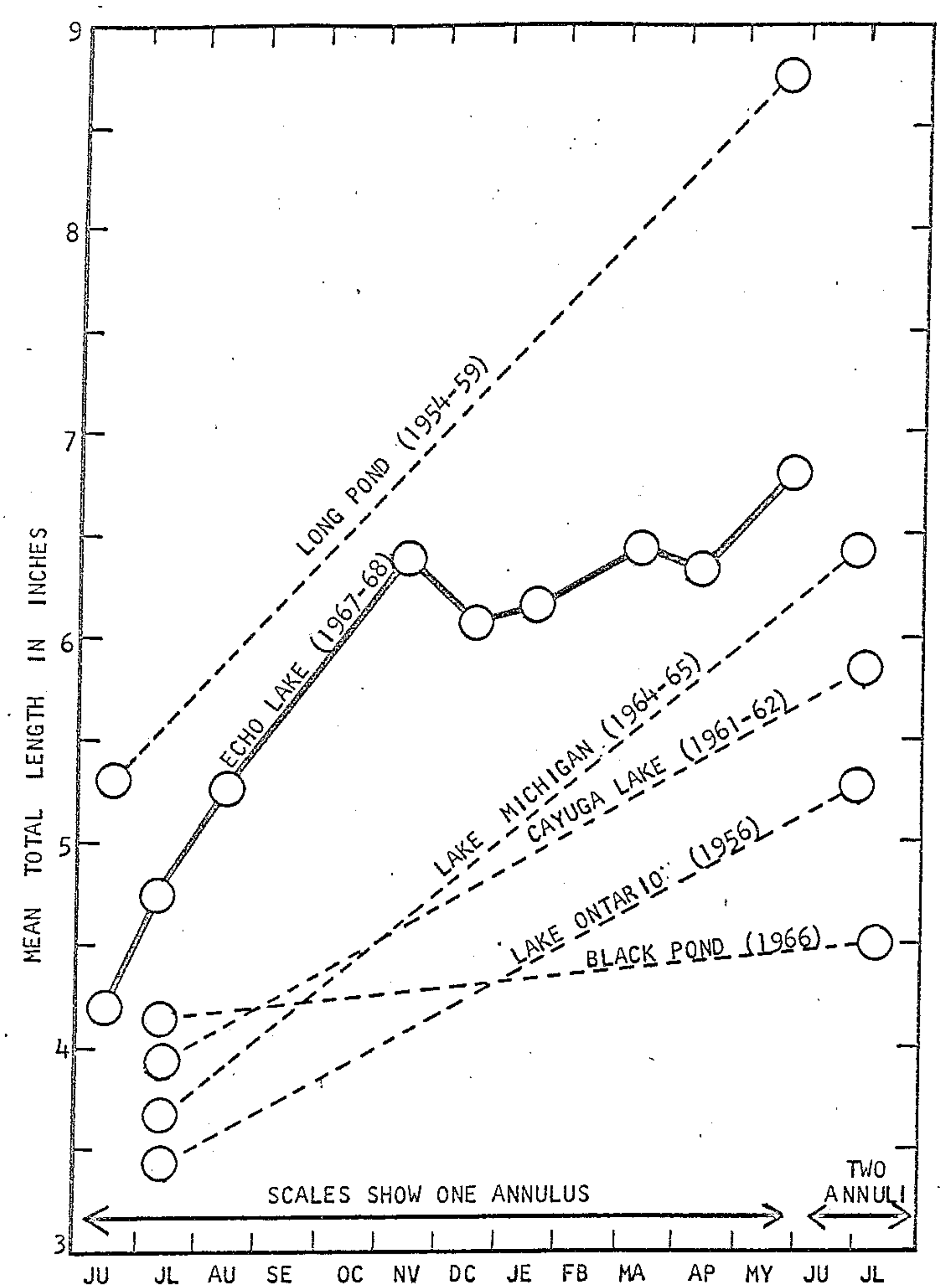


FIGURE 16.—Growth of landlocked alewives in Black Pond (Hutchinson, 1968), Cayuga Lake (Rothschild, 1965), Lake Michigan (Norden, 1967), Lake Ontario (Graham, 1956), and Echo Lake. Anadromous alewives from Long Pond, Maine, backcalculated growth (Havey, 1961).

FIGURE 17.—Alewife scales taken from Cayuga and Echo Lake reared fish:

A. Cayuga Lake Alewife
Length - 6.0 inches
Date Taken - June, 1966
1963 brood year

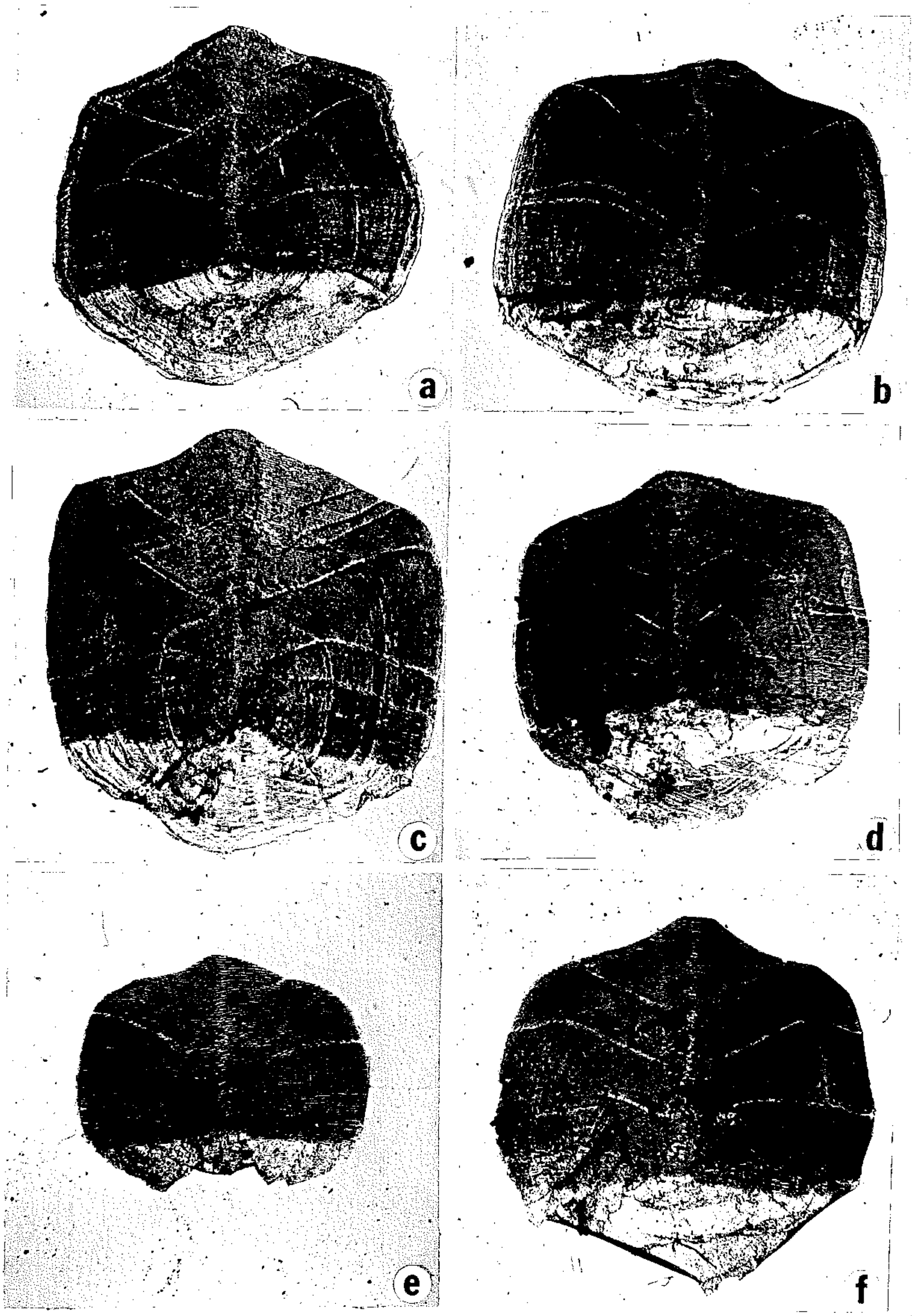
B. Cayuga Lake Alewife
Length - 6.3 inches
Date Taken - June, 1966
1961 brood year

C. Cayuga Lake Alewife Introduced into Echo Lake (1966)
Length - 6.5 inches
Date Taken - June, 1967
1961 brood year

D. Cayuga Lake Alewife Introduced into Echo Lake (1966)
Length - 8.0 inches
Date Taken - November, 1967
1962 brood year

E. Echo Lake Hatched Alewife
Length - 3.5 inches
Date Taken - November, 1967
1967 brood year

F. Echo Lake Hatched Alewife
Length - 5.2 inches
Date Taken - July, 1967
1966 brood year


a
b
c
d
e
f

The growth of 1966 brood year smelt in Echo Lake is difficult to evaluate because of the small number of samples taken in non-summer months. However, the following lengths were obtained during this study:

	June	July	Aug	Sept	Oct	Nov	April
Number Measured	36	39	8	9	2	4	3
Mean Length (inches)	3.5	3.5	3.5	3.6	3.6	4.2	4.2

Discussion

Salmon growth in Echo Lake is roughly comparable to average growth of landlocked salmon in Maine as reported by Everhart (1966):

	Age in Years					
	1	2	3	4	5	6
Total Length (inches)	5.9	11.9	15.2	18.1	20.3	22.2

Growth is highest in Echo Lake during summer and spring, but virtually constant during winter, as might be expected.

Most salmon sampled during June and July, 1967, and many during April and May, 1968, had deep, full bodies, a strong indication of good feeding conditions. Anglers took many of these large fish. It would seem likely that had fish not been selectively harvested, the mean lengths would have been higher during the entire study.

Brook trout showed a growth rate similar to salmon, but were significantly smaller in length (Figure 15). Everhart (1966) reported average lengths of brook trout in Maine lakes to be as follows:

	Age in Years				
	2	3	4	5	6
Total Length (inches)	10.2	13.1	15.9	18.7	20.4

The size of Echo Lake brook trout is roughly equal to the statewide average at Age 2. Not enough data are available on other trout age classes in Echo Lake to make additional comparisons.

Davis (1958) reported growth of trout in Echo Lake, immediately after reclamation, to be similar to other reclaimed lakes in Maine. Monthly mean lengths of trout stocked as legals (about 6 inches) are only slightly greater than observed for 1966 brood year trout planted as fall fingerlings. If these data are representative, it is apparent that the added expense of carrying trout through winter in a hatchery before planting in lakes similar to Echo is unwarranted.

The small group of trout collected near the mouth of Lurvey Brook may be from a plant of 250 trout (6-8 inches) made on May 16, 1967. If these captured trout were from this stocking and the reported lengths are assumed to be accurate, virtually no growth had taken place in 7 to 12 months. This seems an unreasonable conclusion considering summer and spring to be seasons of rapid fish growth.

These trout may be native, spawned and hatched in Lurvey Brook, that have entered the lake after spending part of their lives in the brook. However, this hypothesis does not adequately explain why these fish were not caught in other parts of the lake as might be expected of lake residents.

A third alternative, and perhaps the most acceptable, is that these trout are native and are residents of Lurvey Brook normally, but leave the brook during winter and spring, perhaps in search of food or to escape undesirable conditions in the brook. This question could be conclusively answered through marking by fin removal each planting of fish made in Echo Lake.

The growth of both introduced alewives and alewives hatched at Echo Lake during the first two years after introduction has been extremely rapid. Figure 16 illustrates this high growth rate for 1966 brood year alewives. Newly introduced fish species often grow very rapidly for a relatively short time, but eventually drop to a slower growth rate (Vincent, 1960). Whether this will eventually happen with alewives in Echo Lake can only be determined by additional study in succeeding years.

Smelt growth in Echo Lake appears to be about average for Maine lakes. The following data are given by Rupp (1968) for Maine lakes:

	Total Length (inches)		
Age	Maximum	Mean	Minimum
0	2.2	1.8	1.5
I	4.7	3.5	2.1
II	6.8	5.1	3.3
III	8.9	6.5	3.6

ABUNDANCE

Population estimates of the various fish species inhabiting Echo Lake are important in estimating the general status of the sport fishery and the availability of forage species. The classical methods of estimating fish populations by mark and recapture are the Petersen and Schnabel methods (Schaefer, 1951; Ricker, 1958). Both methods are founded on an assumed binomial distribution of the ratio of marked to unmarked fish. A slight modification of this approach was used during this study in that confidence intervals were based on a normally distributed population estimate rather than a binomially distributed ratio associated with the classical methods.

The following general procedure is usually followed in carrying out a population estimate. A number of fish (M) are caught and marked (usually a fin is removed). These marked fish are released and sufficient time is allowed for these fish to disperse. The time interval may vary from a matter of several days to many months. Another sample (C) is taken after this interval has elapsed. The number of marked fish recaptured (R) in this sample is recorded. The problem is to estimate the population size (N) and the appropriate confidence interval.

Bailey (1951, 1952) has shown that a good estimate of N can be obtained from:

$$\hat{N} = \frac{M\,(C + 1)}{(R + 1)}$$

An exact value of the variance $\sigma^2_{\hat{N}}$ is not available, but a nearly unbiased estimate can be found by:

$$\sigma^2_{\hat{N}} = \frac{M^2 (C + 1) \ (C + R)}{(M + 1)^2 \ (M + 2)}$$

A confidence interval can be constructed using σ_N and the "t" distribution with C - 1 degrees of freedom. The advantage of using this method rather than the classical Petersen confidence interval (based on a binomial distribution of $\frac{R}{C}$) is that the variances are additive and thus pooled standard error can be obtained among several population estimates.

The formulae used to estimate population size are based on a number of conditions:

a) marked and unmarked fish must be subjected to the same degree of natural mortality,

b) marked and unmarked fish are equally vulnerable to the fishing effort taking place,

c) marked fish do not lose their marks,

d) marked fish must become randomly mixed with the unmarked fish,

e) all marks must be recognized and reported,

f) the population being estimated must be nearly constant, with little recruitment.

Methods

Salmon and Brook Trout

An Oneida Lake trap net was maintained in Echo Lake in the spring of 1967 at locations marked on Figure 1. The net was checked periodically to keep mortality low. During this period a number of salmon and trout were marked by fin removal and released. The netting procedure was repeated for several weeks in the fall of 1967. The number of recaptured fish was carefully noted. All fish were released at a location some distance from the trap net site to assure dispersal.

Alewives and Smelt

An attempt at estimating populations of alewives and smelts was made by removing the top lobe of the caudal fin of fish captured in gill nets. The mortality associated with this procedure, as well as declining catches of these species, forced abandonment of this work.

Results

Salmon

The results of 1967 trap net data as well as gill net captures were as follows:

Spring 1967 Marked Fish Released	Fall 1967 Total Captured	Fall 1967 Marked Recaptured
94	82 (trap net) 79 (summer gill netting)	12 (trap net) 6 (summer gill netting)

Considering the trap net data alone, the estimated salmon population is 600 with a confidence interval (α = .05) of 307 - 893. Combining both groups of data yield a population estimate of 802 with a confidence interval of (α = .05) of 570 - 934. Both estimates apply to the population in spring, 1967.

Brook Trout

A population estimate was attempted on brook trout during 1967, but the number of captured trout was too small to make a statistical analysis.

Alewives and Smelt

About 100 1966 brood year alewives and about 50 smelt were marked by fin removal during the late spring and summer of 1967. However, only one marked alewife was recaptured during the entire study. There were no recaptured marked smelt. By observing the actions of recently marked and released fish, it became apparent that considerable mortality was associated with capturing these fish in gill nets as well as handling during fin removal. These factors were responsible for the failure to obtain meaningful population estimates.

Discussion

The problems associated with obtaining an estimate of the brook trout population are likely due to the small population in Echo Lake. It would seem reasonable to expect a higher proportion of the brook trout population to be caught in a trap net rather than salmon, since trout have been shown to be primarily inshore species. Because few trout were captured, it is likely that the trout population is fairly low.

The alewife and smelt population estimates would not be reliable even if enough recaptured fish were available to compute an estimate. The mortality associated with marking these species is very great.

GENERAL CONCLUSIONS

Landlocked alewives have been utilized little as forage fish during this relatively brief study, but several factors may account for minimum utilization. The potential forage value of alewives is likely greatest to larger salmon and trout, of which Echo Lake supports few. The very rapid growth rate of this newly introduced species also minimizes potential utilization.

It has been shown in this study that landlocked alewives are available as forage to salmon during most of the year, if not all the time. The availability to trout is somewhat less, but there is still much overlap in the annual depth distribution of the two species. The pelagic habits of the alewife minimizes competition with the various inshore forage fishes (mainly sticklebacks and killifish). However, the feeding habits of alewives indicate a high degree of food competition with smelt. This may prove to be of management value if this competition tends to maintain both species at stunted sizes.

The successful spawning of alewives apparently resulted in a relatively large population in Echo Lake. This "population explosion" was expected. It is anticipated that population size will stabilize, perhaps shortly, but this hypothesis is by no means certain. Both alewife and smelt populations are characterized by large and sudden die-offs in other lakes.

Present rapid growth of alewives makes it appear that forage utilization will be limited to young of the year fish. However, growth can probably be expected to show a marked decline with time and eventually stabilize at a slower rate, possibly permitting utilization of older fish.

In summary, it appears that the forage value of alewives for landlocked salmon does not yet meet the hoped for success, but a final decision concerning their value in salmon management must be delayed until further studies are completed. These studies must be of sufficient duration to permit work with older, larger salmon, a larger trout population, and a stabilized alewife population.

MANAGEMENT RECOMMENDATIONS

I. Echo Lake

A. Live Bait:

Continue to prohibit the use of live bait to safeguard maintaining only those forage species now established in the lake.

B. Stocking:

Continue odd year stocking of fall fingerling salmon and even year stocking of fall fingerling brook trout.

C. Research:

Continue to evaluate landlocked alewives as forage fish as the salmon and trout in Echo Lake grow to larger size.

II. Additional Research

A. Landlocked Alewives:

Conduct a similar study with lake trout as the game fish and landlocked alewives as the forage fish.

B. Anadromous Alewives:

Investigate the potential of anadromous alewives stocked in lakes in supplying temporary forage.

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A P P E N D I X

(Tables 5 - 8)

TABLE 5.--Stomach contents of landlocked salmon collected in Echo Lake by vertical and horizontal gill netting, 1967-68.

	Sample Period - 1967											
	June 1-15			June 16-30			July 1-15			July 16-31		
No. Stomachs Examined	3			None			9			3		
Mean Total Length (inches)	10.8			Captured			12.7			10.4		
Range of Total Lengths	10.3-11.7						9.0-17.0			9.8-11.1		
Food Item:	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
Alewives	0	0	0	-	-	-	0	0	0	0	0	0
Smelt	1	33	30	-	-	-	2	22	95	1	33	100
Killifish	0	0	0	-	-	-	1	11	80	0	0	0
Stickleback	1	33	90	-	-	-	1	11	100	0	0	0
Unid. Fish	1	33	70	-	-	-	2	22	35	0	0	0
Insects	2	67	55	-	-	-	4	44	55	2	67	52
Crustacea	0	0	0	-	-	-	0	0	0	0	0	0
Unid. Non Fish	0	0	0	-	-	-	2	22	58	1	33	95
Empty Stomachs		0			-			0			0	

TABLE 5.--Stomach contents of landlocked salmon collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967														
Aug 1-15			Aug 16-31			Sept 1-15			Sept 16-30			Oct 1-15		
4			7			6			23			8		
12.3			12.5			13.7			14.0(5)			Not		
11.0-13.1			12.0-13.1			12.0-15.3			13.0-15.8(5)			Taken		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	25	100	2	29	100	3	50	77	13	59	90	2	25	100
0	0	0	0	0	0	0	0	0	1	5	40	0	0	0
0	0	0	1	14	100	1	17	95	0	0	0	0	0	0
2	50	100	1	14	20	3	50	57	4	18	55	2	25	100
0	0	0	2	29	99	2	33	52	8	36	47	3	38	100
0	0	0	1	14	2	0	0	0	0	0	0	0	0	0
0	0	0	2	29	90	0	0	0	1	4	100	0	0	0
1			0			0			2			0		

TABLE 5.--Stomach contents of landlocked salmon collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967														
Oct 16-31			Nov 1-15			Nov 16-30			Dec 1-15			Dec 16-30		
2			No			6			No			None		
12.3			Sample			12.9			Sample			Captured		
11.4-13.2			Taken			11.3-14.0			Taken					
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
1	50	100	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	2	33	100	-	-	-	-	-	-
1	50	100	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0			-			4			-			-		

TABLE 5.--Stomach contents of landlocked salmon collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1968														
Jan 1-15			Jan 16-31			Feb 1-15			Feb 16-29			Mar 1-15		
No			2			No			None			1		
Sample			13.1			Sample			Captured			12.1		
Taken			12.4-13.9			Taken						-		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
-	-	-	1	50	50	-	-	-	-	-	-	1	100	75
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	1	50	100	-	-	-	-	-	-	1	100	25
-	-	-	1	50	50	-	-	-	-	-	-	0	0	0
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
	-			0			-			-			0	

TABLE 5.--Stomach contents of landlocked salmon collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1968														
March 16-31			Apr 1-15			Apr 16-30			May 1-15			May 16-31		
None			4			1			7			7		
Captured			14.8			13.2			14.2(6)			15.5		
			13.5-16.7			-			13.1-15.6			12.4-16.6		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
-	-	-	4	100	91	0	0	0	0	0	0	1	14	100
-	-	-	0	0	0	1	100	85	2	40	100	2	29	100
-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
-	-	-	0	0	0	0	0	0	1	20	50	1	14	5
-	-	-	0	0	0	0	0	0	1	20	100	0	0	0
-	-	-	1	25	15	0	0	0	1	20	100	1	14	100
-	-	-	1	25	20	0	0	0	1	20	50	2	29	98
-	-	-	0	0	0	1	100	15	0	0	0	0	0	0
	-			0			0			2			1	

TABLE 6.--Stomach contents of brook trout collected in Echo Lake by vertical and horizontal gill netting, 1967-68.

	Sample Period - 1967											
	June 1-15			June 16-30			July 1-15			July 16-31		
No. Stomachs Examined	None			None			5			4		
Mean Total Length (inches)	Captured			Captured			11.5			8.8		
Range of Total Lengths							7.2-18.5			7.8-10.4		
Food Item:	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
Alewives	-	-	-	-	-	-	1	20	50	0	0	0
Smelt	-	-	-	-	-	-	2	40	40	0	0	0
Killifish	-	-	-	-	-	-	2	40	80	1	25	99
Stickleback	-	-	-	-	-	-	0	0	0	1	25	40
Unid. Fish	-	-	-	-	-	-	1	20	30	0	0	0
Insects	-	-	-	-	-	-	2	40	10	4	100	54
Crustacea	-	-	-	-	-	-	0	0	0	1	25	5
Unid. Non Fish	-	-	-	-	-	-	1	20	60	1	25	45
Empty Stomachs		-			-			1			0	

TABLE 6.--Stomach contents of brook trout collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967														
Aug 1-15			Aug 16-31			Sept 1-15			Sept 16-30			Oct 1-15		
1			5			None			2			2		
8.5			9.5			Captured			11.1			Not		
-			8.9-10.0						8.8-13.5			Taken		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
0	0	0	0	0	0	-	-	-	0	0	0	0	0	0
0	0	0	0	0	0	-	-	-	0	0	0	0	0	0
1	100	100	0	0	0	-	-	-	0	0	0	0	0	0
0	0	0	1	20	80	-	-	-	1	50	100	0	0	0
0	0	0	1	20	100	-	-	-	1	50	60	0	0	0
0	0	0	3	60	100	-	-	-	1	50	35	0	0	0
0	0	0	0	0	0	-	-	-	0	0	0	0	0	0
0	0	0	1	20	20	-	-	-	1	50	5	0	0	0
	0			0			-			0			2	

TABLE 6.--Stomach contents of brook trout collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967														
Oct 16-31			Nov 1-15			Nov 16-30			Dec 1-15			Dec 16-30		
1			No			5			No			None		
10.1			Sample			9.4			Sample			Captured		
-			Taken			8.2-10.9			Taken					
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	1	20	100	-	-	-	-	-	-
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	0	0	0	-	-	-	-	-	-
0	0	0	-	-	-	1	20	35	-	-	-	-	-	-
0	0	0	-	-	-	4	80	79	-	-	-	-	-	-
0	0	0	-	-	-	1	20	25	-	-	-	-	-	-
0	0	0	-	-	-	1	20	25	-	-	-	-	-	-
	1			-			0			-			-	

TABLE 6.--Stomach contents of brook trout collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1968														
Jan 1-15			Jan 16-31			Feb 1-15			Feb 16-29			Mar 1-15		
No			13			No			None			2		
Sample			7.1			Sample			Captured			8.8		
Taken			5.9-9.8			Taken						7.0-10.5		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
-	-	-	0	0	0	-	-	-	-	-	-	1	50	100
-	-	-	1	8	100	-	-	-	-	-	-	0	0	0
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	2	15	50	-	-	-	-	-	-	0	0	0
-	-	-	2	15	40	-	-	-	-	-	-	1	50	30
-	-	-	6	46	70	-	-	-	-	-	-	1	50	70
-	-	-	6	46	84	-	-	-	-	-	-	0	0	0
-	-	-	1	8	100	-	-	-	-	-	-	0	0	0
	-			0			-			-			0	

TABLE 6.--Stomach contents of brook trout collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1968														
Mar 16-31			Apr 1-15			Apr 16-30			May 1-15			May 16-31		
None			None			4			8			None		
Captured			Captured			9.8			9.3(5)			Captured		
						7.4-10.8			6.8-11.6					
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
-	-	-	-	-	-	0	0	0	0	0	0	-	-	-
-	-	-	-	-	-	0	0	0	2	25	95	-	-	-
-	-	-	-	-	-	0	0	0	0	0	0	-	-	-
-	-	-	-	-	-	1	25	98	1	12	90	-	-	-
-	-	-	-	-	-	2	25	62	2	25	35	-	-	-
-	-	-	-	-	-	2	50	38	5	62	54	-	-	-
-	-	-	-	-	-	1	25	100	2	25	90	-	-	-
-	-	-	-	-	-	0	0	0	0	0	0	-	-	-
	-			-			0			0			-	

TABLE 7.--Stomach contents of 1966 brood year landlocked alewives in Echo Lake by vertical and horizontal gill netting, 1967-68.

	Sample Period - 1967											
	June 1-15			June 16-30			July 1-15			July 16-31		
No. Stomachs Examined	45			11			16			15		
Mean Total Length (inches)	4.3			4.5			4.5			5.1		
Range of Total Lengths	3.8-4.6			4.2-4.8			4.2-5.0			4.6-5.5		
Food Item:	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
Insects	24	53	23	2	18	55	8	50	100	2	13	8
Plankton	28	60	84	8	73	100	5	31	100	15	100	96
Misc. Material	4	9	3	0	0	0	0	0	0	1	7	10
Unidentified	13	29	68	2	18	95	0	0	0	3	27	50
Empty Stomachs	2			0			3			0		

TABLE 7.--Stomach contents of 1966 brood year landlocked alewives collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Aug 1-15			Aug 16-31			Sept 1-15			Sept 16-30			Oct 1-15		
8			None			None			None			None		
5.3			Taken			Taken			Taken			Taken		
4.9-5.6														
No.	% Occ.	$\bar{\%}$ Vol.	No.	% Occ.	$\bar{\%}$ Vol.	No.	% Occ.	$\bar{\%}$ Vol.	No.	% Occ.	$\bar{\%}$ Vol.	No.	% Occ.	$\bar{\%}$ Vol.
4	40	60	-	-	-	-	-	-	-	-	-	-	-	-
8	80	70	-	-	-	-	-	-	-	-	-	-	-	-
0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
	0			-			-			-			-	

TABLE 7.--Stomach contents of 1966 brood year landlocked alewives collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967														
Oct 16-31			Nov 1-15			Nov 16-30			Dec 1-15			Dec 16-30		
None			10			5			None			1		
Taken			6.3			6.4			Captured			6.1		
			6.1-6.8			5.9-7.0						-		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
-	-	-	0	0	0	0	0	0	-	-	-	0	0	0
-	-	-	10	100	100	5	100	100	-	-	-	1	100	100
-	-	-	0	0	0	0	0	0	-	-	-	0	0	0
-	-	-	0	0	0	0	0	0	-	-	-	0	0	0
	-			0			0			-			0	

TABLE 7.--Stomach contents of 1966 brood year landlocked alewives collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1968														
Jan 1-15			Jan 16-31			Feb 1-15			Feb 16-29			Mar 1-15		
No			53			No			None			14		
Sample			6.2			Sample			Captured			6.4		
Taken			5.8-6.6			Taken						6.1-6.8		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	53	100	100	-	-	-	-	-	-	14	100	100
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
-	-	-	0	0	0	-	-	-	-	-	-	0	0	0
	-			0			-			-			0	

TABLE 7.--Stomach contents of 1966 brood year landlocked alewives collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (concluded)

Sample Period - 1968														
Mar 16-31			Apr 1-15			Apr 16-30			May 1-15			May 16-31		
18			16			2			None			3		
6.4			6.4			6.4			Taken			6.8		
6.0-6.8			6.1-6.8			6.4-6.5						6.5-7.0		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
0	0	0	0	0	0	0	0	0	-	-	-	3	100	10
18	100	100	16	100	94	2	100	100	-	-	-	3	100	90
0	0	0	0	0	0	0	0	0	-	-	-	0	0	0
0	0	0	1	6	90	0	0	0	-	-	-	0	0	0
	0			0			0			-			0	

TABLE 8.--Stomach contents of 1966 brood year smelt collected in Echo Lake by vertical and horizontal gill netting, 1967-68.

	Sample Period - 1967											
	June 1-15			June 16-30			July 1-15			July 16-30		
No. Stomachs Examined	16			25			26			13		
Mean Total Length (inches)	3.4			3.6			3.5			3.5		
Range of Total Lengths	3.2-3.8			3.3-4.0			3.3-4.1			3.2-3.7		
Food Item:	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
Insects - Isopods	6	38	51	7	28	83	4	15	100	8	62	72
Plankton	7	44	53	2	8	55	9	35	100	5	38	67
Misc. Material	2	12	38	5	20	63	0	0	0	0	0	0
Unidentified	12	75	71	6	24	82	1	4	100	3	23	97
Empty	1			10			12			1		

TABLE 8.--Stomach contents of 1966 brood year smelt collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967														
Aug 1-15			Aug 16-31			Sept 1-15			Sept 16-30			Oct 1-15		
8			1			1			8			1		
3.5			-			3.9			3.6			3.7		
3.3-3.8			-			-			3.5-3.7			-		
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
1	12	10	0	0	0	0	0	0	0	0	0	0	0	0
4	50	88	1	100	100	1	100	100	0	0	0	0	0	0
1	12	50	0	0	0	0	0	0	0	0	0	0	0	0
1	12	90	0	0	0	0	0	0	0	0	0	0	0	0
3			0			0			8			0		

TABLE 8.--Stomach contents of 1966 brood year smelt collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (continued)

Sample Period - 1967 and 1968									
Oct 16-31			Nov 1-15			Nov 16-30			Dec, Jan, Feb, Mar
1			None			4			None
3.6			Taken			4.2			Taken
-						3.7-4.6			
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	
0	0	0	-	-	-	3	75	100	
0	0	0	-	-	-	0	0	0	
0	0	0	-	-	-	0	0	0	
0	0	0	-	-	-	0	0	0	
	1			-			1		

TABLE 8.--Stomach contents of 1966 brood year smelt collected in Echo Lake by vertical and horizontal gill netting, 1967-68. (concluded)

Sample Period - 1968											
Apr 1-15			Apr 16-30			May 1-15			May 16-31		
1			2			None			None		
4.1			4.2			Taken			Taken		
-			4.0-4.5								
No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.	No.	% Occ.	$\overline{\%}$ Vol.
0	0	0	1	50	100	-	-	-	-	-	-
0	0	0	0	0	0	-	-	-	-	-	-
0	0	0	0	0	0	-	-	-	-	-	-
0	0	0	0	0	0	-	-	-	-	-	-
1			1			-			-		

BIOGRAPHY OF AUTHOR

Robert T. Lackey was born in Kamloops, British Columbia, Canada, on May 18, 1944. He attended elementary school in British Columbia, junior and senior high schools in southern California, and in 1962 graduated from John Burroughs High School in Burbank, California.

In 1962 he entered Los Angeles Valley College in Van Nuys, California, and received an Associate of Arts degree in Biology with honors two years later. He entered Humboldt State College in Arcata, California, in 1964, and received a Bachelor of Science degree with high honors in Fishery Biology in January, 1967. He married another Humboldt student, Lana Jeanne Apparius, on June 24, 1967.

During his undergraduate years he was employed as a Laboratory Assistant in the Department of Biological Sciences and as a Technical Assistant in the Department of Fisheries. His summer work has included employment with the California Department of Fish and Game (1964), the Commercial Fisheries Division of the Alaska Department of Fish and Game (1965), and the Bio-Research Division of the same Department (1966).

In January, 1967, he enrolled for graduate study as a Research Assistant with the Maine Department of Inland Fisheries and Game. He is a member of the American Fisheries Society and the American Association for the Advancement of Science. He is a candidate for the Master of Science degree in Zoology from the University of Maine in August, 1968.