Sampling Red Salmon Fry by Lake Trap in the Wood River Lakes, Alaska

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ABSTRACT

A sampling system utilizing floating lake traps to measure abundance of young red salmon *(Oncorhynchus nerka)* during lake residence was established in the Wood River lakes, Bristol Bay, Alaska, in 1953 and tested over a six-year period. Catches of red salmon fry were heaviest during the first month after breakup of the lake ice in spring, and fell off sharply after the middle of July. The pattern of catch was shown to be associated in some degree to timing of lake-ice breakup, thermal development, and growth and behavior of the red salmon fry. The magnitude and pattern of catch varied considerably from year to year.

Similarity in seasonal changes in catch pattern of red salmon fry and three-spine sticklebacks *(Gasterosteus aculeatus)* showed that environmental changes which influenced both species alike were creating variability in availability of the fish to the gear. Varying availability of the red fry presents a serious problem in indexing their abundance in littoral areas.

In 1957 and 1958, pelagic areas were fished by setting floating lake traps to determine their feasibility as a test of, or substitute for, littoral area sampling. The pelagic area trap used did not provide a reliable measure of fry abundance.

The correspondence in movement patterns of red salmon fry and three-spine sticklebacks suggests that they tend to inhabit feeding areas simultaneously, thus increasing the opportunity for interspecific competition.

INTRODUCTION

THREE AGE groups of young red salmon, comprising fish in their first, second, and third years, are present each year in the Wood River lakes. During the first year the young reds emerge from the gravel and move into the lake areas to feed. A few migrate to sea. Normally the fry remain to winter into their second year in the lakes, migrating seaward in their second summer. A portion remains behind for another year, migrating in the third summer.

Age at seaward migration and growth and mortality rates of Wood

River red salmon have been shown to be influenced by climate and by lake population density of young salmon and their competitors (Burgner, 1962). These conclusions were drawn on the basis of samples of seaward-migrating smolts and returning adults. In order to understand more fully the interplay of mortality factors, periodic measurements of fluctuations in abundance and growth of young salmon during lake residence were needed. These measurements would allow the investigator to follow the success or failure of each year class in relation to the prevailing conditions in the ecosystem. In addition, information as to behavior and distribution of the young salmon would help to determine the adequacy of measures of abundance thus far developed.

It is the purpose of this paper to discuss problems connected with sampling free-swimming young salmon during their first year of residence in the Wood River lakes, and to present results of a trial sampling system which utilized floating lake traps.

In the Wood River lakes, as in many other river systems of Bristol Bay, a major portion of red salmon spawning occurs on lake beaches and in large rivers between lakes, the remainder in the creeks tributary to the lakes. Although sampling of creeks for downstream migrant fry following their emergence from the gravel has been used, this method provides an index of abundance only to a select portion of the total population. For this reason, attention was turned to methods of sampling free-swimming young salmon in the lakes after their entry from creek, river, and lake-beach spawning beds.

Until recent years, efforts to sample the free-swimming fry of red, or sockeye, salmon in lakes had been generally unsuccessful, and their whereabouts was a matter of conjecture. Babcock (1904) reported that in 1903 fry could not be seen in Seton Lake after May; he commented that "heretofore no systematic study of the movements of young sockeye *(O. nerka)* has been recorded." Chamberlain (1907) observed red salmon fry feeding over the entire surface of Yes Lake, southeast Alaska, on quiet evenings in August and September. He concluded that they remained at depths during daytime and rose to the surface during evening to feed on plankton and insects. In late August and September of 1905 he obtained samples after dark by surface hauls with a 130-foot seine in Yes Lake, and in the Naha lakes later in the same season.

In most other lakes under study young red salmon were not as readily observed during their residence. At Lake Aleknagik in Bristol Bay, red fry were reported seen in inshore areas as late as July and early August in 1908 (Marsh and Cobb, 1909) and 1909 (Bower, 1924). At Crawford Lake, British Columbia, Foerster (1925) observed young sockeye throughout the summer in the evening feeding on insects at the surface of the water. However, of the fish at Cultus Lake, B. C., he stated: "They did not possess the habit of coming to the surface of the lake in quest of insects during the evening as did those in Crawford Lake . . . and none could be distinguished in the upper water during the night, attracted by the phenomenon of the diurnal movement of the plankton crustacea."

Ricker (1937) indicated that, after emergence from the gravel, young sockeye salmon fry at Cultus Lake disappeared into the lake and were probably to be found feeding at depths in the vicinity of the lake thermocline. He commented: "Extensive feeding in the upper epilimnion seems barred by the scarcity of food there . . . unless diurnal migrations of the crustacea are sufficient to add greatly to the number inhabiting the region in early morning or late evening."

Scientists sampling young salmon residing in Karluk Lake, Kodiak Island, met with varying degrees of success. Higgins (U. S. Bureau of Fisheries, 1929) remarked: "A good collection of young salmon was made in Karluk Lake with a special net. It never has been possible before to secure young salmon during their sojourn in the lake." However, in commenting on the general success of the sampling ventures, he stated: "It has been impossible to determine the mortality rate between the fry stage and the seaward migrant stage owing to the difficulties involved in collecting adequate samples of fingerlings" (Higgins, 1939).

During fresh-water studies conducted at Karluk Lake from 1950 through 1954, Fisheries Research Institute personnel were successful in sampling all year classes of young by means of gear used along lake beaches (C. E. Walker, personal communication). Inshore availability of the young was found to fluctuate considerably during months of the year when the lake was ice free. Walker considered that fry abundance might be measured by inshore gear, but that inshore availability of yearlings was too brief and irregular to make indexing of their abundance possible. Yearlings were believed to be in deep and/or offshore waters for all but approximately two weeks of the year. Efforts to capture the young in offshore areas were generally unsuccessful, although small collections were obtained by purse seine.

Higgins mentioned (1932-34) that Holmes was successful in collecting young red salmon in Chignik Lake, Alaska Peninsula, but results of this work have not been published. Methods and areas of collection were not given.

More recently Krogius and Krokhin (1948, 1956) reported success in determining the vertical distribution of young red salmon in Lake Dalnee, Kamchatka, by means of fine-mesh gill nets (mesh 10-12 mm). They presented graphs to show the vertical distribution of young red salmon in percentage of all fish caught for each month in 1938 and 1939. Numbers, sizes, or ages of young in the catches were not indicated, and effect of net selection was not discussed. They concluded that after emergence from the gravel the young live in the littoral part of the lake for one to two months, then move to the pelagic areas where they remain until seaward migration. During summer months the young were said to inhabit only the epilimnion but in the fall they moved deeper and by winter inhabited all depths. Hydrological factors and food distribution were felt to be responsible for the vertical distribution of young reds in the lakes.

Rees (1957) was successful in capturing sockeye young by means of gill nets at the forebay of Baker Dam, Washington. However, these fish were presumably on their seaward migration, and thus did not represent fish still resident in the lake.

Johnson (1956, 1958) was successful in sampling "underyearling" sockeye in British Columbia lakes in August and September by means of tow nets. A cone-shaped net 3 feet in diameter was found most satisfactory. It was towed by two outboard boats running parallel, with no lines or bridles directly preceding the mouth of the net during towing. The most successful means of sampling was the use of surface tows during evening hours. Tow nets of this type have been used to study abundance, distribution, and size of age 0 sockeye salmon in lakes of the Skeena River system and in Shuswap Lake in the Fraser system.

METHODS

Adequate methods of sampling lake stages of free-swimming young red salmon prior to seaward migration had not been developed at the time the Wood River investigation began. It was soon found that even though the young salmon might, in part, be in deeper layers of the lakes, they were also available in considerable numbers along the lake shores during summer months. During the summer of the first year of study, 1949, it was possible to make extensive collections of young salmon of both age 0 and age I throughout the lake system (see length-frequency compilations by the writer in Koo, 1962).

From 1949 through 1951 various methods of measuring abundance were tested: beach seining, tow netting, purse seining, cast netting, abundance counts by visual observation, and sampling with lake traps. Disadvantages of beach seining were that success was dependent on visibility unless hauls were made "blind," and the catch was dependent on distribution of fish at the moment the set was made. Tow netting was unsuccessful using a single boat and several types of nets, and the method was discarded. Purse-seine sampling was ruled out because success was dependent on weather and efficiency of set, boat and manpower requirements were heavy, and the fry would be missed until they were of sufficient size to move offshore. Cast-net sampling was discarded as too limited. The effectiveness of visual enumeration was dependent on the changes in light, turbidity, and water surface distortion from wind. Impressions of relative abundance in inshore areas could be obtained by the individual observer, but difficulties arose in assigning numerical values to abundance and in retaining impressions for comparisons with estimates of subsequent visits and subsequent years.

Sampling by lake trap appeared to have several basic advantages: (1) conditions of fishing could be duplicated with precision, (2) the trap could be fished over an extended period to give a measure of average abundance during the time intervals between tending, and (3) samples could be obtained independent of conditions for visual observation, eliminating personal error in estimates. Because of these advantages in sampling by lake traps, attention was directed toward determination of trap efficiency in capturing young reds of assorted sizes and ages found in the lakes.

There were certain operational disadvantages to the use of pile traps. They were difficult to install, could not be shifted readily inshore or offshore with changes in lake level, and were not versatile for use on different types of lake bottom. After limited experiments with pile-trap designs in 1950, the writer turned to floating-trap designs for trial in 1951. Following experiments with design and operation of a floating lake trap in 1951, a modified type was designed in 1952 for use in later experiments.

Saran plastic screen of eight meshes to the inch was used for trap and lead instead of the conventional cotton mesh, the only type of small web then available. Saran screen was found to have certain important advantages over cotton web in that it did not rot, required less skill in hanging, was more transparent in the water, and was more easily cleaned.

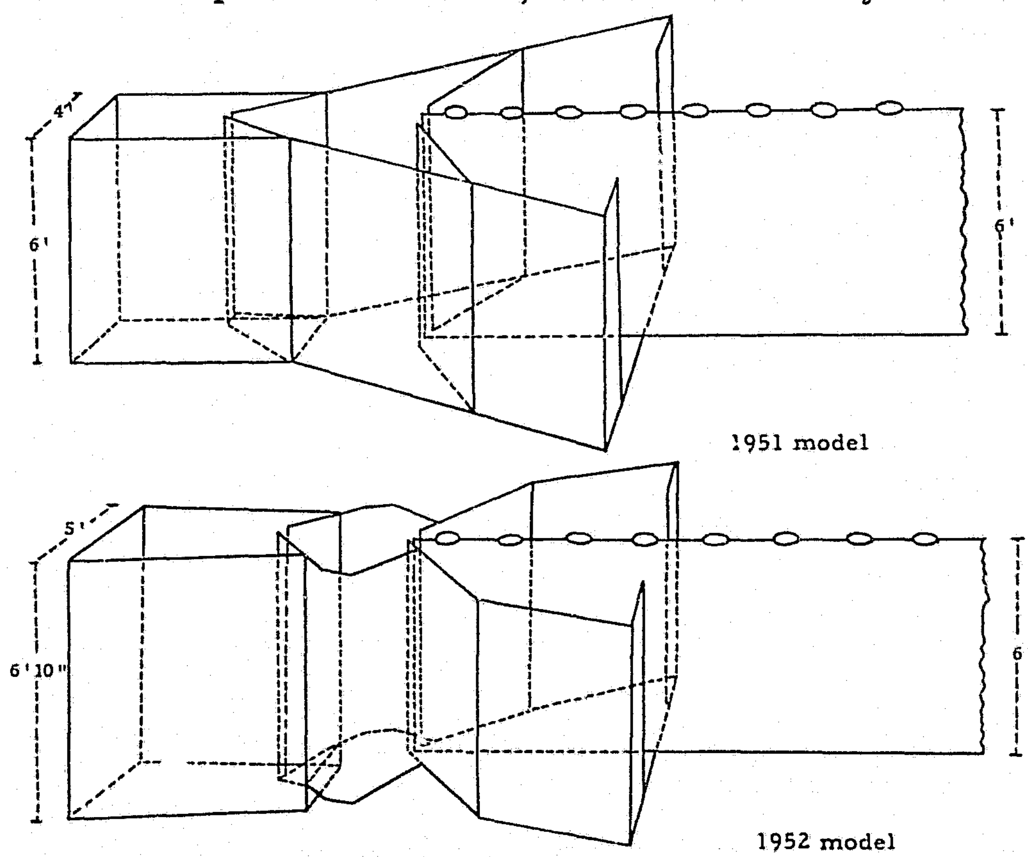

Fig. 1. Web outlines of the 1951- and 1952-model floating lake traps, showing the changes in design incorporated in the 1952 trap to increase the efficiency of capture and retention of red salmon fry.

The web outlines of the 1951 and 1952 traps shown in Figure 1 illustrate the primary changes in design suggested by study of fry behavior in and about the traps. The changes made were based on observations that red fry in the trap sought the widest and deepest parts of the heart and pot. The principle involved in the 1952 trap design was to lead fish from narrow to wide, shallow to deep, inside the trap as far as possible. The pot depth was increased from 6 feet to 6 feet 10 inches in the 1952 design. The lead and the remainder of the trap were 6 feet in depth.

Dimensions and design of the 1952 trap are given in Figures 2 and 3. Four 5-gallon cans were used for floats, and 3-pound leads in the bottom corner angles and at the bottom of the inner "V" aided in holding the trap web in position. An angle-iron held the bottom of the outer "V" in position and served as an attachment for the rigid inner edge of the trap lead. The traps were set out from sloping beaches in approximately 7 feet of water, with the 6-foot-deep lead extending out from shore line and touching bottom until the outer apron of the trap was reached. As the lake level changed, the traps were shifted inshore or offshore to accommodate the changes. A single offshore kedge anchor of 20- to 25-pounds was sufficient to hold the traps in position even in stormy weather.

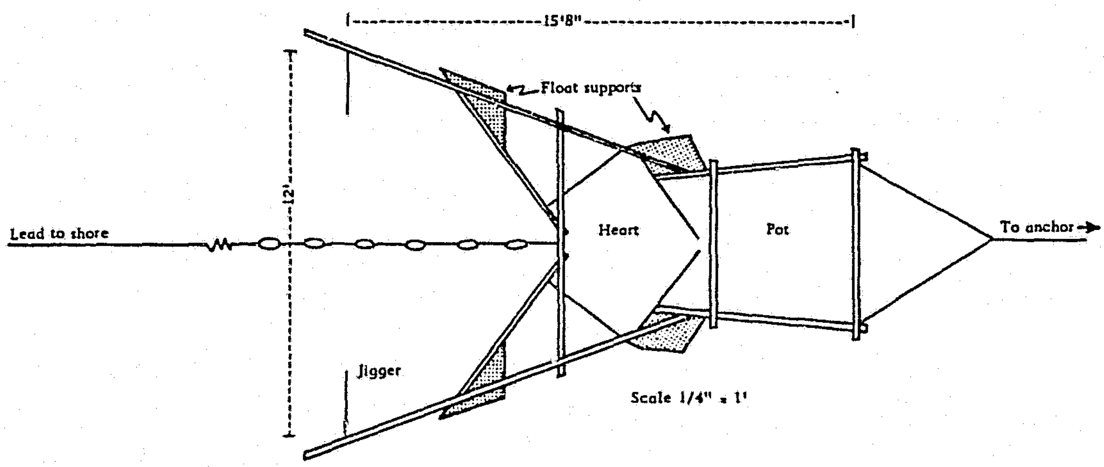

Fig. 2. Plan view of 1952-model floating lake trap used at Lake Nerka.

The pot was emptied from a skiff alongside the trap. The cork-line lead was released at point of attachment to the outer "V" opening and the pot web was pulled up in such a manner that the catch was concentrated at the surface in the rear corner of the pot (See Fig. 4, p. 326). The fish were then brailed by means of a dip net.

All species of fish in the traps were enumerated if the catch was small. Larger catches were sampled in the following manner:

(1) Large fish such as adult chars, rainbow trout, salmon, grayling, and pike were dipped out by a large-mesh dip net and counted.

(2) The remaining fish confined in the corner of the pot were mixed as thoroughly as possible by stirring and a sample then dipped out quickly by means of a wire-mesh dipper. The volume of the sample was obtained

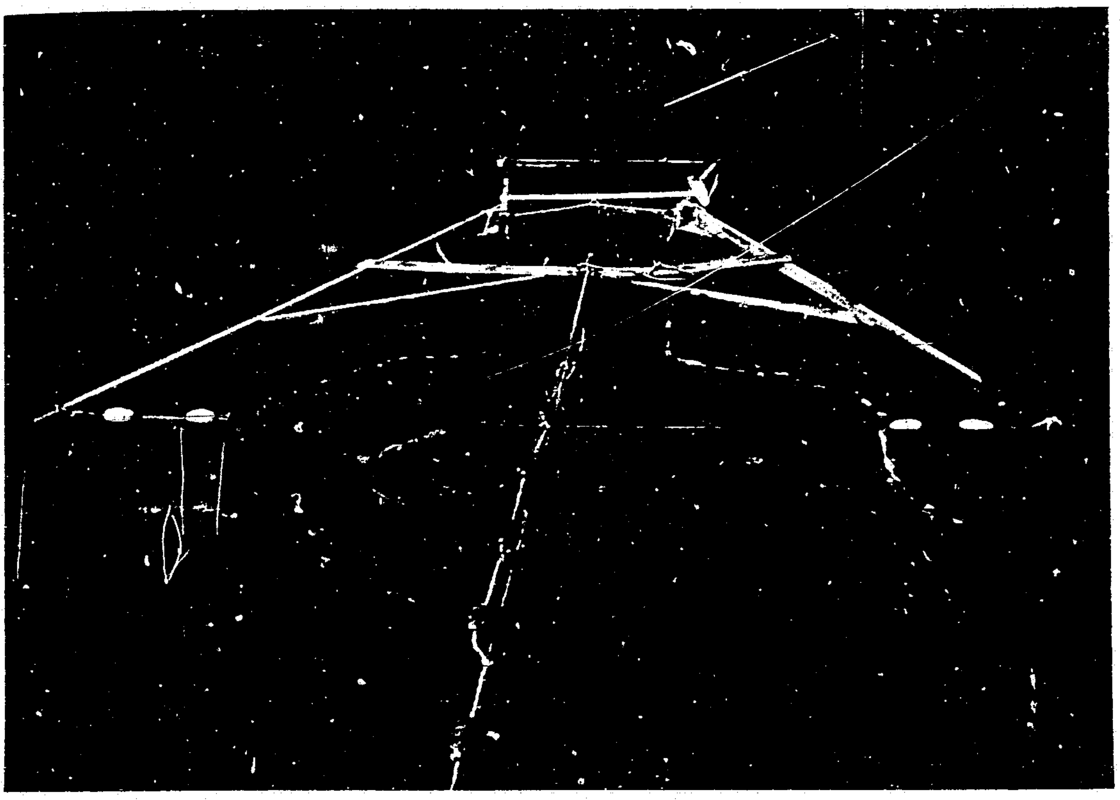

Fig. 3A. The 1952-model floating lake trap. View from lead.

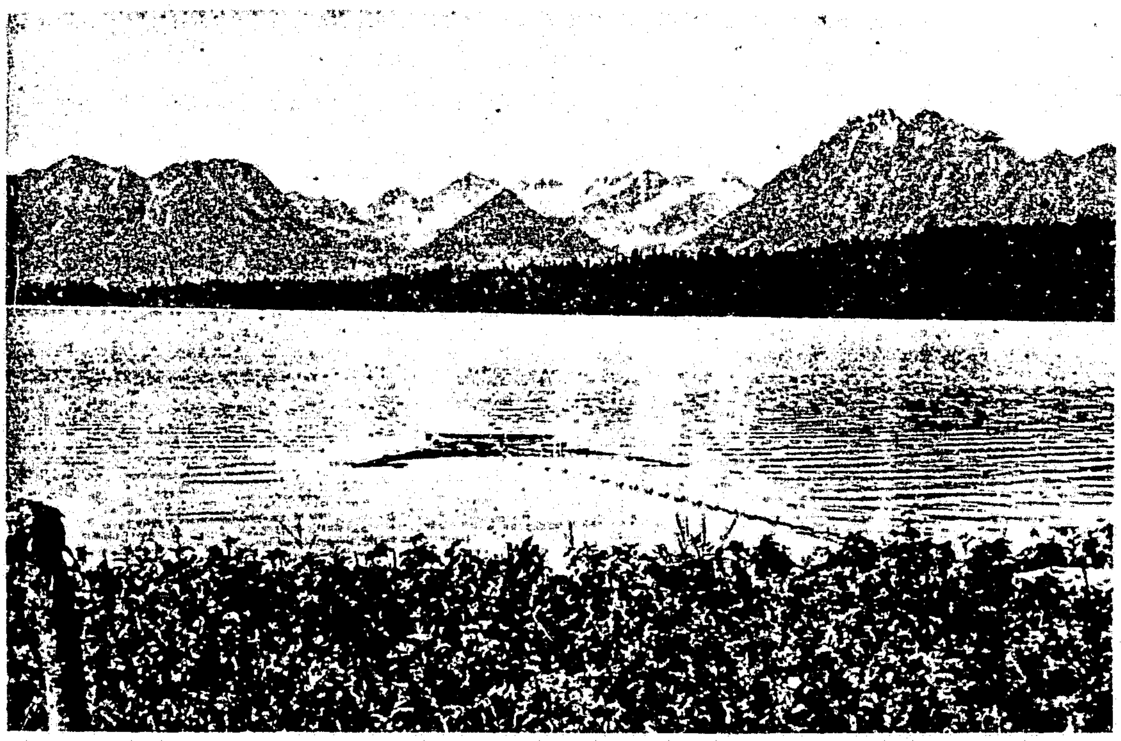

Fig. 3B. View from shore.

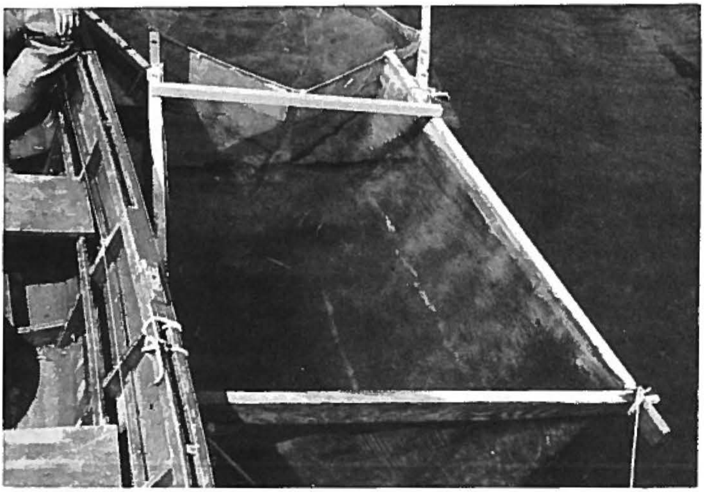

Fig. 4A. Fish in the pot prior to brailing operations.

Fig. 4B. The pot being lifted in preparation for removing the catch.

by displacement and the fish of each species were counted. Then the volume of all remaining fish was determined and the number of each species in the total catch estimated from the composition and volume of the sample.

Lake Nerka was chosen for trial of the lake-trap system of sampling because it is the most important red salmon producer in the Wood River lakes, is centrally located, and is, presumably, most representative. In 1952 several littoral lake-trap sites were fished on Lake Nerka. Of these, four were selected to be fished from breakup of lake ice to midsummer each year.

Three requirements sought in choice of trap site were: (1) evenly sloping beach of suitable gradient, (2) relatively smooth bottom, and (3) protection from prevailing winds. It was found in earlier experiments that both catch and ease of tending the trap were affected if the traps were subjected to heavy wave action.

Beginning in 1953 the traps were installed and fished as consistently as time and funds permitted. The annual fishing periods for each trap are listed in Table 1. Location of the four littoral sites on Lake Nerka are shown in Figure 5. (See p. 328) The traps were tended from the Institute field station at Cabin Bay. In the round trip by boat a distance of 25 miles was traversed to tend the four traps.

TABLE 1. DATES OF OPERATION FOR THE FOUR MAIN LAKE TRAPS, LAKE NERKA, 1953-58

Year	Cabin Bay	Catherine Cove	Pike Bay	Anvil Bay
1953	June 5-Aug. 27	June 8-Aug. 12	June 6-Aug. 13	June 11-Aug. 11
1954	June 7-July 2	June 14-July 2	———	———
1955	June 15-Aug. 6	June 18-Aug. 1	July 3-Aug. 1	June 29-Aug. 1
1956	June 16-Sept. 12	June 16-Aug. 10	June 13-Sept. 12	June 22-Aug. 12
1957	June 6-Sept. 1	June 6-Aug. 9	June 8-Aug. 9	June 7-Aug. 8
1958	June 2-Aug. 22	June 1-Aug. 22	———	———

Experiments conducted in 1951 showed that efficiency of retention of fish by the lake trap varied with species, and that the daily catch obtained by brailing a trap once a day could not be expected to equal that obtained by brailing several times a day. The time of brailing each day would thus be important if the rate of capture varied with time of day. No consistent pattern of catch of the major species in relation to times of daylight and darkness was found in limited experiments in 1951. However, as a precaution, each trap was brailed on a daily schedule at as near the same time of day each year as work schedules permitted.

RESULTS OF LITTORAL AREA SAMPLING

Species Captured

Species of fish caught in the lake traps, listed in approximate order of numerical abundance, were:

threespine sticklebacks *(Gasterosteus aculeatus)*
red salmon *(Oncorhynchus nerka)*: fry, yearlings, age II, and adults
ninespine sticklebacks *(Pungitius pungitius)*
arctic char *(Salvelinus alpinus)*
slimy sculpin *(Cottus cognatus)*
coho salmon *(Oncorhynchus kisutch)*
Alaska blackfish *(Dallia pectoralis)*
rainbow trout *(Salmo gairdneri)*

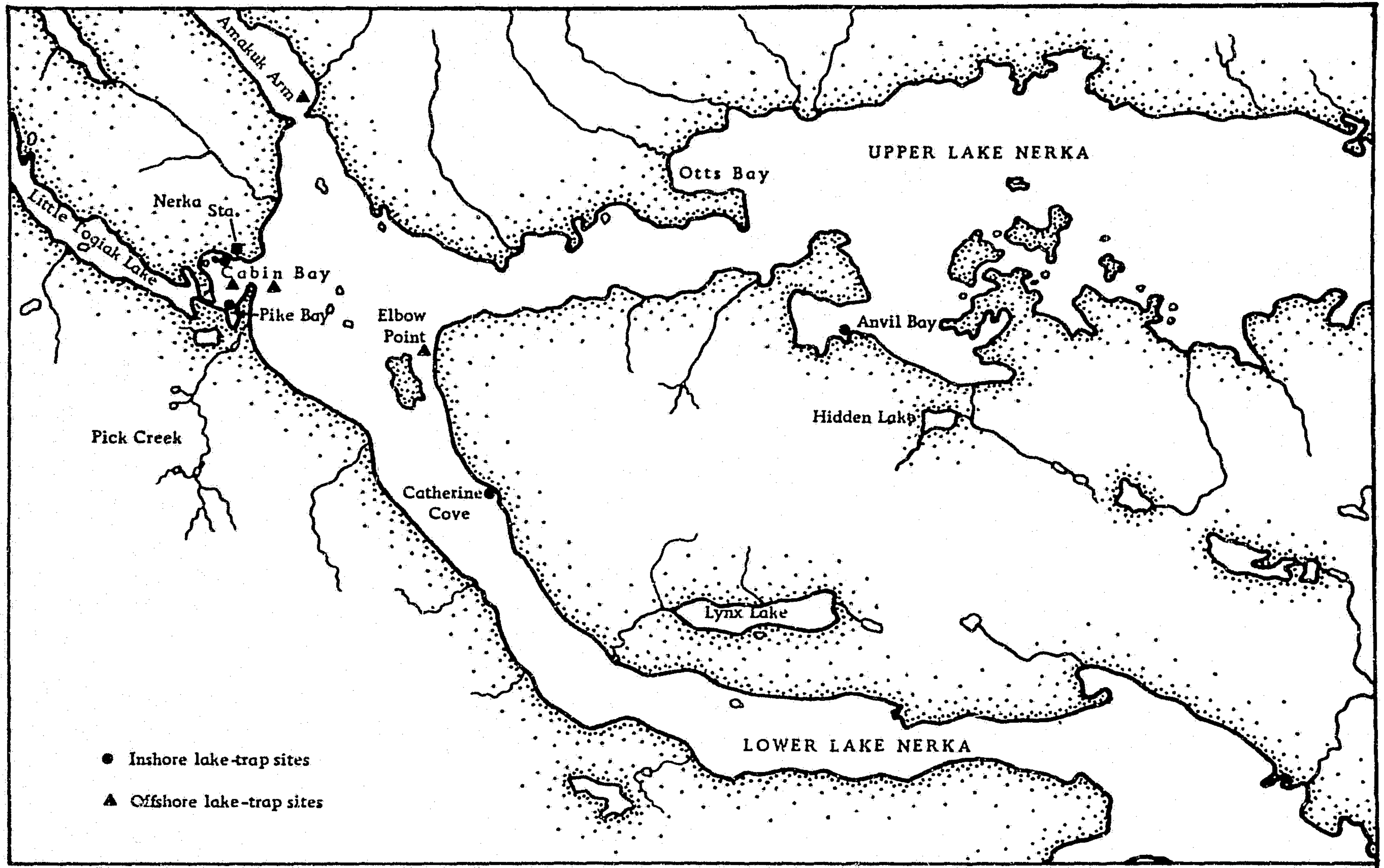

Fig. 5. Location of lake-trap sites at Lake Nerka.

pond smelt *(Hypomesus olidus)*
arctic grayling *(Thymallus arcticus)*
northern pike *(Esox lucius)*
round whitefish *(Prosopium cylindraceum)*
pink salmon *(Oncorhynchus gorbuscha)*
king salmon *(Oncorhynchus tshawytscha)*
Dolly Varden *(Salvelinus malma)*

The list includes all species known to reside in Lake Nerka. The burbot *(Lota lota)* may be present in Lake Nerka but has not been caught to date in various gear used.

Seasonal Trend of Lake-Trap Catches, 1956

If it is assumed that the lake traps were fished with the same efficiency throughout the season, the size of the catch at a trap site such as Cabin Bay was determined by the combination of several variables. The most obvious were:

1. Actual over-all abundance of the species in the area, which we wished to measure.
2. Changes in vertical and horizontal distribution of young salmon resulting from changes in weather or other factors that affected availability to the gear.
3. Changes in behavior associated with growth and feeding habits of the species that affected catchability.
4. Random movement within the area, not necessarily connected with (2) and (3) above.
5. Reduction in numbers by mortality.

As a result of these factors, catches of the several species in the lake traps were extremely variable from day to day and between different periods of the season. The problem resolved into one of determining how closely the trap catches actually reflected (1) the actual over-all abundance of individual species in the area, and (2) how, if at all, corrections could be made for the other factors enumerated above. Catch patterns of the two most abundant groups, threespine sticklebacks and red salmon fry (age 0), were studied from this standpoint.

The 1956 catches of red fry in the four floating lake traps fished at Lake Nerka will be presented first to show seasonal pattern of catches. Each trap was installed at its site as soon as the lake ice disappeared in June. Except during a two-day absence of personnel, the traps were brailed daily. Catherine Cove and Anvil Bay traps were removed on August 10 and 12, respectively, Pike Bay and Cabin Bay traps on September 12.

Daily numbers of red fry caught in the four traps during June, July, and August are presented in Figure 6. Two features of the catch data are particularly apparent for all four trap locations. First, the day-to-day fluctuations in numbers of fry caught were large; second, the catches were much heavier in June and early July than in late July and August. These points require further discussion.

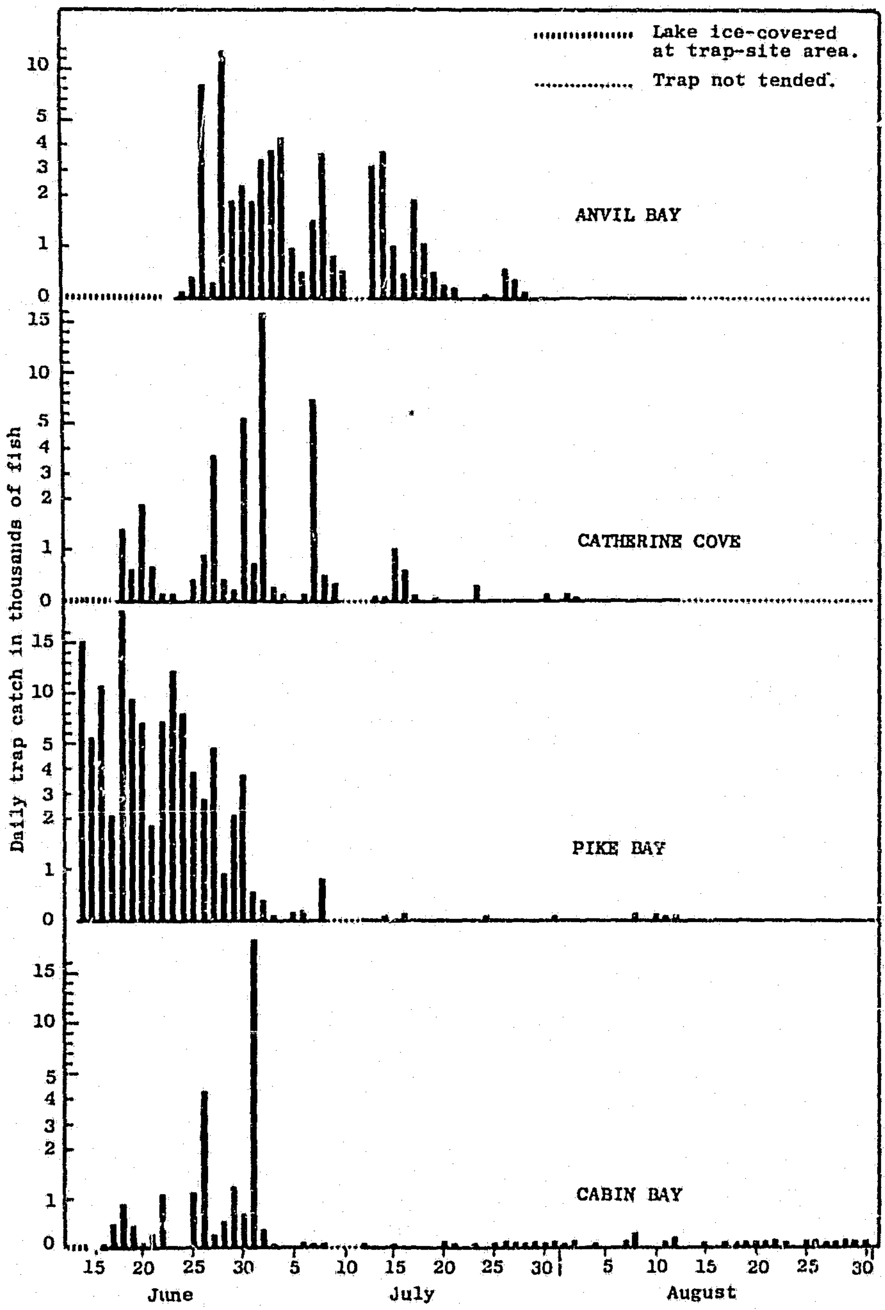

Fig. 6. Daily catches of red fry at the four primary lake-trap sites, Lake Nerka, 1956.

The day-to-day fluctuations in magnitude of fry catches in each trap appeared to occur without relation to fluctuations occurring in other traps. Rankings of the catches over short-term periods in various orders by date of catch failed to disclose that high catch in one trap was associated with high catches in the others, or low with low. With no pattern emerging to relate daily change in magnitude of catch between the different trap sites, it was clear that daily fluctuations could not be related directly to immediate effects of changes in general weather conditions at Lake Nerka. If we assume that the efficiency of the trap did not change from day to day, the changes in catch must then be assigned to local changes in distribution or behavior of the red fry.

As for the seasonal trend of catches at the four traps, there was an unmistakable similarity in pattern. Catches were heaviest during the early season, then dropped sharply to very low level at all traps. This seasonal trend and differences seen between traps in details of catch pattern will be discussed in the light of observed behavior and distribution of red fry during late spring and early summer. These observations are described in the following section.

Fry Distribution and Behavior

Red fry that inhabit the lakes during the season originate in three major types of spawning areas—lake beach, rivers between lakes, and creeks. Time of emergence of fry from spawning-area gravel varies considerably among and within these areas. In 1956, a year of generally late emergence, the first free-swimming fry were observed in one of the creeks under study in early April, but larvae were still abundant in the gravel of this creek on May 16 (W. A. Church, personal communication). On one of the lake beaches, free-swimming fry were observed in late April at a time when redds dug in other beach areas still contained unhatched eggs. In spite of this difference in time, emergence was completed in most areas by the time the first lake trap was installed in mid-June. However, in Anvil Bay, fry with yolk material still unutilized were caught in the lake trap as late as July 4. This indicated that in some areas, presumably portions of beach areas in which spawning is late and perhaps where tempering ground flow in the gravel was low, all fry had not emerged in time to be available for capture during the first days of lake-trap fishing.

Fry emergence in the creeks and the rivers between lakes was essentially completed by the time lake traps were installed in the spring. However, downstream migration does not necessarily occur simultaneously with emergence. While fry do leave the rivers between the lakes soon after emergence, downstream migration of fry in most tributary creeks is not completed for some time after breakup of lake ice. In many of the creeks a portion of the fry population remains to feed, and sometimes the fry acquire considerable growth before entering the lake. For example, in spring-fed Pick Creek on Lake Nerka, schools of fry showing good growth were very abundant along the creek in late June and early July of 1956. Few fry are to be found in Pick Creek by

August, although small schools have been found in the upper creek as late as September 25. In general, however, the decline in numbers of fry remaining in the creeks is quite rapid, and by late June these constitute a very minor portion of the total year class.

Other minor sources of late-entry fry are small lakes such as Lynx Lake and Hidden Lake, tributaries to Lake Nerka. The young migrate out of these lakes into the main lake either as large fry in midsummer or winter over in the small lakes a year or two before leaving. Summer-migrant fry from these small lakes contribute in a very minor way to the main lake population.

Red fry in the Wood River lakes are observed in abundance along the lake shores for at least a month after breakup of lake ice. When the lake level is high early in the season, they are to be found in droves in flooded grass along protected areas of the lake shores, and, except on stormy days, the fry also seek the few inches of water over the fine gravel of upper-beach areas along more exposed shores of the lake. In 1956, these conditions were found in the Wood River lakes as late as July 6-9, when the writer conducted visual surveys of fry along Little Togiak, Beverley, Mikchalk, and Kulik Lake shorelines. The fry in Little Togiak Lake were found distributed around nearly the entire shoreline of the 7-mile-long lake. In Lakes Beverley and Kulik where in general the fry emerge later, they were found still rather closely associated with the known spawning areas. July 13 was the last date fry were seen in abundance in shallow littoral areas at Lake Nerka.

Distribution of fry in the lake is not confined to the shallow beach areas early in the season, for not only do they tend to move deeper on stormy days, but they can be found in numbers around island shorelines where no spawning is known to take place and which are separated from the main lake shore by deep water. It is also possible that the red fry populations which inhabit the shallow littoral areas are a minor portion of the total in the lakes. Although to date early-season fry have not been taken or observed elsewhere than in littoral areas, it may well be that this is because of the techniques employed.

The fry are reasonably consistent in their behavior and range further offshore as they increase in size. During the early season, fry feeding in and over the shore grass submerged by high lake level dart into the grass when frightened. As they develop, they are seen not only in the grassy areas but also in open water a few feet deep, and tend to seek deeper water when disturbed. By mid-July in 1956 the lake level had dropped and the fry had largely disappeared from the inshore observation area at Cabin Bay, Lake Nerka. Only occasional small schools were observed passing over lake bottom observation panels. These panels were placed from shore to a distance approximately 40 feet offshore and to a depth of 5 feet. From the end of July to mid-August fry were observed surfacing over the entire Cabin Bay area (maximum depth, 40 feet; width, $\frac{3}{4}$ mile), and in similar localities in other areas of the lake. Later in the summer numerous large schools of fry were observed at the surface in mid-lake areas several hundred feet deep. Similar offshore movements during the season were observed in other years.

Relation of Stage of Fry Development to Magnitude of Trap Catches

Changes in inshore distribution of the fry were reflected in the lake-trap catches. The early-season fry, although very numerous, were somewhat reluctant to lead out to the trap set at a depth of approximately 6½ feet, and sometimes accumulated in considerable numbers along the inshore portion of the lead. However, by mid-July, schools were observed going out around the end of the trap, and still later in the season the major portion of the observed fry populations were offshore from the traps.

In conjunction with changes in behavior and movement of the fry there occurred changes in distribution. Because of change in feeding habits, movements, distribution, and behavior of fry with increased size and age, it could hardly be anticipated that likelihood of capture by stationary gear would remain constant. Efficiency of the lake trap in capture of fry was therefore related to size and age of the fry in the trap area.

During the season changes in level of lake-trap catches did correspond in a general way to the changes in abundance of red fry observed in littoral areas. However, because of the tendency for fry to move offshore as they increase in size, differences in level of trap catch at different periods during the season could not be regarded as reflecting true changes in over-all abundance in that section of the lake. For comparison of abundance between years, a first requirement would appear to be that catches must be compared for periods when the young were in the same stages of development.

The stages of fry development found at given dates within the season differed between traps sampling different portions of the lake fry population. This is illustrated by the comparison of four sets of small samples taken at Cabin Bay and Anvil Bay traps during the 1956 season (Table 2).

TABLE 2. COMPARISON BETWEEN ANVIL BAY AND CABIN BAY LAKE TRAPS IN SIZE OF RED FRY SAMPLES TAKEN AT APPROXIMATELY SAME DATES DURING 1956 SEASON*

Anvil Bay					Cabin Bay				
Date	Sample Size	Length in Millimeters		Mean Weight in Grams	Date	Sample Size	Length in Millimeters		Mean Weight in Grams
		Mean	Standard Deviation				Mean	Standard Deviation	
June 24	8	27.5	1.50	0.15	June 26	29	29.1	1.75	0.22
July 4	13	27.6	1.26	0.15	July 1	25	29.5	1.58	0.23
July 19	58	27.7	1.58	0.17	July 19	24	36.2	5.25	0.47
Aug. 2	59	27.0	1.49	0.16	Aug. 2	58	38.9	5.58	0.64

*Lengths and weights taken after the samples were preserved.

Fry captured in Cabin Bay were larger early in the season and showed a much greater increase in size subsequently. The continued small mean weight and mean length of the Anvil Bay samples indicated that either growth was very retarded in this area or, more likely, that fry which emerged later were replacing fry which emerged early in the sampling area. Late emergence of fry in the Anvil Bay area is the probable explanation as to why 1956 trap catches at Anvil Bay continued at a high level later in the season than at the other traps (Fig. 6). The smaller size of fry caught in Anvil Bay was a consistent feature in all years of sampling.

Were the seasonal time-abundance patterns of the trap catches the same from year to year at a trap site, it would probably indicate close similarity in timing of fry development and in behavior. The magnitude of the catches from one year to the next could then be compared directly

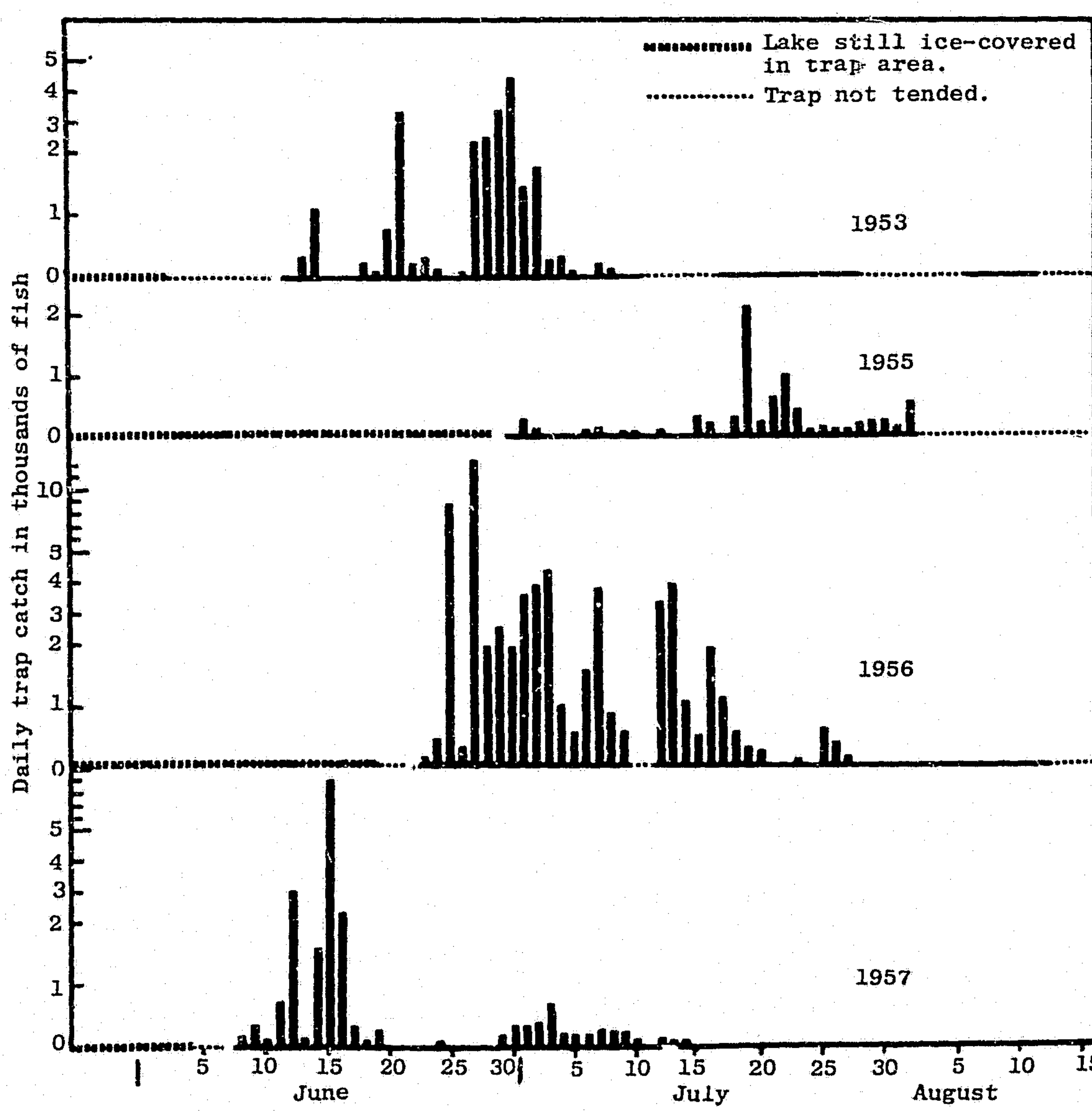

Fig. 7. Daily catches of red fry in Anvil Bay lake trap, 1953, 1955, 1956, and 1957 seasons.

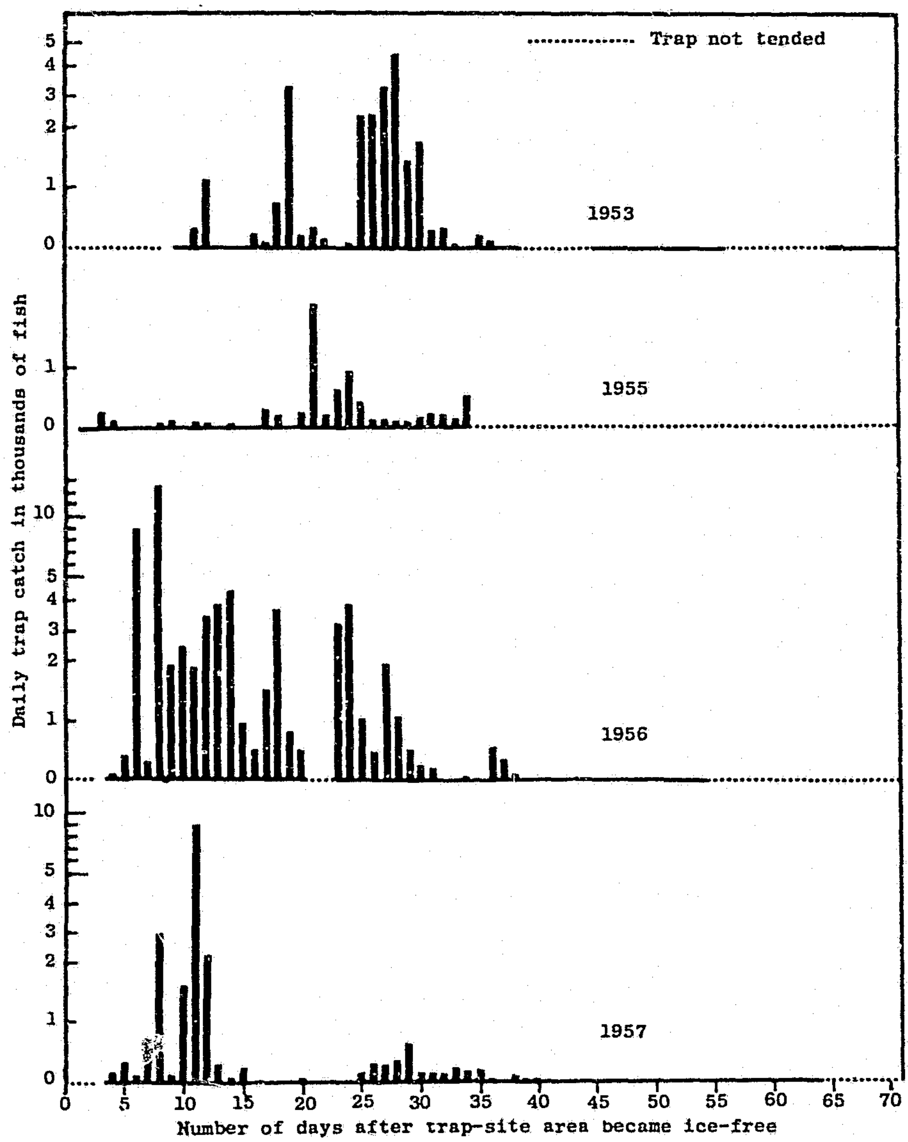

Fig. 8. Daily catches of red fry in Anvil Bay lake trap, 1953, 1955, 1956, and 1957 seasons, graphed from date trap-site area became ice free.

by calendar date to the abundance of fry in the locality. However, a number of factors militated against such a happy occurrence, and the actual pattern of catches varied considerably from year to year. The seasonal patterns at Anvil Bay trap for the years 1953, 1955, 1956, and 1957 are used to illustrate this variability (Fig. 7).

Three facts are at once apparent in Figure 7. First, the date Anvil Bay became clear of ice varied considerably from year to year. Second, there were very obvious differences in seasonal time-abundance sequence of catches. Third, the general level of fry catch was markedly different from year to year. The problem lay in determining whether these differences could be considered meaningful in terms of actual differences in magnitude of fry populations within the sampling area, and if so, how the differences in level of catch could be compared quantitatively.

The dates that the lake areas become ice free depend upon thickness and composition of the ice and snow cover that develop during the winter as well as upon the spring weather conditions prior to and during breakup of lake ice. The timing of breakup does not necessarily show any close relation to the stages of development of the red fry population at that time, for the latter is dependent upon timing of parent spawning; gravel temperatures during egg incubation, hatching, larval development, and emergence; and relative survival of young that develop under different temperature regimens. Summer, fall, and early winter conditions have little bearing on the timing of breakup of lake ice the following spring, but can have a very direct influence on rates of development and survival of incubating eggs and larvae.

On the other hand, breakup of lake ice in the spring does herald a very rapid sequence of changes in the lake environment, and in spite of initial differences in stage of development, fry behavior may be rather closely associated with and influenced by the sequence of environmental changes that follow lake-ice breakup. This is certainly indicated by the improved relation between years in timing of the Anvil Bay fry catches when they are plotted according to number of days after Anvil Bay became ice free rather than by calendar date (compare Fig. 7 with Fig. 8).

Relation of Red Fry and Threespine Stickleback Catches

As seen in Figure 8, there still remained marked differences between years in seasonal pattern of catches even when date of breakup was used as the beginning date of the season. There were not sufficient samples measured each year to show whether the differences between years could be explained by differences in the developmental stages of fry present in the catches. Therefore, other evidence was sought that might bear on the problem. This was found in the catch record of the threespine sticklebacks, *Gasterosteus aculeatus*, the species that rivals the young red salmon in abundance in the Wood River lakes system. Catches of red fry and threespine sticklebacks at Anvil Bay are compared for four years in Figure 9. (Catches of stickleback fry hatched during the season are omitted in these comparisons.) In each year abundance of sticklebacks in the catches did not drop as early during the season as did that of red fry. Except for this difference there existed general similarity in seasonal pattern of catches of the two species. In 1953 the initial low level, the large catches, and the fall-off occurred for both species during the same periods. Again in 1955, a similarity in pattern occurred between species, but it contrasted with 1953. In 1956, and particularly in 1957, catch patterns of the two species were not as similar, yet they contrasted in the same general way with 1953 and 1955. Not only did seasonal catch patterns of the two species tend toward similarity, but changes between years in general magnitude of the catches were similar.

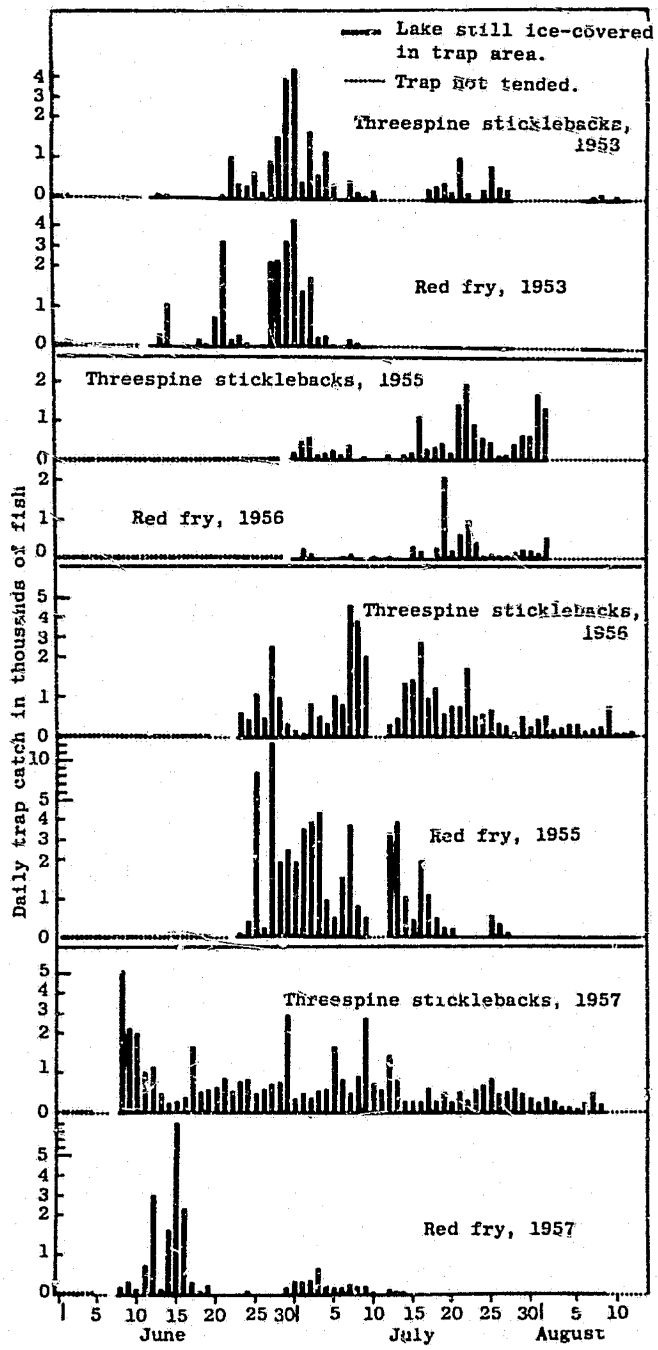

Fig. 9. Comparisons of daily catches of red salmon fry and threespine sticklebacks, Anvil Bay lake trap, 1953, 1955, 1956, and 1957 seasons.

The similarity in seasonal catch pattern of red fry and sticklebacks in the Anvil Bay lake trap suggests that the same factors were operating on both species to affect their catchability by inshore fixed gear during the season. To examine whether or not this was a phenomenon peculiar only to Anvil Bay, the red fry and threespine stickleback catch records were graphed for another lake-trap site, Cabin Bay (Fig. 10). Here the similarities in seasonal catch trends of the two species within individual years were even more striking, and differences between years equally noticeable. Although early season catches of sticklebacks at Cabin Bay in

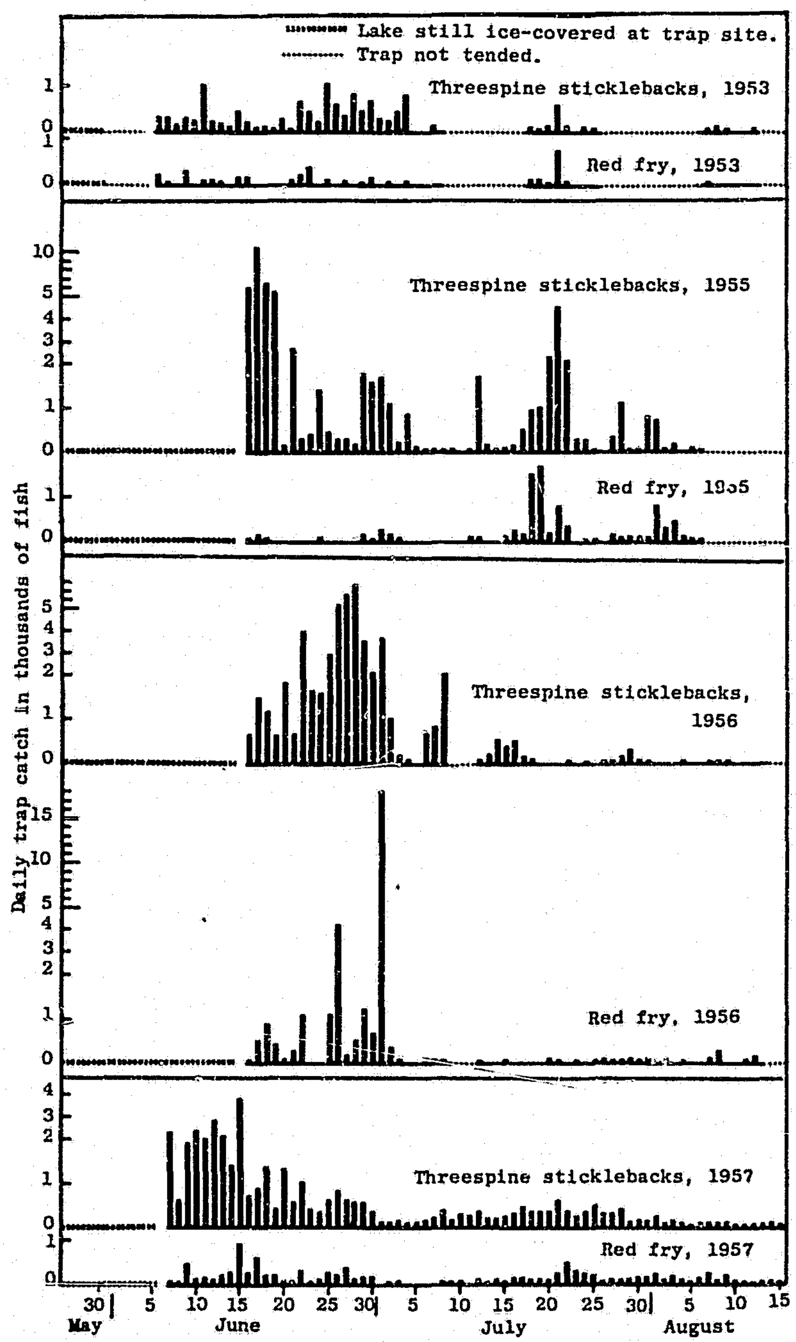

Fig. 10. Comparisons of daily catches of red salmon fry and threespine sticklebacks, Cabin Bay lake trap, 1953, 1955, 1956, and 1957 seasons.

1955 were not matched by fry catches of similar relative magnitude, the pattern in July and early August was much the same for the two species. Aside from this exception in early 1955, the major seasonal characteristics of timing and magnitude of catches were borne out by both red fry and threespine sticklebacks.

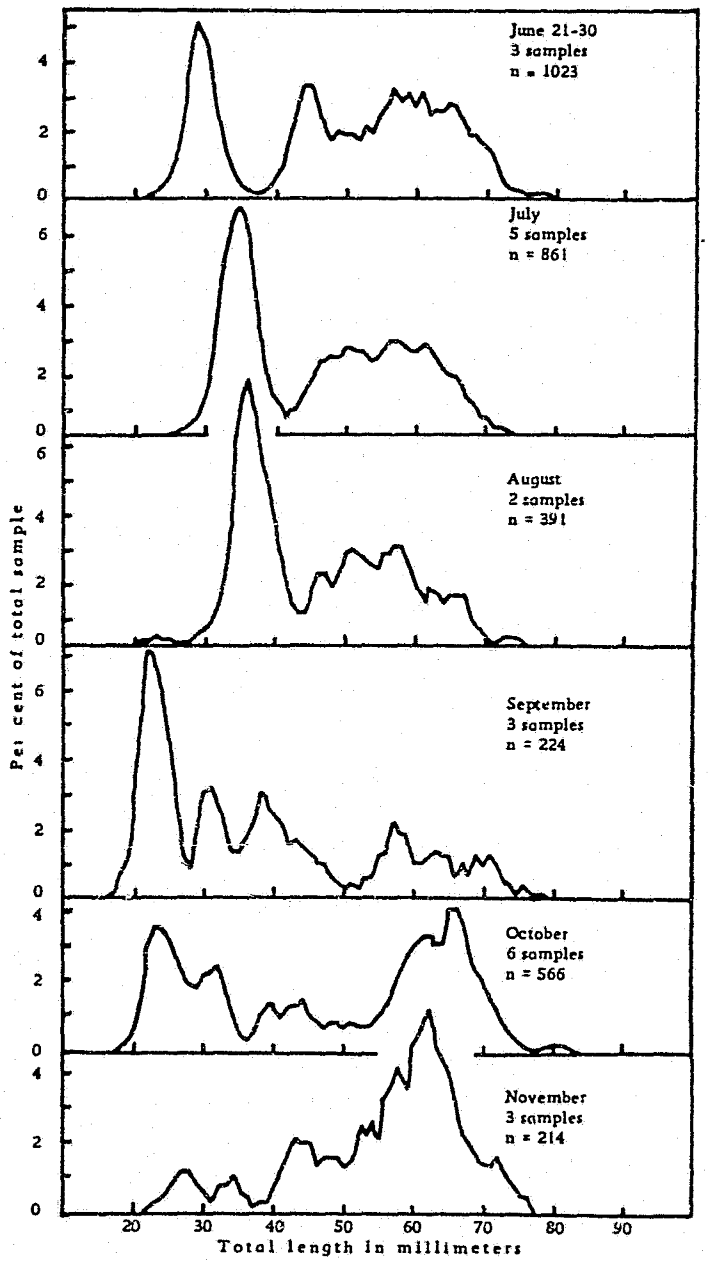

Fig. 11. Length frequencies of threespine sticklebacks *(Gasterosteus aculeatus)* in samples taken at Lake Nerka, 1957, combined by month, showing progression of modal groups during the season. (Fish measured after preservation in formalin. Length frequencies smoothed by moving averages of threes.)

The question arises as to the significance of these relationships between stickleback and red fry catches. Since the red fry were of a single age, changes in catch level could have been associated with behavior change as the fry developed. However, similar changes in catch level of sticklebacks could not be related in the same way to developmental stage because more than one age group was involved. Length-frequency analysis of threespine sticklebacks taken during the 1957 season indicated that at least two or three age groups were present in the catches. This is illustrated in Figure 11, in which all samples preserved from catches made by lake-trap, tow-net, and beach-seine gear are combined by monthly periods.

Stickleback fry of the year did not appear in the catches until August, and were readily separated at that time from older fish because of their small size. As seen in Figure 11, they first appeared in numbers in September samples. During June, July, and early August the strong mode of smaller fish thus represented hatch of the previous summer. The progression of this size group and the trimodality of the June samples strongly suggested the presence of three age groups at the beginning of the year, which would place the maximum age attained at three years or more.[1] As the sticklebacks near maturity, sexual dimorphism in size occurs, and modal progression is probably somewhat obscured.

The stickleback catches, therefore, differed from the red fry catches in that the former were not at a uniform age or stage of development, whereas the fry catches were all of the same year class. The relatively faster decline in numbers of red fry caught in the lake traps during the season may have been due to more uniform change in stage of development and more marked change in behavior with increase in size. However, because of the indications of general similarity in rise and fall of the catches of the two species during a season and of similar contrasts between seasons, it was evident that stage of development of red fry could not alone explain the differences found between years in seasonal pattern of red fry catches.

[1]Trimodality in length-frequency samples of threespine sticklebacks taken at Karluk and Bare Lakes on Kodiak Island was also shown by Greenbank and Nelson (1959). Otolith study confirmed the presence of three year classes. They assigned the group of smallest fish in May and June samples, with mode at about 30 mm, as representing fry of the current season. It appears most likely that these fry were hatched the previous summer but were not taken by collecting gear at that time. In the 1957 Lake Nerka samples, the modal group of new recruits was 23 mm total length at the time of September sampling. The June mode, 29 mm, for the youngest age group of Lake Nerka sticklebacks corresponds approximately with that found at Bare Lake in May and June.

EVALUATION OF RESULTS

Evaluation of Trap Catch Pattern

Catches of red salmon fry made in floating traps set along the lake shore have been evaluated in relation to observed behavior, weather conditions, and catches of threespine sticklebacks. This evaluation is summarized as follows:

1. There were marked differences between years in magnitude and seasonal pattern of catch of red fry in the lake traps.
2. Part of this difference was due to the influence of differences between years in time of lake-ice breakup.
3. The seasonal timing and magnitude of catch of fry and threespine sticklebacks each year tended toward similarity in pattern.
4. While magnitude of catches made during a year must be dependent to some extent on actual numerical abundance, factors influencing both fry and sticklebacks create seasonal variability in availability of these species.
5. The fact that catches of both species showed similarity in seasonal pattern suggests that environmental changes occurred, affecting the distribution and behavior of both species in a similar manner.
6. The pattern also suggests that external factors which affected both species were more influential in determining the catch pattern than were seasonal changes in catchability of red fry due to behavior changes with increase in size.
7. The fact that the lake traps did record similar changes in catches of fry and sticklebacks indicates that the trap catches provided a record of actual changes in inshore availability of these two species. This was substantiated by visual observations of inshore abundance.
8. It should also be noted that the close correspondence in movement patterns of red fry and threespine sticklebacks suggests that, at least during this period of the year, the two species were in competition with each other for food. This was borne out by visual observations, for it was commonplace to find schools of red fry and threespine sticklebacks completely intermingled in littoral areas, sometimes in dense aggregation.

Problems in Use of Inshore Gear to Measure Abundance of Red Fry

The lake trap studies led to certain general conclusions about adaptability of gear set in littoral areas for indexing red fry and threespine stickleback abundance. Changes in inshore availability of the fish present the same problem regardless of indexing method, whether it be by lake trap, visual observation, photography, or other means. Essentially the same difficulty would arise in systematic, periodic sampling at a single location by beach seine or other inshore mobile gear. Tests of reliability of inshore gear in reflecting actual fry abundance need in some way to be independent of fluctuations in availability of red fry in littoral areas. Other methods of measuring inshore abundance might reflect the same fluctuations in availability as did the traps without providing additional information on actual over-all abundance of young.

It might be proposed that reliability of the procedure could be tested by correlating the gear catches with abundance measures at earlier or later stages. For instance, correlations between numbers of eggs deposited the previous year, corrected for winter-kill if feasible, and lake-trap catches of red fry might be tried. However, this would not provide a satisfactory test of the lake-trap method as a measure of abundance, since our objective is to measure fluctuations between years in mortality rate occurring between egg and free-swimming fry stages. The same objection applies to attempted correlations between measured abundance of fry and of subsequent surviving smolts. We prefer not to make any assumptions as to constancy of mortality rates from one stage to the next. An independent method of indexing abundance should be applied, if possible, at approximately the same early-life stage, if it is to satisfy our objective.

Two additional methods of sampling were begun in 1957 to determine the feasibility of pelagic sampling as a test of, or substitute for, littoral area sampling. The first method made use of floating lake traps set in positions over deep water some distance from shore. The second method involved offshore sampling by means of a large net towed between two outboard skiffs. Evaluation of the pelagic trapping method will be presented in the following section. The tow-net method of sampling will be described in a later report.

PELAGIC AREA SAMPLING

In 1957 a lake trap of the same design as the 1952-model trap was fished at Lake Nerka in four locations. These sites varied from 1/8 to 1/2 mile offshore and from 1/2 to 4 miles apart. The only trap modification was the extension of the lead to 140 feet in length. An anchored 55-gallon drum served to hold the trap in position. The trap was attached to the drum by a single line at the pot end. The lake currents set up by wind action were normally sufficient to keep the trap and lead extended out full length "downstream" from point of anchor (Fig. 12). Depths over which the trap was fished ranged from approximately 20 feet to over 100 feet. The trap was set on June 9 and, with the exception of two days, was tended daily until August 10. The locations fished are shown in Figure 5.

Fig. 12. Floating trap anchored to buoy off Elbow Point, Lake Nerka, lead trailing on the right.

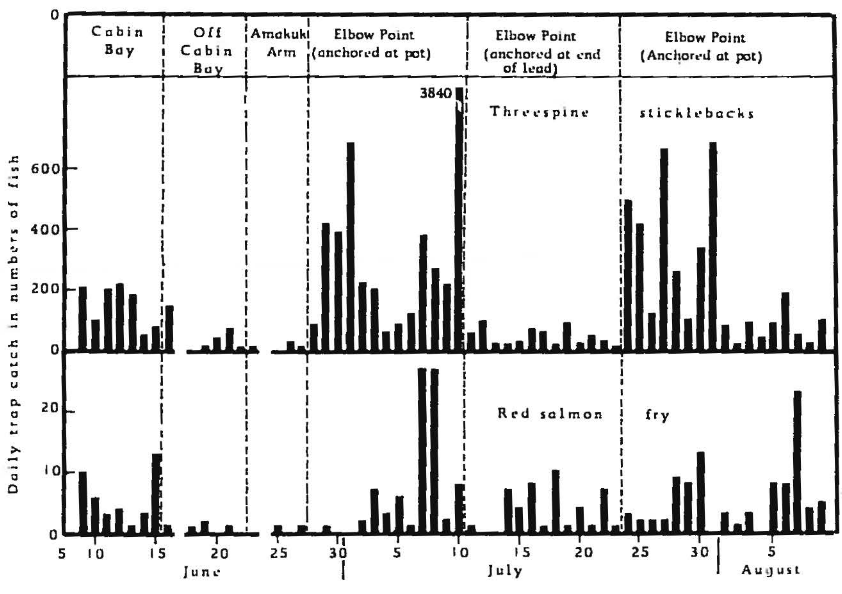

Fig. 13. Daily catches of red salmon fry and threespine sticklebacks in floating lake trap fished in offshore positions, 1957. (Trap anchored at pot end except as indicated. Note that the ordinate scale is not the same for the two species.)

The primary problem encountered in the offshore trap trials was the low level of the red fry catches (Fig. 13). Several sites were fished in an effort to see whether change in trap location might bring about increased catch. No marked improvement in catch level of red fry was obtained by shifting to new locations.

The question exists as to whether low catches were due to scarcity of red fry in the areas or to inefficiency of the trap in leading the fry where there were no natural shore contours so that the fry could sound underneath the trap lead. The stickleback catches were much higher in proportion to red fry catches than in inshore traps. This may have been partially due to differences between the two species in vertical distribution. Results of tow-net sampling in pelagic areas at night have also indicated that the sticklebacks remain nearer the surface.

Catches presumably depend on direction of movement of red fry with respect to lake surface currents and the anchored trap.[2] At Elbow Point, the final location, anchoring of the trap was reversed for a trial period by attaching the lead end rather than the trap end to the anchor buoy. In this position the fish must lead "downstream" in the lake current to the trap opening rather than upstream. No marked change in level of red fry catches was achieved, although the level of stickleback catches was distinctly lower during the 13-day trial period while the trap was downstream from the lead (see Figure 13 and Table 3). It would appear that sticklebacks, and possibly red fry, tend to move or lead upstream, and are thus caught and retained more efficiently when the trap is anchored with the lead trailing.

TABLE 3. COMPARISON OF LEVEL OF CATCHES OF RED FRY AND THREESPINE STICKLEBACKS AT ELBOW POINT BEFORE AND AFTER ANCHORING OF LAKE TRAP WAS REVERSED

Dates	Number of Days	Trap Anchored by	Average Daily Catch	
			Red Fry	Threespine Sticklebacks
June 28-July 10	13	pot	6	530
July 11-July 23	13	lead	3	44
July 24-Aug. 9	17	pot	6	218

No trials were made with the trap anchored in a fixed position with both pot and end of lead fastened. This position, when crosswise to the lake current, would be difficult to hold on stormy days. The test at Elbow Point indicated that the efficiency of the trap would vary with change of

[2]Temperature sections taken at Lake Nerka have revealed that, as a result of wind action, the water masses in Lake Nerka seldom approach horizontal stability during summer. Even on calm days there is usually a perceptible movement of surface layers.

its axis with respect to lake current. Uniform efficiency is, of course, desirable.

The 1957 trials of offshore lake trapping suggested that fluctuations in magnitude of catch from day to day and during the season were less severe than in inshore trap locations, and that offshore catches might persist later in the season than at inshore sites. These, of course, would be highly desirable features. It also appeared desirable to fish the offshore traps later in the season, since tow netting for fry proved more successful at that time.

In 1958 a trap was located again at the site off Elbow Point for the period June 2 to August 20 to determine whether late season catches of red fry would increase witn a shift of red fry from littoral to pelagic areas. The inshore sites at Cabin Bay and Catherine Cove were also fished to detect presence of fry in littoral areas. By July 25 red fry had virtually disappeared in catches of the two inshore traps and fry began to show up regularly after August 1 in catches of a tow net fished during the season near the surface in pelagic areas. However, an increase in red fry catch in the pelagic area trap failed to materialize, and fry catches totaled only 23 for the entire period of over two and one-half months.

The failure to catch red fry was partially attributed to low abundance, as indicated by low parent-spawning density, low fry catches in inshore traps and in the tow nets, and a small seaward migration in 1959. However the stickleback catches were also many times lower than in the previous year in the offshore trap but only slightly lower in the littoral area traps. This would indicate that either vertical or horizontal distribution of the fry and sticklebacks in the pelagic area differed between the two years or the pelagic trap had somehow been modified in efficiency. Because there was considerable difference between 1957 and 1958 in development and extent of thermal stratification, some difference in vertical distribution of fry and sticklebacks is believed to have occurred.

From results of the tests in 1957 and 1958, it was concluded that catches of traps fished in pelagic areas did not provide a reliable measure of red fry abundance. Certainly, modifications that materially increase the magnitude of catch must be achieved before offshore traps can be considered a promising alternate method of enumerating fry abundance.

SUMMARY

The present study concerned primarily trials of floating lake traps as a means of measuring fluctuations in abundance of young salmon in the Wood River lakes, Alaska, during their lake residence. A sampling system that utilized lake traps was established at Lake Nerka in 1953 and tested over a six-year period.

All fish species known to be present in the lake were captured in the traps. The two most abundant species, young red salmon and threespine sticklebacks, were captured in greatest numbers.

Catches of red salmon fry were found to be heaviest during the first month after breakup of the lake ice in late May or early June, and to drop off by mid-July to a low level.

The pattern of catch was shown to be associated to some degree with timing of spring breakup, thermal development, and growth and behavior of the red fry. In early summer red salmon fry were found to inhabit the littoral areas, but gradually moved to habitats in deeper water as they developed.

Aside from the gross feature of decrease in catch by midsummer, the magnitude and pattern of red fry catch varied considerably from year to year. In order to determine whether these patterns of catch could be explained on the basis of changes in abundance and developmental stage alone, red salmon fry catches were compared with those of threespine sticklebacks.

Similarity in seasonal patterns of catch of the two species was found, and differences between years in pattern tended to be the same for both species. These results showed that availability to the gear was variable, which complicates the use of the lake traps for abundance measurements.

A decrease in inshore catches of both red fry and sticklebacks by midsummer suggests that the general offshore shift in distribution of both species was not related primarily to developmental stage, since the sticklebacks in the catches were comprised of several age groups at different stages of development.

The correspondence in movement patterns of red fry and threespine sticklebacks suggests that they tend to inhabit feeding areas simultaneously, thus increasing the opportunity for interspecific competition.

Varying availability of the fish in littoral areas presents a problem in indexing of abundance by means of stationary gear as well as by beach seine or other mobile gear used only in inshore areas.

In 1957 and 1958 floating lake traps set in positions over deep water some distance from shore were fished to determine the feasibility of their use as a test of, or substitute for, littoral area sampling.

Catches of red salmon fry in traps set in offshore locations were much lower than in inshore locations, and the proportion of sticklebacks was higher. Catches of red fry and sticklebacks failed to increase in the pelagic areas with the shift in their distribution away from littoral areas in midsummer. The shift was indicated by decrease in catch in inshore areas and increase in catch in tow nets fished in pelagic areas. It was concluded that the pelagic traps used did not provide a reliable measure of red fry abundance.

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