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DEVELOPMENT AND EVALUATION OF A NET BARRIER TO
REDUCE ENTRAINMENT LOSS OF KOKANEE
FROM BANKS LAKE

by

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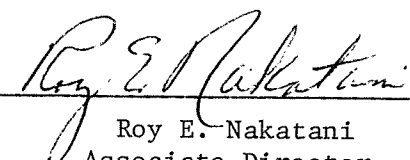
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1.0 ABSTRACT

A net barrier totaling 1,341 m in length was developed to screen mature kokanee from the main irrigation canal intake. The net was constructed of 83 mm stretched-measure dacron. Maintenance equipment was designed and constructed to haul the net and cleaning was done with high pressure water jets. Comprehensive evaluation of the screening efficiency of the barrier was conducted by numerous methods. Annual canal entrainment of kokanee declined from 60-67% before to 18-3% after installation. An estimated 35,381 adult kokanee were retained in the lake during the fall of 1978 based on mark and recapture from purse seine catches. Sonic-tracked kokanee were retained by the barrier and fish late in the season "homed" to beach spawning sites. A creel census estimated anglers caught 46,427 kokanee in 1978. The catch per angler hour was 0.250 while all other species declined to 0.042.

Spawners have been surveyed for four years and found to concentrate along talus shorelines at depths ranging from 1.5 to 4.6 m below full pool. Drawdown of the reservoir during the spring has reduced fry survival due to dessication of the eggs and fry along the beaches. Drawdown limits (rule curves) were developed which could not exceed 5.18 cm/day during the fry emergence period in order to allow survival. The combined use of the barrier net to retain adults in conjunction with drawdown limits to allow fry survival provides a practical and economical management strategy to minimize the operational effects of irrigation on the kokanee salmon sport fishery.

Key Words: Barrier Net, Screening, Entrainment, Kokanee salmon, Lake Whitefish, Yellow perch, Population dynamics, Irrigation, Sonic tracking, Beach spawning, Fry emergence, Drawdown, Creel census, Fry survival, Rule curves, Fishery management, Water management, Limnology, Stock assessment, Artificial spawning beds.

2.0 ACKNOWLEDGMENTS

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The cooperation received from the Washington State Department of Game is greatly appreciated. The Northwest Steelhead and Salmon Council of Trout Unlimited, Wenatchee, Washington, was responsible for providing the materials and manpower to place two artificial spawning beds in Banks Lake for testing. Personnel of the U.S. Fish and Wildlife Service collected the creel census data during 1978 on Banks and Billy Clapp reservoirs. Mr. Jerry Jurkovich (National Marine Fisheries Service, Seattle) provided technical information on the design and use of the purse seine.

Part-time field and laboratory assistance provided by staff and students included the following: Mr. Dave Gaudet, Mr. Steve Davis, Mr. Steve Quinzel, Ms. Susan Paskell, Ms. Penny Wilcock, and Ms. Dea Van Wyk.

3.0 INTRODUCTION

The primary purpose of Banks Lake is to function as the equalizing reservoir for the Columbia Basin Irrigation Project. The operational changes imposed on the lake by irrigation result in dramatic effects on the water quality which are exemplified in the aquatic ecosystem and the important sport fish populations (Stober et al. 1977). Some of the changes imposed on the lake are beneficial, such as nutrient addition and mixing which stimulate primary production. Other changes such as frequent, water level fluctuations as well as entrainment and flushing can impose strict limitations on the ability of the system to produce and sustain aquatic life. Although the impacts of intermediate drawdowns on sportfish survival have not been determined, the extreme drawdown imposed on the lake in 1973 and 1974 created some undesired reductions of the fish populations. The present development of pumped storage power generation on the lake will impose changes which will occur during the winter while expansion of the Columbia Basin Irrigation Project will increase the existing impacts on the aquatic ecology of the lake. The operational use of the lake for water supply and production of electric energy will occur throughout the year once full development is reached.

Despite the operational effects imposed on Banks Lake throughout its history, a popular sport fishery developed due to the production of relatively large populations of kokanee and other species. The fishery developed along with a maximum annual drawdown of about 4.6 m suggesting that some operational fluctuation of the lake level can be tolerated. However, based on the information obtained in the study of the system from 1973-1978, the magnitude, timing and rate of water level change could be managed in the future to achieve a larger and more consistent standing crop of kokanee. The occasional severe reduction of a kokanee year class due to construction or unusual reservoir operation may also be minimized.

The entrainment of kokanee through the irrigation canal is an annual loss which has been imposed on every year class to date. There is little

doubt, however, that the entrainment loss constitutes a substantial reduction of the population of mature age III and IV kokanee. Entrainment of adult kokanee through the irrigation canal has been found to deplete seriously the spawning population remaining in the lake where natural reproduction must take place to sustain the species. This loss of large mature kokanee is especially acute on a year class which has previously been reduced in numbers by lake drawdown. This loss of brood stock in 1976 resulted in insufficient egg deposition needed to produce an adequate number of fry the following year. The entrainment loss of adult kokanee also removed large numbers of fish from the popular sport troll fishery active on Banks Lake. Therefore, management of the lake level to sustain the natural reproductive potential of kokanee along with retention of the adult kokanee by selective screening of the irrigation outlet would help to insure continuation of a viable sport fishery on Banks Lake.

The primary objective of this study was to develop and evaluate a practical and economical method of reducing the loss of kokanee from Banks Lake via entrainment into the irrigation canal. A barrier net was designed, constructed, and operated to contain the kokanee and to isolate the southeast corner of Banks Lake including the irrigation canal outlet works. This approach was selected to avoid more costly design, construction, and maintenance which would be required if, for example, a traveling screen or louver structure were developed, an approach which may in fact be less practical.

The net barrier was specifically designed to lead adult III- and IV-year-old kokanee away from the outlet structure. These age classes are the principal ones entrained and those most desired by the sports angler. Three-year-old kokanee constitute the principal spawning year class and retention of an adequate spawning population in the lake for reproduction is vital to maintenance of the population. Evaluation of the effectiveness of the net barrier required determination of fish entrainment rates into the irrigation canal and the number of kokanee spawners retained in the lake as well as those caught in the sport fishery. Gillnet

and acoustic sampling was used to determine fish densities, and a limited creel census provided additional relevant information during 1977. A mark and recapture experiment, tracking of sonic tagged individuals and a detailed creel census were added to provide a comprehensive evaluation of the barrier net during the 1978 season following improvements in its design and operation.

The survival of kokanee in relation to reservoir drawdown was investigated in greater detail to determine whether a sustained production of kokanee at greater depths could preclude annual impacts due to water level fluctuations. The depths of prime spawning areas were defined and the number and distribution of spawners was surveyed. Artificial gravel beds were established in the lake below the level of minimum drawdown to determine whether kokanee would utilize the deeper spawning habitat. Fry emergence was determined on both natural and artificial spawning beds and the quality of the substrate and water was analyzed.

4.0 DESCRIPTION OF THE STUDY AREA

Banks Lake was established in 1951 by flooding 10,926.5 ha (27,200 ac) along a 46.5-km (28.9-mi) section of the upper Grand Coulee between two earth-filled dams (Wolcott 1964) (Fig. 1). The North Dam constitutes the northern boundary of the lake. Dry Falls Dam (also known as South Dam) bounds the southern end of the lake. The pumping plant located at the left forebay of Grand Coulee Dam pumps water from Franklin D. Roosevelt Reservoir up 111.2 m (365 ft) into a 2.5-km (1.6-mi) long feeder canal which supplies water to Banks Lake adjacent to the North Dam. The pumping plant contains six pumps, each rated at 45.3 m³/sec (1,600 cfs) and two pump generators, each rated at 49.6 m³/sec (1,750 cfs) in the pumping mode. Water for irrigation is withdrawn from Banks Lake through the irrigation canal headworks at Dry Falls Dam to supply the agricultural requirements on about 202,000 ha (500,000 ac) of farmland in the Columbia Basin. The present maximum rate of irrigation withdrawal is 223.6 m³/sec (7,900 cfs).

The location of the sampling stations established in 1973 to monitor the aquatic ecology and fisheries of the lake are shown in Fig. 1. Sampling was continued at stations 4, 5, and 6 during the present study in an effort to sustain the baseline to aid in the evaluation of the net barrier.

Variations in the operational rates of water supply and withdrawal to Banks Lake result in water level fluctuations of the lake. Rates of irrigation water input and withdrawal and changes in water level elevation from January 1973 to December 1978 are presented in Fig. 2. Maximum surface elevation is 478.5 m (1,570 ft) and at maximum drawdown the surface elevation is 469.4 m (1,540 ft). The annual drawdown does not normally exceed 4.6 m (15 ft) but during the past few years drawdown reached 7.6 m (24.9 ft) and 7.2 m (23.6 ft) during the spring of 1973 and summer of 1974 (Fig. 2). Major decline in the water level has not occurred since 1974.

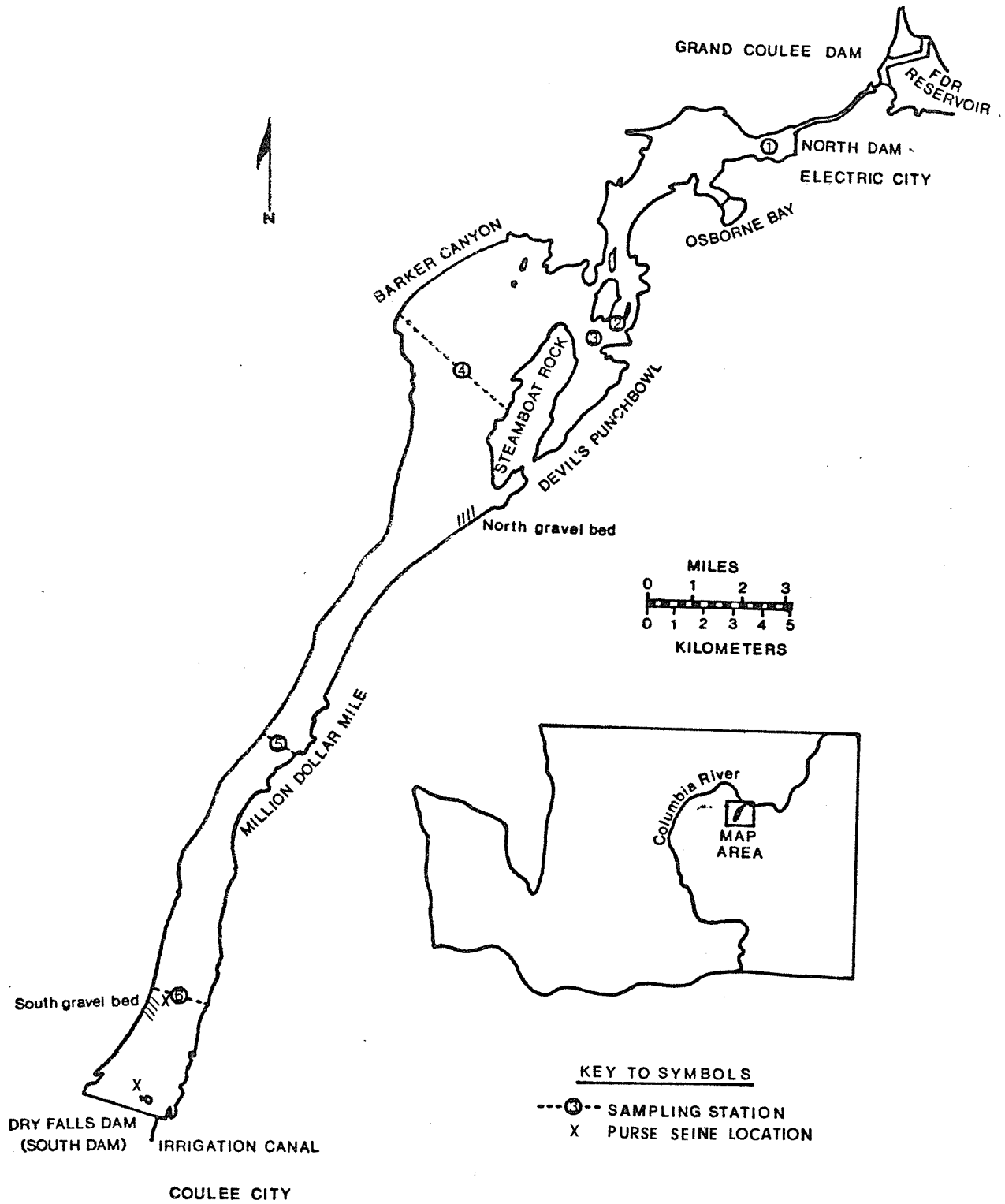


Fig. 1. Geographical location and features of Banks Lake and locations of sampling sites.

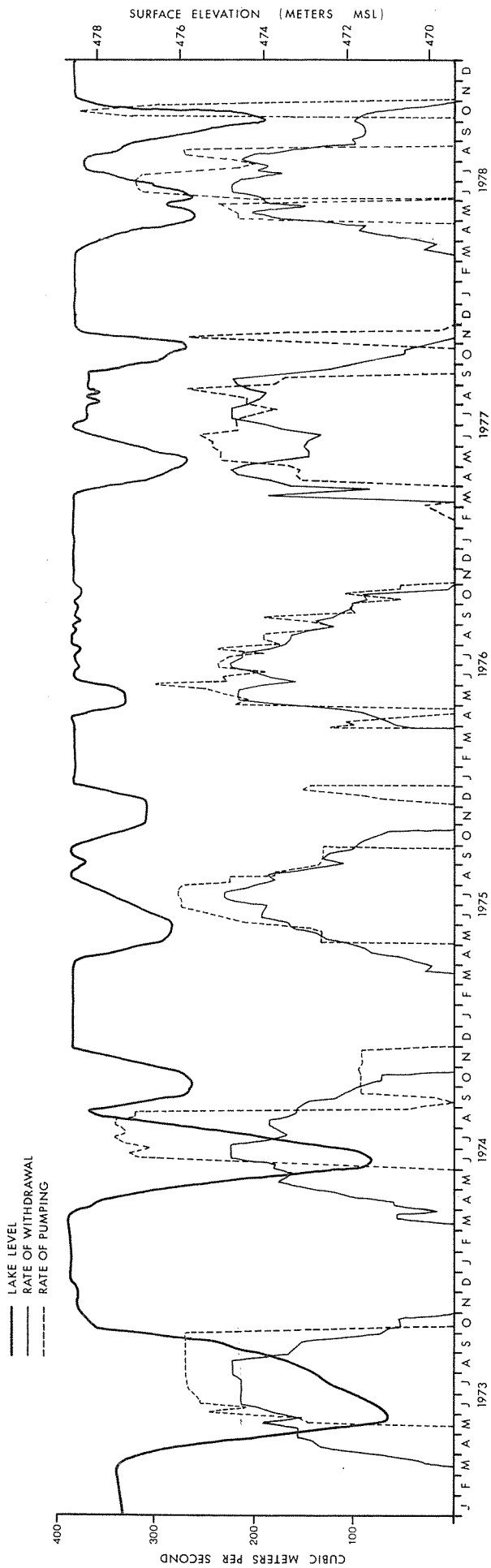


Fig. 2. Banks Lake surface elevations relative to rates of irrigation water input and withdrawal, 1973 to 1978 (USBR).

The south end of Banks Lake near the irrigation outlet is generally less than 12 m deep at full pool. A dredged channel 17 m deep connects the deeper pool to the irrigation canal headworks and allows for irrigation withdrawal at maximum drawdown. The presence of the dredged channel and two islands (Fig. 3) were important features considered in the design and site selection of the net barrier. The irrigation canal (main canal) headworks are located in the east end of the South Dam, a short distance from Coulee City. The canal was cut through basalt rock and extends south for 3.4 km (2.1 mi) where it leads into Bacon Siphon.

The headworks of the irrigation canal is constructed of concrete. A concrete apron extends 32.9 m downstream into the canal where it abruptly ends. Six outlet tunnels, each 3.7 m wide x 6.4 m high (12 x 21 ft), empty into the canal. Flow of water through each tunnel is regulated by radial gates. At maximum lake elevation, 478.5 m, water was discharged under 9.1 m of pressure head directly through the tunnels and into the irrigation canal.

Sampling stations 7, 8, 9, 10, and 11 were located in the lake near (Fig. 3) the irrigation outlet to aid in additional sampling of the fish populations in and around the barrier net.

Billy Clapp Lake (Long Lake Reservoir) was included in the 1978 creel census and kokanee stock assessment with Banks Lake (Fig. 4). Billy Clapp Lake is a 405 ha (1,000 ac) equalizing reservoir 16.9 km (10.5 mi) downstream from Banks Lake on the main canal. The shoreline is composed of vertical cliffs which limit public access to two launch areas. Both access areas are maintained by the Washington Department of Game. One access area is located at Summer Falls State Park at the north end of the lake while the other is located near the reservoir outlet at the south end of the lake (Fig. 4).

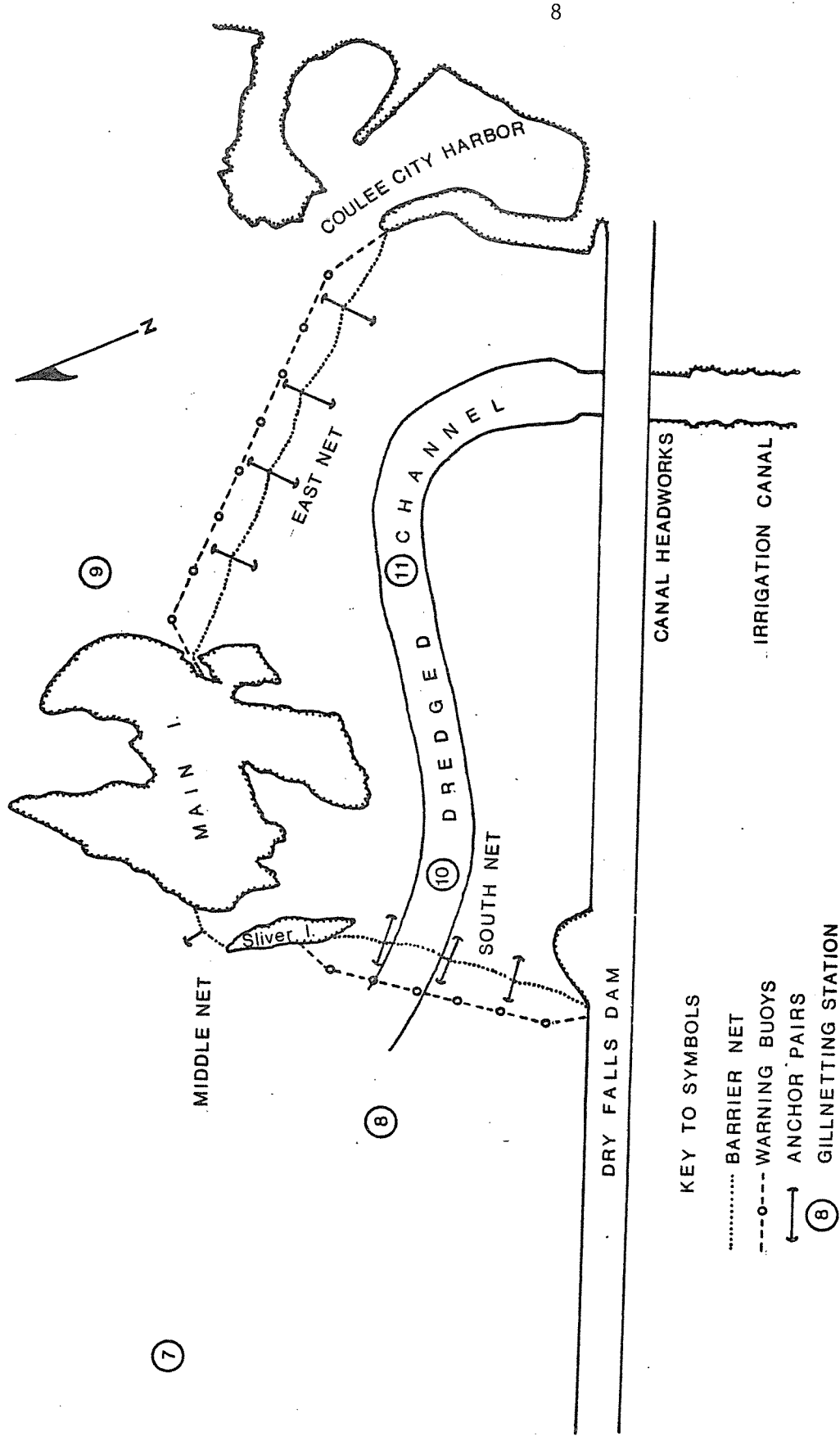


Fig. 3. Southeast corner of Banks Lake showing locations of barrier nets, anchors and gillnet sampling sites.

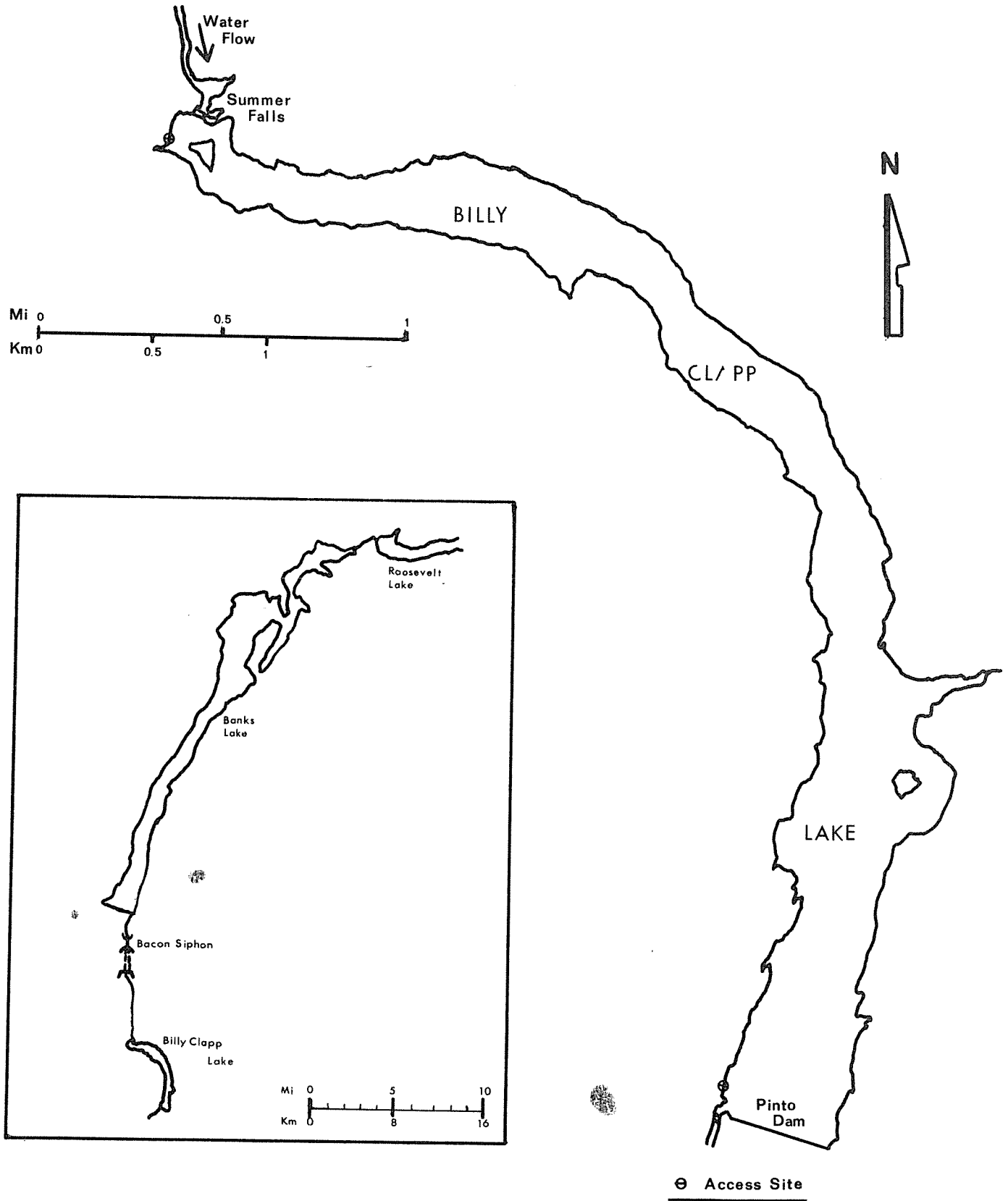


Fig. 4. Geographical location and features of Billy Clapp Lake in relationship to the upper Columbia Basin reservoir and canal system.

5.0 MATERIALS AND METHODS

5.1 Barrier Net Development and Operation

5.1.1 Site Selection

The selection of the barrier net site was a compromise between conflicting factors, some of which favored a location distant from the outlet and others which favored a location near the outlet. Setting the net at greater distance from the outlet meant contending with less current, a more regular bottom contour and better anchoring security. Those factors favoring less distance were decreased cost of the net, less interference with boat traffic and with shoreline anglers on Dry Falls Dam. The final choice was made in favor of the anchoring security which was afforded by interconnecting the net with two small offshore islands. This was done by dividing the net into three segments, east, middle, and south.

Preliminary soundings of the general net sites were made using a recording fathometer during October 1976, to determine the suitability of the bottom contour. The east net site was determined to be very suitable because of its moderate depth (9.7 m maximum) and uniform gradient without ledges or abrupt depth changes (Fig. 5). The south net site was less suitable because of its greater depth (17 m maximum), presence of a dredged channel, and because of 3-m ledges existing near both ends. The small channel between the two islands was less than 3-m deep and uniform as long as the net was set with a slight westerly bow in order to follow a shoal between the islands.

The cross-sectional bottom contour between specific attachment points for all three nets was sounded through the ice during February 1977 in order to obtain an accurate series of length and depth measurements (Fig. 5). Detailed contour maps were drawn of the three net sites for use in construction of nets to fit the cross-sectional openings.

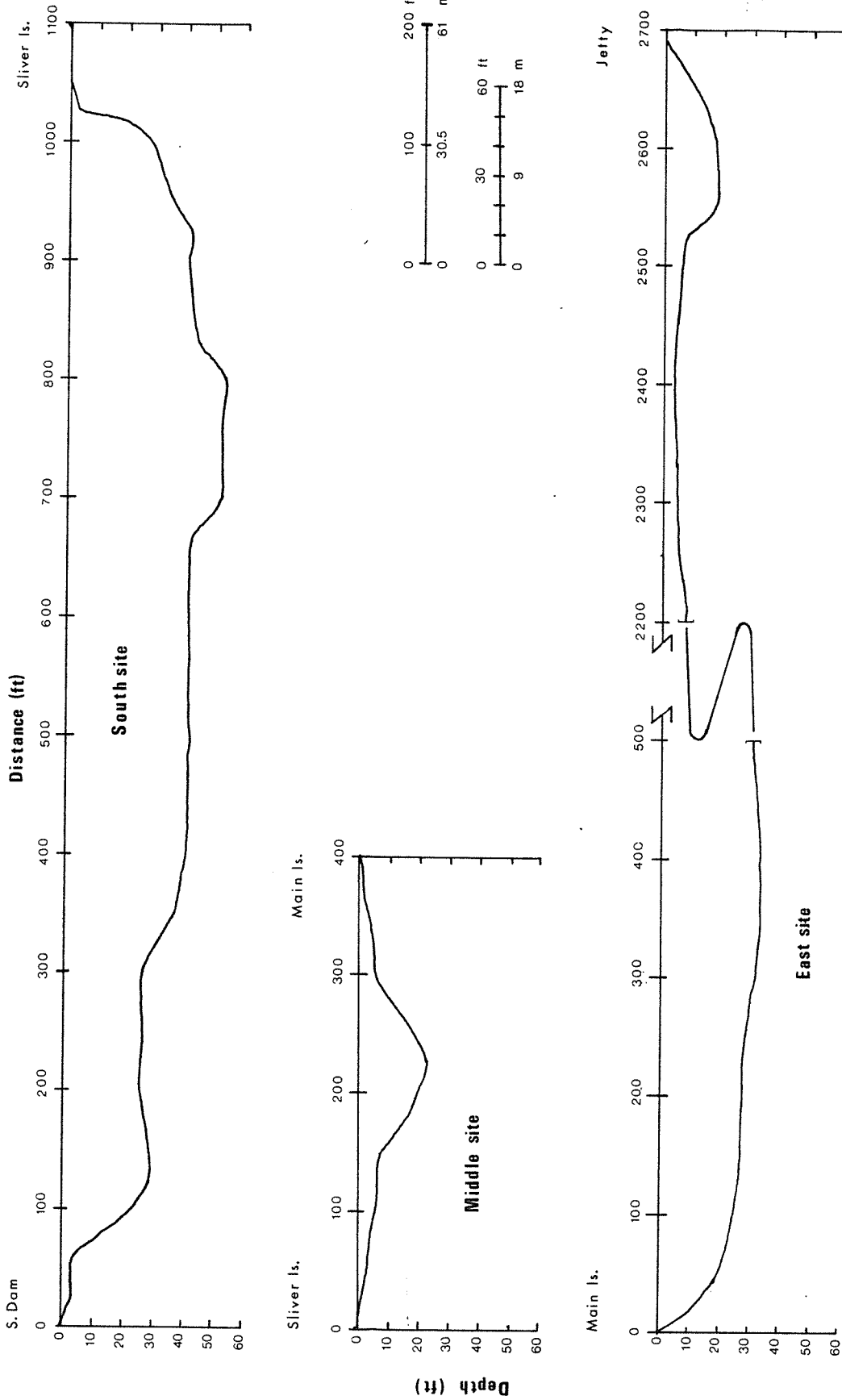


Figure 5. Channel cross-sections where the south, middle and east barrier net sites were located in Banks Lake. The middle 1700 ft. of gradual sloping bottom was not illustrated for the east site.

The nets were designed larger than the cross-sectional openings with the south net measuring 379 m (1,250 ft) by a maximum depth of 24 m (78 ft). The middle net was 126 m (415 ft) by a maximum 8 m (25 ft) deep. The east net was 859 m (2,835 ft) long by 12 m (38 ft) deep. The south net was most difficult to fit due to the rapid increase in depth near each shore and the excavated channel which created an abrupt change in bottom contour.

Shoreline attachment points for the ends of the nets were installed by the Bureau of Reclamation at specified locations. The attachment points on Dry Falls Dam, and the two islands consisted of holes drilled into bedrock at 478.5 m elevation into which 20-cm, eye bolts were set with epoxy plastic. The attachment point on the jetty at Coulee City Harbor consisted of a deadman embedded in the east slope of the jetty with a cable running through the jetty and emerging on the west slope.

Large, highly visible steel buoys were placed by the Bureau of Reclamation immediately outside the barrier net site at about 60-m intervals across the east and south channels as a warning to boaters (Fig. 3). A 1,450-m cork line strung with 15-cm diameter by 20-cm polystyrene floats was stretched between the steel buoys from shore to shore as a positive deterrent to boaters.

5.1.2 Design and Construction

A net was designed to fit the bottom contour of each opening with 10 % added to ensure surface-to-bottom fit. The net material used in construction was 83-mm (3 1/4-in stretched measure) 16-thread knotless dacron. This mesh size was selected because of its low resistance to current and low fouling rate compared with smaller mesh sizes. The estimated life expectancy of the net material is three years.

Body depth and girth measurements of kokanee were compared with various mesh sizes to determine the largest mesh which would exclude adult

kokanee. These comparisons determined that the largest of age II kokanee and age III and IV kokanee (25 cm fork length) could not physically pass through 83-mm mesh. However, if kokanee entered the mesh, they could be caught and held (gilled) anterior to the dorsal fin. A low incidence of gilling was anticipated because of the tendency of salmonids to lead along a visible net without attempting to pass through the mesh.

The visibility of the net was enhanced by treating the net with a clear preservative to maintain the white color of the material. After installation of the net, visibility was maintained by washing accumulated periphyton from the mesh at regular intervals.

The net was hung with 13-mm diameter double-braid nylon cork and lead lines. Weight was added by attaching 5-mm chain along the entire length of the lead line. Polystyrene corks measuring 76 mm diameter x 102 mm long were spaced on 30.5-cm centers along the length of the cork line, except along a 46-m section of the south net which spanned the dredged channel. Corks in this section were spaced on 15.2-cm centers to provide extra flotation where the current was expected to be strongest.

The net was held in position by the shoreline attachments and by anchors attached at intervals to the lead line (Fig. 3). These anchors were 27-kg kedges placed in pairs, with one anchor of the pair upstream, and the other anchor downstream from the barrier net and joined by 27-mm polypropylene lines. The joining lines varied in length from 30 m to 60 m, depending on the water depth at the point of installation. A ring attached midway in the joining lines served as a means of connecting and disconnecting the anchor pairs to the lead line (Fig. 6). This feature and the wide spacing between paired anchors was necessary to permit the net to be lifted out of the water for cleaning. The anchor lines were positioned at 83-m intervals along the south net (three pairs) and at 166-m intervals along the east net (four pairs). The anchors were each stabilized against dragging by adding 6 m of 13-mm anchor chain between the anchors and the joining lines. The initial placement of the anchors

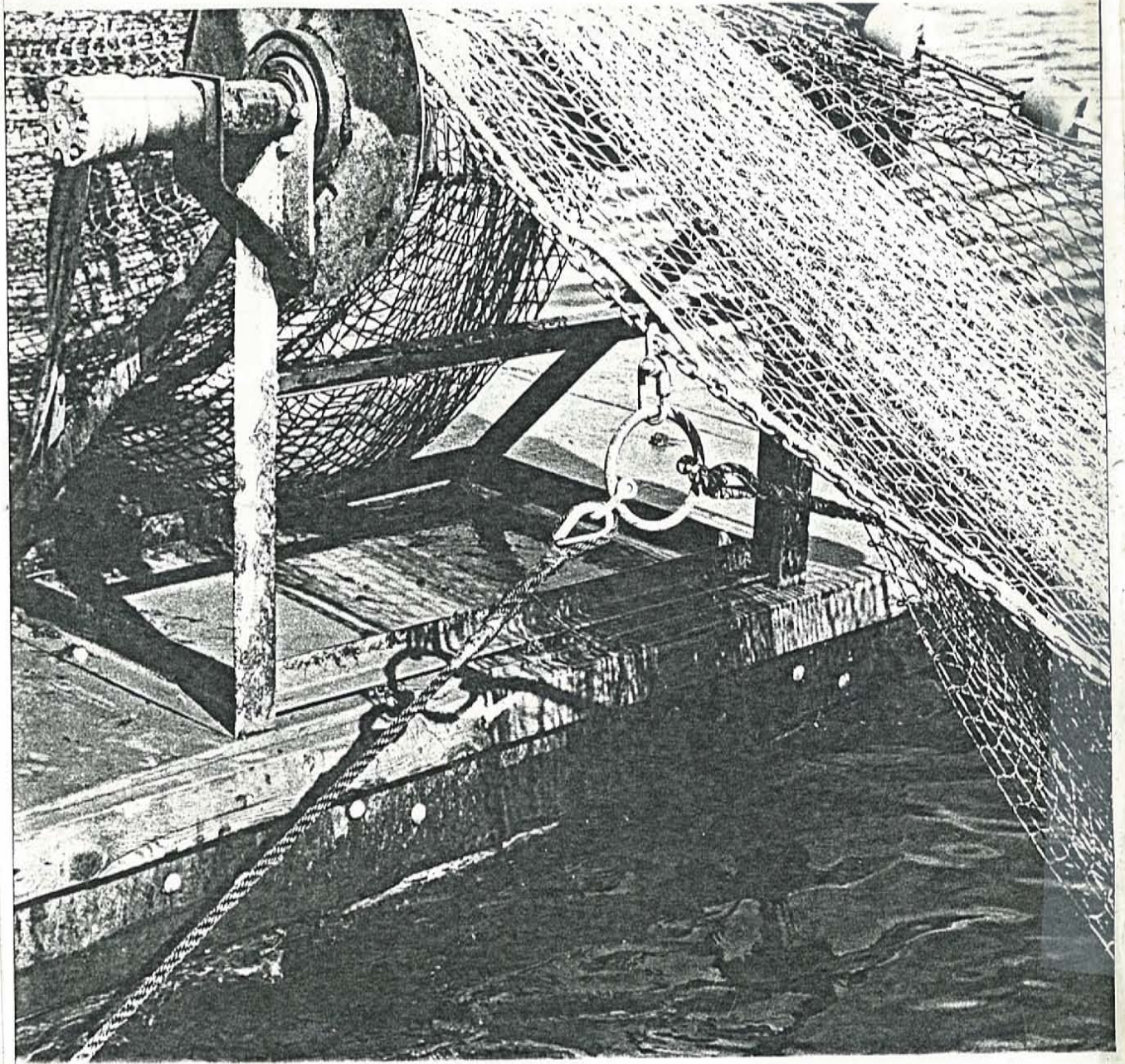


Fig. 6. Stern of the net cleaning barge showing the hydraulically powered roller, the cleaned net and the connecting ring which coupled a pair of anchors to the chain lead line.

and subsequent adjustment of their positions was facilitated by surface-buoyed lines attached to one fluke of each anchor.

5.1.3 Cleaning Gear and Procedure

The net cleaning process was mechanized as much as possible to minimize the labor requirements (Fig. 7). An 8-m flat-bottom fiberglass work boat was procured from Raider Marine Corporation, Anacortes, Washington, by the Bureau of Reclamation for use as a platform on which the gear was mounted and operated. A mast with a boom was mounted on the port side 3 m from the bow which required design modification of the boat hull. A 2.8- x 4-m raft constructed of wood and styrofoam was attached to the stern of the work boat for net-cleaning. The cleaning gear consisted of a 25-hp gas engine coupled directly to a hydraulic pump which circulated oil to three hydraulic motors. One motor powered a V-notch roller (power block) which was suspended from the boom and could be lowered and raised by operating a hand winch on the mast. The power block was used to pull the work boat and raft either forward or backward along the net. A second hydraulic motor powered a wide flat, stern roller mounted on the raft which pulled the net down the length of the work boat and raft to the stern where it was released to fall back into position. In 1977, to increase the net-pulling capability of this roller, four wooden strips were attached across the width of the roller and the entire roller surface was covered with deep-pile carpeting. In 1978, the stern roller was further modified by building two ridges near each end of the roller. The ridges were formed by wrapping the roller with used polypropylene line cemented in place by epoxy. The used line had a rough surface which provided proper friction on the netting. The purpose of this modification was to mechanically separate the cork line from the leadline, each outside a ridge, so that the netting was more exposed to the water spray. A third motor powered a piston water pump which delivered water under 63.2 kg/cm^2 (900 psi) pressure to two hand-operated spray nozzles which were used to remove aquatic weeds and algae from the net.

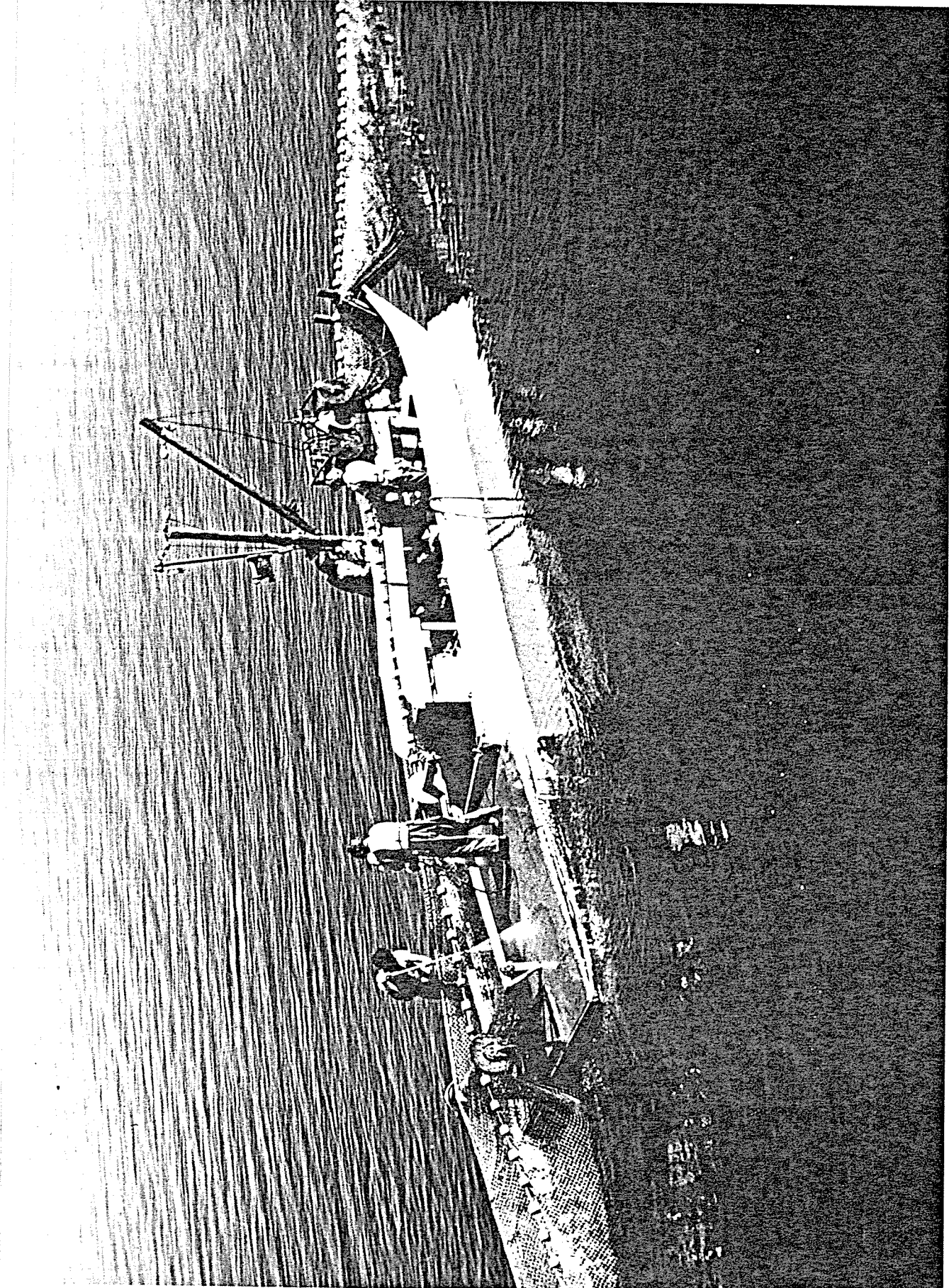


Fig. 7. Apparatus used to lift and clean the barrier net in Banks Lake.

Spray removal of periphyton from the net was further aided in 1978 by adding an elevated, screened platform down the center of the raft. This screen held the netting off the deck and improved the cleaning action of the water sprays.

Additional rollers for guiding the net were positioned at the bow and stern of the work boat and two intermediate guide rollers were positioned atop the net just fore and aft of the power block. With the power block raised in operating position, these rollers increased the degree of contact of the net on the power block and thereby reduced slippage.

The net-cleaning barge was towed by an outboard-powered boat into starting position within 15 m of one end of the net to be cleaned. The net was lifted manually to the surface and inserted into the rollers. Insertion of the net into the power block was facilitated by lowering the block to the level of the intermediate rollers. The block was then raised about 60 cm to operating height. The barge was then moved backward to the shoreline by reversing the rotation of the power block and power roller. Cleaning was begun and the power block control valve was adjusted to move the barge forward along the net at the rate of approximately 2 m/min. The power roller was adjusted to rotate at a slightly faster rate to maintain tension on the netting between the power block and the power roller. One person operated the hydraulic controls while another inspected the net for holes and removed any large debris and gilled fish. Two additional people operated the sprayers to clean the net.

The cleaning proceeded until the bow reached an attachment point of an anchor pair. The operation was halted while a dropline was attached to the connecting ring. The ring was then unshackled from the lead line and released. The cleaning was continued for one barge length, after which the connecting ring was pulled up by means of the dropline and reshackled to the leadline at the stern. An average of about 10 min was required to pass an anchor point. At anchor points situated in relatively high current velocity, such as midway along the east net, difficulty was

experienced in rejoining the net to the connecting ring of the anchor line because the current tended to sweep the net downstream while disconnected. The task of pulling the net back into position in line with the connecting ring was facilitated by towing the barge and net upstream with the outboard-powered boat.

The work boat provided was poorly suited for net cleaning and somewhat handicapped the operation. A more suitable platform would be a lightweight (wood and styrofoam) decked-over barge measuring approximately 3.6 x 7.3 m (12 x 24 ft) with at least 30 cm (12 in) of freeboard and a slightly raised bow for wave suppression during towing. The washing surface ideally should be fitted with gutters for collection and rapid drainage of wash water and debris.

5.1.4 Barrier Net Modifications in 1978

The principal loss of fish past the barrier net during its first year of operation occurred through gaps under the leadline of the south net. An evaluation of the effect of current on the net configuration and of the bottom features in the net vicinity suggested two ways to reduce the loss: 1) suspension of a curtain of netting beneath the leadline of the south net to screen the gaps; 2) moving the shoreline attachment of the south net on Sliver Island to achieve a tangential rather than a perpendicular abutment with a vertical underwater cliff.

In 1978 a net curtain was attached along the entire length of the south net. This continuous curtain ensured that all gaps would remain closed should the position of the barrier net be shifted inadvertently during cleaning. The net curtain measured 365 m long by 6 m deep and was constructed of the same dacron netting as the barrier net (83 mm, 3-1/4 in). A lead-core line measuring 10 mm dia. was attached by hog-rings to the bottom edge of the curtain. The top edge of the curtain was hog-ringed to the leadline of the barrier net.

The attachment of the south net to Sliver Island was changed to abut the cliff at Sliver Island tangentially rather than perpendicularly. This was done by lengthening the net 4.5 m and moving the attachment point of the north end 15 m west to the northwest end of Sliver Island rather than to near the south end as had been done previously. These changes caused the net to lay along the face of the cliff for about 20 m, in which distance the lead line gradually ascended from the bottom to the surface. Because the net merged gradually with the cliff at the point of intersection, fish leading in either direction from the net or from the cliff did not encounter an abrupt change of direction and were less inclined to attempt to pass through the net.

After the south net was set on May 18, scuba divers carefully positioned the curtain to screen all gaps in the steep slope areas at Sliver Island and near Dry Falls Dam. To avoid disturbing the net at these locations subsequent cleaning operations were halted about 50 m, from the shoreline and the ends were left uncleaned during the entire season. Although the netting in the ends accumulated considerable periphyton growth during the summer, the area fouled was too small to impair the function of the net. Initially, we had planned to inspect the fit of the barrier nets by scuba after each cleaning, but this inspection was determined to be unnecessary as long as the net ends were left in place.

The lake-level drawdown in spring, 1978, exceeded the depth to which the ends of the south net were protected by vinyl chafing netting. Because dacron netting abrades easily on sharp basalt rocks during wave action it was necessary to inspect and repair holes in the ends of the south net weekly during the period in the spring when water levels rose. Additional vinyl chafing material is needed on the south net to minimize wear during extreme drawdown.

The total cost of the net barrier including modifications was \$19,400. The combined cost of the equipment used for hauling and cleaning

the net (not including the work boat) was \$10,325. The corkline used to deter boaters was loaned by the Fisheries Research Institute for this study.

5.2 Barrier Net Evaluation

The efficiency of the barrier net in screening fish from the irrigation canal was evaluated by several methods. The principal method used in 1977 and 1978 was by sampling the entrainment of fishes in the irrigation canal. This information provided the most direct and accurate measure of fish passing the barrier net. Other methods tried in 1977 but discontinued in 1978 compared the density of fishes inside and immediately outside the barrier net by means of gillnetting and acoustic sampling. Additional evaluation techniques in 1978 included purse seine sampling, sonic tracking, creel census and stock assessment. These techniques provided information on population size, behavior, sport harvest and genetic background of the population, respectively.

5.2.1 Irrigation Canal Sampling

Sampling methods and gear for determining the entrainment of fish through the irrigation canal were similar to those reported in Stober et al. (1977) except that a new net was used for sampling the entrainment of small fishes. The irrigation canal was sampled during only part of the irrigation season in 1977 and 1978 because our objective was to evaluate the barrier net rather than to estimate the entrainment of fish during the entire irrigation season.

The primary net utilized in all years sampled an area 3.7-m square. It was constructed of 25-mm stretch No. 252 four-stitch knotless nylon and was suspended from a 4.3- x 3.8-m rigid frame (Fig. 7). The net and frame were raised and lowered in the trash rack slots at the canal headworks by means of a lift line through two double blocks which were suspended from an overhead cable (Fig. 7). Lifting power was provided by attaching the

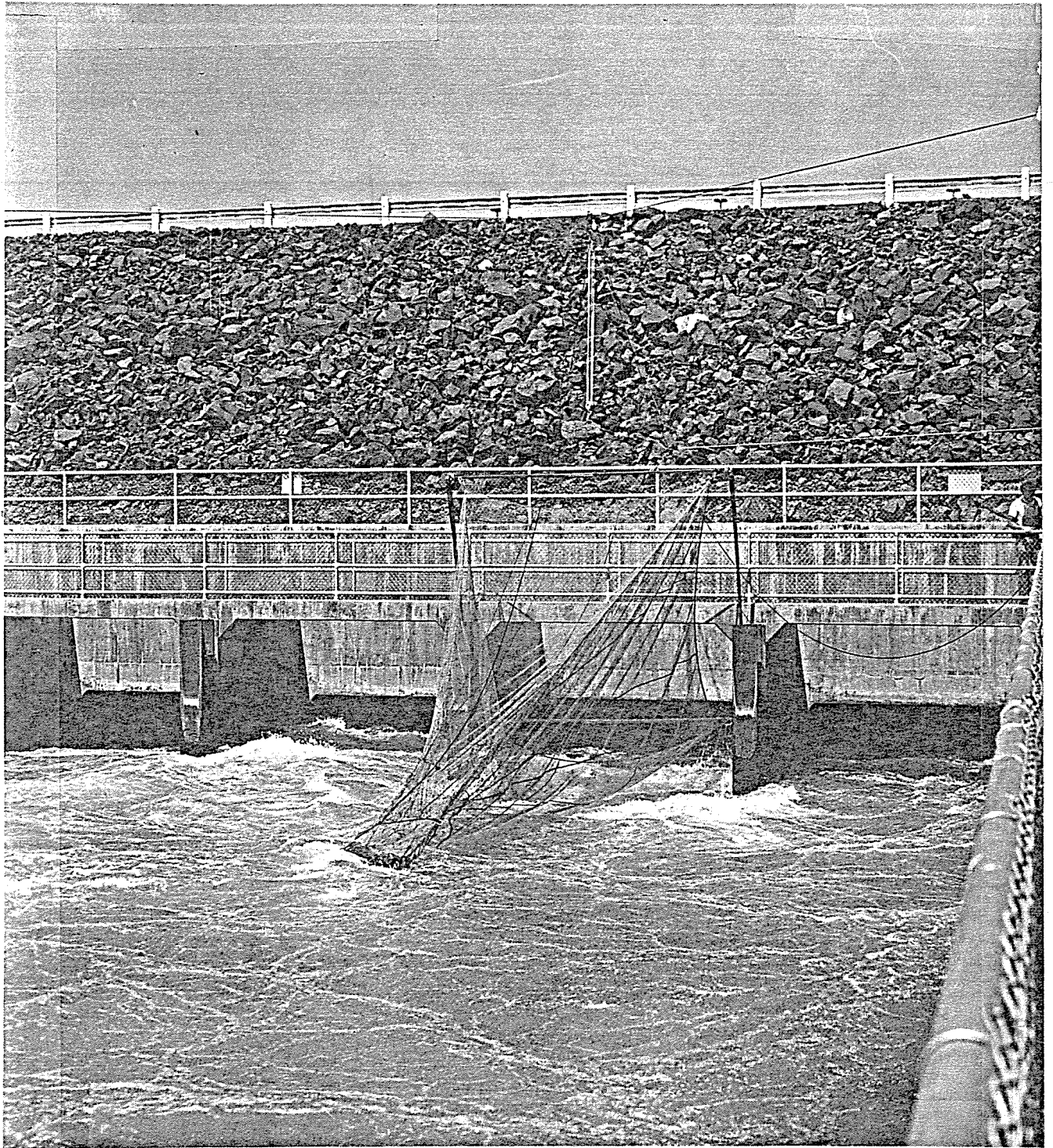


Fig. 8. Irrigation canal sampling net lifted for removal of catch.

lift line to a motor vehicle. These nets were fished in gates 1 (outside gate) and 4 (inside gate) in the 6-gate outlet structure.

In 1977, a method was devised to fish a 1.8- x 2.4-m net (similar construction as above) by suspending it downstream from the frame by cable warps 9.1 m long. This gear replaced the downstream gear used in 1975 and 1976 which was required during low volume ($< 100 \text{ m}^3 \text{ sec}$) high velocity discharge, characteristic of the early and late irrigation season. The primary advantage of the new gear was that it more effectively fished the turbulent flow and decreased the chance of fish avoidance. This gear was also used in 1978.

Since the objective of entrainment sampling was to evaluate the net barrier, the sampling in 1977 was not initiated until June 7, well after the beginning of the irrigation season but approximately one month before the barrier net was installed. Sample effort varied from 2 to 4 days per week, and the catch was removed every 12 hrs. During weeks in which the barrier net was cleaned in 1977, the canal nets were fished continuously throughout the week, in order to determine the effect of barrier net cleaning on the entrainment.

In 1978, the 3.7-m square nets were used in gates 1 and 4 from May 2 to September 11 and the 1.8-m x 2.4-m net was used in gate 1 from April 24 to May 4 and from September 12 to October 4. This sampling preceded installation of the barrier net by one month. The 1.2-m x 1.2-m net was not used because sampling in 1977 showed that the entrainment of age 0 fish into the irrigation canal was negligible and did not affect significantly the population size of any species.

Data were recorded and entrainment rates were calculated in the manner described in Stober et al. (1977). Entrainment rate estimates were corrected for the tendency of the nets in the two outside gates to catch more kokanee than the nets in the four inside gates. This differential was not apparent for any other species.

5.2.2 Purse Seine Sampling

5.2.2.1 Mark and Recapture. A mark and recapture program was implemented in 1978 to determine the movements of adult kokanee in the south end of Banks Lake and to aid in estimation of the spawning population. A purse-seine measuring 183 m (600 ft) long and 14 m (45 ft) deep was used to collect the fish for tagging (Fig. 9). The lead of the seine was constructed of 50.8 mm (2 in) stretch measure #12 knotted nylon and was 195 m (640 ft) long. The bunt end of the seine was constructed of 25.4 mm (1 in) stretch measure #12 knotless nylon, and was 9 m (30 ft) long. The selvage netting was 1.3 m deep and had a stretch measure of 152.4 mm (6 inch).

The purse seine was fished from June 16 through October 19, 1978 in the vicinity of the barrier net west of the Main Island and at Station 6 between Goose Island and the primary spawning area (Fig. 1). Exploratory purse-seining was also done in the vicinity of Million Dollar Mile in early August when kokanee catches were small at the other two sites. The range of the purse-seining operation was restricted to the south end of Banks Lake because the barge had to be towed, which was time-consuming and limited sampling to areas close to a harbor. The depth of the purse-seine (14 m) required at least an equivalent water depth to avoid snagging the bottom, which precluded sampling west of the Main Island between September 20 and October 18 during reservoir drawdown. Gillnet data since 1973 has shown that kokanee abundance was greatest in the vicinity of Station 6, therefore, restrictions on fishing location did not seriously limit the catch.

The purse seine was set and hauled using the barge raft and equipment described for barrier net cleaning, with the following minor modifications. The false deck (net table), used to guide the barrier net over the engine and hydraulic pump during cleaning was removed to increase work space needed for purse seining. A hydraulically powered capstan winch mounted on a small boom attached to the mast was used for pursing.

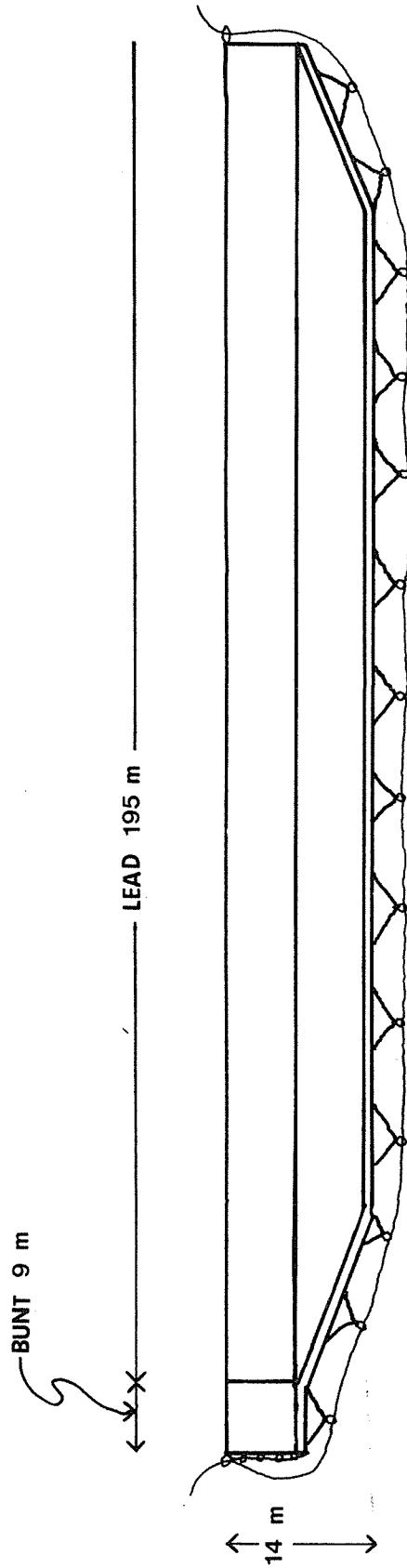


Fig. 9. Diagram of the purse seine utilized to obtain kokanee in Banks Lake for mark and release in 1978.

The raft normally towed behind the barge, was used as a stacking platform for the purse seine. However, during seining it was secured along the portside at the stern of the barge. Two outboard boats normally were used to set the net; one boat towed the barge from the starboard gunwale in a counter clockwise direction while the other boat towed the bunt end of the net in a clockwise circle back to the bow of the barge (Fig. 10). During setting, the net was watched closely by a crew member who prevented tangling of purse rings and purse line. After completing the circle, the bunt end of the net was taken from the towing boat and secured to the port bow of the barge. The towing boat was tied beside the barge.

One boat continued towing the barge from the starboard gunwale during the entire operation to keep the corkline from bunching and encircling the barge and raft. The net was pursed by hauling in the purse line over the capstan winch. When the net was completely pursed the purse rings were lifted out of the water and secured on a specially constructed pipe which suspended the rings at the gunwale (Fig. 11). The lead end of the net was then passed through the powerblock. As the net was hauled aboard the raft with the powerblock three crew members stacked the net while the fourth crew member operated the powerblock to control the rate of hauling. The catch was concentrated in the bunt section of the net during the final stage of hauling. Each fish was brailed individually with a dip net and processed.

All adult kokanee, except those to be tagged with sonic tags, and rainbow trout were anaesthetized in a solution of tricane methane-sulfonate, measured and tagged with a color-coded, numbered Dennison spaghetti tag. Two colors were used. Yellow tags were applied to fish caught near the barrier net. Orange tags were applied to fish caught in the area adjacent Station 6. Use of these two colors enabled identification of tagging location of fish which were later observed by divers on the spawning grounds. Stress due to tagging was low,

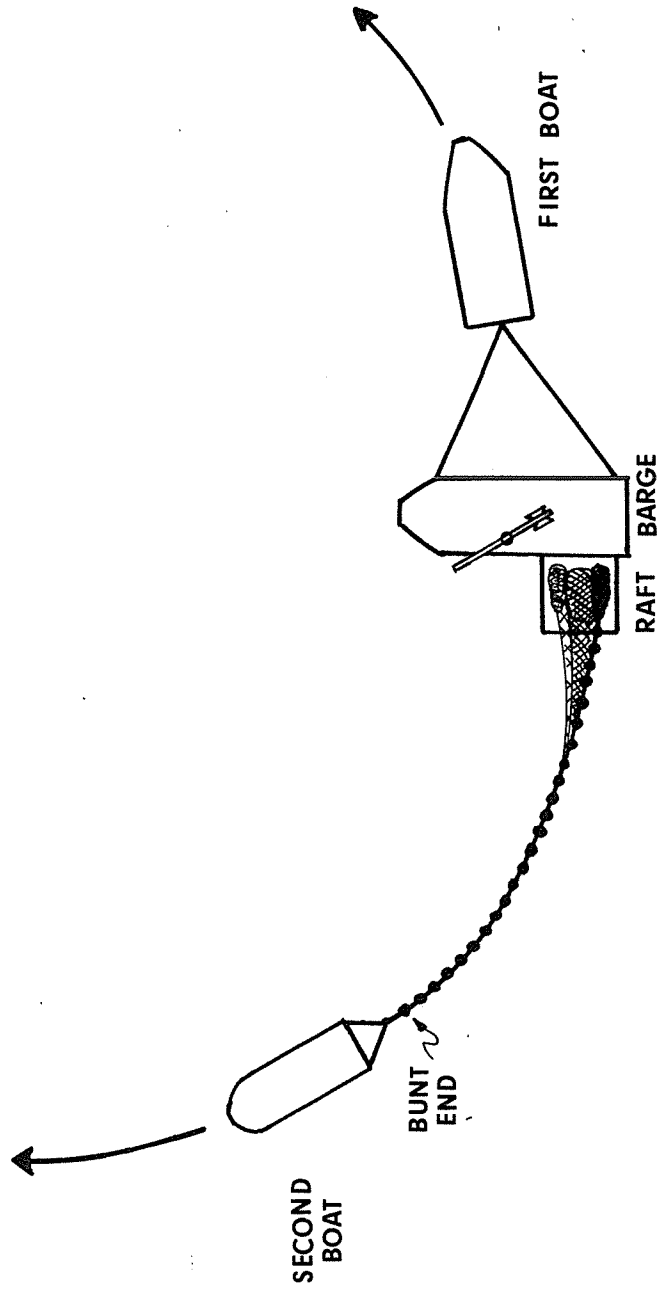


Fig. 10. Configuration of barge, raft and towing skiffs in the setting of the purse seine utilized in the capture of kokanee for mark and release.

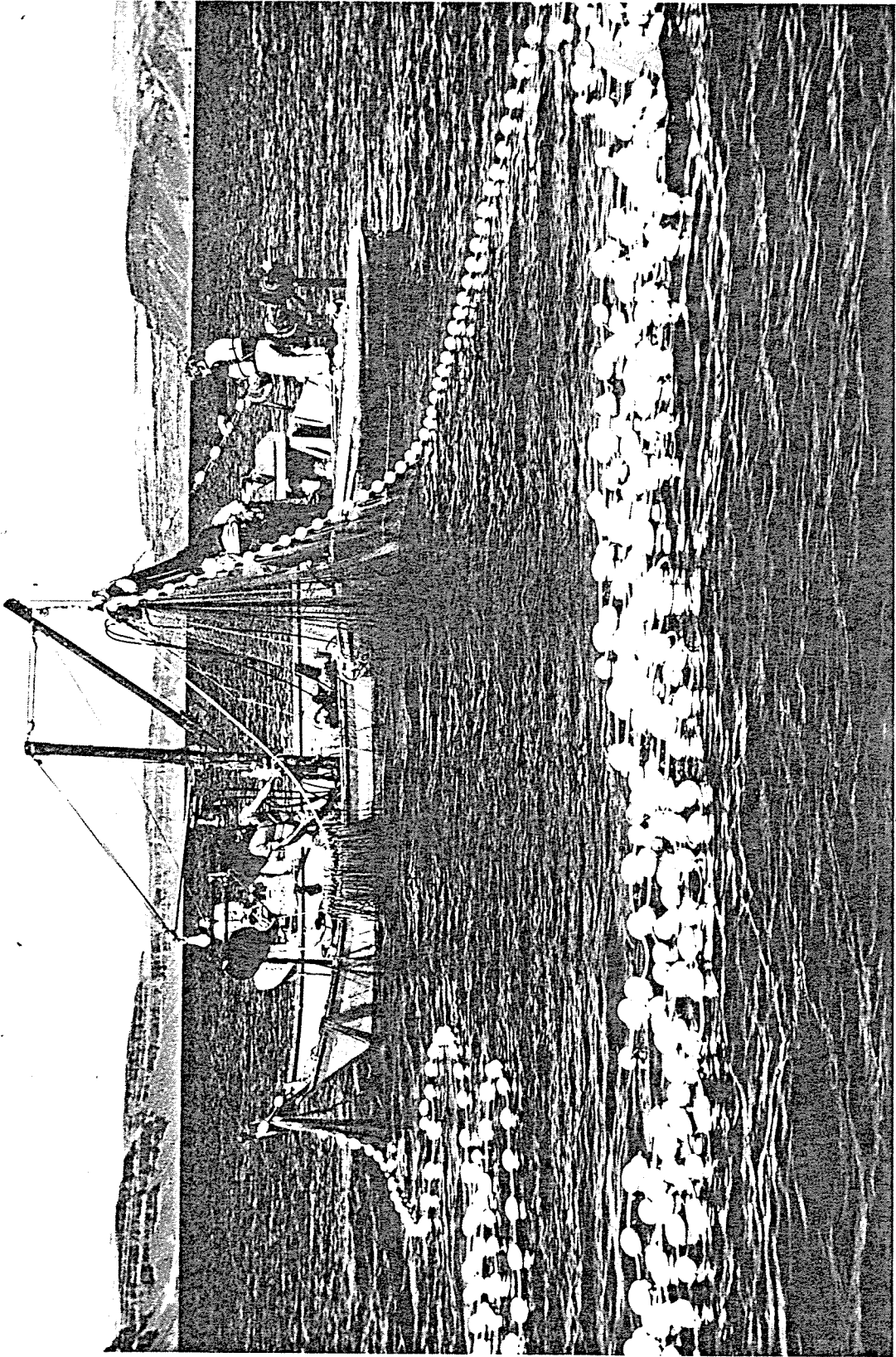


Fig. 11. Purse seining on Banks Lake, 1978.

apparently, because the fish recovered rapidly and short-term mortality was negligible.

Sub-adult kokanee and other species were not tagged, however, length measurements were obtained for all sub-adult kokanee and from a subsample of the lake whitefish and Rocky Mountain whitefish.

Tagged fish were recovered from a variety of sources, including purse seine, gillnet, fish gilled in the barrier net, spawner surveys and creel census interviews. In addition tag returns were encouraged by the placement of collection boxes at Coulee City Harbor, North Million Dollar Mile, Old Steamboat Rock, and the South Dam launch ramps. Questionnaires were supplied requesting that anglers report date, location caught, and tag number of recaptured fish. Numbers of tagged and untagged kokanee from purse seine and gillnet catches were used to estimate the population size. Recaptures from the other methods were used to describe general distribution and movement patterns.

5.2.2.2 Population Estimate. The population of mature kokanee was estimated using the Schumacher and Eschmeyer Multiple Census technique (Ricker 1975). The method requires that the population being estimated remains constant with no mortality or recruitment. The estimate was calculated for the adult kokanee population after Labor Day (September 5 through October 19), when only a limited sport fishery existed and fishing mortality was very low. Sport fishing usually declines after Labor Day. In 1978, the reduction in effort was drastic during the August-October reservoir drawdown which increased the difficulty of boat access. The catch of sub-adult kokanee in the purse seine was easily separable because there was no confusion at this time between mature adults and sub-adults.

The population estimate was calculated from the marked/unmarked ratio of adult kokanee from the purse seine and gillnet catches according to the formula:

$$\frac{1}{N} = \frac{\sum(M_t R_t)}{\sum(C_t M_t^2)}$$

where:

N = population size.

M_t = total marked fish at large at the start of the t^{th} day.

C_t = total sample taken on day t .

R_t = number recaptures in the sample C_t .

m = number of catches examined.

The standard deviation of $1/N$ was calculated as:

$$S(1/N) = \frac{s^2}{\sum(C_t M_t^2)}$$

where:

$$s^2 = \frac{\sum(R_t^2/C_t) - (\sum R_t M_t)^2 / \sum(C_t M_t^2)}{m-1}$$

Confidence limits for $1/N$ were calculated by multiplying the standard deviation by the appropriate t -value corresponding to $m-1$ degrees of freedom. The population size (N), was estimated by inverting the value obtained for $1/N$, and the 95% confidence limits for N were computed as the inverse of the confidence limits for $1/N$.

The confidence limits are not symmetrically distributed around N , because the calculation relies on inverting the estimate and confidence limits of $1/N$. The value $1/N$ is the slope of the line R_t/C_t plotted against M_t and passing through the origin, and its confidence limits are symmetrically distributed.

5.2.3 Sonic Tracking

Kokanee were captured with a 183 m purse seine either near Station 6 or west of the Main Island near the barrier net (Fig. 1). Releases were made at these two sites to determine if behavior patterns differed between the deep open water site at Station 6 and the shallow water site near the barrier net. Releases were made off both the east and south barrier nets in order to determine whether tagged fish behaved differently at the two sites. Higher water velocities prevailed near the east barrier and greater water depths existed in the channel of the south barrier.

Fourteen sonic-tagged kokanee in all were released between July 18 and October 3, 1978. Six sonic-tagged fish were released at Station 6, five off the west side of Main Island and three off the east barrier. A supply of kokanee for these experiments was not consistently available near the barrier; therefore, it was necessary at times to import kokanee from Station 6. Five individuals (2, 4, 9, 11, and 14) were captured at Station 6 and released near the barrier. These displaced fish were transported in 30 L plastic garbage cans and released 15-20 min after capture. All other releases were made at the point of capture. The sonic tagged kokanee were not anesthetized since this is known to alter behavior.

The tracking system consisted of a (Smith-Root) Model TA-25 sonic receiver coupled with a Model SR-70-H hydrophone. A PC-74 pulse counter was used to distinguish the pulse rates of individual fish tags. The Model SR-69 sonic transmitters (tags) emitted a frequency of 74 kHz with a pulsed repetition rate between 0.5 and 8.0 pulses per second. The sonic tags were attached externally. The first four tags released were attached each by a miniature alligator clip glued with Duco cement to one end of the tag and clipped to the posterior base of the dorsal fin. The transmitter was a cylinder 14 x 78 mm; addition of the alligator clip increased the length to about 90 mm. Total weight of the tag and clip was 22.6 g. Stomach placement of the tag was tested but resulted in rupture

of the esophagus and so was not used. Attachment with the alligator clip was discontinued after the first four tags failed to remain on the fish longer than four days. The remaining tags were attached by gluing a metal swivel eye to each tag. Attachment to the fish was made by inserting a loop of hollow vinyl tubing material through the skin under the dorsal fin with a curved needle. The vinyl loop was passed through the eye of the swivel and was then knotted securely. Attachment in this manner allowed the tag to dangle to either side which was probably less desirable, however, none were lost by the fish prematurely.

Transmitters were activated in the field just prior to attachment by twisting the wires together and coating them with silicone sealer. The tag was attached in a matter of seconds and the fish measured and released immediately. A 1.1 x 2.4 m drift drogue was released immediately following release of the fish and a sextant sighting using landmarks was made to initiate the track of both the fish and the drogue. The drogue design followed that of Ebbesmeyer and Okubo (1974) and was suspended at a depth of about 5 m.

The kokanee were tracked continuously during the daylight hours of the first day of release. The boat remained near the release point until the signal from the tag became directional and then was moved closer on a bearing obtained from the hydrophone until the signal became omnidirectional. Kokanee were followed by alternately waiting and moving up. The frequency of this maneuver depended upon speed of kokanee movement, range of tag, and weather conditions. The signal from the tag was highly directional from a distance, however, as the boat was moved to the location of the fish, the signal became omnidirectional and strong. The position was then recorded by sextant sightings of landmarks. The time interval between plots depended on the movement of the fish and varied from a few minutes to over an hour.

Position plots in open water were obtained with a sextant by measuring two adjacent horizontal angles between three landmarks.

Position plots near shore were occasionally determined by observing land features on a topographic map in addition to sextant sightings. Trackings were terminated for the following reasons: 3 tags ceased transmission due to malfunction, 3 tags were shed by the fish, and 8 tags exhausted the power supply. After the initial day of tracking the lake was searched at intervals to locate individual tags and plot their locations. A search pattern was conducted by running the length of one side of the reservoir and returning along the other while stopping to listen for tags at about 500 m intervals. When more than one tagged fish was at large in the lake at a time, the pulse counter was used for specific identification by comparing pulse rates determined prior to release of each tag.

Each track was plotted on a composite of USGS topographic maps at a scale of 1:24,000. A three-arm protractor was used to plot positions based on the sextant sightings, and field notes to locate other position plots along shore. Separate measurements were made of distance tracked during the first day and of subsequent distances tracked. These measurements underestimated the actual distances traveled because they did not account for lateral movement of the fish between locations. Initial and total swimming speeds were then calculated. The water current direction (degrees from true North) at the time of fish release was determined for comparison to the direction (degrees from true North) of initial travel of the fish.

5.2.4 Creel Census

5.2.4.1 Data Acquisition. The 1978 creel census data were collected primarily by personnel of the U.S. Fish and Wildlife Service. The data were analyzed by the Fisheries Research Institute.

The creel census was designed to be comparable with the 1971-1972 census by Duff and the 1975 census by Stober et al.(1976), therefore, similar methods of censusing and data analysis were employed. Each census was conducted by driving to the principal angler access sites at Banks and

Billy Clapp Lakes to check angler use and fishing success. The principal angler access locations included boat launch ramps and popular shoreline fishing areas within reach of access roads. The sampling days were apportioned equally between weekend days and weekdays in order to give the greater consideration to the weekend days during which the fishing effort was considerably greater. The census was directed primarily at the kokanee fishery which was limited to the summer months. Sampling was conducted on 58 days during the period April 10 through October 28, 1978. Sampling took place on two weekends per month and on two pairs of weekdays per month. Sampling times were established at 1300-1500 hrs local time to take advantage of the fact that boats tended not to return until late afternoon or evening and bank anglers generally did not begin fishing until mid- or late morning.

The census entailed driving from south to north, starting at Billy Clapp Lake and proceeding to the north dam on Banks Lake. The feeder canal and north dam area were inaccessible due to construction and were not sampled. The Barker Canyon boat launch also was not sampled because of its remoteness. All other access areas were sampled. The round trip averaged 70 mi and required from 2-5 hrs, depending on angler density.

The census data were recorded directly onto coding sheets under two general categories: interview and non-interview. Interview data were obtained during direct contact with anglers, while non-interview data pertained to such information as the number of empty boat trailers parked at a launch ramp. The data included the following information:

- I. General
 - A. Date
 - B. Location
 - C. Time

II. Interview Data

- A. Time fishing began
- B. Estimated termination of fishing
- C. Lengths and weights of catch, by species
- D. Number of anglers in party

III. Non-Interview Data

- A. Empty boat trailers
- B. Boats on trailers
- C. Empty car-top carriers
- D. Boats on car-top carriers
- E. Boats at the beach or dock
- F. Bank anglers not interviewed

5.2.4.2 Data Analysis (Boat Fishery). The analysis and reporting of the boat and bank fisheries was done separately because of marked differences in the seasonal timing and catch composition. The boat fishery operates principally during the summer months from April through September and concentrates mainly on kokanee and bass. The bank fishery operates throughout the year and concentrates mainly on perch, crappie, and rainbow trout (Stober et al. 1976).

The principal statistics presented herein are the catch per unit of effort (CPUE) and the estimated catch by species. The CPUE is expressed in angler-hours and both statistics are summarized by month and type of fishery.

Analysis of the boat fishery was hampered by lack of interview data because boat anglers could only be contacted within a few minutes of the time they returned to the launch ramp. Because of the difficulty in obtaining interviews, the non-interview data (empty trailers and boat racks) became a very important supplement to the boat fishery data. It was assumed that all empty boat trailers and empty car top racks

represented boats on the water. However, it was recognized early in the study that biases were inherent in the use of these data, therefore considerable effort was spent attempting to minimize bias by developing correction factors. For example, the empty trailer counts were an unknown fraction of the total boats launched for a given day. Thus, it was necessary to establish a rate of boat exchange. Also, since a variety of boating activities occurred on the lake, it was necessary to determine the percentage of boats actually engaged in fishing.

Actual percentages of the various boating activities were calculated by direct counts of the boats on the lake. These counts were made while on the lake in conjunction with other sampling activities and also from shore while traveling between access sites during the census. Counts were also taken during incidental driving trips along the lake. Whenever possible, counts were made during the same time as the creel census. Additional information on boat exchange rate was obtained monthly by recording the license numbers of all vehicles parked at the launch ramps at bi-hourly intervals throughout the day.

The following equations were used to calculate fishing effort and catch statistics:

$$E_e = BRAT$$

where:

E_e = Estimated fishing effort in angler-hours

B = estimated boats fishing during surveys

R = mean daily exchange rate of boats

A = mean anglers per boat

T = mean angler fishing time

$$C_e = E_e \times (\text{CPUE})$$

where:

C_e = estimated total catch

CPUE = observed catch per angler-hour

These statistics were calculated for each month. The boat exchange rate was not significantly different between areas, therefore, a mean figure of 2.0 was used for all areas.

The other principal boating activity was water skiing, which accounted for 11% of the launchings from June through September. This value was established from observations of boating activity on the water as well as from intensive censuses at the launch ramps.

5.2.4.3 Data Analysis (Bank Fishery). Calculation of the effort and catch statistics for the bank fishery was more direct, with one exception, than for the boat fishery because it involved principally interview data which were directly convertible into CPUE. However, where the boat interviews dealt with completed trips, the interviews of bank anglers were usually for incomplete trips. It was necessary therefore to adjust the angler-hours with correction factors when determining the estimated catch. This was done by asking anglers, during the interviews to estimate the termination time of their trip. The validity of this method was determined by Stober et al. (1976) who, in the 1975 creel census, distributed questionnaire postcards to bank anglers to fill out and return upon completion of their trips. The estimates of trip duration compared closely with the information from the questionnaire card returns. The interview estimates were more easily obtained and were considered an adequate basis for adjusting the mean angler-hours.

The following equations were used to calculate fishing effort and catch statistics for the bank fishery:

$$E_e = RAT$$

where:

E_e = estimated fishing effort in angler-hours

R = mean daily exchange rate of anglers

A = mean anglers observed and interviewed during surveys

T = mean daily angler fishing time

$$C_e = E_e \times (\text{CPUE})$$

where:

C_e = estimated total catch

CPUE = observed catch per angler-hour

The daily exchange rate among bank anglers in 1975 was determined by replicate census to be 1.5. In the 1978 census, with primary emphasis on the kokanee fishery, no effort was made to re-calculate this rate.

The mean fishing time per angler was determined to be 3.9 hours for both the boat and shore fishery. Catch and effort means were calculated monthly and sufficient data was obtained to calculate separate means for weekend days and weekdays. In the shore fishery, weekday effort was 1.7 times greater than weekend effort. The weekend effort for the boat fishery was estimated to be 1.5 times greater than for the weekday fishery.

5.2.4.4 Limited Creel Census 1977. Angler effort estimates were obtained for the south end of Banks Lake, from North Million Dollar Mile access area to the South Dam. The number of boats were counted by project personnel on daily drives along the lake and after work. Counts began on August 9, and terminated on October 21, 1977, and usually occurred at 7:30 a.m. and between 5:00 and 8:00 p.m. In addition, boat counts were conducted concurrently with gillnet sampling at stations 4-6 and water quality sampling at stations 1-6. These counts were made during midday from 10:00 a.m. to 3:00 p.m.

Estimates of catch per angler-hour were derived from voluntary angler returns of creel census questionnaires between August 27 and November 2, 1977. Creel census boxes containing questionnaires were placed at prominent locations in the harbor area of Coulee City Park and at North Million Dollar Mile access area for distribution and deposit of the completed forms. The following information was requested:

1. Date.
2. Number of people in party.

3. Hours fished.
4. Total fish caught, number of silvers (kokanee), blackmouth (chinook).
5. Comments.

The following equations were used to calculate fishing effort and catch statistics:

$$E_e = Bwd \times Et/Ewd \times A \times T$$

where:

- E_e = estimated fishing effort in angler-hour,
- Bwd = number of boats fishing during weekday surveys in 1977,
- Et/Ewd = ratio of total effort to weekday effort (based on 1975 census),
- A = average number of anglers per boat (2.7) (based on 1977 data),
- T = average angler fishing time in hr (6.3) (based on 1977 data),
- $CPUE = C_r E_r^{-1}$

where:

- CPUE = catch-per-unit-of-effort (hr),
- C_r = catch reported by anglers in creel census questionnaires,
- E_r = effort in angler-hour reported in creel census questionnaires.

These statistics were calculated on a monthly time basis. Effort statistics for 1975 and 1978 were adjusted to include only the south end of Banks Lake, from North Million Dollar Mile access southward, to facilitate comparison between the years.

5.2.4.5 Billy Clapp Lake. The methods utilized in the acquisition and analysis of data were the same as those applied to Banks Lake in 1978 with the following exceptions. Field sampling was limited to the only two public boat launch ramps on Billy Clapp Lake. The shore fishery was minimal due to the lack of accessible shoreline. Data on the exchange rate for both boat and shore anglers was insufficient for Billy Clapp

Lake, therefore, the exchange rates determined for Banks Lake were utilized in the calculations. Ski boats were not counted on Billy Clapp Lake, therefore, the Banks Lake value of 11% was used.

5.2.5 Kokanee Spawner Surveys

5.2.5.1 Pram Counts. A rapid means of surveying the 96.5-km (60-mi) length of potential spawning shoreline was developed in 1976 to identify the spawning locations and to estimate numbers of spawning kokanee (Stober et al. 1977). A plywood pram measuring 2.4 x 1.1 m was fitted with a 60-x 60-cm window of 6.35-mm plexiglass. A viewing cone constructed of 6.35-mm plywood was placed over the glass bottom to improve viewing efficiency by minimizing overhead light and glare. Viewing was done through a hole at the top of the cone which was cut to fit a diver's face mask.

A 12-volt electric motor with 5.9-kg thrust propelled the pram from the stern. Steering was designed to permit the viewer to maneuver the pram while viewing. During the weekly surveys, the shoreline was paralleled at a rate of about 0.6 m/sec. Numbers of live and dead kokanee, as well as the suitability of the substrate for spawning, were observed and noted.

The 1978 survey duplicated the sites surveyed in 1976 and 1977 except that a few sites with limited potential were dropped and the entire North pool survey, except for the feeder canal was deleted due to time limitations. The 1976 and 1977 glass-bottom pram lake-wide surveys were conducted during the peak of spawning. The 1978 survey was begun after the peak of spawning because of a delay in replacing a broken propeller for the electric motor.

5.2.5.2 Scuba Counts. Surveys of intensively spawned areas were conducted weekly by SCUBA divers. Data recorded included counts of live and dead kokanee, location, depth, temperature, secchi disc readings, and

area of spawning. All glass-bottomed pram and SCUBA surveys were conducted during daylight, usually between 1000 and 1500-hr.

In addition to the above surveys, an underwater sled was designed to tow divers slowly along the shoreline in order to increase the survey range. The plane (Fig. 12) was constructed of a longitudinal 2.4 m long 2 x 4 board. A 25 mm outside diameter galvanized pipe was mounted perpendicular to the 2 x 4 board, 15 cm behind the front of the sled. Control planes, measuring 28 x 46 cm, were attached to the pipe with swivel brackets for vertical control of the sled. At the tail end of the sled, a perpendicular 2 x 4, measuring 61 cm, was counted to support the diver's legs. The sled was towed about 5 m subsurface on 30 m of line behind a boat cruising at a speed of 1 m/s. The entire length of the South Dam and the Million Dollar Mile cliffs were surveyed by diving plane. The diving plane was also used to count kokanee at various depth contours in the prime gravel section.

5.2.5.3 Aerial Survey. An aerial survey of Banks Lake was conducted on November 1, 1978 to determine the feasibility of locating kokanee spawners. An overflight was made by Cessna 180 of the entire talus shoreline of the lake at a speed of 112 - 120 km/hr at altitudes varying from 30 to 60 m. Weather conditions during the survey were good; the water surface was calm, skies were partly cloudy and water transparency was 6.5 m. The visibility for spawners was found to be so limited as to preclude further surveys by air.

5.2.5.4 Spawner Population. The spawning population was estimated on the basis of SCUBA counts, expanded glass-bottomed pram counts, and counts from the aerial survey for comparison with the estimate obtained from mark and recapture. The estimate relied on expansion of the weekly SCUBA counts from the prime gravel section (PGS) to other areas where surveys were conducted less frequently. The spawner estimate at the prime gravel section was calculated according to Lewis (1972) and took into

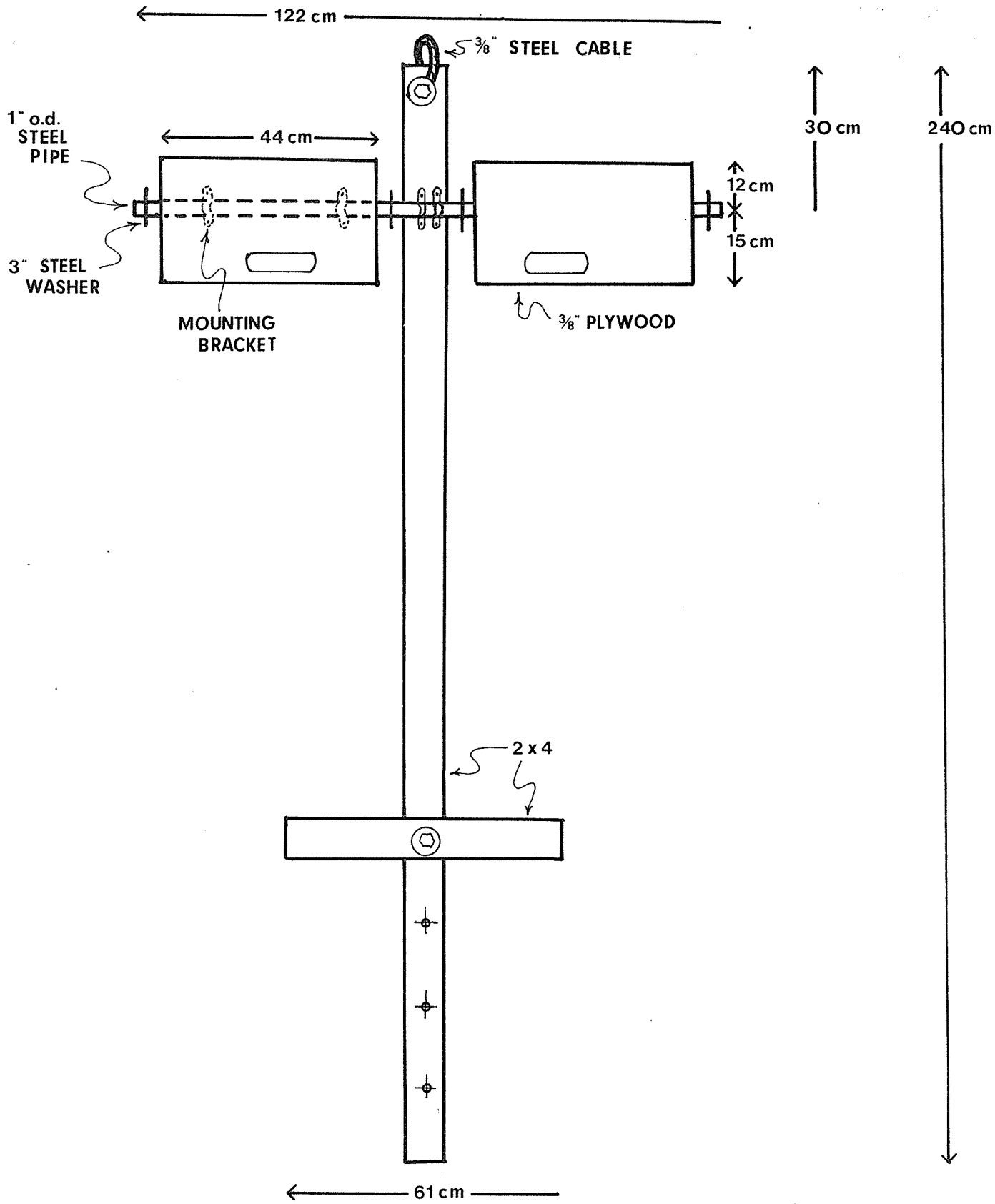


Fig. 12. Design of the diving plane utilized to tow a SCUBA diver during kokanee spawner surveys.

consideration the population size over time and the turnover time of fish on the spawning ground.

Weekly spawner counts for the remainder of the primary spawning area were made by glass-bottomed pram, which underestimated the population by a factor of at least 12.9 in 1978. The spawner population for this area was estimated on the basis of the ratio of maximum count by pram for the remainder of the primary area versus maximum pram count at PGS. The total estimated spawners in PGS multiplied by the above ratio equaled the total estimated spawners in the remainder of the primary spawning area.

Minor spawning concentrations outside the primary spawning area were sampled infrequently due to time required in surveying the large amount of shoreline. Spawner counts obtained in these locations were assumed to be maximum counts. These counts were expanded by the ratio of estimated population size at PGS to the maximum SCUBA count at PGS.

Limited scattered spawning occurred along the West shoreline and road bed fill along highway 155. These areas were subsampled once by glass-bottomed pram. The basis for expanding pram counts in these areas with low spawner density was provided by a comparative survey along the South Dam which indicated at low spawner density, SCUBA counts were 2.0 times larger than pram counts. The pram counts from the highway 155 and west shoreline sites were expanded by the factor 2.0 and corrected for the distance of potentially spawned shoreline versus distance sampled. This expanded value (C_{eh} or C_{ew} , below) was then expanded by the same factor as the areas of minor spawning concentrations to allow for turnover on the spawning grounds.

Mathematically, the population estimate (N) was:

$$N = A_1 t^{-1} + A_1 t^{-1} \left(\frac{C_2}{C_1} \right) + \frac{A_1 t^{-1}}{C_{\max}} (\Sigma C_s + \Sigma C_a + C_{eh} + C_{ew})$$

where:

A_1 = area under the curve of weekly SCUBA counts in prime gravel section plotted against time, measured planimetrically (49318)

t = average time spent by an individual on the spawning grounds (turnover time)

c_1 = maximum count by pram on the prime gravel section

c_2 = maximum count by pram on the remainder of primary spawning area.

C_{\max} = maximum count by SCUBA on the prime gravel section (3000)

C_s = SCUBA counts at minor spawning concentrations (Million Dollar Mile, South Dam, Coulee City Harbor, ta. 6-02)

C_a = aerial counts at minor spawning concentrations (Twin Falls, Steamboat Rock)

C_{eh} = expanded pram count for highway 155

C_{ew} = expanded pram count for West talus shoreline

The expanded pram counts (C_{eh} and C_{ew}) were calculated as:

$$C_e = (\Sigma c_p / \Sigma d_p) (C_{sd} / c_{sd}) D$$

where:

c_p = pram count for representative survey site

d_p = distance of survey site covered by pram

C_{sd} = SCUBA count for South Dam comparison area

c_{sd} = pram count for South Dam comparison area ($C_{sd}/c_{sd} = 2.0$)

D = distance of shoreline (4.0 km for highway 155 and 14.3 km for west shoreline)

5.2.6 Gillnet Sampling

During 1977, the fish densities immediately inside and outside the barrier net (stations 8, 9, 10, and 11, Fig. 3) were determined by semi-monthly gillnet sampling (see section 5.3) as a secondary means of evaluating the efficiency of the barrier net. An additional gillnet site established at station 7 (Fig. 3) was fished semi-monthly in 1977 and monthly in 1978 to provide information on fish density in the area between the South Dam and station 6. All fish caught were held in fresh condition for determination of life history information including length, weight, sex, age, and stage of maturity.

5.2.7 Acoustic Sampling

The acoustic techniques and data acquisition system used in 1977 were those developed by the Marine Acoustic Group at the University of Washington. These methods and equipment have been used extensively to gather acoustic data on fish stocks and have been described in detail by Thorne et al. (1972) and Nunnalee (1973).

During each survey, acoustic data were collected continuously along line transects in the survey area. The transects were located to enable comparisons of fish densities inside the barrier net (transects 1-3), outside the south barrier net (transects 4-7), and outside the east net (transects 8-10), with a deep-water area 3 km northwest of the barrier net (transect 11) (Fig. 12).

The acoustic data were analyzed by the technique of echo counting. Utilizing this method the magnetic tape upon which the data for the survey were recorded was played back through a tape recorder and the analog acoustic data record displayed on an oscilloscope. Fish target echoes were counted as they appeared on the oscilloscope. The peak amplitude and horizontal and vertical location of each target was also determined as the

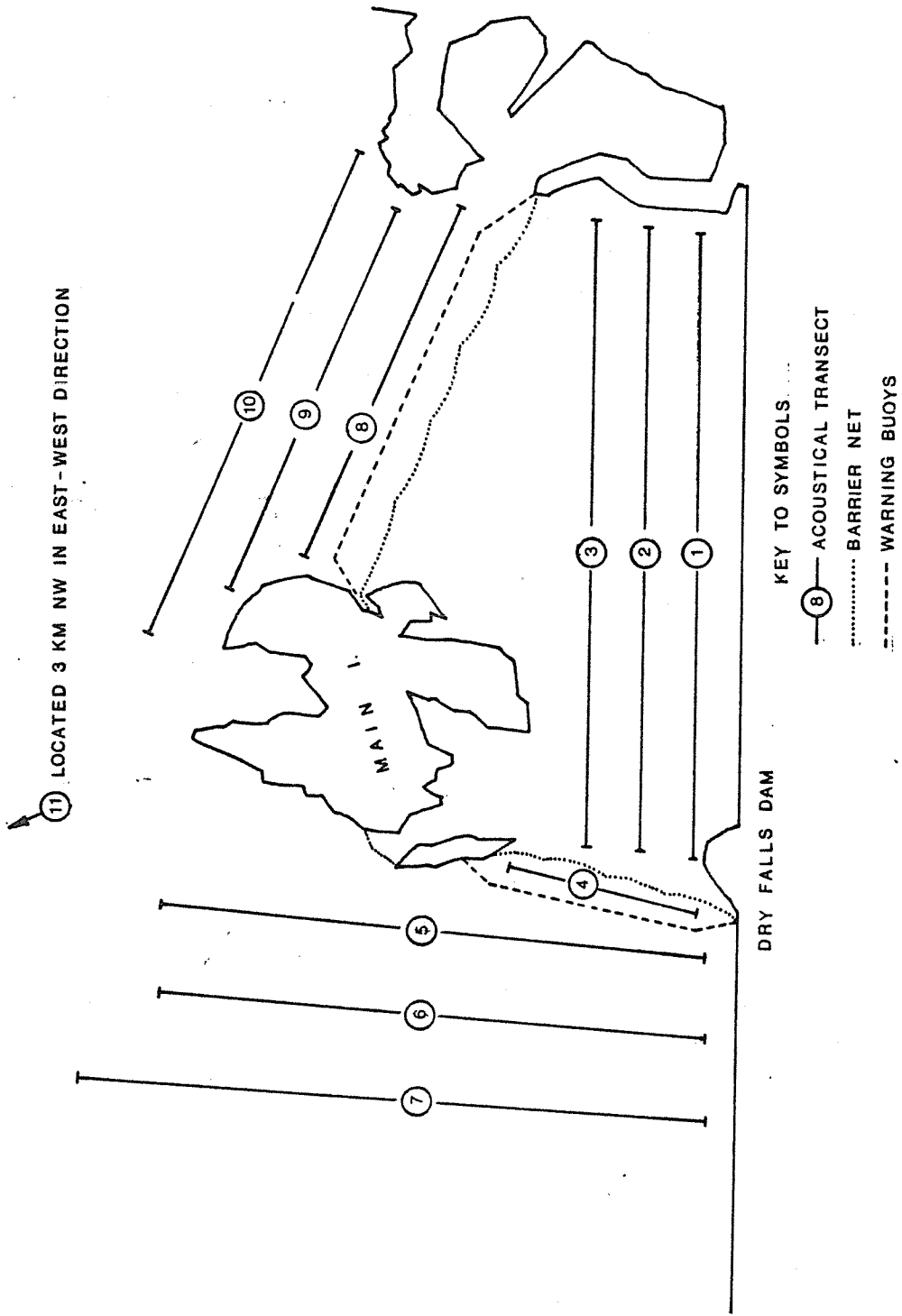


Fig. 13. Locations of acoustical transects near the barrier net in the southeast corner of Banks Lake.

target was counted. Sample volume and target densities were estimated using methods described by Forbes and Nakken (1972).

5.3 Fish Population and Water Quality Sampling

Gillnet sampling in 1977 and 1978 was continued at stations 4, 5, and 6 (Fig. 1) for the purpose of comparing fish population trends. Variable mesh nets 30.5 m long by 1.8 m deep, constructed of monofilament nylon in nine variable mesh panels ranging from 2.5 to 12.7 cm and graduated in increments of 1.3 cm, were set horizontally at the surface and bottom in the manner described in Stober et al. (1977). The gillnets were fished monthly during the summer and fall for two consecutive 24-hr periods. All fish caught were processed for length, weight, sex, age and stage of maturity.

During the gillnet surveys, Model 6D Hydrolab was utilized to measure vertical temperature, conductivity, dissolved oxygen, pH and oxidation reduction potential (ORP) profiles at each of the stations. This effort was designed to monitor the limited number of parameters in order to extend the baseline data on the reservoir which was initiated in 1973.

5.4 Kokanee Stock Assessment

Kokanee samples were collected by gillnet from three locations in the study area: FDR Reservoir, Banks Lake, and Billy Clapp Lake during the period from April to August of 1978. Additional samples were collected in the irrigation canal nets and spawning kokanee were collected from four different sites around Banks Lake during November of 1978. Muscle, liver, and eye tissues were removed, frozen and transported to the Fisheries Research Institute, University of Washington, for analysis. The soluble extracts from these tissues were subjected to electrophoresis following the methods outlined by May (1975). Three buffer systems were used to adequately resolve the twenty enzyme systems that were initially screened

for variations (Table 1). The enzyme staining solutions used were those described in Shaw and Prasad (1970).

5.5 Artificial Spawning Beds

In 1977, the Northwest Steelhead and Salmon Council of Trout Unlimited, Wenatchee Chapter, at the encouragement of the Washington Department of Game (WDG), set the idea of artificial spawning bed development in motion by providing the materials and manpower for the introduction of the gravel into the lake. The Fisheries Research Institute (FRI) research team located suitable areas for bed placement, guided the gravel barge into dumping position, and initiated a limited follow-up evaluation.

5.5.1 Site Selection

Site selection was based on several factors: bottom type, bottom grade, and accessibility. A reasonably solid substrate was necessary for gravel support while the grade had to be of a degree that would not cause the gravel to slide thus dispersing it too thinly. The site also had to be reasonably accessible to minimize barging. After several SCUBA surveys, two sites were selected. The south site was located in the southwest end of the lake approximately 3.2 km from the South Dam and 19 m offshore (Fig. 1). The north site was located along State Highway 155, 30 m offshore from a turnout 3.2 km south of the Steamboat Rock State Park access road. A gravel incubation box was also located on the north site.

The desired water depth of the beds was between 6.1 m (20 ft) and 9.1 m (30 ft). Approximately 38.3 m³ (50 yd³) of gravel was dumped at each site. The north bed ranged in water depth from 7.6 m (25 ft) to 9.1 m (30 ft) and measured 7.6 m (25 ft) wide and 15.2 m (50 ft) long. The south bed ranged in water depth between 6.1 m (20 ft) and 9.1 m (30 ft) and measured 4.6 m (15 ft) wide and 19.8 m (65 ft) long.

Table 1. Tissues and buffer systems used for enzymes examined in this study

Enzyme	Loci	Tissue	Buffer
Aspartate aminotransferase	AAT-1,2	Muscle	A
Aspartate aminotransferase	AAT-3	Eye	C
Alcohol dehydrogenase	ADH	Liver	A
α -glycerophosphate dehydrogenase	AGP	Muscle	B
Aldolase	ALD-1	Muscle	B
Creatine phosphokinase	CPK-1,2	Muscle	A
Esterase	EST	Liver	A
Glyceraldehyde-3-phosphate dehydrogenase	GAPDH	Muscle	A
Glutamate dehydrogenase	GDH	Liver	B
Isocitrate dehydrogenase	IDH-1	Muscle	B
Isocitrate dehydrogenase	IDH-2*	Liver	B
Lactate dehydrogenase	LDH-1,2,3,4	Muscle	A
Lactate dehydrogenase	LDH-5	Eye	A
Malate dehydrogenase	MDH-1,2*	Liver	B
Malate dehydrogenase	MDH-3,4*	Muscle	B
Malic enzyme	ME-1,2	Muscle	B
Peptidase	PEP-1,2	Muscle, Eye	A,C
6-phosphogluconate dehydrogenase	6PGDH-1	Muscle	B
Phosphoglucose isomerase	PGI-1,2,3*	Muscle	A
Phosphoglucomutase	PGM-1*	Muscle	A
Phosphomannose isomerase	PMI	Muscle, Eye	BC
Sorbitol dehydrogenase	SDH-1,2	Liver	A
Tetrazolium oxidase	TO	Liver	A
Xanthine dehydrogenase	XDH	Liver	A

Buffer systems used in this study:

- A. A discontinuous tris, citrate, lithium hydroxide, boric acid system (pH 8.5) described by Ridgway et al (1970).
- B. A continuous amine, citrate system (pH 6.4) described by Clayton and Tretiak (1972).
- C. A continuous tris, boric acid, EDTA system (pH 8.5) described by Markert and Faulhaber (1965).

*indicates genetic variations were observed in one or more populations of this study.

5.5.2 Gravel

The gravel consisted of two types: glacial granite for the north bed and gravel box, and crushed basalt for the south bed. Selection of gravel size was based upon the past experience of project personnel in observing kokanee spawning in Banks Lake. The gravel size selected was large enough to allow adequate interstitial water movement to ensure maintenance of dissolved oxygen (DO) levels necessary for egg survival and small enough for excavation of redds by kokanee. The percent size composition for each site was determined by washing gravel samples of known volume through standard Tyler sieves and determining the percent composition represented by each size in the sample volume. One sample from each site was analyzed.

5.5.3 Gravel Placement

The gravel barge consisted of 45, 50-gal drums supporting a platform and gravel hopper. The gravel capacity of the hopper was approximately 3.1 m^3 (4 yd^3). The craft was propelled and steered by two outboard-powered boats.

As gravel was loaded by power shovel it was washed with water pumped from the lake to remove excess sand and silt. Once the barge was positioned over the dump site by divers, a lever-operated chute was opened and the dumping was begun. A single pass over the area at low speed laid down a gravel strip several centimeters deep and about a meter wide. After several parallel passes, the area was crossed randomly to ensure a thorough covering of the site. A 30.5-cm (12-inch) gravel layer was desired, however, a variable depth averaging about 20.3 cm (8 inches) was achieved.

The gravel-filled egg-incubation box installed at the north site consisted of a 2.1-m (7-ft) x 0.9-m (3-ft) x 35.5-cm (14-inch) pine box with

slots in the sides and bottom to permit water exchange. The box was placed near the north gravel bed and filled with gravel by divers.

Gravel placement occurred on the following days: the north bed, October 10; the south bed, October 11 and 12; the gravel box, December 27, 1977.

5.5.4 Dissolved Oxygen

Dissolved oxygen samples were collected from the north site, south site, and primary natural spawning area on three separate dates during November, 1978 and at approximately 2-week intervals during the emergence period in spring, 1978.

Collection was carried out by two divers using a hand-operated rotary pump with an attached probe which was shoved approximately 10.2 cm (4 inches) into the gravel. Contamination of the water sample by water above the gravel was minimized by placing a sheet of plastic over the sample area and shoving the probe through it. On November 17 five intergravel water samples and five ambient water samples from above the substrate were taken at each of the beds. Analysis of the samples was accomplished by use of a dissolved oxygen meter as well as chemical analysis via Winkler titration in 1977, and by Winkler titration only in 1978.

5.5.5 Siltation Rate

Silt settling out of the water column was collected in wide-mouth jars measuring 80 mm in diameter. In 1977, packs containing three jars each were placed and leveled at the north site, south site, and primary natural spawning area according to the following depth and time periods: 7.9 m (26 ft) from November 4 to November 24, 6.7 m (22 ft) from November 3 to November 30, and 4.0 m (13 ft) from November 3 to November 30, respectively. Sediment jars were maintained at these sites from May 20 to

November 30, 1978. Shallow placement was necessitated at the primary spawning area by the steep slope and unstable gravel. The silt volume was measured after settling in a graduated cylinder. Measurements were converted to siltation rates (cm/day) for between-site comparisons.

5.5.6 Kokanee Egg Plants

Eggs were planted in the two artificial beds and the gravel box during the last week of December 1977. A total of 100,320 eyed eggs was planted with approximately 5,400, 32,000, and 62,400 each in the gravel incubation box, south site, and the north site, respectively.

Eyed kokanee eggs were obtained from the Washington Department of Game (WDG) Lake Whatcom Hatchery on December 27 and transported to Banks Lake on the same date. During transportation, and until shortly before the eggs were planted, they were contained in a standard egg-transport box provided by WDG. Inside the box, the eggs were contained in three trays, wrapped in wet burlap and packed in ice. Considerable care was taken to maintain the temperature of the eggs at 1°-2° C.

The eggs planted each day were transferred to 500 ml stoppered bottles containing approximately 2,000 eggs each. Initially, two divers dug planting trenches in the gravel beds. The trenches were usually dug downslope by one diver followed by a second who widened and deepened the trenches to approximately 10 cm (4 in). Once all the trenches were dug, one diver poured eggs from the bottles into the trenches while the other followed, filling the trenches. The trenches were slightly mounded, so the actual planting depth was about 12.5 cm (5 in). The eggs at the north site were planted deeper than at the south because the gravel layer was thicker.

The eggs were planted in the gravel incubation box in two densities; at one end 1,800 eggs were planted in four 1 m rows (2,143 eggs per m²), and at the other end 3,600 eggs were planted in three 1 m rows (4,286 per m²). A 1-ft center space was left to separate the two densities.

During the kokanee spawning season, counts of live and dead kokanee were made by SCUBA divers on both artificial beds and the primary natural spawning areas.

5.6 Fry Sampling

5.6.1 Fry Trap Development

The present fry trap design was based largely on experience gained from the construction and testing of fry traps in 1976 during a preceding contract. During February 1976, 100 emergent fry traps were deployed over the primary kokanee spawning area. These traps were constructed of low-cost wooden frames and plastic screen and sampled an area of the bottom 1 m^2 . The traps were constructed inadequately to withstand the effects of rockslides and wave action and all traps were destroyed. Based on this experience, a fry trap constructed of more durable materials was developed in 1977.

The trap was conical for maximum resistance to rockfall, gravel slides, and wave action. The cone was constructed of 20-gauge galvanized sheet metal (Fig. 13). The bottom edge of the cone was turned out to form a 5-mm lip for rigidity and to engage rocks which were piled against the outside for added stability. The cone measured 56.4 cm diameter by 48.8 cm high and sampled $1/4 \text{ m}^2$ of substrate. The slope of the cone was 60° , for efficient leading of fry into the cod-end (Collins 1974), and good stability. An opening at the top measured 12 cm diameter. A removable cod-end, which fitted over the opening, incorporated several features enabling SCUBA divers to replace the cod-end easily without disturbing the cone. The cod-end was quickly and tightly attached and detached by means of two draw-pull catches. A fyke was built into the cod-end which prevented the catch from escaping while the cod-end was being replaced and transported underwater. The catch was easily removed at the surface by unscrewing a cap and pouring out the 2 liters of contained water.

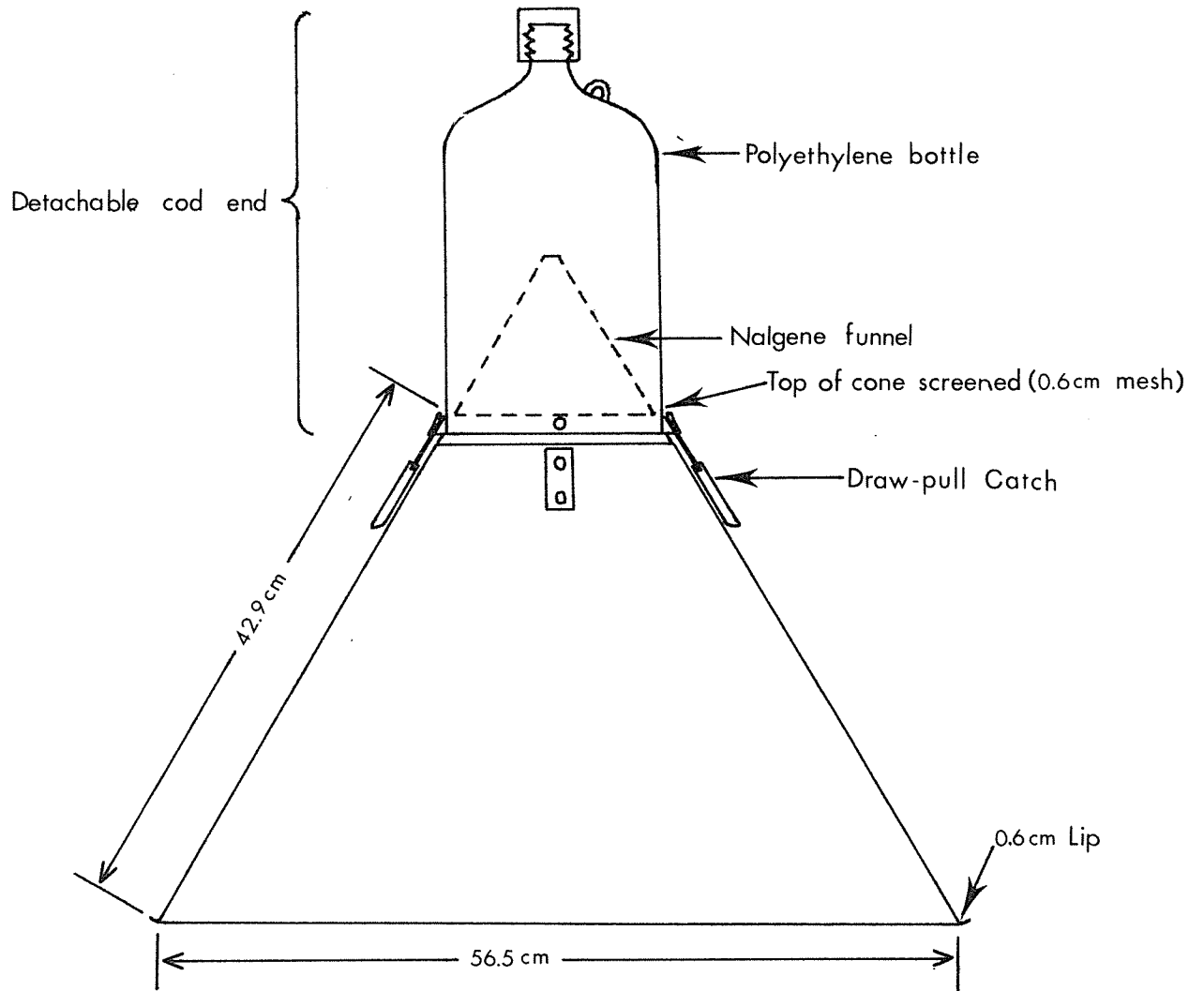


Fig. 14. Kokanee fry emergent trap with detachable cod end.

The cod-ends were assembled from available heavy-gauge plastic products; a 2-liter polypropylene bottle from which the bottom was removed, and a polyurethane funnel with a slope which closely matched the slope of the cone. The stem of the funnel was cut to an opening of 16 mm and inserted into the cutaway bottom of the bottle to form a fyke. The bottle and funnel were joined by pop rivets.

On March 11, 1977, 40 traps were emplaced over the primary spawning area by divers. The cod-ends were exchanged weekly until June, by which time emergence had ceased. The contents of the cod-ends were poured through a strainer and all organisms captured were preserved in 5% formalin.

After several weeks it became apparent that sculpins were trapped along with the fry and constituted a source of error because fed on the fry. Most of the cod-ends were subsequently screened by placing wire mesh over the top of the cone between the cone and the cod-end. The mesh was of stainless steel with 5-mm square openings. Some of the traps were left unscreened in order to determine the effects of screening on the catch rates of sculpin and fry. To facilitate this comparison, half of the traps which were placed over the natural spawning area were left unscreened in 1977.

Tests were conducted to determine whether the presence of the traps decreased the dissolved oxygen content of water inside the cone or within the underlying substrate. This was determined by inserting standpipes into the gravel inside and outside of five traps. Dissolved oxygen readings were read from a meter at the surface while a diver lowered the probe into each of the standpipes. No difference was found between the two readings.

To test the effect of ventilation holes in the cones on dissolved oxygen, five cones were ventilated by cutting 12 holed each of 5-cm diameter near the base. The holes were screened to prevent the escape of

fry. The dissolved within the ventilated traps was measured on two occasions for comparison with measurements taken from the unventilated traps. Again, no difference was found and later traps were constructed without ventilation holes.

5.6.2 Trap Deployment

The successful use of the emergent fry traps in 1977 prompted a more intensive sampling program in 1978 involving the construction and employment of 45 additional traps. These were constructed similarly except that ventilation holes were omitted and a more positive throw type latch was used to secure the cod-end. The new traps were employed in groups as they became available from the builder. Consequently, the schedule of trapping was complicated by the varied number of traps during the early period of emergence.

On March 17, 1978, traps were placed on the north gravel bed, 2 were placed on the gravel incubation box, 10 traps were placed on the south bed and 6 traps on the primary spawning area. On March 31, all 10 traps on the south gravel bed were relocated to correspond better with the area in which the eggs had been planted, and a tenth trap was placed on the north bed. Ten more traps each were set in place on April 19 at the north site and on April 20 at the south site and primary spawning areas. Trap cod-ends were checked weekly through the season.

5.6.3 Natural Substrate Analysis

The size composition of the gravel in the prime gravel section was determined by sampling along each of 6 transects to define vertical and horizontal compositional changes. A table of random numbers was used to determine the shallowest depths to be sampled on each transect.

Successive samples were taken by 1.5 m increments of depth to 10.4 m, working from deep to shallow to minimize the impact of gravel slides in the samples. Scoop samples were obtained by divers who attempted to dig substrate samples to a depth of 15 cm. The gravel was contained in a 7.6 L bucket at the end of a graduated line lowered from a boat. The graduated line was also used to establish the depth of the sample. Scoop samples were also obtained from above the water line during the drawdown in October. The samples were sorted with standard Tyler sieves, ranging in mesh size from 0.841 to 107.6 mm. Volumetric measurements were made by water displacement for each sieve sample.

6.0 RESULTS AND DISCUSSION

6.1 Barrier Net Development and Operation

6.1.1 Installation and Maintenance

The three segments of the barrier net were initially installed on June 23 and 24, 1977. An inspection by divers determined that the east net completely screened the east access to the irrigation canal; however, the south net required lengthening in order to screen the south opening. A 25-m section of net was added near the middle of the south net 2 weeks later. Reinspection of the south net revealed gaps remained near the north and south ends and at both sides of the dredged channel where rapid changes in the bottom contour of the lake existed. These gaps occurred because of excessive tension on the leadline which prevented conformance of the leadline to abrupt changes in the slope of the bottom.

The length and depth of the gaps was observed to vary depending on the amount of tension on the net. Tension increased due to fouling by algae and wind-generated currents, which caused the net to bag between anchor points and the leadline to lift at the gaps. Occasional strong north winds created a visible east flowing surface current along Dry Falls Dam which caused the leadline to lift. During calm weather, the surface current was not easily discernible. Fouling by periphyton prior to the biweekly net cleaning was suspected of contributing to tension on both south and east nets. During a 3-week period in August, streamers of periphyton hanging from the meshes grew from 10 to 20 cm long between cleaning periods (Fig. 15).

The net cleaning operation contributed to the loss of fish in two ways. During the first month of operation, for convenience, the nets were washed only in one direction. After repeated washings of the south net in a northerly direction, it was discovered that slack leadline had accumulated at the north end and the leadline at the south end was under



Fig. 15. Periphyton growth on the barrier net after a three-week period in August, 1977.

considerable tension. This tension caused large gaps to form across two ledges and undoubtedly was the avenue of escape for most fishes entrained in the canal during this period. After this was recognized, the net was shifted back into position and washed subsequently in alternating north and south directions.

Fish undoubtedly escaped under the leadline while it was raised during the washing operation. However, because this escapement was not detectable in the canal net catches, it was considered of minor importance relative to the steady escapement through gaps around the south net. A considerable escapement of kokanee occurred on September 6 and 7, 1977, when failure of the hydraulic equipment halted the washing operation midway along the south net. The center of the net remained lifted for a period of about 16 hr, while repairs were being made. On the following morning when washing was resumed, numerous kokanee were observed jumping inside the barrier net. An increase in canal catches during and shortly after this period indicated that a substantial escapement of kokanee had occurred during the breakdown.

A few remaining gaps in the south net were closed eventually by suspending curtains of weighted netting from the leadline. Because the current was negligible along the bottom, these curtains were hung vertically without tension and conformed well to irregularities in the bottom.

A substantial number of kokanee escaped during October 1977 due to a large tear in the south end of the south barrier net caused when a warning buoy broke loose from its moorings and drifted into the net near its attachment at Dry Falls Dam. This tear probably occurred 2 weeks before it was detected because the net was left in place without cleaning during the final 7 weeks of the irrigation season in an effort to minimize the loss of kokanee.

6.1.2 Drag Due to Irrigation Flow

The theoretical force acting on the barrier net due to irrigation flow was calculated for the conditions which prevailed in 1977 and for conditions which may be encountered in any future operation of the barrier net. The calculations were based on net porosity, wetted cross-sectional area of the net, and peak flow for a range of lake level conditions to -6.1 m, according to the formula:

$$\text{force on net (F)} = \frac{Q^2}{2g} W_a P n$$

where:

- Q = irrigation flow,
- A = cross-sectional area at the net site,
- g = gravitational acceleration,
- W = weight of water,
- a = wetted cross-sectional area of the net,
- P = porosity of the net,
- n = viscosity coefficient of water at temperature.

These calculations indicated relatively minor forces owing to two factors; high net porosity (91%) and large cross-sectional area of the net site (8,141 m² at full lake level, 2,275 m² at 6.1 m drawdown). The force increased with increasing drawdown. Under the present irrigation regime in which maximum flows reach 223.7 m³/sec, a drawdown of 6.1 m will produce a force of 442 kg. Under the future regime in which maximum flows may reach 566 m³/sec, a drawdown of 6.1 m will produce a force of 2,767 kg. With the present net-suspension system, this force was divided between four shoreline attachment points and seven intermediate anchor points. The distribution of this force was unequal because of unequal currents through the two major openings. The largest force observed in 1977 acted on the intermediate anchor points, particularly those of the east net where the current was greatest. Nearly all of this force was

transmitted to the leadline chain and thus to the upstream anchors. Although the force acting on individual upstream anchors was not measured, it could be estimated roughly from actual experience in manually reconnecting the anchor pairs during the net-cleaning operation.

In practice, fouling by periphyton greatly increased the frictional drag of the net. The additional drag created by periphyton growth probably far exceeded the force of water current on the net material. The greatest tension in 1977 was encountered during rapid fouling of the net following a windstorm which caused large quantities of rooted aquatic plants to accumulate on the east net. This tension was estimated at about 181.4 kg (400 lb).

The construction and anchoring of the barrier net was adequate to withstand forces considerably greater than were encountered during the 1977 operation. The net cork and leadlines were of 13-mm (1/2-in) diameter double-braid nylon, which has a breaking strength of 3,402 kg (7,500 lb). The dacron netting used in the net has a breaking strength of 34 kg (75 lb) per strand.

During the week of June 18, 1978 the anchors holding the middle half of the east barrier net were dragged downstream approximately 30 m because of excessive force caused by a combination of strong current and fouling of the net. The strong current resulted from a high irrigation flow (224 m³/s or 7,910 cfs) and a lake surface drawdown of 2.4 m which reduced the area available for the flow. The fouling resulted from an accumulation of periphyton during the first 35 days of net operation in which the net was not cleaned. That the excessive drag on the net was due largely to fouling was evident from the release of tension on the net after cleaning. Until this occurrence, one anchor of each pair had been set upstream and one downstream to hold the net in place against potential currents from either direction. It was obvious that at the center of the net single upstream anchors were insufficient and the downstream anchors were unnecessary. The situation was corrected by hauling the net back

into position with a boat and setting the paired anchors upstream from the net. The net was cleaned at 3-week intervals during July and August.

In any future operation of the barrier net in which tension in the lead or cork lines may approach the breaking strength or results in handling problems during net cleaning, the tension may be relieved by adding additional anchors and by lengthening the net to create more sag or by more frequent cleaning.

6.2 Barrier Net Evaluation

6.2.1 Irrigation Canal Entrainment

The number of each species of fish entrained into the irrigation canal was estimated following the same procedures used in preceding years. Seasonal variations and age compositions of each species were compared with similar data collected during comparable time periods in 1975 and 1976. The entrainment estimates for 1975 and 1976 reported in Stober et al. 1977, were derived from sampling which was conducted during nearly the entire irrigation season, whereas the 1977 and 1978 estimates were based on shorter sampling periods beginning on June 9, 1977, and on April 24, 1978 and ending October 25. Estimates of the escapement of fishes past the barrier net were based on canal catches following the complete installation of the barrier net which occurred on July 9, 1977 and on May 18, 1978. Comparisons between years were made by considering similar time periods from July 9 to the end of the irrigation season (Table 2).

The rate of drafting through the irrigation canal was distinctly bi-modal in 1977, with an unusually large volume in April, which declined during May and early June, with a second period of peak flow during July and August (Fig. 16). The discharge curve in 1978 more closely approximated a typical flow curve. The peak flow rate during both years was 224 m^3 (7,910 cfs).

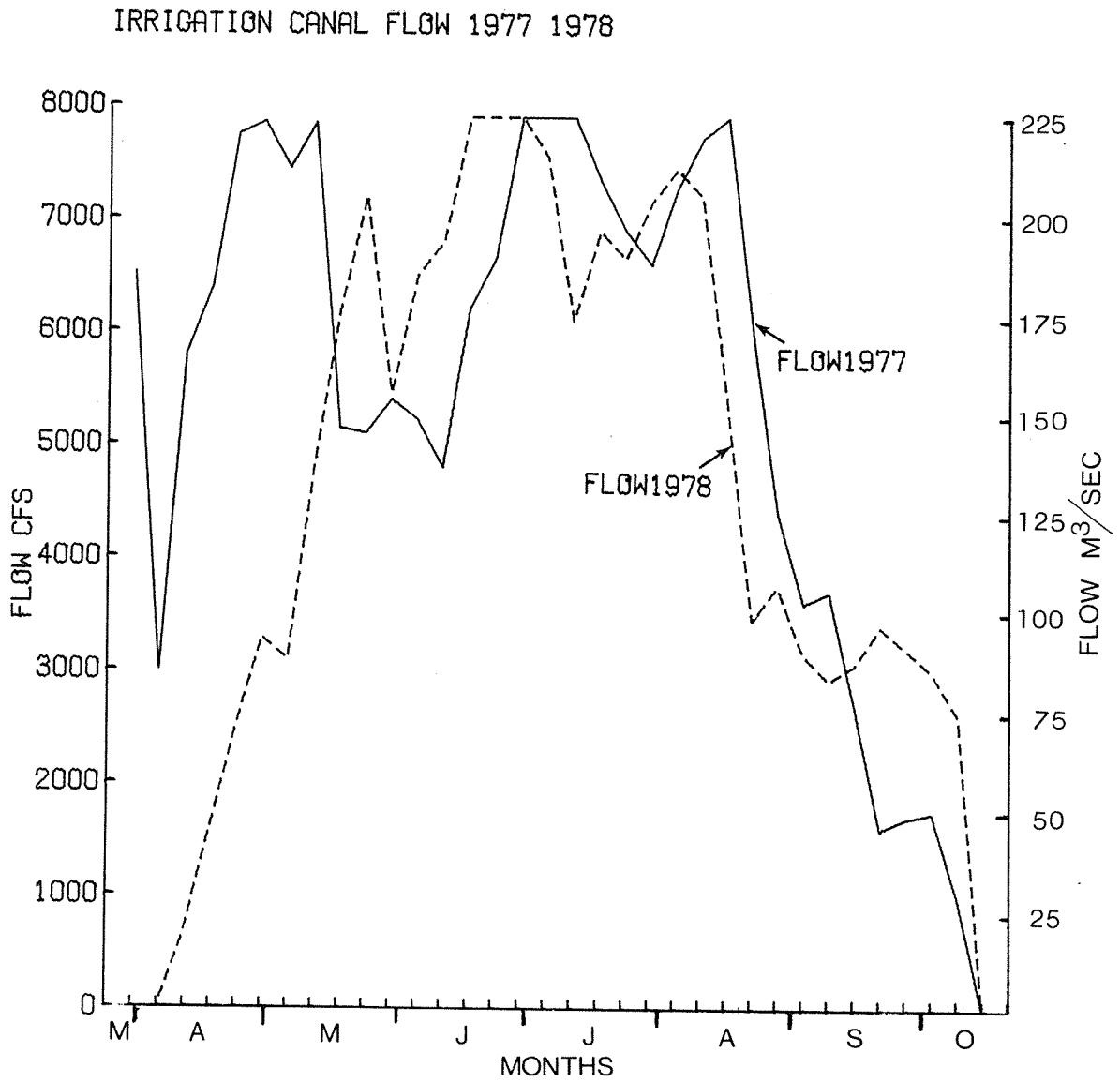


Fig. 16. Average weekly water discharge through the irrigation canal during 1977 and 1978 (USBR data).

Table 2. Estimated entrainment, 95% confidence intervals and percent composition by species in the irrigation canal for the period July 9, through October 25, 1975, 1976, 1977 and 1978.

	1975		1976		1977		1978		Percent of Total			
	Estimated Number Entrained	Interval Estimate $\alpha = .05$	Estimated Number Entrained	Interval Estimate $\alpha = .05$	Estimated Number Entrained	Interval Estimate $\alpha = .05$	Estimated Number Entrained	Interval Estimate $\alpha = .05$	1975	1976	1977	1978
Kokanee	100,908	+6,013	32,119	+5,450	7,031	+2,513	726	+298	67.4	59.6	17.8	2.5
Yellow perch	16,408	+4,409	3,516	+3,223	22,022	+29,290	9,148	+4,725	11.0	6.5	55.9	31.1
Lake whitefish	11,825	+3,533	4,998	+2,870	96	+159	264	+281	7.9	9.3	0.2	.9
Carp	6,055	+5,506	1,763	+668	3,228	+1,964	3,249	+1,074	4.0	3.3	8.2	11.1
Chinook salmon	5,005	+2,440	279	+274	292	+434	-	-	3.3	0.5	0.7	-
Longnose sucker	2,247	+1,174	4,987	+3,672	1,978	+1,243	2,229	+1,163	1.5	9.3	5.0	7.6
Mountain whitefish	2,009	+1,049	1,058	+523	841	+928	2,218	+615	1.3	2.0	2.1	7.5
Prickly sculpin	1,789	+1,109	3,578	+2,501	2,062	+1,901	7,315	+2,939	1.2	6.6	5.2	24.9
Rainbow trout	1,659	+549	385	+202	94	+251	227	+23	1.1	0.7	0.2	.8
Peamouth	903	+747	928	+585	1,591	+1,524	1,204	+187	0.6	1.7	4.0	4.1
Pumpkinseed sunfish	553	+445	105	+171	9	+42	657	+136	0.4	0.2	T	2.2
Black Crappie	129	+263	36	+118	-	-	1,158	+180	0.1	0.1	-	3.9
Walleye	80	+172	30	+68	84	+184	408	+15	T	0.1	0.2	1.4
Largemouth bass	56	+96	20	+65	-	-	85	+119	T	T	-	.3
Brown bullhead	38	+61	30	+90	52	+130	512	+248	T	0.1	0.1	1.7
Burbot	-	-	-	-	-	-	-	-	-	-	-	-
Largescale sucker	-	-	13	+44	-	-	-	-	-	T	-	-
Dolly Varden char	-	-	-	-	-	-	-	-	-	-	-	-
White sturgeon	-	-	-	-	12	+58	-	-	-	-	-	-
Total	149,664		53,880		39,392		29,400					

T = trace

6.2.1.1 Kokanee. The estimated entrainment of kokanee during operation of the barrier net in 1977, was 7,031 (Table 2). During similar time periods in 1975 and 1976, 100,908 and 32,119 kokanee were entrained, respectively. Total entrainment of kokanee during the 1975 and 1976 irrigation seasons was 128,397 and 50,007, respectively. The relative abundance of kokanee in the irrigation canal in 1977 was 17.8% as compared to 67.4% in 1975 and 59.6% in 1976. Kokanee entrainment in 1977 reached a maximum in early September which was later in the irrigation season than observed previously (Fig. 17). Kokanee entrainment for the 4-week period preceding the installation of the barrier net in 1977 was low (1,115) and did not provide a useful preoperational comparison for evaluation of the barrier.

The estimated total entrainment of kokanee during operation of the canal nets in 1978 (April 24 to October 25) was 3,592. The estimated entrainment during a time period equal to that of the 1977 operation (July 9 to October 25) was 726 (Table 2). The 1978 entrainment during comparable periods, therefore, was 0.1 as large as the 1977 entrainment.

The weekly entrainment rates are compared between years in Fig. 16. Kokanee entrainment was very erratic and may have been partially affected by the volume of irrigation water withdrawal, maturation, and the active feeding movements in the south pool.

A comparison of length-frequency distributions of entrained kokanee (Fig. 18) over the last 4 yr shows a predominance of ages III and IV during most of the irrigation season. However, in June and July 1977, age II kokanee were entrained at a relatively high rate indicating that the 1975 year class (age II) was relatively large. This observation was corroborated by the 1978 population estimate based on purse seine sampling (Section 6.2.2).

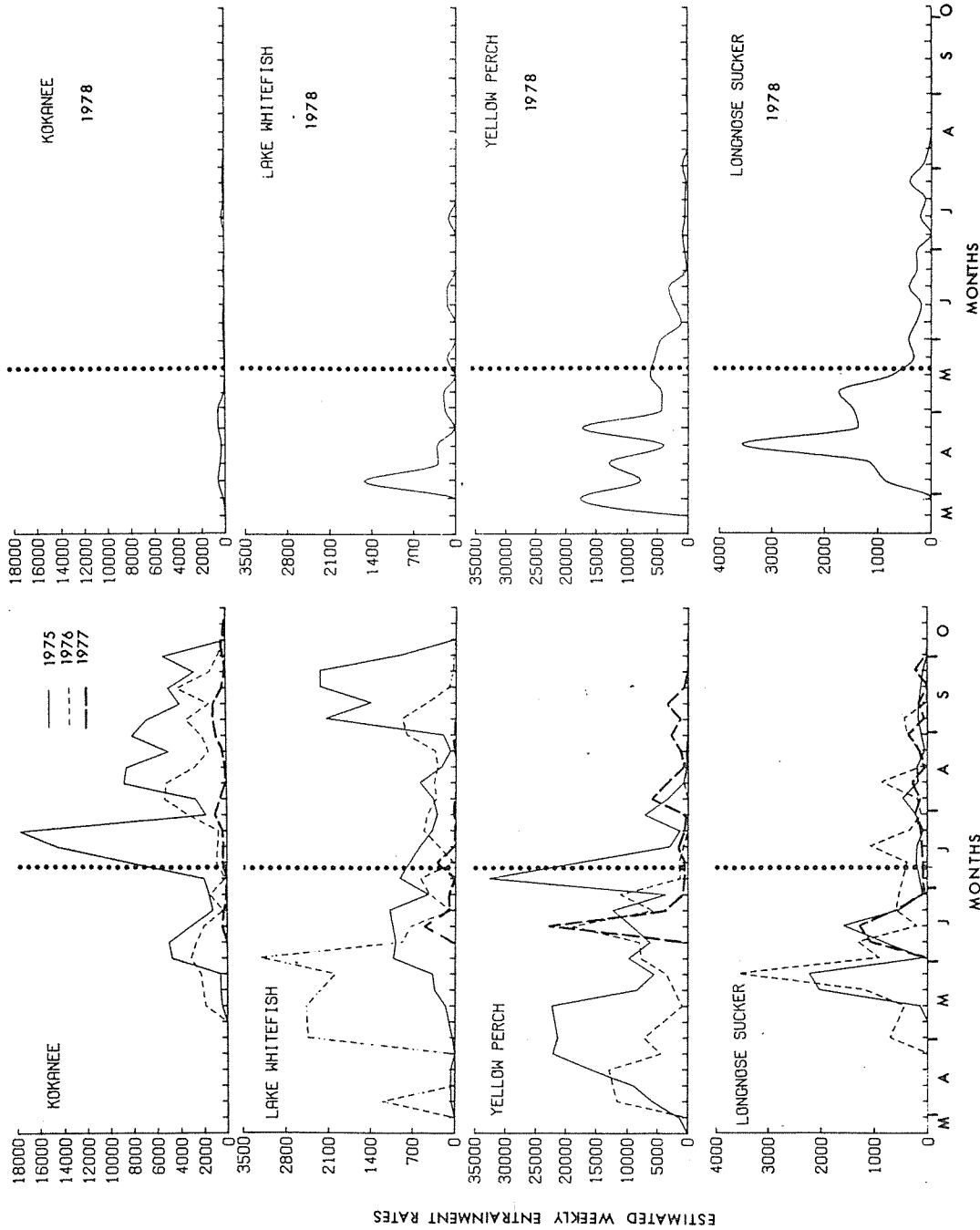


Fig. 17. Total estimated weekly entrainment rates of kokanee, lake whitefish, yellow perch and longnose sucker through the irrigation canal in 1975, 1976, 1977 and 1978. Dotted columns mark installation of the barrier net in 1977 and 1978.

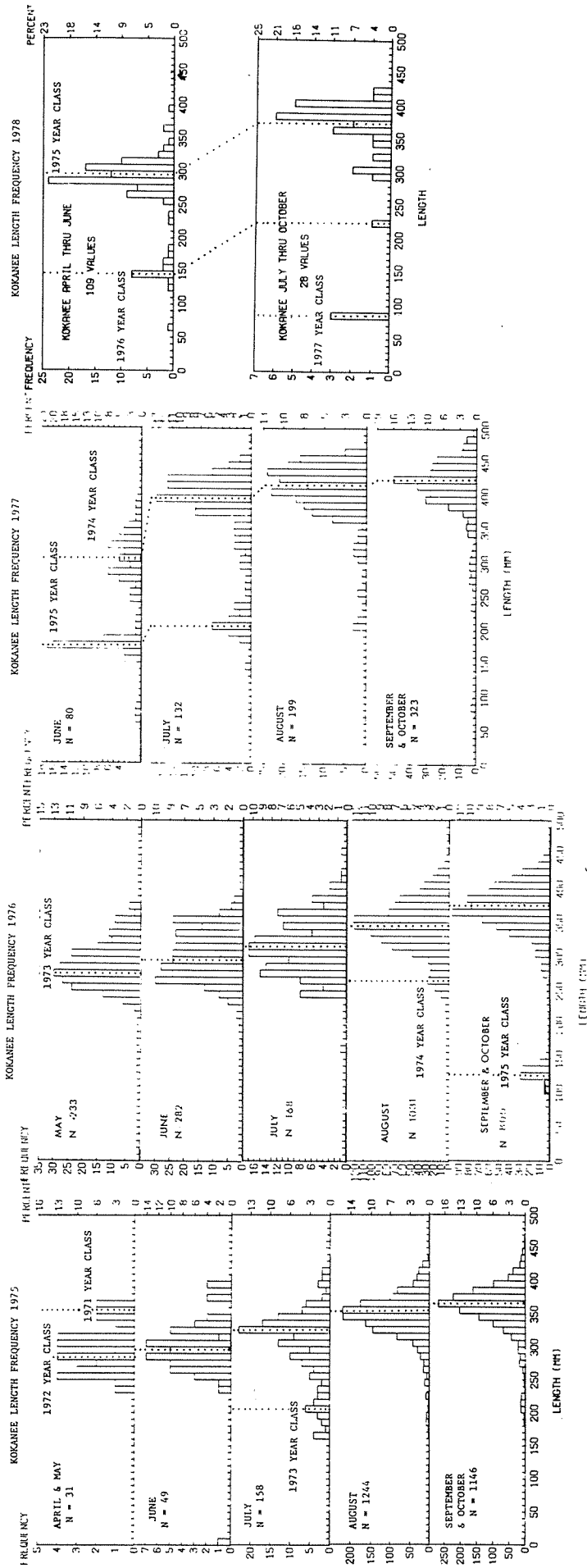


Fig. 18. Monthly length frequency and year class of kokanee from irrigation canal entrainment samples during 1975 to 1978.

The irrigation canal sampling in 1977 indicated that 7,031 kokanee passed the barrier net into the irrigation canal and that the peak entrainment occurred in early September. This entrainment was by far the smallest observed in 3 yr of sampling. The peak occurred later than during the previous 2 yr indicating that the net may have delayed the escapement of kokanee. Some entrainment in 1977 was expected due to difficulty in fitting the south net to irregularities in the bottom contour. The breakdown in early September of the net-cleaning gear on the south net was known to have allowed an increase in entrainment. However, entrainment alone cannot be considered a complete measure of the efficiency of the barrier net. The spawning population and sport catch was increased by that portion of the population which was retained by the net.

6.2.1.2 Lake Whitefish. Among the major fish species in Banks Lake, lake whitefish are most effectively blocked by the barrier net. This is probably true because of their highly pelagic nature which causes them to shy away from the net.

In the years before the barrier net was established, lake whitefish constituted the largest quantity by weight of fish entrained into the irrigation canal. Their seasonal entrainment pattern was strongly influenced by intolerance to warm surface water, which isolated them during the summer from the outlet. Consequently, their entrainment rate was high during the spring and fall and low during the summer.

Establishment of the barrier net has greatly reduced the entrainment of lake whitefish. In 1975 and 1976, without the barrier net, 19,326 and 23,731, respectively, were estimated to have been entrained. During the period July 9 through October 25 entrainment estimates for 1977 and 1978 with the barrier net were 96 and 264, respectively, (Table 2). These data for a similar period can be compared to 11,825 and 4,998 for 1975 and 1976, respectively. Outmigration during the fall has been almost

completely blocked, and outmigration during the spring has been effectively blocked during the period of net installation (Fig. 16).

The canal sampling has afforded the opportunity to examine the growth rate of lake whitefish without the bias for size which is characteristic of gillnet samples. The analysis was aided by the dominance in the lake whitefish population of the 1974 year class. The 1974 year class was initially identified from scale and otolith readings and was subsequently identified by its prominence in the length frequency graphs. Accurate reading of lake whitefish scales and otoliths has been difficult because false annuli form irregularly during summer when the older age classes become inactive. A compilation of length frequencies from 1975 through 1978 shows the growth increment of the 1974 year class (Fig. 19). Because of the seasonal availability of samples and limited sample sizes in some years, the analysis is limited to comparisons of growth between years and between summer and winter growth. These data are shown in Table 3 and the length at age is shown in Fig. 20.

6.2.1.3 Yellow perch. The entrainment of yellow perch in the irrigation canal has tended to be very large in the spring, moderate in the early summer, and low during the late summer and fall (Fig. 16). Operation of the barrier net in 1977 and 1978 altered this pattern only slightly because the net was installed both years after the period of high entrainment and because most yellow perch were too small to be screened by the barrier net. The principal effect of the barrier net on the yellow perch population has been to retain in Banks Lake yellow perch larger than 160 mm (age III and older).

The effect of the barrier net on yellow perch entrainment is shown in Fig. 21 in which the length frequencies are grouped by month for each of the four years sampled. In 1975, the entrainment consisted almost entirely of ages I and II yellow perch; age III yellow perch (1972 year class), for an unknown reason, were almost non-existent in Banks Lake. In 1976, the entrainment consisted largely of the same year classes, which

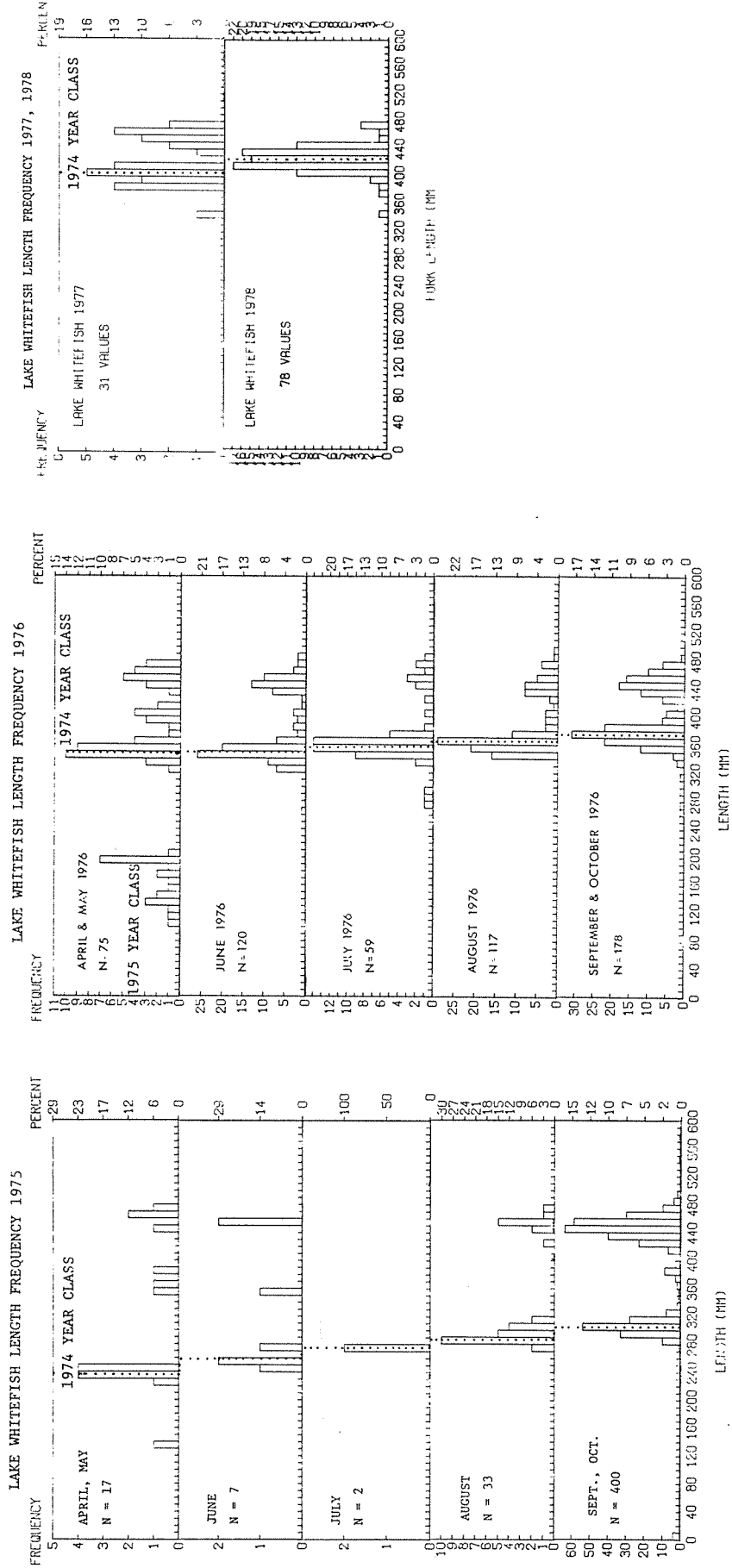


Fig. 19. Monthly length frequency and year class of lake whitefish caught from the irrigation canal in 1975, 1976, 1977 and 1978.

Table 3. Growth and length at age of the 1974 year class of lake whitefish in Banks Lake.

Date	Age	Growth (mm)			length (mm)
		Apr.-Oct.	Nov.-Mar.	Annual	
April, 1974	0	-	-	-	10
April, 1975	I	no sample	no sample	230	240
April, 1976	II	55	65	120	360
April, 1977	III	15	25	40	400
April, 1978	IV	no sample	no sample	25	425

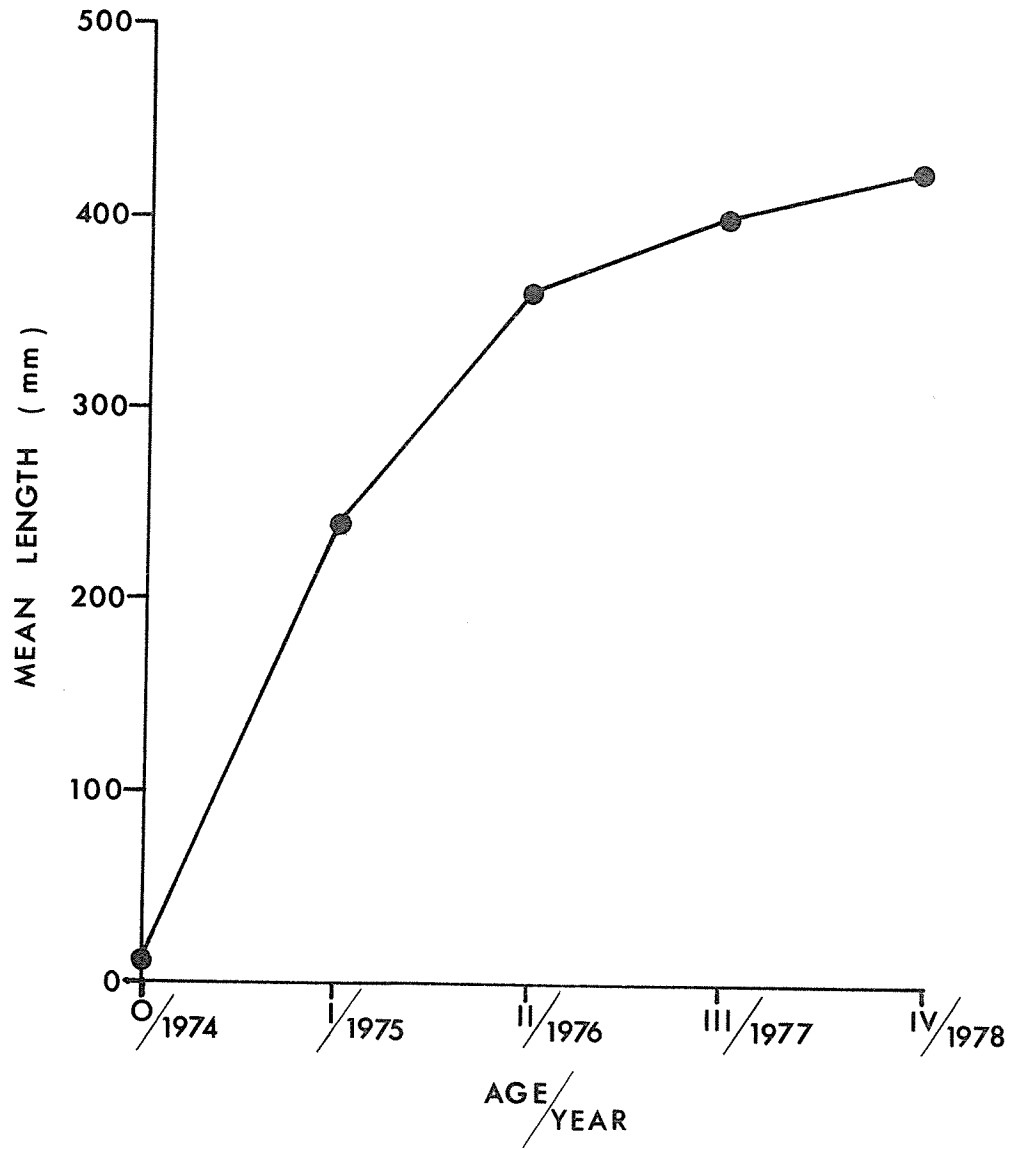


Fig. 20. Length at age of the 1974 year class of lake whitefish based on net samples from the irrigation canal.

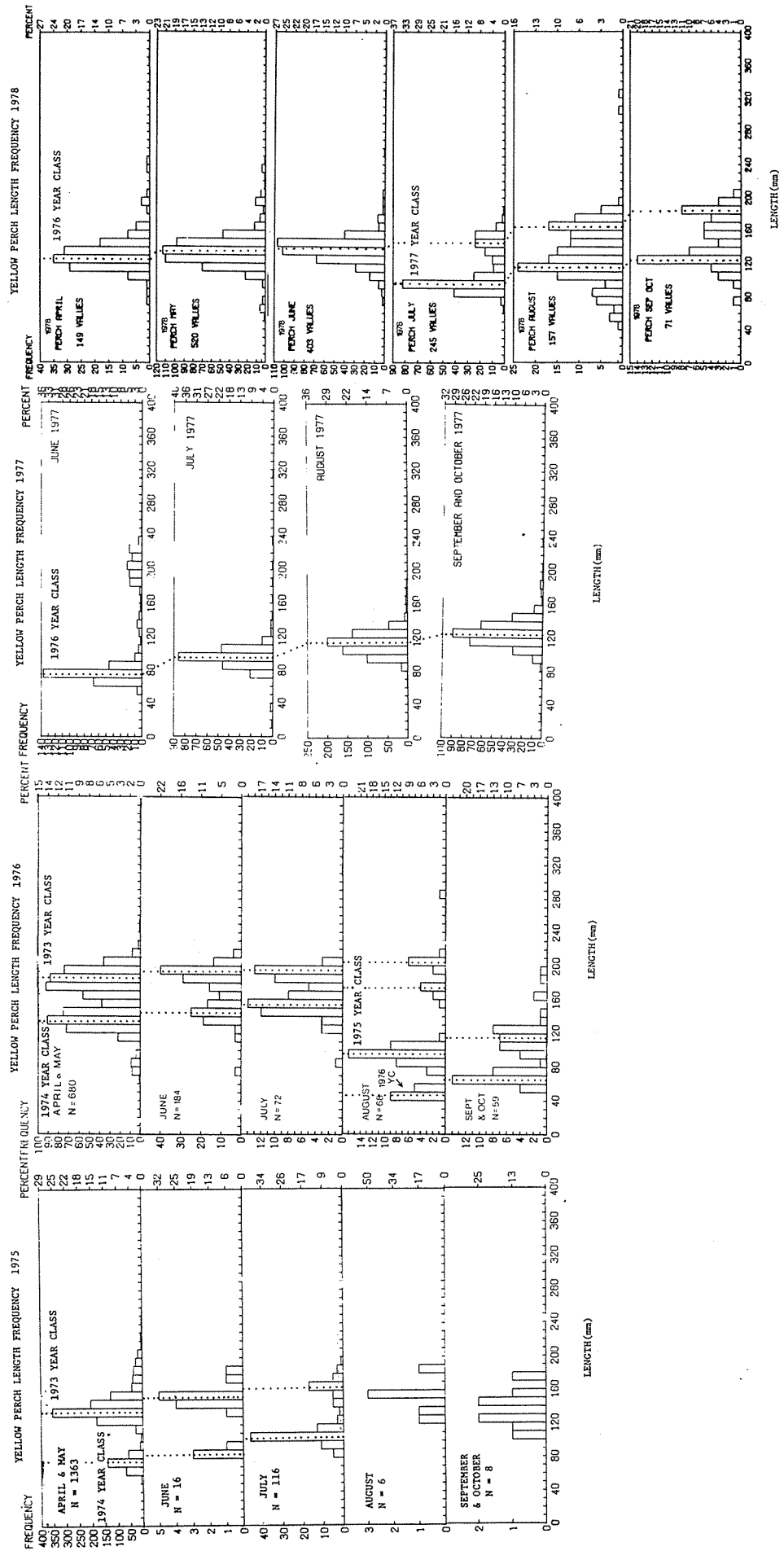


Fig. 21. Monthly length frequency and year class of yellow perch from irrigation canal entrainment samples during 1975 to 1978.

were by then ages II and III. A substantial portion of the entrained yellow perch, therefore, were larger than 160 mm. In 1977, the only large perch entrained entered the canal in June before the barrier net was installed. Once the barrier net was installed the entrainment of yellow perch larger than 160 mm ceased. In 1978, the same situation occurred; after the barrier net was installed on May 18 the entrainment of large yellow perch ceased.

In 1978, the estimated entrainment of yellow perch during the period in which the canal was sampled (April 24 - October 25) totaled 94,453 (Table 2). Of this total, 9,148 were entrained after the barrier net was installed on May 18. In 1977, the estimated total entrainment during the period in which the canal was sampled (June 9 to October 25) totaled 50,697. Of this total, 22,022 were entrained after the barrier net was installed on July 9.

By reducing the entrainment of other species, the barrier net has effectively changed the relative numerical importance of yellow perch in the canal catch. Yellow perch comprised 55.9 and 65.5% of the canal catches in 1977 and 1978, and 11.0 and 6.5% of the catches in 1975 and 1976.

6.2.1.4 Longnose sucker. The entrainment of the longnose suckers in the irrigation canal has tended to be largest during the May and June spawning period, moderate during July and August, and lowest during April, September, and October (Fig. 16). The operation of the barrier net probably has reduced the entrainment of adult longnose suckers because they are too large to pass through the mesh, however, in 1978 many succeeded in passing the net during May and early June. The reason for this passage was revealed during routine SCUBA inspection of the net in which hundreds of longnose suckers were seen caught under folds of the barrier net curtain which was lying on the bottom beside the leadline. Many had succeeded in wiggling under the leadline and had passed under from 4 to 6 m of netting before being gilled or trapped in folds of

netting. This behavior revealed the persistence of the longnose sucker during spawning season and explained why an estimated total of 8,506 were entrained during 1978.

The entrainment of longnose suckers during the comparative periods of barrier net operation (after July 9) in 1977 and 1978 were 1,978 and 2,229, respectively (Table 2). During similar time periods in 1975 and 1976, 2,247 and 4,987 respectively, were entrained. Longnose suckers comprised 5.0% of the 1977 entrainment and 9.8% of the 1978 entrainment.

The length frequency distribution of longnose sucker in the canal catches ranged from 250 to 450 mm and a single mode occurred at about 385 mm.

6.2.1.5 Carp. The entrainment of carp into the irrigation canal has tended to be moderate to large throughout the summer months, and low during spring and fall (Fig. 22). The installation of the barrier net appears to have had little effect on the entrainment of carp, and the canal catch curves have shown no decline after the dates of installation in 1977 and 1978. Adult carp were seen frequently ramming the webbing of the barrier net and jumping over the cork line in both directions. This behavior is not interpreted as attempts to enter the canal as the numbers of carp inside the net appeared to equal those outside.

During comparative periods when the barrier net was installed, the estimated entrainment of carp was 3,228 and 3,249 in 1977 and 1978, respectively (Table 2). During similar time periods in 1975 and 1976, entrainment of 1,763 and 6,055 occurred, respectively.

Length frequency analysis by year showed that carp lengths were distributed roughly into 3 modes in 1975, 1976, and 1977 and into 4 modes in 1978 (Fig. 23).

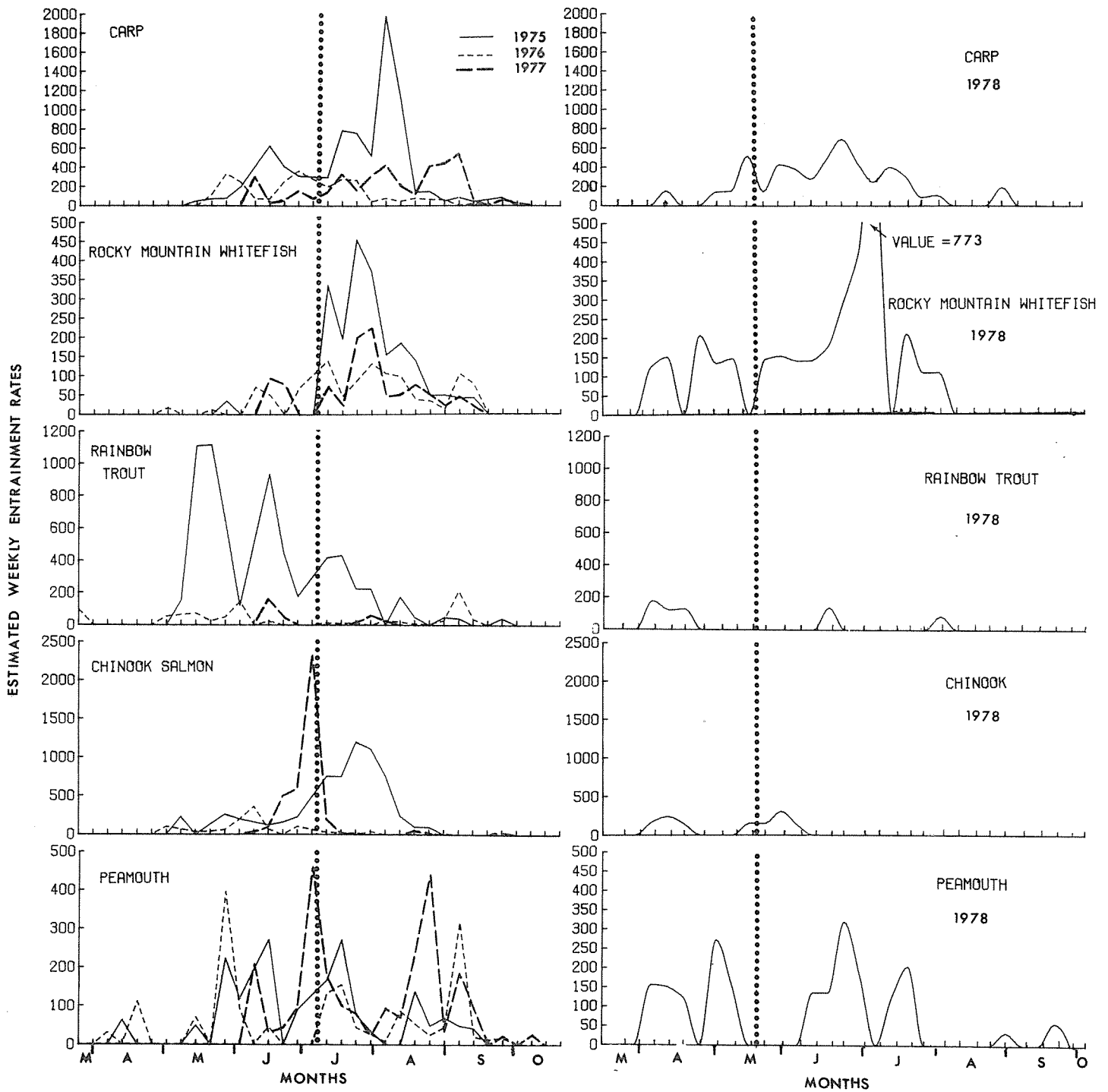


Fig. 22. Total estimated weekly entrainment rates of carp, Rocky Mountain whitefish, rainbow trout, chinook salmon and peamouth through the irrigation canal in 1975, 1976, 1977, and 1978. Dotted columns mark installation of the barrier net in 1977 and 1978.

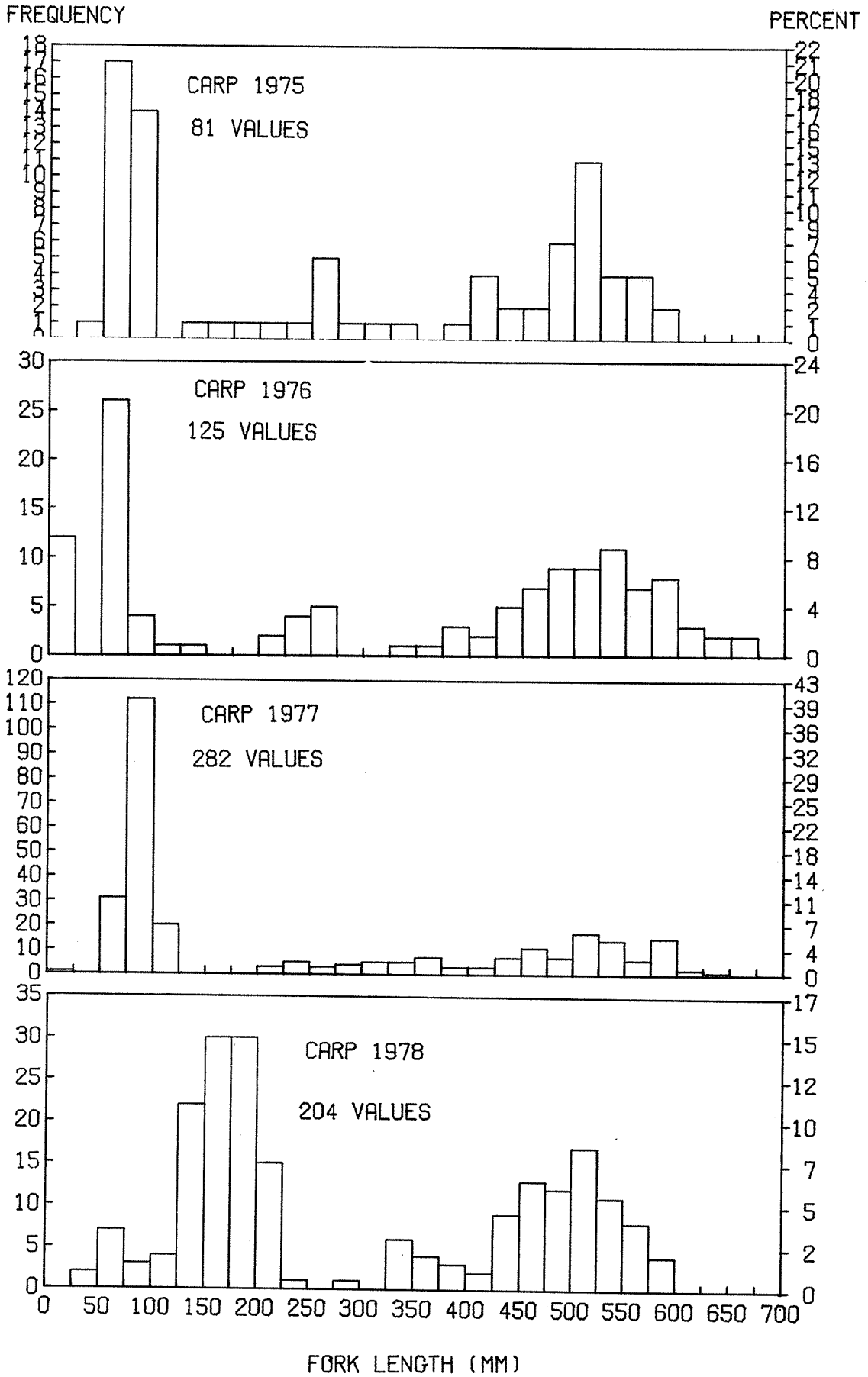


Fig. 23. Composite length frequency analysis of carp caught in irrigation canal entrainment samples in 1975, 1976, 1977 and 1978.

Large numbers of carp in schools of 5 and 10 were seen continually cruising along both sides of the barrier net apparently feeding on the periphyton growing on the net. The stomach content of a single specimen was examined and determined to be almost entirely composed of zooplankton, predominately of the species Daphnia. The feeding behavior of these carp, while not directed at periphyton, was believed to be helpful inadvertently in reducing the fouling of the barrier net by dislodging the streamers of periphyton during feeding activities.

6.2.1.6 Rocky Mountain Whitefish. The entrainment of Rocky Mountain whitefish has occurred chiefly from mid-June to mid-September and has been negligible in the spring and fall (Fig. 21). The operation of the barrier net has had little obvious effect on the entrainment of Rocky Mountain whitefish by comparison of pre- and post-barrier net entrainment data. This was probably due to the small round body shape of this species. The entrainment during the comparative period (after July 9) was 841 in 1977 and 2,218 in 1978 (Table 2). During this period in 1975 and 1976, an estimated 2,009 and 1,058 were entrained.

The length frequencies of Rocky Mountain whitefish in the past four years have ranged from 90 mm to 420 mm (Fig. 24). During 1978, a single mode occurred at 295 mm. During 1977 and 1975, modes occurred at approximately 230 mm and 315 mm. During 1976, the modes were slightly larger at approximately 305 and 345 mm.

6.2.1.7 Rainbow Trout. The estimated entrainment of rainbow trout during the comparative period in 1977 and 1978 was 94 and 423, respectively, as compared to 1,659 and 385 in 1975 and 1976 (Table 2). The entrainment rates in 1977 and 1978 were higher during the spring before the barrier net was installed; 211 in 1977 and 424 in 1978. The barrier net may have caused a reduction in the entrainment of rainbow trout, but the catches were too small to show this conclusively. The reduced entrainment after 1975 is attributed to low population abundance

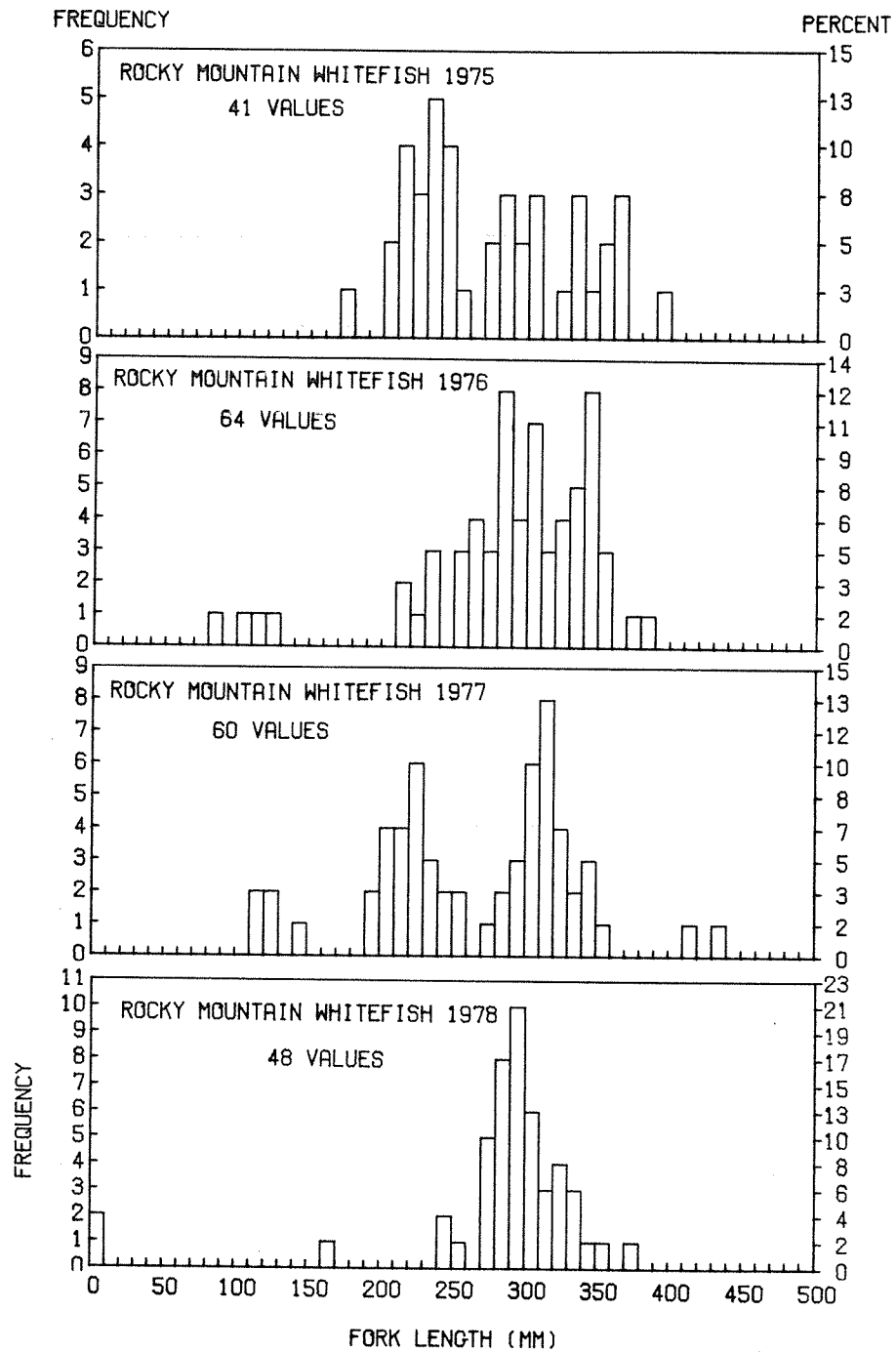


Fig. 24. Length frequency of Rocky Mountain whitefish from the irrigation canal, 1975, 1976, 1977 and 1978.

in Banks Lake, as the numbers of rainbow trout were correspondingly lower in the gillnet catches.

Length frequencies showed two size groups were entrained with modes at approximately 250 mm and 410 mm in 1975 and 1976 and at approximately 260 mm and 490 mm in 1977 and 1978 (Fig. 25). Only seven rainbow were caught in 1978 and are not plotted.

6.2.1.8 Chinook Salmon. Estimated entrainment of 292 and 0 chinook salmon occurred during the comparative period (after July 9) in 1977 and 1978, respectively (Table 2). During the same periods in 1975 and 1976, 5,005 and 279 chinook salmon were entrained. The entrainment timing of chinook salmon since 1975 has occurred principally during May and June. For an unknown reason the entrainment in 1975 peaked much later during late July and early August. The effect of the barrier net on the entrainment of chinook salmon is difficult to ascertain because of this variation in timing. In 1978, chinook were entrained at a moderate rate for the three weeks immediately preceding installation of the barrier net, then stopped completely for three weeks after the barrier net was installed. A second period of moderate entrainment occurred during 4 weeks in late June and July. In 1977, the entrainment rate dropped from very high to very low coincident with the installation of the barrier net.

The chinook salmon entrained ranged in length from 165 mm to 470 mm and in age from I to IV years old (Fig. 26).

6.2.1.9 Peamouth. The estimated entrainment of peamouth during the comparative period in 1977 and 1978 was 1,591 and 1,204, respectively, as compared to 2,048 and 1,692 during similar time periods in 1975 and 1976 (Table 2). The entrainment rates were sporadic during all four years of sampling and did not appear to be affected by the barrier net. The slender, rounded body shape of the peamouth allows all but the largest to pass through the mesh of the barrier net.

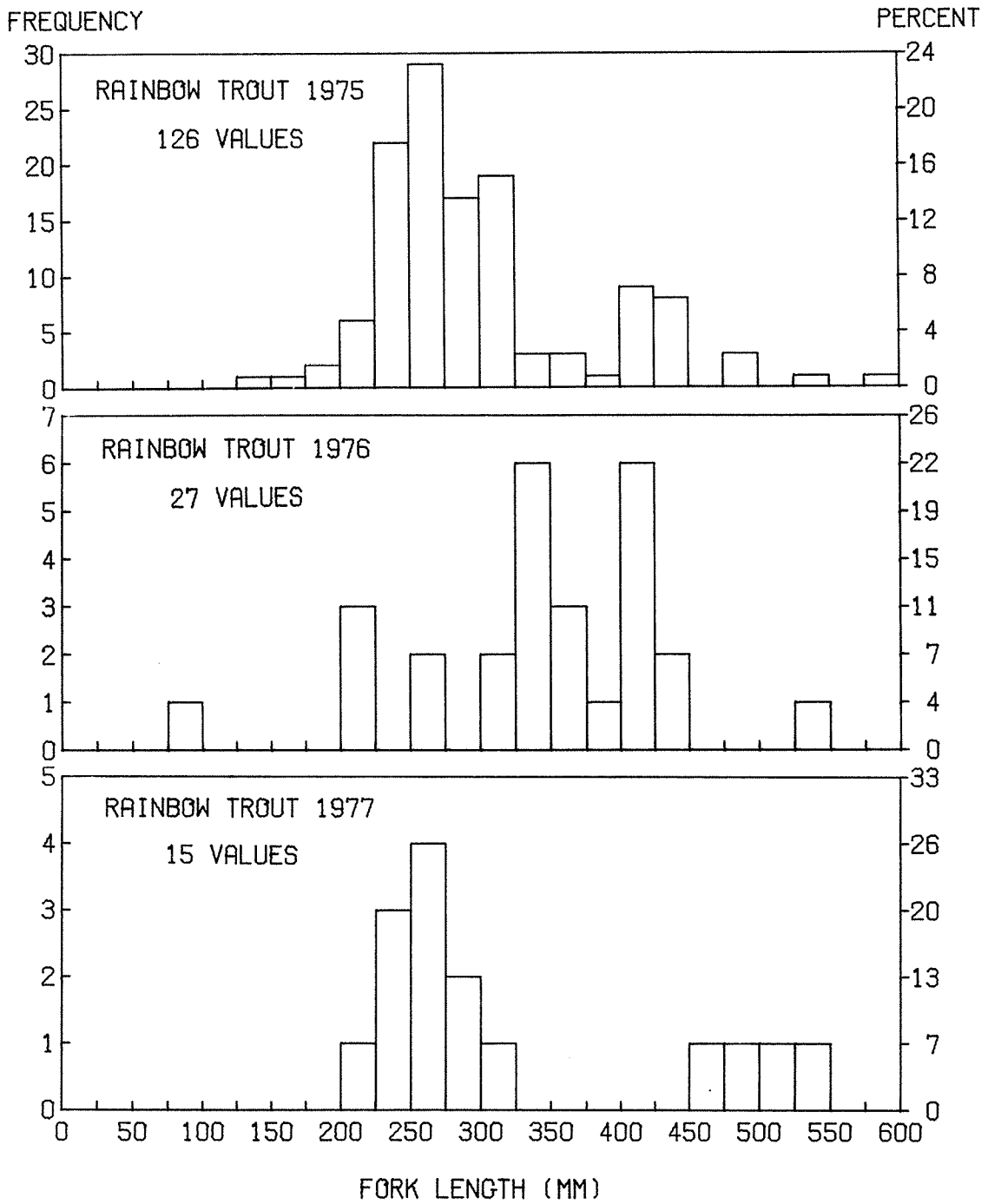


Fig. 25. Length frequency of rainbow trout from the irrigation canal in 1975, 1976 and 1977.

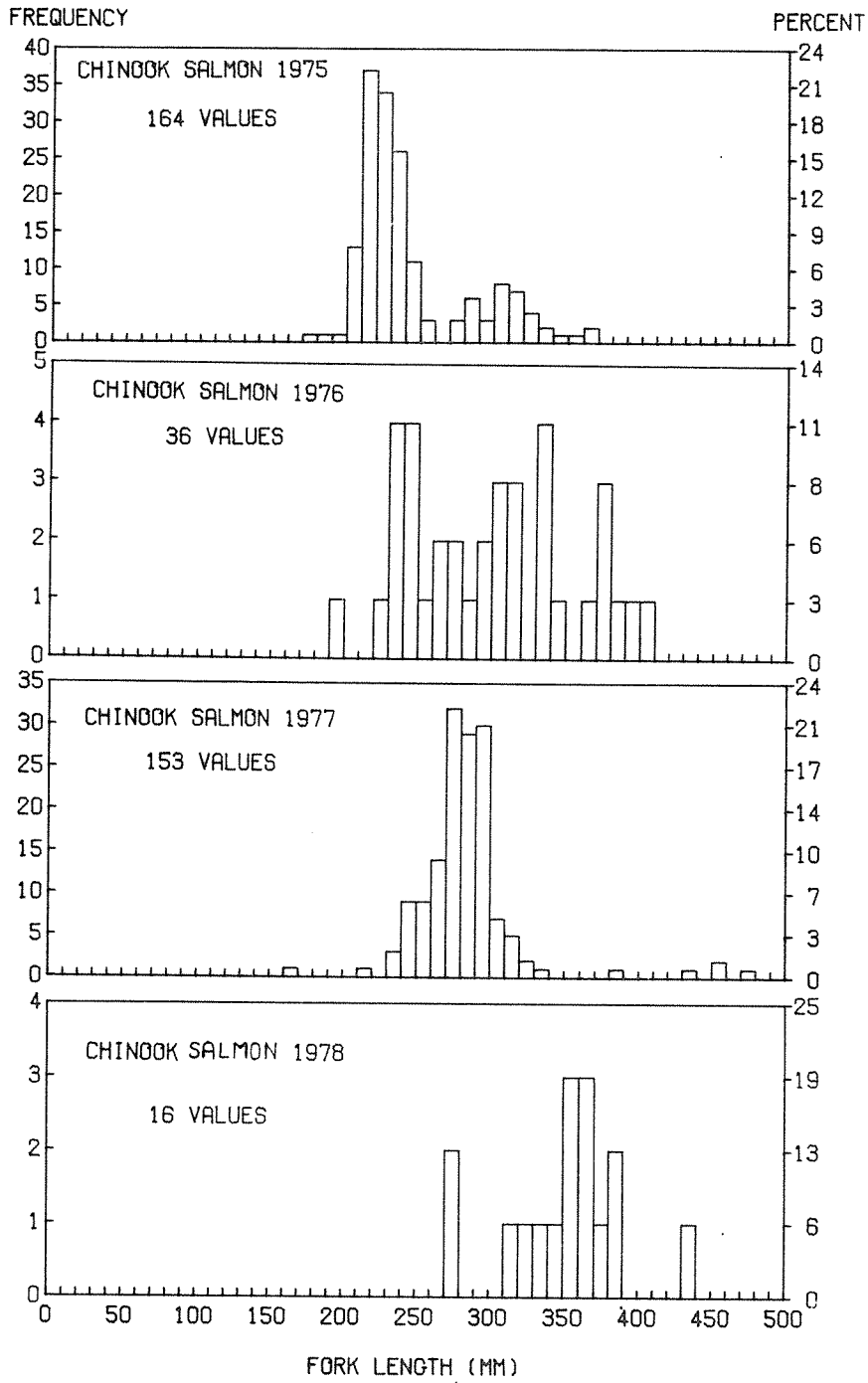


Fig. 26. Length frequency of chinook salmon from irrigation canal 1975, 1976, 1977 and 1978.

6.2.1.10 Prickly sculpin. The estimated entrainment of prickly sculpin during the comparative period in 1977 and 1978 was 2,062 and 7,315, respectively (Table 2). Numerically, prickly sculpin were second to perch in the entrainment in 1978, but because of their small size, ranked low in terms of biomass. The entrainment of prickly sculpin during the comparative period in 1975 and 1976 was 4,174 and 5,657, respectively (Table 2). Prickly sculpin are probably unaffected by the barrier net because of their small size and bottom-dwelling habit. In 1977, an unusually large number of prickly sculpin, 14,916, was entrained during the 4 weeks preceding installation of the barrier net. The entrainment of prickly sculpin has been relatively constant throughout the irrigation season with sporadic increases which do not appear to be related to season or flow (Fig. 27).

A length-frequency histogram of prickly sculpin in 1978 shows a size range from 40 to 165 and a mode at 90 mm (Fig. 27).

6.2.1.11 Other species. Additional species were entrained sporadically in small numbers (Table 2). In 1978, these included pumpkinseed sunfish, black crappie, walleye, largemouth bass, and brown bullhead. In earlier years burbot, largescale sucker, Dolly Varden char, and white sturgeon were also caught.

6.2.2 Purse Seine Sampling

6.2.2.1 Catch per effort. A total of 1,824 fish representing 6 species was caught in 144 purse seine hauls between June 15 and October 19, 1978. The total catch by species was 1,121 kokanee, 434 lake whitefish, 215 Rocky Mountain whitefish, 27 rainbow trout, 26 carp and 1 chinook salmon. Catch per purse seine haul at Station 6 and near the barrier net was calculated for semi-monthly intervals for adult kokanee, sub-adult kokanee, rainbow trout, lake whitefish, and Rocky Mountain whitefish (Table 4).

ESTIMATED ENTRAINMENT

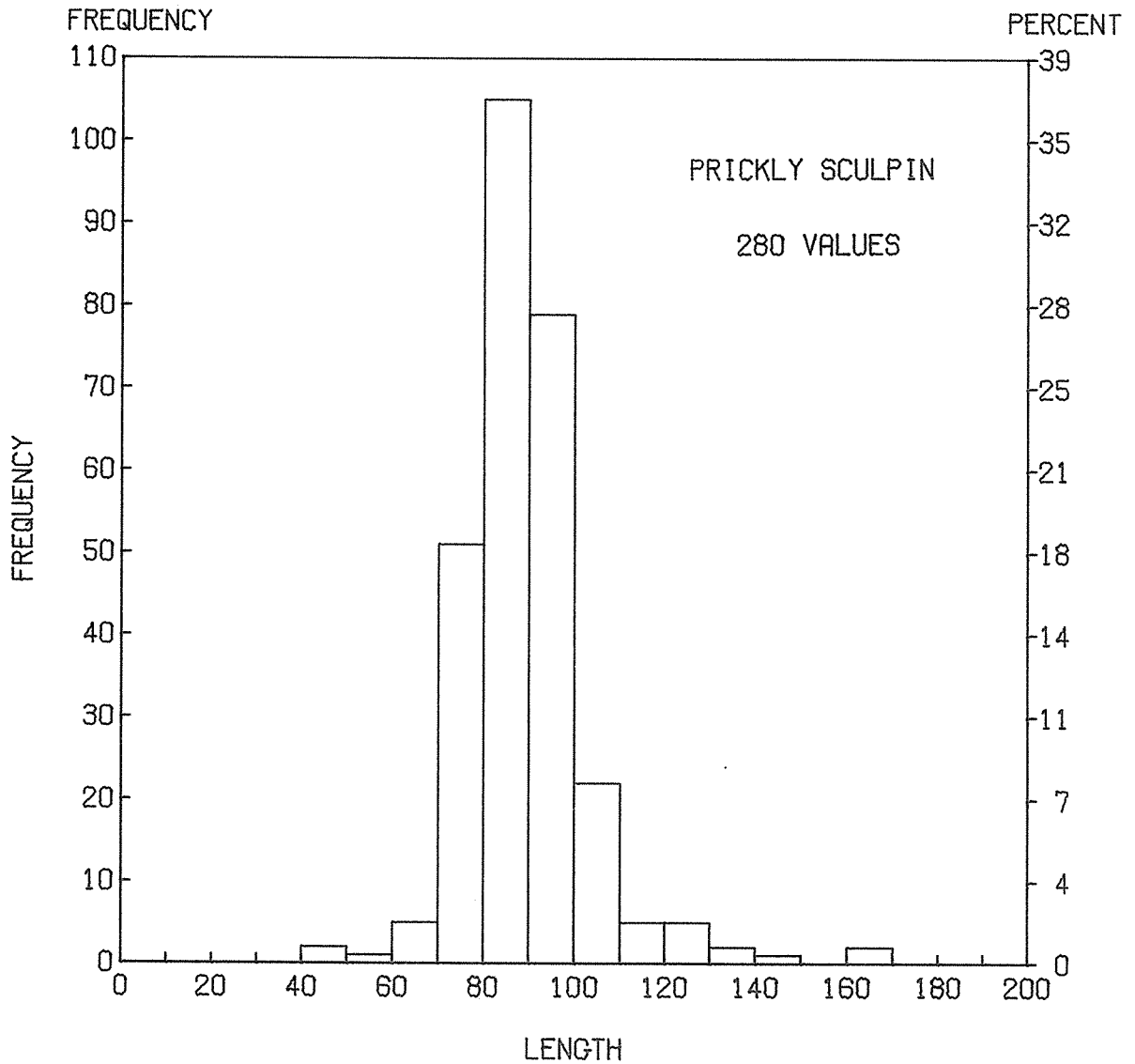
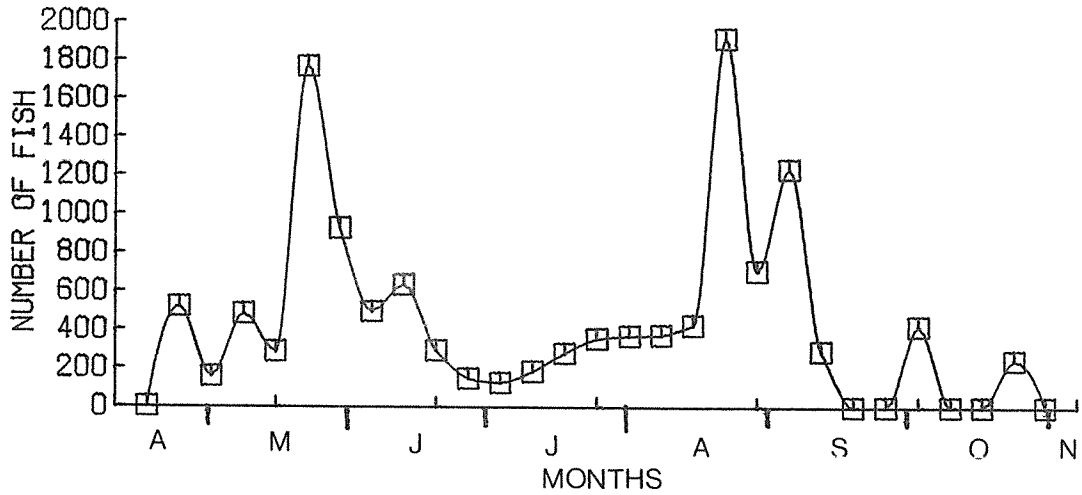


Fig. 27. Length frequency and estimated entrainment of prickly sculpin in the irrigation canal, 1978.

Table 4. Catch per purse seine haul (CPUE), standard deviation (SD), and number of hauls (n) for adult and sub-adult kokanee, rainbow trout, lake whitefish and Rocky Mountain whitefish for Station 6 area and barrier net vicinity, Banks Lake, 1978.

Time Period	Adult Kokanee		Sub-adult Kokanee		Rainbow Trout		Lake Whitefish		Rocky Mountain Whitefish	
	Sta. 6	Barrier Net	Sta. 6	Barrier Net	Sta. 6	Barrier Net	Sta. 6	Barrier Net	Sta. 6	Barrier Net
6/15-31/78	CPUE	1.58	-	0	-	0.33	-	0	-	0.83
	S.D.	2.71	-	0	-	0.65	-	0	-	1.11
	(n)	(0)	(0)	(12)	(0)	(12)	(0)	(12)	(0)	(12)
7/1-15	CPUE	10.25	0	0	0.25	0.33	0	0	0.50	1.67
	S.D.	5.44	0	0	0.50	0.58	0	0	1.00	0.58
	(n)	(4)	(3)	(4)	(4)	(3)	(4)	(3)	(4)	(3)
7/16-31	CPUE	2.63	0	0	0.63	0	0	0	0.37	0
	S.D.	3.61	0	0	0.96	0	0	0	0.76	0
	(n)	(19)	(2)	(19)	(19)	(2)	(19)	(2)	(19)	(2)
8/1-15	CPUE	0.82	0	0	0.09	0	0	0	0	0
	S.D.	1.47	0	0	0.30	0	0	0	0	0
	(n)	(11)	(2)	(11)	(11)	(2)	(11)	(2)	(11)	(2)
8/16-31	CPUE	5.44	11.14	1.00	0.21	0.22	0.07	1.11	2.64	0.22
	S.D.	5.53	15.79	2.35	0.58	0.44	0.27	3.33	3.65	0.44
	(n)	(9)	(14)	(9)	(14)	(9)	(14)	(9)	(14)	(14)
9/1-15	CPUE	14.00	3.23	2.50	0.23	0.17	0.12	7.50	10.65	1.33
	S.D.	4.77	4.04	3.2	0.65	0.41	0.33	9.01	19.50	1.21
	(n)	(6)	(26)	(6)	(26)	(6)	(26)	(6)	(26)	(6)
9/16-30	CPUE	17.75	3.0	2.25	0.50	0	0	3.42	1.25	0
	S.D.	34.04	2.58	5.34	1.00	0	0	4.19	2.50	0
	(n)	(12)	(4)	(12)	(4)	(12)	(4)	(12)	(4)	(4)
10/1-15	CPUE	43.20	-	0.20	-	0	-	0.80	-	0.20
	S.D.	67.17	-	0.45	-	0	-	0.84	-	0.45
	(n)	(5)	(0)	(5)	(0)	(5)	(0)	(5)	(5)	(0)
10/16-31	CPUE	12.67	1	0.11	3.0	0.11	0	0.78	6.00	0
	S.D.	32.65	-	0.33	-	0.33	-	1.09	-	0
	(n)	(9)	(1)	(9)	(1)	(9)	(1)	(9)	(1)	(9)

Differences in catch per seine haul of adult kokanee were evident over time and fishing area (Fig 28). The catch per haul was affected by schooling behavior, maturation, and temperature avoidance. There were low numbers of adult kokanee in the vicinity of the barrier net from June until mid-August. Catches increased substantially in late August and then the catch per haul declined. Catches in the vicinity of Station 6 were moderate to large in July and declined as the water temperature increased. The depressed catches most likely resulted from avoidance of the high surface water temperature which reached a maximum of 23.3° C at Station 6 on August 8, 1978. Adult kokanee were present in the hypolimnion during this period, as evidenced by gillnet sampling on the lake bottom. Exploratory purse seining in the Million Dollar Mile area in early August yielded similar results as the Station 6 area: five hauls caught a total of 8 adult kokanee, 2 lake whitefish, and 1 Rocky Mountain whitefish. When water temperature declined on August 17 to 18.9° C, catch per haul at Station 6 increased along with catches near the barrier net. Catches continued to increase at Station 6, through September whereas they declined near the barrier net. The 4.6 m drawdown in the fall precluded sampling in the vicinity of the barrier net between September 20 and October 15, 1978. Only one haul was made in this area on October 16, therefore, catch per effort values were not plotted.

Adult kokanee began to school late in the season, as indicated by high catch per haul values and large standard deviations (Table 4, Fig. 28). Schools were often located by observing jumping fish, especially offshore near the primary spawning area. The decline in catch per haul at the end of October was mainly due to the fish moving onshore into water which could not be sampled with the purse seine.

Sub-adult kokanee began to appear in the purse-seine catches in late August (Fig. 27). Mean catch per haul was always less than 3.0. Sub-adults contributed 15.5% of the total kokanee catch in August, 12.5% in September, and 0.6% in October when the fishing effort shifted to the shoreline along the primary spawning area. There was a tendency for

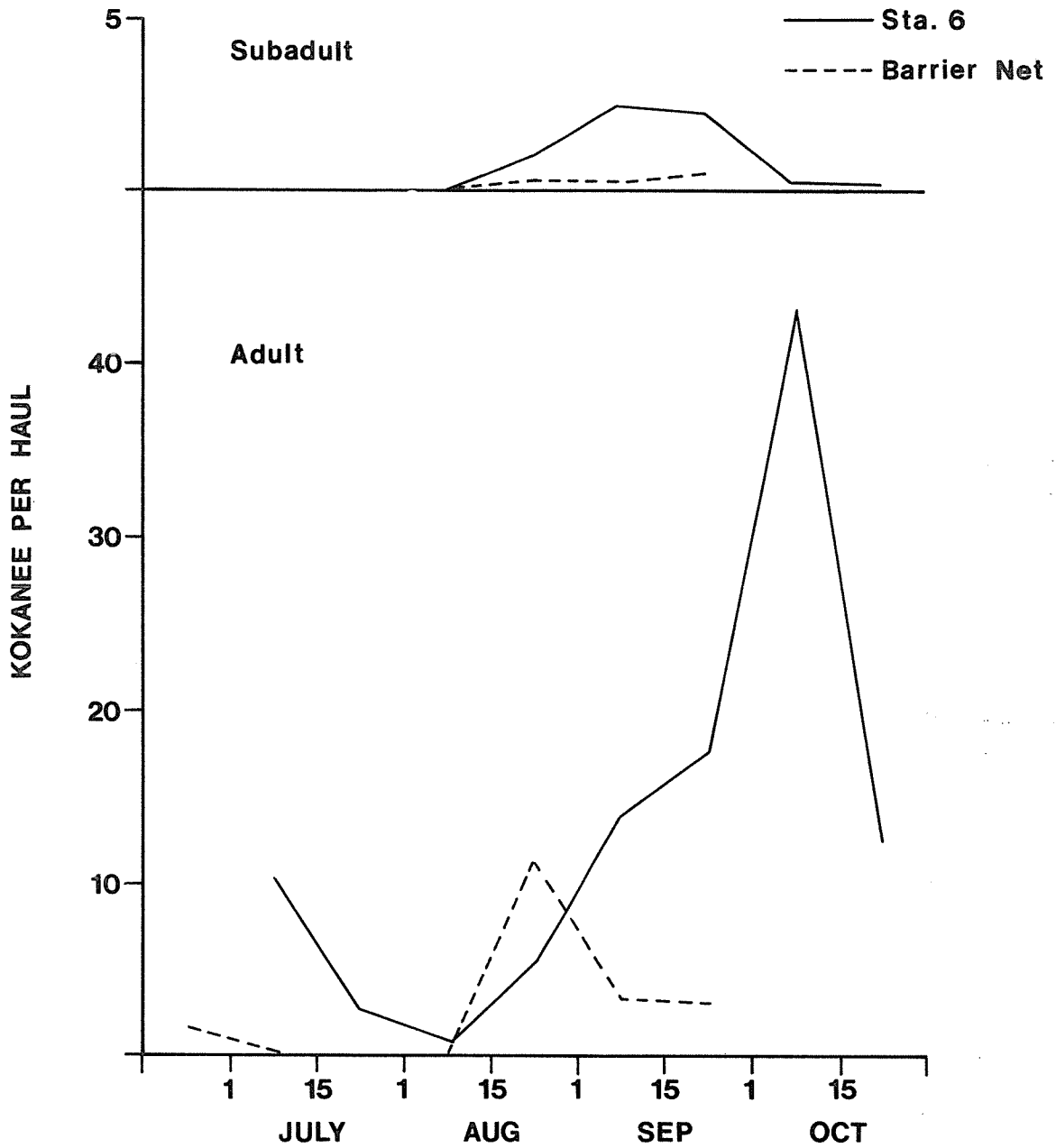


Fig. 28. Semi-monthly catch of adult and sub-adult kokanee per purse seine haul in the vicinity of the barrier net and Station 6, Banks Lake, 1978.

catches to be larger in the vicinity of Station 6 than near the barrier net.

Semi-monthly catch per haul for rainbow trout was always less than 1.0 at both the Station 6 and barrier net locations (Fig. 29). Catch per haul of Rocky Mountain whitefish varied seasonally and by location. Catches were largest near the barrier net in August. Rocky Mountain whitefish apparently move into the vicinity at this time each year since entrainment into the irrigation canal was highest during July and August in 1975-1977 and gilling rate in the barrier net was highest in August during 1977. Catches of lake whitefish varied seasonally. Lake whitefish were absent from purse-seine hauls until late August when catches increased during falling water temperatures. Catch per haul was similar at both the Station 6 and barrier net locations.

6.2.2.2 Length-frequency. Length-frequency distribution of kokanee, calculated semi-monthly, showed that adults (age III and IV) grew from about 300 mm in June to about 380 mm in late August (Fig. 30). Immature kokanee were first recruited into the purse-seine catch in late August and were generally smaller than 300 mm.

Length-frequency distribution of rainbow trout, Rocky Mountain whitefish and lake whitefish were tabulated for the entire sample season. Rainbow trout ranged in length from 170 to 380 mm (Fig. 31) with a modal length of 310 mm. Rocky Mountain whitefish ranged in length from 210 to 390 mm. Modes were apparent at 280 mm and 340 mm. Lake whitefish caught by purse-seine were primarily adults. One mode was apparent at 420 mm and only one lake whitefish smaller than 360 mm was captured. None of the carp captured by purse-seine were measured but all were estimated to be larger than 500 mm and the single chinook captured was 357 mm fork length.

6.2.2.3 Kokanee sex ratio. The composition of male and female kokanee in the catch was tabulated for Station 6 and the barrier net vicinity on a weekly basis beginning August 13, at which time sexual

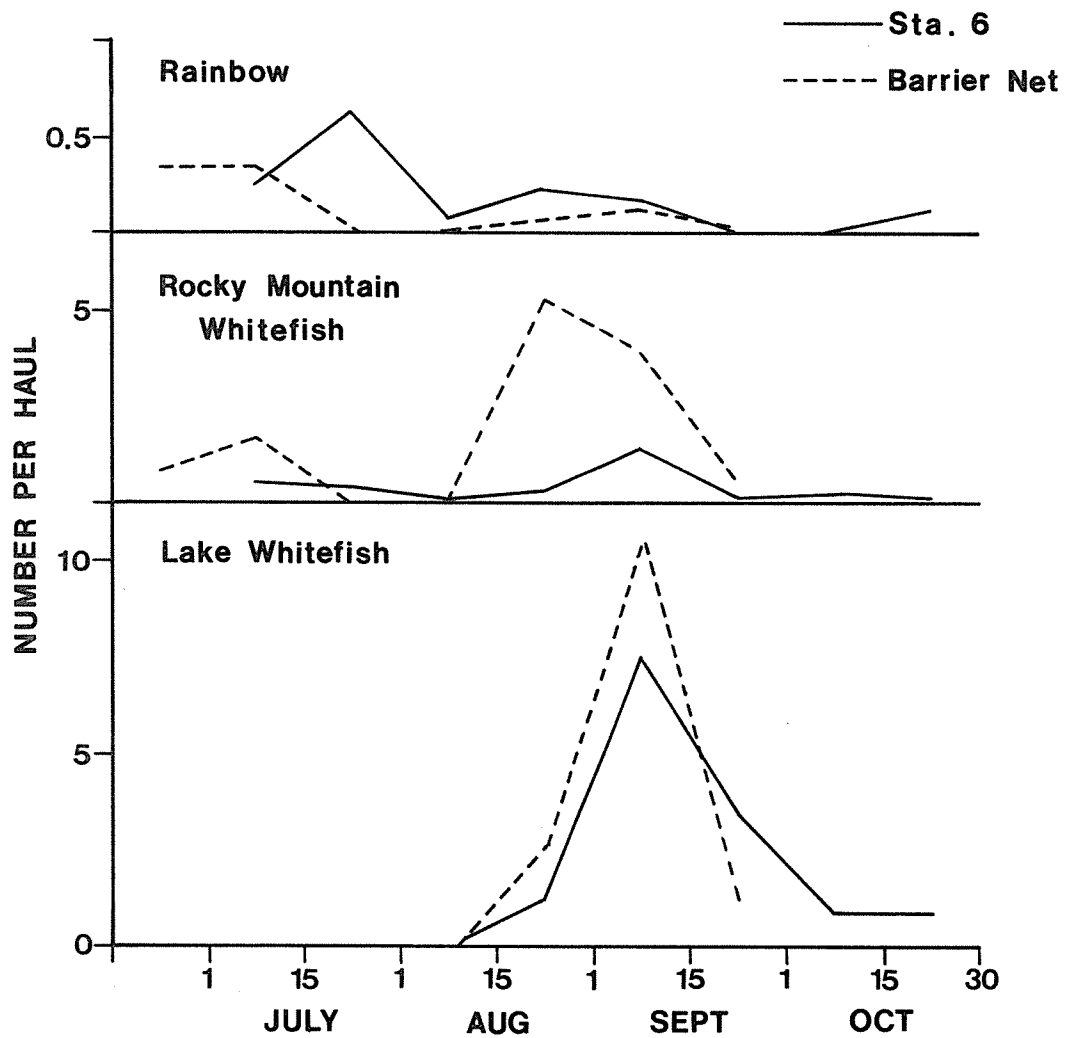


Fig. 29. Semi-monthly catch of rainbow trout, Rocky Mountain whitefish, and lake whitefish per purse-seine haul in the vicinity of the barrier net and Station 6, Banks Lake, 1978.

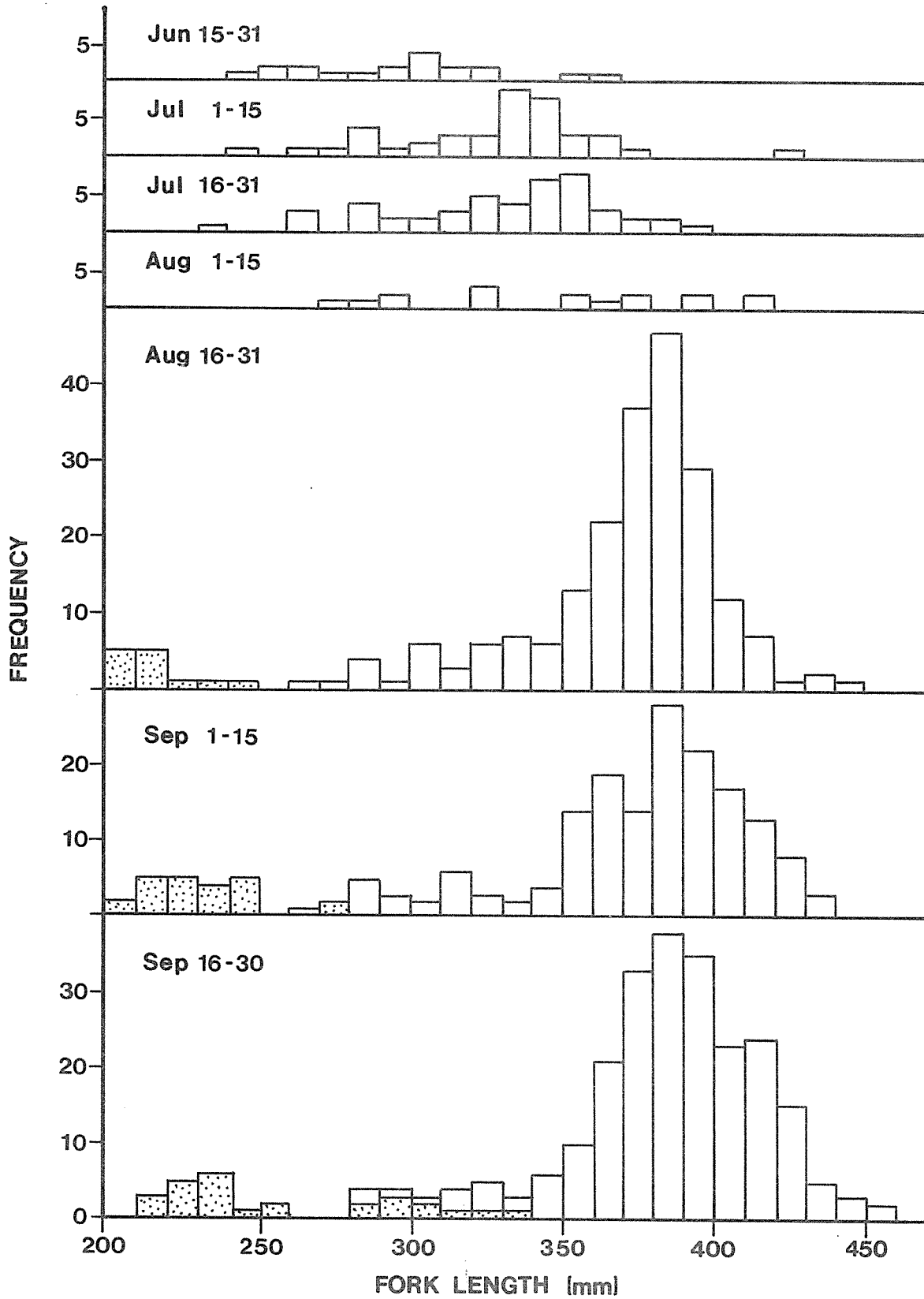


Fig. 30. Semi-monthly length frequency distributions of kokanee caught by purse-seine in Banks Lake, 1978. Shaded areas indicate fish identified as sub-adults.

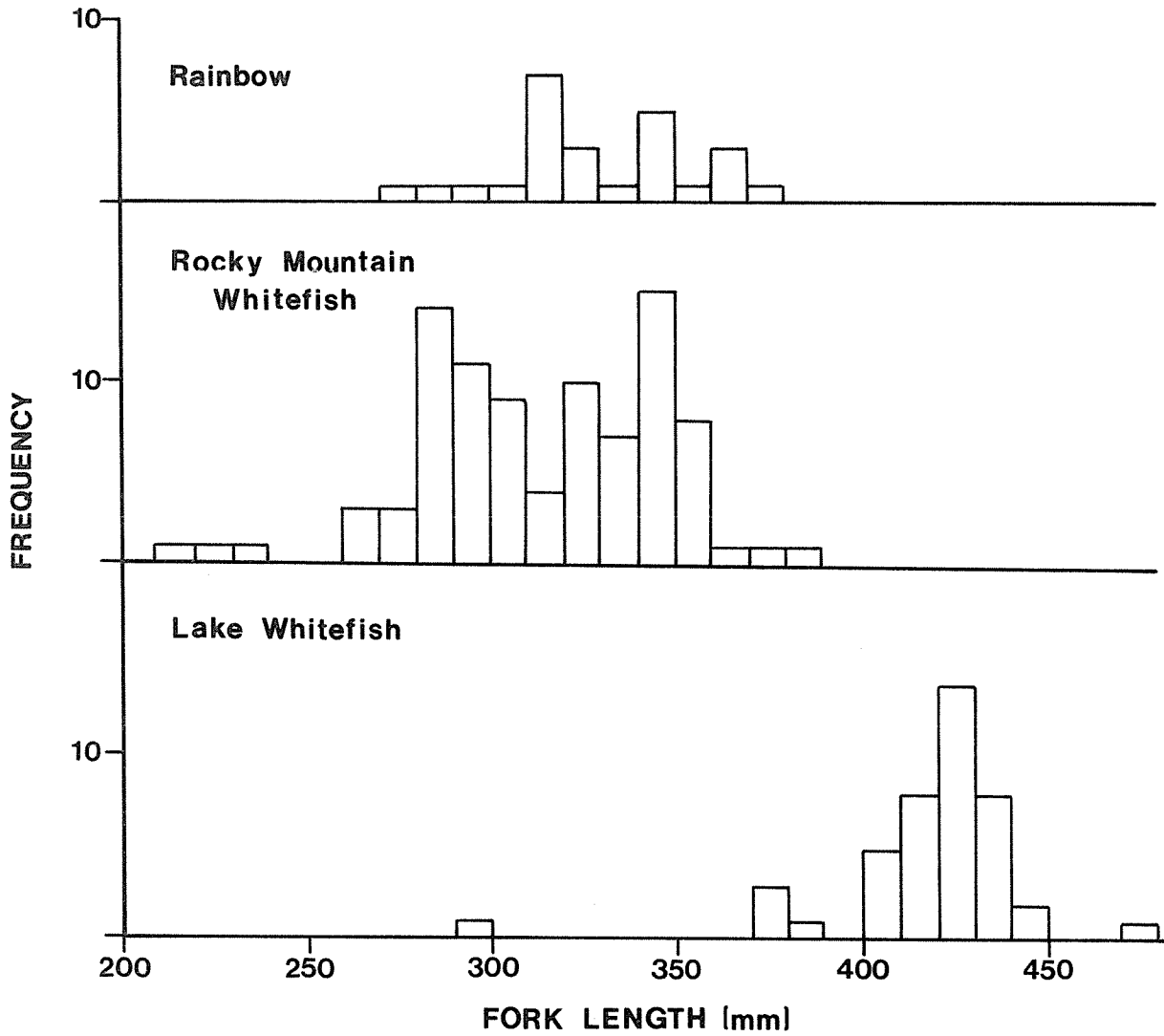


Fig. 31. Length frequency distributions of rainbow trout, Rocky Mountain whitefish and lake whitefish caught by purse seine in Banks Lake, 1978.

dimorphism became obvious (Fig. 32). A predominance of males was caught near the barrier in mid-August while later samples showed a nearly equal distribution of males and females. Station 6 samples indicated an opposite trend from nearly equal distribution of both sexes in August to early September to a predominance of females in schools offshore of the primary spawning area during late September and October.

A sex ratio of the kokanee catch was calculated for the period September 1 through September 21, 1978. The period of consideration was limited to this interval because the kokanee had matured enough to be positively identified as mature males or females but had not yet congregated along shore where some schooling by sex was apparent. A total of 76 males and 87 females was captured during this period. The composition was not significantly different ($P \leq .05$) from a 1:1 ratio, using a chi-square test (Steel and Torrie 1960).

6.2.2.4 Population Estimate. The general procedure for a multiple census population estimate, such as the Schumacher-Eschmeyer, is that fish are marked and added to the population over a period of time while samples are taken concurrently and examined for recaptures (Ricker 1975). Care must be taken to avoid the systematic errors which can seriously bias the population estimate. The basic conditions which must be met include random mixing of marked and unmarked fish, randomly distributed fishing effort, limited mortality and limited recruitment to the population being sampled.

Any representative mark and recapture population estimate requires that either the marked fish or the total fishing effort be randomly distributed over the population being sampled. Ricker defines randomness as relative to the population structure, not necessarily to a geographical area. With the exception of the gillnet captures, the population estimate was conducted entirely at the south end of the lake in the vicinity of Station 6 and the barrier net. The tag and recapture operations were not random according to geographical area. If marked fish did not

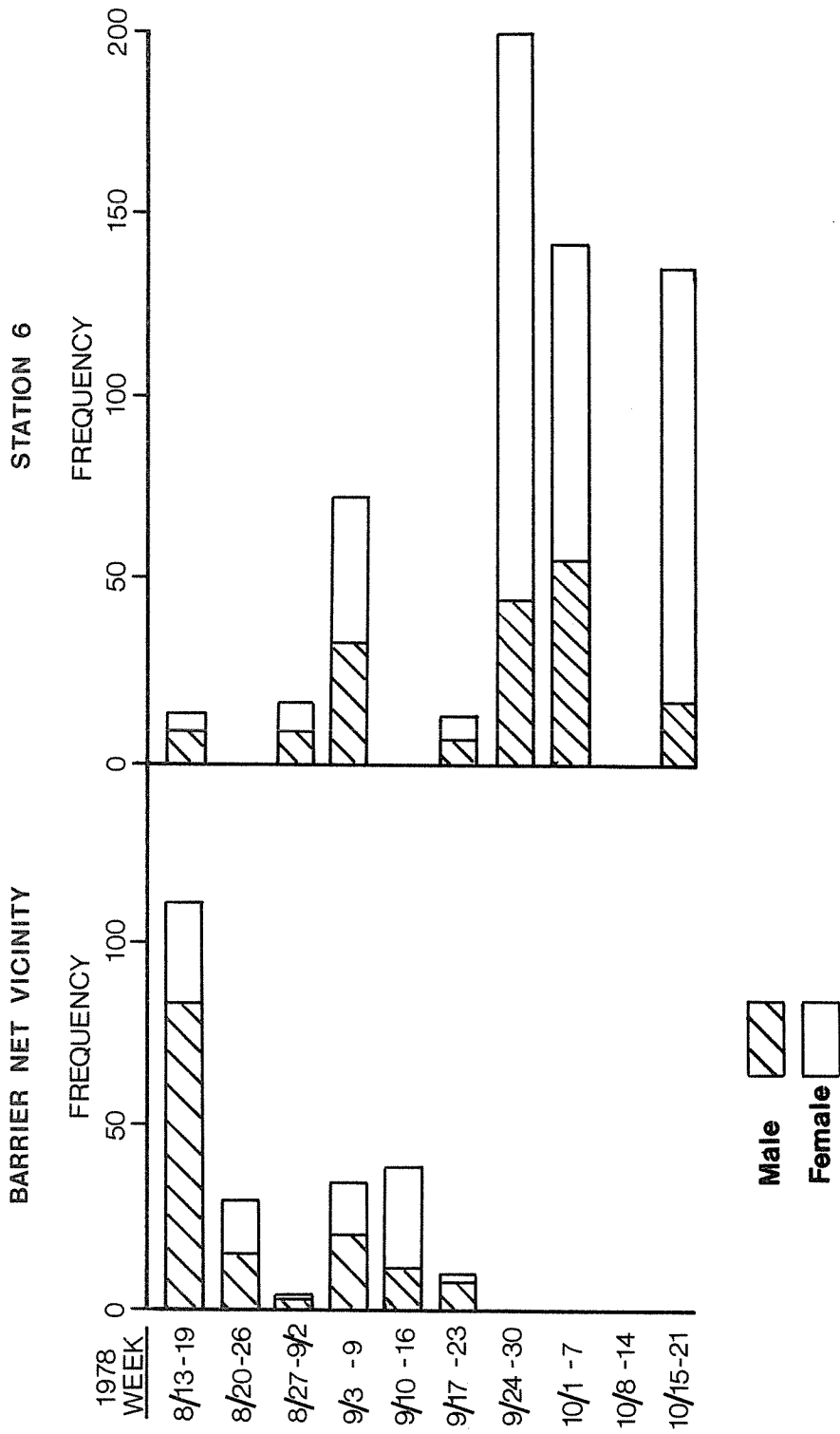


Fig. 32. Weekly sex composition of kokanee caught by purse seine in the vicinity of the barrier net and station 6, Banks Lake, 1978.

redistribute randomly with respect to the unmarked, the result would be an artificially high recapture rate and thus the estimate would be lower than the population size. However, the assumption that the marked fish were randomly distributed with the unmarked seemed acceptable based on tracks of sonic-tagged fish which showed extensive movement (Section 6.2.3) and on returns of Dennison-tagged fish from the sport fishery and gillnet sampling which showed uniformity of tagged-to-untagged ratio.

Mortality in the absence of recruitment, affecting marked and unmarked fish equally would cause the Schumacher-Eschmeyer estimate to be less than the initial, though greater than the final population size. Fishing mortality during the estimate was minimal because the estimate was made after Labor Day when sport fishing pressure was low. Total estimated sport catch of kokanee for the period was 780 fish. Natural mortality was probably low during this period because water temperature had declined and feeding and growth had ceased. An estimated 63 kokanee were entrained into the irrigation canal and 425 were gilled in the barrier net during this period.

Unequal mortality directed against the tagged fish, or undetected loss of tags, would result in a lower recapture rate and thus the estimate would be greater than the population size, however, there appeared to be little stress on the tagged fish and short term mortality was negligible. Complete checking of marks was assured by the use of the Dennison tags which were highly visible. Tags were always inserted behind the dorsal fin on the left side of the fish, and no evidence of tag loss (such as a wound in the tag area) was found.

The possibility of systematic error due to recruitment, which would bias the estimate upwards, was slight because the estimate was calculated only for adult kokanee. Recruitment of sub-adults into the samples was unlikely because the adults had assumed spawning coloration and sexual dimorphism had occurred.

Apparently, the systematic errors which can seriously bias a Schumacher-Eschmeyer population estimate were for the most part avoided. The population estimate for the period September 5 through October 19, 1978 was 35,381 adult kokanee with a 95% confidence interval range from 26,360 to 53,812 (Table 5). Limited mortality did occur during the period, but was small compared to the estimate and the confidence intervals.

6.2.2.5 Tag Recoveries. The distribution of recovered tags provides several inferences relative to movements of kokanee in Banks Lake and, more specifically, near the barrier net. Two individuals moved about 30 km, the entire length of the south pool of Banks Lake, to the vicinity of Steamboat Rock (Table 6, Fig. 33). Kokanee number 404-Or was tagged near the barrier net June 27 and caught by an angler near the North end of Steamboat Rock 68 days later. The other individual recaptured near Steamboat Rock (759-Or) was tagged offshore of the primary spawning area just prior to the spawning season (September 29) and recaptured in a gillnet at Station 4 twelve days later.

Except for the two tags noted above, the remainder of the tag returns were recovered between Million Dollar Mile and Dry Falls Dam. Gillnet surveys indicated that the relative density of mature kokanee was higher in the south end of Banks Lake during the period mid-summer through autumn. The distribution of recovered tags presents a general distribution of kokanee in the south pool, however, some bias may have resulted due to the impracticality of randomly distributing the recovery methods.

Evidence that kokanee which were retained by the barrier net, re-entered the sport fishery was provided by tag returns. Purse-seine catch data indicated a migration toward the barrier net in August. A total of 129 mature kokanee was captured and tagged on August 18, West of the Main Island. Eleven of these fish were recovered at later dates and only one (055-Y) was found in the vicinity of the barrier net (gillnet

Table 5. Schumacher-Eschmeyer multiple census values used to calculate a population estimate for adult kokanee in Banks Lake for the period September 1 through October 19, 1978.

Date	No. Caught (Ct)	Recaptures (Rt)	No. Marked (Less removals)	Marked Fish at Large		Ct	Mt ²	Rt ² /Ct
				Mt	Rt			
9/5	26	0	26	0	0	0	0	0
9/6	8	0	8	26	0	5,408	0	0
9/7	84	0	84	34	0	97,104	0	0
9/8	2	0	2	118	0	27,848	0	0
9/12	2	0	2	120	0	28,800	0	0
*9/12	18	0	0	122	0	267,912	0	0
9/13	4	0	4	122	0	59,536	0	0
*9/13	19	0	0	126	0	301,644	0	0
9/14	36	0	36	126	0	571,536	0	0
9/19	12	0	12	162	0	314,928	0	0
9/21	11	0	11	174	0	333,036	0	0
*9/26	12	0	0	185	0	410,700	0	0
*9/27	33	0	0	185	0	1,129,425	0	0
9/28	60	0	60	185	0	2,053,500	0	0
9/29	141	0	141	245	0	8,463,525	0	0
10/3	63	1	62	386	386	9,386,748	.0159	
10/6	153	3	77	448	1,344	30,707,712	.0588	
*10/10	20	0	0	525	0	5,512,500	0	
*10/11	34	1	-1	525	525	9,371,250	.0294	
10/18	101	2	99	524	1,048	27,732,176	.0396	
10/19	13	0	13	623	0	5,045,677	0	
					3,303	116,864,501	.1437	

Estimate:

$$1/N = 3303/116,864,501 = 2.826 \times 10^{-5}; \text{ hence } N = 35,381$$

Variance from regression line:

$$S^2 = \frac{(3303)^2}{21-1} \cdot .1437 - \frac{116,864,501}{116,864,501} = .002515$$

$$s(1/N) = \sqrt{\frac{.002515}{116,864,501}} = 4.6390 \times 10^{-6}$$

95% Confidence Intervals (C.I.):

Since $t = 2.086$ for 20 df, the 95% C.I. $(1/N) = 1/N \pm .96769 \times 10^{-5}$
 Reciprocals give limits for N or; 95% C.I. (N) = 26,360 to 53,812

*Gillnet sample

Table 6. Distribution of recovered tags, time interval before recovery and distance of recovery from tagging location.

Tag Date	Tag Location	Tag No.	Fl.*	Sex	Recaptured Kokanee		Recovery Location	Recovery Method	Elapsed Time (Days)	Distance (Km)
					Date Recovery	Location				
6/27/78	W. Main Is.	404-Or	329	-	9/3	N. Steamboat	Angler	68	31.2	
7/12	Sta. 6	445-Or	353	-	7/30	W. of M.D.M.**	"	18	13.2	
7/27	Sta. 6	424-Or	368	-	8/31	Sta. 6	"	35	0	
8/18	W. Main Is.	125-Y	379	M	8/21	Chase Draw	"	3	5.3	
8/18	"	134-Y	389	F	8/24	Goose Is.	"	7	2.6	
8/18	"	128-Y	404	M	8/27	Chase Draw	"	9	5.3	
8/18	"	046-Y	378	M	8/30	Goose Is.	"	12	2.6	
8/18	"	016-Y	373	-	9/3	Twin Falls***	"	16	8.6	
8/18	"	072-Y	369	M	9/24	M.D.M.	"	37	12.5	
8/18	"	055-Y	385	M	9/26	Sta. 7	Gillnet	39	0.7	
8/18	"	019-Y	384	M	9/29	Primary Spawning Area	Purse-Seine	42	3.1	
8/18	"	004-Y	388	F	9/29	"	"	42	3.1	
8/18	"	151-Y	383	M	10/6	"	"	49	3.1	
8/18	"	098-Y	383	F	11/14	"	"	88	3.1	
8/23	Sta. 6	542-Or	355	M	8/30	MDM	Spawned-out	7	10.5	
8/23	W. Main Is.	157-Y	369	F	10/3	Primary Spawning Area	Angler	42	3.1	
8/31	Sta. 6	547-Or	335	I	10/18	W. Main Is.	Purse-Seine	48	2.4	
9/6	W. Main Is.	197-Y	397	M	9/11	Twin Falls	"	5	9.6	
9/7	Sta. 6	596-Or	398	F	11/1	S. Barrier Net	Angler	55	3.1	
9/28	"	614-Or	385	M	11/13	Primary Spawning Area	Gilled	67	0.8	
9/28	"	707-Or	350	M	11/1	S. Barrier Net	Gilled	34	3.1	
9/28	Primary Spawning Area	699-Or	370	F	11/16	MDM	Spawned-out	49	10.5	
9/29	"	587-Or	379	F	10/3	Primary Spawning Area	Purse-Seine	4	0	
9/29	"	721-Or	373	F	10/6	"	"	7	0	
9/29	"	797-Or	384	F	10/6	"	"	7	0	
9/29	"	759-Or	388	F	10/11	Sta. 4	Gillnet	12	26.9	
10/3	"	886-Or	381	F	10/6	Primary Spawning Area	Purse-Seine	3	0	
10/3	"	907-Or	388	F	10/18	"	"	15	0	
10/3	"	905-Or	378	F	11/1	S. Barrier Net	Gilled	29	3.7	
10/3	"	894-Or	380	F	11/22	Coulee City Harbor	Spawned-out	50	4.3	
10/6	"	955-Or	412	F	10/18	Primary Spawning Area	Purse-Seine	12	0	
10/6	"	945-Or	432	M	11/1	S. Barrier Net	Gilled	26	3.7	
10/18	"	1003-Or	377	F	11/1	"	"	14	3.7	
10/18	"	1005-Or	394	F	11/13	Primary Spawning Area	Spawned-out	26	0	

* Fork length at time of tagging.

** Million Dollar Mile

*** Shrock Draw and McDonald Draw

Table 6. continued

Tag Date	Tag Location	Tag No.	FL*	Sex	Recaptured Rainbow		Recovery Location	Recovery Method	Elapsed Time (Days)	Distance (Km)
					Date	Recovery				
6/28/78	W. Main. Is.	419-Or	314	-	7/20		Twin Falls	Angler	22	8.6
7/27	Sta. 6	507-Or	306	-	8/3		Primary Spawning Area	"	7	1.0
7/27	"	505-Or	351	-	12/6		MDM	"	132	10.5
8/16	"	530-Or	317	-	9/14		W. Main Is.	Purse-Seine	29	2.4
9/14/78	W. Main Is.	216-Y	350	-	4/6/79		Steamboat Rock	Angler	204	~30.0

* Fork length at time of tagging.

** Million Dollar Mile.

*** Shrock Draw and McDonald Draw.

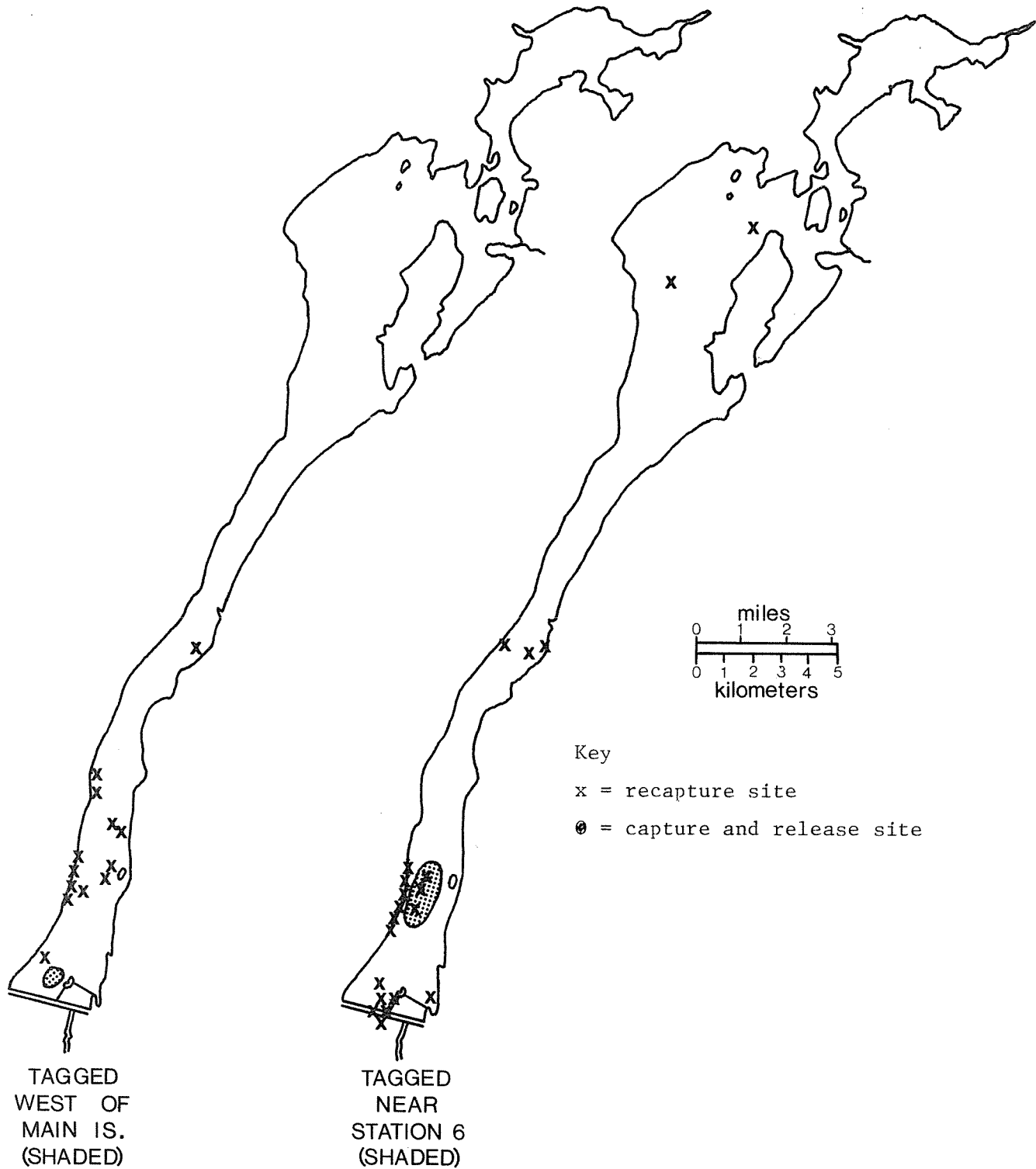


Fig. 33. Distribution of recapture locations of kokanee tagged west of Main Island (left) and in the vicinity of Station 6 (right) of Banks Lake, 1978.

Station 7). Anglers returned 6 out of the remaining 10 tags from as far away as Million Dollar Mile (12.5 km).

At least some of the kokanee retained by the barrier net contributed to spawning. Fish number 098-Y, a female, was found spawned out on the primary spawning area and fish numbers 004-Y, 019-Y, and 151-Y were recaptured by purse-seine offshore of the primary spawning area prior to spawning. Visual observation of tags on the spawning grounds during glass bottomed pram and SCUBA surveys accounted for 7 yellow tags (tagged near the barrier net) and 20 orange tags (generally tagged in the vicinity of Station 6).

The recaptured tags also gave some idea of movements of kokanee at the time of spawning. Twelve fish which were tagged offshore of the primary spawning area between September 29 and October 18 were recaptured. Half of these were recaptured by purse seine and one was found spawned out in the same area. The other 5 dispersed. Three were found gilled in the barrier net, one apparently spawned on the jetty in Coulee City harbor and the final one moved 27 km to Station 4 before it was caught in a gillnet.

A relatively high percentage of tagged rainbow trout was recaptured (Table 6). Twenty-six rainbow were tagged over the sample period. Anglers returned 4 tags and a fifth was recaptured by purse seine. Distances between tagging location and recapture location ranged from 1.0 to ~30.0 km.

6.2.3 Sonic Tracking

The sonic tracking was designed to determine the behavior of adult kokanee which may encounter the net barrier. Kokanee were released and tracked over the months of July, August, September, and October. During the early part of this period the fish were feeding and in the final stages of growth, while the latter half was characterized by sexual maturation and spawning. There was no particular location to which any

fish could be expected to "home" since the reservoir lacks spawning tributaries. The rate at which water was drafted through the irrigation canal changed from a maximum in July to zero on October 28 (Fig. 16). The currents induced near the outlet decreased in this period in which the fish were tracked. Sonic tagged kokanee were released both at Station 6 and near the barrier in order to ensure some encounters with the barrier net as well as to determine whether a change in behavior would occur as fish came under the influence of the flow of water from the lake.

Movements of 14 purse-seined kokanee salmon were tracked from the area of Station 6 and near the barrier net. Six fish were released at Station 6, four near the south barrier net and four north of the east barrier. The tracks are discussed in chronological order. The fish released on July 18 (#1) and 19 (#2) both showed movement northward into the deeper area of the lake south of Million Dollar Mile (Fig. 34). Even though one was released at Station 6 and the other near the barrier net both moved northward. The fish released on July 19 may have encountered the north end of the south barrier net, however, this happened very quickly during the initial stages of tracking. If the fish detected the net, it was for a very brief time as it turned toward the north. The tracks of fish on August 2 (#3) and 16 (#4) (Fig. 35), ended prematurely due to failure of the tag on the first fish and loss of the tag by the second fish. During the brief track made on August 2, the kokanee moved generally east and north from Station 6. The fish released near the south net on August 16 moved along the south dam where the tag remained.

The kokanee released on August 30 (#5) and 31 (#6) (Fig. 36), again moved northward after an initial period of orientation. The tag released on August 30 ceased operation prematurely, but the kokanee released on August 31 was tracked for a total of 33 days (August 31 to October 3). This kokanee moved as far north as North Million Dollar Mile and extensive movement was centered around Station 6 and the barrier net. This fish was located on both the east and south barriers on September 28 and 29, respectively. The track terminated north of the east barrier on October 3

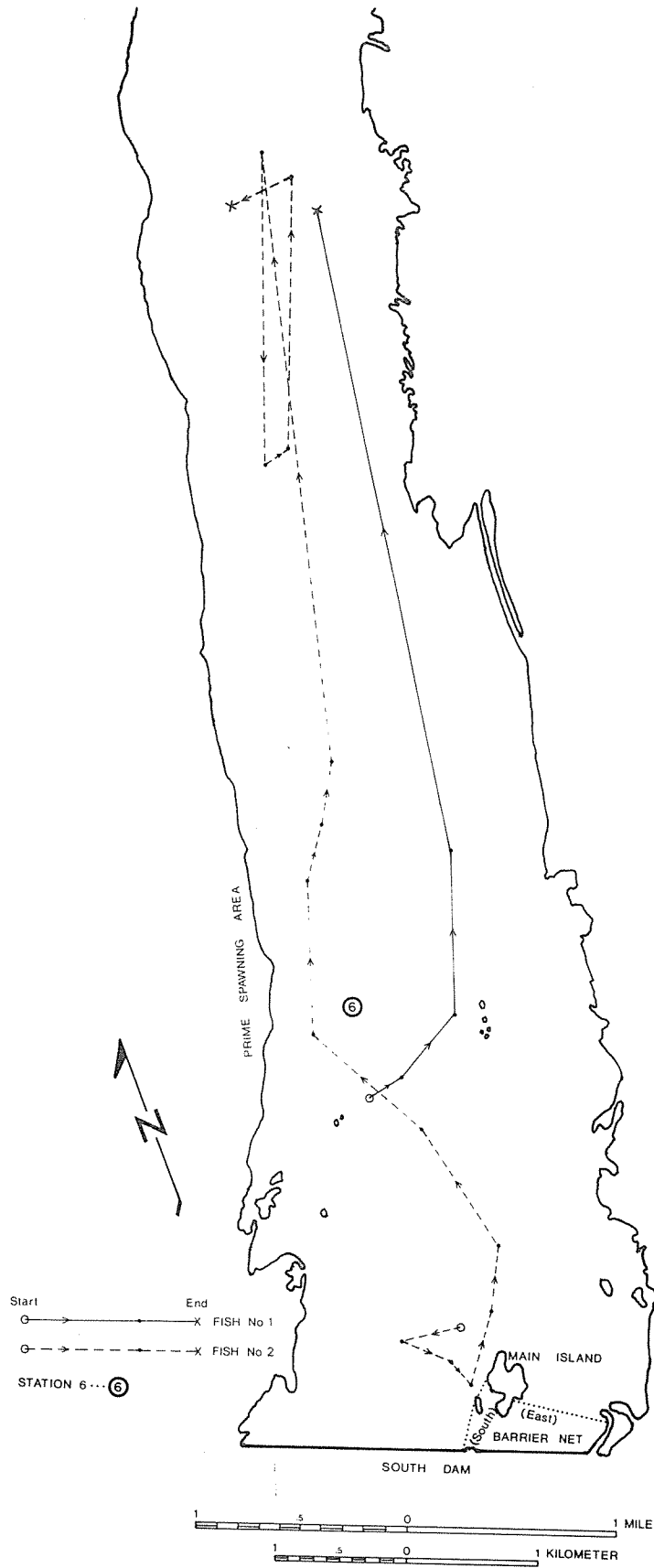


Fig. 34. Movement in Banks Lake of kokanee salmon sonic tagged on July 18 (#1) and 19 (#2).

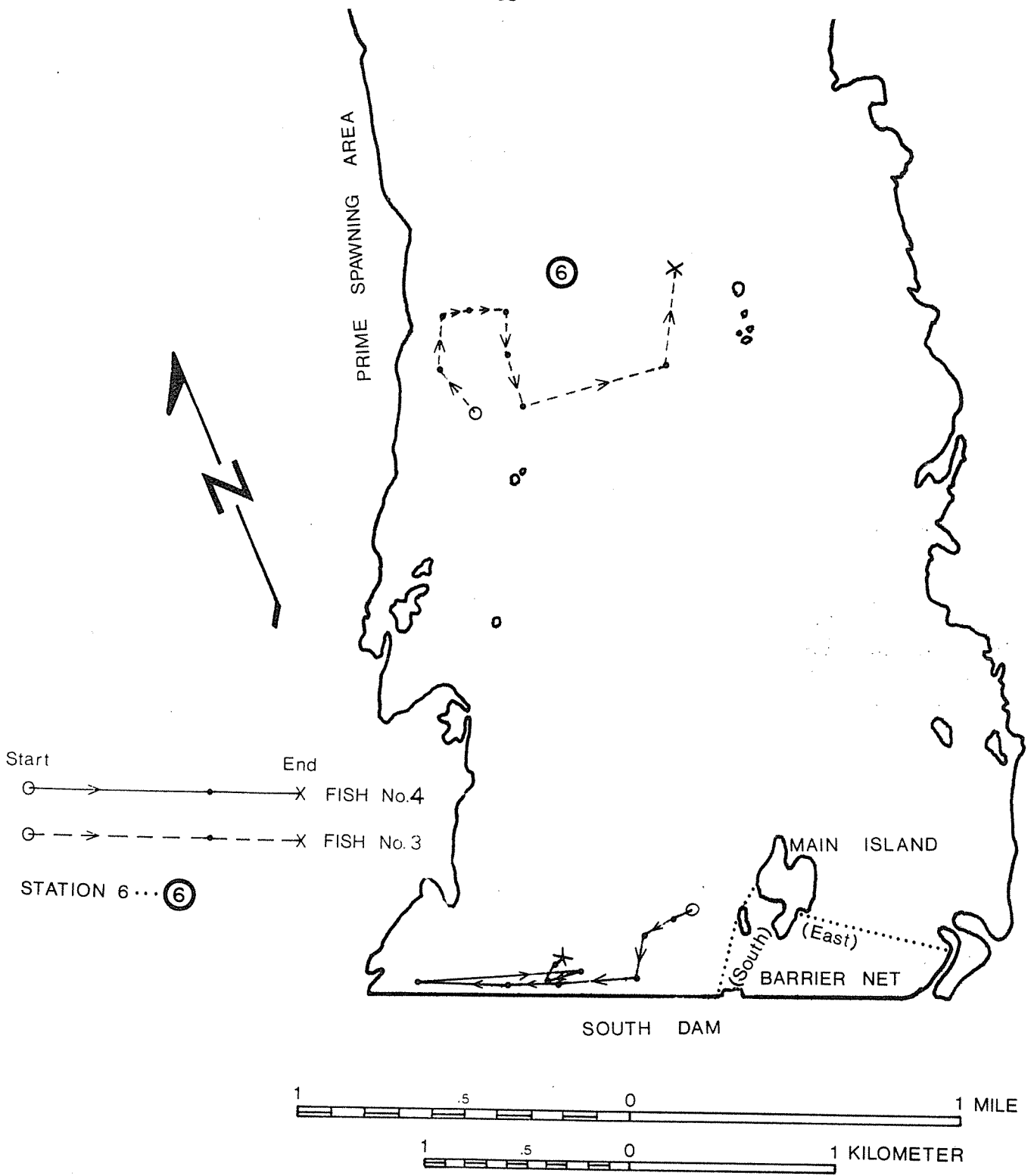


Fig. 35. Movement in Banks Lake of kokanee salmon sonic tagged on August 2 (#3) and 16 (#4).

indicating retention of this fish by the barrier net. During mid-September, this kokanee was located several times on the spawning beaches along the west talus shoreline and on the shore of Dry Falls dam.

Kokanee were released on September 12 (#7) and 14 (#8). The tag released on September 12 ceased operation prematurely, however, during the two days the fish was tracked it moved northward from release near the south barrier to the vicinity of Station 6 with an excursion to the west shoreline (Fig. 37). The fish released on September 14 north of the east barrier net, after an initial movement to the east barrier, moved north to the north Million Dollar Mile area. This fish remained in this general area until it was last located near the west beach in the general area of Station 6.

The kokanee released on September 20 (#9) and 21 (#10) (Fig. 38), were both active in the vicinity of the barrier net. The fish released on September 20 west of the south barrier moved north after a brief orientation period traveling nearly to Haystack Rock by September 26. This kokanee returned to near the release point by October 12 and remained near the south barrier until the track was terminated on October 20. The fish released on September 21 at Station 6 moved between Station 6 and the barrier net and then circulated considerably near the Main Island on both the east and south barrier nets during the 25 days ending on October 16.

Kokanee released on September 28 (#11) and 29 (#12) (Fig. 39) indicated the amount of movement was beginning to decrease. The kokanee released on September 28 north of the east barrier moved between the barrier and the spawning areas along the west shoreline near Station 6. The track ended on the primary spawning site on October 23. The fish released on September 29 was caught close to the primary spawning area. During this time it moved north as far as south Million Dollar Mile where it was tracked on October 9. The track terminated on a talus shoreline area north of the prime spawning area on October 20.

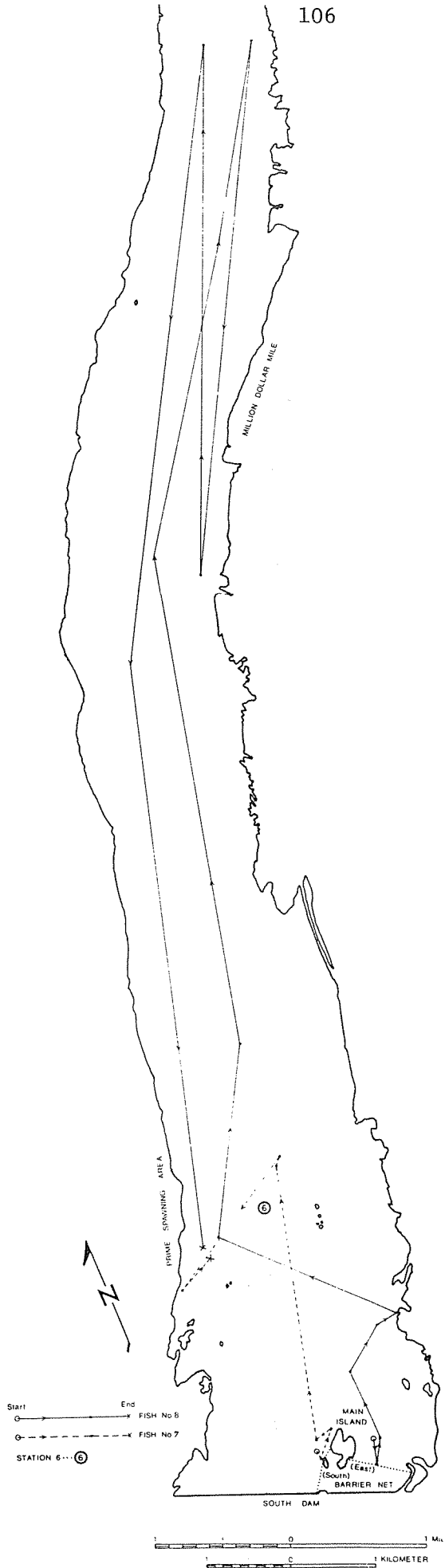


Fig. 37. Movement in Banks Lake of kokanee salmon sonic tagged on September 12 (#7) and 14 (#8).

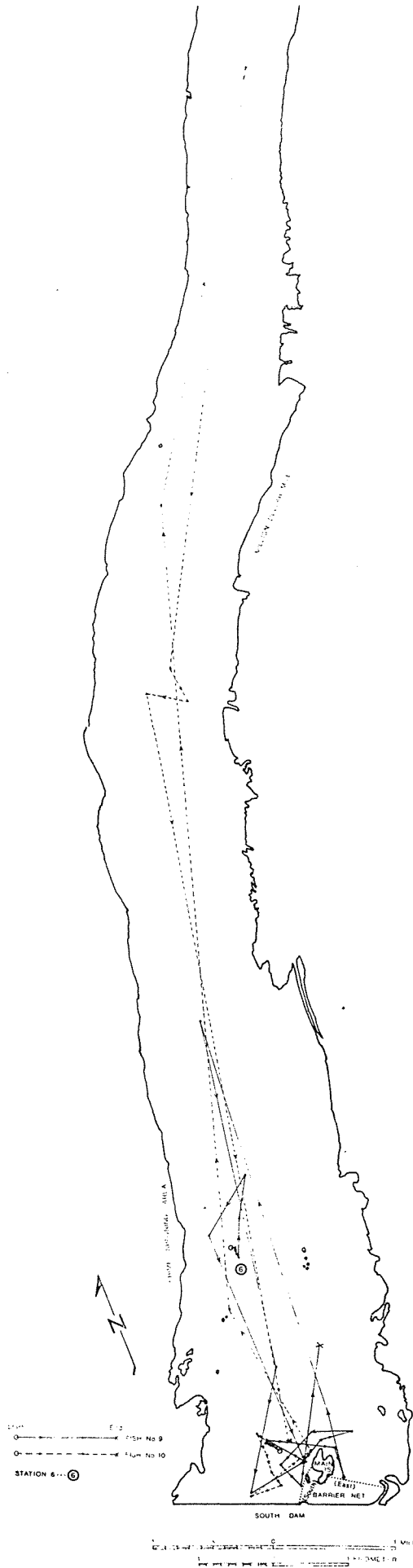


Fig. 38. Movement in Banks Lake of kokanee salmon sonic tagged on September 20 (#9) and 21 (#10).

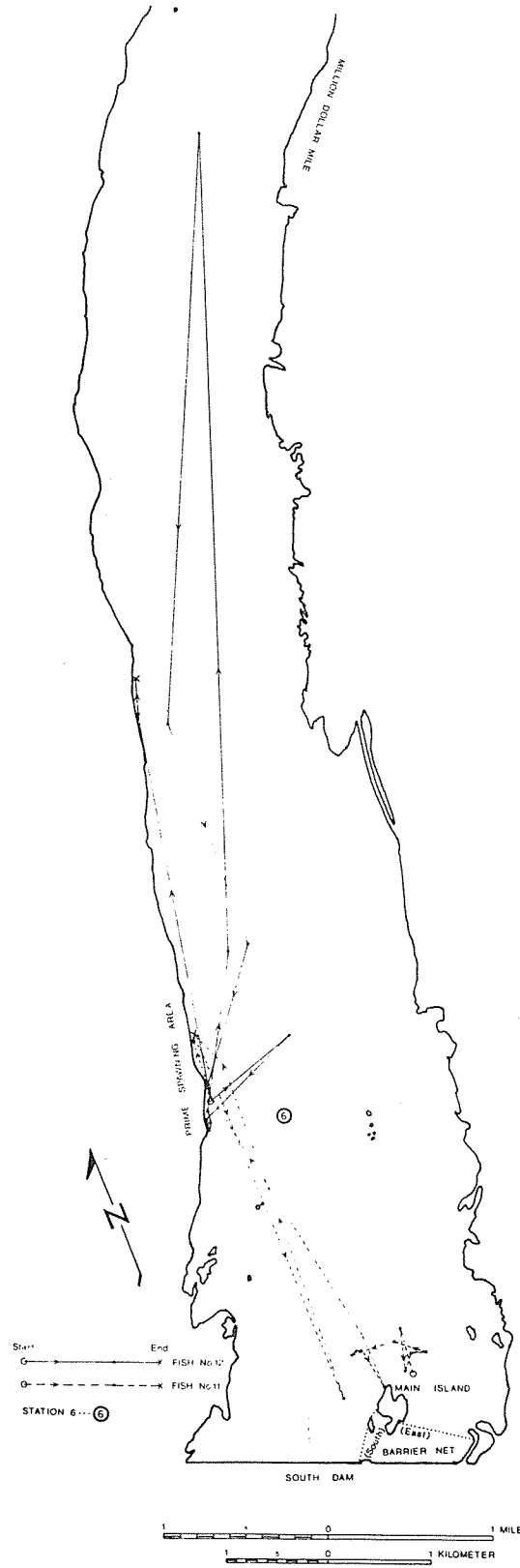


Fig. 39. Movement in Banks Lake of kokanee salmon sonic tagged on September 28 (#11) and 29 (#12).

Releases made on October 3 (#13 & 14) (Fig. 40) indicated a further decrease in movement compared to the previous pair of fishes. The fish released at Station 6 was tracked to the shore along the south dam where the track terminated and the fish apparently spawned. The final release was near the east barrier and the fish was tracked to the beach spawning sites along the west shoreline. The tracks of the last four fish released terminated at shoreline spawning areas between October 20 and 27.

Water currents may have affected the orientation of the kokanee upon initial release, however, consistent relationship of initial fish travel to the direction of current drogue drift was difficult to determine (Fig. 41). Statistical analysis of the data was precluded by the small size of the sample and the fact that common release points were not used. It is apparent that even when fish were released in the weak currents near the outlet that kokanee did not consistently attempt to move downstream and come within visual contact with the barrier.

Initial swimming speeds were calculated to average 12.9 cm sec^{-1} with a range from 0.85 to 33 cm sec^{-1} . Individual swimming speeds seemed to be higher during July and August when the fish were feeding. Swimming declined as the spawning season approached and the temperature declined.

6.2.4 Creel Census

6.2.4.1 Banks Lake

6.2.4.1.1 Catch and Effort. A creel census of the sport fishery was conducted in 1978 to provide comparative data of the first full year of barrier net operation against previous years without a net barrier. The recovery of marked kokanee and rainbow trout in the catch was also facilitated by the creel census. Determination of the size of the catch of each species by month was made simultaneously in Banks and Billy Clapp Lakes which allowed comparisons between years on Banks Lake and an initial comparison between these two reservoirs.

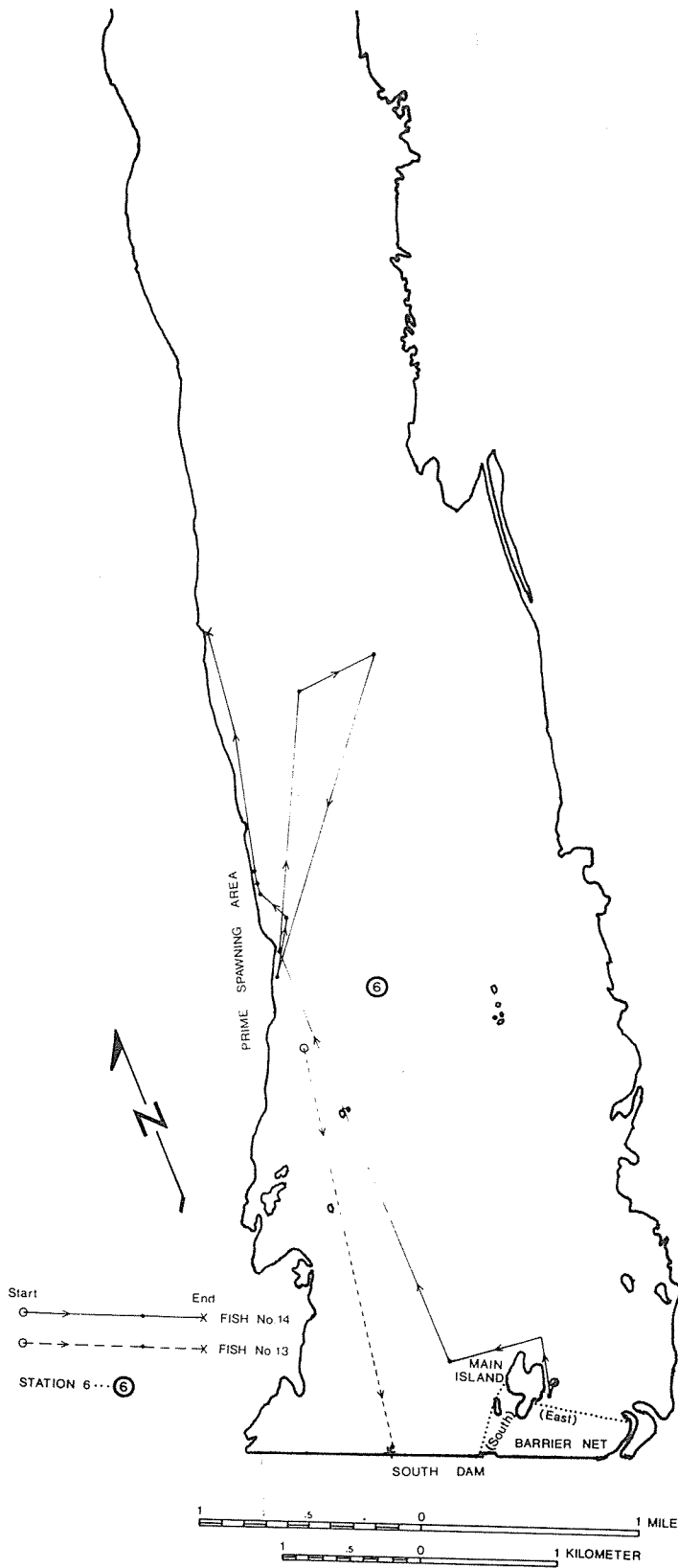


Fig. 40. Movement in Banks Lake of kokanee salmon sonic tagged on October 3 (# 13 and #14).

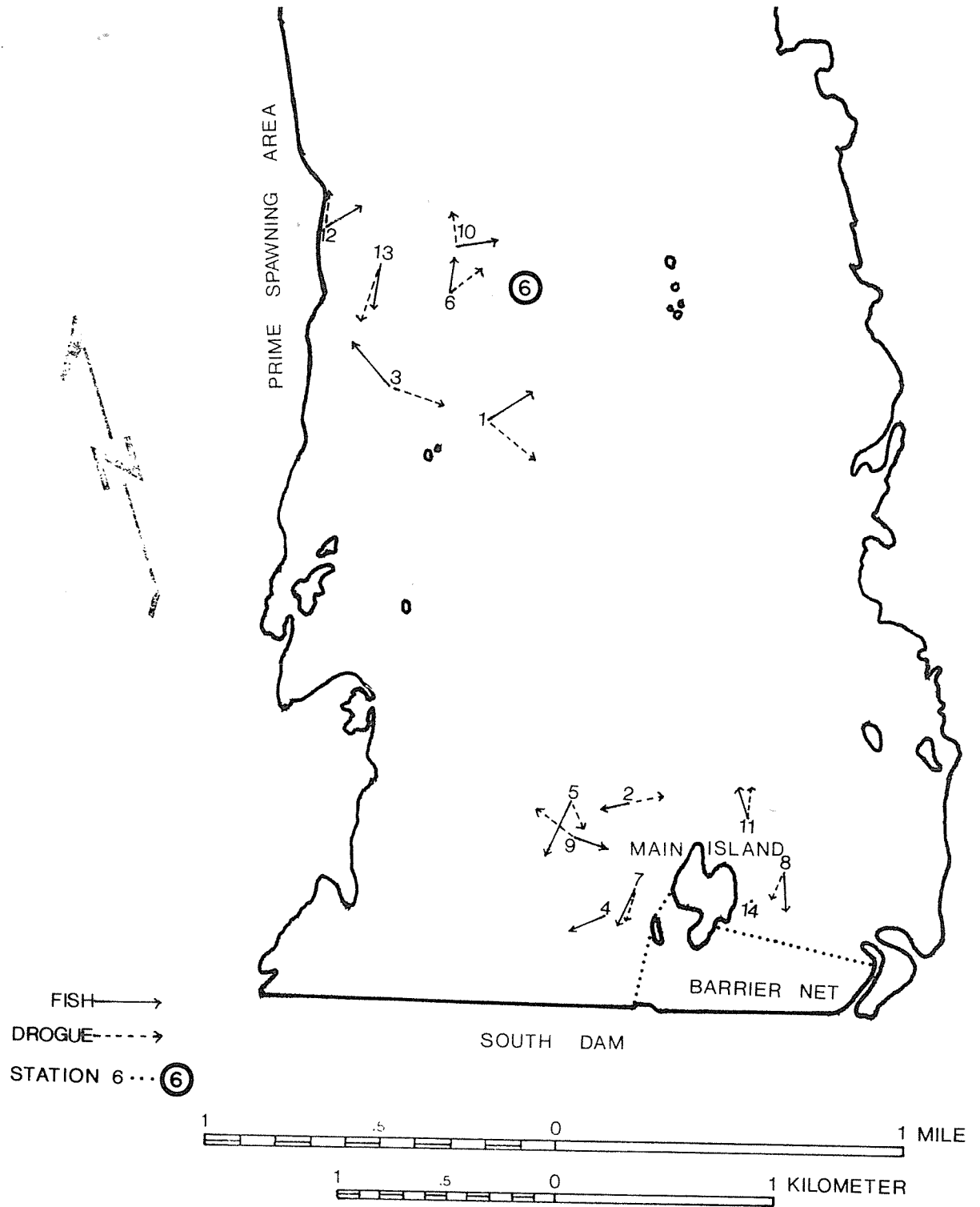


Fig. 41. Initial direction of movement of sonic tagged kokanee and drift drogues.

The results of the census are based on interviews of 898 anglers on 58 days from April 10 to October 28, 1978. An estimated total of 214,768 angler-hours was expended to catch an estimated 55,465 fish of all species or about 0.26 fish per angler-hour.

The effort, CPUE, and estimated catch for the ten most commonly caught species in the boat and shore fisheries are summarized for the period April-September 1978 (Table 7). The species in decreasing order of abundance in the total catch were: kokanee, 83.7%; yellow perch, 5.9%; rainbow trout, 4.0%; chinook salmon 2.7%; crappie, 2.3%; bass, 0.8%; sunfish, 0.2%; and brown bullhead, 0.2%. Lake whitefish and walleye were also taken but comprised less than 0.2% of the total catch.

The boat fishery began early in April, continued actively through August and diminished during September. Boat fishing after the first week of September was limited. Kokanee was the species most sought by the boat fishery. Because kokanee were fished principally by trolling offshore, the fishery was easily identified. Observations of the boat fishery made from promotories at several locations along the length of Banks Lake indicated 89% of the boats seen were engaged in fishing for kokanee and 11% were fishing for spiny-rayed fish. A majority of the rainbow and chinook catch was made incidentally in the offshore troll fishery.

The boat fishery accounted for all of the estimated 46,427 kokanee caught during the sampling period. The maximum monthly catch was 14,651 in July. The rainbow catch was estimated at 2,243. The estimated chinook catch was 1,521. The maximum monthly catch of chinook occurred in April. Kokanee, rainbow, and chinook were caught predominantly in the troll fishery. A few rainbow and chinook were caught by the shore fishery thus indicating wider habitat and feeding preferences for these species than for kokanee which are pelagic in distribution. The catch of chinook represented about 3.3% of the 1976 plant of 46,000.

Table 7. Summary of Banks Lake sport fishery catch, effort, and catch per unit of effort April thru September, 1978.

Months	Fishery	Total Effort (Angler-hrs.)	Kokanee		Rainbow		Chinook		Yellow Perch		Bass		Crappie		Sunfish		Walleye		Whitefish		Brown Bullhead		
			Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch
April	Boat (Spiny Ray)	3,541																					
	Boat (Salmonid)	26,021	10,762	0.414	552	0.021	414	0.016	31	0.009	51	0.028	163	0.089	16	0.009	16	0.009					
	Shore	1,833	10,762	0.414	42	0.023	16	0.009	32	0.290	51	0.028	163	0.089	16	0.009	16	0.009					
	Total	31,395			594		430		563		51		163		16		16						
May	Boat (Spiny Ray)	4,758																					
	Boat (Salmonid)	33,898	7,600	0.224	491	0.015	393	0.012	117	0.025	107	0.023	475	0.100									
	Shore	1,226	7,600	0.224	13	0.011			771	0.629	107	0.023	159	0.130									
	Total	39,882			504		393		888		107		634										
June	Boat (Spiny Ray)	3,240																					
	Boat (Salmonid)	28,610	5,473	0.191	215	0.008	375	0.013	73	0.077	121	0.128	169	0.179	73	0.077							
	Shore	943	5,473	0.191	25	0.026	375		73	0.077	194		211		73								
	Total	32,793			240				149		194		211		73								
July	Boat (Spiny Ray)	6,023																					
	Boat (Salmonid)	48,418	14,651	0.303	600	0.012	300	0.006	414	0.427	13	0.013	201	0.207	38	0.039	10	0.002			50	0.052	
	Shore	970	14,651	0.303	600	0.012	300	0.006	563	0.427	13	0.013	294	0.207	48	0.039	10	0.002			50	0.052	
	Total	55,411			600		300		617		13		294		48		10				50	0.052	
August	Boat (Spiny Ray)	3,621																					
	Boat (Salmonid)	33,855	5,854	0.173	251	0.007	0		287	0.590	72	0.148									72	0.148	
	Shore	486	5,854	0.173	251	0.007	0		904	0.590	72	0.148									72	0.148	
	Total	37,962			251		0		617		72										72	0.148	
Sept.	Boat (Spiny Ray)	2,109																					
	Boat (Salmonid)	14,938	2,087	0.140	54	0.004			8	0.004													
	Shore	278	2,087	0.140	54	0.004			251	0.904													
	Total	17,325			54		23		259														
	TOTAL	214,768	46,427		2,243		1,521		3,250		437		1,302		137		10				16	122	

The estimated catch of yellow perch was 3,250. Perch were caught mainly by the shore fishery. The catch of perch was low relative to their high abundance in the lake. The mean length of perch was 176 mm which may have discouraged an active sport fishery for this species, since the minimum size acceptable to most anglers is about 200 mm.

The estimated catch of largemouth bass was 437 and the maximum monthly catch occurred in June. Two bass tournaments were held during June and July, however, statistics on the catch were difficult to obtain because the anglers released all fish. The bass fishery occurred during early morning and late afternoon requiring special census timing which was not practical with this limited effort. An estimated 1,302 crappie was taken about evenly between boat and shore anglers during the April-July period.

An estimate of the incidental species taken in the creel included 16 lake whitefish, 10 walleye, and 122 brown bullhead. The lake whitefish were caught by the shore fishery during April. Walleye were caught in the July troll fishery and the brown bullhead were caught during July and August, primarily in the Osborne Bay area shore fishery.

The effort expended in the shore fishery in 1978 was largest in April and declined through September. The principal species caught in the fishery in decreasing order of abundance were yellow perch, crappie, largemouth bass, and rainbow trout. Chinook salmon and lake whitefish also entered the shore catch in small numbers. During 1975-1976 the shore fishery was most active during winter and early spring (Stober et al. 1976).

6.2.4.1.2 Comparison between years. A limited creel census to determine sport fishing effort and catch, specifically for kokanee, was conducted in late summer and fall 1977. The study was limited in scope because it was conducted before and after regular working hours. The primary goal was to determine angler CPUE in a year with a low population

of age III kokanee (1977) which could be compared to the 1975 and 1978 creel census.

The census results were based on boat counts on 66 occasions between August 9 and October 23, 1977, and on returns of 68 questionnaires representing 171 anglers who expended 1,246 angler-hr.

The 1977 weekday boat counts declined steadily during the census period from an average of 17 in early August to 0.1 for the month of October. The angler-effort for the south end (from North Million Dollar Mile to Dry Falls Dam) of Banks Lake for the period August through October was 65% less in 1977 than in 1975 (Table 8). The kokanee catch per angler-hr was 5.6 times greater.

The kokanee sport fishery in 1977 was very poor as recounted by anglers during interviews and in the questionnaires. Some 68% of the creel census questionnaires returned contained a comment regarding the poor fishing. In addition, many comments referred to poor fishing in 1976.

The kokanee sport fishery depends primarily on age III fish, although some immature age II fish are also creeled during the summer months (Stober et al. 1977). The 1974 year class (age III in 1977) was very weak prior to barrier net operation. The sport catch in 1977 was estimated at about 12,283 with 11,039 spawners remaining in the lake. Of the total number of fish available in this year class about 77% were retained in the lake.

During 1978, the sport fishery showed improvement in the overall CPUE (0.167) for August-October over the low of 0.047 observed for the period in 1977. The increased effort of 41% in 1978 probably reflected the response of the fishermen to the greater availability of fish. However, neither effort nor the CPUE reached the levels observed in 1975 of 49,781 angler-hrs and 0.263 kokanee per hr. The reduction in the entrapment

Table 8. Angler-effort for the south end of Banks Lake and kokanee catch per unit effort for the period August through October, 1975, 1977 and 1978.

	1975		1977		1978	
	Effort south end (hrs.)	Kokanee CPUE	Effort south end (hrs.)	Kokanee CPUE	Effort south end (hrs.)	Kokanee CPUE
August	29,900	0.275	13,175	0.105*	19,023	.177
September	19,657	0.217	4,177	0.030	10,142	.147
October	224	1.519	195	0.022	623	**
	<u>49,781</u>	<u>0.263</u>	<u>17,547</u>	<u>0.047</u>	<u>29,788</u>	<u>.167</u>

*August 1977 CPUE based on data from 8/27-31 only.

**No creel census interviews taken.

loss of kokanee in 1978 undoubtedly contributed to the relatively high CPUE achieved in 1978.

A comparison of monthly catch and effort statistics between 1972, 1975, and 1978 is presented in Table 9. The 1978 census followed a drastic decline in the kokanee sport fishery during 1976 and 1977 partially indicated in Table 8. The effort and catch statistics in 1978 indicate substantial improvement in the kokanee fishery. The 1978 kokanee catch increased to a level about 63% of the 1975 catch. The effort in 1978 was 75% of the record 1975 effort. The 1978 catch of all species other than kokanee amounted to only 9,038 fish which was much less than the catch of other species in 1975.

The combined CPUE for kokanee during the period April-September was 0.286, 0.222, and 0.216 during 1972, 1975, and 1978, respectively. The CPUE for all other species was 0.372, 0.234, and 0.042 for 1972, 1975, and 1978, respectively. The sharp decline in the CPUE for all other species except kokanee in 1978 indicates a severe decline in the fishery similar to that observed for kokanee (0.047) in 1977. The barrier net apparently improved the kokanee fishery in 1978 by retaining adults which would otherwise have been lost into the irrigation canal.

6.2.4.1.3 Length-frequency analysis. Fork length measurements of the catch were recorded during the interview portion of the 1978 creel census. Samples of the most abundant species (kokanee, yellow perch, rainbow, and chinook) were sufficiently large to characterize a length-frequency distribution.

Monthly length frequency distributions were plotted for kokanee caught in Banks Lake for the period April through September (Fig. 42). The dominant group caught in the sport fishery was age III, which was the progeny of the 1974 adult year class. The mean length during April and May was 294 and 290 mm, respectively. Subsequent length indicated growth throughout the summer occurred at an average rate of 11.3 mm per month.

Table 9. Comparison of Banks Lake sport catch and effort between creel censuses conducted in 1972, 1975, and 1978

Month	Year	Total Fishing Effort (hr)	Kokanee	Rainbow	Chinook	Perch	Crappie	Bass	Sunfish	Lake		Brown Bullhead
										Whitefish	Walleye	
Apr.	1972	16,094	1,757	677	16,791	253	173	0	122			
	1975	40,556	3,381	2,794	1,674	3,874	3,054	67	44	17		
	1978	31,395	10,762	594	430	563	163	51	16	16		
May	1972	47,611	17,946	1,064	20,119	7,726	92	1,194				
	1975	86,569	25,412	3,261	2,759	5,465	2,561	517	999			
	1978	39,882	7,600	504	393	888	634	107	0			
June	1972	32,743	5,121	1,560	-	9,158	1,137	280	93			
	1975	62,312	8,995	1,430	1,447	6,406	801	411	1,002			
	1978	32,793	5,473	240	375	73	211	194	73			
July	1972	36,548	10,121	2,068	-	4,289	818	1,728	250	93	406	0
	1975	60,618	15,382	4,451	1,132	9,076	0	39	850	0	0	0
	1978	55,411	14,651	600	300	563	294	13	48	0	10	50
Aug.	1972	36,193	22,794	1,798	-	3,724	93	789	1,859	46		
	1975	53,058	14,291	2,597	1,027	9,098	0	0	507	0		
	1978	37,962	5,854	251	0	904	0	72	0	0		
Sept.	1972	76,050	12,380	1,239	-	9,457	322	365	664			
	1975	28,963	6,170	1,397	56	8,785	82	0	121			
	1978	17,325	2,087	54	23	259	0	0	0			
Totals	1972	245,239	70,119	8,406	-	63,538	10,349	4,327	4,060	215	452	0
	1975	332,076	73,631	15,940	8,095	42,704	6,498	1,034	3,523	17	0	0
	1978	214,768	46,427	2,243	1,521	3,250	1,302	437	137	16	10	122

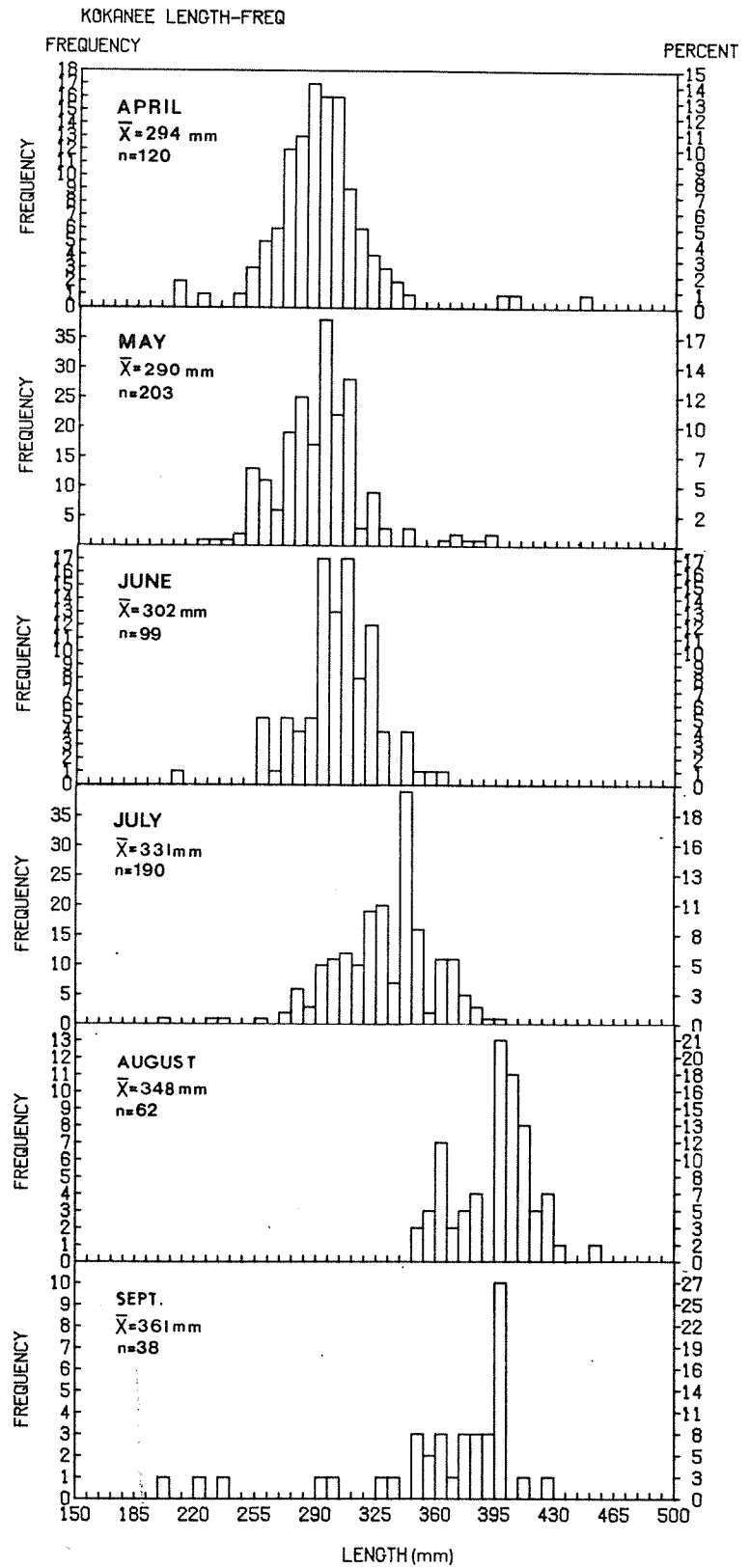


Fig. 42 Monthly length frequency distributions of Banks Lake kokanee in the sport catch from April through September, 1973.

This was a faster rate of growth than was observed in 1975 and may be attributed to the smaller population size. The largest mean length (361 mm) occurred in September. When compared to the 1975 population, the 1978 stocks had a smaller average size initially but surpassed the 1975 stocks in size by July. The mean length of gillnet caught kokanee for the census period was 312 mm and the average weight of the sport catch was 453 gm. The weight was estimated from the length-weight relationship of kokanee in the gillnet catch.

Yellow perch are caught by anglers of many age groups, including young children in a predominantly shore based fishery. The young anglers are the primary reason why two modes are shown in Fig. 43. The lower mode which occurs at approximately 20 mm are fish caught generally by children and not normally consumed. The upper mode which occurs at approximately 200 mm is marginally acceptable to most perch anglers. The small size of the fish caught may explain the reduction in effort expended because anglers are reluctant to fish for or keep perch smaller than approximately 200 mm. The mean length for all the perch sampled is 176 mm but if the lower mode is excluded, it becomes 191 mm approaching an acceptable size.

The size distribution of rainbow trout in the creel was comprised of several modes which represented separate hatchery plants. The three plants most recently recruited into the creel are represented by three distinct modes (Fig. 43). The plants made in March and October 1976, and October 1977 may correlate to the modes occurring at 320 mm, 240 mm, and 180 mm, respectively. However, none of the fish sampled were fin-clipped so firm identification was not possible. The planting record for all species has been updated in Appendix Table 1.

Chinook salmon were last released in Banks Lake during September 1976. Individuals from this plant appeared in the 1978 creel averaging 330 mm in length (Fig. 42).

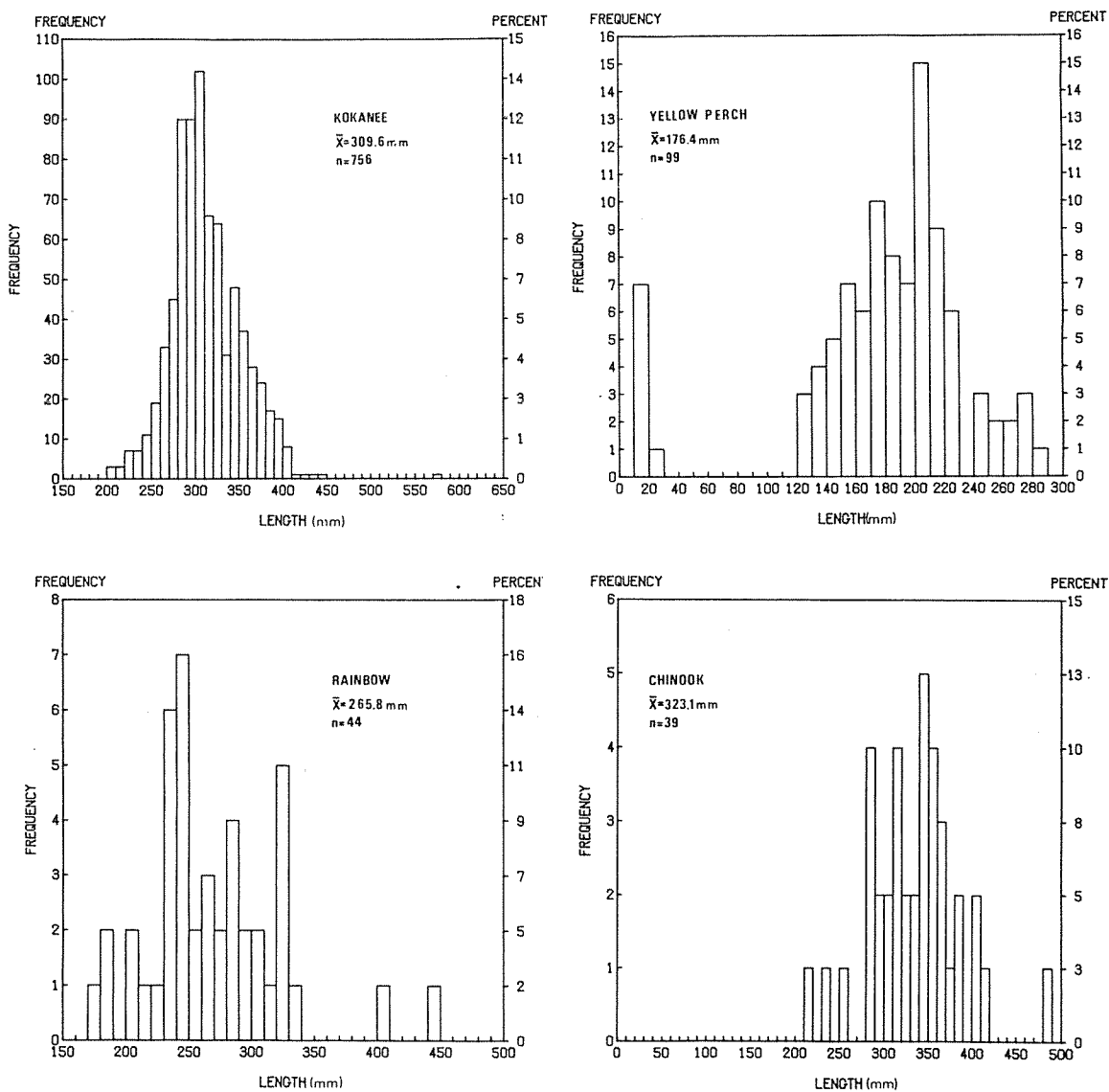


Fig. 43. Length frequency distributions of kokanee, yellow perch, rainbow trout and chinook salmon in the Banks Lake sport fishery from April through September, 1978.

6.2.4.2 Billy Clapp Lake (Long Lake Reservoir). Billy Clapp Lake is a 405 ha irrigation equalizing reservoir located 16.9 km downstream from Banks Lake on the main irrigation canal. Although no previous creel census had been conducted on Billy Clapp Lake it was generally believed by biologists of the Washington Department of Game and local anglers that the kokanee fishery in years past has been partially dependent on the annual entrainment of kokanee from Banks Lake (M. Spence, personal communication). The primary purpose of the creel census of Billy Clapp Lake was to determine the extent of the fishery and the secondary purpose was to evaluate the effects of the barrier net. Creel census' on both reservoirs were conducted concurrently.

Based on interviews of 38 anglers on 44 days during the period April-September, an estimated 11,509 angler-hrs were expended to catch an estimated 6,455 fish. This equates to a relatively high CPUE of 0.561 fish per angler-hr. The effort, CPUE, and estimated catch for each of the four species caught in both the boat and bank fisheries, are summarized for the period April-September, 1978 (Table 10). The species in order of decreasing abundance in the catch were: kokanee, 94.9%; chinook, 2.5%; rainbow trout, 1.4%; yellow perch, 1.2%; and carp, 0.1%.

The boat fishery began early in April, continued with increasing activity through September, and diminished during the first half of October. Very little boat fishing occurred after mid-October. Rainbow and chinook were caught incidentally with kokanee which was the principal target species.

The shore fishery was limited to a few areas at the Summer Falls State Park and near the reservoir outlet (Fig. 4). Shore fishing comprised less than 1% of the total fishing effort. This was probably due to lack of accessible shore fishing areas. Only four species of fish were observed during the 38 interviews.

Table 10. Summary of catch, catch per unit effort and effort statistics for Billy Clapp Lake (April-Sept. 1978).

Month	Fishery	Total	Kokanee		Chinook		Rainbow		Perch		Carp	
		Fishing Efforts	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
April	Boat	366	196	0.536	5	0.014	3	0.007	0		0	
	Bank	<u>10</u>	<u>0</u>		<u>0</u>		<u>1</u>	0.074	<u>10</u>	0.963	<u>1</u>	0.074
		376	196		5		4		10		1	
May	Boat	1,657	888	0.536	23	0.014	12	0.007	0		0	
	Bank	<u>14</u>	<u>0</u>		<u>0</u>		<u>1</u>	0.074	<u>13</u>	0.963	<u>1</u>	0.074
		1,671	888		23		13		13		1	
June	Boat	1,215	651	0.536	17	0.014	9	0.007	0		0	
	Bank	<u>14</u>	<u>0</u>		<u>0</u>		<u>1</u>	0.074	<u>13</u>	0.963	<u>1</u>	0.074
		1,229	651		17		10		13		1	
July	Boat	3,509	1,881	0.536	49	0.014	25	0.007	0		0	
	Bank	<u>14</u>	<u>0</u>		<u>0</u>		<u>1</u>	0.074	<u>13</u>	0.963	<u>1</u>	0.074
		3,523	1,881		49		26		13		1	
Aug.	Boat	2,179	1,168	0.536	31	0.014	15	0.007	0		0	
	Bank	<u>14</u>	<u>0</u>		<u>0</u>		<u>1</u>	0.074	<u>13</u>	0.963	<u>1</u>	0.074
		2,193	1,168		31		16		13		1	
Sept.	Boat	2,503	1,342	0.536	35	0.014	18	0.007	0		0	
	Bank	<u>14</u>	<u>0</u>		<u>0</u>		<u>1</u>	0.074	<u>13</u>	0.963	<u>1</u>	0.074
		2,517	1,342		35		19		13		1	
Total		11,509	6,126		160		88		75		6	

An insufficient number of interviews were obtained to allow a monthly breakdown of the CPUE values. Therefore, a seasonal mean for each species was calculated.

Length measurements of 32 kokanee in all were obtained during the boat interviews, which only occurred in April, May, and August. The data were grouped into time periods April-May, and August, because of the small sample sizes. Although the sample sizes were too small to be conclusive, two modes were indicated in each time period. Length-frequency data taken from gillnet samples in May and June also indicated a bimodal distribution (Fig. 44). These modes do not correlate to sexual dimorphism or to age groupings, but may be attributed to two populations within the lake which may result from smaller-sized residents in the Billy Clapp population mixed with the larger individuals entrained down the irrigation canal from Banks Lake.

Anglers seemed to be of the general opinion that Billy Clapp kokanee were smaller in size than the Banks Lake kokanee. The mean length for April-May was 260 mm with modes occurring at 230 mm and 290 mm. In August, the mean length was 270 mm with modes occurring at 245 mm and 305 mm. The upper mode of the April-May period for Billy Clapp Lake of 290 mm compared closely with the Banks Lake mean length for April and May of approximately 292 mm. Since the barrier net was not installed until May 18, fish passage was uninhibited for approximately two months. The mean length for Banks Lake in August was 348 mm while the upper mode of the Billy Clapp mean length was at 305 mm. If the upper mode does represent Banks Lake fish introduced before installation of the barrier net, the difference in mean length could be caused by a reduction in growth rate. This reduced growth rate may have been due to stress caused by rigors of passage through the canal which include Bacon Siphon and Summer Falls and/or a different lake environment. The mean weight of kokanee in the gillnet sample from Billy Clapp Lake for May and June 1978 was 225 g while the mean weight for Banks Lake during a comparable period was 307 gm.

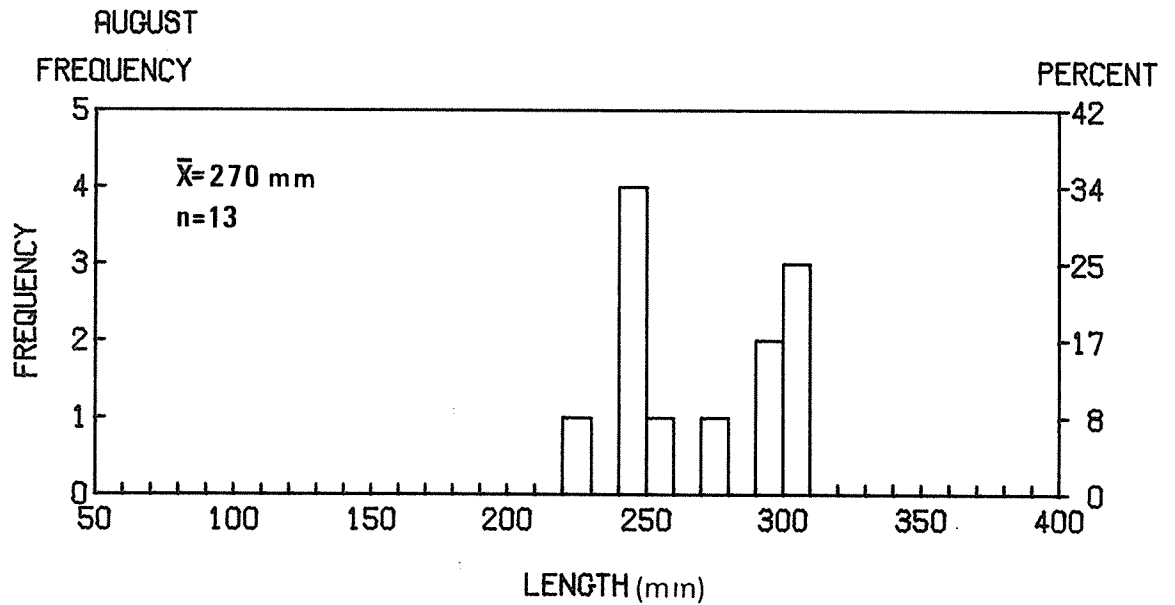
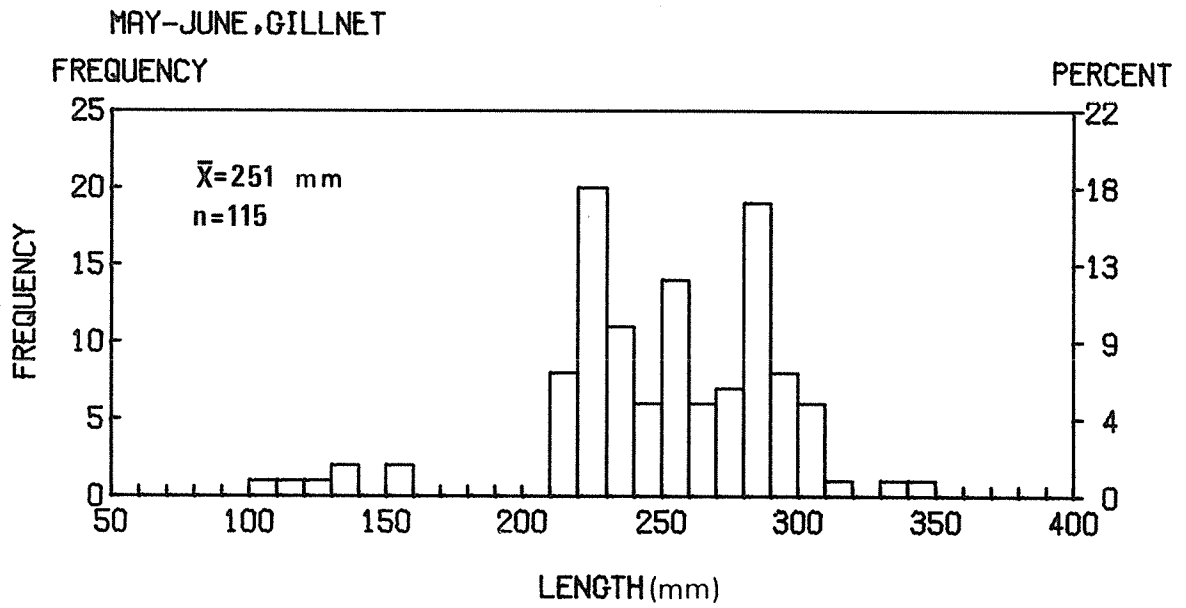
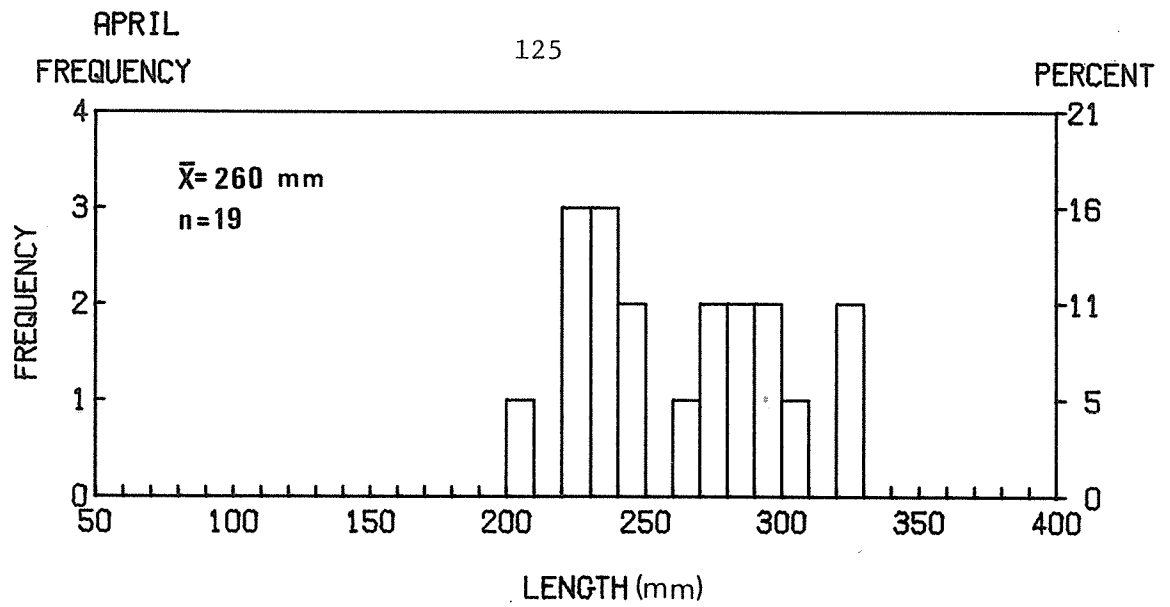


Fig. 44. Length frequency distributions of the April and August sport caught kokanee and the May-June gillnet caught kokanee in Billy Clapp Lake in 1978.

Scale analysis from 104 kokanee indicated that age composition of the gillnet catch was 3% age 1, 43% age 2, 53% age 3, and 1% age 4. Mean back-calculated fork lengths were 135 mm at annulus 1 (n = 3), 226 mm at annulus 2 (n = 45), 273 mm at annulus 3 (n = 55), and 285 mm at annulus 4 (n = 1). The regression line of fork length (FL) on the scale radius (SR) was computed, using the least squares method, and found to be: $FL = 48.8 + 2.0 (SR)$ ($r^2 = .74$). Billy Clapp kokanee were smaller than those in Banks Lake which were calculated at 162 mm at annulus 1, 276 mm at annulus 2, and 339 mm at annulus 3 (Thomas 1978).

6.2.5 Kokanee Spawner Surveys

Systematic observations of kokanee spawning by means of SCUBA divers were begun in 1975. An estimated 5,000 to 10,000 kokanee spawned on steep talus shorelines primarily along areas in the southwest and east (Million Dollar Mile) portions of Banks Lake in 1975. Smaller concentrations of spawning kokanee were observed at Coulee City Harbor, the west shore (Million Dollar Mile), Northrup Creek and in the vicinity of the feeder canal. Spawning occurred during October and November at depths from 1 to 8 m and kokanee appeared to utilize all available gravel of suitable size. The 1976 and 1977 spawning populations were relatively small and the 1978 population was large, but all were similar with respect to timing and location.

The surveys conducted in 1976, 1977, and 1978 were more comprehensive in area covered and frequency of observation than the 1975 survey and relied primarily on the use of a glass-bottomed pram for underwater viewing as well as observations by divers. The present survey was designed primarily for comparison with earlier surveys to help assess the effectiveness of the barrier net on kokanee reproduction.

6.2.5.1 Spawning Season. Kokanee spawning in 1978 began in mid-October and continued through mid-November, while water temperature at a depth of 3 m was dropping from 14° to 4°C. Peak spawning occurred in

early November over a temperature range of 12° to 10° C. The peak of spawning and the end of the spawning season occurred about a week earlier than either 1977 or 1976. This was probably due to a somewhat earlier temperature decline in 1978 (Fig. 45). Water transparency was generally about 6 m during the 1978 spawning season which was similar to conditions in 1976. During the 1977 spawning season, the water was more turbid (Fig. 45) due to wave action during drawdown. Drawdowns of 4.6 m (15 ft) and 2.7 m (9 ft) occurred in October of 1978 and 1977, respectively (Fig. 45). The reservoir was filled prior to the peak of spawning during both years and, therefore, the drawdowns had little effect on depth of spawning on the primary spawning area.

6.2.5.2 Distribution. Kokanee spawning in 1978 was concentrated in one major area designated the primary spawning area (Fig. 46) along the southwest shore of the lake, and five areas with smaller numbers of spawners (Million Dollar Mile, Coulee City Harbor, South Dam, Twin Falls, and Steamboat Rock). Very limited spawning was observed outside these areas. The locations of spawning in 1978 were similar to those found in 1977 (Fig. 47) and 1976, with minor exceptions. New minor concentrations of spawners were found during the aerial survey at Twin Falls and at Steamboat Rock in 1978. Fewer kokanee spawned along the South Dam than in 1977. In general, spawning during 1975 and 1978 was more widespread than in 1976 and 1977, however, areas of concentration were generally the same.

6.2.5.2.1 Primary site. Most kokanee spawning in 1978 occurred in a section of shoreline near the southwest corner of the lake in the vicinity of Station 6 (primary spawning area). Intensive use of this site by spawners also occurred in 1975, 1976, and 1977. General observations indicated that a greater quantity of fine, clean substrate existed on the talus slopes (Fig. 48) in the primary spawning area than elsewhere and was considered to be the reason for the high concentration of spawners.

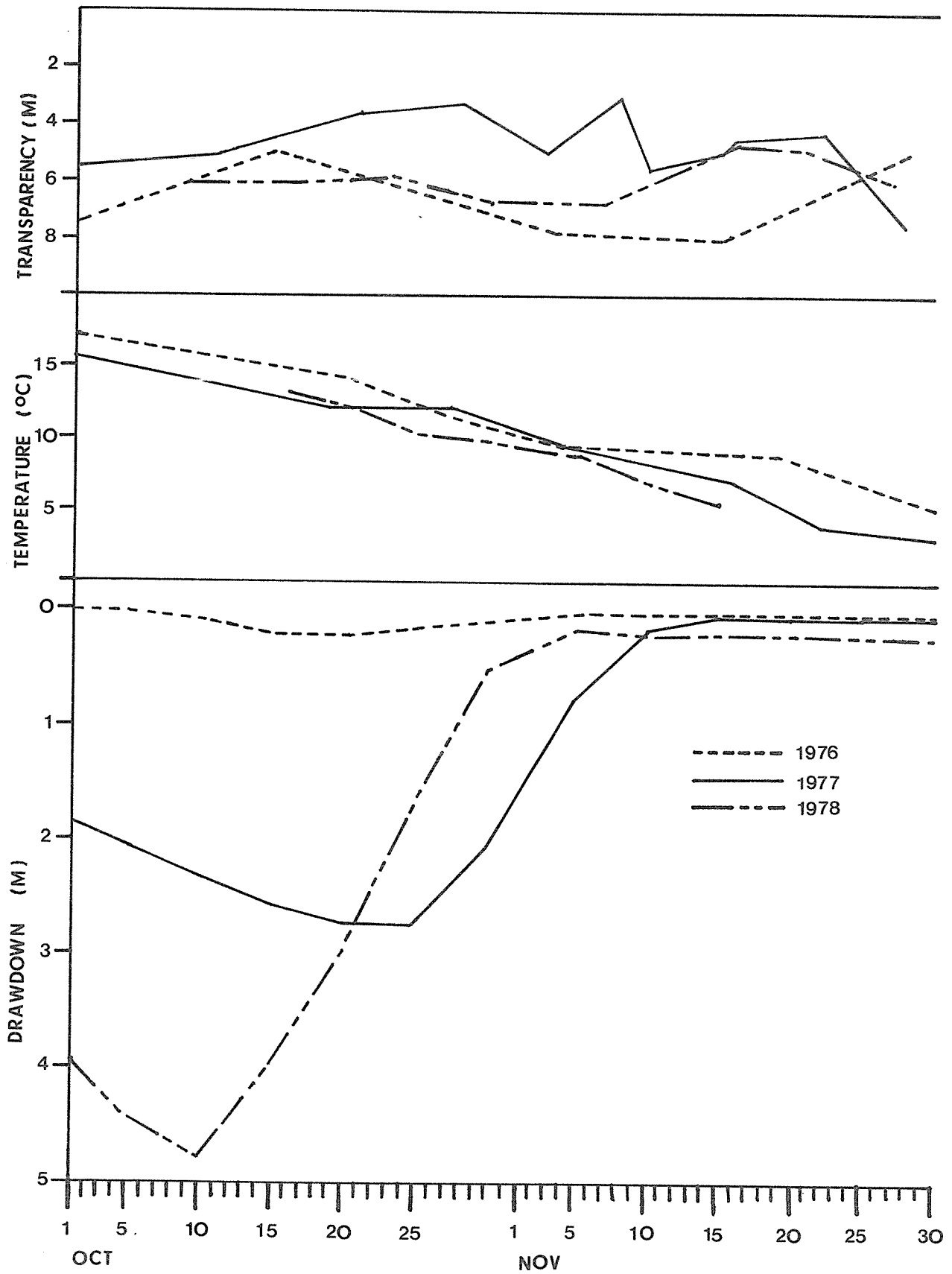


Fig. 45. Water transparency, temperature and reservoir drawdown in Banks Lake during kokanee spawning seasons in 1976, 1977 and 1978.

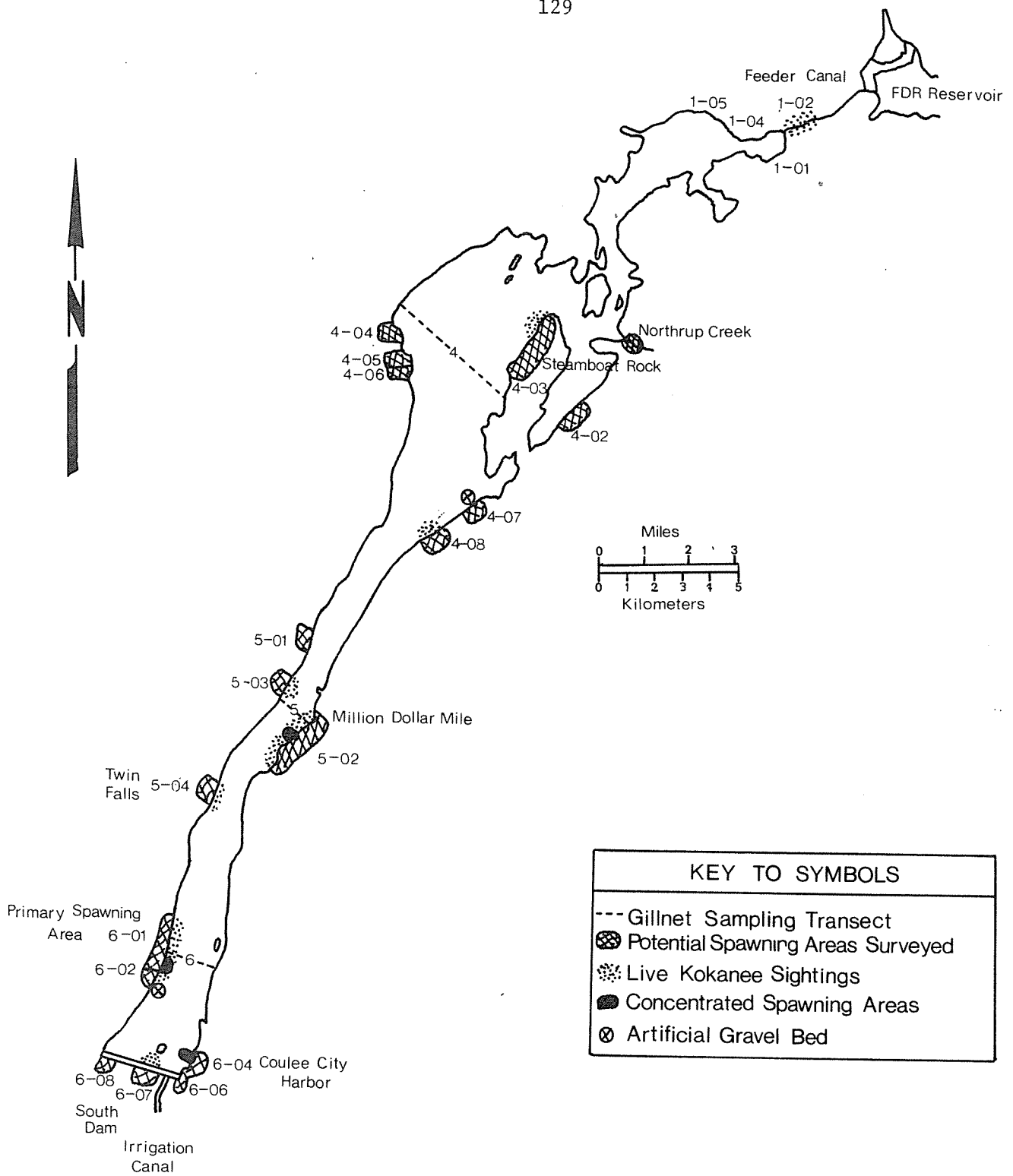


Fig. 46. Map of Banks Lake indicating the areas where suitable shoreline spawning substrate occurred and where live kokanee spawners were observed during 1978. The primary kokanee spawning area is located in the southwest sector of the lake.

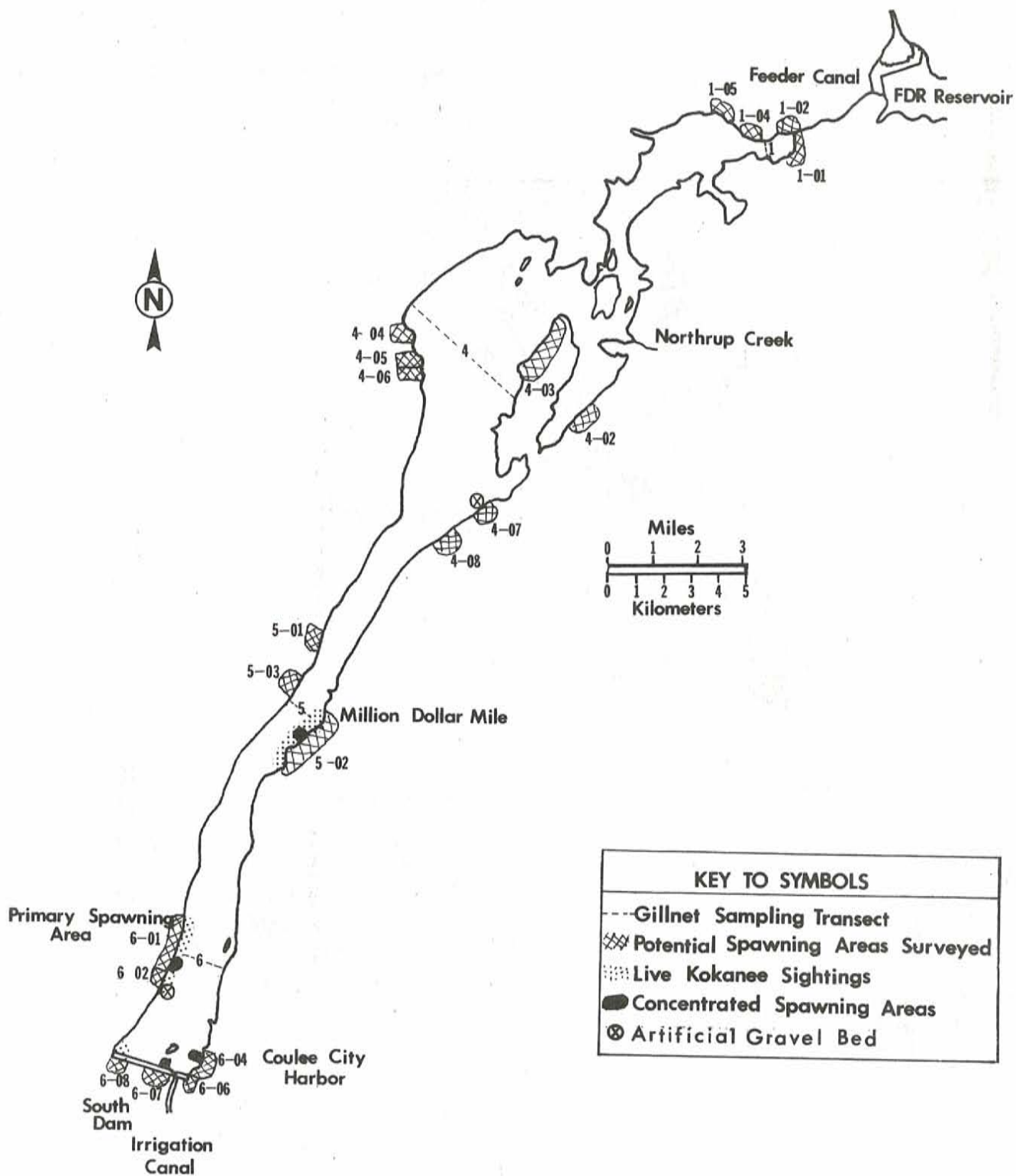


Fig. 47. Map of Banks Lake indicating the areas where suitable shoreline spawning substrate occurred and where live kokanee spawners were observed in 1977. The primary kokanee spawning area is located in the southwest sector of the lake.



Figure 48. Talus slope above the primary kokanee spawning area at maximum Banks Lake elevation.

A 2,400 m long section of shoreline was surveyed weekly by glass-bottomed pram. Numbers of kokanee counted in this primary spawning area were slightly higher in 1978 than in 1977 and 2 to 3 times higher than in 1976 (Fig. 49). Counts of dead kokanee were higher in 1978 than in other years. SCUBA observations in the prime gravel area indicated relatively few dead kokanee were located near the redds. Most dead kokanee were found downslope (usually at depths greater than 5 m) or away from the area of concentrated spawning. The single largest concentration of spawning in the primary spawning area over the past 4 yr has been in a 113-m stretch of talus shoreline containing smaller, cleaner gravel (prime gravel section). Spawner count density (no./m) from the glass-bottomed pram was 1 to 2 orders of magnitude higher for the prime gravel section than for the remainder of the primary spawning area in 1978 and 1977 (Fig. 50). Spawner count density inside the prime gravel section was similar during the two years except that spawning occurred slightly earlier in 1978. The count density outside of the prime gravel section was higher in 1978 than 1977, however, this indicated that the spawning area expanded laterally along the shoreline in 1978.

Weekly counts of spawners in the prime gravel section, conducted by SCUBA divers indicated a much larger spawning population in 1978 than in 1977 (Fig. 51). A maximum number of 3,000 was counted in 1978 compared to 500 in 1977. This contrasted greatly with counts obtained with the glass-bottomed pram which indicated little difference between the two years.

The spawning area utilized in the prime gravel section was measured again by divers at the end of the 1978 spawning season. The area of concentrated spawning was 568 m² in 1977 (Fig. 52) compared to 863 m² (Fig. 53) in 1978 and only 165 m² in 1976. The same prime spawning area is shown in both Figs. 52 and 53. The difference in the overall plan view between years was due to different survey methods. A plane table survey was conducted in 1978. More spawning activity was observed below the 5-m depth in 1978 than in 1977. Redds were located as deep as 16.7 m but redd

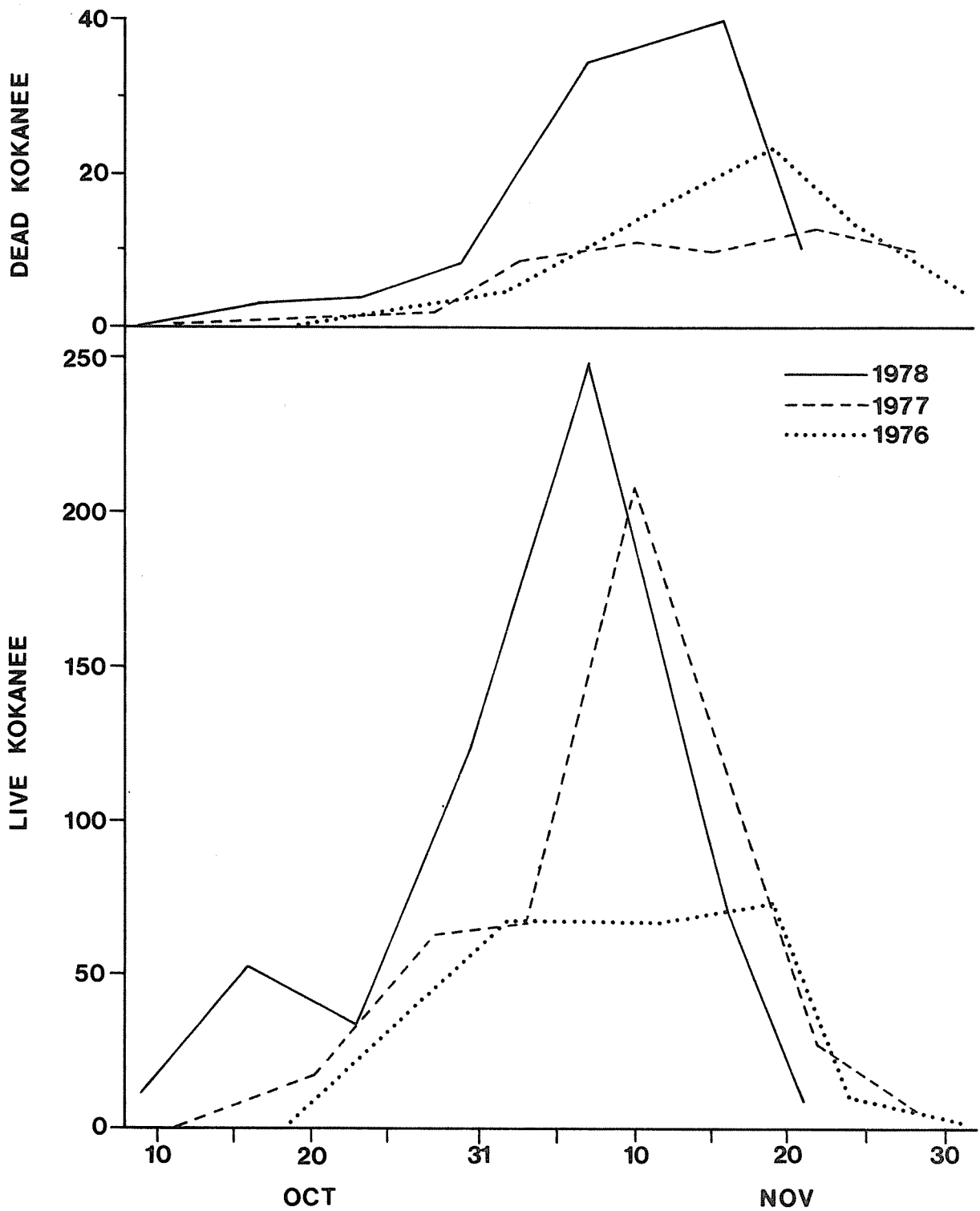


Fig. 49. Number of live and dead kokanee observed during glass-bottomed pram surveys in the primary spawning area in Banks Lake during 1976, 1977 and 1978.

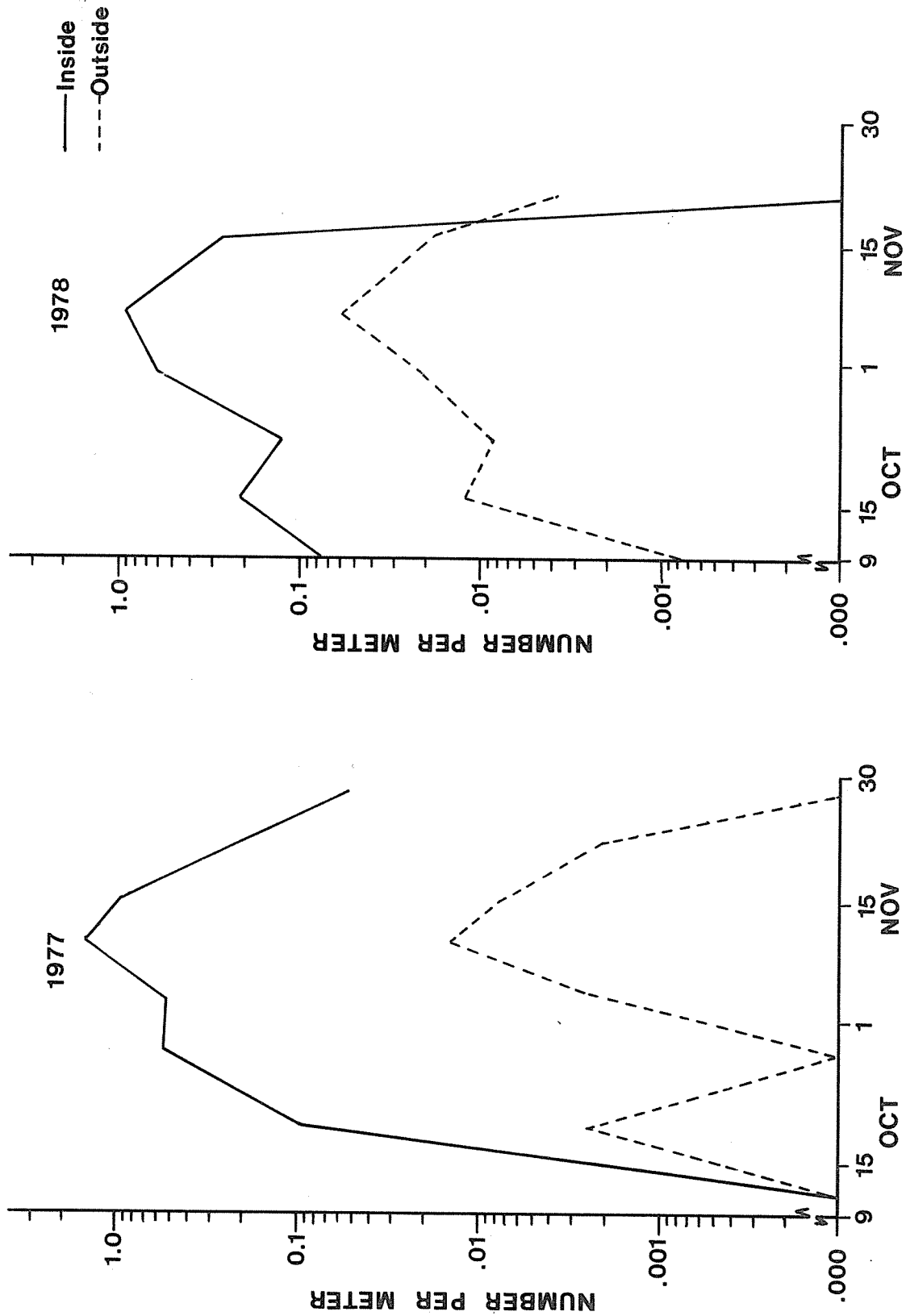


Fig. 50. Number of spawning kokanee per meter observed by glass-bottomed pram inside and outside the prime gravel section of the primary spawning area in Banks Lake during 1977 and 1978.

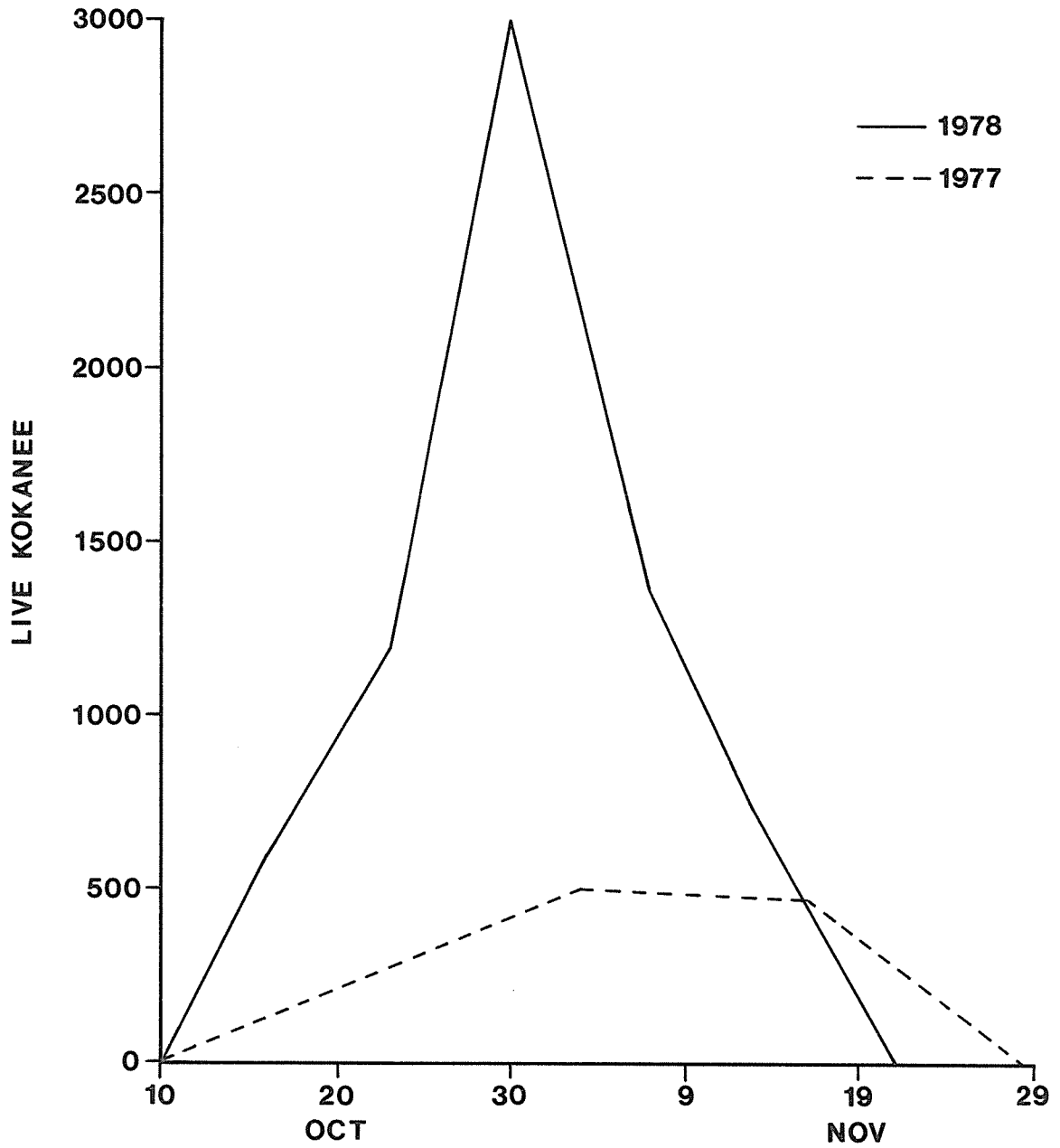


Fig. 51. Counts of live kokanee by SCUBA divers in the prime gravel section of Banks Lake in 1977 and 1978.

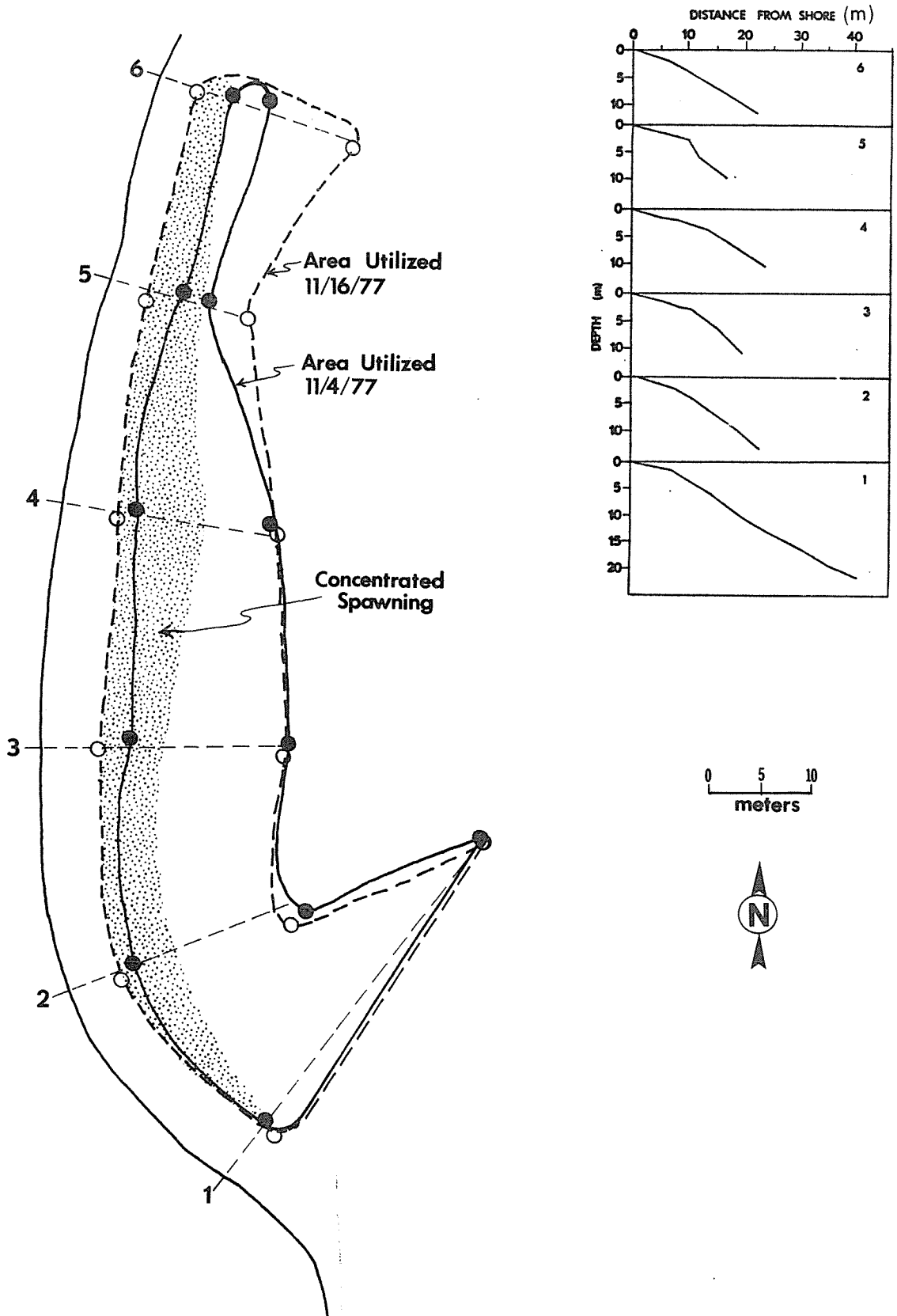


Fig. 52. Spawning areas utilized and areas of concentrated spawning in the prime gravel section of Banks Lake on 11/4/77 and 11/16/77.

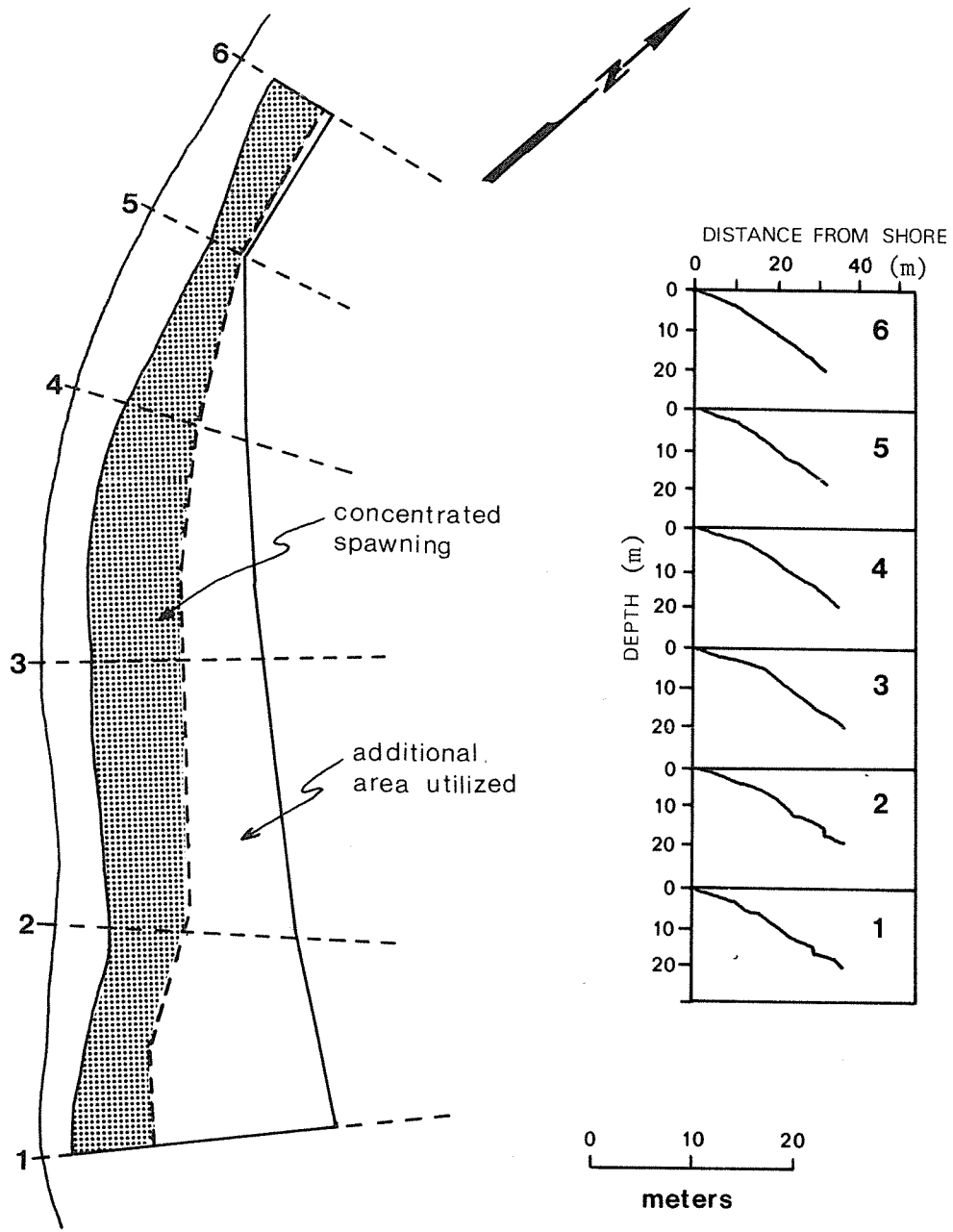


Fig. 53. Spawning areas utilized and areas of concentrated spawning in the prime gravel section of Banks Lake on October 16, 23, 30 and November 7, 13, 21, 1978.

density was still lower in the deep part of the spawning bed compared to the prime spawning area. The total area utilized in the prime gravel section was 1690 m² in 1978 compared to 1579 m² in 1977. In 1976, kokanee apparently did not spawn in the deeper area due to their low density.

Redd density, though difficult to measure, was apparently greatest near transects 3 and 4 and at depths from 1.5 to 4.6 m. Spawning did not occur much shallower than 1.5 m. An underwater sled survey was conducted November 13, 1978 between transects 1 and 6 at the 4.6, 9.1, and 13.7 m contours. Live kokanee were counted along a 3 m wide path during each pass. A total of 71, 26, and 15 live kokanee were counted on respective passes. The majority of spawners was shallower than 4.6 m. These counts, therefore, present only a general indication of the spawning activity with depth because most kokanee were not on identifiable redds at the time of the surveys.

Certain limitations are evident in each of the spawner survey methods used. The SCUBA diving surveys were limited by the length of shoreline that could be sampled and the spawner counts were somewhat ambiguous since each diver estimated the size of the school differently as he swam through it. Even with this ambiguity, the counts obtained by diving appear more reliable than those obtained by glass-bottomed pram, especially at higher densities of kokanee. Conversely, the use of the glass-bottomed pram allows for more consistent and wider coverage. Tests comparing the counting rates of different observers using the pram over the same area and the same group of fish yielded equivalent results. At higher spawner densities, however, kokanee were distributed over a greater range of depths, some of which exceeded the visibility limit of observers using the glass-bottomed pram. Observations have shown that kokanee shied from the glass-bottomed pram early in the spawning season. This explains the fact that peak counts by pram occurred 1 week later than the peak SCUBA counts in 1978.

The population size of kokanee spawners at the prime gravel section has ranged widely over the past three years and this has allowed for a comparison of the two survey methods. Spawner density in 1976 was very low and the SCUBA team concluded that the majority of the fish had been observed through the window of the glass-bottomed pram. The population was larger in 1977, but SCUBA counts were at least 4.5 times larger than pram counts. This was due primarily to the fact that the kokanee were spawning over a greater depth range than in 1976. In 1978, the disparity was at least 12.9 times greater for the SCUBA count. The population size was much larger than in 1977, but observers in the glass-bottomed pram could not detect much difference at the depth (less than 5 m) surveyed. Apparently, the glass-bottomed pram counts are useful only as a relative index, and furthermore, only when densities are moderate to low. These conditions predominated for most of the lake during all years surveyed, except in the areas of concentrated spawning.

6.2.5.2.2 Million Dollar Mile. An underwater sled count of 340 kokanee was obtained at Million Dollar Mile on November 6, 1978. SCUBA counts were not made in previous years and pram counts were probably biased at this location for the reasons discussed above. Pram counts, made during peak spawning activity in 1976 and 1977 were 17 and 32, respectively (site 5-02, Table 11). The 1978 pram survey was conducted after the peak of spawning and only 18 live kokanee were observed. Spawning along Million Dollar Mile occurred on the talus shoreline which has similar gravel and slope as the primary spawning area. The available spawning substrate was limited, however, because much of the shoreline was a vertical cliff with silt deposits at the base. The water was frequently turbid because of wave action across a shallow spit of land to the north of the cliffs. Respective transparency readings on the survey dates in 1976, 1977, and 1978 were 7.0, 3.0, and 3.2 m. The frequent turbid conditions might indicate greater sedimentation rates than at the primary area, which could be detrimental to fry survival.

6.2.5.2.3 Other areas. Spawning kokanee have been observed in two general types of areas in Banks Lake: natural talus shorelines and gravel fill along roadbeds or jetties. Kokanee spawner counts obtained by snorkeling along the jetty entrance to the Coulee City boat harbor (site 6-04, Table 11) in 1978 and 1977 were 225 and 257, respectively. The jetty was entirely exposed by drawdown prior to the 1978 spawning season and partially exposed in 1977. The fact that the jetty was used for spawning implies that there was at least some kokanee movement after spawning had begun on the primary site.

A small amount of spawning probably occurred along the entire west shoreline of the lake in 1978, wherever pockets of good spawning gravel existed. Thirty mature kokanee were observed during the aerial survey along Steamboat Rock (site 4-03). None were observed there during the glass-bottomed pram survey and evidence of actual spawning redds was slight. Twelve kokanee were observed from the air in the vicinity of Twin Falls (site 5-04). Spawning was evident there during the glass-bottomed pram survey, based on the relatively large amount of disturbed gravel and presence of fish. A small concentration of mature kokanee was found along the talus shoreline south of the primary spawning area (site 6-02). Generally, except for the areas of concentration, observable spawning along the talus slopes was not much different in 1978 than 1977 or 1976 even with a larger spawner population.

A small amount of spawning occurred during all three years in the gravel fill along roadbeds. In 1977, 90 kokanee spawners were observed by divers at a site on the South Dam (6-07) just east of the basalt outcrop adjacent to the barrier net. No concentration existed there in 1978 but a smaller concentration of about 30 fish was found about midway along the length of the dam. Small numbers of spawners were found along roadbed fill in all years but, except for the concentrations noted above, no trends attributable to population size were evident.

Table 11. Observations per meter of live and dead* kokanee observed by glass bottomed pram at sample sites with minor concentrated spawning, talus shoreline sites and roadbed fill sites in 1976, 1977 and 1978.

<u>Minor Concentrated Spawning Areas</u>	<u>Length of site(m)</u>	<u>Spawner Observations* Per Meter</u>		
		<u>1976</u>	<u>1977</u>	<u>1978</u>
Million Dollar Mile (5-02)	1634	.011	.021	.013
Coulee City Harbor (6-04)	250	.116	.256	-
South of Primary Area (6-02)	480	.079	.019	.044
<u>Talus Shoreline</u>				
1-04	360	0	0	-
1-05	360	0	0	-
4-03	1560	.00064	0	0
4-04	360	.0028	0	0
4-05	360	0	0	0
4-06	360	0	0	0
5-01	360	0	0	0
5-03	360	0	0	.0056
5-04	540	-	-	.0074
<u>Roadbed Fill</u>				
1-01	360	0	0	-
1-02	430	.0046	0	-
4-02	360	.017	0	0
4-07	360	.017	0	0
4-08	360	0	0	.0056
6-06	180	.022	0	.0028
6-07	360	.011	.0028	.017
6-07A	180	-	.072	.0056
6-08	360	.0056	.0056	0

*Sum of live and dead kokanee were used because 1978 glass-bottomed pram surveys were conducted after the peak of spawning activity.

The artificial gravel beds, established in 1977, were checked for evidence of spawning activity on November 29, 1978. There was no evidence of spawning at either location. Silt had accumulated to a thickness of about 5 mm on each bed and had seeped into the interstitial spaces. A total of 30 and 1 dead kokanee were observed on the South and North beds, respectively.

Kokanee spawners were present in the feeder canal in 1978 but no number estimate was possible. A survey of the canal outlet on October 10 when the canal flow resumed indicated that kokanee were being attracted by the flow. Three kokanee were observed at the outlet structure over a small accumulation of spawning-sized gravel. Kokanee were also observed in small numbers at a later date (October 30) but turbidity from construction activity in the canal made observations difficult.

6.2.5.3 Spawner Estimate. Population estimates calculated from spawner surveys varied depending on the value used to represent the length of time an individual spent on the spawning grounds (turnover time). The population estimate and turnover times varied inversely (Fig. 54).

Turnover time was not determined for this study because it would have involved an additional mark and recapture experiment conducted on the spawning grounds where the steep unstable shoreline imposed sampling problems. Literature values for turnover time of kokanee spawners ranged from 5.7 days (calculated from data given by Lewis 1972) to 15.4 days (Pfieffer 1978). Using these values, respective spawner estimates were 18,111 to 6,717 lake-wide and 8,652 to 3,202 on the prime gravel area.

The total population of potential spawners present from September 5 through October 19 was estimated by Schumacher-Eschmeyer technique to be 35,381 with a 95% confidence interval from 26,360 to 53,812. Based on this estimate which was considered most accurate, the higher estimate from the 1978 spawner survey underestimated the population.

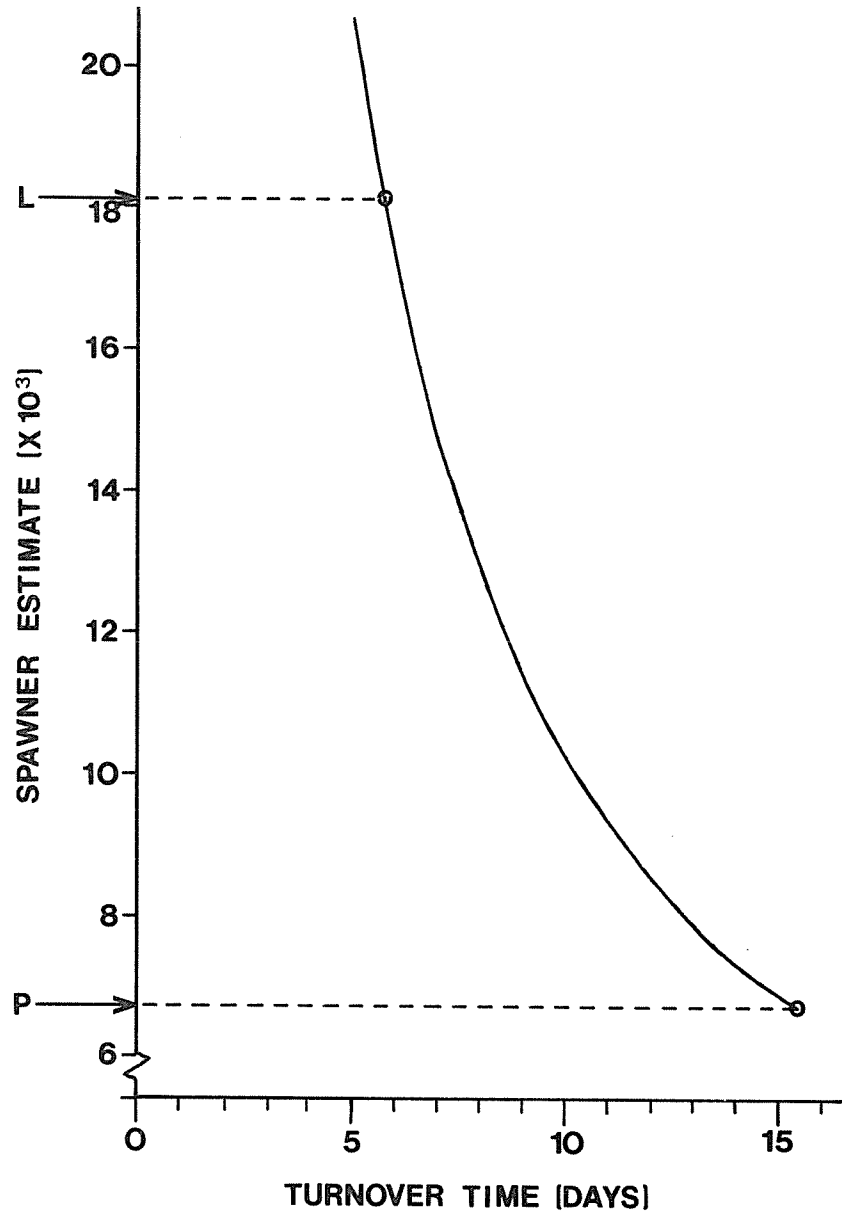


Fig. 54. Kokanee spawner estimate based on variable turnover time (mean length of time spent on spawning grounds) for Banks Lake, 1978. The higher estimate was based on Lewis' (1972) value of 5.4 days (L) and the lower estimate on Pfiefer's (1978) value of 15.7 days (P).

Several reasons are possible for the discrepancy between the estimates, in addition to the unknown turnover time. Population estimates based on spawner surveys were somewhat tenuous because peak spawning occurred over a 2-week period, which severely limited the intensity of sampling. Other complications involved in spawner estimates were due to the difficulty in making accurate SCUBA counts, variable counts by pram depending on fish density and water clarity, and the possibility that not all spawner concentrations in the lake were located. These problems occurred during all spawner surveys since 1976 but with the large population encountered in 1978, the biases were probably increased.

The 1977 and 1976 spawner survey estimates were recalculated to correspond with methods used in 1978. Using turnover times of 15.4 and 5.7 days, the 1977 and 1976 spawner estimates ranged from 2084 to 5630 and 346 to 944, respectively. Regardless of the criteria selected to estimate the number of spawners from the survey data, the 1978 spawner population was much larger than the 1976 or 1977 populations.

6.2.5.4 Potential Egg Deposition. Estimation of the 1978 egg deposition was plagued with the same problems as the spawner estimate, hence, a range of estimates was calculated for comparison with 1977 and 1976. Egg deposition was estimated by the multiplication of the number of female kokanee by the average fecundity. The number of females was half the total spawner population because a 1:1 sex ratio had been observed in purse seine catches. The average fecundity of Banks Lake kokanee had previously been determined to be 1,222 eggs per female (Stober et al. 1976). Spawning was assumed to be complete in 1978, as in past years, although a few unspawned females were observed along shorelines after the 1978 spawning season was over. Undoubtedly, eggs were lost during spawning to predators like the abundant spiny sculpin (Moyle 1977). Because these losses were not measured, an arbitrary value of 10% was assumed for all three years. Predation loss in 1978 may have been greater than the previous two years because of superimposition of redds.

The estimate of potential egg deposition in 1978 ranged widely. Lake-wide estimates ranged from 3,693,678 eggs, based on spawner surveys and an assumed turnover time of 15.4 days to 19,456,011 eggs, based on the mark and recapture study (Table 12). Regardless of the estimation technique used, egg deposition in 1978 was much greater than in 1977 or 1976 when 1.1 to 3.1 million and 190 to 519 thousand eggs were deposited, respectively.

Egg deposition estimates at the prime gravel section in 1978 ranged from 1,760,780 to 4,757,735 based on respective assumed turnover times of 15.4 and 5.7 days. Egg deposition in 1978 was considerably higher than in 1977 or 1976 when estimates were calculated on the basis of total area utilized in the prime gravel section. The egg density estimate for 1978 ranged from 1042/m² to 2815/m² for turnover times of 15.4 and 5.7 days, respectively. Both estimates are considerably higher than 1977 and 1976 egg densities of 327 to 884/m² and 383 to 1036/m², respectively. Egg densities in the shallower part of the spawning bed were probably much greater than these values indicated because spawning was concentrated at depths less than 4.6 m. Relative density of redds by depth could not be measured because redds were indistinct due to superimposition in the shallow area and to shifting substrate in the deeper area.

6.2.6 Gillnet Catches Adjacent Barrier Net

The relative abundance of fishes inside (near irrigation canal outlet) and outside (adjacent barrier, main lake basin) the barrier net and seasonal abundance was determined semiweekly in 1977 by comparative gillnet sampling. These results were also compared with gillnet catches from midlake at stations 4, 5, and 6. This gillnetting was not continued in 1978.

Kokanee were caught in approximately equal numbers inside and outside the barrier net during the entire period of barrier net operation (Fig. 55). The catches of kokanee in the barrier net vicinity were

Table 12. Kokanee spawner population estimate, potential egg deposition and egg density for Banks Lake and the prime gravel area 1976-1978. Spawner survey estimate range was based on turnover time of 5.7 and 15.4 days.

Lake Wide	SPAWNER-SURVEY ESTIMATE			Purse-seine Mark-Recapture
	1976	1977	1978	
Population Estimate	346-944	2,084-5,630	6,717-18,111	35,381
Egg Deposition	190,265-519,106	1,145,991-3,095,937	3,693,678-9,959,239	19,456,011
Prime Gravel Section				
Population Estimate	115-311	940-2,539	3,202-8,652	-
Egg Deposition	63,239-171,019	516,906-1,396,196	1,760,780-4,757,735	-
Egg Density	383-1,036/m ²	327-884/m ²	1,042-2,815/m ²	-
TOTAL AREA UTILIZED	165m ²	1,579m ²	1,690m ²	-

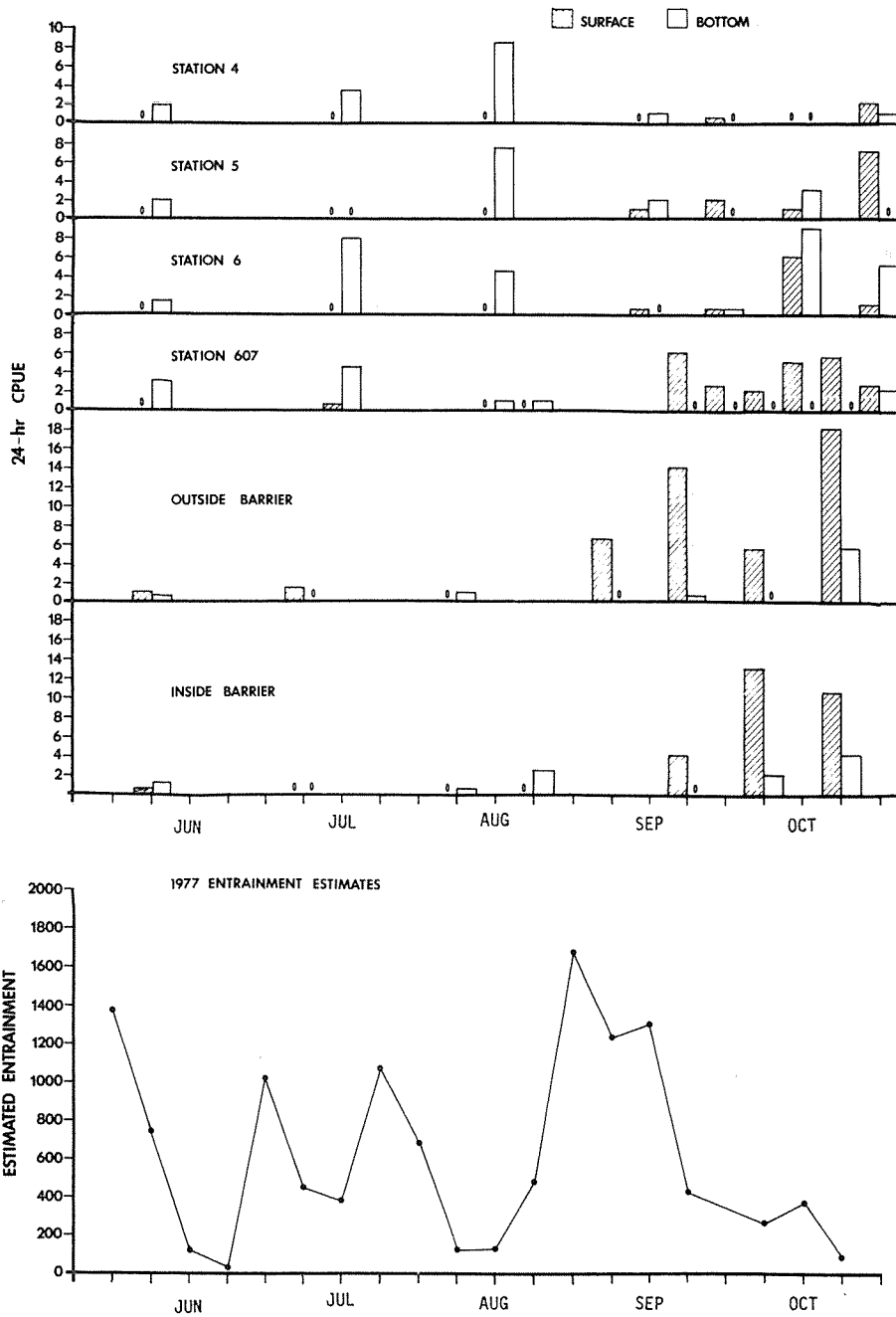


Fig. 55. Surface and bottom gillnet 24-hr catch per unit effort of kokanee inside (near irrigation canal outlet) and outside (adjacent barrier main lake basin) barrier net compared with main basin sampling stations and estimated irrigation canal entrainment during 1977.

approximately equal to the catches at stations 4, 5, and 6 until September, when the catches became larger at the barrier net. The age composition of kokanee gilled at the barrier net was almost entirely age III, with very few age II, whereas at Stations 4, 5, and 6, the composition was nearly equally divided between II's and III's (Fig. 56).

Unlike kokanee, the gillnet CPUE of lake whitefish was dramatically lower inside the barrier net than outside (Fig. 57). This difference was not obvious until September, at which time lake whitefish became abundant near the barrier. The low abundance inside the barrier net was consistent with the canal sampling data which showed a low entrainment of lake whitefish during operation of the barrier net. Comparisons of length-frequency distributions for lake whitefish indicated a higher proportion of juveniles in the catch inside the barrier net than outside or at transects 4-6 (Fig. 58). Apparently, the barrier net effectively screened the adults but was somewhat less effective in screening the smaller juvenile lake whitefish.

The yellow perch population was apparently not affected by the presence of the barrier net. Numerous observations were made of yellow perch swimming through the net in both directions. Catches of yellow perch inside the barrier net were larger than catches outside and at transects 4, 5, and 6 (Fig. 59). This difference was probably related more to habitat preference than to presence of the barrier. The gillnets inside and outside the barrier net caught a higher proportion of juveniles than did the gillnets at transects 4, 5, and 6 (Fig. 60).

Relative abundance of fish populations inside and outside the barrier net in 1977 was determined by gillnet sampling. Kokanee catches, consisting primarily of maturing age III's, were similar inside and outside the barrier net. Kokanee apparently actively followed the irrigation flow and successfully found the gaps along the south barrier net. Lake whitefish catches were lower inside the barrier net than outside, which suggested that lake whitefish were effectively screened out

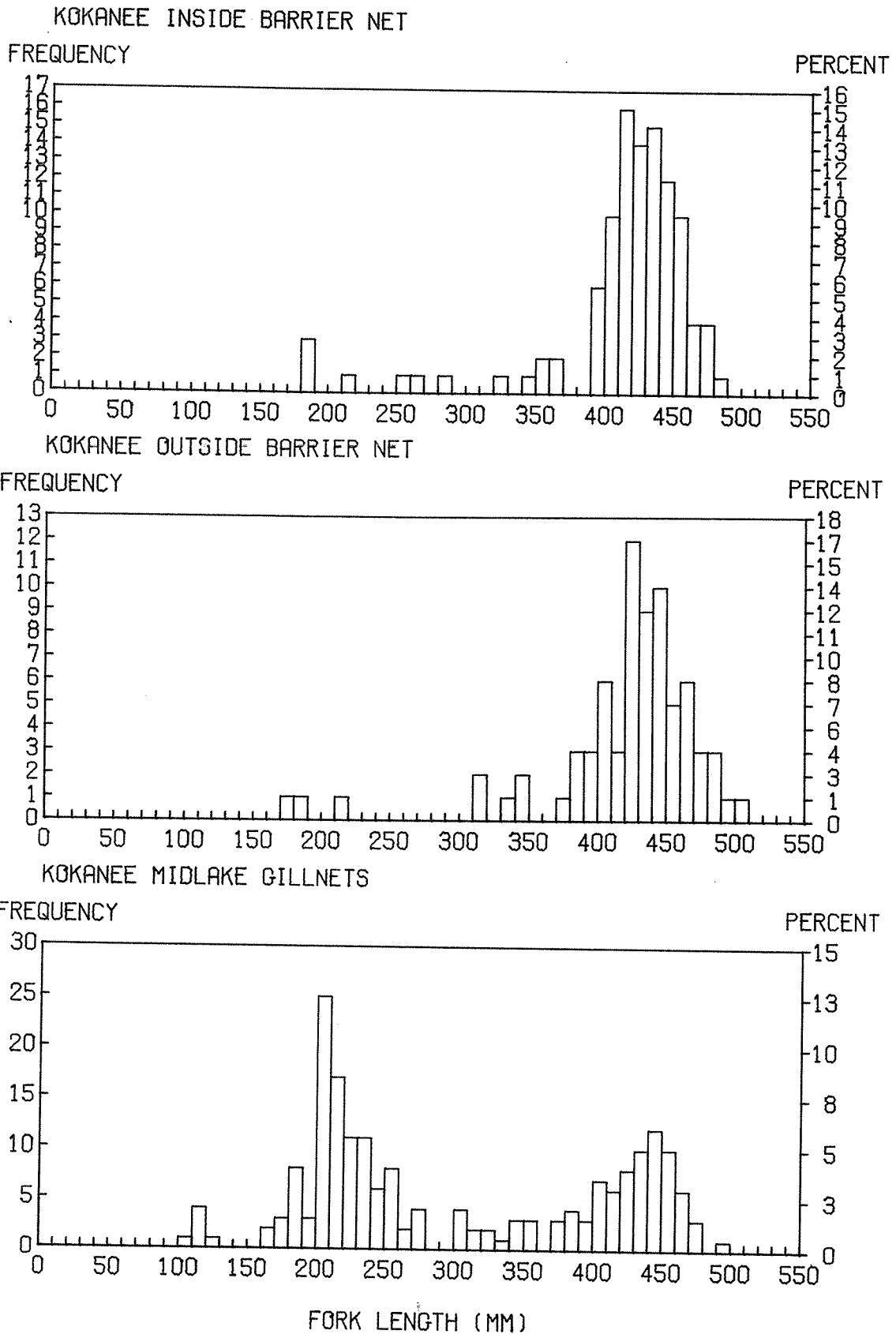


Fig. 56. Length frequency analysis of kokanee caught in gillnet samples inside (near irrigation canal outlet) and outside (adjacent barrier main lake basin) barrier net compared with midlake stations in 1977.

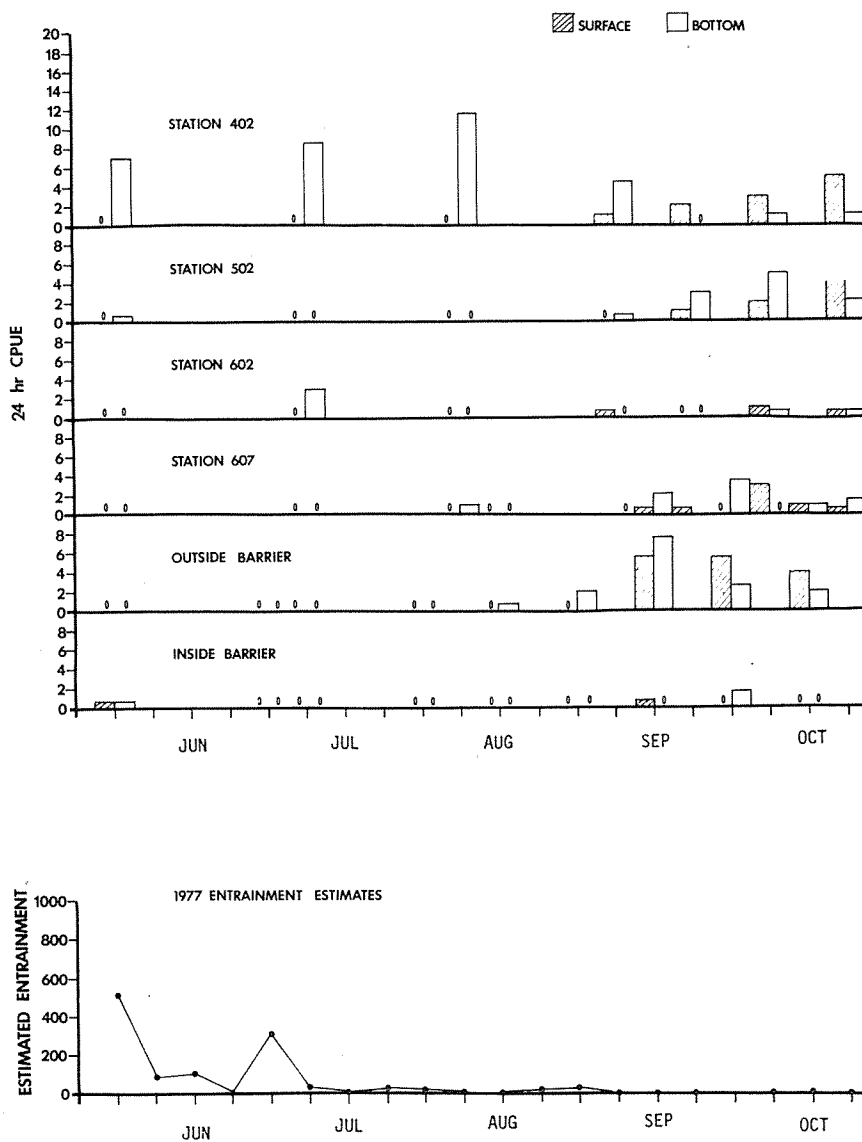


Fig. 57. Surface and bottom gillnet 24-hr catch per unit effort of lake whitefish inside (near irrigation canal outlet) and outside (adjacent barrier main lake basin) barrier net compared with main basin sampling stations and estimated irrigation canal entrainment during 1977.

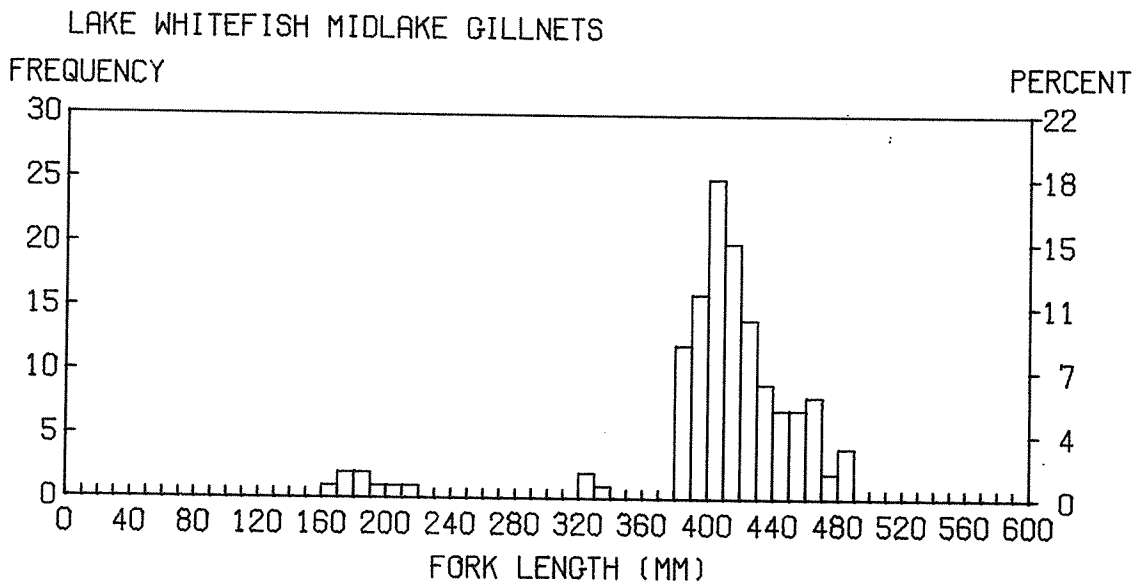
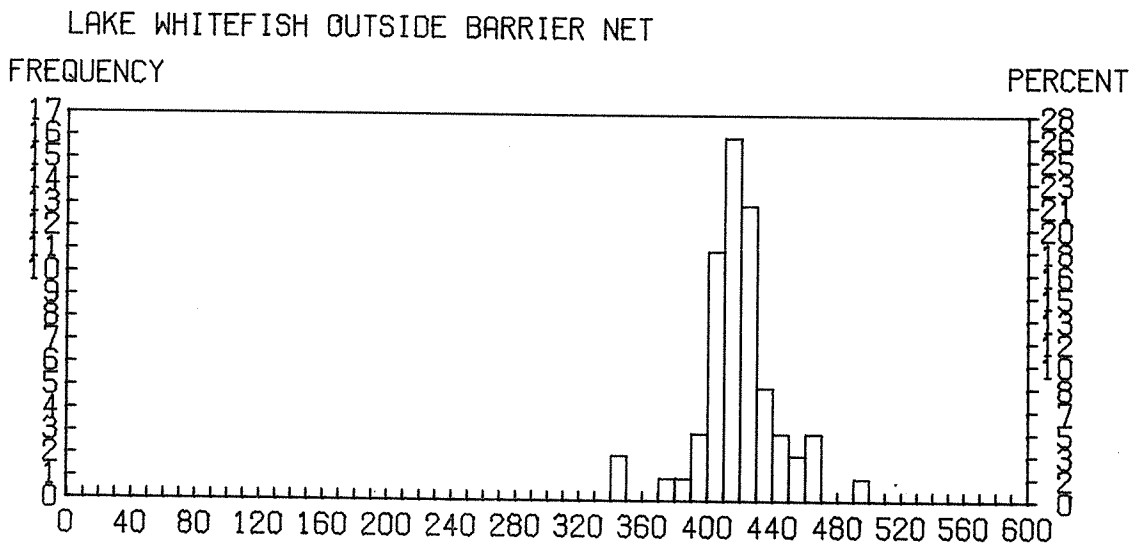
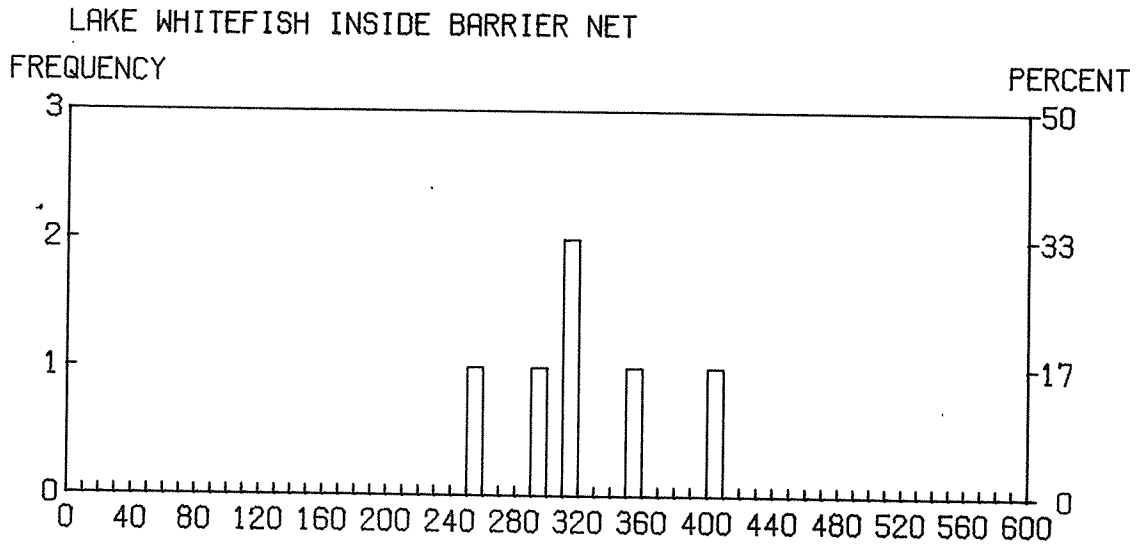


Fig. 58. Length frequency analysis of lake whitefish caught in gillnet samples inside (near irrigation canal outlet) and outside (adjacent barrier main lake basin) barrier net compared with midlake stations in 1977.

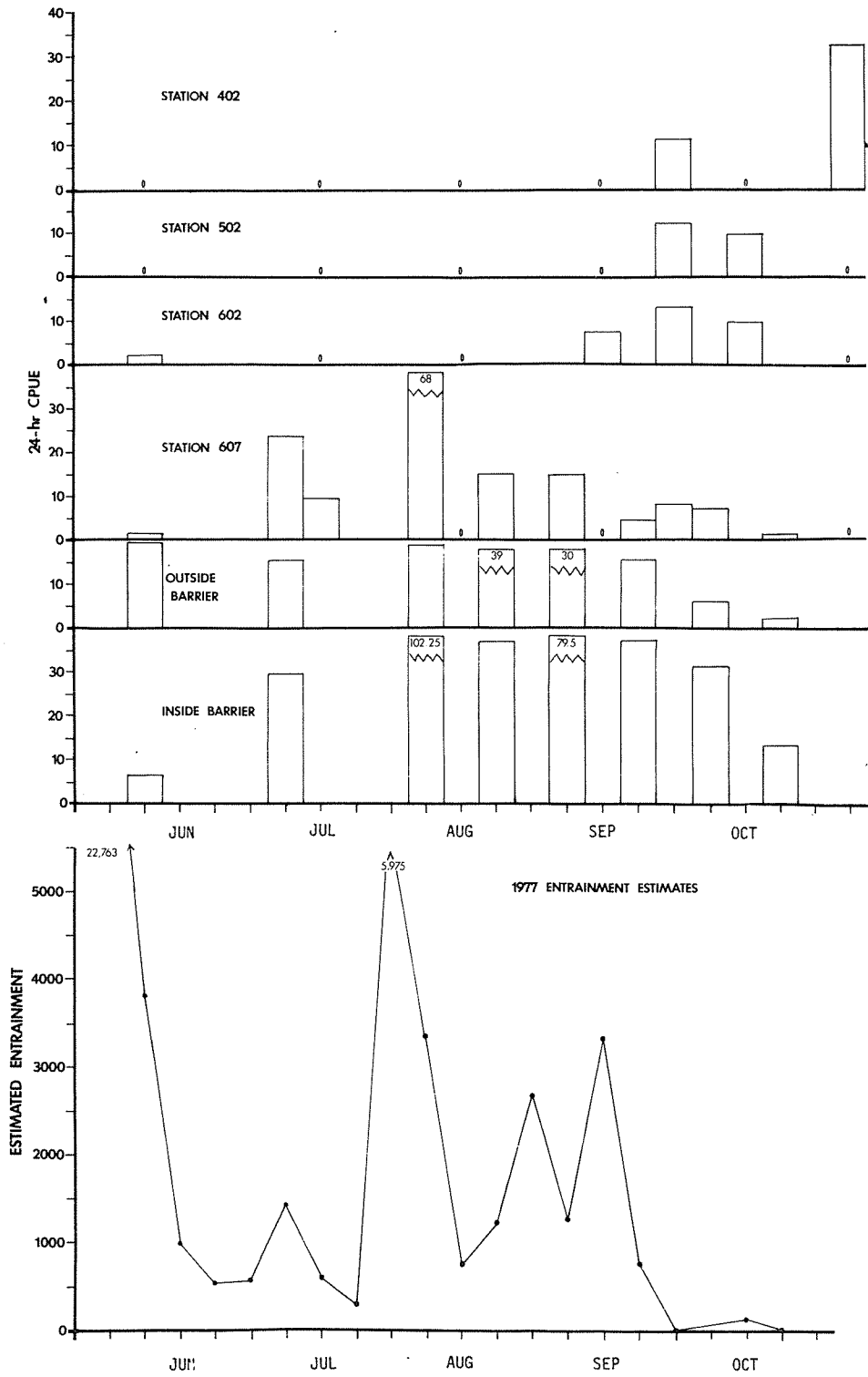


Fig. 59. Surface and bottom gillnet 24-hr catch per unit effort of yellow perch inside (near irrigation canal outlet) and outside (adjacent barrier main lake basin) barrier net compared with main basin sampling stations and estimated irrigation canal entrainment during 1977.

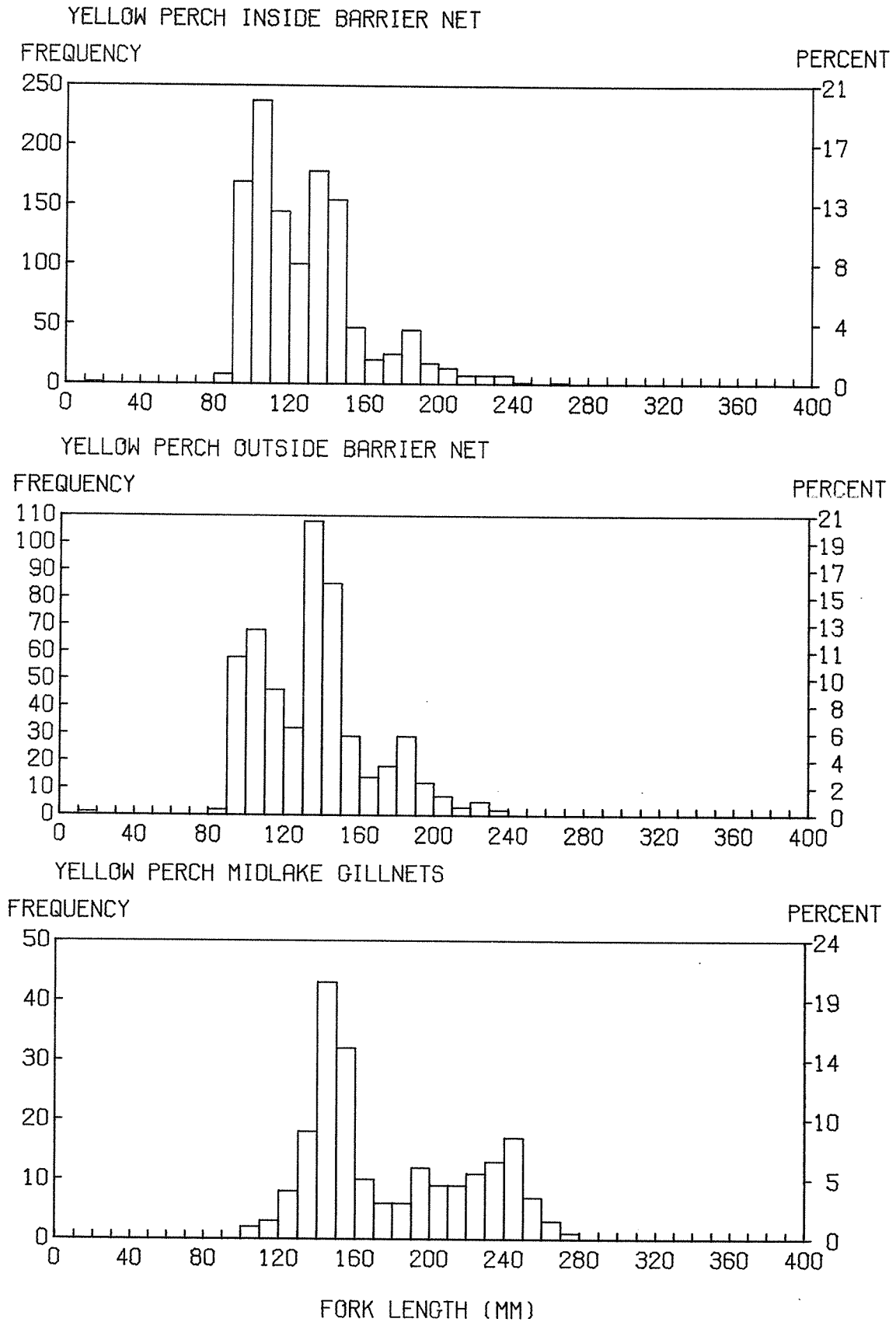


Fig. 60. Length frequency analysis of yellow perch caught in gillnet samples inside (near irrigation canal outlet) and outside (adjacent barrier main lake basin) barrier net compared with midlake stations in 1977.

of the irrigation canal. Yellow perch were apparently unaffected by the presence of the barrier net and were observed swimming through the mesh of the net on numerous occasions.

6.2.7 Acoustic Surveys

Acoustic surveys of fish densities were made monthly in 1977 inside and outside of the barrier net as a supplemental means of evaluating the fish-screening effectiveness of the barrier net and to determine whether areas of fish concentration or avoidance could be detected. This sampling was not continued in 1978.

In the analysis of the echograms, large targets were separated from small targets and the depth distribution was divided into three strata: surface to 9.1 m (30 ft), 9.1 to 18.3 m, (30 to 60 ft) and >18.3 m (> 60 ft) (Appendix Table 2). Analysis of the echogram target strengths revealed that the targets were readily separable into two distinct size groups, large targets being about 30 times larger than small targets. Because the species and size composition of fishes near the barrier net was well known from SCUBA observation, gillnetting, and canal sampling, the small targets were assumed to be age I perch. Age I perch were abundant and distributed narrowly about a mean size of 90 mm (15 g). The large targets were a combination of species probably including kokanee, carp, chinook, whitefish, and suckers which ranged in size from 250 mm (200 g) to 550 mm (3,500 g). This separation of targets persisted strongly during all acoustic surveys, enabling perch to be excluded from the analysis.

The acoustic data were analyzed in an effort to identify the possible effects of the following variables: 1) seasonal period; 2) diel period; 3) depth; 4) inside versus outside the barrier net; 5) distance upstream from the barrier net; and 6) target size. In general, the survey results were irregular and did not show significant differences between the variables compared. No consistent diel variation existed in either the

vertical or horizontal distributions of targets or in the absolute number of targets irrespective of distribution. Acoustic assessments of fish populations customarily show greater densities at night and a greater proportion of targets at shallower depths, but these effects were not observed in the transect areas near the barrier net.

A Friedman's two-way analysis of variance test (Siegel 1956) was used to test for differences in target densities between transects inside the barrier net (transects 1-3) and transects outside the barrier net (transects 4-7, 8-11). There was no significant difference at the 5% level. The density of large targets in the vicinity of the barrier net appeared unaffected by the presence of the net.

The seasonal variation in target density was determined by comparing the mean target density of all transects outside the barrier net (transects 4-10) for each survey. Target density tended to be higher in July and September than in August and October, but monthly differences were not significant at the 5% level.

Target densities outside the south barrier net were greatest at transects nearest the net and lowest at transects farthest from the net (Fig. 61). This difference occurred consistently during the nighttime surveys but never during the daytime surveys. Interpretation of these results is speculative but nighttime stratification of fishes suggests that screening occurred at night, perhaps because the openings under the leadline were not visible. This effect, however, was not observed outside the east net. Target density inside the barrier net was lower than outside.

6.2.8 Gilling Rate in Barrier Net

The species and size of the fish gilled by the barrier net was determined throughout the period of operation. Fish were recovered principally during cleaning operations; however, a few which had dropped

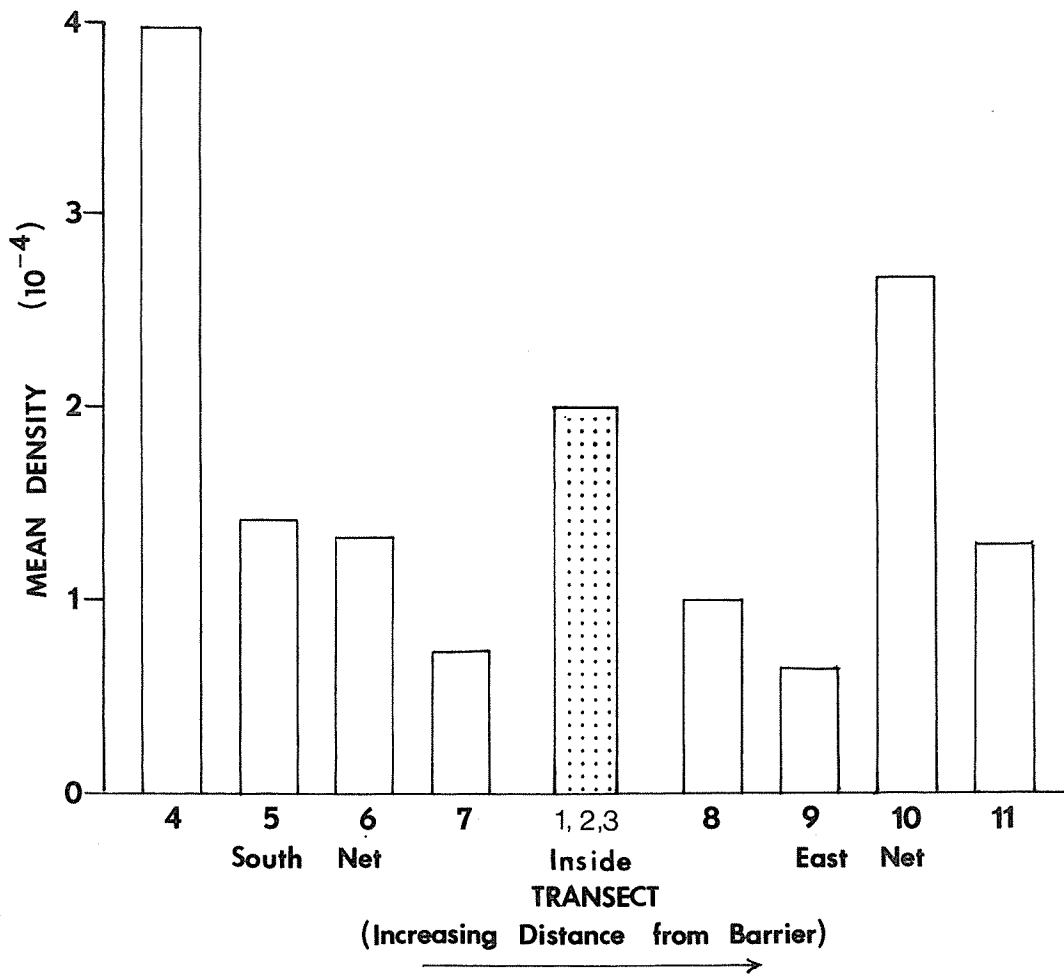


Fig. 61. Mean acoustic target density (night only) by transect at increasing distance from south and east barrier nets compared with mean of inside transects.

out of the net were recovered from the bottom by divers during routine inspections of the net. Some fish were unidentifiable because they had gilled early in the period between net-cleaning operations and decomposed. The decomposition rate was greatest during July and August when water temperatures were warmest.

The gilling rate of all species was low and unimportant relative to the potential losses due to entrainment. In 1978, as in the previous year, 13 species were identified (Table 13). Kokanee were again by far the most abundant (465) accounting for 75% of the 621 total number of fishes identified. This number is 2.5 times greater than the number of kokanee which were gilled in 1977 (194). The number of chinook increased from 26 in 1977 to 72 in 1978. The number of Rocky Mountain whitefish decreased from 24 in 1977 to 20 in 1978. Despite their vast numbers and strong tendency to concentrate along the net, few perch were gilled either year. The totals of gilled perch for 1977 and 1978 were 13 and 19, respectively. The number of gilled lake whitefish (2 in 1977, 1 in 1978) was also extremely low relative to their abundance in Banks Lake. Only 16 carp gilled in the net in 1978, and only 1 gilled in 1977. Most gilled carp were quite small ranging in size from 175 to 240 mm but a few large individuals (500-600 mm) were entangled in the net by their serrated dorsal spines. Carp were often observed near the net by divers and were occasionally seen to attempt to force themselves through the net by ramming, but the large size and somewhat truncated form of carp prevented them from gilling despite their great abundance near the net.

The seasonal gilling rates of kokanee, chinook, and Rocky Mountain whitefish in the barrier net were 1.60, 0.19, and 0.19 fish/day, respectively, in 1977 and 2.78, 0.43, and 0.12 fish/day, respectively, in 1978 (Table 14). Very few kokanee were gilled prior to mid-August (8 in 1977, 38 in 1978), however, the incidence increased markedly during the period from late August thru October. A total of 427 was caught during this time span in 1978 compared to 186 in 1977.

Table 13. Species composition, number and length of fish gilled in the barrier during 1977 and 1978.

Species	Scientific Name	1977				1978					
		No.	Mean Length (mm)	Length Range (mm)		No.	Mean Length (mm)	Length Range (mm)			
				Min	Max			n	Min	Max	
Kokanee salmon	<u>Oncorhynchus nerka</u>	194	372	103	288	505	465	377	181	227	480
Chinook salmon	<u>Oncorhynchus tshawytscha</u>	26	301	20	280	350	72	351	60	305	397
Rocky Mt. whitefish	<u>Prosopium williamson</u>	24	319	12	281	406	20	324	6	276	370
Yellow perch	<u>Perca flavescens</u>	13	224	12	100	290	19	264	10	212	284
Peamouth	<u>Mylocheilus caurinus</u>	9	348	5	325	394	0	-	0	-	-
Longnose sucker	<u>Catostomus catostomus</u>	8	293	4	218	327	13	332	6	272	379
Rainbow trout	<u>Salmo gairdneri</u>	5	305	3	299	312	8	334	8	300	360
Lake whitefish	<u>Coregonus clupeaformis</u>	2	-	0	-	-	1	461	1	-	-
Black crappie	<u>Pomoxis nigromaculatus</u>	2	192	1	-	-	2	280	1	-	-
Brown bullhead	<u>Ictalurus nebulosus</u>	1	238	1	-	-	1	-	0	-	-
Carp	<u>Cyprinus carpio</u>	1	200	1	-	-	16	268	12	175	600
Largemouth bass	<u>Micropterus salmoides</u>	1	287	1	-	-	2	282	2	241	322
Pumpkinseed sunfish	<u>Lepomis gibbosus</u>	1	168	1	-	-	0	-	0	-	-
Prickly sculpin	<u>Cottus asper</u>	0	-	0	-	-	1	-	0	-	-
Walleye	<u>Stizostedion vitreum</u>	0	-	0	-	-	1	-	0	-	-
Total identified		287					621				
Unidentified		12					75				
TOTAL		299					696				

Table 14. Number and seasonal rate of gilling by kokanee, chinook, and Rocky Mountain whitefish in the barrier net in 1977 and 1978.

Year	Net	Period	Days	Number			Rate (No./day)			Total		
				Kokanee	Chinook	RMW ¹	Total	Kokanee	Chinook		RMW ¹	
1977	South	6/23-7/6	13	0	2	0	2	0	0.15	0	0.15	0.15
		7/8-7/14	6	3	5	2	14	0.50	0.83	0.33	0.33	2.33
		7/14-7/26	12	2	2	3	9	0.17	0.17	0.25	0.25	0.75
		7/26-8/10	15	2	0	0	5	0.13	0	0	0	0.33
		8/10-8/23	13	0	0	1	3	0	0	0.08	0	0.23
		8/23-9/6	14	15	2	6	26	1.07	0.14	0.43	0.43	1.86
		9/6-10/24	48	122	0	5	141	2.54	0	0.10	0.10	2.94
		6/23-10/24	121	144	11	17	200	1.19	0.09	0.14	0.14	1.65
		6/24-6/30	6	0	6	0	9	0	1.00	0	0	1.50
		6/30-7/14	14	0	7	1	11	0	0.50	0.07	0	0.79
1978	South	5/18-6/26	39	0	1 ²	0	1	0	0.03	0	0.03	0.03
		6/26-8/24	59	23	1	7	31	0.39	0.02	0.12	0.12	0.53
		8/24-10/4	41	55	0	2	57	1.34	0	0.05	0	1.39
		10/4-11/2	30	273	0	6	280	9.10	0	0.20	0.20	9.33
		5/18-11/2	169	351	2	15	369	2.08	0.01	0.09	0.09	2.18
		5/18-6/22	35	3	25	0	28	0.09	0.71	0	0	0.80
		6/22-6/29	7	0	34	1	35	0	4.86	0.14	0.14	5.00
		6/29-7/6	7	0	11	1	12	0	1.57	0.14	0	1.71
		7/6-8/24	48	14	0	1	15	0.29	0	0.02	0	0.31
		8/24-10/4	42	26	0	0	26	0.62	0	0	0	0.62
1978	East	10/4-10/31	27	71	0	2	73	2.63	0	0.07	0.07	2.70
		5/18-10/31	166	114	70	5	189	0.68	0.42	0.03	0.03	1.14
		TOTAL	167.5	465	72	20	558	2.78	0.43	0.12	0.12	3.33

1 - Rocky Mountain whitefish
2 - Diver observation 7/10

A comparison of the mean lengths of kokanee gilled in the barrier net with kokanee caught in the irrigation canal nets indicated several trends (Table 15). Figure 62 compares the mean lengths of kokanee from the barrier net and from the canal nets during 1977 and 1978. During the early portion of the season (May to late June) the barrier net selectively gilled large members of the kokanee population because the mean length of the population was near the minimum gillable size. Canal net catches during this period indicated that many fish passed directly through the mesh of the barrier net. The observed mean lengths for kokanee from the irrigation canal were 254.1 mm and 288.8 mm in 1977 and 1978, respectively, while the three kokanee that gilled in the barrier net in 1978 had a mean length of 340.0 mm (Table 15). This indicates the selectivity of the barrier net for only the largest individuals and accounts for the low gilling rate during this period.

During the following two month period from late June to late August, the mean lengths of fish taken from both nets in both years were all very similar (Table 15). As kokanee grew during the summer, their mean length increased to a size which made them susceptible to gilling in the barrier net (368.2 mm in 1977 and 340.7 mm in 1978). Because of the lesser efficiency of the barrier net in 1977 more kokanee escaped into the irrigation canal (9,198). A smaller population size in 1977 resulted in fewer kokanee being gilled (8). In 1978, however, the improved fit of the barrier reduced the number of kokanee caught in the canal nets in mid-season (16) from the number caught during the earlier part of the season (56).

During the last two months of operation, September and October, kokanee from the canal nets averaged larger than kokanee gilled in the barrier net. This difference between lengths was 70 mm between August 24 and September 15, and was 30 mm between September 15 and October 24 in 1977. In 1978, this difference was 17 mm between August 24 and October 4, but could not be calculated for October since only one kokanee was captured in the canal nets. This difference resulted primarily from the

Table 15. Mean length of kokanee gilled in the barrier net and caught in the irrigation canal nets in 1977 and 1978.

Year	Period	Irrigation Canal			Barrier Net		
		Mean Length (mm)	n	Length Range (mm) Min Max	Mean Length (mm)	n	Length Range (mm) Min Max
1977	5/18-6/24	254.1	75	152-392	-	0	
	6/24-8/24	368.2	198	143-551	349.2	8	315-377
	8/24-9/15	402.8	362	222-564	341.9	18	288-420
	9/15-10/24	419.2	84	290-495	389.7	81	292-505
1978	5/18-6/24	288.8	56	135-362	340.0	3	318-352
	6/24-8/24	340.7	16	228-425	349.7	24	286-390
	8/24-10/4	386.9	10	325-415	370.2	30	310-455
	10/4-11/1	(381)	(1)		384.1	123	227-480

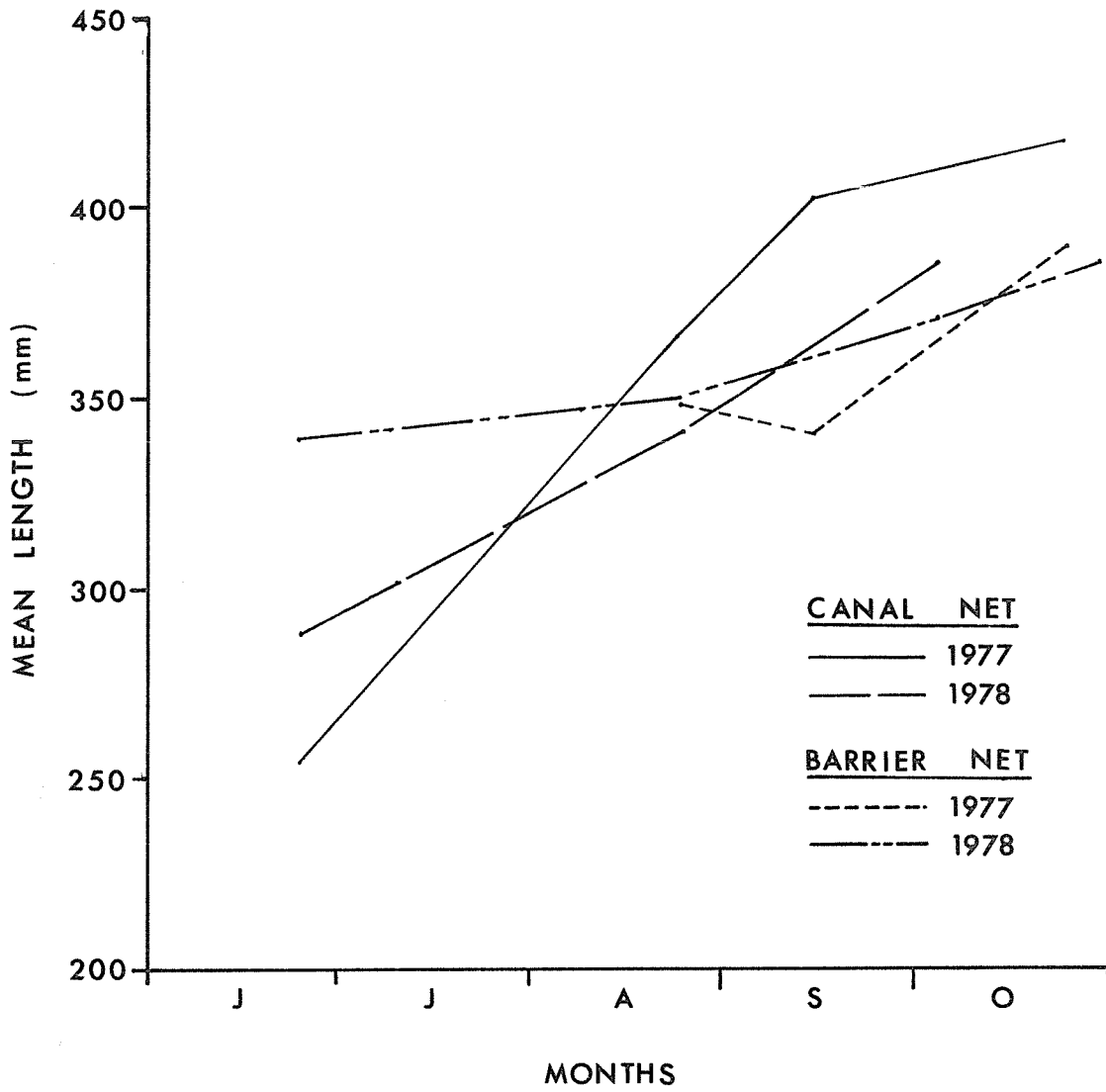


Figure 62. Mean length of kokanee gilled in the barrier net versus those caught in the canal sampling nets during June-October 1977 and 1978.

gilling selectivity of the barrier net for smaller kokanee that were within the susceptible gilling size range. This difference became less with advancing maturity because the males tended to become entangled in the mesh more easily due to their protruding teeth and elongated snouts. The increased gilling rates during September and October were probably due mainly to increasing effort of the maturing kokanee to follow the irrigation flow. The highest gilling rate occurred in the south barrier net which indicated that channel was the main avenue of movement.

Chinook, similarly, were gilled at a greater rate in 1978 than in 1977 (2.3 times greater), but also increased in mean length from 301 mm to 351 mm. This growth rate made them more susceptible to gilling and increased the gilling rate even though their population number decreased.

The gilling rate of Rocky Mountain whitefish was high relative to their low abundance in Banks Lake and in the entrainment catches from the irrigation canal. All individuals gilled were large and maturing and apparently of ideal size and body shape for gilling in the mesh of the barrier net.

In general, the loss of fishes of all species by gilling in the barrier net was of little consequence compared to their population sizes and to potential losses which would have occurred due to entrainment. If these fishes had not been gilled, they would have very likely been entrained into the irrigation canal and lost from the lake.

6.3 Fish Population Monitoring

The standard gillnet sampling was continued at transects 4, 5, and 6 to maintain the baseline monitoring of the relative population sizes of the kokanee, lake whitefish, yellow perch, and other species in Banks Lake. Determination of the relative abundance was necessary as a means of evaluating the effects of the barrier net on entrainment of the principal fish species, and on the effect of the barrier net on the size of these

populations in the lake. If substantial numbers of kokanee or other species were prevented from leaving Banks Lake, an increase in their relative numbers might be detected, particularly at the south sampling sites.

6.3.1 Kokanee.

Gillnet sampling of kokanee monitored primarily the abundance of ages II and III. The relative abundance of kokanee in the gillnet catches since 1973 is shown in Fig. 63. In 1978, the relative abundance of kokanee was monitored monthly from June to December at Stations 4, 5, 6, and 7. Using the data from Stations 4, 5, and 6 to compare with similar periods in previous years indicates that the 1978 population abundance ranked intermediate. During June, July, and August, kokanee were distributed relatively evenly between Stations 4, 5, and 6. This southerly shift has been apparent most years and is attributed to "homing" behavior of maturing kokanee to spawning grounds which are located principally at the southern end of Banks Lake.

A summary of the length frequencies of kokanee since 1973 is shown in Fig. 64. The 1971, 1972, and 1976 year classes were prominent numerically, while the 1970, 1973, and 1974 year classes were relatively minor (year class identified by year of fry emergence).

A decline was apparent in the offshore catch of age II kokanee (roughly < 300 mm) in 1975 and of age III kokanee (> 300 mm) in 1976 (Fig. 65). A comparable decline of age II kokanee was noted in 1976 and of age III kokanee in 1977. Thus, it appears that the sizes of the 1973 and 1974 year classes (age III in 1976 and 1977, respectively) were equally small, even though data points, based on gillnetting, varied widely between samples. Both the 1973 and 1974 year classes were subjected to large spring drawdowns prior to emergence of the fry from the gravel.

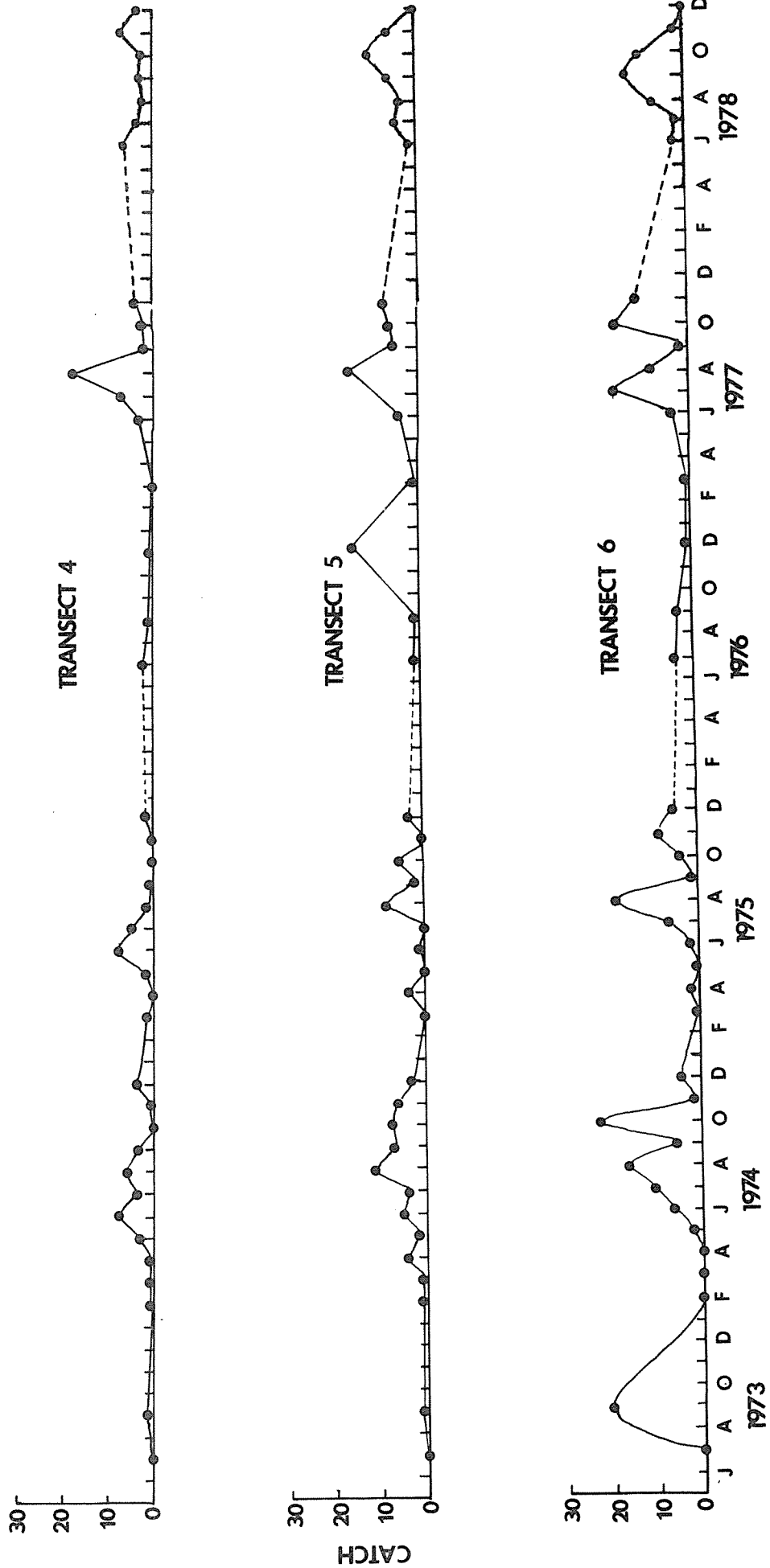


Fig. 63. Distribution of kokanee salmon at stations 4, 5 and 6. Data points represent the catch from horizontally-placed gillnets at surface and bottom during two 24-hr. periods.

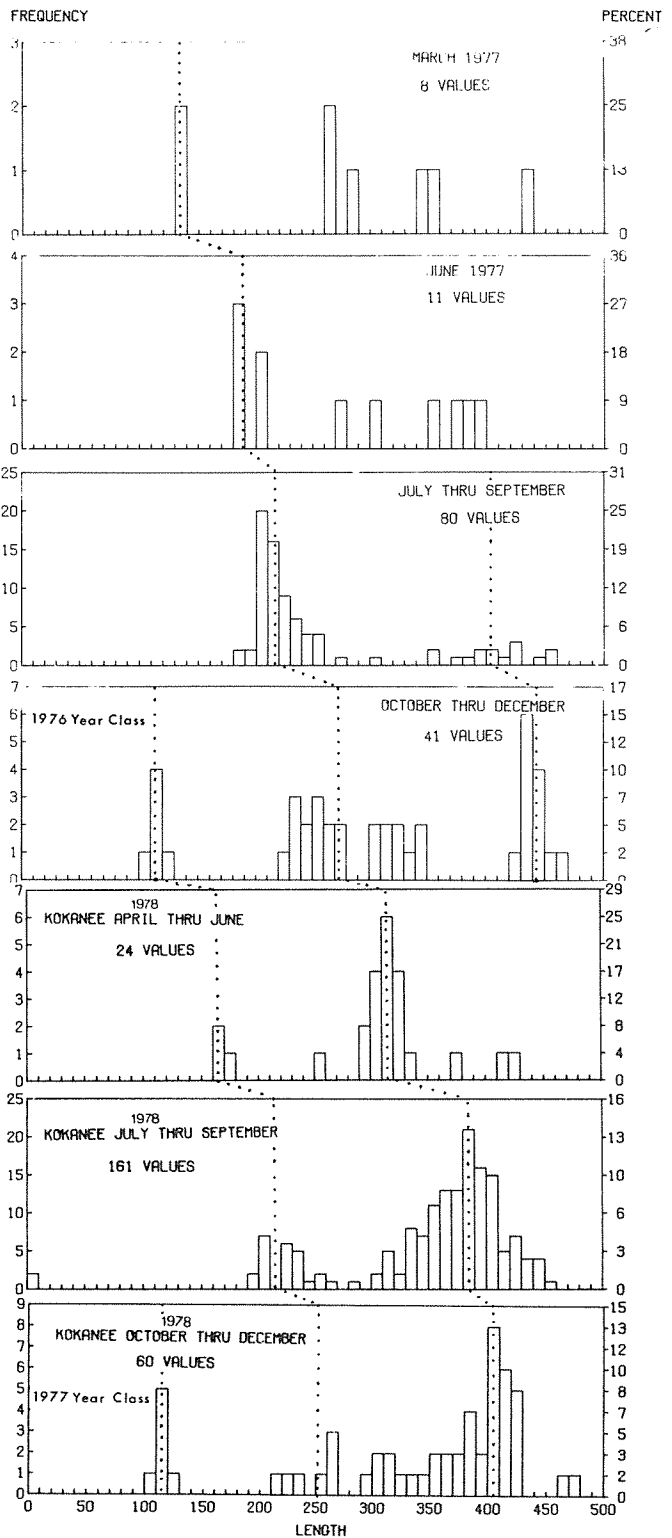
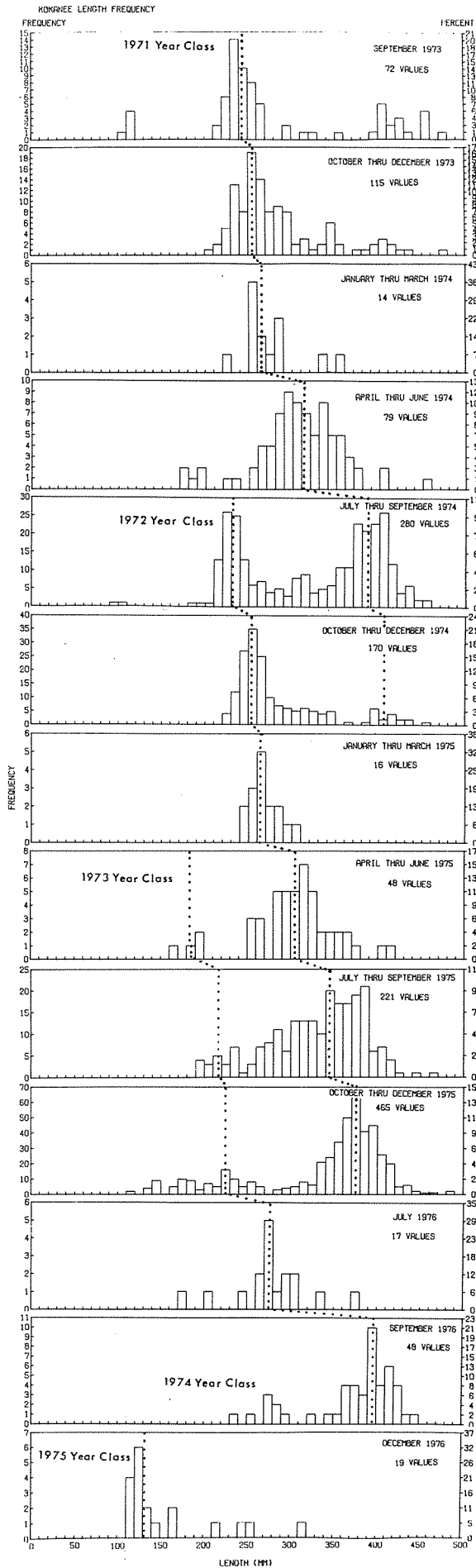


Fig. 64. Length distribution and year class of kokanee from the monthly and quarterly gillnet samples during 1973 to 1978 grouped by quarter.

TOTAL OFFSHORE CATCH OF KOKANEES

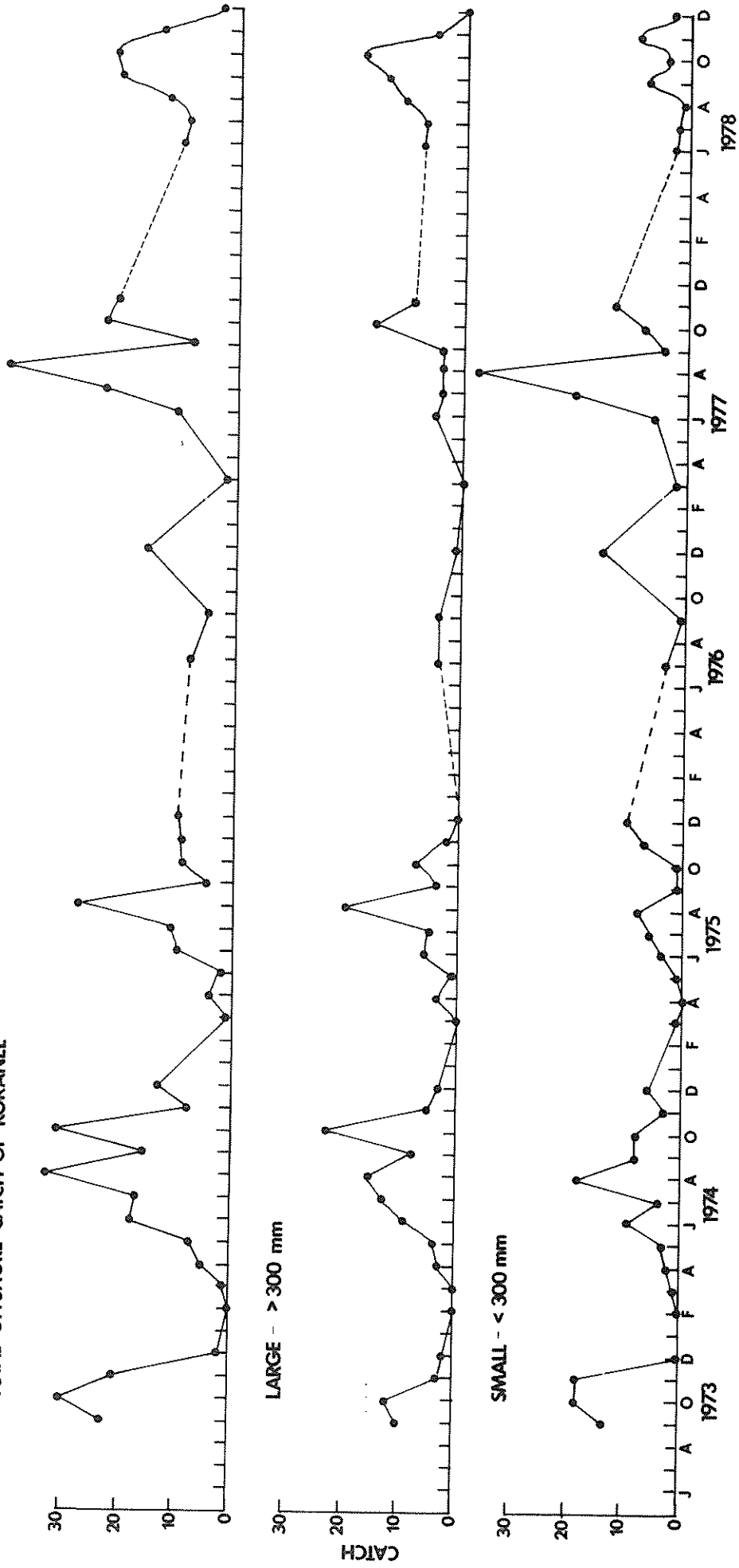


FIG. 65. Relative abundance of large and small kokanee in the gillnet catches at stations 4, 5 and 6, 1973-1978.

A comparison of the numbers of age II kokanee between years showed a pronounced increase in 1977 over 1976, which suggested a larger population of age III kokanee and improved sport fishing in 1978. This indication was borne out by all measures during the 1978 season.

It is also apparent in Fig. 65 that the sample catches of maturing kokanee (> 300 mm) increased sharply during October, 1977. The increased catches at mid-lake indicated a surprising amount of offshore movement at a time when kokanee are normally concentrated along the shoreline for spawning. This widespread offshore movement, apparently in search of spawning sites, may be attributable to the introduction of 110,000 kokanee fingerlings into Banks Lake in October, 1974. This stocked population had no instinct to home to Banks Lake spawning sites because it was not stocked until after olfactory cues relating to home stream had been established. Banks Lake as a spawning site was totally foreign to these fish which had been hatched and reared for 9 months at the Washington Department of Game Leavenworth Hatchery.

The low incidence of age II kokanee in the gillnet catches in 1978 indicates that a relatively small number of age III kokanee will be available to the sport fishery in 1979. These kokanee are the progeny of the 1975 spawners.

6.3.2 Lake Whitefish.

The composition of the lake whitefish population since 1973 has been influenced largely by the very successful 1974 year class. The 1974 year class was first recruited to the gillnet catches in late summer, 1974 and has since predominated numerically (Fig. 66). Succeeding year classes have been uniformly small. Individuals of the 1974 year class have reached a length equal to that of the old-age group and the frequency modes have merged (Fig. 67). The old-age group consists of individuals of mixed ages > age V, which are of uniform size and which have largely ceased growth at about 450 mm (Fig. 68).

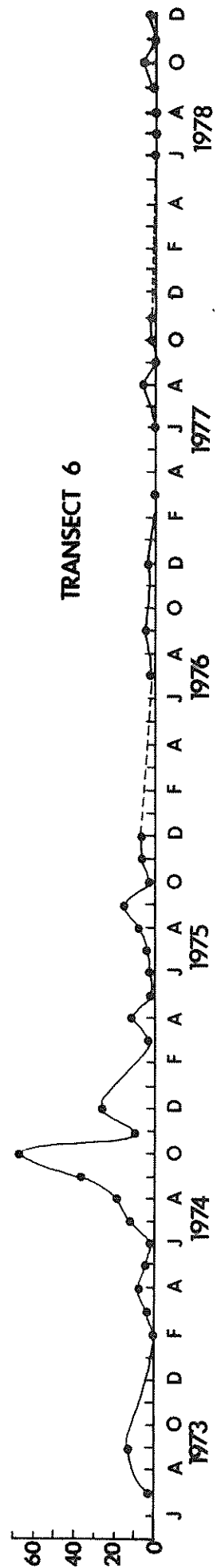
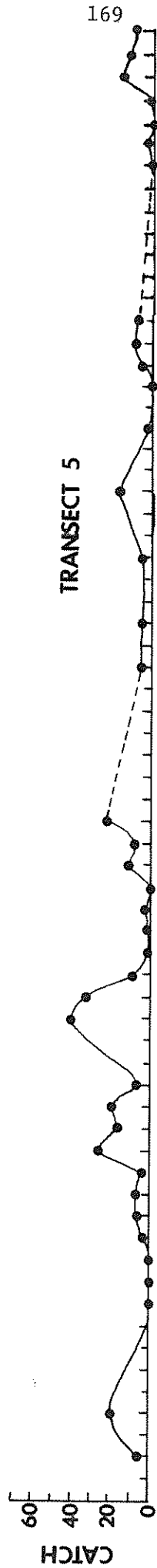
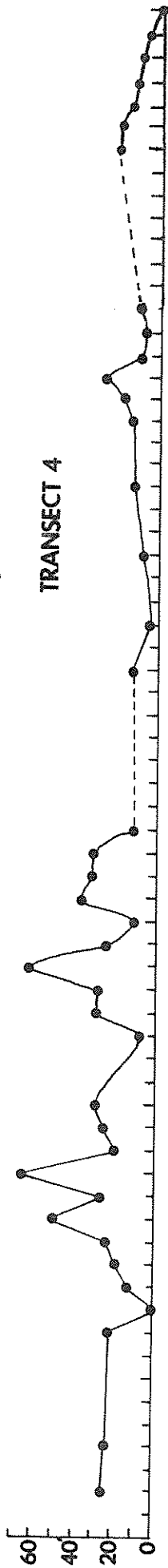


Fig. 66. Distribution of lake whitefish at stations 4, 5 and 6. Data points represent the catch from horizontally-placed gillnets at surface and bottom during the 24-hr periods

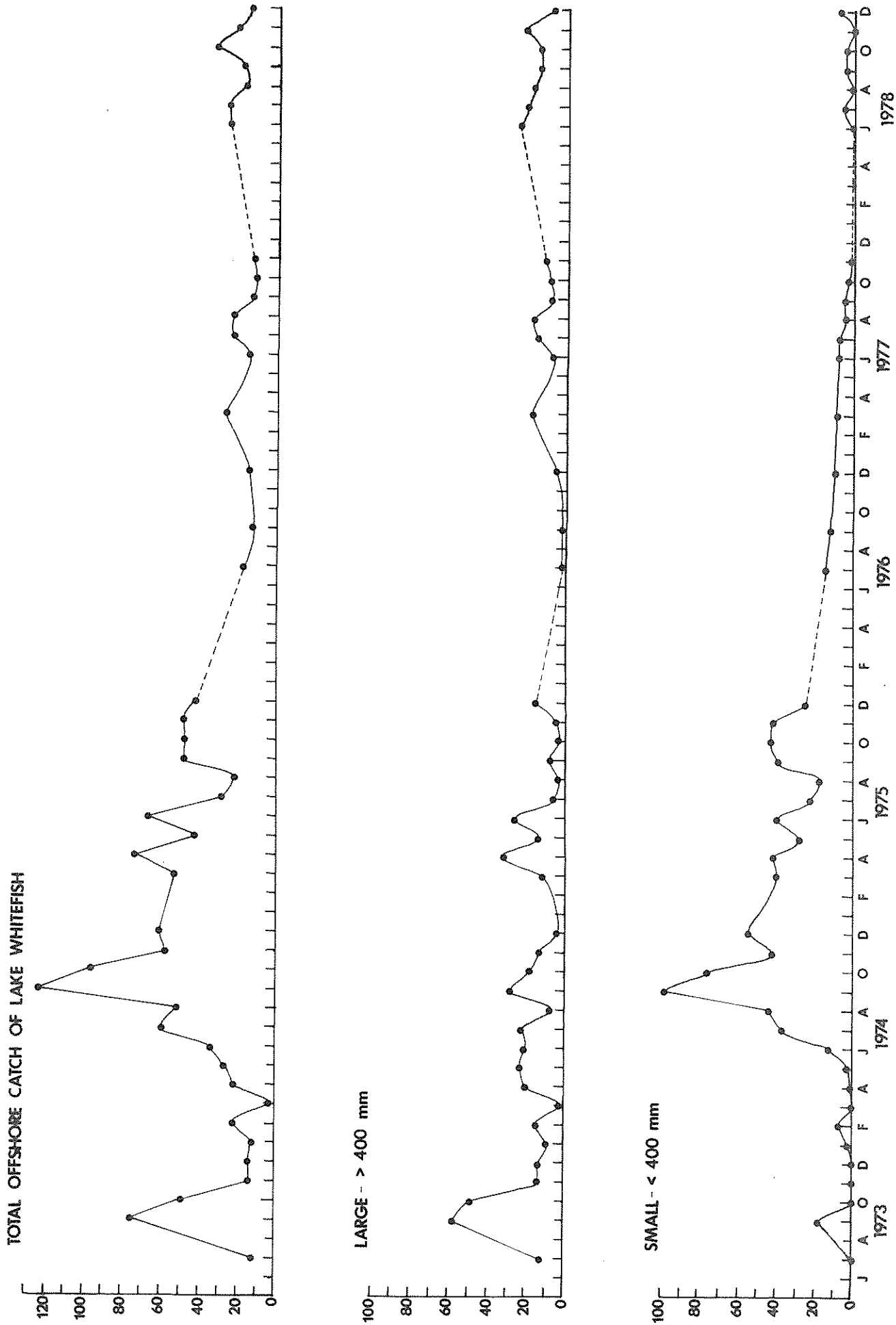


Fig. 67. Relative abundance of large and small lake whitefish in the gillnet catches at stations 4, 5, and 6, 1973-1978.

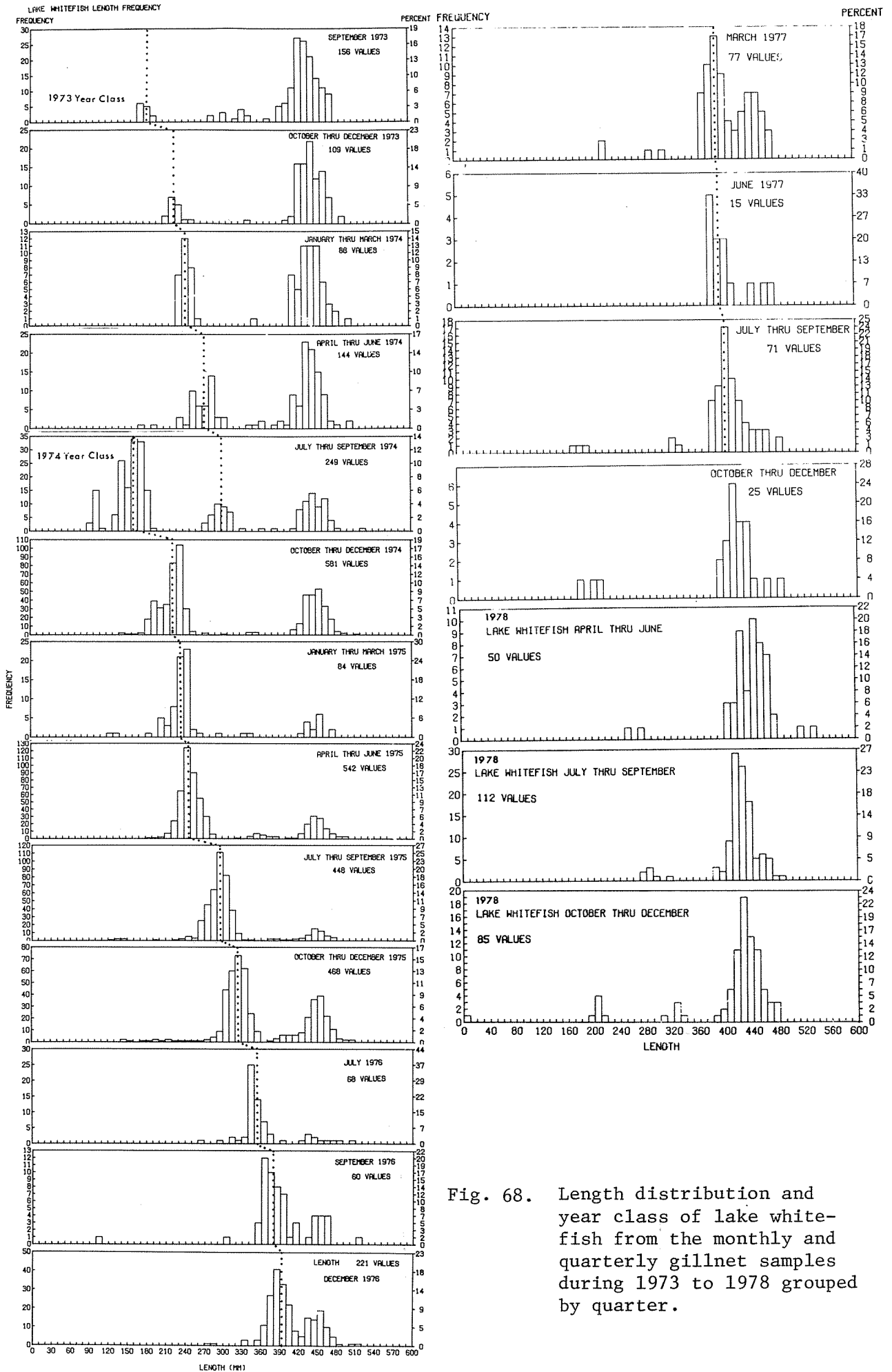


Fig. 68. Length distribution and year class of lake whitefish from the monthly and quarterly gillnet samples during 1973 to 1978 grouped by quarter.

The estimation of lake whitefish in Devil's Hole was documented in 1977 (Stober et al. 1977) and 1978 by periodic transecting with a recording fathometer during the summer. The concentration of lake whitefish in the Devil's Hole area of Banks Lake was monitored during August and September, 1978 to determine the effect of discontinued water flow into Banks Lake. The U.S. Bureau of Reclamation announced plans to cease irrigation pumping into Banks Lake beginning August 9 in order to draw down the lake level for weed control and to force kokanee to spawn at a lower level. Anticipating that this action might adversely effect the estivating lake whitefish in Devil's Hole we began acoustic and hydrographic surveys of the population at approximately bi-weekly intervals. The surveys began August 8 and continued until September 26. The pumping, however, was not stopped as originally planned but was stopped on August 28 after the critically warm period was passed. The survey results are presented as additional background information to complement similar data collected in 1976 (Stober et al. 1977).

On August 8, lake whitefish were concentrated densely between the depths of 24 and 35 m in a band which extended from shore to shore in both transverse and longitudinal transects. The depth of occurrence coincided exactly with the thermocline in which the temperature ranged from 12.0 to 5.5° C and the dissolved oxygen ranged from 39 to 48% of saturation. The surface temperature was 25.5° C. The same conditions prevailed on August 17 except that the surface temperature had cooled to 20° C.

On August 29 the concentration of lake whitefish, water temperature, and dissolved oxygen remained unchanged except that the lake whitefish within 100 m of the shoreline had dispersed upward throughout the water column to within 9 m of the surface. At this depth the temperature was 18.5° C.

On September 18 the distribution of lake whitefish was divided into three fairly distinct areas. The dense concentration between 25 and 35 m subsurface remained only in the offshore, central third of Devil's Hole.

Outside this area was a zone in which individuals were scattered sparsely throughout the water column between 9 and 35 m subsurface. The peripheral third of Devil's Hole was devoid of lake whitefish.

By September 26 the concentration of lake whitefish had completely dispersed. A sparse scattering of targets was recorded throughout the area at random depths from 0 to 35 m.

The discontinuation of irrigation pumping on August 8 came after the moderation of the temperature and dispersion of the dense concentration of lake whitefish had begun. Dispersal began at the shoreline about August 15, progressed outward gradually during the following month, and was complete by September 26. The interruption of pumping from August 28 to October 10 did not appear to have affected either the timing of dispersal or the depth of occurrence.

6.3.3 Yellow Perch

Yellow perch abundance, as measured by gillnet catches at transects 4, 5, and 6, declined in 1976, 1977, and 1978 (Fig. 69). This decline may have been partially the result of reduced recruitment of the 1973 and 1974 year classes due to dessication of spawning and incubation habitat in the spring of 1973 and 1974 (Stober et al. 1977).

A comparison of length-frequency distributions over the period 1973 to 1978 (Fig. 70) indicated a decline in the catch of larger individuals (> 200 mm) during 1976, 1977, and 1978.

6.3.4 Hydrological Monitoring

The specific objective of the hydrological monitoring in Banks Lake was to document temporal and spatial changes in several factors which influence the well-being of fish populations, particularly of the cold-water species. The fact that these factors have been monitored

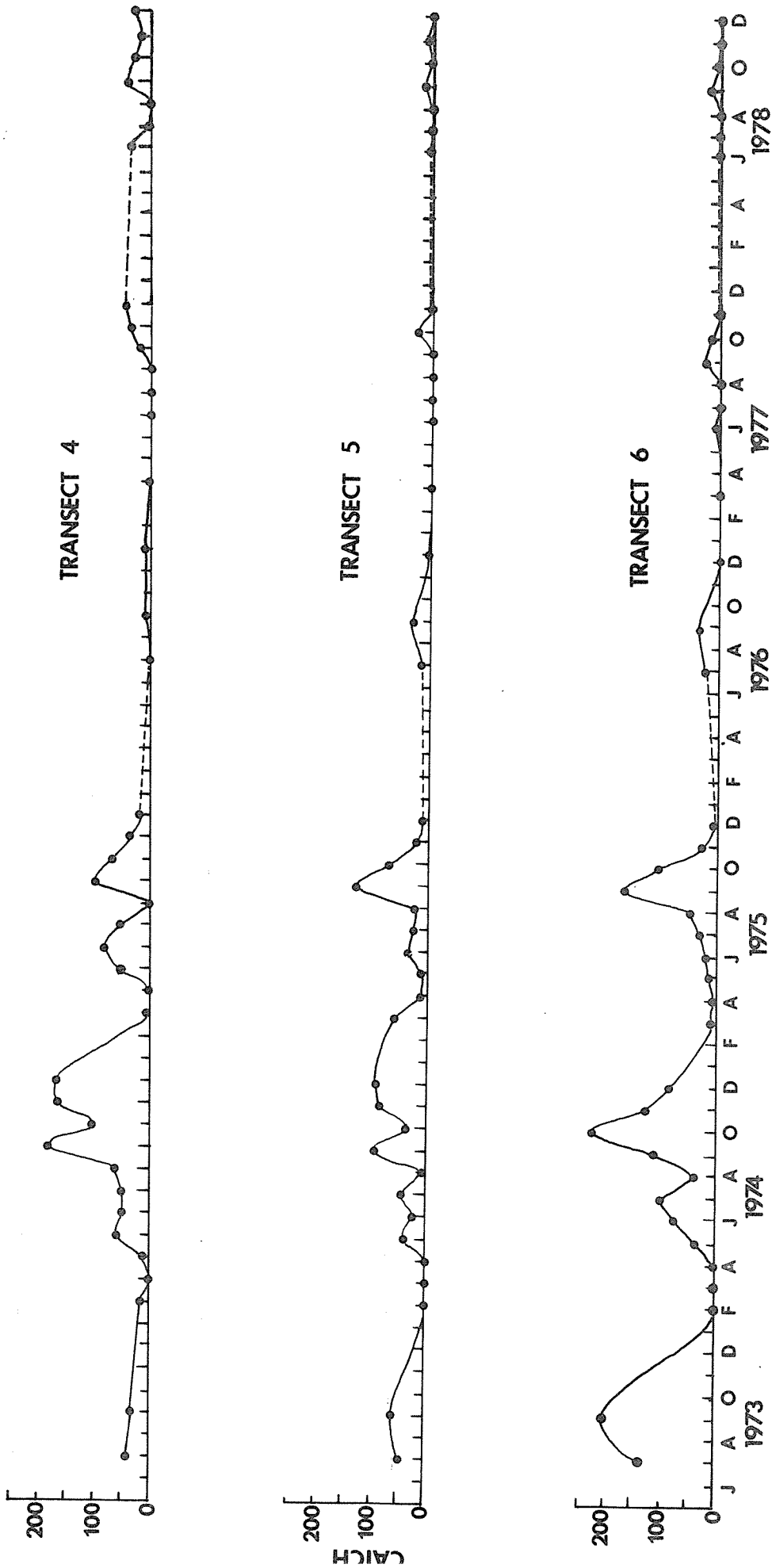


Fig. 69. Distribution of yellow perch at stations 4, 5, and 6. Data points represent the catch from horizontally-placed gillnets at surface and bottom during two 24-hr. periods.

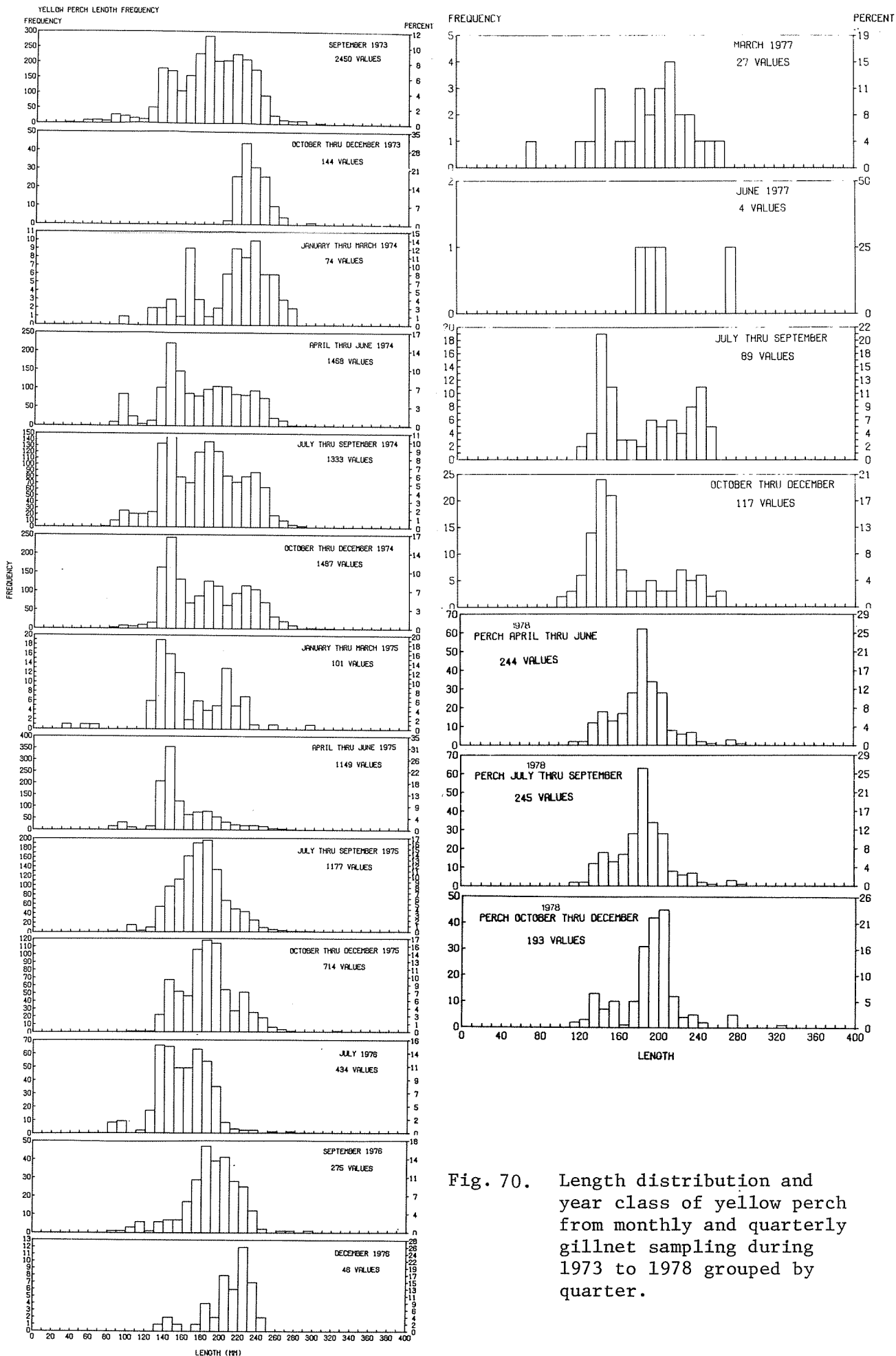


Fig. 70. Length distribution and year class of yellow perch from monthly and quarterly gillnet sampling during 1973 to 1978 grouped by quarter.

annually since 1973 emphasized the importance of continuing the observations as long as any research was continuing on the lake.

Measurements of dissolved oxygen, water temperature, pH, and conductivity were made monthly at 2 m depth intervals from surface to bottom at 6 stations along the length of Banks Lake. The data for 1977 and 1978 are reported in Appendix Tables 3 through 11. Additional measurements of temperature and dissolved oxygen were made during August and September at the Devil's Hole area of Banks Lake in 1978 to coincide with acoustic monitoring of the distribution of estivating lake whitefish (Appendix Table 11).

Water temperatures were relatively warm during July and August of 1978. The maximum temperature recorded was 25.4° C at Station 4 on August 8. In 1977, the warmest temperature recorded was 23.9° C at Station 3.

The dissolved oxygen readings, expressed as percent saturation at temperature, were consistently less in 1978 than in 1977. The mean percentage difference for the water column was 15.6. Since this difference could not be explained by any environmental factor observed, we assume the 1978 readings are in error. The error appears to be consistent and the readings are useful for comparison within the 1978 data set. All dissolved oxygen readings were at desirable levels for all fish species except those taken below the thermocline at Devil's Hole. The lake whitefish which concentrated at the thermocline in Devil's Hole during July and August apparently tolerated low dissolved oxygen by estivating.

Apparently, pH and conductivity readings in 1978 were affected by the same error source as dissolved oxygen, as they also were from 10 to 15 percent below the 1977 readings.

6.4 Stock Assessment

The beach spawning kokanee in Banks Lake are essential to the natural reproductive success of this species in the lake. Prior to the development of coordinated draw-down and fisheries management strategies it would be helpful to know whether the beach spawning kokanee represent a unique stock which either resulted from native Columbia River or from introduced stocks.

The uniqueness of the Banks Lake kokanee spawning stock was tested in 1978 by comparing kokanee from FDR Reservoir and Banks Lake. Kokanee were collected and their tissues analyzed for protein (enzyme) variations by electrophoretic separation and histochemical staining techniques. These protein variations reflect simple genetic differences and their frequencies can sometimes be used to characterize population units (Utter et al. 1979). Biochemical genetic differences were used to identify component populations of sockeye salmon in Cook Inlet, Alaska (Grant 1977) and Alberni Inlet, British Columbia (Allendorf and Mitchell 1977).

Recent genetic studies of Oncorhynchus nerka populations of the Pacific Northwest suggest that these populations originated from two distinct ancestral stocks. The frequencies of certain variant proteins found in two anadromous sockeye populations of the Columbia River (Utter, unpublished data) and indigenous kokanee populations from Issaquah Creek (Seeb et al. 1977) and from Lake Stevens in western Washington (Pfeifer and Hershberger, unpublished data) are distinct from those found in more northern populations such as Cultus Lake and Baker Lake sockeye and Lake Whatcom kokanee (Seeb et al. 1977).

Extensive hatchery plants of kokanee by the Washington State Department of Game were made in both the FDR Reservoir and in Banks Lake (Appendix Table 12). It is not known to what extent these introduced fish have become established.

If the indigenous kokanee of the FDR Reservoir-Banks Lake system originated from the postulated southern ancestral stock (and have the corresponding characteristic gene frequencies of that stock), then they should be distinct from the introduced stocks that originated from Lake Whatcom. We could, therefore, use these differences in gene frequencies to estimate the proportionate contributions of introduced and indigenous kokanee in Banks Lake.

Certain behavioral differences exhibited by the kokanee, such as spawning site selection, may have a genetic basis. We also examined different spawning groups of kokanee within Banks Lake to see if they comprised distinct population units.

Although over 30 genetic loci were screened, only four showed distinctive variation. The results of our analysis of these four polymorphic loci for each of the areas examined is listed in Table 16. Also listed for comparison are kokanee data from Lake Whatcom (Seeb et al. 1977).

As can be seen from Table 16, there is little variation among the allele frequencies of the kokanee samples from the four areas examined in this study. Chi-square homogeneity tests of these frequencies were performed on all samples for each locus. No significant differences among the allele frequencies were detected. There were also no significant differences between the allele frequencies of FDR Reservoir and Banks Lake kokanee and those of Lake Whatcom kokanee.

The introduced stocks of kokanee in FDR Reservoir and Banks Lake originally came from Lake Whatcom (Appendix Tables 1 and 12). This similarity of allele frequencies suggests that most of the present day kokanee in the FDR Reservoir and in Banks Lake are progeny from hatchery transplants. To substantiate this, indigenous kokanee populations from the Columbia River drainage should be examined to see if their allele frequencies are indeed distinct from those of Lake Whatcom kokanee. This

Table 16. Frequency of allele variants found in kokanee samples examined in this study for each of the form polymorphic loci.

Location	Month of Collection	Sample Size	Frequencies of Variant Alleles			
			PGM-1	MDH-1	MDH-3	PGI-3
FDR Reservoir	April-May	81	.179	0	0	.006
Billy Clapp Lake	June	50	.196	0	0	0
Irrigation Canal	July-Aug.	24	.104	0	0	0
Banks Lake	June-Aug.	60	.138	.017	.008	.008
Banks Lake (spawners)	November	61	.131	0	.004	0
Primary Spawning Area - 29			.155	0	0	0
Million Dollar Mile - 5			0	0	0	0
Coulee City Harbor - 20			.050	0	0	0
South Barrier site - 7			.357	0	.036	0
FDR-Banks Lake TOTAL		276	.158	.004	.004	.004
Lake Whatcom Seeb, et al, 1977 unpublished		100	.163	0	0	0

has not been done because of the difficulty of obtaining sufficient sample sizes from the small native populations. Due to the difficulty of finding such stocks in Washington these samples may have to be obtained from the Canadian portion of the Columbia River. The total gillnet catch and species composition in the sampling effort in FDR Reservoir and Billy Clapp reservoir indicated the low availability of kokanee (Appendix Table 13).

Spawning kokanee were collected in November from four different sites in Banks Lake. Allele frequencies of the kokanee sampled at each of these sites were compared. A chi-square homogeneity test of these frequencies revealed some significant differences of PGM-1 variants among the four sites ($X^2 = 9.8$ $df = 3$). This indicates some degree of non-random mating among the kokanee in Banks Lake is occurring. To determine if these spawning groups are sufficiently isolated to constitute genetically distinct sub-populations would require more extensive sampling and observation.

6.5 Fry Emergence

6.5.1 Artificial Spawning Beds

Artificial spawning beds described in this section were emplaced by the Northwest Steelhead and Salmon Council of Trout Unlimited, with the aid of Fisheries Research Institute personnel. The purpose was to test the feasibility of establishing spawning beds in Banks Lake below the level of draw-down to provide the kokanee population in the lake with a more stable spawning area which would be unaffected by draw-down. It has been found that lowering the lake level during late winter and early spring for irrigation exposes a portion of the lakeshore spawning beds and causes the destruction of eggs and larvae within. Most kokanee spawning occurs in a depth range of 1.5 to 4.6 m below full pool because suitable spawning substrate exists in only limited amounts below this level. In the future, spring drawdown may have an increasingly adverse effect on

population stability if the magnitude of drawdown increases with increasing irrigation demand. With the eventual doubling of irrigation flow and increased drawdown of the lake level, egg exposure may increase, possibly resulting in severe reductions in fry survival which was exemplified in the 1976 and 1977 adult year classes.

Artificial spawning beds may be one means of inducing spawning at a lower level. The beds may be utilized to attract spawning fish, or they may be planted with eggs for the development of a spawning stock which would return to the same bed to spawn annually. If artificial spawning beds were successful, self-sustaining populations of kokanee may be developed which would be unaffected by operational changes in lake level.

The two beds (Fig. 1) were placed at a level below that of maximum drawdown and each received 38.2 m³ (50 yd³) of gravel distributed in a 10.2-cm (4-inch) to 15.2-cm (5-inch) layer. The gravel was selected so that it was large enough to allow adequate interstitial water movement and small enough for the fish to excavate.

There are a number of factors which can influence the success of the artificial spawning beds. Most obvious among these are: 1) intergravel dissolved oxygen; 2) siltation rate; 3) gravel size; 4) water depth; 5) gravel depth; and 6) egg density. Since each one of these factors is critical to egg survival, a study was initiated to determine their effects on eggs planted in two artificial beds and one gravel incubation box.

The artificial beds were not utilized by kokanee for spawning in either 1977 or 1978. A number of small excavations was observed on the south bed in 1977 which may have been caused by kokanee, but no kokanee redds were found. The only fish found on either of the beds were dead and these probably drifted in from natural spawning areas. The respective season totals of dead kokanee found on the artificial beds were: north site, one dead each year; south site, 27 and 30, respectively in 1977 and 1978.

6.5.1.1 Gravel Analysis. The gravel placed at the north and south sites and the gravel box was analyzed (Table 17) to determine percent composition by size. Gravel placed at the south site was 49.9 percent in the size range from 6.7-13.2 mm and 40.4 percent in the size range from 13.2-26.9 mm. Gravel placed at the north site was 89.0 percent in the size range from 13.2-26.9 mm and 10.3 percent in the size range from 6.7-13.2 mm. The percentage of pansilts ($< .85$ mm) was very small; ≈ 1.2 percent in all three gravel types.

6.5.1.2 Dissolved Oxygen. Dissolved oxygen concentration (D.O.) was relatively high in the two artificial beds, and the primary spawning area (Table 18). The lowest mean D.O. recorded during the 6 1/2 month sampling period was 4.5 mg/L at the south site and the highest was 13.1 mg/L at the primary spawning area. The low value of 4.5mg/L was recorded on June 1, after emergence was essentially complete. The artificial gravel beds had slightly lower average concentrations than the primary area, averaging 8.3, 8.9, and 9.7 mg/L at the north, south, and primary sites, respectively. There was little difference between interstitial dissolved oxygen measurements and ambient D.O. measurements taken above the substrate, although all ambient values except two were slightly higher than interstitial measurements from the same day. There was little observed difference between D.O. measurements taken at the primary site in 1978 and those taken in 1977.

6.5.1.3 Sedimentation Rate. Sedimentation rates at the artificial gravel sites were considerably higher than at the primary spawning area (Table 19). The north bed had the highest average of 0.065 mm/day for the four periods sampled, while the average at the south site was 0.060 mm/day. A gravel slide at the primary site overturned the sediment sampling jars during the fourth sampling period, therefore, the average represents only cumulative siltation through September. Lack of fourth quarter data from the primary site tended to bias the average sedimentation rate downward because the highest rates occurred during the fourth quarter. Rates of .081 and .075 mm/day on the north and south

Table 17. Percent size composition by volume of gravel placed at two artificial gravel beds and one gravel box in Banks Lake, 1977.

Gravel Size (mm)	<u>Percent Composition</u>		
	Gravel Box	South Site	North Site
>26.9	8.77	0.00	0.00
13.2 - 26.9	78.68	40.44	89.04
6.7 - 13.2	10.31	49.88	10.27
3.35 - 6.7	1.45	7.48	.30
1.70 - 3.35	.04	.47	0.00
.85 - 1.70	.02	.61	0.00
pansilts (<.85)	.72	1.21	.38
Total sample volume (ml)	4560	2139	3650

Table 18. Measurements of dissolved oxygen in artificial gravel beds and primary spawning site.

Bed	Date	Dissolved Oxygen(mg/L)			Above Substrate
		Mean	Range		
		D.O.	Low	High	
South	11/17/77	9.8	8.8	10.6	10.1
	11/30/77	11.6	11.0	12.0	11.8
	4/13/78	11.3	10.6	12.6	15.6
	5/18/78	7.3	7.1	7.5	8.0
	6/1/78	4.5	3.3	5.5	7.8
North	11/17/77	10.0	9.8	10.1	10.0
	11/29/77	9.2	7.6	11.3	11.6
	4/27/78	7.0	6.4	7.5	8.6*
	5/17/78	7.0	6.3	7.6*	7.8
Primary	11/17/77	11.2	10.6	12.3	10.6
	11/30/77	10.7	10.0	11.1	11.1*
	4/13/78	13.1	11.6	14.0	15.0
	4/28/78	7.0	5.9*	7.8*	9.3*
	6/1/78	6.6	6.3	7.0	7.9

*Mean of two samples.

Table 19. Sedimentation rates at the artificial gravel beds and primary spawning area.

Bed	Period	Mean Rate (mm/day)	Std. Dev.
South	11/3-11/30/77	0.057	0.003
	3/30-5/25/78	0.053	0.004
	5/25-9/27/78	0.056	0.003
	9/27-11/29/78	0.075	0.005
North	11/4 11/24/77	0.071	0.005
	3/30-5/24/78	0.033	0.004
	5/24-10/2/78	0.074	0.004
	10/2-11/29/78	0.081	0.009
Primary	11/3-11/30/77	0.016	0.011
	3/30-5/25/78	0.023	0.004
	5/25-9/27/78	0.037	0.005

gravel beds, respectively, were observed during the fourth sampling period, in October and November 1978. The average sedimentation rates at the artificial beds through September, however, were much higher than at the primary area. Figure 71 illustrates the observed seasonal increase in sedimentation rate at all sites.

6.5.1.4 Planting of Eyed Eggs. Natural spawning did not occur on the artificial beds; therefore, eyed eggs were planted in December of 1977 in an effort to establish a spawning population which may utilize the beds in the future. The survival of the planted eggs was monitored to determine the potential of the gravel beds as an incubation medium and to test the success of these plants.

Measurements of D.O. and siltation rates which were made in November 1977 in the gravel beds determined that the intergravel D.O. concentrations before egg planting compared favorably with optimum conditions, as described in the literature (Koski 1975). Some of the redds observed in the primary spawning area were dug in cobble at least twice the size of the gravel in the artificial bed. Therefore, the natural spawning potential of the artificial bed should have been improved by the composition selected.

Siltation is of greatest concern since silt can filter down into the gravel beds and eventually fill in the interstitial gravel spaces. This would render the beds unsuitable for spawning and incubation since it would reduce water movement and the exchange of D.O. around the eggs. If the north site, south site, and primary site accumulated silt at the rates determined in the sedimentation rate experiment (Table 19), the three sites would accumulate 23.7 mm, 21.9 mm, and 9.1 mm of silt per year, respectively. Such accumulations would render the beds unsuitable in a short time. However, several observations indicated that these rates may not be entirely representative of annual ranges. During October 1977, the lake level was dropped 2.7 m (9 ft) and was returned to full pool around mid-November. During the period of drawdown, divers observed increased

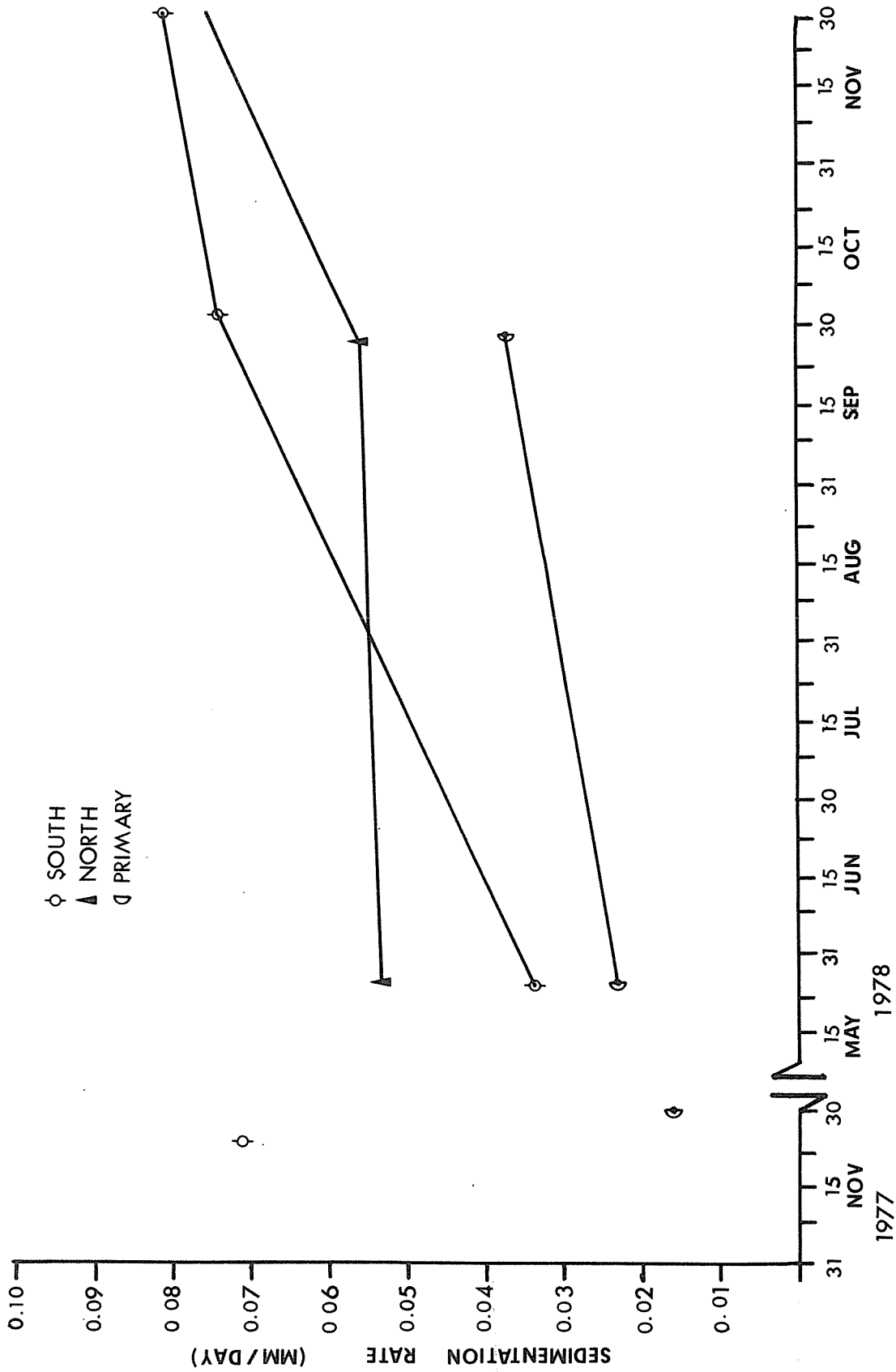


Fig. 71. Mean sedimentation rates in Banks Lake on the north and south artificial spawning beds and on the primary natural spawning area in 1977 and 1978.

turbidity. The siltation rates on the artificial beds, while high during the period of drawdown, ceased almost entirely after the lake returned to full pool. Thus the drawdown probably caused the sedimentation by exposing lakeshore sediment deposits to wave action. One month after the experiment was concluded, the artificial beds were bare of silt, indicating a sharp decline in the siltation rates. Reasons for the disappearance of the silt deposits are unknown, but may be related to fall and spring turnover. The same phenomenon occurred again in the spring of 1978 to a somewhat lesser degree.

6.5.1.5 Kokanee Fry Survival. Emergent fry in the artificial gravel beds were sampled with emergent fry traps during the period from March 30 to June 1, 1978 (Fig. 72) to determine whether production could be obtained from the beds. The peak emergence at both the north and south sites occurred midway in this period near the first week of May.

The survival rate of the planted eggs was estimated roughly by comparing the number of eggs planted with the estimated total fry emergence based on fry catches. The accuracy of these survival estimates is tenuous because it depends on estimates for which precise data are not available.

The area of each artificial gravel bed was measured by divers to include the area which contained all traps and all planted eggs. The area of the north gravel site was estimated as 116 m² and that of the south site as 36 m² (Table 20). The fry traps within these areas were placed randomly by divers; however, the eggs planted in trenches were not.

The emergence from 18 traps at the north site and 20 traps at the south site was 29 and 169 fry, respectively. Assuming that the traps were 100 percent efficient, capturing all fry which emerged beneath them, these values were extrapolated to respective total emergence estimates of 748 and 1,213 fry for the north and south gravel beds. The actual efficiency of the traps was unknown, but undoubtedly was less than 100 percent. The only available information on trap efficiency with kokanee fry is from laboratory experiments (Collins 1974) in which screened, pyramid-shaped

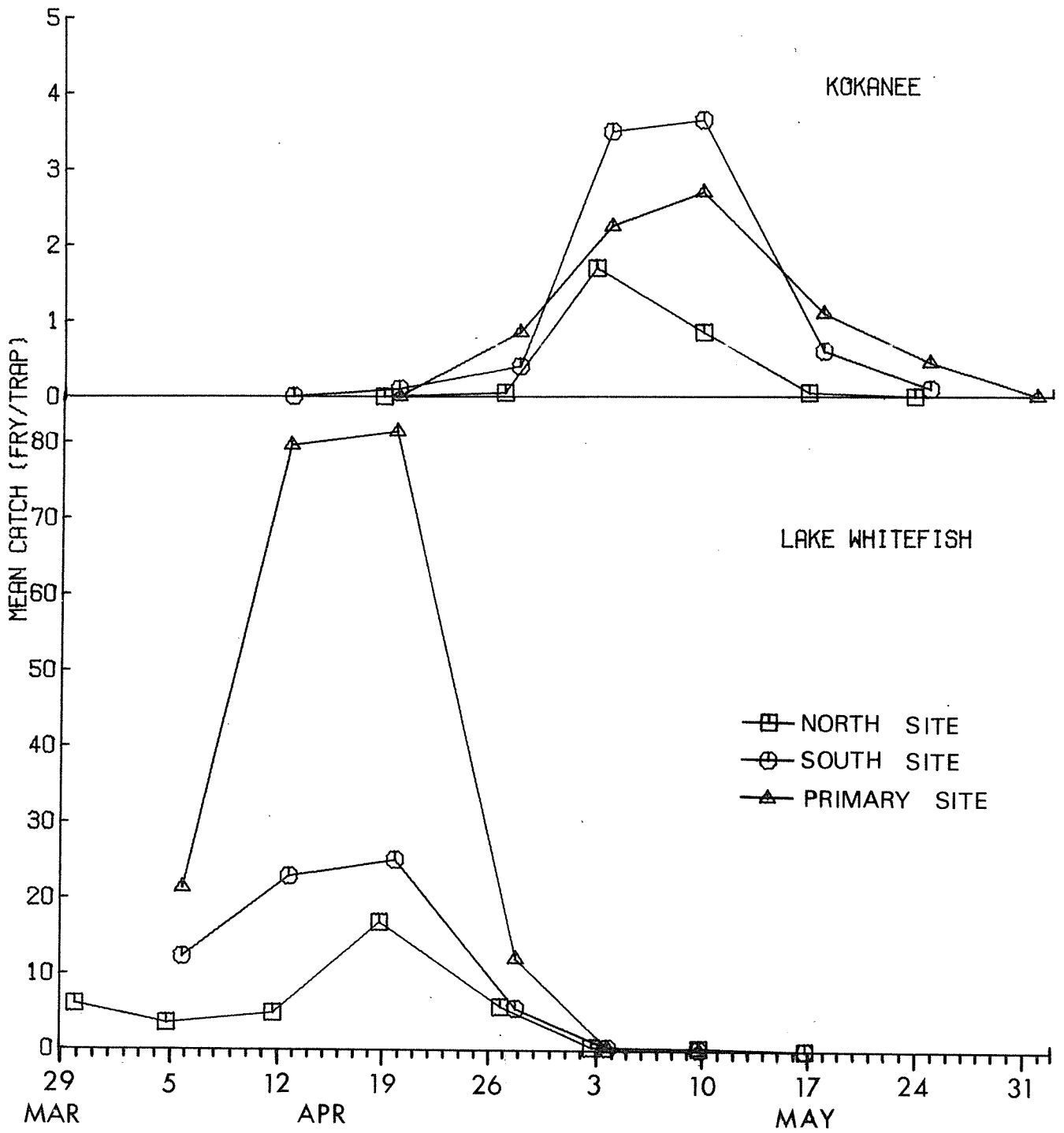


Fig. 72. Mean weekly catch of kokanee and lake whitefish fry from the north and south artificial spawning beds compared to the primary spawning area during 1978.

Table 20. Emergence and survival of kokanee fry from egg plants at the south and north artificial gravel beds.

Emergence Year	Bed	Traps (No.)	Trap Area (m ²)	Total Area (m ²)	Total Catch (No.)	Estimated Emergence		Total Eggs Planted (No.)	Survival (% of planted)
						Trap Efficiency	100%		
1978	South	20	5.00	36.30	167	1213	1736	32,000	3.79
	North								
	Gravel Bed	18	4.50	116.10	29	748	1071	62,400	1.24
	Incubation Box	2	0.50	1.90	24	91	130	5,400	1.20
	High Density	1	0.25	0.95	18	68	93	3,600	1.69
	Low Density	1	0.25	0.95	6	23	33	1,800	1.89
									1.28
									100% ¹
									69.9% ²

1. Assuming 100 percent trap efficiency.

2. Assuming 69.9 percent trap efficiency from Collins 1974.

traps with a slope of 56° were 69.9 % efficient. Applying this value to data from the artificial gravel beds increased the estimated total fry emergence to 1,071 fry at the north site and 1,736 fry at the south site. Emergence from the gravel incubation box located on the north site was 91 fry and 130 fry for 100% efficiency and 69.9% efficiency, respectively.

The survival rates estimated from these values were all very low (Table 20), and ranged from 1.20% survival at the north gravel site assuming 100% trap efficiency to 5.4% at the south site assuming an efficiency of 69.9%.

The absence of kokanee spawners on the artificial gravel beds during the 1977 spawning season did not necessarily indicate that such beds would never be utilized. Reasons why spawners were not attracted to spawn in 1977 area not known, but can be inferred based on well-established behavior patterns which are true for all salmonid species. The instinct of salmon to return to natal spawning gravel is well-documented. Stream-spawning salmon return to a particular tributary and even to a particular reach within the tributary with a remarkable degree of reliability. The 1977 kokanee spawners resulted from lakeshore spawning by parent stock in 1973. Thus, it is likely that the 1977 spawners were returning to specific locations from which they emerged as fry. The introduction of gravel beds of different origin and chemical composition just prior to spawning may not have allowed sufficient time for straying to occur.

Diver observations during the kokanee spawner survey of 1978, however, indicated that accumulations of silt on the artificial gravel beds had filled the interstitial gravel spaces of the south site down to the original substrate and of the north site down to a depth of two inches. Undoubtedly, this heavy siltation lessened the attractiveness of the beds to spawning kokanee in 1978. The observations of the divers coupled with high sedimentation rates and low survival estimates indicate that the artificial beds are probably unsuitable for further use as either

spawning substrate or incubation medium for kokanee eggs. In the future, the possibility exists that locations could be found in Banks Lake where siltation is much less than the present sites, however, an extensive sediment sampling study would be required to locate such areas.

6.5.1.6 Lake Whitefish Fry. Respective totals of 359 and 723 lake whitefish fry were trapped incidentally in the north and south artificial gravel beds between March 30 and May 5 (Fig. 72). The peak emergence from the gravel sites, as well as from the primary spawning area, occurred near the middle of April. The earlier emergence timing of lake whitefish likely reduced the vulnerability of this species to annual spring draw-down as compared to kokanee. The exact incubation requirements of whitefish eggs and alevins are not known, but it may well be that the artificial gravel beds will continue to produce whitefish fry even though they are unsuitable for kokanee.

6.5.1.7 Yellow Perch Fry. Only one yellow perch fry was captured (north bed on May 10) although many egg masses were found deposited at both sites. The low capture of yellow perch fry was probably the result of placing the traps on beds prior to the yellow perch spawning season.

6.5.2 Natural Spawning Beds

6.5.2.1 Kokanee Fry Survival. Emergent naturally spawned fry in the primary spawning area were captured during the period from March 29 to May 31, 1987, and from April 20 to June 1, 1978 (Fig. 73). In 1978, peak emergence occurred near the second week of May. The average catch per trap was slightly higher in 1977 than in 1978.

The survival rate of eggs spawned naturally in the primary area was estimated roughly by comparing the theoretical deposition of eggs based on number of spawners with the estimated total fry emergence based on fry catches. The accuracy of the survival estimates is tenuous because it depends on several estimates for which precise data are not available.

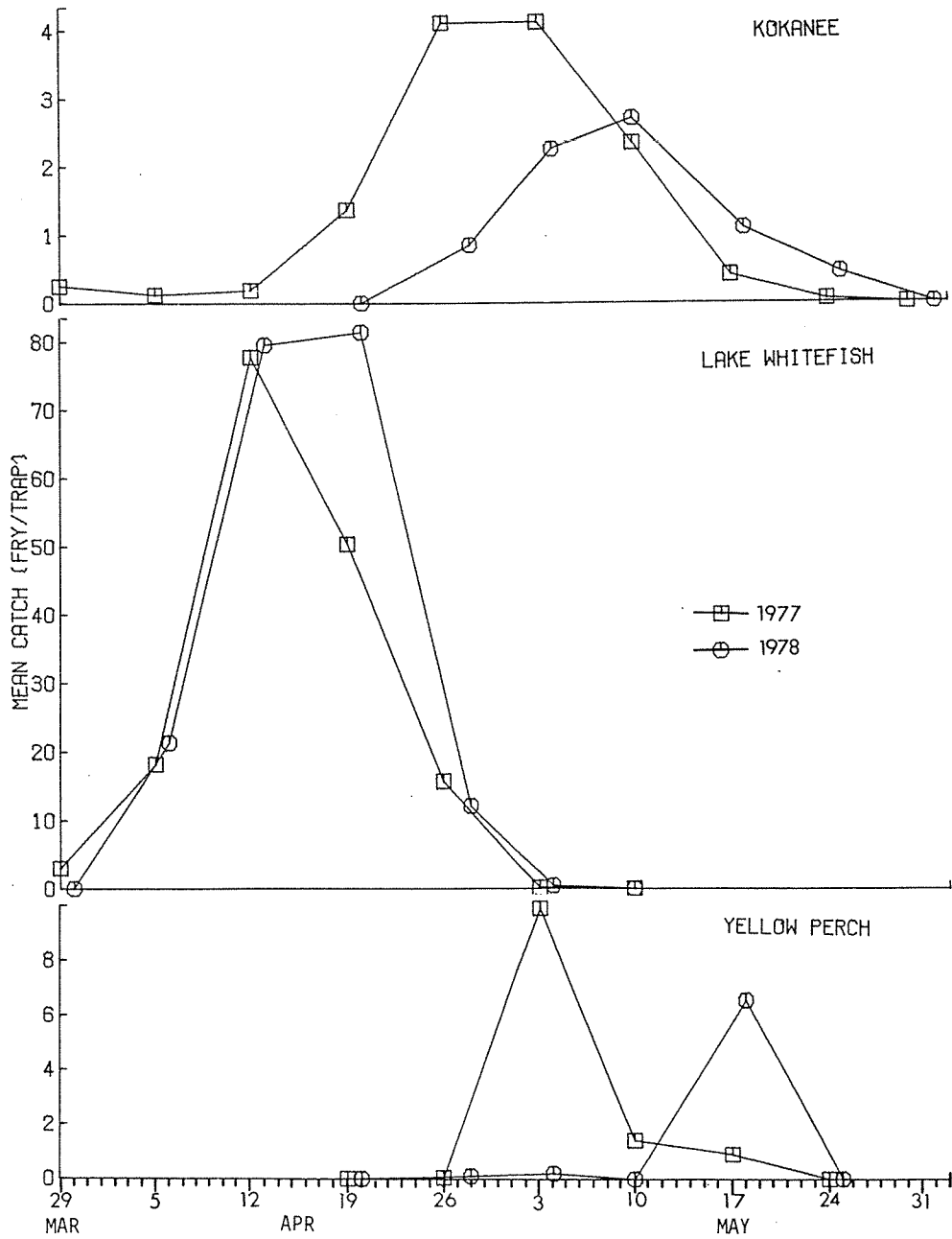


Fig. 73. Mean weekly catch of kokanee, lake whitefish and yellow perch fry from the primary spawning area during 1977 and 1978.

During the spawning period of 1977, two areas of differing spawning densities within the prime gravel section were observed with the highest concentration of spawners occurring above the 4.6 m contour. This area of concentrated spawning was measured to be 568 m², while the total utilized area of the prime gravel section, deep and shallow, was estimated at 1,579 m² (Table 21). Ten emergent fry traps were positioned over each of the two areas prior to the 1978 emergence period, capturing totals of 98 fry in the shallow section (corresponding to the area of concentrated spawning) and 48 fry in the deep section. Catches from the nine other traps which were installed after peak emergence were not included in calculations.

Before the 1977 emergence season 40 traps were installed in the lake, but eventually about half of these were rendered inoperable by rockslides. Emergence from only 15 traps was sampled consistently throughout the spring, with a total catch of 239 kokanee within an estimated spawning area of 165 m². Because all the traps were placed randomly within the limits of each measured area, the catches were representative of fry emergence for the entire measured area.

Estimates of emergence and survival based on trap efficiencies of 100 percent and 69.9 percent, as described previously, are presented in Table 21. Definitive estimates of theoretical egg deposition were also hindered by the wide range of values for turnover time (redd life) for individual spawners on the spawning grounds reported in the literature. Ranges of egg deposition were calculated for redd lives of 5.7 days (Lewis 1972) and 15.4 days (Pfeifer 1978). A total of four values each year for estimated survival rate from deposition to emergence could be calculated depending on the trap efficiency and redd life selected. These survival estimates ranged from a low of 3.0 percent surviving in 1978, at 69.9 percent trap efficiency and 5.7 days redd life, to a high of 23.9 percent emerging in 1977 at a trap efficiency and a redd life of 100 percent and 15.4 days, respectively.

Table 21. Kokanee fry emergence and survival rates on the primary spawning area in 1977 and 1978.

Emergence Year	Bed	Traps (No.)	Trap Area (m ²)	Total Area (m ²)	Total Catch (No.)	Estimated Emergence		Total Egg Deposition(No.)	Survival (% of Deposition)				
						Trap Efficiency	Total Egg Deposition(No.)		100%	69.9% ²			
1977	Primary	15	3.75	165	238	10,516	15,044	63,000	171,000	16.69	6.15	23.88	8.80
1978	Primary			1579		41,677	59,624	500,000	1,400,000	8.34	2.98	11.92	4.26
	Shallow	10	2.5	568	98	22,266	31,854						
	Deep	10	2.5	1011	48	31,854	27,770						

1. 100 percent trap efficiency.
2. 69.9 percent trap efficiency from Collins (1974).
3. Turnover time in days from Pfeifer (1978).
4. Turnover time in days from Lewis (1972).

Regardless of which efficiency or redd life is used, several consistent differences existed between the 1977 and 1978 survival rates. The deposition of eggs from the 1977 spawning was 8 times larger than the deposition in 1976. However, the resulting emergence in 1978 was only 4 times larger than the emergence of the previous year, and therefore, the resultant survival rate in 1978 was half the 1977 rate. The difference may have resulted from one or more factors including superimposition of redds, increased predation and/or fungal infection resulting from higher egg densities following the 1977 spawning. However, even though the survival rate declined at higher densities more fry were produced.

6.5.2.2 Lake Whitefish Fry. A total of 2,968 lake whitefish fry was trapped incidentally in the prime kokanee spawning area between March 29 and May 2, 1977 (Fig. 73). A total of 1,989 was trapped during approximately the same period in 1978. The peak emergence in 1977 occurred near April 12, and the 1978 peak occurred only a few days after April 12. Mean catches (fry/trap) were also quite similar for both years.

It appears that emergence of lake whitefish fry was much greater in the deep portion of the prime gravel section than in the shallow portion, although results were inconclusive because traps in the shallow section of the bed were not installed until after peak whitefish emergence in 1978. If, in fact, lake whitefish spawn deeper and emerge earlier than kokanee then the vulnerability of this species to annual spring irrigation drawdown is much less than kokanee.

6.5.2.3 Yellow Perch Fry. Yellow perch occurred in the traps in 1977 from April 26 to May 24, and in 1978 from April 28 to May 25, however, the 1977 peak on May 3 occurred 2 weeks earlier than the corresponding peak in 1978 (Fig. 73).

6.5.2.4 Substrate Analysis. In 1977 and 1978, approximately one half of the kokanee spawning in Banks Lake occurred along 2,400 m of shoreline at the primary spawning area. About half of these spawned

within a 113 m section designated the prime gravel section. Because this area is so important to maintaining the natural production which is the main support of the kokanee sportfishery it is essential that the factors which influence its function are well understood. The factor which seemed most important to the establishment of natural spawning was the availability of suitable gravel. Efforts, therefore, were directed toward an analysis of the composition of the natural spawning substrate and an estimation of kokanee fry production in the prime gravel area. Measurement of other important factors including dissolved oxygen and sedimentation rate were discussed earlier in sections 6.5.1.2 and 6.5.1.3.

Gravel composition varied by depth and between transects (Fig. 74). Transect 1 differed from the others in that it was located on a very unstable slide area and contained a larger proportion of medium-sized gravel (3.36-26.9 mm) in the deeper locations than in shallower locations. Other transects contained generally more large boulders and cobble (> 53.8 mm) and proportionally less gravel (3.36-26.9 mm) and fines (< 3.36 mm) in the deeper locations than in the shallow (0-4.6 m) depth locations. Also observed, were generally decreasing proportions of fines (3.36-26.9 mm) from transect 2 to transect 6, especially in the 1.6-4.6 m depth interval (corresponding to the area of concentrated spawning).

Andrew and Geen (1960) summarized preferences by spawning salmon for certain types and sizes of substrate. Sockeye salmon (of which kokanee is the land-locked form) preferred gravel smaller than 50.8 mm (2 inches) in diameter. Gravel obtained from redds of sockeye contained less than 2 % by weight gravel larger than 101.6 mm (4 inches) in diameter. Preferred sizes of spawning gravel among salmonids were believed to be partially a function of body size, thus gravel size preferred by kokanee is undoubtedly smaller than for sockeye.

A composite of all transects (Fig. 75), illustrated that the 1.6-4.6 m depth stratum contained the highest proportions of gravel smaller than 53.8 mm. Koski (1975) has documented the adverse effects of high

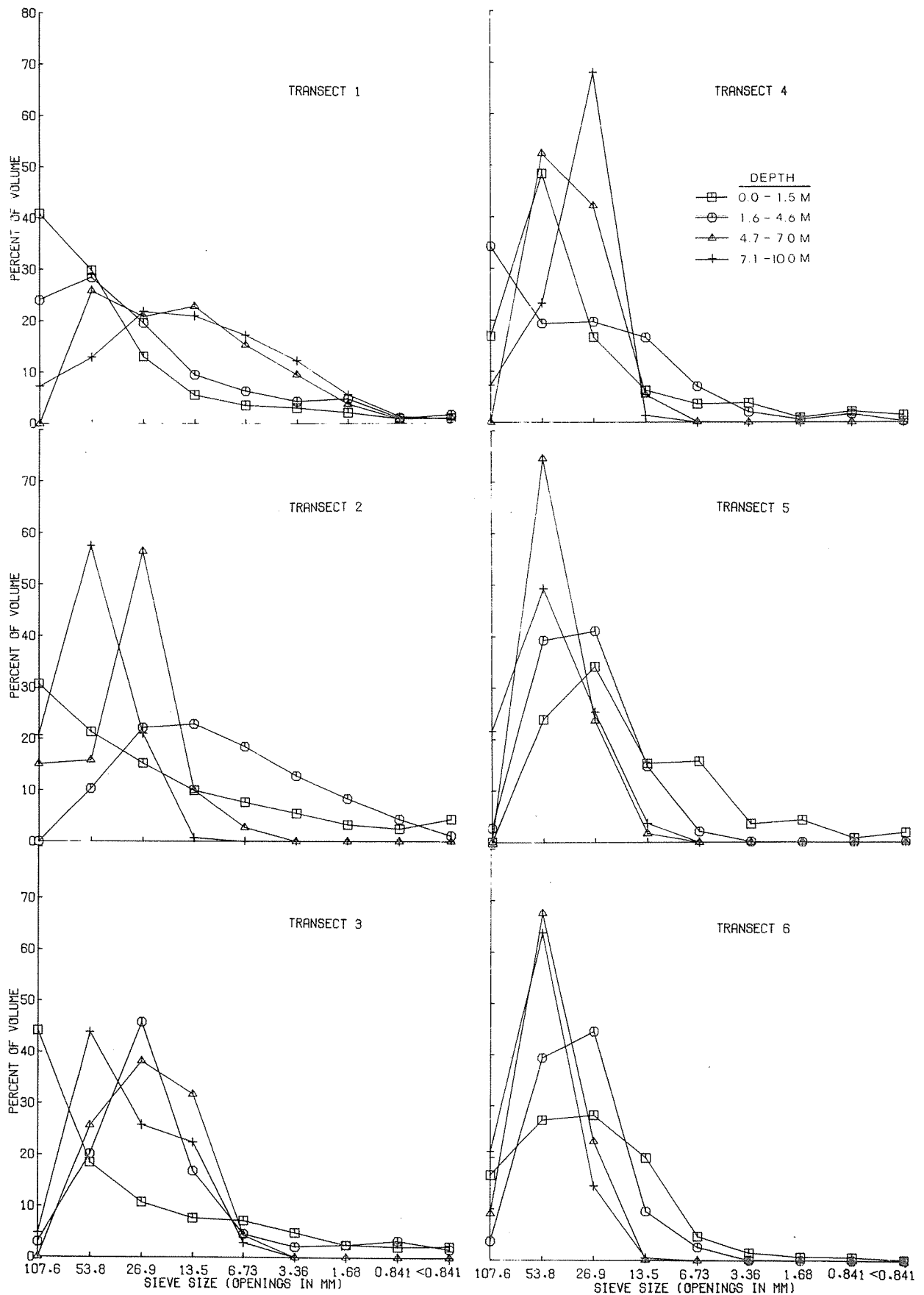


Fig. 74. Substrate analysis at four depth intervals and six vertical transects in the prime kokanee spawning area of Banks Lake.

COMPOSITE - ALL TRANSECTS

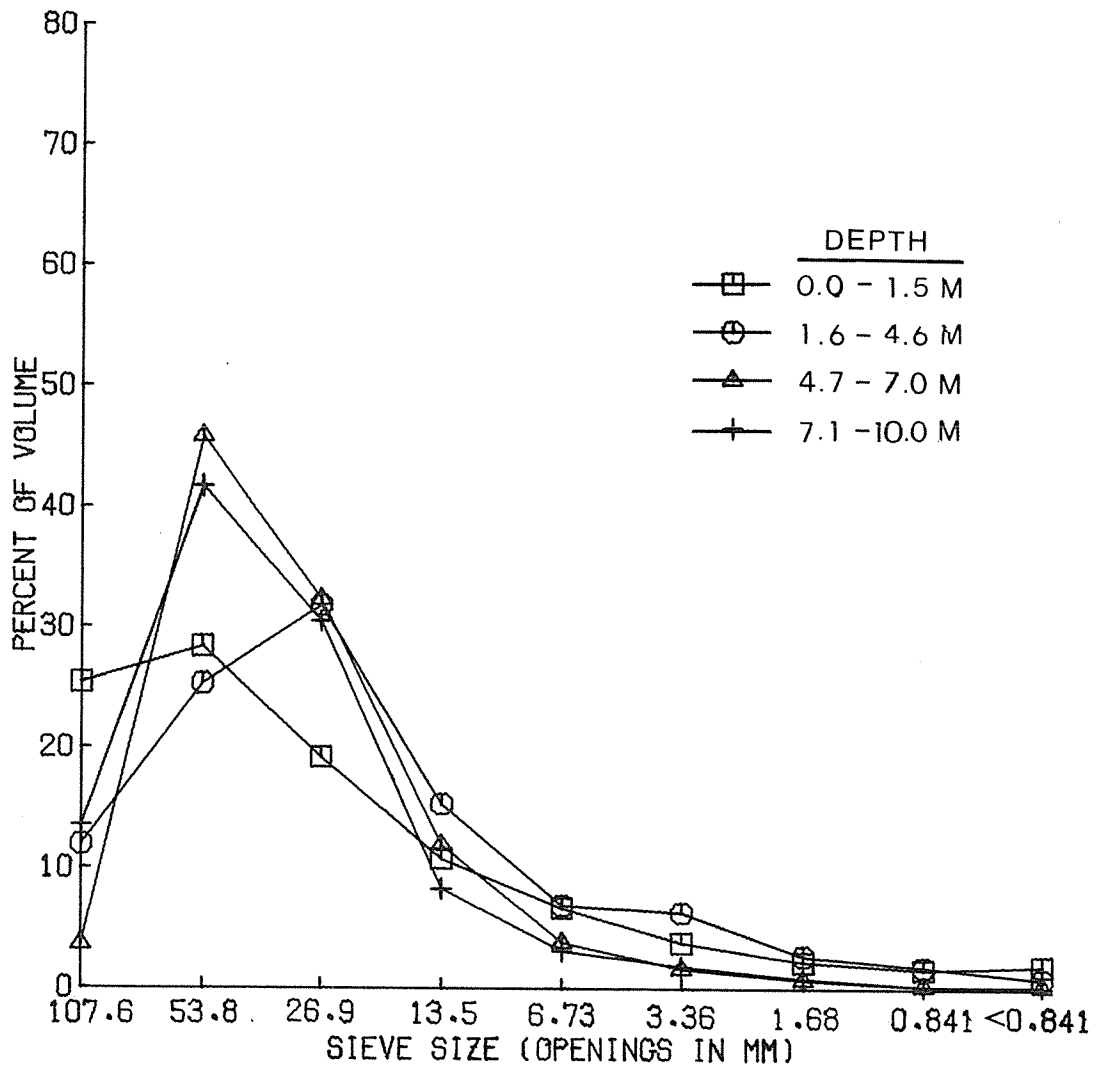


Fig. 75. Composite substrate analysis of six vertical transects at four depth intervals in the prime kokanee spawning area of Banks Lake.

proportions of sand and silt (< 3.327 mm) on chum salmon fry survival, but also noted that smaller salmonid fry in the presence of fines have higher survival rates than larger fry of both the same and other species. Because of the small relative size of kokanee fry and the low proportion of fines less than 3.36 mm (8.9%) present, the 1.6-4.6 m depth stratum was considered to have the highest productive potential of all depth strata. The high intra-gravel dissolved oxygen values recorded also indicate that this substrate was relatively clean and highly suitable as an incubation medium.

The suitability of the prime gravel section for spawning is due to the presence of particle sizes of substrate in the size range preferred by spawning kokanee and to the absence of sediments. The absence of silt and sand promotes circulation of oxygen-bearing water into the gravel which is particularly important for embryo survival in the lakeshore gravel where no streamflow exists.

6.6 Drawdown, Spawning, and Emergence 1971-78

Figure 76 shows the relationship between the depth range of the prime kokanee spawning area in Banks Lake with the timing of the kokanee fry emergence in the spring and spawning in the fall. The depth of the prime spawning area was determined to be between 1.5 and 4.6 m (4.9 and 15 feet) below full pool (Section 6.2.5). Additional spawning was observed below 4.6 m (15 feet) during 1978 apparently due to crowding by a larger spawning population. However, the size of the substrate increases with depth and below 4.6 m (15 feet) is probably less desirable for spawning and incubation. The size of the substrate was thus considered limiting. Both early and late spawners were observed to utilize the entire depth interval (1.5-4.6 m) uniformly throughout the spawning season. Based on our present lack of data regarding fry survival below 4.6 m (15 feet) survival must conservatively be considered negligible. Little spawning was observed above 1.5 m (4.9 feet). Present information indicates that

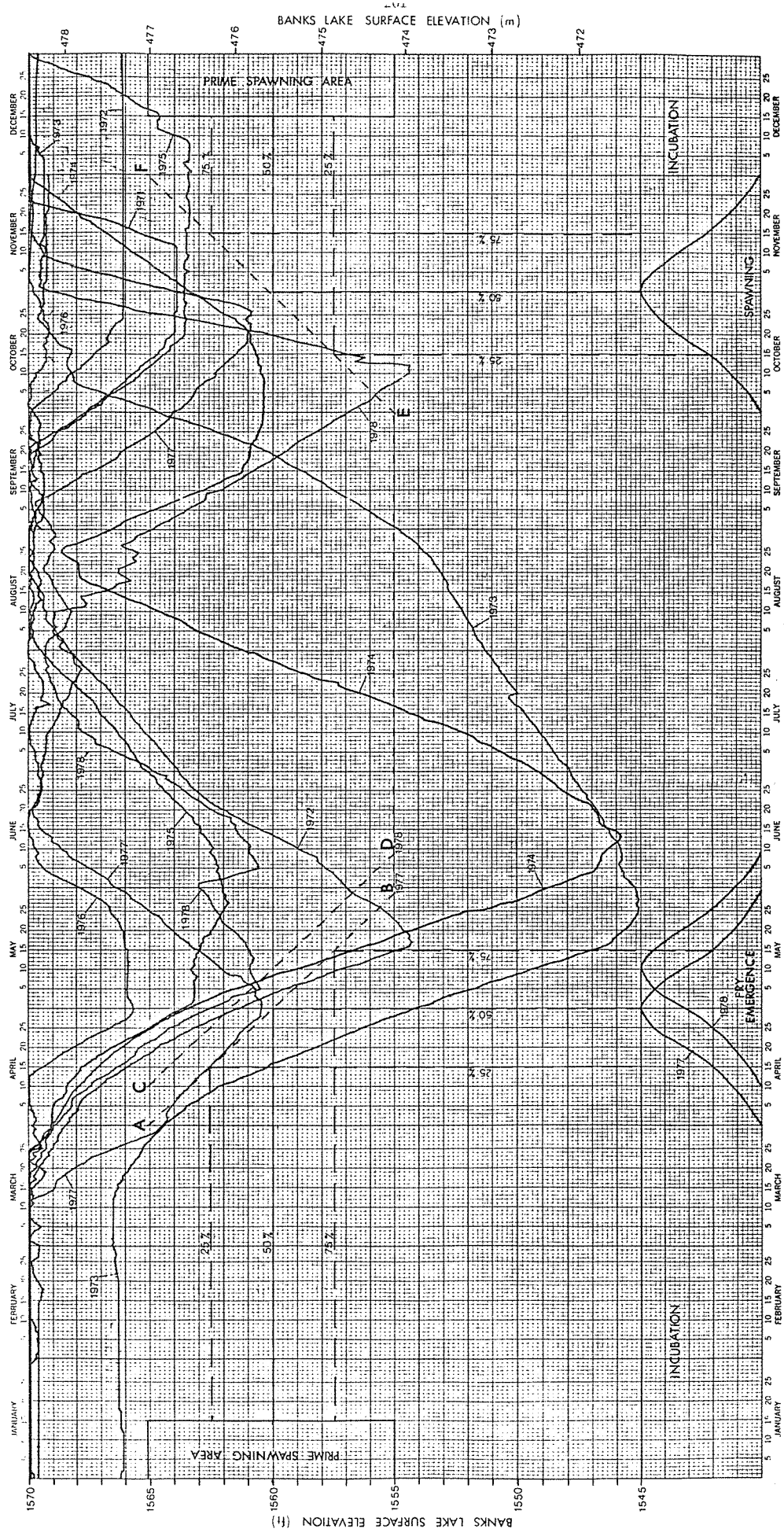


Fig. 76. Water level elevation on Banks Lake for the period September 1971 to December 1978 with the depth of the prime kokanee salmon spawning area correlated with the time of spawning and fry emergence. Drawdown limits (rule curves=AB, CD, EF) for early and late emerging fry have been determined by correlating the area of prime spawning with the time of kokanee fry emergence. A drawdown limit for spawning has been determined similarly.

egg deposition is uniform throughout the vertical dimension of the prime spawning area.

Fry emergence has been observed from late March until early June (Fig. 76). Maximum emergence has occurred on April 28 and May 8 during the two years of observation in 1977 and 1978, respectively. Based on this timing, normalized emergence curves were plotted with peaks on May 1 and 10 corresponding to early and late years. Two day safety margins were added to allow for error in estimating the emergence peaks. The mid-depth of the prime spawning area was aligned with the time of maximum emergence to establish the timing of the drawdown which would expose 50% of the prime spawning area. Fifteen day intervals preceding and following maximum emergence were aligned with 25 and 75% exposures of the prime spawning area, respectively. A drawdown limit (rule curve) which would allow fry sufficient development time to emerge by regulating the timing and rate of reservoir drawdown was derived by fitting a line through the three points. Two rule curves are shown which relate to early (AB) and late (CD) fry emergence based on presently available data. The rate of drawdown prescribed by these limits cannot exceed 5.18 cm/day (0.17 ft/day) and if followed precisely through a specific fry emergence period would reduce potential survival by 25%. An assumption is made that pre-emergent (yolk-sac) fry do not move significantly through the spawning ground to allow avoidance of dessication or loss due to increased predation. This is an area where additional research is needed. These limits area, therefore, a compromise between limited fry mortality and operational flexibility of the reservoir.

The daily water surface elevations of Banks Lake for the period from September 1971 to December 1978 have been plotted (Fig. 76). Although the timing of the emergence of kokanee fry is not precisely known for the years preceding 1977, it is informative to compare the annual spring drawdown with the limits which have been derived. A drawdown which exceeds a limit in time or rate, such as that which occurred in 1973, imposes a very serious impact on the survival of kokanee fry. In

addition, the lake level in late 1972 and early 1973 was held at about 4 feet below full pool which reduced the reservoir storage capacity and ensured early interference at greater depth with the survival of the fry. The rate of drawdown in 1974 also exceeded the limit and reduced the survival of fry. This graphic analysis shows that drawdown reduced fry survival during five (1972, 73, 74, 77, and 78) of the seven years plotted. Very large impacts occurred in 1973 and 1974 due to the extreme drawdowns imposed (~7.6 m; 25 feet) which also reduced the total lake volume by 50% and concentrated all surviving fishes. The fact that small numbers of kokanee survived the 1973 and 1974 drawdowns suggests that fry either emerged early and/or from deep substrate during both years.

When the timing of emergence is known, as for 1977 and 1978, this graphic analysis can be utilized to make rough estimates of the fry mortality due to drawdown. Based on the timing and rate of drawdown, about 25% of the fry may have been lost in 1977 and < 5% may have been lost in 1978. Since there were critically small numbers of eggs deposited both years no additional loss due to drawdown should have been allowed to occur in either year. Based on the low spawning populations observed in 1976 and 1977, artificial stocking is needed to increase the 1977 and 1978 fry populations. The fry population was increased by stocking 2,083,373 kokanee fry in 1978; however, the 1977 fry year class is expected to result in a small population of adults maturing in 1980.

During years when spawning populations are moderate to large the relationship between partial fry losses due to drawdown and an appropriate mitigation strategy (size of fry plant) are not well defined. In fact, fry plants may not be needed even with a relatively large fry mortality due to drawdown because mortality to emergence is typically high in most populations. The consistent use of the barrier net may sufficiently reduce the loss of adults in each year class as to preclude the need for fry plants except in extreme situations. To reach such a definition will require further study of the various mortality factors acting collectively on the Banks Lake kokanee population. In addition, determination of the

fry emergence timing during the spring of 1979 may provide evidence of an even later emergence time than was used in the present analysis which would require adjustment of the drawdown limit (rule curve) during colder incubation periods.

In the future, the drawdown limits should be applied to management of the reservoir water surface elevation to allow for adequate kokanee fry survival. The timing of drawdown should be adjusted each year to allow for anticipated variation in the timing of fry emergence. If no information is available to predict the emergence timing, the later and most conservative limit should be followed (i.e. 1978). However, the emergence timing could be predicted each year based on water temperatures in Banks Lake during the incubation period (October through May). Because incubation time is closely related to water temperature, calculation of accumulated temperature units enables the timing of emergence to be predicted about one month in advance. Proper lake level could be maintained by pumping adequate amounts of water during the spring to avoid exceeding the drawdown limit for fry survival.

Spawning (adult) kokanee are less sensitive to manipulation of the lake level (Fig. 76). The development of a drawdown limit for spawners (line EF) was constructed in a similar way as that for fry. It can be seen that the lake level has not affected the distribution of spawners except for the upper 20% of the prime spawning area in 1975. The deliberate drawdowns in 1977 and 1978 which were intended to force spawners to deposit their eggs at greater depths did not achieve this purpose. In order to manipulate the depth of spawning it is necessary to hold the level of drawdown at a depth greater than 1.5 m below full pool through the end of November. The consequences of such an action are unknown but may negatively impact the kokanee by removing the prime spawning area from production. The level of drawdown from May through September (line BDE) should be limited to 4.6 m (15 ft) in order to minimize the predator-prey and competitive interactions of the surviving fish populations.

6.7 Kokanee Population Index and Management

The kokanee spawner and fry year classes are summarized in Table 22 to aid discussion of the known impacts due to drawdown and the benefits to the population resulting from use of the barrier net. Drawdown affecting spawning occurred only on the 1975 adult year class and probably had little perceptible effect on the population. Kokanee fry survival was reduced by drawdown during five of the last seven years as illustrated in Section 6.6. The initial drawdown level affecting fry survival is given along with the maximum drawdown level for each year. The general year class size has been projected forward based primarily on 1973 and 1974 which were two years in which extreme reservoir drawdown reduced fry survival and resulted in correspondingly small adult populations in 1976 and 1977. The relative designation of high (H), medium (M), or low (L) for fry survival and adult year class size suggests management action is required particularly when the low designation occurs. The mitigation strategy applied since 1971 indicates the number of kokanee fry planted each year and the development and use of the barrier net. It is important to note that 2.083 million fry were planted during the spring, summer, and fall of 1978. This plant was needed to increase the small population of fry in the lake which resulted from the small adult spawning population in the fall of 1977. It is also important to note that the small adult population in 1976 and corresponding low production of fry in 1977 has not yet been mitigated. As a result the adult population in 1980 is expected to be low and a fry plant will probably be necessary during 1981. Otherwise, this small year class may remain small for several more generations. If future extreme drawdown impacts on fry are anticipated one year in advance, it would be possible to make fry plants during the year of impact in order to maintain a consistent sport fishery. Annual fry plants as a standard management procedure are not required.

The beneficial effects of the barrier net (Table 22) in 1977 and 1978 have been tested against the preceding two years in which no screening was available to reduce kokanee entrainment into the irrigation canal. The

Table 22. Summary of the kokanee year class sizes from 1971 to 1978, indicating drawdowns affecting fry survival, spawning and mitigation measures. Estimates of the irrigation canal entrainment, sport catch, spawner count, population index and percent of population index retained are compared.

Mitigation	General Adult Yearclass Size (H,M,L)	Drawdown Affecting Spawners(ft)	Fall Spawner Yearclass	Spring Fry Yearclass	Drawdown Affecting Fry (Max)ft.	General Fry Survival (H,M,L)	Irrigation Canal Ent-ainment	Sport Catch	Spawner Count	Spawner Population Index	% Retained
150,000 planted	-	0	1971	→1972	8 (15.7)	M		72,885			
---	-	0	1972	1973	5 (25)	L					
---	M	0	1973	1974	9.4(24.2)	L					
110,000 planted	M	0	1974	1975	0 (8.2)	H					
---	H	6.6	1975	1976	0 (4.3)	H	123,397	75,035	10,000	213,432	40%
---	L	0	1976	1977	5 (9.5)	L	50,007	~15,000	1,851	66,858	25%
75,753 marked 2,007,620 unmarked partial barrier	L	0	1977	1978	8.8(9.5)	M	7,031	12,283	11,039	30,353	77%
Barrier Net	M	0	1978	1979			3,592	46,427	35,381*	85,400	96%
	M		1979	1980							
	L		1980	1981							
	M		1981	1982							
			1982	1983							

*Mark-recapture estimate

entrainment estimates were made using consistent techniques during the last four years. Comparable creel census data was only obtained during 1975 and 1978. A limited creel census was conducted during the latter part of the 1977 season. The effort expended during August-October in 1975 and 1978 in the south end of Banks Lake was found to be about 15% of the season total (April-September). The 1977 effort was, therefore, expanded by 85% to obtain a total estimate of 116,980 angler-hours. The August 1977 CPUE (0.105) was applied to this effort to obtain a total catch of 12,283 kokanee. The average CPUE for the August-October period in 1977 was not utilized because it was considered less representative of the early part of the season when catches are normally higher. The catch in 1976 was considered as poor as that in 1977; therefore, a catch of 15,000 was utilized to compile a population index.

The estimate of spawners by the mark-recapture method is considered the most accurate thus far. Lake wide estimates of spawners based on counts were shown to be consistently low; therefore, estimates based on counts in 1976 and 1977 were increased by 49%, which is the difference between the mark-recapture estimate and the spawner counts in 1978. Spawner counts were adjusted to 1,851 and 11,039 in 1976 and 1977, respectively. Spawner counts in 1975 were estimated to range from 5,000 to 10,000; the upper estimate was used in calculating the population index. The population index was obtained by totaling the estimates for entrainment, sport catch and spawner count. The percentage of kokanee retained was calculated by determination of the percentage of the population index due to the sport catch and spawner count. The 1975 population was the largest observed during the four years. Forty percent of this population remained in the lake without a barrier. However, it is interesting to speculate on what the sport catch might have been had a barrier prevented entrainment of 128,397 kokanee. In 1976, with a smaller population, only 25% remained in the lake and a large proportion were entrained which severely reduced the number of spawners remaining and resulted in the production of a small number of fry. With an increase in the screening efficiency of the barrier net from 1977 to 1978, the

retention of fish increased from 77 to 96%, respectively. The barrier net served to enhance the sport fishery as well as to increase the number of spawners in the lake ensuring that an adequate number of spawners was available for reproduction. The combined use of the barrier net to retain adults along with constraint on the fry losses imposed by drawdown (rule curves) should provide the management needed to ensure a stable population of kokanee in Banks Lake to meet the needs of an important sport fishery.

7.0 SUMMARY AND CONCLUSIONS

A net barrier was established in the southeast sector of Banks Lake to reduce the entrainment of mature kokanee into the main irrigation canal. The area of the outlet was enclosed by three nets totaling 1,341 m (4,400 ft) in length. The net, constructed of 83-mm (3.25 inch) stretched-measure dacron, was chosen because it retained salmonids greater than 25 cm (fork length), presented low resistance to current, and was less encumbered by fouling when compared with smaller mesh. The nets were installed on June 9, 1977 and on April 24, 1978 and maintained until termination of the irrigation season on October 25. Modifications to the barrier net were made in 1978 to improve the fit with the bottom contours of the lake which increased the screening efficiency.

Maintenance equipment was designed and constructed to lift and clean the barrier net. This included a 25 hp engine, hydraulic pump, power block and roller, and a high-pressure water pump. This equipment was mounted aboard a small boat-barge combination which traversed the length of the nets during cleaning to remove aquatic weeds and algae with high-pressure water jets. Cleaning intervals were variable through the summer growth periods to control fouling and maintain net visibility. Maximum irrigation flow of 224 m³/sec (7,910 cfs) resulted in negligible drag on the net. Calculation of the forces due to increase in the irrigation canal discharge and reduction of the lake level indicated the barrier net could be operated under conditions more rigorous than those encountered during either 1977 or 1978.

The escapement of fishes past the barrier net was measured directly by sampling the irrigation canal entrainment, using methods developed during 1975. The estimated kokanee entrainment rates for the period from July 9 to October 25, 1975, 1976, 1977, and 1978 were 100,908, 32,119, 7,031, and 726, respectively. The percentage of kokanee in the total composition of all species declined each year from

67.4% and 59.6% in 1975 and 1976 without the barrier net to 17.8% and 2.5% with the barrier net in 1977 and 1978. The greater loss of fish into the irrigation canal in 1977 was expected due to the difficulty of fitting the south net to irregularities in the bottom contour. This problem was not encountered with the east and middle nets. The screening efficiency of the south net was improved in 1978. Other species effectively screened by the barrier net were lake whitefish, chinook salmon, and rainbow trout. The barrier was not effective for yellow perch, mountain whitefish, prickly sculpin, or peamouth due to their small size. Carp were observed to ram and jump the barrier and were not effectively screened. Longnose suckers were observed attempting to wiggle under the lead line which was a partially successful means of escape for this species.

The purse seine sampling utilized in 1978 captured a total of 1,824 fish of 6 species. The catch by species was 1,121 kokanee, 434 lake whitefish, 215 Rocky Mountain whitefish, 27 rainbow trout, 26 carp, and 1 chinook salmon. The catch of kokanee per haul was affected by schooling behavior, maturation, and temperature avoidance. Maximum catches of adult kokanee occurred during late August near the barrier net and near the major shoreline spawning area in early October. Maximum numbers of lake whitefish were seined during early September near the barrier net as well in the pelagic area offshore. The sex ratio of kokanee was 1:1.

A population estimate for kokanee was based on mark and recapture of the adults in the purse seine catch. An estimate of 35,381 spawners was obtained with a 95% interval range from 26,360 to 53,812 for the September 5 through October 19 period after most of the mortality due to the sport fishery, entrainment, and other losses had occurred. Tag recoveries by the sport fishery, purse seine, and gillnet sampling showed that kokanee had moved as far as 30 km (Steamboat Rock area) from the point of tagging. Most of the tagged kokanee recaptured were in the south end of the lake.

Adult kokanee were fitted with sonic tags to determine the behavior of fish in the south pool of Banks Lake, especially those encountering the barrier. Fourteen kokanee were tracked during the months of July, August, September, and October, 1978. Movement was extensive throughout the south half of the south pool through late September. The barrier net excluded several of the tagged fish from the irrigation canal intake. During October all fish were "homing" to beach spawning sites along the west shoreline or the South Dam.

A creel census on Banks Lake showed that an estimated 214,768 angler-hours were expended to catch 55,465 fish of all species or about 0.26 fish per hour. The catch by species in decreasing order of abundance was 83.7% kokanee, 5.9% yellow perch, 4.0% rainbow trout, 2.7% chinook salmon, 2.3% crappie with the remainder composed of largemouth bass, sunfish, brown bullhead, lake whitefish, and walleye. The troll fishery took all of the 46,427 kokanee in 1978. The kokanee catch per hour in the south end of Banks Lake for 1975, 1977, and 1978 was 0.263, 0.047, and 0.167, respectively. This indicated a poor sport fishery in 1977 which was also apparent in 1976 based on reports from local fishermen. The increase in the catch per hour in 1978 indicated an improvement in the fishery. Creel census statistics for 1972, 1975, and 1978 indicated an increase in effort of 26% between 1972 and 1975 along with an increase in catch of kokanee of about 5%. Following the 1977 decline in catch the 1978 fishery returned to about 63% of that in 1975. The catch per angler hour of kokanee during the April-September period was 0.286, 0.222, and 0.216 in 1972, 1975, and 1978, respectively. The catch per angler hour for all other species was 0.372, 0.234, and 0.042 in 1972, 1975, and 1978, respectively. The sharp decline in catch of all other species in 1978 with the stable catch of kokanee indicates that the reduction in the entrainment loss of kokanee provided additional fish to the fishery in 1978. A simultaneous creel census conducted on Billy Clapp Lake during 1978 showed an estimated 11,509 angler hours were expended to catch 6,126 kokanee. Kokanee comprised 94.9% of the catch with a CPUE of 0.536.

Systematic observations of the relative number and location of spawning kokanee by means of SCUBA diving were begun in 1975. In order to increase the survey area and the frequency of observation a glass-bottom pram was employed in addition to divers in 1976. The spawning season occurred during October and November with maximum activity around November 1. The major concentration of spawners was along the southwest shoreline of the lake in a talus area designated the prime spawning area. Several other smaller concentrations of spawners occurred around the lake shore where suitable gravel existed; however, when the total spawner population was small, most occurred in the prime spawning area. The depth of maximum spawning ranged between 1.5 and 4.6 m (4.9 and 15 ft).

Surveys of live and dead kokanee by divers and with the glass-bottomed pram were intended to provide an index of the numbers in the prime spawning area. Pram counts were found to underestimate the spawners due to shying of the fish and the limited transparency of the water when compared to counts by divers. As a result pram counts did not reflect the large increase in numbers from 1977 to 1978 observed by diving. The pram counts did, however, indicate an increase in the number of spawners outside the prime gravel area in 1978 and provided more consistent counts between observers. Diver observations showed an increase in spawning activity at depths greater than 4.6 m in 1978. Spawning in the prime area was characterized by the lack of well defined redds and mass spawning during all years. Comparison of the spawner populations by both estimates since 1976 concluded that the majority of the fish was observed from the pram in 1976, a low population year. However, pram counts were unable to detect changes in population size due to the larger numbers spawning at greater depths, which could be detected only by divers. Therefore, pram counts are useful only as a relative index when densities are moderate to low.

Population estimates calculated from spawner surveys varied depending on the value used to represent the turnover time on the

spawning grounds. Literature values range from 5.7 to 15.4 days resulting in an inverse relationship with the population estimate. The spawner estimate for 1978 ranged from 6,717 to 18,111 which was only 0.19 to 0.51 of the estimate derived by mark and recapture. Spawner surveys clearly underestimated the actual population and were useful only on a relative basis. Similar estimates derived for 1976 and 1977 were 346 to 944 and 2,084 to 5,630, respectively. These estimates indicate that the low abundance of kokanee in 1976 was compounded by unrestricted entrainment; however, improvement in 1977 and 1978 was evident with the increased efficiency of the barrier net. The potential numbers of eggs deposited by these populations indicated a similar improving trend from 1976 to 1978.

Gillnet and acoustical sampling adjacent to both sides of the barrier net was conducted in 1977 to determine if differences in abundance and size composition occurred. These data indicated that no significant differences existed except for lake whitefish which was most effectively screened. Acoustical surveys showed a consistent increase in fish targets immediately outside the south net during the night, but this was not evident during the day suggesting that fish may temporarily delay when encountering the barrier at night. Sampling with gillnets and acoustic methods was ineffective in assessing the efficiency of the barrier net because these techniques did not account for the behavioral response of the fish.

The gilling rates of fishes in the barrier net were monitored to determine whether gilling loss significantly impacted the populations. A total of 299 fish was gilled during 4 months of operation in 1977. Included were 194 kokanee, 26 chinook, and 24 Rocky Mountain whitefish. During 6 months of operation in 1978 a total of 696 fish was gilled including 465 kokanee, 72 chinook, and 20 Rocky Mountain whitefish. The number gilled during either year was not significant when compared to the population size and the potential loss due to entrainment.

Baseline monitoring of the fish stocks in Banks Lake was continued during this study. The catch of age II kokanee during 1977 indicated a larger population of 3-year-old fish would be present in 1978, a fact which was later borne out. However, the number of age II kokanee caught in 1978 suggests the adult population in the 1979 sport fishery may be smaller. Hydrological parameters including water temperature, dissolved oxygen, pH, and conductivity were monitored during both years.

An assessment of the genetic makeup of the beach spawning kokanee in Banks Lake was conducted in 1978 to determine if these fish represented a unique stock. Tissue analysis for protein (enzyme) variations by electrophoretic separation and histochemical staining techniques was conducted. This analysis indicated that most of the present-day kokanee in FDR reservoir and Banks Lake are the progeny from large hatchery plants in both reservoirs. Indigenous native Columbia River stocks have not been obtained to substantiate this; however, the dominance of planted kokanee from Lake Whatcom appears certain.

Two artificial spawning beds were created in Banks Lake by dumping about 38.3 m³ of gravel at each site located below the maximum drawdown level. Kokanee spawners did not utilize the gravel during either year; however, during the first year eyed eggs were planted in both beds. Dissolved oxygen and sedimentation rates were monitored. Sedimentation was identified as a potential limiting factor. Egg survival was monitored with emergent fry traps and ranged from 1.2 to 5.4% depending on the assumed efficiency of the fry trap. Survival of kokanee fry to emergence was monitored on the natural prime spawning area in 1977 and 1978. Kokanee fry emergence occurred between late March and early June. The maximum emergence was on April 28, 1977 and on May 8, 1978 indicating a 2-week shift in timing between years. Fry survival estimates were complicated by the assumptions necessary for fry trap efficiency and turnover time (redd life) of the spawners. Survival es-

timates ranged from a low of 3.0% in 1978, at a 69.9% trap efficiency and 5.7 day redd life, to a high of 23.9% in 1977 at a trap efficiency and redd life of 100% and 15.4 days, respectively. Regardless of which efficiency or redd life is used, several consistent differences exist between 1977 and 1978 survival rates. The deposition of eggs from the 1977 spawning was about eight times larger than the deposition in 1976. However, the resulting emergence in 1978 was only four times larger than the emergence of the previous year; and therefore, the resultant survival rate in 1978 was half the 1977 rate. However, even though the survival rate declined at higher densities, more fry were produced.

Drawdown limits (rule curves) which allow fry emergence by regulation of the timing and rate of drawdown were determined. Graphic analysis of the prime spawning area located 1.5 to 4.6 m below full pool and daily normalized fry emergence and spawning curves were used to prescribe the limits which should not exceed 5.18 cm/day (0.17 ft/day). Water surface elevations for the period 1971-1978 were analyzed. Reduced fry survival occurred in 5 of the 7 years plotted, while spawners were affected during a single year. Drawdown limits can be used to provide a rough estimate of the percentage of fry lost if the limit cannot be met. Management of the lake surface elevation should utilize appropriate drawdown limits to assure adequate future kokanee fry survival. The impact of drawdown on spawning was found to be less critical unless the spawners were prevented from utilizing the prime spawning area.

A kokanee population index was calculated to demonstrate the benefits of the barrier net. Two years without the net (1975 and 1976) were compared to 2 years with the barrier (1977 and 1978). The largest population of 213,432 occurred in 1975. The entrainment loss was 128,397 while 40% remained in the reservoir. The 1976 population was 66,858; however, 50,007 were entrained and only 25% remained. Development of the barrier net in 1977 retained 77% of a small population of 30,353. Improvement of the barrier in 1978 increased the

percentage retained to 96%. Only 3,952 were lost by entrainment from a total population of 85,400.

The combined use of the barrier net to retain adults along with some constraint on the drawdown losses imposed on the fry should provide the management strategy needed to ensure a stable population of kokanee in Banks Lake for an important sport fishery.

8.0 RECOMMENDATIONS

Recommended future management and research options for Banks Lake are listed in order of increasing complexity from Option I-IV. Optimal management of the kokanee sport fishery is considered the primary objective.

Option I: Operate the barrier net annually.

- a. Modify the ends of the south net with additional chafing material to withstand large drawdowns.
- b. Install, clean, and remove barrier net and inspect regularly by divers.
- c. Sample canal entrainment with nets in order to determine screening efficiency.
- d. Monitor gilling of fish in barrier net.

This option will reduce the operational impact of entraining large numbers of adult kokanee into the irrigation canal. Retention of the adult year classes will improve the sport catch and ensure an adequate brood stock for reproduction of the next generation. Operation of the barrier net should be conducted by the Washington State Department of Game which is responsible for the management of the kokanee sport fishery.

Option II:

1. a - d. Operate the barrier net annually.
2. Plant kokanee fry to mitigate any extreme drawdown due to construction and to bolster any weak year classes.
 - a. Spring 1979 (if drawdown exceeds limits determined in Section 6.6).
 - b. Spring 1981 to increase the anticipated small fry production due to a small spawner population in 1980.

This management option would entail both kokanee fry plants and operation of the barrier net. A potentially extreme drawdown in the spring of 1979 due to feeder canal modification may require a supplemental fry plant. The small 1980 year class should be enhanced by a fry plant in the summer of 1981. Criteria (rule curves) which should be used to determine the impact of drawdown on fry are presented in Section 6.6.

Option III:

1. a - d. Operate barrier net annually.
2. Plant kokanee fry to mitigate extreme drawdown effects on wild fry survival.
3. Evaluate fry emergence during spring of 1979.
 - a. Develop diver-operated hydraulic egg sampler.
 - b. Sample eggs and pre-emergent fry in the gravel prior to emergence to determine actual density and location.
 - c. Determine timing of emergence vs. depth with fry traps.
 - d. Determine relative survival vs. depth.
 - e. Determine fry quality vs. depth.
 - f. Determine substrate quality vs. depth.
 - g. Determine effect of rate, timing, and magnitude of drawdown on wild fry survival.

An estimated 35,381 spawners were observed in the lake during 1978, which may be the largest number of spawners ever to utilize the lake. This number resulted directly from successful retention of spawners by the barrier net. Due to the limited amount of prime spawning gravel available to accommodate this population, spawning occurred at greater depths than observed previously. Thus, the barrier net, by retaining larger populations, may force some spawning at depths greater than the prime spawning area (4.6 m). This potentiality should be evaluated by extending the present research through the spring of 1979. The size of the substrate is known to increase with depth which indicates that the spawning habitat may become less productive;

however, verification will require fry sampling. In addition, the extensive period during which incubation temperatures have been lower than normal during the winter of 1978-1979 may result in an extremely late emergence period during spring 1979. These data are important in determining a more complete range of spring drawdown limits (rule curves) for Banks Lake which will aid the management of water and natural fish production in the future.

Option IV:

1. a - d. Operate barrier net annually.
2. a - b. Plant kokanee fry to mitigate extreme drawdown effects on wild fry survival.
 - c. Evaluate fry plants through 1982.
3. a - g. Evaluate fry emergence annually through 1982.
 - h. Sample egg densities in the gravel periodically throughout the incubation period to determine egg survival rates at several depths in the reservoir.
 - i. Determine effect of egg-density on survival.
 - j. Determine effect of predation during incubation period.
 - k. Determine ability of pre-emergent fry to avoid water level decline.
 - l. Determine efficiency of fry traps.
 - m. Determine gravel replacement rates and percolation of water through the prime spawning area.
4. Test feasibility of forcing spawners deeper and of controlling aquatic weeds by lowering the lake during the fall.
 - a. Evaluate by Item 3 a - m above.
 - b. Determine turnover time for spawners in Banks Lake.
5. Monitor year-class strength of II- and III-year-olds.
 - a. Continue gillnet sampling to extend baseline information.

- b. Continue purse seining and mark-recapture experiments to estimate populations of immature age II and mature age III kokanee for comparison with spawner counts.
6. Monitor effects of pumped storage operation with six units on-line.
 - a. Monitor temperature in the north pool of Banks Lake and in FDR forebay to evaluate heating and circulation effects on fish and fishery.
 - b. Monitor the number and species of fish entrained by the reversing flow into and out of Banks Lake via the feeder canal.

This option constitutes a long-term commitment to obtain the additional fishery data needed to develop a comprehensive multiple-use management plan for the lake. The emphasis should focus on evaluation of the survival of natural fry in relation to fluctuation of the reservoir surface elevation and the survival of introduced fry. Both evaluations would require a sustained commitment for at least 4 years in order to achieve confidence in the conclusions. This effort would further define the impact of drawdown on natural fry and provide a model which would predict annual emergence timing of the fry, thus achieving the greatest operational tolerance on the reservoir.

The speculation that fall reservoir drawdown could be utilized to force spawning to occur at greater depths in order to achieve greater operational flexibility in the spring should be tested. Such action may only result in an additional impact on the kokanee population by depriving spawners of the prime reproductive habitat in the reservoir. Studies to evaluate fry survival at depths greater than 4.6 m should be conducted before implementation of such a management procedure.

Monitoring of the immature kokanee produces information needed in predicting the size of the population 1 or 2 years in advance of entry

into the sport fishery as well as probable impact on each specific year class. Quantitative techniques should continue to be tested against simplified monitoring methods normally used in routine fishery management. This would provide greater confidence in the survey methods for monitoring the annual success of spawning and forecasting the potential of the sport fishery. The conduct of such a study through 1982 would follow the recent fry plants and the progeny of the 1978 spawning population through one complete cycle.

The effects of pumped-storage operation were never fully assessed because only limited testing of two generators was conducted. The large quantity of water to be circulated by all six units should be evaluated for potential effects on the sport fish populations.

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10.0 APPENDIX TABLES

Appendix Table 1. Known fish introductions to Banks Lake¹

Date	Number	Species	Common Name	Size	Origin
2/53	4,000	<i>Salmo gairdneri</i>	Rainbow trout (Kamloops)	30/lb	-
4/56	10,010	<i>Salmo gairdneri</i>	rainbow trout	11/lb	-
5/56	1,504,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
10/56	14,190	<i>Salmo gairdneri</i>	rainbow trout	11/lb	-
6/57	1,533,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	-
9/57	12,250	<i>Salmo gairdneri</i>	rainbow trout	12.5/lb	-
10/4-8/57	28,000	<i>Salmo gairdneri</i>	rainbow trout	14/lb	-
4/4/58	10,035	<i>Salmo gairdneri</i>	rainbow trout	9/lb	-
6/5/58	39,500	<i>Salmo gairdneri</i>	rainbow trout	59/lb	-
6/13/58	39,600	<i>Salmo gairdneri</i>	rainbow trout	66/lb	-
7/2/58	53,000	<i>Salmo gairdneri</i>	rainbow trout	45/lb	-
8/5/58	18,000	<i>Salmo gairdneri</i>	rainbow trout	30/lb	-
9/3-16/58	97,300	<i>Salmo gairdneri</i>	rainbow trout	20/lb	-
5/23/58	1,298,800	<i>Oncorhynchus nerka</i>	kokanee salmon	1,640/lb	Leavenworth
6/10/59	89,060	<i>Salmo gairdneri</i>	rainbow trout	20-22/lb	-
6/3-9/59	59,980	<i>Salmo gairdneri</i>	rainbow trout	9-18/lb	-
7/14/59	28,270	<i>Salmo gairdneri</i>	rainbow trout	22/lb	-
7/23/59	24,988	<i>Salmo gairdneri</i>	rainbow trout	30-45/lb	Tucannon
3/23/60	949,560	<i>Oncorhynchus nerka</i>	kokanee salmon	5,790/lb	Leavenworth
4/27/60	946,400	<i>Oncorhynchus nerka</i>	kokanee salmon	5,200/lb	Leavenworth
6/28/60	14,400	<i>Salmo gairdneri</i>	rainbow trout	18/lb	-
7/1-17/60	72,000	<i>Salmo gairdneri</i>	rainbow trout	17-20/lb	-
8/16/60	50,100	<i>Salmo gairdneri</i>	rainbow trout	14-19/lb	-
9/28/60	12,000	<i>Salmo gairdneri</i>	rainbow trout	15/lb	-
1961 NO RECORDS					
6/13/62	31,430	<i>Salmo gairdneri</i>	rainbow trout	14/lb	Columbia Basin
6/15/62	14,300	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Columbia Basin
7/13/62	14,980	<i>Salmo gairdneri</i>	rainbow trout	14/lb	Columbia Basin
9/20/63	65,680	<i>Salmo gairdneri</i>	rainbow trout	8.5-12/lb	Columbia Basin
8/20/63	10,000	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin

¹Unpublished information obtained from Washington State Departments of Game and Fisheries.

Appendix 1 (cont.) Known fish introductions to Banks Lake (cont'd.)

Date	Number	Species	Common Name	Size	Origin
7/1-2/63	47,340	<i>Salmo gairdneri</i>	rainbow trout	10-12/1b	Columbia Basin
6/17-24/63	44,040	<i>Salmo gairdneri</i>	rainbow trout	11-12/1b	Columbia Basin
4/25/63	506,000	<i>Oncorhynchus nerka</i>	kokanee salmon	6,175/1b	Leavenworth
5/8/64	954,000	<i>Oncorhynchus nerka</i>	kokanee salmon	5,600/1b	Leavenworth
5/6/64	56,000			125/1b	Spokane
5/20-26/65	1,000,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
9/65	25,000	<i>Oncorhynchus nerka</i>	kokanee salmon	9/1b	Leavenworth
10/65	85,000	<i>Oncorhynchus nerka</i>	kokanee salmon	7-12/1b	Leavenworth
9/22/65	24,000	<i>Oncorhynchus nerka</i>	kokanee salmon	25/1b	Leavenworth
	26,300			20/1b	Leavenworth
5/13/66	1,000,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
4/27-29/66	50,400			9/1b	Columbia Basin
5/6/66	9,000			9/1b	Columbia Basin
7/7/66	8,500			12/1b	Columbia Basin
6/21/66	17,550	<i>Salmo gairdneri</i>	rainbow trout (Kamloops)	15/1b	Columbia Basin
8/25-31/66	39,120	<i>Salmo gairdneri</i>	rainbow trout	10-12/1b	Columbia Basin
6/13/67	46,000	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
7/19/67	32,300	<i>Salmo gairdneri</i>	rainbow trout	9-10/1b	Columbia Basin
8/8/67	11,600	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
	5,400	<i>Salmo gairdneri</i>	rainbow trout	-	-
10/31/67	6,500	<i>Salmo gairdneri</i>	rainbow trout	19/1b	Chelan
11/21/67	15,000	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
10/3/68	20,000	<i>Salmo gairdneri</i>	rainbow trout	20/1b	Columbia Basin
10/3/68	21,150	<i>Salmo gairdneri</i>	rainbow trout	9/1b	Columbia Basin
10/30/68	11,250	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
11/6/68	32,600	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
11/7/68	28,525	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
11/8/68	16,500	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
6/11/69	8,500	<i>Salmo gairdneri</i>	rainbow trout	5/1b	Columbia Basin
5/23/69	12,000	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
9/25/69	12,000	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin

Appendix 1 (cont.) Known fish introductions to Banks Lake (cont'd.)

Date	Number	Species	Common Name	Size	Origin
9/30/69	26,100	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/1/69	24,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/6/69	11,500	<i>Salmo gairdneri</i>	rainbow trout	9-10/lb	Columbia Basin
10/15/69	12,300	<i>Salmo gairdneri</i>	rainbow trout (Kamloops)	12/lb	Chelan
10/8/69	11,160	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/20/69	19,575	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Tucannon
9/2/70	50,883	<i>Salmo gairdneri</i>	rainbow trout	21/lb	Chelan
9/4/70	20,265	<i>Salmo gairdneri</i>	rainbow trout	21/lb	Columbia Basin
10/8/70	20,230	<i>Salmo gairdneri</i>	rainbow trout	7/lb	Columbia Basin
10/13/70	12,500	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/21/70	26,200	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/22/70	13,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/29/70	10,350	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
11/10/70	10,950	<i>Salmo gairdneri</i>	rainbow trout	4/lb	Columbia Basin
11/18/70	7,600	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
11/18/70	11,825	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
3/30/71	20,000	<i>Salmo gairdneri</i>	rainbow trout	16/lb	Columbia Basin
3/30/71	9,000	<i>Salmo gairdneri</i>	rainbow trout	18/lb	Columbia Basin
3/30/71	42,000	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/5/71	21,750	<i>Salmo gairdneri</i>	rainbow trout	25/lb	Columbia Basin
4/19/71	20,116	<i>Salmo gairdneri</i>	rainbow trout	18/lb	Columbia Basin
5/10/71	150,000	<i>Oncorhynchus nerka</i>	kokanee salmon	fry	Leavenworth
5/12/71	12,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
4/27/71	8,850	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
4/30/71	32,000	<i>Oncorhynchus kisutch</i>	coho salmon	160/lb	Columbia Basin
4/30/71	69,750	<i>Oncorhynchus kisutch</i>	coho salmon	150/lb	Columbia Basin
10/29/71	18,000	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/1/71	16,515	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/2/71	8,820	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
11/2/71	7,850	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/5/72	11,475	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin

Appendix Table 1 (cont.) Known fish introductions to Banks Lake (cont'd.)

Date	Number	Species	Common Name	Size	Origin
5/5/72	8,550	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/30/72	15,000	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
5/31/72	11,280	<i>Salmo gairdneri</i>	rainbow trout	19/lb	Columbia Basin
6/6/72	1,800	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
6/6/72	10,400	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/28/72	11,050	<i>Salmo gairdneri</i>	rainbow trout	13/lb	Columbia Basin
6/28/72	3,500	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/28/72	10,800	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/29/72	7,600	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/29/72	4,950	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
6/29/72	16,335	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/2/72	15,500	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/3/72	6,215	<i>Salmo gairdneri</i>	rainbow trout	10/lb	Columbia Basin
10/3/72	25,542	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/26/72	3,120	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
11/8/72	3,300	<i>Salmo gairdneri</i>	rainbow trout	8.5/lb	Columbia Basin
11/8/72	37,290	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
5/1/73	110,660	<i>Salmo gairdneri</i>	rainbow trout	12/lb	Columbia Basin
8/73	16,445	<i>Salmo gairdneri</i>	rainbow trout	22/lb	Winthrop
5/28/74	40,000	<i>Oncorhynchus tshawytscha</i>	rainbow trout	13/lb	Columbia Basin
8/11/74	23,202	<i>Salmo gairdneri</i>	chinook salmon	3/lb	Ringo
10/23/74	12,615	<i>Salmo gairdneri</i>	rainbow trout	9/lb	Columbia Basin
10/24/74	110,000	<i>Oncorhynchus nerka</i>	rainbow trout	10.7/lb	Columbia Basin
10/24/74	11,748	<i>Salmo gairdneri</i>	kokanee salmon	50/lb	Leavenworth
10/31/74	21,004	<i>Salmo gairdneri</i>	rainbow trout	11/lb	Columbia Basin
10/31/74	22,375	<i>Salmo gairdneri</i>	rainbow trout	8/lb	Columbia Basin
11/6/74	15,750	<i>Salmo gairdneri</i>	rainbow trout	12.5/lb	Columbia Basin
11/13/74	1,350	<i>Salmo gairdneri</i>	rainbow trout	12.5/lb	Columbia Basin
11/13/74	11,024	<i>Salmo gairdneri</i>	rainbow trout	13.5/lb	Columbia Basin
			rainbow trout	10.6/lb	Columbia Basin

Appendix Table 1 (cont.). Known fish introductions to Banks Lake (cont'd.)

Date	Number	Species	Common Name	Size	Origin
4/23/75	18,810	<i>Salmo gairdneri</i>	rainbow trout	19/1b	Columbia Basin
4/23/75	250	<i>Salmo gairdneri</i>	rainbow trout	25/1b	Columbia Basin
4/24/75	1,500	<i>Salmo gairdneri</i>	rainbow trout	25/1b	Columbia Basin
4/24/75	7,820	<i>Salmo gairdneri</i>	rainbow trout	17/1b	Columbia Basin
4/25/75	13,753	<i>Salmo gairdneri</i>	rainbow trout	17/1b	Columbia Basin
4/25/75	9,800	<i>Salmo gairdneri</i>	rainbow trout	24/1b	Columbia Basin
4/27/75	10,735	<i>Salmo gairdneri</i>	rainbow trout	19/1b	Columbia Basin
4/27/75	15,950	<i>Salmo gairdneri</i>	rainbow trout	25/1b	Columbia Basin
4/29/75	11,320	<i>Salmo gairdneri</i>	rainbow trout	22/1b	Columbia Basin
4/29/75	6,825	<i>Salmo gairdneri</i>	rainbow trout	21/1b	Columbia Basin
6/3/75	11,030	<i>Salmo gairdneri</i>	rainbow trout	13.5/1b	Columbia Basin
6/3/75	10,050	<i>Salmo gairdneri</i>	rainbow trout	13/1b	Columbia Basin
6/3/75	11,264	<i>Salmo gairdneri</i>	rainbow trout	10.5/1b	Columbia Basin
6/3/75	8,997	<i>Salmo gairdneri</i>	rainbow trout	10/1b	Columbia Basin
3/21/75	30,696	<i>Salmo gairdneri</i>	rainbow trout	24/1b	Columbia Basin
3/21/75	25,168	<i>Salmo gairdneri</i>	rainbow trout	26/1b	Columbia Basin
3/22/75	44,640	<i>Salmo gairdneri</i>	rainbow trout	32/1b	Columbia Basin
6/75	19,000	<i>Oncorhynchus tshawytscha</i>	chinook salmon	3/1b	Green River
10/75	35,000	<i>Oncorhynchus tshawytscha</i>	chinook salmon	17/1b	Deschute River
3/21/76	30,696	<i>Salmo gairdneri</i>	rainbow trout	24/1b	Columbia Basin
3/21/76	25,168	<i>Salmo gairdneri</i>	rainbow trout	26/1b	Columbia Basin
3/22/76	44,640	<i>Salmo gairdneri</i>	rainbow trout	32/1b	Columbia Basin
9/23/76*	23,000	<i>Oncorhynchus tshawytscha</i>	chinook salmon	24/1b	Skykomish River
9/24/76*	22,840	<i>Oncorhynchus tshawytscha</i>	chinook salmon	24/1b	Skykomish River
10/27/76	12,045	<i>Salmo gairdneri</i>	rainbow trout	16.5/1b	Columbia Basin
9/14/77	12,400	<i>Oncorhynchus nerka</i>	kokanee salmon	124/1b	Leavenworth
10/19/77	19,200	<i>Salmo gairdneri</i>	rainbow trout	81/1b	Columbia basin
10/21/77	25,545	<i>Salmo gairdneri</i>	rainbow trout	7.8/1b	Columbia basin
10/21/77	5,480	<i>Salmo gairdneri</i>	rainbow trout	8/1b	Columbia basin
10/21/77	7,448	<i>Salmo gairdneri</i>	rainbow trout	7.6/1b	Columbia basin
07/25/78	712,320	<i>Oncorhynchus nerka</i>	kokanee salmon	742/1b	Leavenworth
07/26/78	785,036	<i>Oncorhynchus nerka</i>	kokanee salmon	742/1b	Leavenworth
10/23/78	510,264	<i>Oncorhynchus nerka</i>	kokanee salmon	171/1b	Leavenworth
10/24/78	75,753	<i>Oncorhynchus nerka</i>	kokanee salmon	171/1b	Leavenworth

* Reared 112 days at Rocky Reach

** Adipose clipped because fry were fed tetracycline

Appendix Table 2. Acoustic target densities by target size and depth, 1977.

		Target Density (per 1000 m ³) and Sample Volume (m ³)										
Date	Diel Period	Transect No.	Surface to 30 ft (9.1 m)		30 ft (9.1 m) to 60 ft (18.3 m)		>60 ft (18.3 m)					
			Large	Small	Large	Small	Large	Small	Volume			
			m ³	m ³	m ³	m ³	m ³	m ³	m ³	m ³	m ³	m ³
July	Day	1	0	1.01	3950	0	0.48	2112	0			0
		2	0	0.33	3073	0.91	0	2189	0			0
		3	0.28	0.83	3596	0	0	1816	0			0
		4	0	0	195	0.26	0.80	3742	0			0
		5	0	0	1032	0.09	0.09	34234	0			0
		6	1.37	1.37	731	0.14	0.09	21089	0			0
		7	0	0	2802	0.10	0.07	29933	0			0
		8	0.48	1.45	4127	0	0	0	0			0
		9	0	0.70	4285	0	0	0	0			0
		10	0.80	0.53	3746	0	0	0	0			0
		11	0	0	795	0.08	0	12955	0.05	0.01	95131	
Night	Night	1	0.27	0	3686	0	0	1795	0			0
		2	0	0	2927	0	0	1724	0			0
		3	0	0	4001	0	0	2252	0			0
		4	0	0	242	0	0.30	3377	0			0
		5	0	0	586	0	0.05	18854	0			0
		6	1.75	0	1140	0.20	0	14843	0			0
		7	0	0	599	0.13	0.13	22877	0			0
		8	0	0	3746	0	0	0	0			0
		9	0	0	4239	0	0	0	0			0
		10	0	0	4239	0	0	0	0			0
		11	0.53	0.27	3746	0.12	0	41666	0.04	0	83047	

Appendix Table 2. continued

		Target Density (per 1000 m ³) and Sample Volume (m ³)								
Date	Diel Period	Transect No.	Surface to 30 ft (9.1 m)		30 ft (9.1 m) to 60 ft (18.3 m)		>60 ft (18.3 m)			
			Large	Small	Large	Small	Large	Small	Volume	
			Volume	Volume	Volume	Volume	Volume	Volume		
			m ³	m ³	m ³	m ³	m ³	m ³		
Sept	Day	1	2.01	0	1986	0.66	0	1517		
		2	0	0	1882	0	0	1285		
		3	0	0	3405	0.15	0	6784		
		4	0	0	472	1.16	0	3437		
		5	1.02	0	1954	0.34	0.04	26100		
		6	0	0	1263	0.36	0	27863		
		7	0	0	977	0.04	0.12	25298		
		8	0.44	0	2290			0		
		9	0	0	3562			0		
		10	0.25	0.25	3967			0		
		11	0	0	1844	0.23	0.11	8743		
								0.05	0	77553
Night		1	0	0.56	1800	0	0	1030		
		2	0	0	2984	0	0	1529		
		3	0	0	2524	0	0	9465		
		4	1.84	0	543	0.19	0	5252		
		5	0	0	1133	0.22	0	27722		
		6	0	0	1308	0.07	0	30357		
		7	0.29	0	6974	0.10	0	31129		
		8	0	0	2190			0		
		9	0	0	3722			0		
		10	1.14	0	3511			0		
		11	0.32	0.32	3091	0.33	0	9040		
								0.25	0.04	79339

Appendix Table 2. continued

		Target Density (per 1000 m ³) and Sample Volume (m ³)								
Date	Diel Period	Transect No.	Surface to 30 ft (9.1 m)		30 ft (9.1 m) to 60 ft (18.3 m)		>60 ft (18.3 m)			
			Large	Small	Large	Small	Large	Small		
		Volume m ³		Volume m ³		Volume m ³				
Oct	Day	1	0.87	8.75	2286	0	0.78	1277		
		2	1.85	4.17	2158	0	0	1429		
		3	0.70	0.70	4289	0	0	5048		
		4	0	0	556	0.27	0.82	3644		
		5	0	0	1948	0.04	0.32	24810		
		6	0	0.43	2341	0.10	0.10	19285		
		7	0	0	1391	0.11	0.11	26190		
		8	0	0.83	2421			0		
		9	0	0.29	3426			0		
		10	0	0.60	3333			0		
		11	0	0.48	2073	0.31	0.20	9784		
						0.31	0.20	0.15	0.06	80681
Night		1	0	1.67	2399	0.64	0.64	1574		
		2	1.38	0	2907			1608		
		3	0.18	0.18	5713			8092		
		4	0	0	629	0.24	0.48	4203		
		5	0	0	1122	0.11	0.11	28509		
		6	0	1.86	1074	0.06	0.31	31926		
		7	0	0	4144	0.20	0.59	5055		
		8	0	1.57	3181			0		
		9	0.20	0.40	4996			0		
		10	0.23	0.46	4379			0		
		11	0	0.51	1979	0.27	0.54	11201		
						0.27	0.54	0.29	0.42	94664

Appendix Table 3. Water temperature in degrees Celsius for selected depth strata for Banks Lake for June through December 1978.

Station	Depth(m) Strata	21 June	19 July	8 Aug.	17 Aug.	29 Aug.	15 Sept.	26 Sept.	10 Oct.	15 Nov.	6 Dec.
1	0	14.0	17.2	20.5	18.0	20.0	18.5	17.1	15.3	8.3	4.6
	4	13.2	16.5	19.3	19.0	19.6	18.5	16.4	15.3	8.9	4.6
	8	13.0	16.4	18.2	18.8	19.5	18.0	16.3	15.2	8.9	4.6
	12	13.0	16.5	17.8	18.2	19.4	+	16.2	+	8.8	4.6
	16	+	+	+	+	+	+	+	+	+	+
2	0	19.5	22.3	25.3	20.1	20.3	17.5	17.3	15.4	7.9	3.7
	4	13.7	18.7	19.6	20.0	19.5	17.8	16.3	15.4	7.9	3.3
	8	13.2	17.0	19.0	19.8	18.9	17.7	15.7	15.4	7.8	3.7
	12	13.0	16.2	18.6	18.9	+	+	+	+	7.6	3.8
	16	+	+	+	+	+	+	+	+	+	+
3	0	19.8	23.5	25.4	20.0	20.6	17.5	17.7	15.5	8.4	4.4
	4	17.5	18.5	20.4	19.9	19.4	17.5	16.2	15.5	8.4	4.4
	8	15.2	16.4	19.0	20.1	18.7	17.5	15.8	15.5	8.1	4.4
	12	13.5	+	17.0	19.7	18.2	+	+	+	7.0	4.4
	16	+	+	+	+	+	+	+	+	+	+
4	0	18.1	22.2	24.6	20.0	20.9	17.5	17.2	15.5	8.7	5.0
	4	16.0	20.0	20.8	20.0	19.8	17.5	16.3	15.2	8.8	5.0
	8	15.2	17.1	18.7	20.0	19.2	17.0	16.0	15.3	8.9	5.0
	12	14.9	15.5	17.0	17.5	19.1	17.0	15.8	15.0	8.9	5.0
	16	13.5	15.0	15.0	15.0	15.7	17.0	15.7	+	9.0	5.0
5	0	18.0	20.3	22.5	19.1	19.7	+	16.0	14.5	8.1	3.8
	4	16.0	18.1	21.2	18.8	18.3	+	15.7	14.6	8.2	4.0
	8	15.3	17.3	19.4	17.9	18.0	+	15.7	14.6	8.2	+
	12	14.9	15.8	17.1	16.5	17.3	+	15.6	14.6	8.0	+
	16	14.2	15.0	15.6	15.8	16.3	+	15.5	14.6	7.9	+
6	0	16.7	20.6	23.3	18.9	20.0	15.6	16.5	15.0	7.4	+
	4	15.8	20.0	22.6	18.6	18.8	15.5	16.1	15.0	7.4	+
	8	15.6	19.4	21.7	18.5	18.5	15.5	16.2	14.9	7.3	+
	12	15.5	15.8	16.9	18.3	18.3	15.5	15.8	15.0	7.3	+
	16	14.4	15.3	15.5	16.8	17.6	15.5	15.7	14.9	7.3	+

+ = no samples taken

Appendix Table 4. Temperature in degrees Celsius for selected depth strata for Banks Lake from April through October 1977.

Station	Depth Strata (m)	April	May	June	July	August	Sept	Oct
1	0	7.0	11.2	12.5	17.9	19.6	18.6	13.5
	4	6.5	10.1	11.4	17.3	18.6	18.5	13.5
	8	6.5	10.0	11.2	17.2	18.5	18.5	13.5
	12	6.5	10.0	11.1	17.0	18.5	18.5	13.5
	16	6.5	+	+	+	18.4	18.5	13.5
2	0	8.0	12.5	16.0	20.0	23.5	18.5	12.0
	4	7.5	11.0	13.5	17.8	19.5	18.4	12.0
	8	7.0	10.9	13.0	17.5	18.5	18.4	12.0
	12	7.0	10.9	12.8	17.1	18.4	17.9	12.0
	16	+	+	+	+	18.4	17.9	12.0
3	0	9.0	13.5	17.9	20.6	23.9	18.5	12.0
	4	8.5	12.0	14.5	19.1	20.0	18.4	11.6
	8	8.2	11.5	12.9	18.0	18.8	18.3	11.5
	12	7.3	11.0	12.7	17.2	17.6	18.0	11.5
	16	+	+	12.7	+	17.6	18.0	11.5
4	0	8.5	13.5	17.9	19.8	23.1	18.0	+
	4	8.2	12.5	15.9	18.9	21.9	17.7	+
	8	8.0	11.5	13.8	18.5	19.0	17.5	+
	12	8.0	10.6	12.6	17.8	18.0	17.5	+
	16	8.0	9.7	12.3	15.0	16.5	17.5	+
5	0	+	+	15.5	17.5	21.8	17.6	10.5
	4	+	+	15.5	17.0	21.2	17.4	10.5
	8	+	+	14.9	16.5	20.0	17.3	10.5
	12	+	+	14.9	15.6	18.0	17.3	10.3
	16	+	+	14.0	15.1	16.6	17.3	10.3
6	0	6.9	11.4	16.0	17.4	23.8	17.3	10.5
	4	6.9	11.3	15.8	16.9	23.5	17.0	10.8
	8	6.9	11.0	15.8	16.9	21.7	17.0	10.8
	12	6.9	10.7	15.6	6.8	18.6	17.0	10.8
	16	6.9	10.6	13.5	16.5	17.5	17.0	10.8

+ = no samples taken

Appendix Table 5. Average percent dissolved oxygen saturation by depth strata for Banks Lake from June to December 1978.

Station	Depth Strata (m)	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for each Depth Strata
1	* 0-6	97.5	95.0	94.4	93.3	94.5	97.0	93.8	95.1
	** B-4	98.6	94.5	88.7	90.8	92.0	94.0	95.0	93.4
	*** W.C.	98.0	94.6	92.0	92.2	93.7	95.8	94.4	94.4
2	0-6	104.8	97.3	96.4	93.8	96.3	93.8	91.0	96.2
	B-4	98.5	89.5	84.2	86.5	95.5	91.0	92.5	91.1
	W.C.	101.9	94.0	91.9	91.3	96.0	92.6	91.4	94.2
3	0-6	98.5	94.0	98.3	92.9	96.0	93.0	93.3	95.1
	B-4	97.5	86.0	74.8	90.3	95.0	76.5	93.0	87.6
	W.C.	98.1	91.3	90.0	92.4	95.8	86.6	93.3	92.5
4	0-6	94.8	94.5	94.2	91.8	95.3	94.8	96.0	94.5
	B-4	71.5	58.0	34.5	83.5	91.5	92.0	95.8	75.3
	W.C.	87.0	81.1	72.8	88.4	93.8	93.3	96.0	87.5
5	0-6	89.0	91.0	88.8	87.8	96.8	94.3	98.8	92.4
	B-4	62.5	52.5	41.5	85.5	91.5	90.0	100.5	74.9
	W.C.	79.7	74.2	69.2	87.3	94.2	92.6	98.8	85.1
6	0-6	90.3	93.5	91.3	94.3	95.0	95.0	+	93.2
	B-4	71.5	56.0	43.8	88.8	92.5	91.5	+	74.0
	W.C.	82.6	76.9	73.2	91.8	94.0	92.9	+	85.2
Devil's Hole	0-6	+	+	95.7	92.0	+	+	+	93.9
	B-4	+	+	5.7	1.1	+	+	+	3.4
	W.C.	+	+	51.7	40.4	+	+	+	46.1
South Barrier Net	0-6	+	+	89.8	93.3	+	+	+	91.6
	B-4	+	+	75.3	91.0	+	+	+	83.2
	W.C.	+	+	85.0	92.5	+	+	+	88.8
East Barrier Net	0-6	+	+	88.0	+	+	+	+	88.0
	B-4	+	+	81.0	+	+	+	+	81.0
	W.C.	+	+	85.7	+	+	+	+	85.7
High		104.8	97.3	98.3	94.3	96.8	97.0	100.5	96.2
Low		62.5	52.5	5.7	1.1	91.5	76.5	91.0	3.4
Monthly Mean	0-6	95.8	94.2	93.0	92.4	95.7	94.7	94.6	93.3
	B-4	83.4	72.8	58.8	77.2	93.0	89.2	95.4	73.8
	W.C.	91.2	85.4	79.1	84.6	94.6	92.3	94.8	84.4

*0-6 = mean of surface to 6 meters

**B-4 = mean of bottom 4 meters

***W.C. = means of water column

+ = no samples taken

Appendix Table 6. Average percent dissolved oxygen saturation by depth strata for Banks Lake from April through October 1977.

Station	Depth Strata (m)	April	May	June	July	August	Sept	Oct	Mean for each depth strata
1	*0-6	109	108	103	108	103	109	103	106
	**B4	110	111	108	106	100	107	101	106
	***W.C.	109	109	105	107	101	108	102	106
2	0-6	115	112	122	122	118	116	115	117
	B4	116	113	111	110	101	101	108	109
	W.C.	115	113	117	117	109	109	112	113
3	0-6	117	115	122	116	117	111	119	117
	B4	113	115	107	107	94	103	111	107
	W.C.	115	115	115	112	107	107	116	112
4	0-6	110	111	113	111	114	104	+	111
	B4	110	103	100	69	57	102	+	90
	W.C.	110	107	106	98	90	103	+	102
5	0-6	+	+	114	109	106	102	116	109
	B4	+	+	95	82	56	99	106	88
	W.C.	+	+	107	97	85	100	111	100
6	0-6	110	112	113	110	110	105	113	110
	B4	106	105	90	88	63	98	106	94
	W.C.	108	108	105	103	90	102	100	104
High		122	117	131	127	127	117	129	-
Low		106	89	80	57	40	91	101	-
Monthly mean	0-6	112	112	115	113	111	108	113	112
	B4	111	109	102	94	79	102	106	100
	W.C.	111	110	109	106	97	105	110	107

*0-6 = mean of surface to 6 meters
 **B4 = mean of bottom 4 meters
 ***W.C. = mean of water column
 + = no samples taken

Appendix Table 7. Average pH by depth strata in Banks Lake from June through December, 1978

Station	Depth Strata (m)	21 Jun	19 Jul	19 Aug	29 Aug	15 Sept	26 Sept	10 Oct	15 Nov	6 Dec.	Mean for each Depth Strata
1	*O-6	8.8	8.8	7.5	7.6	7.8	7.6	7.6	6.4	6.4	7.6
	**B-4	8.8	8.8	7.4	7.5	7.7	7.3	7.5	6.4	6.4	7.5
	***W.C.	8.8	8.8	7.5	7.5	7.8	7.5	7.6	6.4	6.4	7.6
2	O-6	8.8	8.8	7.8	7.9	7.8	7.9	7.6	6.6	6.5	7.7
	B-4	8.8	8.8	7.6	7.6	7.8	7.8	7.6	6.6	6.5	7.7
	W.C.	8.8	8.8	7.7	7.8	7.8	7.9	7.6	6.6	6.5	7.7
3	O-6	8.8	8.8	7.8	8.0	7.8	7.9	7.6	6.6	6.7	7.8
	B-4	8.8	8.8	7.4	7.8	7.7	7.9	7.6	6.6	6.6	7.7
	W.C.	8.8	8.8	7.7	7.9	7.7	7.9	7.6	6.6	6.6	7.3
4	O-6	8.8	8.8	7.9	7.8	7.4	7.7	7.4	6.7	6.7	7.7
	B-4	8.8	8.8	7.3	7.0	7.3	7.4	7.4	6.6	6.6	7.5
	W-C	8.8	8.8	7.6	7.5	7.4	7.5	7.4	6.7	6.6	7.6
5	O-6	8.8	8.8	7.8	7.8	+	7.6	7.3	6.7	6.6	7.7
	B-4	8.8	8.8	7.2	7.1	+	7.5	7.2	6.7	+	7.6
	W-C	8.8	8.8	7.5	7.4	+	7.5	7.2	6.7	+	7.7
6	O-6	8.8	8.8	7.7	7.8	+	7.7	6.9	6.7	+	7.8
	B-4	8.8	8.8	7.2	7.1	+	7.6	6.9	6.7	+	7.6
	W.C.	8.8	8.8	7.5	7.6	+	7.6	6.9	6.7	+	7.7
High		8.8	8.8	7.9	8.2	7.9	8.0	7.7	6.8	6.8	-
Low		8.8	8.8	7.2	6.9	7.2	7.4	6.8	6.4	6.4	-
Mean for Date of ea. Depth Strata	O-6	8.8	8.8	7.8	7.8	7.7	7.7	7.4	6.6	6.6	7.7
	B-4	8.8	8.8	7.4	7.4	7.6	7.6	7.4	6.6	6.5	7.6
	W.C.	8.8	8.8	7.6	7.6	7.7	7.7	7.4	6.6	6.5	7.6

O-6 = mean of surface to 6 meters
 **B-4 = mean of bottom 4 meters
 **W.C. = mean of water column
 + = 110 samples taken

Appendix Table 8. Average pH by depth strata in Banks Lake from April through October 1977.

Station	Depth Strata (m)	April	May	June	July	August	Sept	Oct	Mean for each depth strata
1	*0-6	11.3	9.0	8.6	8.3	8.6	8.4	8.1	8.9
	**B4	10.0	8.6	8.2	8.2	8.3	8.3	8.1	8.5
	***W.C.	10.9	8.8	8.4	8.3	8.5	8.3	8.1	8.8
2	0-6	8.8	8.6	8.7	8.7	8.9	8.7	8.7	8.7
	B4	8.7	8.3	8.2	8.4	8.4	8.4	8.4	8.4
		8.7	8.4	8.5	8.6	8.7	8.5	8.6	8.6
3	0-6	8.9	8.7	8.6	8.7	8.9	8.7	8.5	8.7
	B4	8.7	8.3	8.2	8.3	8.5	8.5	8.3	8.4
	W.C.	8.8	8.5	8.4	8.5	8.7	8.6	8.4	8.6
4	0-6	9.2	8.8	8.7	8.4	9.0	8.5	+	8.8
	B4	8.7	8.1	8.0	7.9	8.2	8.3	+	8.2
	W.C.	8.9	8.5	8.3	8.2	8.6	8.4	+	8.5
5	0-6	+	+	8.7	8.5	8.8	8.4	8.5	8.6
	B4	+	+	8.1	8.1	8.1	8.2	8.0	8.1
	W.C.	+	+	8.4	8.3	8.4	8.3	8.3	8.3
6	0-6	8.7	8.5	8.7	8.5	8.8	8.4	8.8	8.6
	B4	8.5	8.1	8.1	8.2	8.2	8.1	8.2	8.2
	W.C.	8.6	8.3	8.4	8.3	8.5	8.3	8.5	8.4
High		11.4	9.1	8.9	8.8	9.2	8.8	9.1	-
Low		8.5	8.1	8.0	7.8	8.1	8.1	8.0	-
Monthly mean for each depth strata	0-6	9.4	8.7	8.7	8.5	8.8	8.5	8.5	8.7
	B4	8.9	8.3	8.1	8.2	8.3	8.3	8.2	8.3
	W.C.	9.2	8.5	8.4	8.4	8.6	8.4	8.4	8.6

*0-6 = mean of surface to 6 meters

**B4 = mean of bottom 4 meters

***W.C. = mean of water column

+ = no samples taken

Appendix Table 9. Mean conductivity ($\mu\text{mhos}/\text{cm}^2$) for Banks Lake for 1978.

	Stations						Mean
	1	2	3	4	5	6	
21 June	95	97	97	100	107	118	102
19 July	107	114	110	110	112	114	111
19 August	98	99	99	100	100	100	99
29 August	97	99	101	102	104	103	101
15 Sept	102	103	103	100	+	+	102
26 Sept	107	107	107	106	112	106	108
10 Oct.	104	107	109	109	109	109	108
15 Nov.	90	91	91	93	100	100	94
6 Dec.	89	89	89	93	+	+	90
High	107	114	110	110	112	118	-
Low	89	89	89	93	100	100	-
Mean	99	101	101	101	106	107	102

+ = no sample taken.

Appendix Table 10. Mean conductivity ($\mu\text{mhos}/\text{cm}^2$) for Banks Lake for 1977.

	Stations						Mean
	1	2	3	4	5	6	
April	147	148	139	124	+	119	113
May	115	109	121	116	+	118	116
June	110	110	112	120	123	121	116
July	127	126	125	140	134	130	130
August	120	119	123	128	133	133	126
Sept	111	110	110	112	114	114	112
Oct	115	118	117	+	113	112	115
High	147	148	139	140	133	133	-
Low	110	109	110	112	113	112	-
Mean	121	120	121	123	123	121	122

+ = no samples taken

Appendix Table 11. Water temperature and percent saturation dissolved oxygen at depth intervals taken in Devil's Hole during 1978.

Depth (m)	August 8		August 17		August 29		Sept. 18		Sept. 26	
	Temp	D.O. % Saturation	Temp	D.O. % Saturation	Temp	D.O. % Saturation	Temp	D.O. % Saturation	Temp	D.O. % Saturation
0	25.2	102	19.9	110	20.1	100	16.8	101	17.5	97
4	20.4	90	20.0	89	19.4	95	16.8	88	16.1	90
8	19.2	89	19.6	86	18.7	86	16.8	83	15.7	88
12	17.5	72	17.5	49	18.1	79	16.8	80	15.7	85
16	15.0	54	15.5	47	16.2	44	15.5	27	15.4	76
20	14.0	38	13.8	35	13.8	28	12.0	21	11.1	19
24	12.0	39	10.5	36	11.3	31	9.6	25	9.6	22
28	8.5	43	6.0	37	9.1	37	7.6	32	8.0	31
32	6.0	48	6.0	43	6.6	45	5.7	33	6.1	33
36	5.0	41	5.0	35	5.1	33	4.9	21	4.8	18
40	4.5	29	4.5	23	4.9	21	4.7	13	4.7	8
44	4.5	20	4.5	18	4.9	18	4.7	7	4.6	4
48	4.5	11	4.5	14	4.9	12	4.7	2	4.6	1
52	4.5	12	4.5	6	4.9	1	4.7	1	4.6	1

Appendix Table 12. A summation of known introductions of kokanee from planting records of WSDG for FDR reservoir and Banks Lake 1942-74.

<u>Area</u>	<u>Source</u>	<u>Number</u>	<u>Year</u>
FDR	Leavenworth	1,300,000 fry	1942
"	"	2,800,000	1943
"	"	2,000,000	1944
"	"	1,400,000	1945
Banks Lake	Leavenworth	1,504,000 fry	1956
"	"	1,533,000	1957
"	"	1,298,800	1958
"	"	1,895,960	1960
"	"	506,000	1963
"	"	1,010,000	1964
"	"	1,160,300	1965
"	"	1,000,000	1966
"	Columbia Basin	67,900 9/lb.	1966
"	Leavenworth	150,000	1971
"	"	110,000	1974

Appendix Table 13. Percent composition by species for gillnet caught fish in FDR reservoir forebay and Billy Clapp reservoir from March 21 to May 26, 1978. These samples were taken in an effort to obtain kokanee for genetic analysis of the population structures in both reservoirs.

<u>FDR Reservoir Forebay</u>								
Date	Total #	Squawfish	Walleye	Kokanee	Rainbow	Lg. Scale Sucker	Chinook	Other Species
3/21-3/31	15	60.0	6.6	6.6	6.6	6.6	6.6	Burbot-6.6,Lk.Whitefish 6.6,Lng.Ns.Sucker-6.6
4/01-4/10	45	13.3	24.4	22.2	4.4	0.0	6.6	Burbot-2.2,Lk.Whitefish 8.9, Longnose Sucker- 15.6, Peamouth- 2.2
4/11-4/17	65	13.8	15.4	32.3	7.7	0.0	24.6	Longnose Sucker-3.1, Cutthroat-1.5, Peamouth- 1.5
4/18-4/28	60	6.7	15.0	21.7	18.3	10.0	8.3	Longnose Sucker-3.3, Peamouth - 15.0, Bridgelip Sucker- 1.7
4/29-5/8	131	21.4	21.4	17.6	6.9	8.4	9.2	Peamouth - 9.9, Bridge- lip sucker - 3.8, Lake Whitefish - 1.5
5/9-5/19	79	5.1	0.0	20.2	15.2	25.3	6.3	Longnose Sucker- 1.3, Peamouth - 13.9, Bridge- lip Sucker - 8.9, Lake Whitefish - 3.8
5/20-5/26	23	34.8	4.3	13.0	8.7	0.0	0.0	Peamouth - 17.4,Bridge- lip Sucker - 13.0, Lake Whitefish - 8.7

<u>Billy Clapp Reservoir</u>								
Inclusive Dates	#	Kokanee	Perch	Walleye	Lng.Nose Sucker	Lk. White Fish	Peamouth	Other Species
5/8-5/19	49	24.5	16.3	0	20.4	32.7	4.1	Carp - 2.0
5/20-5/26	24	70.8	20.8	4.2	4.2	0	0	
5/30-6/9	32	68.8	0	3.1	3.1	21.9	0	Carp - 3.1
6/10-6/16	83	75.9	6.0	0	0	15.7	1.2	Burbot - 1.2