March 1986

EFFECT OF OPERATION OF KERR AND HUNGRY HORSE DAMS OF THE REPRODUCTIVE SUCCESS OF KOKANNE IN THE FLATHEAD SYSTEM

Annual Report 1986

DOE/BP-39641-4

DOE/BP-39461-4

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do r necessarily represent the views of BPA.

This document should be cited as follows:

Beattie,Will; Pat Clancey, Project Biologists, Montana Departrrrent of Fish, Wildlife and Parks, Tom Vogel, Project Manger, United States Department of Energy, Bonneville Power Administration, WA Agreement DE-AI79-1983BP39641, Project 1981S-5, 74 ELECTRONIC PAGES (BPA Report DOE/BP-39461-4)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

EFFECT OF OPERATION OF KERR AND HUNGRY HORSE DAMS ON THE REPRODUCTIVE SUCCESS OF KOKANEE IN THE FLATHEAD SYSTEM

Annual Progress Report
FY 1986

By: Will Beattie and Pat Clancey
Project Biologists

Montana Department of Fish, Wildlife and Parks
Post Office Box 67
Kalispell, Montana 59903

Prepared for:
Tom Vogel, Project Manger
United States Department of Energy
Bonneville Power Administration

Funded by:
BPA Agreement DE-AI79-83BP39641

Project 81S-5

March 1987

EXECUTIVE SUMMARY

The 1985 kokanee spawning run in the Flathead system was the strongest in five years. Escapement to the Flathead River system was 147,000 fish, including 123,000 in McDonald Creek and an estimated 20,OOOin the main stem. Enumeration of spawners and redds in the Flathead River was hindered by high fall flows and early freezing in November. The upstream spawning migration from Flathead Lake began in late August. Schools of kokanee were seen six miles above the lake on September 4. We counted 1,156 redds in Flathead Lake, distributed primarily along the southeastern shore. An unusually high proportion (90 percent) of lakeshore spawning occurred in the zone above minimum pool, where egg mortality is very high because of exposure from drawdown. Escapement to the Swan River was 1,350 fish.

Four year old (III+) fish comprised 95 percent of the spawning run in the Flathead system. This continues a five-year trend toward dominance of the III+ year class. The age composition of spawners has varied considerably for the past 15 years. The average size of spawning fish was 365 mm, which is identical to the average size of the parent year class in 1981. One of the goals of managing Flathead kokanee is to produce mature fish 300-330 mm in length.

In the main stem Flathead River, pre-emergent survival was 80 percent. Survival in McDonald Creek, unaffected by hydroelectric operations, was 83 percent. Sampling showed few hatched alevins, probably due to unusually cold winter temperatures. Egg survival at Blue Bay, a spawning area on Flathead Lake where redds are concentrated below minimum pool, varied in relation to depth and dissolved oxygen concentration in the substrate. Eggs survived 78 days at 2,880 feet where dissolved oxygen was 5.7 mg/l. Eggs survived 35 days at 2,870 feet where dissolved oxygen concentration averaged 2.9 mg/l. Low dissolved oxygen contributed to poor survival to emergence at all elevations in Blue Ray. Experiments in Skidoo Bay confirmed that survival of eggs above minimum pool depends on redds being wetted by groundwater seeps. After 40 days exposure by drawdown, eggs in groundwater seeps showed 86 percent survival, whereas outside of the groundwater seeps eggs survived less than six days. These results confirm that exposure by drawdown is the primary factor that limits kokanee reproductive success in redds above minimum pool.

We surveyed the west and south shoreline of Flathead Lake to locate potential kokanee spawning habitat. We found conditions which could support incubating eggs at two sites in South Ray and two sites on the west shore of the lake. Seven other sites on the west shore were not suitable due to low groundwater discharge or low dissolved oxygen. In all these areas suitable substrate existed only within the drawdown zone. The lake should be drafted earlier in the fall, and filled earlier in the spring to improve recruitment from lakeshore spawning.

We conducted creel surveys during 1985, and estimated that anglers caught 192,000 kokanee. Anglers harvested 49,200 fish during the ice fishery in Skidoo Bay, 129,000 fish during the summer fishery on the lake, and 13,800 during the fall river fishery. Estimated fishing pressure for the year exceeded 188,000 angler hours.

The abundance of mysid shrimp in Flathead Lake, measured at six index stations, increased to $130/m^2$ in 1986. Mysids increased tenfold from 1984 to 1985, and about threefold from 1985 to 1986. Monitoring of mysid shrimp and zooplankton populations in Flathead Lake is supplementing an investigation of the growth and survival of juvenile kokanee. Kokanee and mysid shrimp feed primarily on planktonic crustaceans. This work was designed to detect a potential decline in kokanee recruitment or growth brought about by competitive interaction with mysid shrimp. Fluctuation in adult kokanee year class strength is in part attributable to the negative effects of hydroelectric dam operation on reproductive success in the main stem Flathead River and in Flathead Lake. Our results show that egg survival in the river has improved in response to stabilized discharge from Hungry Horse Dam. Drawdown exposure continues to limit egg survival in lakeshore redds. Study of the variability in growth and survival of young-of-the-year fish in Flathead Lake will further the understanding of factors which cause fluctuation in the kokanee population.

ACKNOWLEDGMENTS

John Fraley served as project manager and reviewed the manuscript. For contributing to the successful planning and implementation of this portion of the study, our sincere thanks to Scott Rumsey, Laney Hanzel and our field crew — Rick Adams, Jon Cavigli, Mark Gaub, Greg Smith, and Rick Malta. We appreciated the ready advice of Jim Vashro in dealing with aspects of fishery management. Stewart Kienow, at the Somers Hatchery, assisted us with egg survival experiments. Many of those mentioned edited the manuscript and helped clarify the discussion. Dennice Hamman typed the final draft. Bonneville Power Administration funded the study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

APPENDIX FIGURES AND TABLES

INTRODUCTION

Flathead Lake is a large (477 km^2), oligomesotrophic inland water in northwestern Montana. The lake has a maximum length of 44 km and a maximum width of 25 km. The mean depth is 32.5 m and the maximum depth, near Yellow Bay, is 113 m (Potter 1978). The 199-km shoreline is characterized by protected bays along the west shore and uninterrupted steep shoreline on the east shore. Approximately 50 percent of the shoreline is made up of gravel and cobble beaches. Cliffs and bedrock outcroppings comprise another 33 percent. Over 90 percent of the shore is developed for summer and permanent homes or agriculture. The southern half of the lake, marked by a line from Rollins to Yellow Bay, lies on the Flathead Indian Reservation.

Kerr Dam, located 7 km downstream of the natural lake outlet at the south end of the lake, was completed in 1938. A license was issued to Rocky Mountain Power Company, a subsidiary of the Montana Power Company (MPC), on May 23, 1930. The license was transferred to MPC in 1938 when the dam was completed. The first 56,000 kilowatt (KW) generator began operating on May 20, 1939, followed by a second similar unit in May, 1949. These two turbines utilized the 1.217 million acre-feet of storage created in Flathead Lake by Kerr Dam. When Hungry Horse Dam was completed on the South Fork of the Flathead River in 1953, MPC installed a third 56,000-kw generator at Kerr Dam in December, 1954. In 1984, the Federal Energy Regulatory Commission (FERC) ruled that the operating license will be assumed by the Confederated Salish and Kootenai Tribes in 30 years. Until that time MPC will retain the license and operate the facility, while paying a lease fee to the Tribes.

The operation of Kerr Dam has altered the seasonal water level fluctuations of Flathead Lake. Prior to impoundment by Kerr Dam, the water level of Flathead Lake remained near 2,882 feet from September to mid April. Spring runoff increased the lake elevation to 2,893 feet in May and June. Flood control and recreational constraints on the project require that the lake be drafted to 2,883 feet by April 15, refilled to 2,890 feet by May 30, and that full pool (2,893 feet) be maintained through Labor Day (Montana Power Company 1976). Drawdown begins in mid September. The operation agreement provides that high or unseasonal runoff be spilled to prevent the lake level from exceeding 2,893 feet. Natural channel restriction at the southern end of the lake limits outflow to 55,000 cfs when the lake is at full pool. At minimum pool (2,883 feet) outflow is 5,200 cfs (Graham et al. 1981).

Kerr Dam provides most of MPC's system load frequency control, i.e., it is used to supply peaking power demands. It provides 180,000 kw of peaking power and 119,000 kw of critical period energy (MPC 1976). The system load typically has a winter peak in

December and January, and a daily peak from 5:00 to 7:00 pm. When high runoff provides excess water, the dam is operated primarily to provide baseload.

Two tributaries to the Flathead River and Lake system, the South Fork and Swan River, are also regulated by hydroelectric facilities. The Swan River diversion at Bigfork (Figure 1), built in 1902 and operated by the Pacific Power and Light Company, provides 4,150 kw of generating capacity (Graham et al. 1981). Hungry Horse Dam, located 7.5 km above the confluence of the South and Middle forks of the main stem Flathead River, was completed in 1953. It regulates one third of the entire Flathead watershed, and at capacity, supplies 328,000 kw of power. Power from Hungry Horse Dam, which is operated by the Bureau of Reclamation, is marketed by the Bonneville Power Administration.

Kokanee salmon (*Oncorhynchus nerka*), the landlocked form of sockeye salmon, were introduced to Flathead Lake in 1916. By 1933 kokanee were established in the system (Alvord 1975), providing a popular summer and fall fishery. Flathead Lake supports the second highest fishing pressure on any Montana lake (Montana Department of Fish & Game 1976). The kokanee fishery comprises more than 90 percent of the catch and fishing effort on the Flathead system (Hanzel 1977, Graham and Fredenberg 1982). A creel survey conducted in 1985 estimated that over 188,000 angler-hours were spent fishing on Flathead Lake and Flathead River upstream of the lake (Hanzel 1986). Kokanee provide a year-round fishery to anglers, as well as forage to larger game fish such as bull trout and lake trout (Leathe and Graham 1982).

Most kokanee in the Flathead system become sexually mature in their fourth growing season (age III+), but some fish mature in either their third (age II+) or fifth year (IV+). Kokanee mature in Flathead Lake, whether they are spawned on the lakeshore or in tributary rivers. Spawning along the Flathead Lake shoreline was first documented in the 1930's (Alvord 1975). Kokanee were seined from shoreline spawning areas in 1933, and 21,000 cans of fish were distributed to the needy. Stefanich (1952 and 1953) observed spawning at 30 shoreline areas in the 1950's. Kokanee were first observed spawning in McDonald Creek, a tributary of the Middle Fork, in the early 1930's and in the Whitefish and Flathead Rivers in the late 1940's and early 1950's (Stefanich 1953). Substantial spawning runs developed in the main stem and South Fork of the Flathead River in early 1950's, when winter water temperatures increased due to the construction and operation of Hungry Horse Dam.

The winter decline in the water level of Flathead Lake caused by the operation of Kerr Dam has reduced the reproductive success of kokanee spawning along the shore of the lake (Decker-Hess and McMullin 1983). The lake level is high during spawning in October and November. Winter drawdown exposes redds built in shallow water to freezing and desiccation. Groundwater seeps at various

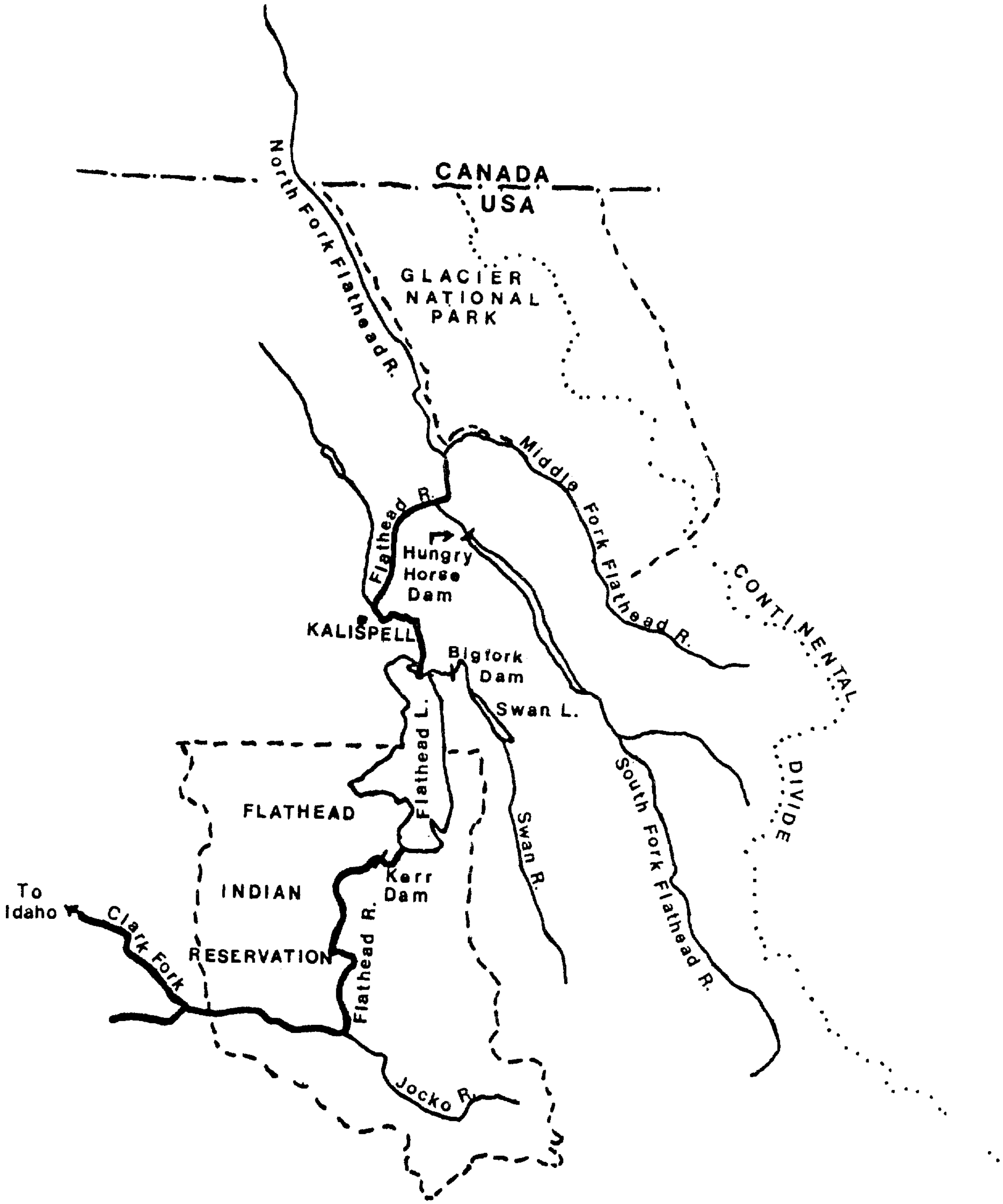


Figure 1. The Flathead Lake - River drainage.

spawning areas ameliorate the effects of exposure and permit a small percentage of eggs to hatch (Decker-Hess and Clancey 1984, Beattie et al. 1985). Emergent sac fry cannot reach the lake unless groundwater seepage is high, or the redd is near lake level (below 2,885 feet). Recruitment from redds above minimum pool is very low. Successful reproduction from lakeshore spawning areas occurs primarily where redds are built below the minimum pool elevation (2,883 feet).

Recent studies have shown that the operation of Hungry Horse Dam reduced reproductive success in spawning areas in the Flathead River (McMullin and Graham 1981, Fraley and Graham 1982, Fraley and McMullin 1983). Most kokanee spawned in the river during high flow. Declining flows later in the winter, due to the operation of Hungry Horse Dam, exposed eggs to freezing and desiccation — a similar situation to what occurs in Flathead Lake. The result has been increased dependence on recruitment from tributaries not affected by dam operation. Over 75 percent of Flathead kokanee now spawn in McDonald Creek. Main stem Flathead River spawning once comprised 40-50 percent of the total run (Hanzel 1975). In 1981, the Montana Department of Fish, Wildlife and Parks recommended that lower and more steady flows (3,500-4,500 cfs, 24 hours per day) be maintained during the spawning season (October 15 - December 15) in the main stem Flathead River. These flow recommendations, made through the Northwest Power Planning Council, have been met since 1982. Egg survival in the main stem river has improved to match survival rates in McDonald Creek.

Up to the spring of 1986, the primary goals of the Flathead Kokanee Study have been to assess how the operations of Kerr and Hungry Horse Dams affect the reproductive success of kokanee. Methods to mitigate impacts on the fish population, such as the flow recommendations described above, will continue to be developed. We have quantified the effects of water level fluctuations on egg-to-fry survival at lakeshore and riverine spawning areas. In addition, we have identified potentially suitable spawning habitat around the lakeshore where kokanee could spawn successfully if drawdown-associated mortality did not limit egg survival.

The study has also been charged with designing and testing methods to mitigate losses in kokanee production. The establishment of the opossum shrimp (Mysis relicta) in the lake has added a new dimension to the problem. This introduced planktivore competes with kokanee for food, and can potentially reduce the growth and survival of juvenile fish in Flathead Lake. We have redirected a part of the study to address this problem, by monitoring the abundance of mysid shrimp, changes in zooplankton community structure, and measuring growth and survival of juvenile kokanee. If the establishment of Mysis relicta causes changes in the trophic structure of Flathead Lake, the carrying capacity of the lake with respect to juvenile kokanee may be reduced. Young-of-the-year kokanee production goals from spawning areas may need to be adjusted to minimize intraspecific competition during the early spring when food abundance is low and large numbers of fry reach the lake. If survival of naturally produced fry is low, recruitment could be supplemented by releasing fry from Somers Hatchery in July, when zooplankton is more abundant. These studies began in the spring of 1986. In this report, we include preliminary information on mysid abundance.

The objectives of the study are:

1. Determine the production potential of the Flathead Lake shoreline for kokanee salmon.

2. Determine the impacts of the historical and present operation of Kerr and Hungry Horse Dams, groundwater hydrologic regime, and other environmental factors on kokanee reproduction in Flathead Lake.

3. Develop a recovery and mitigation plan for kokanee shoreline spawning in Flathead Lake.

4. Continue to develop a stock-recruitment relationship for kokanee in the Flathead system.

5. Quantify the effect of controlled flows on the distribution and reproductive success of kokanee in the regulated portion of the Flathead River. Determine the relative contribution of day and nighttime spawning.

6. Determine the relative contributions of major river system spawning areas to the total kokanee population.

7. Identify the timing and destination of successive runs of kokanee spawners in the Flathead River and their use by fishermen, and determine if timing is affected by discharges from Hungry Horse Dam.

8. Identify changes in the structure of the zooplankton community that might be caused by an increasing population of mysid shrimp in Flathead Lake.

9. Test for changes in the growth, survival, and diet of kokanee that might be caused by competitive interaction with mysid shrimp in Flathead Lake.

FLATHEAD LAKE SEGMENT

METHODS

Spawner Surveys

Kokanee redds were counted at the principal Flathead Lake shoreline spawning areas at 14-day intervals in October and November. Redds in shallow water, no deeper than six feet, were counted from the bow of a boat. Deeper spawning areas were surveyed using SCUBA gear. We flew two aerial surveys in a helicopter to locate other spawning areas on the west and east shore.

Boat surveys were conducted at the following east shore locations: Woods Bay (east and west sites), Yellow Bay, Blue Bay, Talking Water Creek, Doc Richards Bay (Station Creek), Pineglen, Staples, Orange House, Gallagher's, and Thurston's. The latter five locations are distributed along the eastern shore of Skidoo Bay. Two additional sites in Crescent Bay, on the west shore, were also checked by boat. Extremely cold temperatures froze much of the shoreline by the third week in November, precluding further surveys. Where possible, we measured the elevation of all shallow water redds by comparing the depth of water over the center of each redd to the known elevation of the lake that day. We used SCUBA gear only at sites where we had previously observed deepwater spawning. These sites included Woods Bay West, Yellow Bay, Blue Bay, and Gravel Bay - all on the east shore.

We counted spawners in the Swan River, below the diversion dam and in the vicinity of the powerhouse downstream, at two-week intervals from the last week of September until the end of November. Pairs of divers made duplicate counts on each survey date. Age and standard length were determined in spawning kokanee sampled in Swan River, at the Somers Hatchery, and at seven spawning areas around Flathead Lake. Gill nets and beach seines were used to collect fish. Age was determined by examining otoliths under a stereoscope with reflected light against a dark background.

Stock Composition of the Skidoo Bay Aggregation

Following ice-out in early April, 1985, we purse seined and tagged 4,000 adult kokanee in Skidoo Bay at the southeast extent of Flathead Lake. The ice fishery in February of 1985 had shown that, as in previous years, a large aggregation of kokanee wintered in Skidoo Bay. We followed fish in the aggregation as they dispersed through the lake during the summer, and migrated to their spawning grounds. Anglers have harvested as many as 100,000 fish during the winter fishery. It was necessary to understand which spawning stocks might be supporting such a harvest. The term "stock" is used loosely here to signify subunits of the kokanee population which spawn in different parts of the Flathead system; we have no evidence that these subunits are genetically distinct.

We used a 30' x 600' purse seine, deployed from two boats: a 25' I/O Wooldridge with a hydraulic winch and boom, and a 24' outboard-powered pontoon barge. Schools of kokanee were located with a Sitex HR-456 sonar. We fished successfully in the early morning when fish were porpoising to feed and late in the afternoon when the fish were distributed between 25 and 40 feet. Adult fish were dip-netted into live cars, and lavender Floy tags attached to them. No anesthetic was used on the fish, and they were released immediately. A sample of 50 tagged fish held for 24 hours in a live car showed two percent mortality.

Tag returns were obtained from the summer fishery (May to September) on ehe lake, the fall fishery in the Flathead River, and from spawning surveys. Radio and newspaper advertising helped to publicize the tag return program. Creel survey technicians monitoring the summer fishery checked for tagged fish. Tag observations during the spawning season came from snorkeler surveys of McDonald Creek and Swan River, brood stock collection at Somers Hatchery, and routine collection of spawners around the lakeshore and in river spawning areas.

Egg Survival Experiments

Eyed kokanee eggs obtained from the Somers Hatchery were enclosed in fine mesh screen bags and buried at three depths below minimum pool (2,870, 2,875, 2,880 feet) at Blue Bay, and three depths in the zone above minimum pool (2,884, 2,886, 2,888 feet) at Thurston's (Skidoo Bay V). The mesh bags each contained 50 eggs and some coarse gravel to facilitate water exchange. The Blue Bay eggs were sampled weekly, and the Skidoo Bay site biweekly, from mid-December until the end of March. In mid January, another line of egg bags was buried in a zone of active groundwater seepage at the Skidoo Bay site.

Groundwater apparent velocity and dissolved oxygen were measured at each elevation on each sampling date. Apparent velocity was measured with seepage meters (Lee and Cherry 1968, Woessner and Brick 1985) over a 30-minute period. Seepage meter construction and the hydrologic theory supporting the method have been described in previous reports (Beattie et al. 1985, Woessner and Brick 1985). Briefly, groundwater flows through aquifers upslope, and percolates through the lake bed on the shoreline. Percolating groundwater is collected in seepage meters over a known area and time interval. The resultant volume of groundwater collected per unit area and time (cm^3/cm^2/hour) is termed "apparent velocity" because the units reduce to cm/hour. Seepage meter readings are most accurate when a good seal is achieved between the collector and the lake bed. In water shallower than two meters, hydrostatic forces from waves can pump lake water into the seepage meter through the substrate. Overestimates of apparent velocity result.

Winkler titrations were used to measure the dissolved oxygen concentration in groundwater samples drawn from the substrate with a hand-driven peristaltic (Jackrabbit) pump. Pairs of egg bags were sampled at each elevation on each sample date, and the numbers of live and dead eggs counted. Live eggs were distinguished by a clear pink cell membrane and movement of the embryo within. Sampling the deep site required diving beneath a 12-inch layer of ice to depths of 30 feet. Water temperature at each egg bag line was measured and recorded by Taylor multi-probe recording thermographs (Model 5-062408).

West Shore Habitat Surveys

We surveyed fifteen lakeshore sites, principally along the west shore, which reportedly had been kokanee spawning areas before the runs were decimated by the operations of Kerr Dam. These sites were O'Neill's (Deep Bay), Crescent Bay, Goose Bay, Hyde Bay, Dewey Bay, Zelezney Bay, Safford's (Dayton Bay), Wildhorse Island, White Swan Bay, Hockaday Bay, Polson Golf Course, Kerwin's, Slack Point, and Finley Point (Figure 2). We measured dissolved oxygen and groundwater apparent velocity at each site, once during the summer and once in the fall to detect seasonal variation. Groundwater samples were also pumped from the substrate and sent to the University of Montana Water Lab for assay of the following ions: Calcium, sodium, potassium, chloride, sulphate, nitrate, and pH. Apparent velocity was measured with seepage meters placed along a transect parallel to the beach at a depth of 2-3 meters. Where suitable substrate existed at greater depth, additional horizontal and vertical transects of apparent velocity and dissolved oxygen were sampled. Seepage meters were embedded in the substrate and sealed with fine sand. Groundwater discharged through the lake bed was collected in evacuated plastic bags over a 30-minute interval and the discharge volume measured with a graduate cylinder.

We measured the dissolved oxygen concentration in water collected in seepage meters which had equilibrated for a period long enough to displace all ambient lake water. These dissolved oxygen measurements were compared with those done on groundwater pumped directly from the substrate with a perstaltic pump. This latter method was found to be more reliable, and so we used it exclusively later in the season. Winkler titrations were used for all oxygen assays. In **situ** measurements of dissolved oxygen in interstitial water, using a polarigraphic probe, would be more accurate. Any method that extracts water from the substrate can

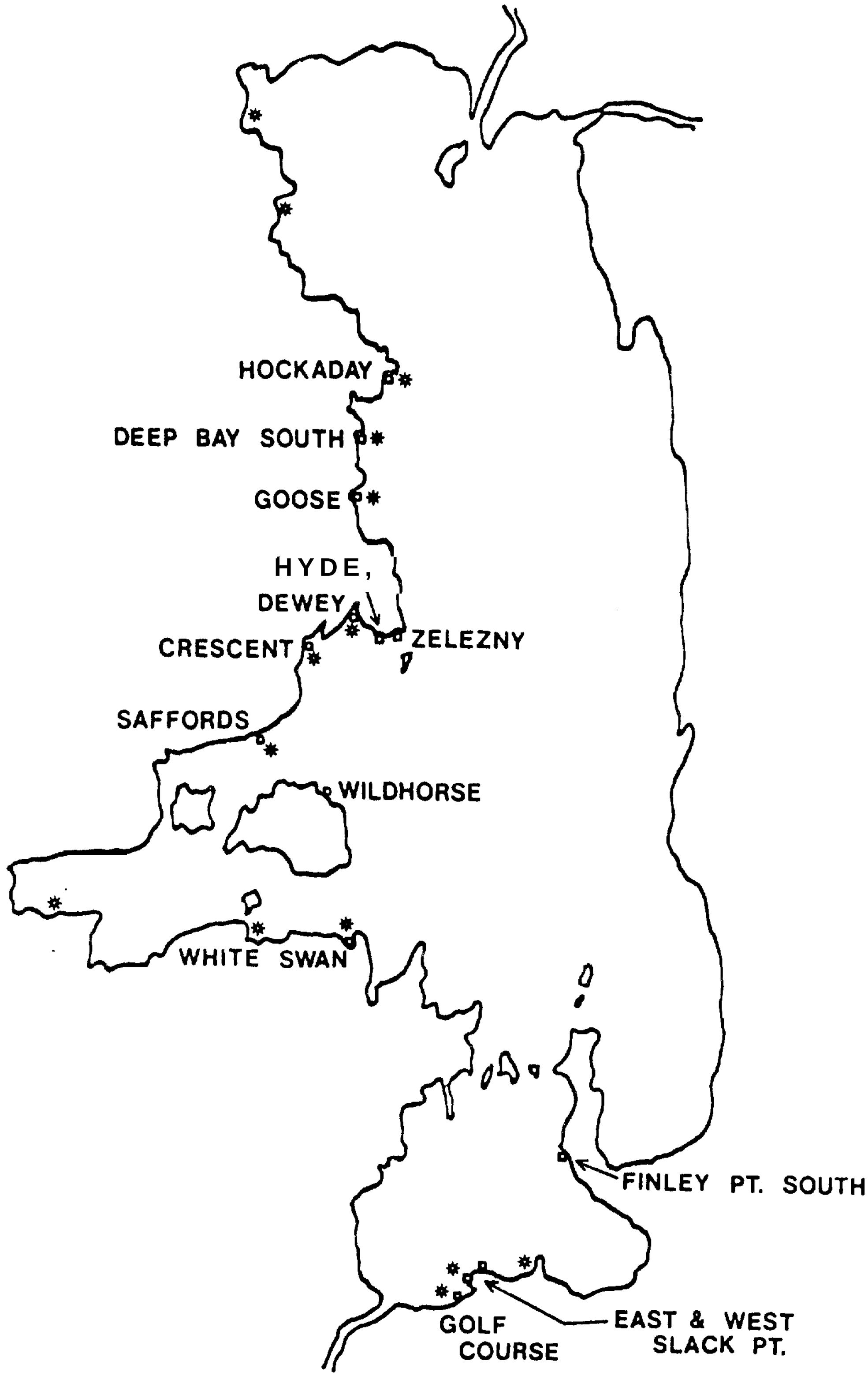


Figure 2. The location of study sites for potential spawning habitat on the west and south shores of Flathead Lake. Historic spawning areas are marked with an asterisk.

change its original oxygen content by mixing with lake water or by aeration. We recommend in situ measurement for any future habitat assessment.

Substrate size composition was evaluated by taking photographs of representative 1-meter square plots, using a Nikonos underwater camera (Ektachrome 400 film, no flash). Each photograph included a meter stick to establish scale. At least two, and as many as ten photographs were taken at each elevation transect, dependent on the variation of substrate observed and the length of the transect. The resulting slides were projected on a screen, the scale adjusted to life-size with a zoom projection lens. The size of particles at 100 points on the image was measured. Geometric mean particle size and fredle number were calculated according to methods previously described by Beattie et al. (1985).

Creel Surveys

Winter Fishery

In 1985, the ice fishery began in late January and lasted through February. Flathead Lake froze completely in early January. A randomized block creel survey was conducted over successive seven day strata. One weekday and weekend day were chosen randomly as sample days in each period. Sampling frequency was doubled in mid February, as the harvest quota was approached. Ice fishermen were counted at hourly intervals to estimate fishing pressure. Interviews with fishermen produced estimates of catch rate. The fishery was closed by joint action of the Montana Fish and Game Commission, and the Confederated Salish and Kootenai Tribes when the harvest reached 50,000 fish.

Summer Fishery

The summer fishery in 1985 was monitored by similar means. The period from June 1 to September 7 was divided into two-week strata. Four weekdays and three weekend days were chosen randomly as sample days. Two aerial surveys were flown in fixed wing aircraft on each sample day, to count fishing boats in each of five areas of the lake. The times of these flights were also chosen randomly so that one flight was made between 0600 and 1230 and one between 1230 and 1900 hours. Fishermen were interviewed at various access points around the lake and while fishing to determine catch rate and catch species composition.

The daily estimates of fishing pressure and catch rate were averaged over each two-week period. The average boat counts were expanded to the total length of the period to derive the pressure estimate. Harvest for each period was calculated from the catch rate within each period, i.e., pressure (angler-hours) x catch rate (fish/hour) = catch.

Estimation of Mysis Relicata Abundance

We sampled opossum shrimp, *Mysis relicta*, monthly at six stations on Flathead Lake. The six stations (Figure 3) represent the variety of depth environments found in the lake. The stations were sampled at least one hour after dark, within seven days of new moon because the diel vertical migration of mysid shrimp is suppressed by moonlight. We pulled replicate vertical hauls of a 1.0-meter diameter, 500 micron Nitex mesh Wisconsin plankton net with an electric winch. The winch retrieved the net at 0.5 meters/second. The entire water column was sampled at each station. Samples were preserved in 95 percent denatured ethanol. Adult (>10 mm) and juvenile (<10 mm) mysids in each sample were counted under a stereo microscope.

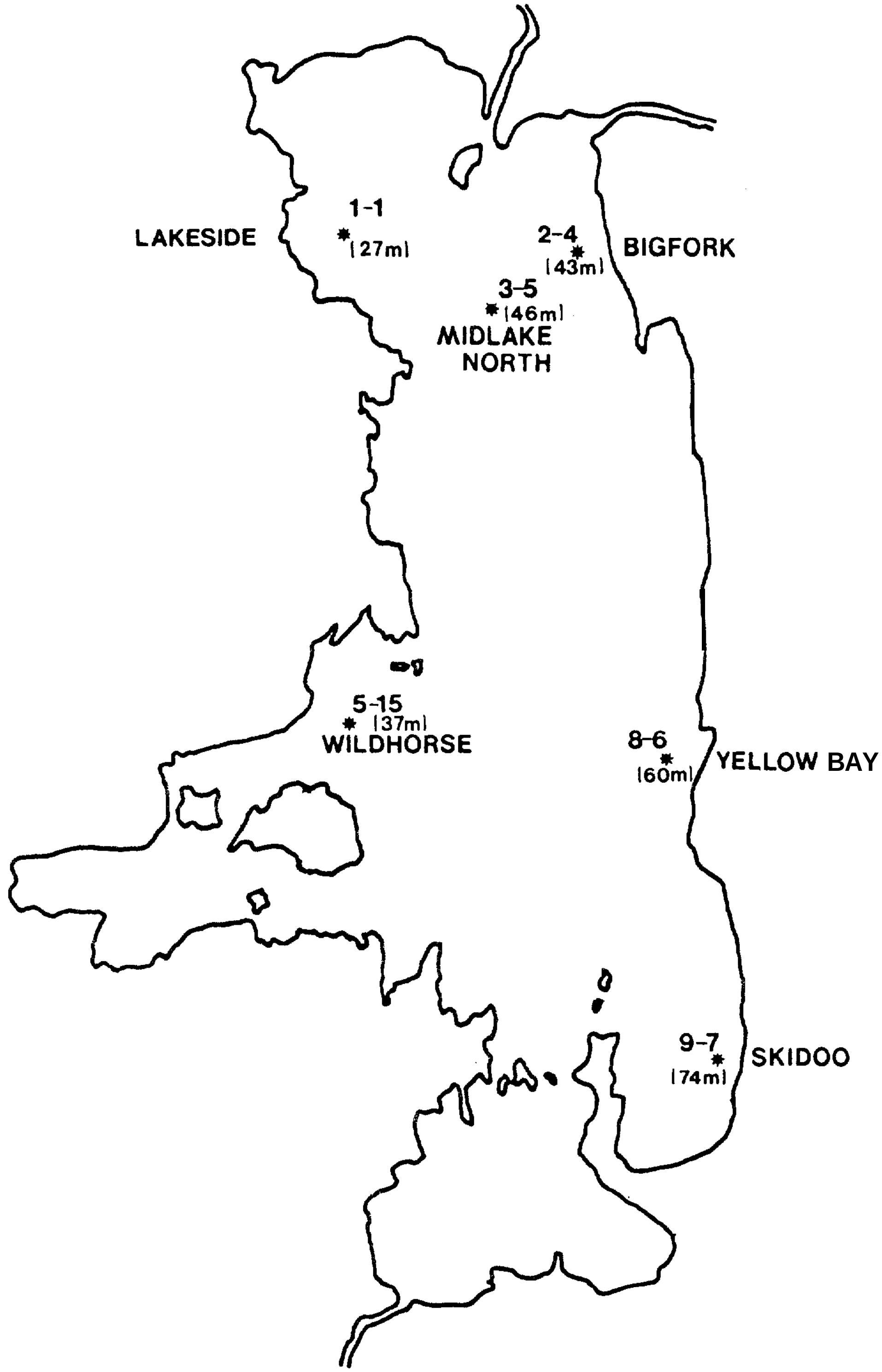


Figure 3. Sampling stations for zooplankton and mysid shrimp on Flathead Lake. The depth at each station is noted.

RESULTS AND DISCUSSION

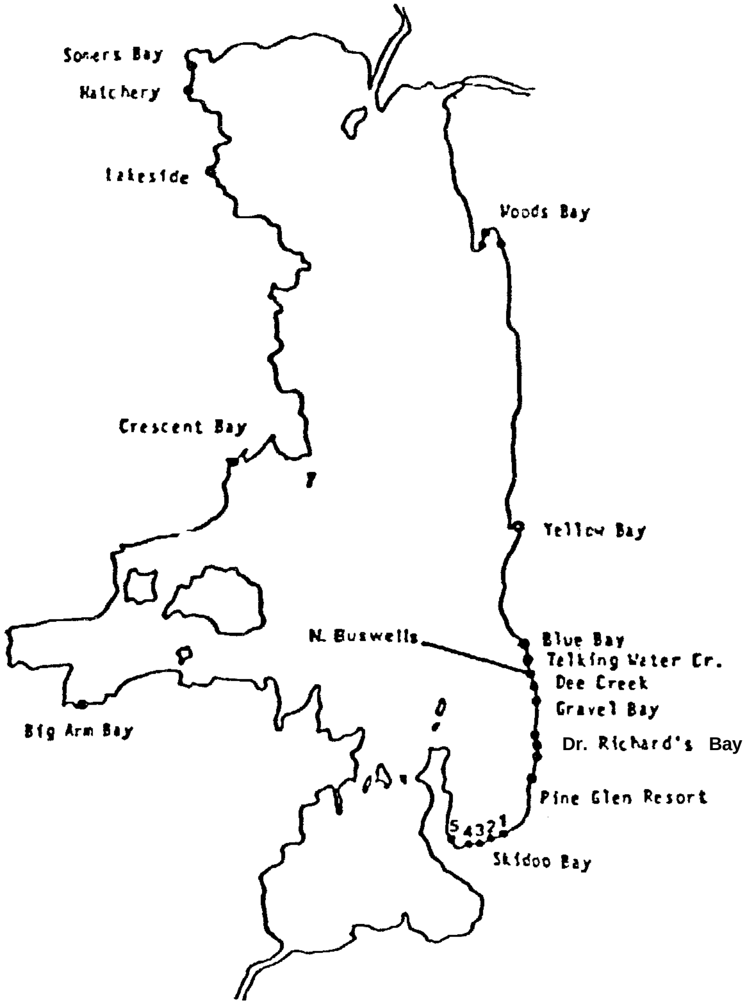
Spawner Surveys

Surveys of Flathead lakeshore spawning began at the end of October and were completed by December 10, 1985. Observation of many shoreline areas ended in mid November due to early freeze up. In spite of this factor, the redd count total (1,153) was the highest since 1981, when this study began. The distribution of redds at the known lakeshore spawning areas was markedly different than in previous years, as was the depth distribution. Helicopter surveys located two "new" spawning areas: in Juniper Bay, 0.25 miles north of Somers Hatchery, and at Lindner's (Wood's Bay) on the east shore (Figure 4). As in previous years, the majority of spawning took place along the eastern and southern shores of Skidoo Bay, from Pineglen to Thurston's. Within this stretch of shoreline, spawning was concentrated at Pineglen and from Staples to Orange House. Spawning also occurred at Talking Water Creek, Woods Bay, and Crescent Bay. The redd count at Talking Water Creek was the largest at that site in five years.

Compared with previous years, spawning was sparse or non existent at Yellow Bay, Gravel Bay, and at Thurston's (Skidoo Bay V). Parent year escapement to Yellow Bay in 1981 was substantial, when 152 redds were counted, but egg-to-emergent fry survival was only 0-10 percent the following spring. Low dissolved oxygen and substrate movement reduced egg survival. The mean dissolved oxygen concentration in the substrate of deep-water redds was 2.8 mg/l in January, 1982. Movement of the substrate associated with high flows from Yellow Bay Creek agitated and killed eggs in shallow redds (Decker-Hess and Graham 1982).

The low 1985 escapement to Gravel Bay may relate to the low parent year escapement in 1981, when only 37 redds were counted there (Decker-Hess and Graham 1982). However, comparison of redd counts in 1981 with those in 1985 at the various lakeshore spawning areas does not show a clear relationship. Redd counts in 1985 at Wood's Bay, Talking Water Creek, Buswells, Pineglen, and Skidoo Bay exceed 1981 redd counts by a factor of two to ten. This suggests that in Flathead Lake kokanee do not return to spawn at the specific site where they were born. The spawner/recruitment relationship is also confounded by variable egg survival at the different spawning areas.

Spawning at Crescent Bay was enhanced by fry plants in 1982. Crescent Bay was planted with 27,000 tetracycline-marked kokanee fry in the spring of 1982 (Decker-Hess and Graham 1982). We examined 40 spawners collected at Crescent Bay in 1985 but found no marks in vertebrae or ribs on any of the 40 fish. Other marking experiments have suggested that tetracycline does not leave a permanent mark in very young fry (Jim Petersen, MDFWP Fish



AREA	REDD COUNT				
	1981	1982	1983	1984	1985
WOOD'S BAY	57	188	76	176	112
YELLOW BAY	152	197	79	0	0
BLUE BAY	45	55	45	30	38
TALKING WATER CR.	12	4	33	45	164
NORTH BUSWELLS	0	0	15	115	71
DEE CREEK	0	16	0	0	0
GRAVEL BAY	37	238	187	326	21
DOC RICHARDS BAY	101	87	52	101	34
PI NEGLEN	45*	85	0	90	207
SKIDOO BAY	103	126	200	169	351
BIG ARM BAY	0	0	0	13	0
CRESCENT BAY	5	31	19	18	99
LAKESIDE BAY	0	2	2	0	0
HATCHERY	15*	10*	12*	50*	N/A
SOMERS BAY	0	0	28	1	59
TOTAL	652	1039	748	1134	1156

* ESTIMATED COUNTS

Figure 4. **Kokanee spawning areas and redd counts** on Flathead Lake, from 1981 to 1985.

Pathologist, pers. comm.). The strong 1985 escapement to Crescent Bay cannot be attributed to a strong parent year class, since the 1981 redd count there was only five redds.

The timing of the Flathead lakeshore run appeared similar to previous years. Previous surveys have shown that lakeshore spawning begins in late October, and peaks about the first of November. The timing of a second later peak has varied more, from mid to late November (Figure 5). Spawning at all lakeshore sites adheres to this temporal pattern. The 1985 redd count does not show this later peak because surveys were prevented by freeze-up.

Four year-old (III+) fish continue to dominate the lakeshore spawning run. Ninety-five percent of the spawners collected from lakeshore areas were age III+, and five percent were age IV+. This age composition characterized all areas except Woods Bay East, where 21 percent of the spawners were IV+. Age II+ fish were collected only at the Somers Hatchery. All spawners collected in the Swan River were age III+. The contribution of IV+ fish to the spawning year class has declined from over 65 percent to 5 percent during the last six years (Figure 6). Spawner age composition showed similar variation in the 1970's, with IV+ fish comprising from 20 to 65 percent of the year class (Hanzel 1984). Earlier maturity in kokanee populations may be caused by the higher growth rate attained when intraspecific competition is low (Fraley and Graham 1982). In their final year in Flathead Lake, the 1985 spawners were competing primarily with a relatively weak 1986 year class.

Weekly snorkel surveys to count the number of kokanee spawners in the Swan River yielded sound estimates of run strength and timing. Spawners began arriving at the dam on October 1. A large number of fish moved upstream coincident with high runoff on October 20 (Figure 7). A late run of fish arrived at the dam about November 15. The last count, on December 2, showed at least 600 fish at the dam. Later counts were precluded by freeze-up. Spawning fish were observed at the powerhouse, two miles downstream, on October 21. We also observed small schools of spawners at the powerhouse and 0.5 miles below the powerhouse in late November. Total escapement to the Swan River was estimated to be 1,350, by combining the peak counts from below the dam and at the powerhouse on October 21 and November 18. The 1985 run peaked a month later than in 1984 (Rumsey, 1985).

Some uncertainty arose in counting the numbers of spawners below the dam because a number of kokanee used the fish ladder to pass the dam and reach spawning areas in Swan Lake. We recovered a kokanee, tagged in Flathead Lake in the spring of 1985, on spawning grounds at the south end of Swan Lake. Kokanee which are resident in Swan Lake spawn concurrently at this site. The number of Flathead Lake kokanee that spawn in Swan Lake may depend on fall runoff, as the fish ladder is more accessible when discharge is high (Scott Rumsey, pers. comm.). Samples from previous years

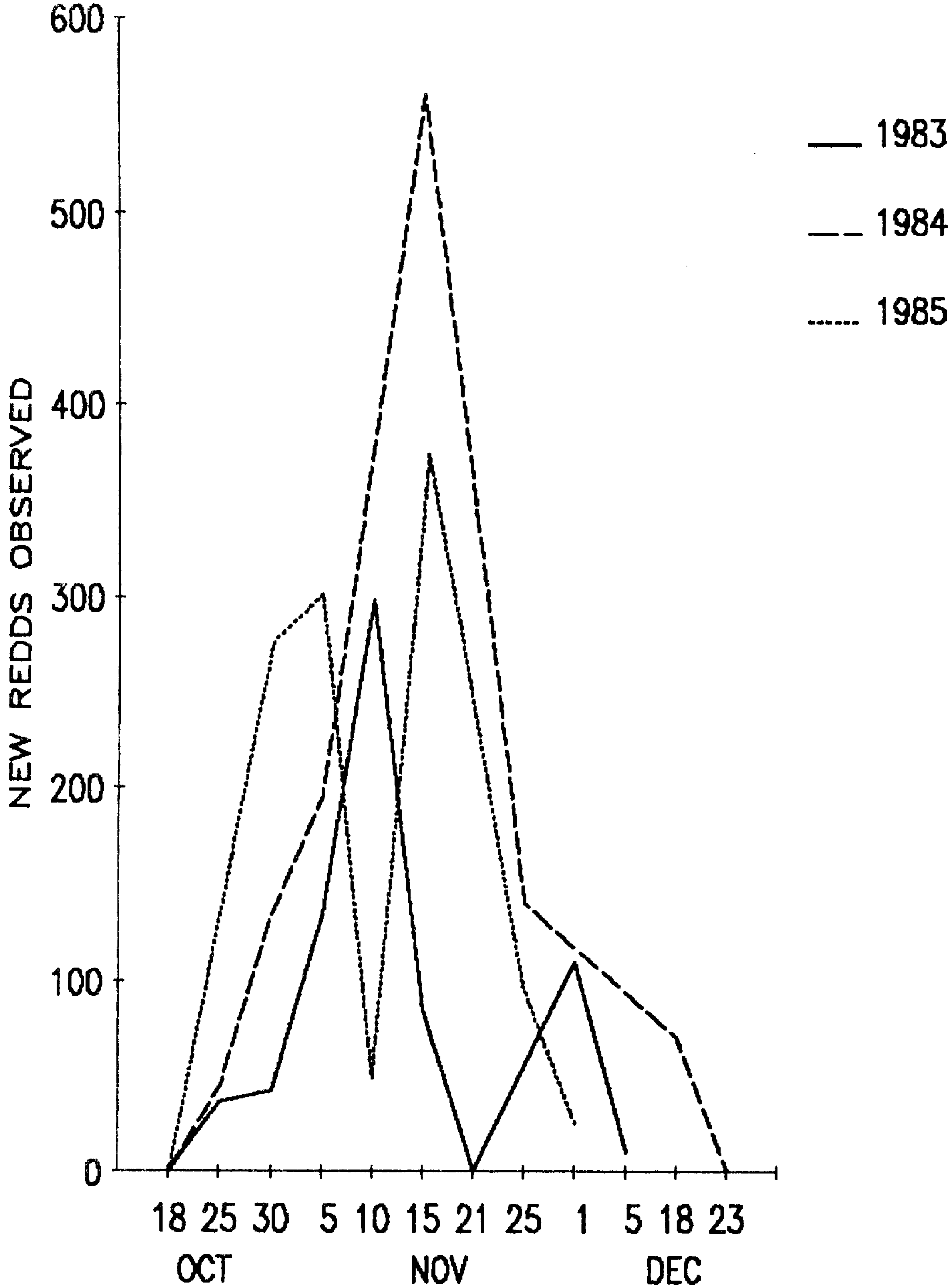


Figure 5. The timing of the kokanee spawning run on the shoreline of Flathead Lake, from 1983 to 1985.

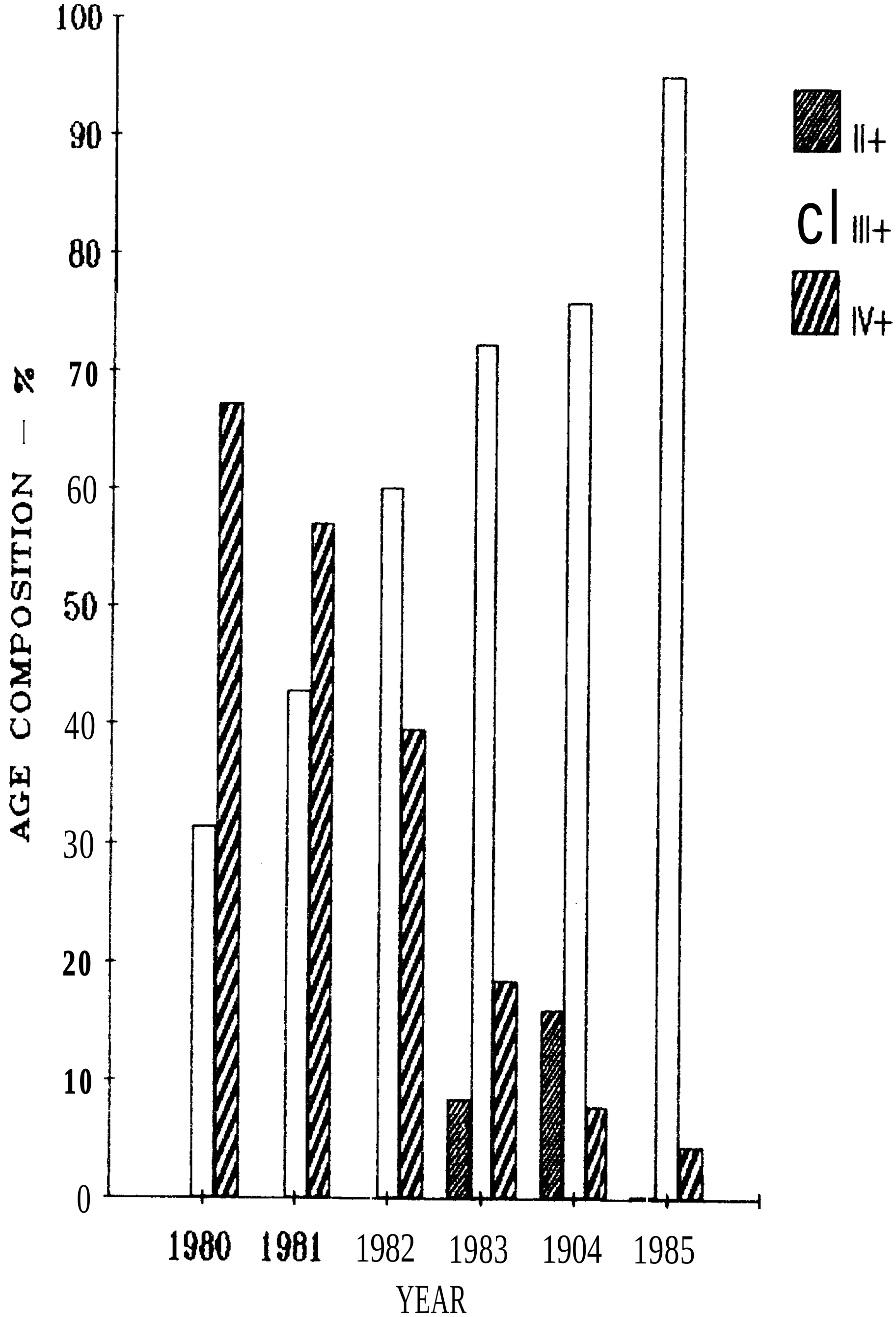


Figure 6. The age composition of kokanee spawners in the Flathead system from 1980 to 1985 (from Hanzel 1984).

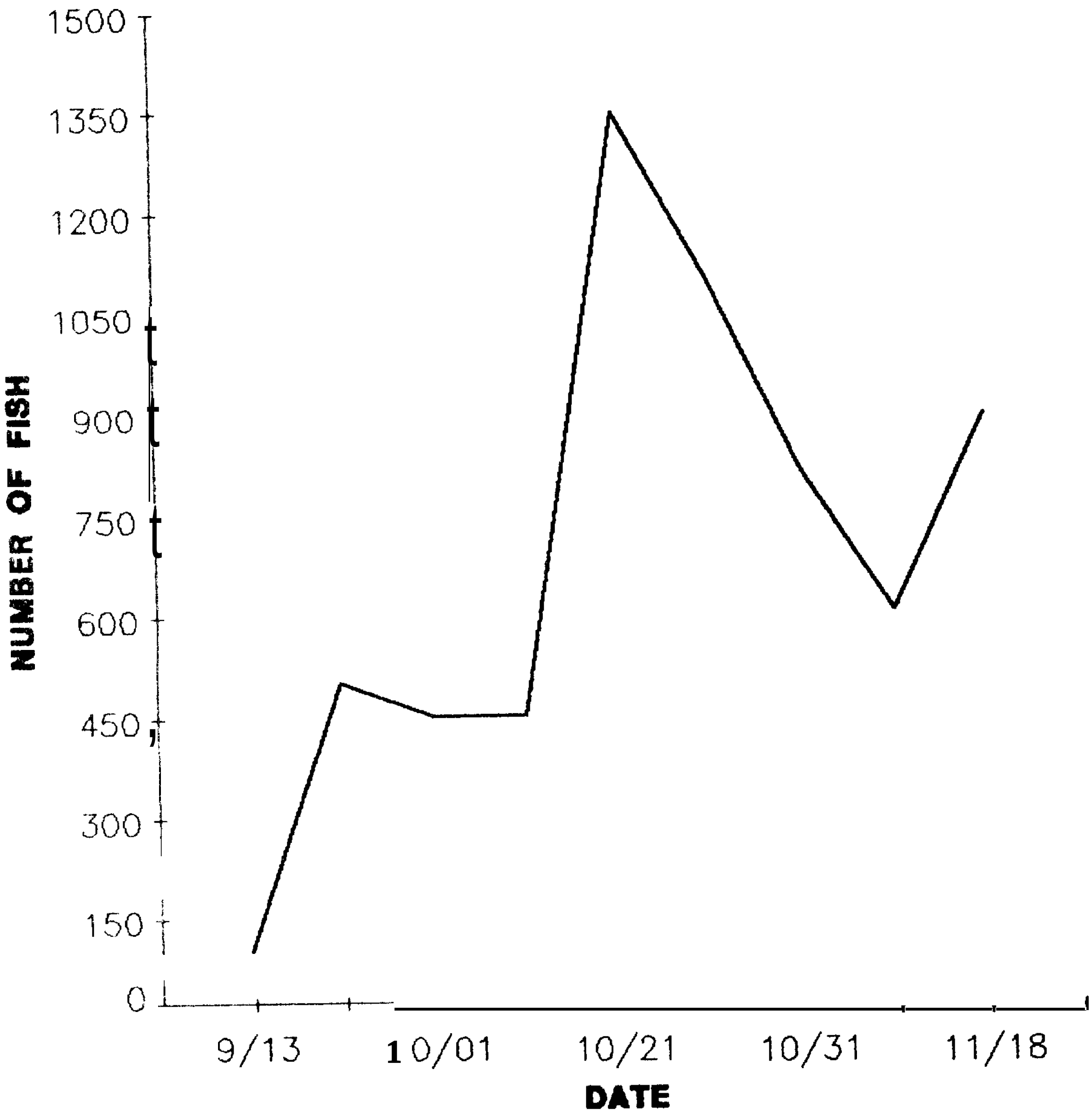


Figure 7. **Timing** and abundance of the kokanee spawning escapement to the Swan River in 1985.

of kokanee spawning in Swan Lake have shown two size classes. The larger size class may represent fish that mature in Flathead Lake. Kokanee that mature in Swan Lake are significantly smaller. We have not quantified the escapement from Flathead to Swan Lake or the interchange between the two populations.

The depth distribution of kokanee redds at lakeshore spawning sites in Flathead Lake was markedly different in 1985 compared to the previous four years. Over 91 percent of the redds (Figure 7) were in shallow water, above the 1985-86 minimum pool elevation of 2,884.5 feet. From 1981 to 1984, 50-63 percent were above minimum pool elevation. In 1985 we found very few redds in areas where spawning had occurred in deep water in previous years, e.g., Woods Bay, Gravel Bay, and Blue Bay. The depth distribution of redds at each lakeshore spawning area in 1985 is shown in Appendix Figure 1. The factors which influence such a shallow spawning distribution are not understood.

Flathead Lake was near full pool later into the year in 1985 due to very high runoff in September and October and lower discharge at Kerr Dam (Figure 9). November and December lake levels were one to two feet higher during 1985 than 1984. The lowest lake level, 2,884.5 feet, was reached on March 1, 1986. The lake was held below 2,885 feet from February 25 to April 1, 1986.

From previous studies, we know that eggs deposited in shallow water around the shores of Flathead Lake suffer mortality as high as 90-100 percent within seven days after they are exposed by lake drawdown (Decker-Hess and McMullin 1982, Decker-Hess and Clancey 1983). Because such a high percentage of the redds were at high elevation in 1985, we expect very poor survival to emergence from the 1985 lakeshore run.

Egg Survival Experiments

Previous experiments on Flathead Lake (Decker-Hess and McMullin 1983, Decker-Hess and Clancey 1984) and in the Flathead River (McMullin and Graham 1981, Fraley and Graham 1982) have measured the tolerance of kokanee eggs to exposure in a variety of spawning habitats. The 1986 experiment in Skidoo Bay was designed to increase the accuracy of estimates of egg mortality rates in redds above minimum pool, in groundwater seep zones, and in dry sites. The Blue Bay experiment was designed to clarify which environmental factors are contributing to the very low survival from egg to emergence observed there the past three years.

We planted eyed eggs at the Skidoo Bay V (Thurston's) site at three elevations above minimum pool; 2,884, 2,886, and 2,888 feet. Eggs at the two deeper elevations showed complete mortality within three weeks because of low dissolved oxygen within the substrate. Oxygen concentrations at 2,888 and 2,886 feet averaged

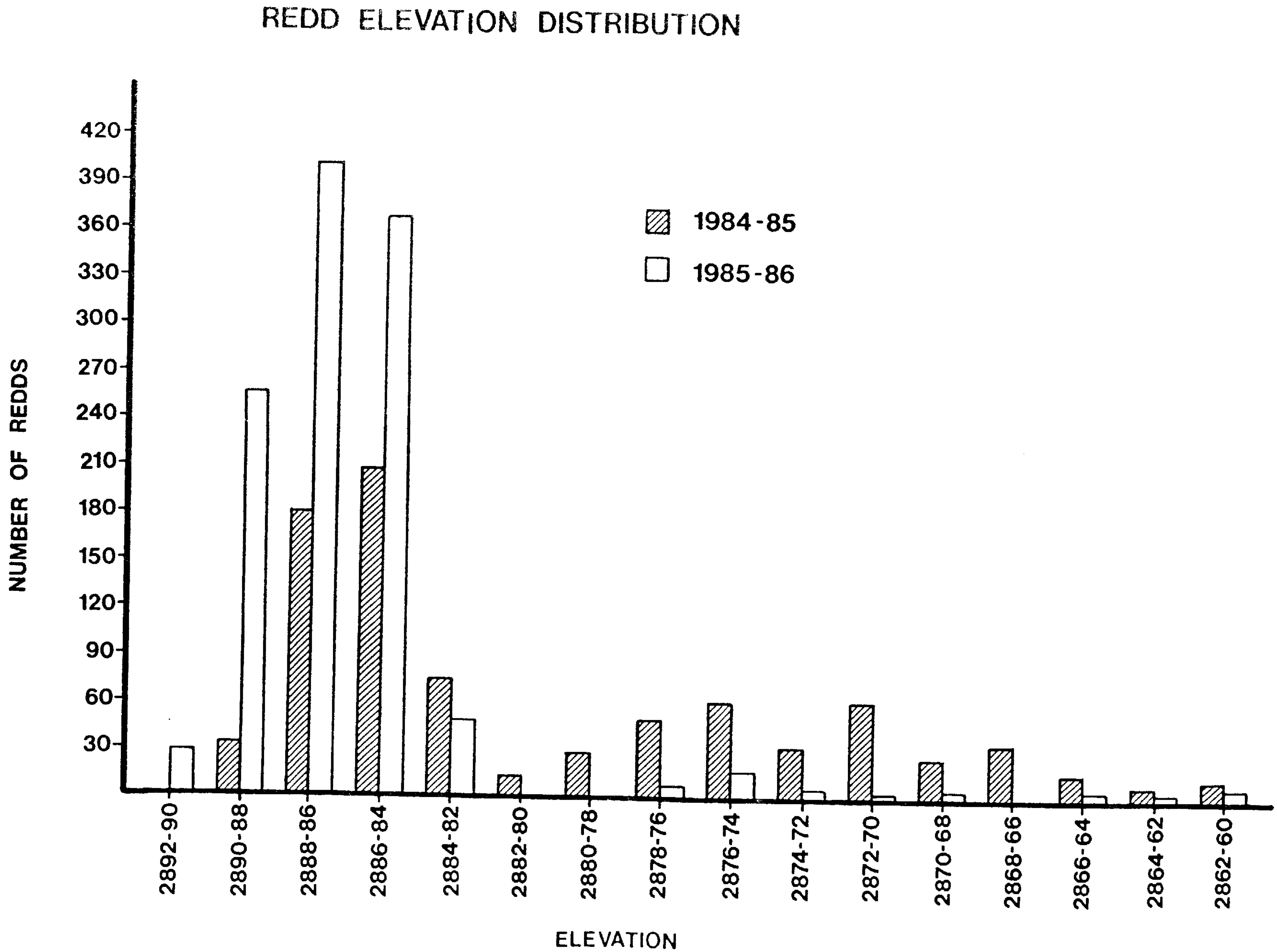


Figure 8. The depth distribution of kokanee redds at Flathead Lake shore spawning areas in 1984 and 1985.

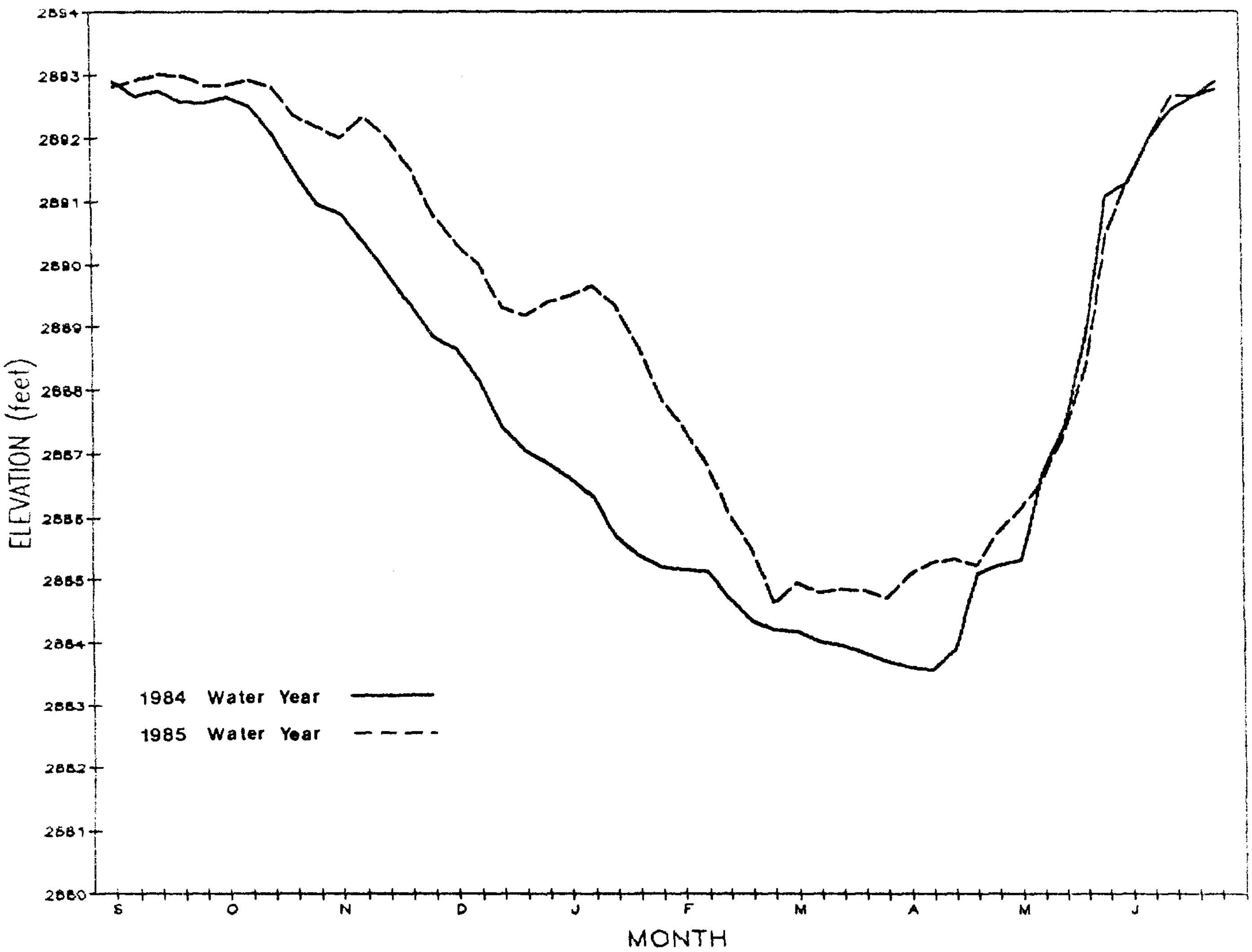


Figure 9. Water level fluctuations in Flathead Lake during water years 1984 and 1985.

2.7 mg/l and 4.6 mg/l, respectively (Table 1). The substrate at both elevations contained a high percentage of fine gravel and sand. Many studies have identified dissolved oxygen as the factor which limits the survival of incubating salmonid eggs. Concentrations above 6.0 mg/l characterize ideal spawning habitat (Decker-Hess and Clancey 1984, Shumway et al. 1964, Alderdice et al. 1958).

We planted two lines of eggs at 2,884 feet at the Skidoo Bay site, one in a zone of active groundwater seepage, and one outside of the seep (the "dry" site). Drawdown exposed the dry site on January 18, 30 days after the experiment began. Egg survival outside of the groundwater seep, measured at two-week intervals, declined steadily from 98 percent at day 10 to 2 percent at day 45 (Figure 10). The mean dissolved oxygen concentration during this period was 5.6 mg/l, showing a consistently upward trend. We could not measure groundwater apparent velocity because the seepage meters are inaccurate in water shallower than two meters. Eggs were not planted in the groundwater seep area until after it had been exposed by drawdown. Egg survival within the groundwater seep was 86 percent after 40 days of exposure (Figure 9). The mean dissolved oxygen concentration inside the seep area was 4.4 mg/l.

At Blue Bay, we planted lines of eyed eggs at three elevations below minimum pool: 2,880, 2,875, and 2,870 feet. The deepest line, at 2,870 feet, showed rapidly increasing mortality after 35 days incubation (Figure 11). Dissolved oxygen concentration varied widely across the sampling points at this elevation (Table 2). The mean dissolved oxygen concentration was 2.7 mg/l. Groundwater apparent velocity averaged 0.17 cm^3/cm^2/hour. Survival at 2,875 feet was highly variable. Early and late samples showed complete mortality, but single replicates sampled after 53 and 70 days showed about 80 percent survival. Groundwater apparent velocity averaged 0.30 cm^3/cm^2/hour at 2,875 feet. Average dissolved oxygen was 4.9 mg/l, slightly lower than at 2,880 feet. Eggs survived longer at 2,880 feet, with samples showing 86 percent survival after 78 days incubation. Mortality increased rapidly following that date, reaching 100 percent after 92 days. Groundwater apparent velocity averaged 0.25 cm^3/cm^2/hour at 2,880 feet. The average dissolved oxygen concentration was 5.7 mg/l.

The Skidoo Bay experiment verified that kokanee eggs incubating in redds above minimum pool cannot survive unless they are wetted by groundwater. Eggs in the dry area did not survive longer than six days after exposure. Eggs within groundwater seeps survived much longer, even where the dissolved oxygen concentration was below 6.0 mg/l. Environmental conditions in spawning gravels vary greatly. Measurements of dissolved oxygen and groundwater apparent velocity show large spatial and temporal variability. Our results suggest that low dissolved oxygen concentration can be compensated for by high rates of groundwater discharge. Groundwater discharge and substrate size influence the

Table 1. Mean groundwater apparent velocity (V*=cm^3/cm^2/hour) and the mean range of dissolved oxygen (D.O.=mg/l) in artificial redds planted at three elevations at Thurston's (Skidoo Bay V). Apparent velocity was not measured at 2,084 feet.

		2888 feet			2886 feet			2884 feet		
			D.O.			D.O.			D.O.	
DATE	Day No.	V*	x̄	range	V*	x̄	range	V*	x̄	range
12/19	2	.24	.2	0.0-0.3	.43	3.0	0.7-6.8		3.6	1.6-4.9
12/27	10	.17	3.3	0.9-6.7	.24	6.0	2.2-10.0		3.1	2.0-3.7
l/3	17	.20	2.6	2.6	.37	3.9	2.5-6.5		4.5	1.7-7.2
l/10	24	.31	.3	0.0-0.9	.25	5.5	0.4-10.3		5.5	2.8-7.8
l/17	31	.14	7.6	4.5-10.6	.25	4.4	2.4-5.9		5.3	0.6-9.8
l/24	38	.06	2.1	0.0-3.7		5.7	5.5-5.8		6.3	5.2-0.2
l/31	45	.28	3.0	0.7-5.7		3.6	1.1-5.3		10.7	10.4-11.0

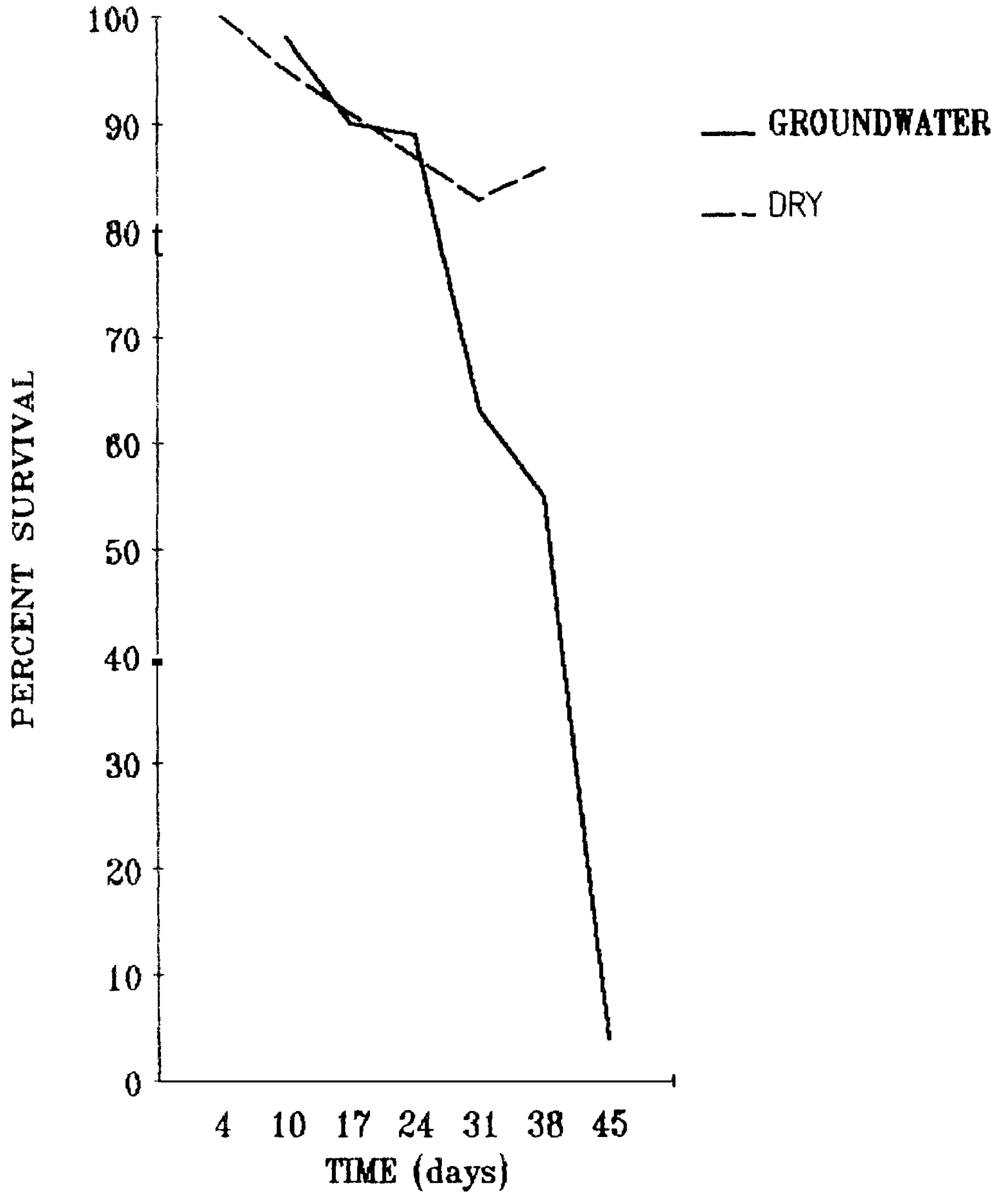


Figure 10. Survival of artificially planted kokanee eggs in dry and groundwater-wetted sites at Thurston's (Skidoo Bay V) on Flathead Lake.

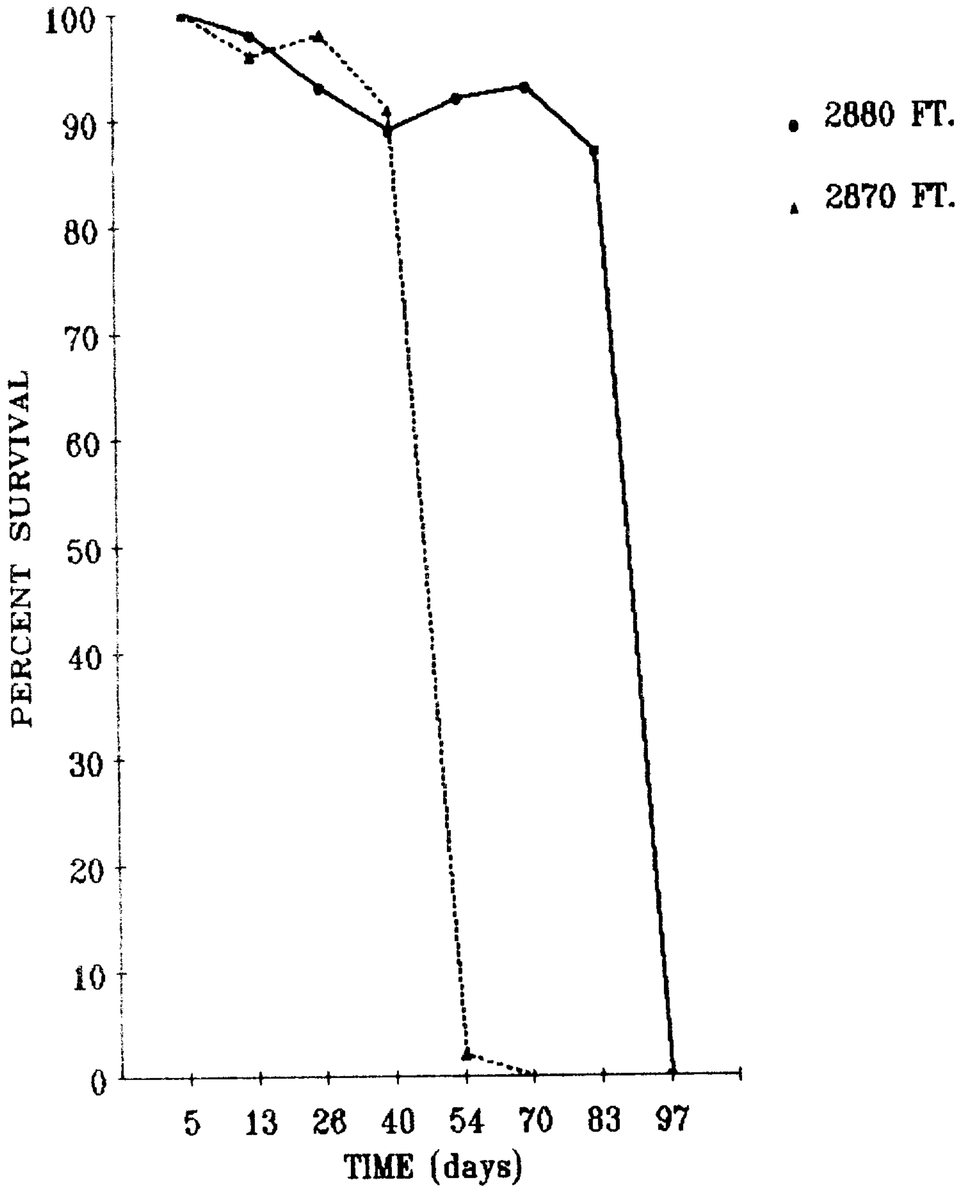


Figure 11. Survival of artificially planted kokanee eggs at two elevations at Blue Bay, a spawning area below minimum pool on the east shore of Flathead Lake.

Table 2. Mean groundwater apparent velocity ($V^*=cm^3/cm^2/hour$) and the mean range of dissolved oxygen (D.O.=mg/l) in artificial redds planted at three elevations at Blue Bay.

DATE	Day No.	2880 feet			2875 feet			2870 feet		
			D.O.			D.O.			D.O.	
		V*	$\bar{x}$	range	V*	$\bar{x}$	range	V*	$\bar{x}$	range
12/23	5	.27	2.0	0.0-3.1	.46	3.7	2.5-5.1	.37	3.7	1.9-5.1
12/31	13	.12	2.9	0.0-6.2	.19	3.2	0.7-5.1	.11	4.0	0.9-6.8
1/13	26	.22	4.2	0.0-8.3	.32	5.2	2.4-10.3	.37	6.4	1.8-11.0
1/27	45	.25	3.3	0.0-5.2	.33	2.8	4.5-8.2	.27	6.8	2.2-9.8
2/10	54	.14	4.7	0.0-7.5	.43	5.3	3.5-6.2	.24	4.8	2.9-7.1
2/26	70	.00	2.5	0.3-3.7	.24	5.7	4.3-7.5	.15	6.5	5.6-7.5
3/11	83	.06	2.6	0.0-5.5	.13	5.7	5.0-6.4	.20	5.7	2.9-8.4
3/25	97	.31	1.4	0.0-2.8	.30	5.0	2.8-6.2	.31	3.5	0.6-5.3
Average		.17	2.9		.30	4.9		.25	5.7	

rate that water flows over incubating eggs. The rate at which oxygen diffuses into eggs, and the rate at which metabolic wastes are removed around the egg membrane are enhanced as the exchange rate in the substrate increases.

Because of the diverse and variable environment at lakeshore spawning areas, measurements of egg survival in natural redds above minimum pool in past seasons have also varied greatly. Most spawning occurs in zones of groundwater discharge. Egg survival to the eyed stage is commonly 70 - 80 percent in these areas (Decker-Hess and McMullin 1983). As drawdown causes the elevation of the groundwater table to drop, egg mortality in exposed redds increases. Combining data from many spawning areas, Decker-Hess and Clancey (1984) showed a strong negative correlation between egg survival and the length of exposure by drawdown. Their conclusion that eggs can survive from 45 to 90 days of exposure is based on samples from redds kept wetted by groundwater. Results this year show that eggs survive less than a week in dry redds. Egg survival can also be adversely affected by air temperatures below -10°C (Fraley and Graham 1982). In general, eyed kokanee eggs are remarkably tolerant, and survive long periods in moist gravel. Alevins, however, cannot tolerate desiccation. They die within a few days of hatching unless the redd is kept saturated.

Experiments at Blue Bay confirm earlier findings of poor survival to emergence (Decker-Hess and Clancey 1984). Eggs survive about twice as long at shallow depths than at deeper elevations, probably due to higher dissolved oxygen concentration. Dissolved oxygen was less than 6.0 mg/l in most of the samples taken at Blue Bay. Dissolved oxygen concentration in groundwater is related to the retention time of the aquifer as well as the presence of decomposing organic matter in the sediments. As noted in the preceding discussion, high groundwater discharge compensates for low dissolved oxygen concentration, at least through the early stages of eff development (Phillips et al. 1975). The Blue Bay experiment showed that eggs survive well for a period of time ranging from 80 days at 2,880 feet to 40 days at 2,870 feet. Mortality then increased sharply, as the increasing metabolic demands of the kokanee embryos exceeded the availability of oxygen in the substrate.

Experiments in natural spawning areas allow factors such as groundwater discharge, dissolved oxygen, substrate size, and temperature to interact in determining egg survival. To clarify the effect of variation in any one of these factors on egg survival, all other factors must be held constant. Artificial redds built in hatchery channels have proven useful in investigating the effects of air temperature and desiccation on egg survival. The hydrologic environment in lakeshore redds, however, is difficult to duplicate in hatchery channels.

Drawdown exposure is the primary factor that limits the reproductive success of lakeshore spawning kokanee. Viable alevins and fry emerge only from redds near minimum pool which are continually wetted or exposed briefly or from the few redds in high-volume groundwater seeps. At deeper spawning areas below minimum pool a low dissolved oxygen concentration within the substrate limits egg survival. This year's experiment at Blue Bay, and previous work at Yellow Bay (Decker-Hess and McMullin 1983, Decker-Hess and Clancey 1984), demonstrate the negative effect of low dissolved oxygen. In contrast, where groundwater dissolved oxygen is 6.0 mg/l or greater, e.g., Gravel Bay, survival to emergence ranges from 20-30 percent (Decker-Hess and Clancey 1984, Beattie et al. 1985).

West Shore Habitat Surveys

Spawner surveys in the 1950's and undocumented historical records indicate that kokanee once spawned in a number of shoreline areas on Flathead Lake (Stefanich 1953 and 1954) in addition to those east shore areas where spawning has been concentrated in the last five years. These historical spawning areas included many sites along the western shore and in South Bay (Figure 2). We searched these areas for beaches composed of suitable size substrate. We assumed that if the operations of Kerr Dam were more favorable to successful kokanee reproduction, and if suitable environmental factors still characterized these beaches, that successful spawning could occur. Fifteen potential areas were chosen for study. At most of these sites suitable substrate exists only at elevations above minimum pool (2,883 feet). The beach slope commonly decreases at greater depth where deposits of fine substrate accumulate.

Criteria defining spawning habitat were set based on extensive studies of active spawning areas on the east shore of Flathead Lake (Decker-Hess and McMullin 1983, Decker-Hess and Clancey 1984, Beattie et al. 1985). Ideal spawning habitat is defined by substrate composed primarily of material less than 50 mm in diameter, with fine material (<6.5 mm) comprising no more than 20 percent of the total. The mean particle size should be 10 to 25 mm. Dissolved oxygen in the interstitial water should be above 6.0 mg/l. Groundwater apparent velocity should be 0.05 cm^3/cm^2/hour or higher. We examined water chemistry for elevated levels of bicarbonate, chloride, sulfate, and nitrate. Domestic water use will contribute 50-100 mg/l of bicarbonate, 20-50 mg/l of chloride, 20-40 mg/l of nitrate, and 15-30 mg/l of sulfate to groundwater (Glenn Phillips, MDFWP pers. comm.). Contamination of groundwater might be expected in heavily developed shoreline areas around Flathead Lake.

A brief discussion of our findings at each of the fifteen areas follows. We took into account that groundwater discharge and dissolved oxygen might fluctuate seasonally. We measured these factors during the summer at several known spawning areas and compared them with measurements during the spawning and incubation period (Table 3). There were no consistent differences between summer and fall/winter values at spawning areas.

Hockaday Bay. Clean, suitably-sized substrate exists along the western and northern shoreline of the bay. At depths greater than five meters the bottom profile drops sharply, and the bottom is covered with larger rubble and boulders. Mean values of groundwater apparent velocity at two sites within the bay varied from 0.15 to 0.22 cm^3/cm^2/hour (Table 4), and did not vary seasonally. Mean dissolved oxygen levels varied from 5.0 to 9.1 mg/l. The shore upslope of the site is not heavily developed, and water quality assays did not indicate contamination. In general, Hockaday Bay fits the criteria for spawning habitat.

Goose Bay. Residents in this area told us that kokanee used to spawn along the shoreline here, but could not give specific dates. Bottom substrate was larger than optimum, as indicated by mean particle sized ranging from 31 to 40 mm (Table 4). Patches of smaller, more suitable substrate exist. Mean dissolved oxygen concentration (4.1 mg/l) was too low during the spawning season. Groundwater apparent velocity varied seasonally but was adequate in the fall (0.40 cm^3/cm^2/hour. Higher than average bicarbonate and total dissolved solids in one sample indicate possible groundwater degradation (Table 5). Overall, Goose Bay habitat is not suitable for kokanee spawning.

'Neill's Deep Bay South). This area attracted spawners until the mid 1960's, when fill from construction of state Highway 93 above the shore covered the original substrate. Fines comprised 27 percent to 48 percent of the gravel. Average dissolved oxygen level during the spawning season was too low to maintain viable embryos (5.1 mg/l). Groundwater apparent velocity was adequate, averaging 0.12 cm^3/cm^2/hour. Seeps are visible during the winter on the exposed beach. The shoreline is fairly heavily developed, and high bicarbonate and total dissolved solids suggest groundwater contamination. This site would not support kokanee spawning.

Zelezney, Hyde, and Dewey Bays. These bays are typical of many west shore sites where the shoreline is rocky and steep, but smaller, shallow gradient beaches have been built up at the protected head of the bay. Dissolved oxygen levels during the spawning season were marginal at Zelezney (4.1 mg/l), but adequate at Hyde Bay (6.6 mg/l). We did not obtain a reliable measurement of dissolved oxygen at Dewey Bay. Substrate size was suitable at these three sites, but mean particle size ranged up to 34 mm at Hyde Bay and 29 mm at Zelezney Bay. One water sample from

Table 3. Seasonal variation of mean groundwater apparent velocity at three spawning sites on the east shore of Flathead Lake.

SITE	APPARENT VELOCITY (cm^3/cm^2/hour)		
	June/July	August/September	October/November
Gravel Bay	.13	.16	.17
Skidoo Bay	.22	.20	.21
Yellow Bay	.32	.19	.21

Table 4. Potential spawning habitat on the west and south shores of Flathead Lake. Suitable spawning habitat is defined as having the mean particle size less than 25 mm, fines less than 20 percent, groundwater discharge above cm^3/cm^2/hour, and dissolved oxygen above 6.5 mg/l. Geometric mean particle size abbreviated (d_g).

Location	Date of Sample	Dissolved Oxygen (mg/l) Mean	(n)	Range	Apparent Velocity cm^3/cm^2/hour Mean	(n)	Range	Substrate Compos. d_g-mm	%Fines
Hockaday Bay W.	6/25/85				0.17	(7)	.11 - .22		
	9/10/85	7.6	(4)	5.6 - 8.9	0.22	(7)	.15 - .27		
	10/30/85	5.0	(4)	1.3 - 7.7	0.17	(7)	.05 - .29		
Hockaday Bay E.	6/25/85				0.19	(7)	.15 - .30		
	9/10/85	7.6	(3)	5.4 - 8.9	0.15	(5)	.11 - .21		
	11/08/85	7.9	(3)	4.8 - 9.6					
O'Neill's Deep Bay So.	7/18/85	8.3*	(9)	8.0 - 8.6	0.18	(8)	.12 - .24	7-11	27-48
	9/09/85	5.9	(3)	4.5 - 6.8	0.22	(6)	.20 - .25		
	10/30/85	5.1	(4)	2.5 - 7.3	0.12	(7)	.05 - .28		
Goose Bay	7/01/85	8.4*	(7)	6.8 - 9.0	0.12	(6)	.09 - .14	31-40	0-1
	9/09/85	7.6	(4)	5.5 - 8.8	0.09	(6)	.03 - .19		
	11/07/85	4.1	(3)	1.6 - 7.8	0.40	(8)	.08 - .62		
Zelezney Bay	7/12/85	8.1*	(8)	7.2 - 8.6	0.15	(7)	.12 - .20	24-29	0-3
	9/11/85	3.5	(4)	1.6 - 6.1	0.15	(6)	.12 - .18		
	11/18/85	4.1	(4)	1.3 - 6.5	0.19	(8)	.11 - .25		
Hyde Bay	7/12/85	8.7*	(7)	7.8 - 9.1	0.10	(6)	.06 - .12	24-34	0-3
	9/11/85	5.7	(3)	3.6 - 7.5	0.11	(4)	.07 - .16		
	11/18/85	6.6	(3)	3.5 - 8.4	0.22	(6)	.02 - .42		
Dewey Bay	7/16/85	7.5*	(8)	6.3 - 8.6	0.16	(8)	.14 - .19	23	1
	8/29/85	7.7*	(5)	7.0 - 8.3	0.10	(7)	.06 - .13		
Safford's Rollins Bay	7/22/85	7.9*	(6)	7.5 - 8.1	0.20	(5)	.15 - .26	14-25	1-12
	8/29/85	7.7*	(3)	7.0 - 8.4	0.17	(5)	.12 - .19		
	11/19/85	3.2	(3)	0.8 - 5.6	0.28	(6)	.17 - .45		
Wild Horse Is.	8/23/85	8.2*	(4)	7.9 - 8.5	0.09	(8)	.03 - .16	8-12	17-42
	11/19/85	4.0	(3)	1.4 - 8.6	0.38	(5)	.25 - .64		
White Swan Bay	8/23/85	7.5*	(4)	6.6 - 9.1	0.13	(7)	.08 - .16	14-20	11-14
	11/05/85	0.6	(4)	0.0 - 1.6	0.24	(7)	.15 - .34		
Polson Golf Course	8/07/85	8.2*	(4)	7.8 - 8.6	0.19	(6)	.07 - .24	13-30	2-16
	11/06/85	7.2	(3)	4.0 - 10.0	0.22	(6)	.09 - .44		
Kerwin's	8/14/85	8.6*	(6)	8.3 - 8.7	0.14	(6)	.12 - .18	23-35	0-10
	11/06/85	6.2	(3)	3.3 - 9.4	0.43	(8)	.27 - .52		
Bird Point	8/13/85	8.7*	(8)	8.2 - 9.2	0.15	(9)	.09 - .25	12-22	18-35
Finley Point	8/16/85	8.6*	(3)	8.6 - 8.7	0.09	(9)	.06 - .10	19-21	3-7

*Dissolved oxygen measured in samples from seepage meters.

Table 5. Water chemistry of groundwater samples from potential habitat study sites on the west and south shore of Flathead Lake.

Location	mg/liter								Total dissolved solids
	Bicarbonate	Chloride	Sulfate	Nitrate-N	Calcium	Magnesium	Sodium	Potassium	
Hockaday Bay West	259.2	1.80	3.60	0.019	31.4	26.7	11.2	1.5	335.5
Hockaday Bay West	203.0	0.98	4.10	0.172	32.4	19.5	5.6	1.0	267.4
Hockaday Bay West		0.22	2.10	—	25.7	6.2	1.4	0.5	
Hockaday Bay West		0.22	2.50	—	24.8	6.1	1.2	0.0	
Hockaday Bay East		0.13	1.90	—	32.9	4.6	0.8	0.3	
Hockaday Bay East		0.16	2.60	—	25.7	5.6	1.2	0.4	
Hockaday Bay East	43.7	0.08	1.10	0.007	10.4	2.3	0.4	0.2	58.2
Hockaday Bay East	83.7	0.45	2.70	0.080	14.4	7.4	1.9	0.4	111.3
Goose Bay		0.16	3.30	—	23.7	5.6	1.0	0.4	
Goose Bay		0.16	2.30	—	24.0	5.7	1.0	0.4	
Goose Bay	72.6	0.60	2.30	0.068	14.7	5.1	1.5	0.4	97.5
Goose Bay	164.4	0.76	1.20	0.012	18.3	17.7	7.0	0.4	209.8
Deep Bay South	55.6	0.22	3.20	—	43.4	5.6	1.1	0.5	
Deep Bay South	41.9	0.13	2.70	—	98.4	5.2	0.9	0.4	
Deep Bay South	204.1	1.46	5.00	0.152	34.8	16.8	7.6	1.1	271.6
Deep Bay South	191.8	1.39	5.30	0.018	36.8	14.0	6.7	0.9	257.0
Crescent Bay	159.5	1.02	2.40	0.081	29.4	12.0	3.1	1.2	208.9
Crescent Bay	112.6	1.90	2.80	0.072	13.2	11.7	5.9	1.6	150.0
Crescent Bay	54.0	1.45	2.80	—	55.4	7.4	3.4	1.1	
Polson Golf Course		0.31	3.00	—	38.5	5.8	1.4	0.6	
Polson Golf Course	80.4	0.28	2.50	0.013	13.9	7.5	1.8	0.5	106.5
Polson Golf Course	108.6	0.23	2.20	0.017	26.7	4.9	1.0	0.4	144.1
East Slack Point		0.06	1.70	—	43.4	4.1	0.7	0.3	
East Slack Point		0.09	1.90	—	34.1	4.5	0.8	0.3	
Zelezney Bay		0.16	2.00	—	23.3	5.8	1.1	0.4	
Zelezney Bay		0.16	2.50	—	22.9	5.6	1.1	0.4	
Zelezney Bay	146.4	28.90	5.30	0.550	27.4	14.6	16.5	0.6	242.1
Zelezney Bay	94.7	0.20	2.50	0.004	18.0	7.6	1.1	0.4	124.5
Hyde Bay		0.19	2.30	—	23.7	5.6	1.0	0.4	
Hyde Bay		0.16	2.40	—	23.3	6.1	1.0	0.4	
Hyde Bay	106.9	0.20	2.40	0.022	22.6	7.2	1.0	0.4	140.8
Hyde Bay	84.6	0.20	2.30	0.018	17.8	5.9	1.0	0.4	112.3
Dewey Bay	50.8	0.19	2.50	—	86.3	5.7	0.9	0.5	
Dewey Bay	50.8	0.22	2.40	—	41.3	5.9	1.2	0.5	
Wildhorse Island		0.19	2.50	—	36.9	5.6	1.0	0.5	
Wildhorse Island		<0.01	1.70	—	32.5	2.1	0.4	0.2	
Wildhorse Island	106.3	0.25	1.70	0.011	24.8	5.6	0.9	0.4	140.1
O'Neill's	46.4	0.25	2.50	—	47.4	5.4	0.9	0.3	
O'Neill's	37.6	0.50	2.50	—	40.1	5.4	0.9	0.4	
O'Neill's	120.6	11.20	3.60	0.004	19.8	12.4	6.8	0.6	175.0
O'Neill's	129.6	5.10	7.00	0.202	20.1	13.1	7.7	0.5	183.9
White Swan Bay	147.9	0.47	3.00	0.011	33.0	8.4	3.7	0.5	197.0
White Swan Bay	112.7	0.25	2.20	0.004	23.7	7.4	1.6	0.9	148.8
White Swan Bay	53.2	0.15	1.80	0.005	10.2	4.2	0.9	0.1	83.0
White Swan Bay	192.2	3.90	26.70	0.006	26.3	11.8	33.8	1.1	295.8

Zelezney Bay contained high chloride levels (Table 5). Groundwater discharge was adequate in the three bays. Though the evidence that kokanee ever spawned in these bay is limited, our survey indicated that suitable habitat does exist in Hyde Bay.

Safford's Dayton Bay). Substrate size and groundwater discharge are within the limits defining kokanee spawning habitat at this site. The shoreline is heavily developed, but no water quality parameters other than elevated bicarbonate indicate groundwater contamination. Spawning season dissolved oxygen levels (3.2 mg/l) are below tolerance limits. Heavy deposits of gravel have accumulated behind jetties and boat docks along this stretch of shore. It is conceivable that if the jetties were redesigned, so gravel deposits were allowed to distribute more evenly, that groundwater flow and dissolved oxygen would increase. Habitat might then be suitable for kokanee spawning.

Wildhorse Island. We studied one of many coves along the northwest shore of the island which contained deposits of clean gravel. One substrate sample contained 42 percent fines, though mean particle size was within limits. Groundwater apparent velocity was markedly higher in November than in August, averaging 0.38 $cm^3/cm^2/hour$. Average dissolved oxygen in November was 4.0 mg/l, but individual samples ranged up to 8.6 mg/l. The Wildhorse Island site is marginal habitat for kokanee spawning.

White Swan Bay. A resident of this area told us that kokanee spawners were caught in White Swan Bay in the late 1950's. Suitable substrate exists, but dissolved oxygen concentration during the spawning season was too low, averaging 0.6 mg/l Apparent velocity readings averaged 0.24 cm^3/cm^2/hour in November. Low dissolved oxygen would prevent successful kokanee spawning.

South Bay Sites. We looked at potential spawning habitat at three sites in South Bay - west of the mouth of a small stream draining from the Polson Municipal Golf Course, and along the west shore (Kerwin's) and north shore of Slack Point. There is some evidence that kokanee spawned at the mouth and in the small creek at the Golf Course. Substrate size was adequate at all three sites, except that Slack Point samples contained 35 percent fines. Mean dissolved oxygen levels at the creek mouth and Kerwin's were adequate to support incubating kokanee eggs, as were groundwater apparent velocities at the three sites. November apparent velocity values were higher than summer readings at all three sites (Table 4). One water sample from Slack Point showed elevated bicarbonate and sulfate, probably due to heavy shoreline development. The evidence suggests that kokanee could spawn successfully at the creek mouth and at Kerwin's.

Finley Point. Surveys showed a number of sites along the western shore of Finley Point with clean, suitable substrate extending three to five meters deep. Substrate analysis at one site confirmed the survey, and summertime dissolved oxygen levels (8.6 mg/l) and groundwater apparent velocity 0.15 cm^3/cm^2/hour met the criteria for spawning habitat. Water quality analyses showed no evidence of groundwater contamination. Spawning season values of dissolved oxygen and groundwater apparent velocity are needed to confirm that habitat along West Finley Point is suitable for kokanee spawning.

In summary, Hockaday Bay, Hyde Bay, Polson Golf Course Creek, and Kerwin's showed potentially good spawning habitat. Goose Bay, O'Neills, Zelezney and Dewey Bay, and White Swan Bay were not suitable. Wildhorse Island and Safford's were marginal sites. We stress that egg survival at potentially good spawning sites is prevented by winter drawdown. Low dissolved oxygen was also a limiting factor at many of our study sites. Groundwater dissolved oxygen, sampled in sandpoint wells upslope of the lake, were consistently below 3.0 mg/l Higher readings from the lake bed indicate that lake water is exchanged in the substrate. The extent to which groundwater influences dissolved oxygen in spawning substrate depends on the apparent velocity i.e., discharge rate.

Creel Surveys

Winter, 1985. Management of the kokanee fishery in Flathead Lake has depended on creel surveys to monitor harvest and provide information on the abundance of adult age classes of fish. Kokanee enter the fishery in their third year (age II+), but the majority of fish are caught in their fourth (III+) or fifth (IV+) year. A large aggregation of mature fish spend the winter in Skidoo Bay from late December to mid April. We do not know why this aggregation persists. Zooplankton density and water temperature are not different from other areas of the lake (Leathe and Graham 1982).

The winter fishery in Skidoo Bay, in the southeast corner of Flathead Lake, has become increasingly popular since 1979. Catch rates and harvest vary considerably between years that Skidoo Bay freezes and ice-free years. Harvest during this period has usually been 40,000-50,000 fish, though it reached 113,000 in 1982 (Graham and Fredenberg 1982). Daily limits were reduced to 10 in 1983. Overharvest has been of particular concern recently, when we have sought to manage spawner year class harvest conservatively to improve spawner escapement and recruitment.

Flathead Lake froze completely in mid January of 1985, and the ice fishery in Skidoo Bay began late that month. We monitored the fishery from January 31 to March 1 when the harvest quota of

50,000 was met and the fishery closed. During that period 49,200 ±2,072 (p=0.5) kokanee were caught, and the estimated fishing pressure was 15,090 angler hours. We calculated the average angler day to last 1.8 hours, so that the above pressure estimate translates to over 8,300 anglers days. The catch rate for single sample days ranged from 1.0 to 5.1 fish/hour, and the overall catch rate for the survey was 3.3 fish/hour. The fishing success of the ice fishery, about triple that of the summer troll fishery, accounts for it's popularity. We counted as many as 400 fishermen on the ice at one time, concentrated in a small area along the eastern shore of the bay.

Summer, 1985. The following results are condensed from an extensive report on the 1985 creel survey (Hanzel 1986). Seventy-five percent of the kokanee caught in Flathead Lake are taken during the summer. Fishing is concentrated in the southern end of the lake around Wildhorse Island and Big Arm in the early summer. Fishing effort increases rapidly in early June as the summer resident and tourist population increases. In late summer, fishing effort shifts to the northeastern quadrant of the lake, where schools of mature fish aggregate before the spawning migration into the Flathead River.

Average trip length was 3.26 hours and average party size was 2.1 anglers, based on 360 interviews. Fishing pressure for each two-week period ranged from 7,045 to 10,919 angler-hours, assuming that the daily fishing period was 16 hours. Pressure increased to about 10,000 angler-hours per period in July and August, except during a period of poor weather in early August (Table 6). Total fishing effort was 53,895 angler-days. Weekend fishing effort was consistently twice that on weekdays.

The total harvest of kokanee for the 12-week survey period was 129,300 (Figure 12). This represented 95.4 percent of the total catch of all sportfish in Flathead Lake. Forty-four percent of the harvest occurred in the last two survey periods - from August 11 to September 7, 1985. A very small proportion of those kokanee caught (2.5 percent) were released.

The catch rate for each survey period ranged from 0.63 to 0.89 fish per hour, and for the entire survey averaged 0.76 fish per hour. Fishermen were most successful in the northeast quadrant of Flathead Lake, where overall catch rate was 0.89 fish per hour. The catch rate was highest during the fourth and fifth periods, from July 28 to August 24 (Figure 12). Kokanee are at their highest density during the late summer in the north end of Flathead Lake, before the spawning migration into the Flathead River begins.

Table 6. Fishing pressure for kokanee, by creel survey period from June 1 to September 7, 1985.

Period	Fishing Pressure (Angler-Days)		
	Weekdays	Weekends	Total
1. 6/01 - 6/29/85	3,586	3,459	7,045
2. 6/30 - 7/13/85	3,962	4,307	8,269
3. 7/14 - 7/27/85	5,586	5,333	10,919
4. 7/28 - 8/10/85	3,500	2,946	6,446
5. 8/11 - 8/24/85	5,713	5,026	10,739
6. 8/25 - 9/07/85	5,782	4,695	10,477
TOTAL	28,129	25,766	53,895

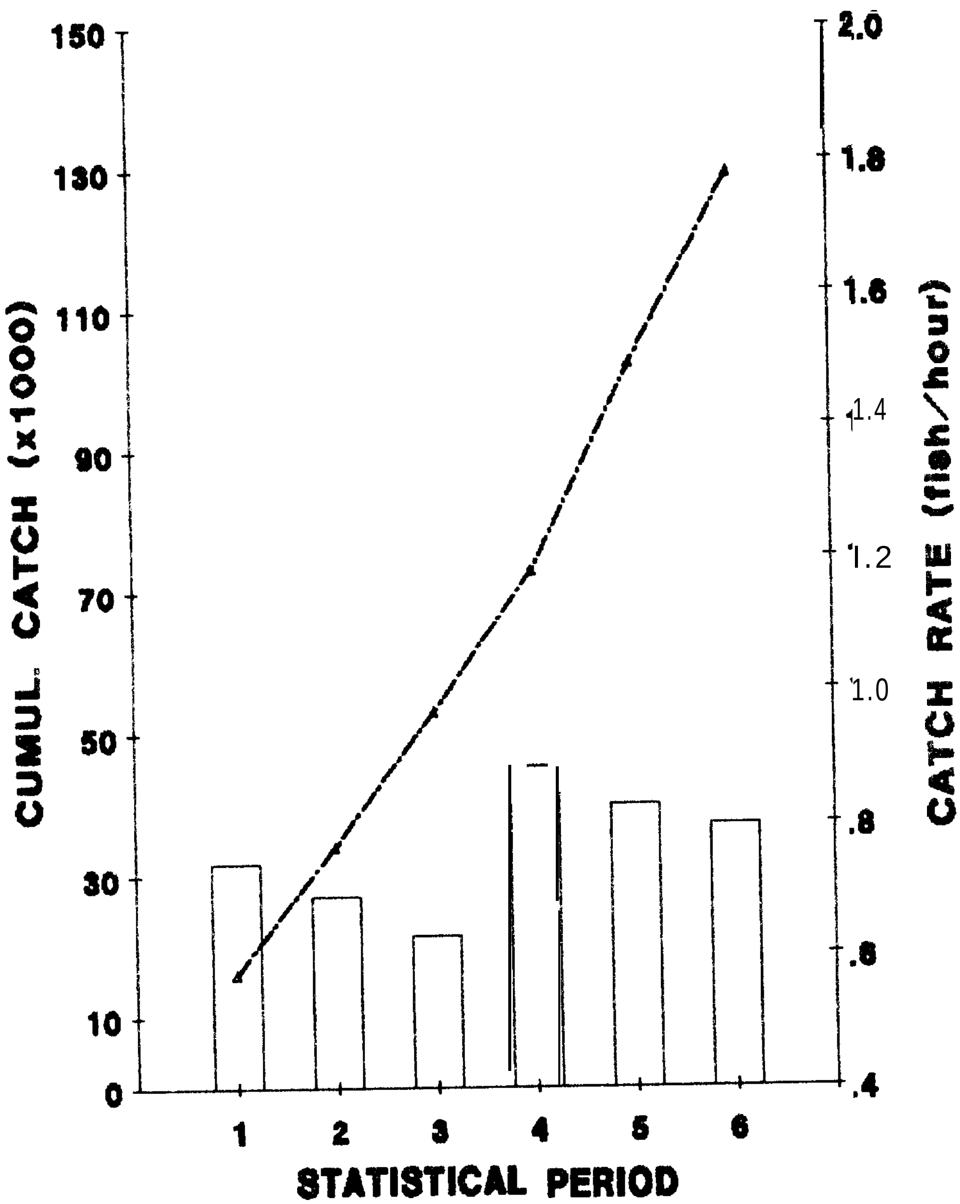


Figure 12. The cumulative harvest of kokanee and catch rate, by statistical period, during the summer fishery on Flathead Lake, from June 15 to September 7, 1985.

The total harvest of kokanee in 1985 was 192,300, including 13,800 fish taken in the fall river fishery. The summer and fall harvest of 143,100 kokanee was much lower than that estimated by the 1981 creel survey, which estimated a combined summer and fall catch of 355,300 kokanee (Graham and Fredenberg 1982). Combined summer and fall fishing pressure in 1985 was 188,000 angler-hours, whereas it was estimated to be 454,300 angler-hours in 1981. The methods for estimating fishing pressure were different for the two surveys. In 1981, pressure was estimated by a complex reduction of traffic data gathered at shoreline access points. Interviews were used to establish trip length, party size, and what proportion of the traffic was fishing boats. The aerial counts done in 1985 represent a more accurate estimate of pressure. Summer catch rates for kokanee were about the same, varying from 0.6 to 0.9 fish per hour, for both the 1981 and 1985 surveys. High spawning escapement followed both the 1981 and 1985 summer/fall fishing periods. Escapement in 1981 and 1985 were 132,000 and 146,900, respectively.

Stock Composition of the Skidoo Bay Kokanee Aggregation

The tagging of adult (age III+ and IV+) kokanee in early spring in Skidoo Bay, and recovery of these tagged fish during the summer fishery and on the spawning grounds, was intended to replicate the previous year's study (Beattie et al. 1985). Purse-seining was done slightly later in 1985 than in 1984, from April 15-19. Four sets of the seine caught 7,863 kokanee. We tagged 4,034 (51.3 percent) III+ and IV+ fish.

Seventy-five tags were recovered during the summer fishery, and eight during the fall river fishery. In June tag returns came from Skidoo Bay, the Narrows, Big Arm, and along the west shore (Figure 13). In July tagged fish were recovered from Bird Island, Wildhorse Island, Angel Point, and from Woods Bay to Bigfork. August recoveries came from Angel Point and from Woods Bay to Bigfork on the east shore. Later recoveries came mostly from the river fishery. These returns confirm what was found in 1984, i.e., that kokanee disperse quickly westward and northward from Skidoo Bay in the early summer. They are found in the western extent of Big Arm until the end of June, when the temperature of shallow water there rises rapidly. Kokanee concentrate near Angel Point and in the nearshore area from Woods Bay to Bigfork in late summer.

Forty-nine tagged fish were recovered at various spawning areas. The spawning run up the Flathead River begins as early as late July, though large numbers of fish do not usually enter the river until late in August. Three tags were recovered from the main stem Flathead River, and one from Brenneman's Slough. Four tags were recovered from the Middle Fork of the Flathead, and three tags from the South Fork. Twenty-six tags were observed during snorkel surveys of McDonald Creek, a tributary of the

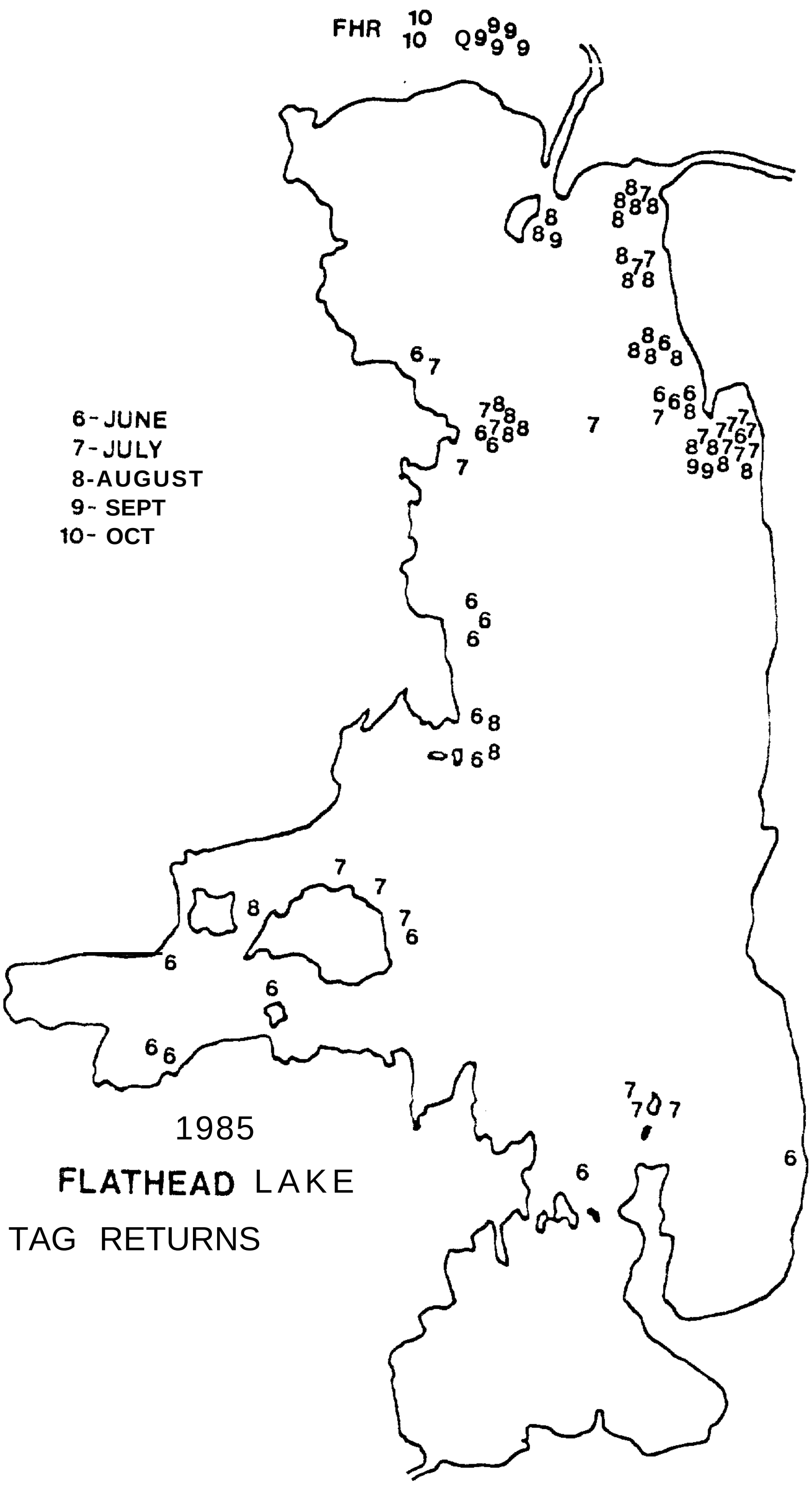


Figure 13. The date and location of recoveries of tagged kokanee during the summer fishery on Flathead Lake and the fall fishery on Flathead River, in 1985. These fish were tagged in Skidoo Bay, in April, 1985.

Middle Fork, where 75 percent of all the spawning in the Flathead system takes place. Four tags were recovered during egg takes at Somers Hatchery, and nine tags were observed during snorkel surveys of Swan River. The disproportionately high number of observations in Swan River is related to the greater survey effort expended there.

These results confirm that most of the spawning areas in the Flathead system contribute to the winter Skidoo Bay aggregation. Intensive fisheries, such as that which occurs during the winter in Skidoo Bay, can overharvest numerically weak stocks if they are mixed with stronger stocks. The absence of tag recoveries from lakeshore spawning areas might indicate that these weaker stocks are over-fished. However, the difficulty of observing and counting lakeshore spawning kokanee reduces the chance of observing tagged fish there. Redd counts indicate that lakeshore spawning stocks were the strongest in five years, even though they comprised only about two percent of the total spawning run.

Abundance of *Mysis relicta* in Flathead Lake

In May, 1986, we began monitoring the abundance of *Mysis relicta*, the opossum shrimp, at six index stations (Figure 2) on Flathead Lake. The average 'lake-wide' density has increased to over $130/m^2$. Average densities from May, June, and July range from $132/m^2$ to $136/m^2$ (Table 7). Because of bad weather we could only sample four of the index stations in September. The four station average density was $100/m^2$. However, a concurrent larger sample from eighteen stations done in early September showed the average density to be $129/m^2$ (R. Bukantis, pers. comm.). Mysid density dropped again at all stations in October (Table 7). We do not know if this fall decline in density represents actual population decline or a change in distribution. It is apparent that mysid abundance is increasing rapidly in Flathead Lake (Figure 14). Average density in 1985 was ten times that in 1984. However, the exponential increase observed between 1983 and 1985 did not continue in 1986.

In Flathead Lake, mysids become sexually mature in their first year. Gravid females release their young from February through May. A female can produce up to 20 young. May and June samples reflect the preponderance of juveniles in the population in the spring. Adults die within four to six months after releasing their young, so they continue to exert grazing pressure on zooplankton in late spring. High fecundity produces a rapidly increasing population, even when overwinter mortality and predation pressure is high. That the average density of mysids in Flathead Lake did not decline from May to September suggests that summer predation, when fish feed most actively, did not affect mysid abundance. We have found mysids in the stomachs of lake trout, lake and pygmy whitefish, cutthroat trout, and some kokanee sampled in 1986.

Table 7. The density of *Mysis relicta* at six index stations on Flathead Lake in 1986.

		Number *Mysis*/meter²						
Date		Lakeside l-l	Bigfork 2-4	Midlake 3-5	North Wildhorse 5-12	Yellow Bay 8-7	Skidoo Bay 9	Average
May 6	Adults	0	1	—	8	20	8	7
	Juvenile	48	236	—	83	140	127	127
	Total	48	237	—	91	160	135	134
June 8	Adults	5	18	9	13	23	40	18
	Juvenile	13	60	15	145	252	196	114
	Total	18	78	24	158	275	236	132
July 12	Adults	47	76	149	101	107	56	89
	Juvenile	18	84	89	32	48	10	47
	Total	65	160	238	133	155	66	136
Sept.10	Adults	73	—	—	102	103	83	90
	Juvenile	10	—	—	8	6	14	10
	Total	83	—	--	110	109	97	100

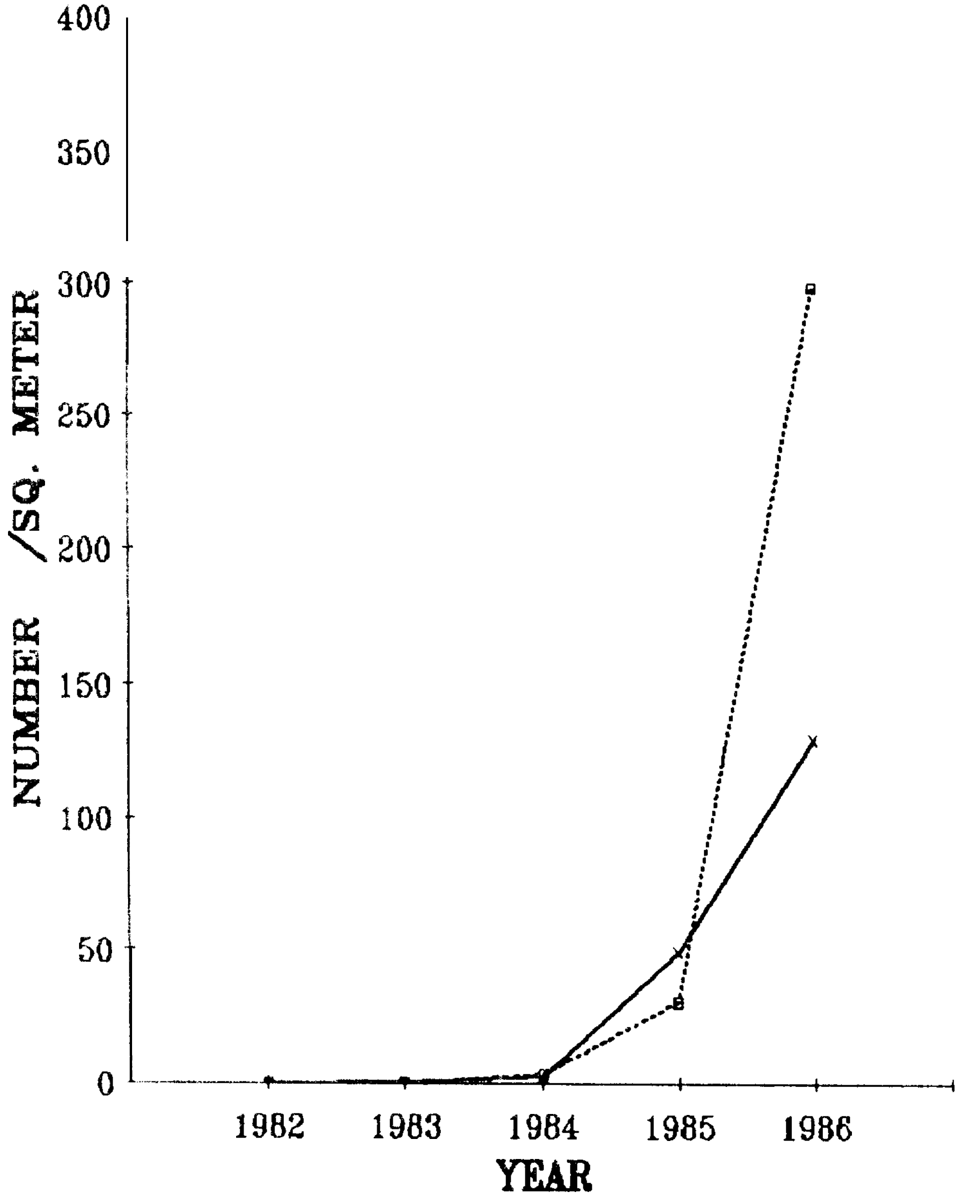


Figure 14 . The increase in the abundance of Mysis relica, the opossum shrimp, in Flathead Lake, from 1982 to 1986. Logarithmic increase is shown by the dotted line for comparison. Note that the rate of increase fell below the logarithmic rate in 1986.

FLATHEAD RIVER SEGMENT

METHODS

Spawner Surveys

Migrating kokanee salmon were counted twice daily by aerial surveys between August 25 and October 22. Survey frequency coincided with the creel survey schedule. High runoff and ice formation in the river made surveys impossible after that date. Schools of kokanee were categorized as small (25-100 fish), medium (100-300 fish), or large (300-500 fish). The midpoint of each of those ranges was used as the estimated number of kokanee in the school.

Spawner counts in McDonald Creek were made by snorkelers and a data recorder following in a canoe. The snorkelers swam or floated downstream counting the kokanee which passed between them. Counts of the school were made by the smallest practical unit (10,20, or 50). Each snorkeler then reported their count to the data recorder. These counts were used as the low and high estimates for that school. Counts were made every two weeks, on Tuesdays, from early September through late November, to coincide with National Park Service counts of bald eagles along lower McDonald Creek.

Numbers of spawners in other areas were estimated by multiplying the number of complete redds by 2.4, the estimated number of kokanee per completed redd (Fraley and McMullin 1984).

Samples of spawning kokanee were collected by gill net from several spawning areas throughout the river system for length and age analysis.

Creel Survey

Harvest and fishing pressure during the fall river fishery were estimated by a stratified random block creel survey method similar to that used on Flathead Lake. Four 2-week strata were delineated from August 25 through October 19. Five weekday and three weekend sample days were randomly chosen within each stratum. Angler counts were made twice daily on these days from a fixed wing aircraft. The length of the fishing day was reduced as daylight hours became shorter. Anglers were queried regarding number of anglers per party, total hours fished, species preference, fish kept and released, angler origin and whether their fishing trip was complete.

Fishing pressure (angler-hours) was estimated by expanding the instantaneous counts made during aerial surveys. Catch rate was calculated for weekdays and weekends as:

Fish/hour = (sum of catch/sum of effort)

Harvest was estimated by multiplying the average number of anglers per count by the average catch rate. Separate harvest estimates were made for weekday and weekend days within each strata, and added to calculate total harvest.

Egg Survival Experiments

A hydraulic egg sampler (McNeil 1963, Graham et al. 1980) was used to collect eggs and alevins from spawning gravels for survival estimates. We counted live and dead eggs and alevins in each sample to estimate survival in each area. Sampling was completed during February in McDonald Creek and three main stem spawning areas, and during March in Beaver Creek and the South Fork of the Flathead River.

Fry Emigration

Estimates of production of kokanee fry in the Flathead River and its tributaries were made using drift nets. The filtering areas of the net mouth and the current velocity were measured. Captured fry were enumerated and the total volume of water filtered was calculated. Total fry emigration was estimated by expanding the number of fry per volume filtered to the total volume of flow. This sampling method is subject to error due to two factors. Filtering efficiency of the nets varies because debris clogs the nets during runoff, causing backflushing and reducing the amount of water actually filtered. The second source of variation concerns the distribution of fry through the water column. Emigrants may not be randomly distributed throughout the entire river. Fry may concentrate in the areas of higher velocity, so random sampling of the entire water column may not yield accurate estimates.

RESULTS AND DISCUSSION

Spawner Surveys

Thefirst schools of migrating kokanee in 1985 were seen in the main stem of the Flathead River on September 4, approximately five to six miles upstream of Flathead Lake. The peak count occurred on October 2 and was nearly achieved again on October 9 and 22 (Figure 15). Nearly twice as many kokanee were present in the Flathead River in late October 1985 than at that time in any previous year.

Based on redd counts and aerial surveys, an estimated 20,000 kokanee spawned in the main stem Flathead River. Eight hundred sixty-three redds (2,100 spawners) were counted on the South Fork of the Flathead River, which was three times higher than the redd count in 1981, the parent year. The redd count in Beaver and Deerlick creeks, tributaries of the Middle Fork (Figure 1), was 761 (1,830 spawners), higher than any previous year. Forty-two redds (100 spawners) were counted in the Middle Fork, near Beaver Creek. Most of the Middle Fork and all of the Whitefish River were not surveyed.

Kokanee redd counts were incomplete due to fall river flows 300 percent above normal and ice formation in November. Due to unusually high amounts of precipitation in October and early November, natural runoff from the North and Middle Forks never got as low as 4,500 cfs, the maximum recommended kokanee spawning flow. Visibility in the river during this period was limited or nil. No aerial kokanee counts were attempted after October 22. Discharge from Hungry Horse Dam during this period was 145 cfs, the minimum amount of water that can be passed.

Extremely cold temperatures, usually below zero, lasted through November and caused ice formation throughout most of the river system. After temperatures moderated and the river opened, redd counts were completed. The counts cited above underestimated escapement because redds were made unrecognizable by high flows and ice scour.

Snorkel trend counts in McDonald Creek peaked at 122,900 kokanee on October 29. This is the greatest number of spawners ever counted in McDonald Creek. An estimated total of 146,900 kokanee spawned in the Flathead River system in 1985, the highest number since counts began in 1979 (Table 8).

Average length of spawners in the river system in 1985 was 365 mm, an increase of 20 mm over the 1984 average length and nearly identical to the average length of the 1981 cohort (Appendix Tables 2 and 3). In 1984, 18 percent of the spawners

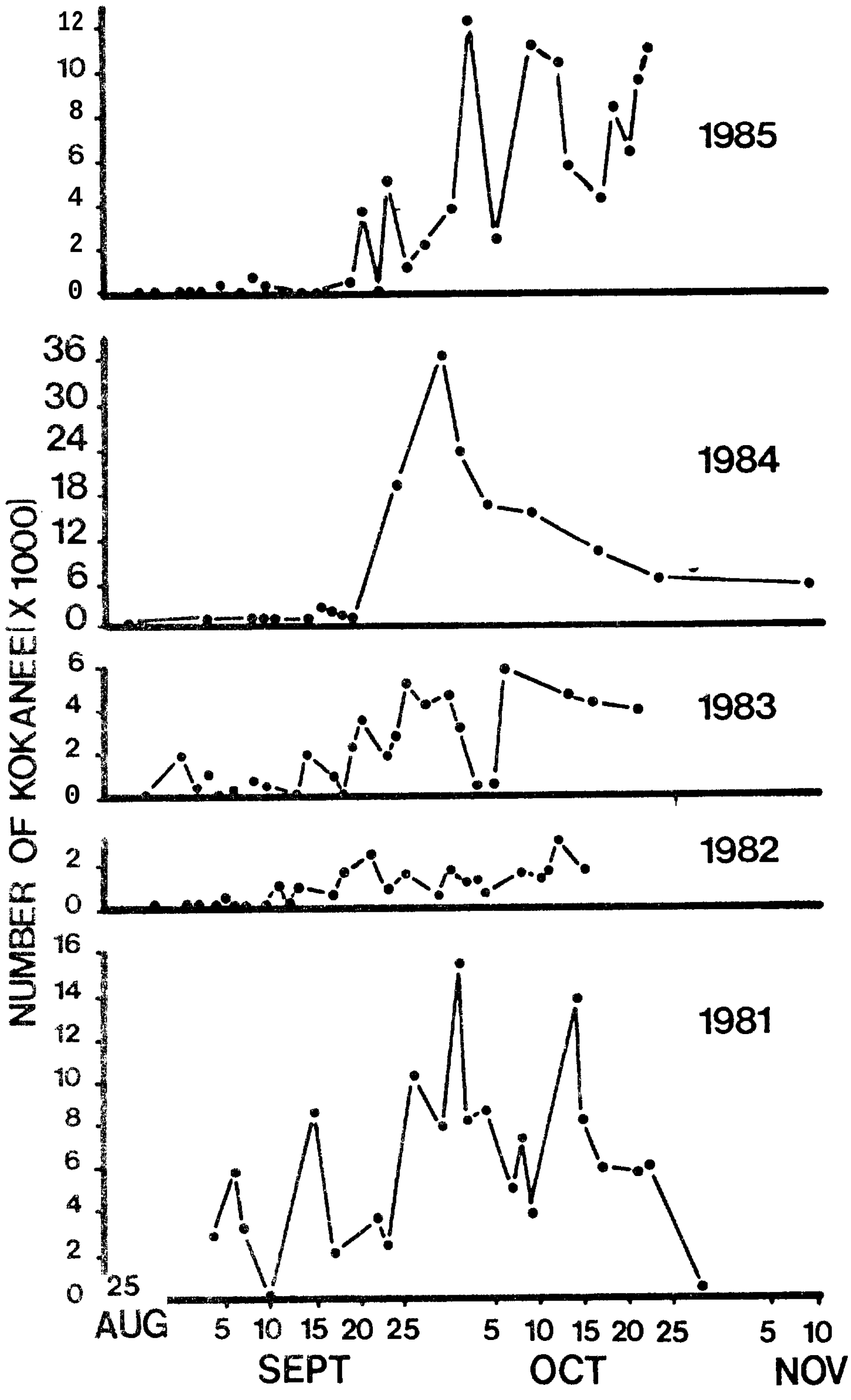


Figure 15. Aerial spawner counts and migration timing in the Flathead River, 1981-1985.

Table 8. Estimated numbers of post harvest kokanee spawners in the Flathead River system, 1979-1985. The percent contribution for each area is in parentheses.

	Estimated number of spawners						
	1979	1980	1981	1982	1983	1984	1985[d]
McDonald Creek[a]	65,000 (90)	49,520 (96)	103,[illegible] (79)	30,965 (80)	34,306 (60)	86,729 (75.8)	122,875 (83.7)
Main stem Flathead River[b]	6,785 (10)	1,1[illegible]1 (2)	19,073 (15)	3,720 (10)	16,279 (28)	17,839 (15.6)	20,000 (13.6)
Whitefish River[b]	—	1,022 (2)	998 (<1)	1,836 (5)	1,272 (2)	2,359 (2.1)	—[c]
South Fork[b] Flathead River	—[c]	—[c]	720 (<1)	480 (1)	4,493 (8)	7,510 (6.5)	2,071 (1.4)
Beaver-Deerlick[b] Creeks	0	—[c]	1,723 (1)	101 (<1)	1 (<1)	0	1,826 (1.2)
Middle Fork Flathead River	—[c]	—[c]	5,520 (4)	1,802 (4)	1,330 (2)	400 (0.3)	100 (.1)
TOTAL	71,785	51,643	131,534	38,904	57,681	114,837	146,872

a/ Live peak snorkel count plus dead fish.
b/ Estimated by multiplying redd counts by 2.4.
c/ No count.
d/ Redd counting was difficult to accomplish due to fall flows 300 percent above normal and nearly complete ice formation in most areas before the completion of spawning. The count for the main stem is the estimated minimum number of spawners.

were II+, but in 1985, no II+ spawners were found in the samples. The large number of III+ kokanee in 1985 probably precluded many II+ fish from becoming sexually mature.

One of the department's management goals is to maintain a kokanee population that will produce spawners 300 to 330 mm in length. This is the size of fish that was deemed desirable by anglers. If kokanee are density dependent, this size of fish would be produced by conditions similar to those which produced the 1975 year class, which averaged 308 mm and numbered 300,000 to 330,000 main stem spawners (Fraley et al. 1986).

Creel Survey

We estimated that anglers caught 13,800 kokanee in the Flathead River from August 25 through October 20, 1985 (Table 9). Nearly 70 percent of the kokanee harvested in the river were caught in river section 1 (the Salmon Hole and Foys Bend), where spawners stage for two to three days before continuing their upstream migration.

In 1984, spawners stayed in the Salmon Hole area of the Flathead River for an extended period of time, and anglers harvested 12,063 in 12 days. This resulted in an emergency closure of the river kokanee fishery. During most years, the harvest is low enough so that it doesn't significantly reduce escapement. During years when parent year class is weak, harvest quotas are imposed to ensure that sufficient spawning occurs to maintain the population.

Egg Survival Experiments

Egg and alevin sampling was completed in McDonald Creek, Beaver Creek, the South Fork of the Flathead River, and three areas of the main stem Flathead River. Other areas were not sampled because redds were unrecognizable due to the high flows and ice scour. Midwinter embryo survival in the main stem areas averaged 78 percent (Figure 16). No hatching had occurred in the river at the time of sampling in mid-February. Embryo development may have been slow due to the extreme cold during the early winter.

Survival in McDonald Creek was 84 percent. Only 8.6 percent of the embryos sampled in McDonald Creek had hatched by mid February. Sampling in McDonald Creek in mid January 1984 showed 29 percent hatch, and in mid February in 1985 the hatching rate was 20 percent. Cold water temperatures, and to a lesser degree redd superimposition, may have been responsible for the slower

Table 9. Estimated kokanee harvest from the Flathead River, 1985. Estimated pressure (in hours) is in parentheses.

Survey Strata		River Section*				
		4.1	4.2	4.3	4.4	2.1
1	Aug. 25 - Sept. 7	4,526 (3,324)	0 (0)	0 (0)	0 (0)	0 (0)
2	Sept. 8 - Sept. 21	4,481 (4,144)	9 (835)	947 (676)	975 (553)	0 (0)
3	Sept. 22 - Oct. 5	318 (1,023)	105 (621)	430 (639)	1,428 (570)	172 (120)
4	Oct. 6 - Oct. 19	0 (0)	39 (228)	300 (222)	66 (108)	0 (0)
5	Oct. 20 -	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Totals		9,325 (8,491)	153 (1,684)	1,677 (1,537)	2,469 (1,231)	172 (120)
Percent of total		67.6 (65.0)	1.1 (12.9)	12.2 (11.8)	17.9 (9.4)	1.2 (0.9)

* River Sections

- 4.1 Flathead Lake to the mouth of the Stillwater River.
- 4.2 Mouth of the Stillwater to Pressentine Fishing Access.
- 4.3 Pressentine Fishing Access to Highway 2 bridge in Columbia Falls.
- 4.4 Highway 2 bridge at Columbia Falls to confluence of North and Middle Forks.
- 2.1 Middle Fork Flathead River confluence with North Fork, to McDonald Creek.

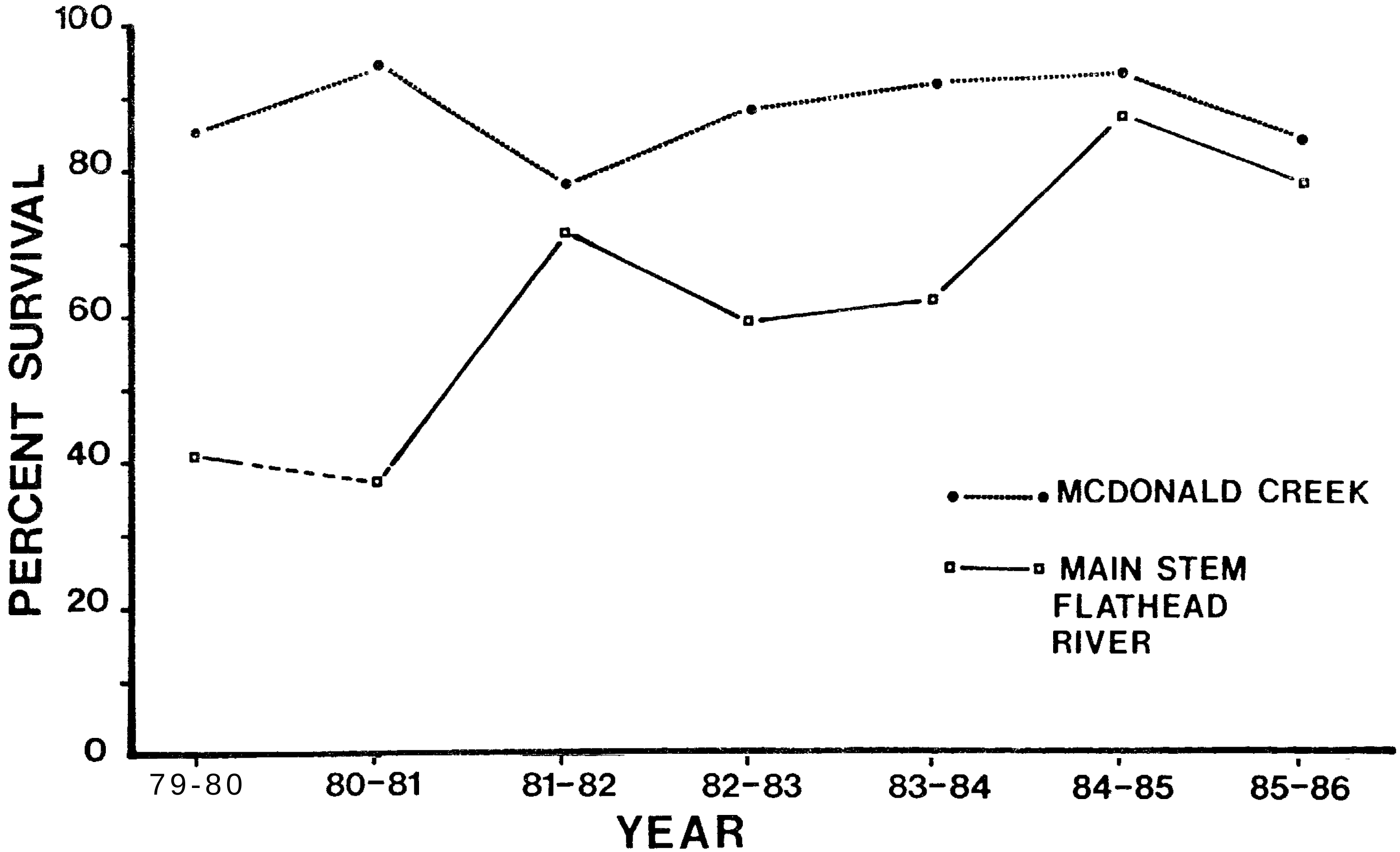


Figure 16. **Midwinter kokanee embryo survival in McDonald Creek and the main stem Flathead River. A limited sample size in the river during the winter of 1981 indicated embryo survival was less than 40%, but an exact figure could not be derived.**

development. In Beaver Creek and the South Fork of the Flathead, sampled in mid March, survival was 92 and 93 percent, respectively. Nineteen percent of the embryos in the South Fork and 92 percent of the embryos in Beaver Creek had hatched.

Embryo survival rates, especially in the main stem river, may actually have been lower than those reported here. Redds which were built during the high flows and later dewatered were not sampled. They were unrecognizable due to ice scour and/or snow cover. We do not know how many redds may have been dewatered when river flows returned to the normal regime in December.

Fry Emigration

An estimated 9.9 million fry emigrated from McDonald Creek in the spring of 1986. Emigration in McDonald Creek began in early March, peaked in late May, and ended in early July. The Flathead Lake kokanee population is largely dependent on fry production from McDonald Creek. Annual fry production from McDonald Creek remains constant at 10 to 13 million despite wide variation in spawner escapement. This is probably due to limited spawning area in the creek (Fraley and McMullin 1983).

Fry emigration from Beaver Creek was well underway when netting began in mid March. The peak occurred in late March-early April and emigration ended in mid May. A minimum of 343,000 fry emigrated from Beaver Creek.

Kokanee fry were first captured in the Flathead River at the Sportsman's Bridge, two miles upstream of Flathead Lake, in early April, the peak of fry movement past the Sportsman's Bridge was in early to mid June, and no fry were captured after early July. We estimated 2.2 million fry passed the Sportsman's Bridge on their way to Flathead Lake. Netting in the river was difficult due to debris in the nets, high current velocities during spring runoff, and slack water conditions due to the increase in Flathead Lake water levels in late spring. The estimate for the Flathead River at the Sportsman's Bridge is believed to be low due to these factors. Mortality in the river is probably not as high as the data may suggest. We believe most of the 9.9 million fry from McDonald Creek completed the trip to Flathead Lake.

Eyed egg plants were made in three river spawning areas and in Deerlick Creek. In late March, river spawning areas 13, 25, and 27 (Clancey and Fraley 1986) received 40,000 eyed eggs each, in anticipation of losses from redd desiccation and freezing, and 20,000 eyed eggs were planted in Deerlick Creek in an attempt to supplement the run there. Survival to emergence of previous eyed egg plants in the Flathead River system averaged 40.5 percent (Clancey and Fraley 1986).

LITERATURE CITED

Alderdice, D.F., W.P. Pickett and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal of the Fisheries Research Board of Canada. 15(2):220-249.

Alvord, W. 1975. History of the Montana Fish and Game Department. Montana Department of Fish and Game, Helena, MT.

Beattie, W., P. Clancey, J. Decker-Hess, and J. Fraley. 1985. The impacts of water level fluctuations on kokanee reproduction on Flathead Lake. Project 81S-5. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Clancey, P. and J. Fraley. 1986. Effects of the Operation of Kerr and Hungry Horse dams on the kokanee fishery in the Flathead River system, final research report, 1979-1985. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Decker-Hess, J. and P.J. Graham. 1982. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Decker-Hess, J. and S.L. McMullin. 1983. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Decker-Hess, J. and P. Clancey. 1984. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Fraley, J.J. and P.J. Graham. 1982. Impacts of Hungry Horse Dam on the fishery in the Flathead River - Final Report. USDI Bureau of Reclamation. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Fraley, J.J., and S.L. McMullin. 1983. Effects of the operation of Hungry Horse Dam on the kokanee fishery in the Flathead River system. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Fraley, J.J., S.L. McMullin and P.J. Graham. 1986. Effects of hydroelectric operations on the kokanee population in the Flathead River system, Montana. North American Journal of Fisheries Management 6(4):560-568.

Graham, P.J., R. Penkal, S. McMullin, and P. Schladweiler. 1981. Montana recommendations for a fish and wildlife program. Submitted to the Pacific Northwestern Electric Power and Conservation Council.

in Flathead Lake has been increasing rapidly for the last three years. They feed primarily on the same planktonic crustaceans that kokanee depend on. Competition could result in lower survival and growth of kokanee, particularly of juvenile year classes. Monitoring the abundance of mysid shrimp, the zooplankton community structure, and the growth and survival of juvenile kokanee will enable us to better predict the consequences of competitive interaction on the kokanee fishery.

LITERATURE CITED

Alderdice, D.F., W.P. Pickett and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal of the Fisheries Research Board of Canada. 15(2):220-249.

Alvord, W. 1975. History of the Montana Fish and Game Department. Montana Department of Fish and Game, Helena, MT.

Beattie, W., P. Clancey, J. Decker-Hess, and J. Fraley. 1985. The impacts of water level fluctuations on kokanee reproduction on Flathead Lake. Project 81S-5. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Clancey, P. and J. Fraley. 1986. Effects of the Operation of Kerr and Hungry Horse dams on the kokanee fishery in the Flathead River system, final research report, 1979-1985. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Decker-Hess, J. and P.J. Graham. 1982. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Decker-Hess, J. and S.L. McMullin. 1983. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Decker-Hess, J. and P. Clancey. 1984. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Fraley, J.J. and P.J. Graham. 1982. Impacts of Hungry Horse Dam on the fishery in the Flathead River - Final Report. USDI Bureau of Reclamation. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Fraley, J.J., and S.L. McMullin. 1983. Effects of the operation of Hungry Horse Dam on the kokanee fishery in the Flathead River system. Montana Department of Fish, Wildlife & Parks, Kalispell, MT.

Fraley, J.J., S.L. McMullin and P.J. Graham. 1986. Effects of hydroelectric operations on the kokanee population in the Flathead River system, Montana. North American Journal of Fisheries Management 6(4):560-568.

Graham, P.J., R. Penkal, S. McMullin, and P. Schladweiler. 1981. Montana recommendations for a fish and wildlife program. Submitted to the Pacific Northwestern Electric Power and Conservation Council.

Graham, P.J. and W. Fredenberg. 1982. Flathead Lake fisherman census, U.S. Environmental Protection Agency. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Hanzel, D.A. 1986. Seasonal area and depth distribution of cutthroat, bull trout (Dolly Varden) and lake trout in Flathead Lake. Montana Department of Fish, Wildlife and Parks, Job Progress Report, Project No. F-33-R-20, Job No. I-a. Kalispell, MT.

Hanzel, D.A. 1984. Measure annual trends in recruitment and migration of kokanee populations and identify major factors affecting trends. Montana Department of Fish, Wildlife and Parks, Job Performance Report F-73-R-1, Job No. I-b.

Hanzel, D.A. 1975. Measure annual trends in recruitment and migration of kokaee populations and identify major factors affecting trends. Montana Department of Fish and Game, Project No. F-33-R-10, Job No. lb. Job performance report. Kalispell, MT.

Leathe, S.A. and P.J. Graham. 1982. Flathead Lake fish food habits study - Final Report. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Lee, D.R. and J.A Cherry. 1978. A field exercise on groundwater flow using seepage meters and mini-piezometers. Journal of Geology Education 27:6-10.

Malvestuto, S.P., 1983. Sampling the recreational fishery. Pp 397-420 in Neilson, L.A. et al. (eds) Fisheries Techniques. American Fisheries Society.

McMullin, S.L. and P.J. Graham. 1981. The impact of Hungry Horse Dam on the kokanee fishery of the Flathead River. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Montana Power Company. 1976. Application by MPC to FERC for relicensing the Kerr Project.

Morgan, M.D., C.R. Goldman, and R.C. Richards. 1981. Impact of introduced populations of *Mysis relicta* on zooplankton in oligotrophic subalpine lakes. Verh. Internat. Verein. Limnol. 21:339-345.

Phillips, R.W., R.C. Lantz, E.W. Claire, and J.R. Moring. 1975. Some effects of gravel mixtures on the emergence of coho salmon and steelhead trout fry. Transactions of the American Fisheries Society 104(3):461-466.

Potter, D.S. 1978. The zooplankton of Flathead Lake: an historical review with suggestions for continuing lake resource management. PhD dissertation University of Montana, Missoula, MT.

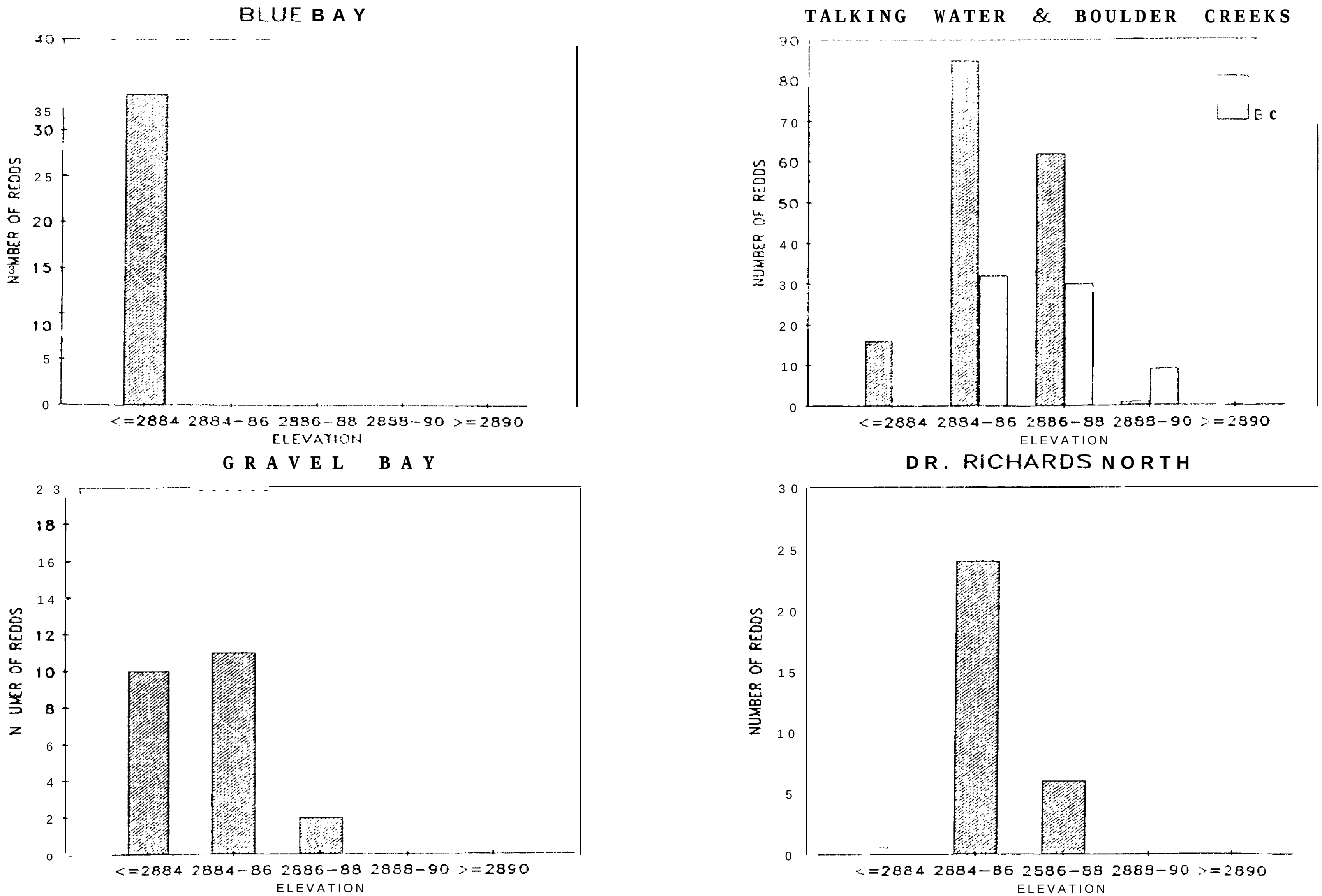
Rieman, B.E. and C.M. Falter. 1981. Effects of the establishment of Mysis relicta on the macrozooplankton of a large lake. Transactions of the American Fisheries Society 110:613-620.

Rumsey, S. 1985. Mysis monitoring in western Montana Lakes. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

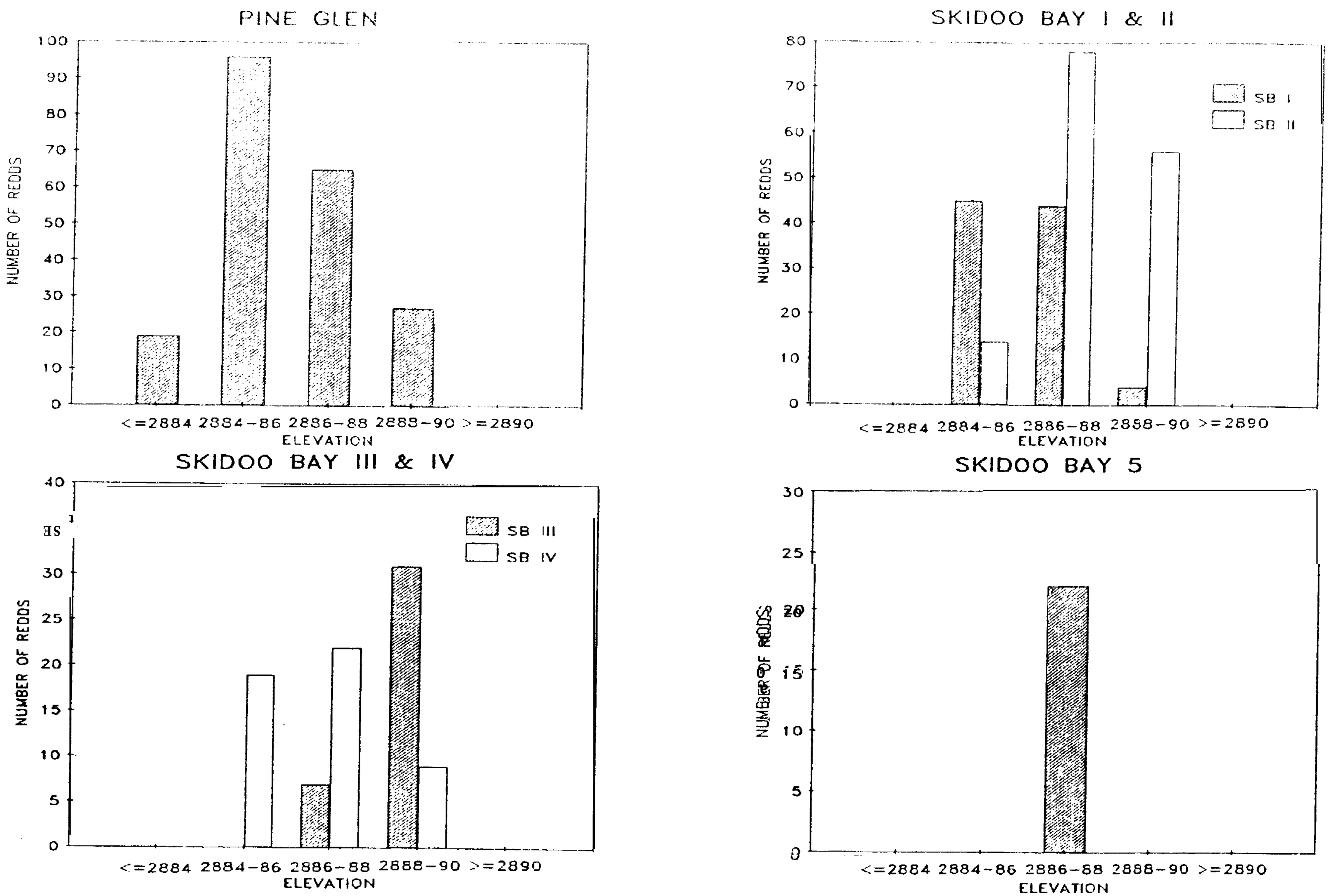
Shumway, D.L., C.E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society 93(4):342-356.

APPENDIX A

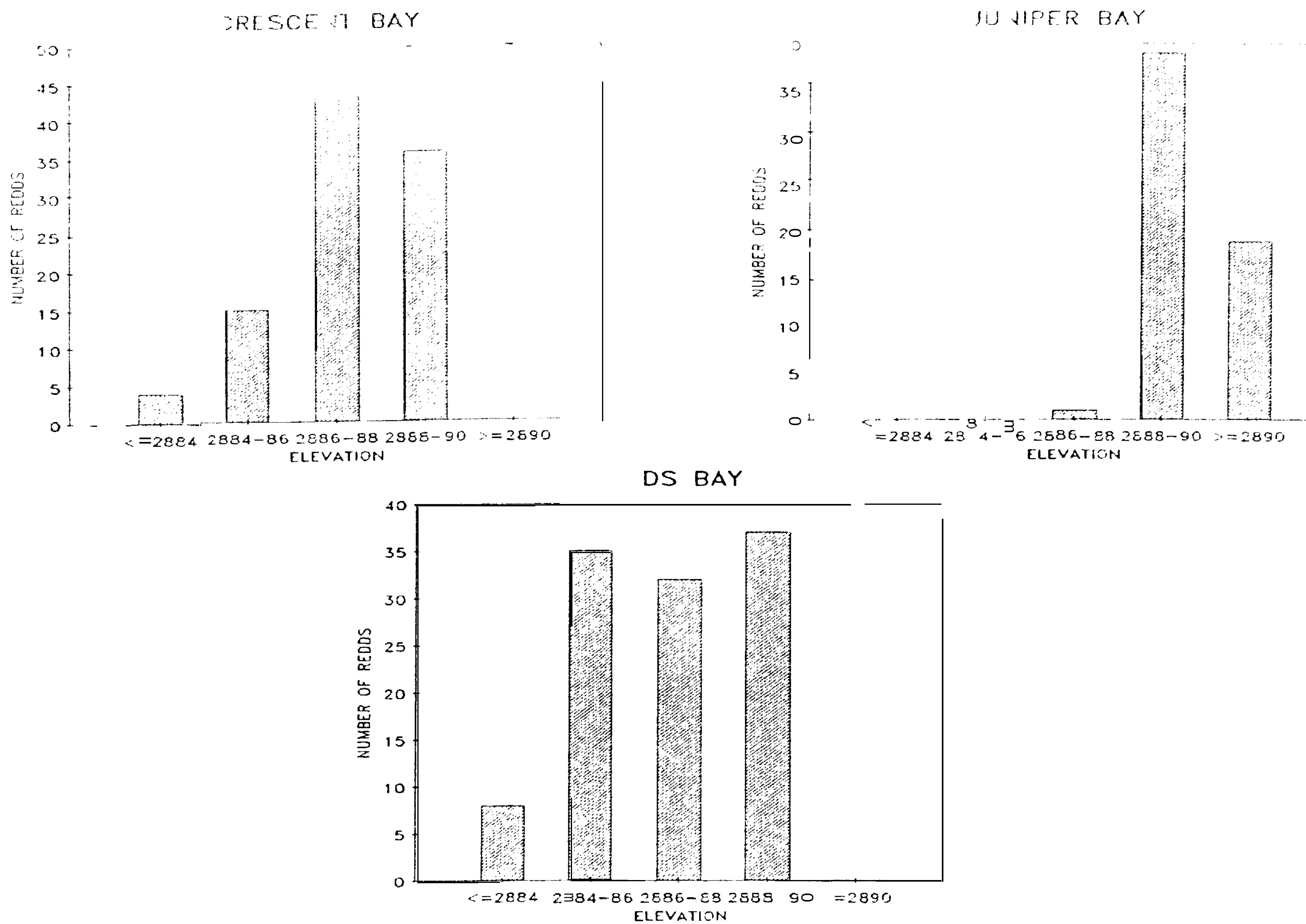
FIGURES AND TABLES



Appendix Figure 1. The depth distribution of kokanee redds at Flathead Lake shoreline spawning areas in **1985**.



Appendix Figure 1 (continued). The depth distribution of kokanee redds at Flathead Lake shoreline spawning areas in 1985.



Appendix Figure 1.(continued). The depth distribution of ee redds at Flathead Lake shoreline spawning areas in 1985.

Appendix Table 2. Summary data for length (mm) and age of kokanee salmon collected in the Flathead River system from 1970-1985. Data are from Hanzel and Rumsey, Progress Reports F-7-R-33, 1970-85.

	No. fish			Average length a/			% Age II+ b/			% Age III+			% Age IV+		
Year	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.
1985	96	96	192	371	358	365	0	0	0	95	95	95	5	5	5
1984	141	161	302	354	337	345	18	11	14	81	88	85	1	1	1
1983	116	140	256	376	361	369	3	1	2	88	96	92	9	3	6
1982	107	106	213	381	367	374	2	1	2	79	89	84	19	10	14
1981	85	120	205	373	356	364	0	0	0	82	95	89	18	5	11
1980	47	69	116	371	343	357	0	0	0	36	65	51	64	35	49
1979	92	102	194	345	328	336	0	0	0	85	98	92	15	2	8
1978	175	143	318	333	312	321	0	0	0	85	95	90	15		10
1977	321	309	630	323	310	316	4	1	2	89	94	92	7	5	6
1976	253	145	398	312	300	306	6	6	6	81	71	76	13	53	18
1975	114	123	237	315	302	308	0	0	0	56	69	63	44	31	37
1974	114	78	192	315	302	308	0	0	0	60	72	66	40	28	34
1973 c/	44	22	66	305	292	298	2	14	8	82	73	78	16	13	14
1972	49	27	76	333	318	325	0	0	0	32	37	34	68	63	66
1971	99	112	211	333	320	327	0	23	11	29	69	49	33	8	20
1970	74	83	157	325	310	318	0	0	0	34	31	33	66	69	67

a/ Combined length is an average of the mean male and mean female lengths.
b/ Combined age structure is an average of the mean male and mean female age structure.
c/ Figures from 1970-1973 are McDonald Creek fish only.

Appendix
Table 3. Length and age data for kokanee salmon collected in Flathead River system spawning areas from 1970-1985.

Year	No. fish Male	Female	Comb.	Average length Male	Female	Comb.	% Age-II+ Male	Female	Comb.	% Age III+ Male	Female	Comb.	% Age IV+ Male	Female	Comb.
Flathead River, Spring (Brenneman's Slough)															
1985	22	12	34	372	351	362	0	0	0	95	92	94	5	8	6
1984[a/]	123	138	261	354	345	350	14	13	14	71	a7	82	14	0	4
1983	29	51	80	381	366	374	0	0	0	100	98	99	0	2	1
1982[b/]	168	225	393	388	369	378	6	3	4	83	97	90	11	0	6
1981	29	29	58	384	361	372	0	0	0	64	93	79	36	7	21
1980	32	40	72	372	343	358	0	0	0	30	61	46	70	39	54
1979	51	48	99	345	329	337	0	0	0	81	96	88	19	4	12
1978	36	18	54	335	317	326	0	0	0	89	94	91	11	6	9
1977	53	49	102	323	315	319	8	0	4	77	96	87	15	4	9
1976	51	35	86	320	307	314	0	8	4	82	52	67	18	40	29
1975	27	25	52	323	310	316	0	0	0	59	83	71	41	17	29
1974	33	11	44	325	310	318	0	0	0	79	91	85	21	9	15
Flathead River, Non-spring (Eleanor Island 1974-1979, House of Mystery 1981-1985, Kokanee Bend-1984)															
1985	17	33	50	370	369	370	0	0	0	87	100	95	13	0	5
1984	55	74	129	351	336	343	17	13	14	83	86	85	0	1	1
1983	36	31	67	373	353	363	0	0	0	100	93	97	0	7	3
1982	31	24	55	377	362	369	0	0	0	89	96	93	11	4	7
1981	27	27	54	358	345	351	0	0	0	96	96	96	4	4	4
1980	---	---	---				---	---	---	---	---			---	---
1979	15	21	36	348	323	336	0	0	0	79	100	90	21	0	10
1978	49	49	98	329	310	320	0	0	0	84	96	90	16	4	10
1977	35	41	76	318	302	310	3	3	3	91	91	91	6	6	6
1976	50	47	97	302	295	298	10	2	6	82	84	83	8	14	11
1975	50	50	100	310	302	306	0	0	0	48	62	55	52	38	45
1974	50	43	93	305	297	301	0	0	0	56	60	58	44	40	42

Continued

Appendix
Table 3. Continued

Year	No. fish Male	No. fish Female	No. fish Comb.	Average length Male	Average length Female	Average length Comb.	% Age II+ Male	% Age II+ Female	% Age II+ Comb.	% Age III+ Male	% Age III+ Female	% Age III+ Comb.	% Age IV+ Male	% Age IV+ Female	% Age IV+ Comb.
McDonald Creek															
1985	26	29	55	373	358	365	0	0	0	96	93	94	4	7	6
1984	109	-77	186	356	340	348	25	14	20	73	86	78	2	0	2
1983	31	32	63	371	358	365	14	4	9	72	93	83	14	3	8
1982	26	24	50	389	369	379	0	0	0	54	76	65	46	24	35
1981	29	64	93	381	361	371	0	0	0	89	97	93	11	3	7
1980	11	24	35	368	345	357	0	0	0	40	71	56	60	29	44
1979	26	33	59	348	330	339	0	0	0	96	0	48	4	100	52
1978	20	17	37	328	318	323	0	0	0	84	94	89	16	6	11
1977	41	50	91	315	305	310	0	0	0	96	83	90	4	17	10
1976	152	63	215	315	300	308	4	12	8	76	64	70	20	24	22
1975	37	48	85	312	300	306	0	0	0	65	71	68	35	29	32
1974	32	26	58	318	305	311	0	0	0	53	81	67	47	19	33
1973	64	22	86	305	292	299	2	14	8	82	73	77	16	14	15
1972	49	27	76	333	318	325	0	0	0	32	37	34	68	63	66
1971	--	---	--	---	--	---	---	--	--	---	---	---	---	---	---
1970	74	83	157	325	310	318	0	0	0	34	31	33	66	69	67
Whitefish River															
1984	24	40	64	354	336	345	4	3	3	96	94	95	0	3	2
1983	20	26	46	384	363	374	0	0	0	78	96	87	22	4	13
1982	12	17	29	383	362	373	0	0	0	100	77	88	0	23	12
1980	4	5	9	375	339	357	0	0	0	75	75	75	25	25	25
1974	3	3	6	315	300	307	0	0	0	67	100	84	33	0	16
1972	28	12	40	284	338	311	0	0	0	65	74	69	26	35	31
South Fork Flathead															
1985	31	22	53	368	353	361	0	0	0	100	95	98	0	5	2

a/ Aging based on 7 males, 14 females.
b/ Aging based on 36 males, 35 females.