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

Final Report FY 1987

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EXECUTIVE SUMMARY

Studies of kokanee reproductive success in the Plathead system from 1981 to 1987 have assessed the losses in fish production attributable to hydroelectric operations. Ve estimated that the Flathead Lake shoreline spawning stock has lost at least 50,000 fish annually, since Kerr Dam vas completed in 1938. The Flathead River spavning stock has lost 95,000 spavners annually because of the operations of Hungry Horse Dam.

Lakeshore spavning has been adversely affected because Flathead Lake has been drafted to minimum pool during the vinter when kokanee eggs are incubating in shallov shoreline redds. Egg mortality from exposure and desiccation of kokanee redds has increased since the mid 1970's. vhen the lake vas drafted more quickly and held longer at minimum pool. Escapement surveys in the early 1950's, and a creel survey in the early 1960's have provided a baseline to vhich the present escapement levels can be compared, and loss estimated.

Main stem Flathead River spavning has also declined since the mid 1970's vhen fluctuating discharge from Hungry Horse Dam during the spavning and incubation season exposed redds at the river margin and increased mortality. This decline folloved an increase in main stem spavning in the late 1950's through the mid 1960's attributable to higher vinter water temperature and relatively stable discharge from Hungry Horse Dam. Spawning escapement in the main stem exceeded 300,000 kokanee in the early 1970's as a result. Spawning in spring-influenced sites has comprised 35 percent of the main stem escapement from 1979 to 1986. We took that proportion of the early 1970's escapement (105,000) as the baseline against which to measure historic loss.

Agricultural and suburban development has contributed less significantly to degradation of kokanee spavning habitat in the river system and on the Flathead Lake shoreline. Their influence on groundwater quality and substrate composition has limited reproductive success in fev sites.

Studies of the effects of hydroelectric operations on the reproductive success of kokanee in the Flathead system have been ongoing since 1980. Results of these studies have been published in a series of annual progress reports which are detailed in Appendix G. The reports summarize spawning site inventories and spavning escapement, egg and alevin mortality rates and the mechanisms by vhich water level fluctuations influence mortality, creel surveys, and investigation of the population dynamics of Flathead kokanee. The Region 1 offices of the Montana Department of Fish, Vildlife and Parks (P.O. Box 67, Kalispell, MT 59903) distribute this material to the scientific community and the general public.

Until recently, it vas considered feasible to recover losses to the Flathead kokanee fishery by enhancing and diversifying natural reproduction. But the establishment of opossum shrimp (M. relicta) in Flathead Lake has reduced the availability of zooplankton forage in the spring and summer, and may reduce the viability of juvenile kokanee. In 1986. research was redirected to quantify this competitive interaction and to investigate artificial means of enhancing the kokanee fishery.

The average density of mysid shrimp in Flathead Lake has increased to $108/m^2$ in 1987, and at some locations density exceeds $500/m^2$. Mysid grazing pressure has delayed the pulse of zooplankton production in the spring and reduced zooplankton standing crop in the summer. Cladocerans such as Daphnia thorata, the preferred food of kokanee of all ages, are the most markedly affected species. The peak density of D. thorata in the summer has declined from 4.8/liter in 1983 to O.9/liter in 1987.

Grovth rates of underyearling and yearling kokanee have declined, apparently as a result of the reduction in their food supply. Spawning escapement has also declined, falling from 150,000 in 1985. to 25,000 in 1986, to 600 in 1987. Fry-to-adult survival has declined from 2.5 percent to near zero. The causes of high mortality, and which age-classes are most susceptible, are not completely understood, but the observed decline in juvenile growth rate implicates mysid-induced change in the trophic ecology of Flathead Lake.

These biological changes in the Flathead system wi11 delay the formulation of a recovery plan for kokanee. Three scenarios represent the possible alternatives for such a plan. If mysid-induced changes in kokanee survival do not persist, or are limited in scope, we can proceed vith enhancement of natural kokanee reproduction. This alternative includes protection of main stem spavning vith stable fall and vinter discharge from Hungry Horse Dam, and enhancing spavning in other tributaries. If the increase in wild fry mortality is limited, main stem flows can be tailored to optimize production from wild escapement and the kokanee fishery can be supplemented with hatchery-produced fry. If the kokanee fishery is not viable over the long term, the emphasis for management wi11 shift to other species, including lake trout, bull trout, and vestslope cutthroat trout. In lieu, mitigation could be appropriate should this alternative be followed.

INTRODUCTION

Project Background

Kokanee (*Oncorhynchus nerka*) were introduced into Flathead Lake in 1916. Fishery records indicate that the species was established by the early 1930's. Until the early 1980's, kokanee supported a summer troll fishery, a fall snag fishery during the spawning run. and a winter troll or ice fishery. Kokanee have comprised over 90 percent of the total sport harvest in Flathead Lake and in the Flathead River (Graham and Fredenberg 1982, Hanzel 1986). The lakeshore snag fishing harvest was estimated to be over 100 tons (about 200.000 fish) in the early 1930's (Alvord 1975). Historical references shov that this popular lakeshore fishery persisted through the 1960's (Robbins and Vorlund 1966). but has since declined to the point where lakeshore spawners represent only two to four percent of the total spavning run.

From the mid 1930's until 1955. hatchery-produced kokanee fry were planted to enhance kokanee spawning in Flathead Lake. Most of this supplementation came from the Somers Hatchery, vhere kokanee production began in the mid 1930's. Another hatchery vas operated at Station Creek, at the southeast end of Flathead Lake in 1920. Kokanee fry vere raised there until 1959. Eggs were taken at several lakeshore spawning sites, in Swan River, at Lake Mary Ronan, at McDonald Creek (a tributary of the Middle Fork in Glacier National Park), and from the main stem river to supply these hatcheries. Between one and three million fry were planted along the Flathead Lake shoreline between 1935 and 1955 (Table 1). Two million fry were planted into the lake in 1961, 1962, 1965, 1967, and 1969. After 1970, 200,000 fry were released at the hatchery, principally to maintain a spavning run into Hatchery Bay for egg collection.

Kokanee spawn in shallow water, along lakeshores and in streams, thereby leaving their eggs susceptible to desiccation and freezing when either lake level or streamflow fluctuates. Decline in the fall fishery for kokanee spawners along the Flathead lakeshore in the mid 1960's (Decker-Hess and McMullin 1983) was linked circumstantially to declining reproductive success in shoreline spawning areas. Spawning runs in the Flathead River also declined in the late 1970's. Hydroelectric operations at Kerr Dam, which regulated the dravdovn of Flathead Lake in the fall and winter. and at Hungry Horse Dam. which influenced main stem Flathead River discharge during the spawning and incubation season, were linked, at least circumstantially, to the decline in the kokanee fishery (Graham et al. 1979).

Study of the effects of hydroelectric dam operations on kokanee reproductive success in the Flathead Lake/River system began in 1979 under Bureau of Reclamation funding, and continued in 1981 under Bonneville Power Administration funding by Northwest Power Planning and Conservation Act mandate. The goal of studies

Table 1. Kokanee egg collection and plants of hatchery-reared kokanee fry in Flathead Lake, 1935 - 1987.

Year	Egg Collection (millions) Flathead River	Flathead Lake	Svan Lake	Other	Fry Plants (millions)
1935					1.44
1936		3.955			2.85
1937		6.662			3.17
1938		4.781			2.63
1939		4.622			2.43
1940		3.988			2.29
1941		4.539			2.61
1942		1.044			1.45
1943		1.867			1.00
1944		2.236			1.30
1945		3.301			1.06
1946		3.519			1.65
1947		2.019			1.44
1948		3.590			1.33
1949		3.547			2.46
1950		4.287			2.71
1951	1.201	8.209			2.04
1952		3.414			1.69
1953	0.557	7.468			0.97
1954	0.355	9.296		0.168	1.21
1955	0.391	1.889		0.320	1.12
1956	0.018	11.158	0.258	0.885	1.15
1957		9.634		0.548	1.65
1958		7.372		0.755	0.21
1959	1.021	2.041		1.582	
1960	0.134	6.187		1.081	
1961	1.382	0.992	0.249	2.013	0.19
1962	0.867	2.930	0.090	3.742	2.12
1963	5.406	2.026	0.502	0.729	2.07
1964	2.384	2.411	0.038	1.143	0.07
1965	2.823	4.975	0.048		2.00
1966	2.299	7.934		0.129	
1967	5.648	1.598		0.702	2.03
1968	2.936	4.173		0.839	0.01
1969	2.966	2.539		1.347	2.02
1970	5.279	0.966		1.192	
1971	1.295	1.717		1.760	
1972	0.780	1.210	0.105	1.666	0.11
1973		0.058	2.292	1.468	0.10
1974	0.023	0.947	0.597	1.609	0.11
1975	0.134	1.685	0.083	0.596	0.09
1976		1.184	0.361	0.773	0.08
1977	0.093	2.032	0.569	0.093	0.09
1978		1.791	0.265	0.818	0.10
1979	0.066	2.174			0.15
1980		0.471		0.785	0.10
1981	0.263	0.422	0.293	0.805	0.10
1982	0.493			0.522	0.15
1983	0.049	0.045	0.437	2.024	0.10
1984		0.909	0.301	1.528	0.60
1985		2.211		2.937	0.18
1986			0.025	2.499	0.10
1987			0.032	2.056	0.90

has been to identify and quantify impacts on kokanee reproductive success related to hydropower operations, and to develop means of mitigating those losses.

Objectives

Study of the effects of hydroelectric operations at Kerr and Hungry Horse dams on the reproductive success of kokanee in the Flathead River system and in Flathead Lake has been designed to address the following objectives:

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

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

3. Determine the impacts of the historical and present operation of Kerr and Hungry Horse dams, and the influence of other environmental factors, on kokanee reproductive success at shoreline spawning areas on Flathead Lake.

4. Identify the timing and destination of successive runs of kokanee spawners in the Flathead River, measure the sport harvest, and determine if timing is affected by discharges from Hungry Horse Dam.

5. Quantify the effect of controlled flows on the distribution and reproductive success of kokanee in the regulated portion of the Flathead River.

6. Develop a stock-recruitment relationship for kokanee in the Flathead system.

7. Develop a recovery plan for kokanee spawning on the shoreline of Flathead Lake.

The establishment of the opossum shrimp (Mysis relicta) in Flathead Lake has effected dramatic changes on the trophic ecology of the fish and zooplankton communities. Since the spring of 1986. the BRA-funded studies have been partially redirected to investigate the interactions of kokanee and mysid shrimp, predict changes in the kokanee fishery that might result, and to develop means, if possible, of pursuing mitigation for hydropower-related losses in the context of mysid-related changes in trophic ecology. In 1986 three additional objectives were drafted.

8. Measure changes in the zooplankton community, upon which kokanee feed, related to the increase in mysid shrimp abundance.

9. Measure change in the growth and survival of juvenile kokanee associated with their competitive interaction with mysid shrimp.

10. Test the feasibility of planting hatchery-reared kokanee fry in supplementing the Flathead kokanee fishery.

This report concludes the studies on kokanee reproductive success in the Flathead River and in Flathead Lake. It identifies the spawning areas that are susceptible to fluctuating water levels and river flovs, and the life stages that suffer resulting mortality. Decline in spavning escapement in the river system, and on the lakeshore is quantified in loss statements. Annual progress reports detail the research on Flathead River and Flathead Lake kokanee stocks that has been conducted by MDFVP since 1980 (Appendix B). These reports summarize spawning site inventories and spawning escapements, and document the mortality rates of eggs and alevins exposed to fluctuating vater levels. The groundwater hydrology of the Flathead Lake shore aquifer was described, and the effects of groundwater discharge on egg survival investigated, in a subcontract study conducted by Geology Department staff at the University of Montana (Woessner and Brick 1984 and 1985). Historic fluctuation of the Flathead kokanee population was studied in an effort to forecast the results of the proposed recovery effort (Fraley and McMullin 1983). MDFWP proposed, and the Bureau of Reclamation implemented, a more stable fall discharge regime at Hungry Horse Dam. Enhanced kokanee egg survival resulted at spavning areas on the main stem Flathead River (Clancey and Fraley 1985). These reports are available for scientific and public reference from MDFWP (Region 1. P.O. Box 67, Kalispell, MT 59903).

Development of mitigation alternatives has required that changes in the trophic ecology of Flathead Lake, related to the establishment of Mysis relicta, be investigated. The methods. results, and conclusions of this research are presented as a background to formulating the mitigation alternatives.

Three mitigation plans are outlined to meet the various scenarios that could result from kokanee/mysis shrimp interaction in Flathead Lake. As the outcome of this interaction, still in its early stages, cannot be predicted yet, flexibility in the mitigation plan is necessary.

SYNOPSIS OF IMPACTS ON THE FLATHEAD KOKANKEE FISHERY:

Flathead River System

Located 8 km upstream of the mouth of the South Fork, Hungry Horse Dam is operated by the Bureau of Reclamation. Construction of the dam began in 1948 and vas completed in 1952. The dam created a reservoir 66 km long, storing 3.461 million acre-feet of vater. The dam is operated to provide flood control and electric energy, in cooperation vith 19 dams on the Columbia River system. Hungry Horse Reservoir holds approximately 40 percent of the total storage of the Columbia system. At present four turbines generate 328 megavatts of electric pover. The penstocks are located 75 m belov the crest of the dam.

Hypolimnial discharge from Hungry Horse Reservoir has lowered the summer vater temperature and raised the vinter vater temperature in the Flathead River belov the dam (Fraley and Graham 1982). Kokanee spavning runs vere established in the river system before Hungry Horse Dam vas constructed. A large number of spavning kokanee vere observed belov the dam in September, 1951 (Stefanich 1953). Warmer fall vater temperature and relatively stable flovs, from 1955 to 1966, increased the reproductive success of kokanee spavning in the main stem and the South Fork. Stronger spavning escapements developed in the main stem Flathead River. The strong main stem spavning run in 1975, estimated to exceed 300.000 fish (Hanzel 1976). resulted from favorable flov and high egg survival in 1971.

Beginning in 1967, peaking pover generation at Hungry Horse Dam resulted in fluctuating flovs dovnstream which adversely affected the reproductive success of kokanee. In five of the eight years betveen 1967 and 1975, the average main stem river flov during the incubation season (December 15 to March 31) was less than the average flov during the spavning season (October 15 to December 15). This peaking pover operational regime resulted in high egg mortality in the South Fork and main stem Flathead River. In 1975, 1976, and 1978-1980, river discharge fluctuated more videly. and the impacts on kokanee reproduction vere more severe (Figure 1). A large proportion of redds built at the margins of the river in shallow water during high flov were subsequently exposed vhen flov declined during the incubation period. Desiccation and freezing subject kokanee eggs to very high mortality in these exposed redds (Fraley and Graham 1982, Fraley and Decker-Hess 1986). Spavner year class strength was shown to be highly dependent on the fall and winter operational regime of Hungry Horse Dam.

Through the Northwest Power Planning Council, the Montana Department of Fish, Wildlife and Parks (MDFWP) recommended that flovs in the main stem be held betveen 3.500 and 4.500 cfs during the spavning period (October 15 to December 15). and that a

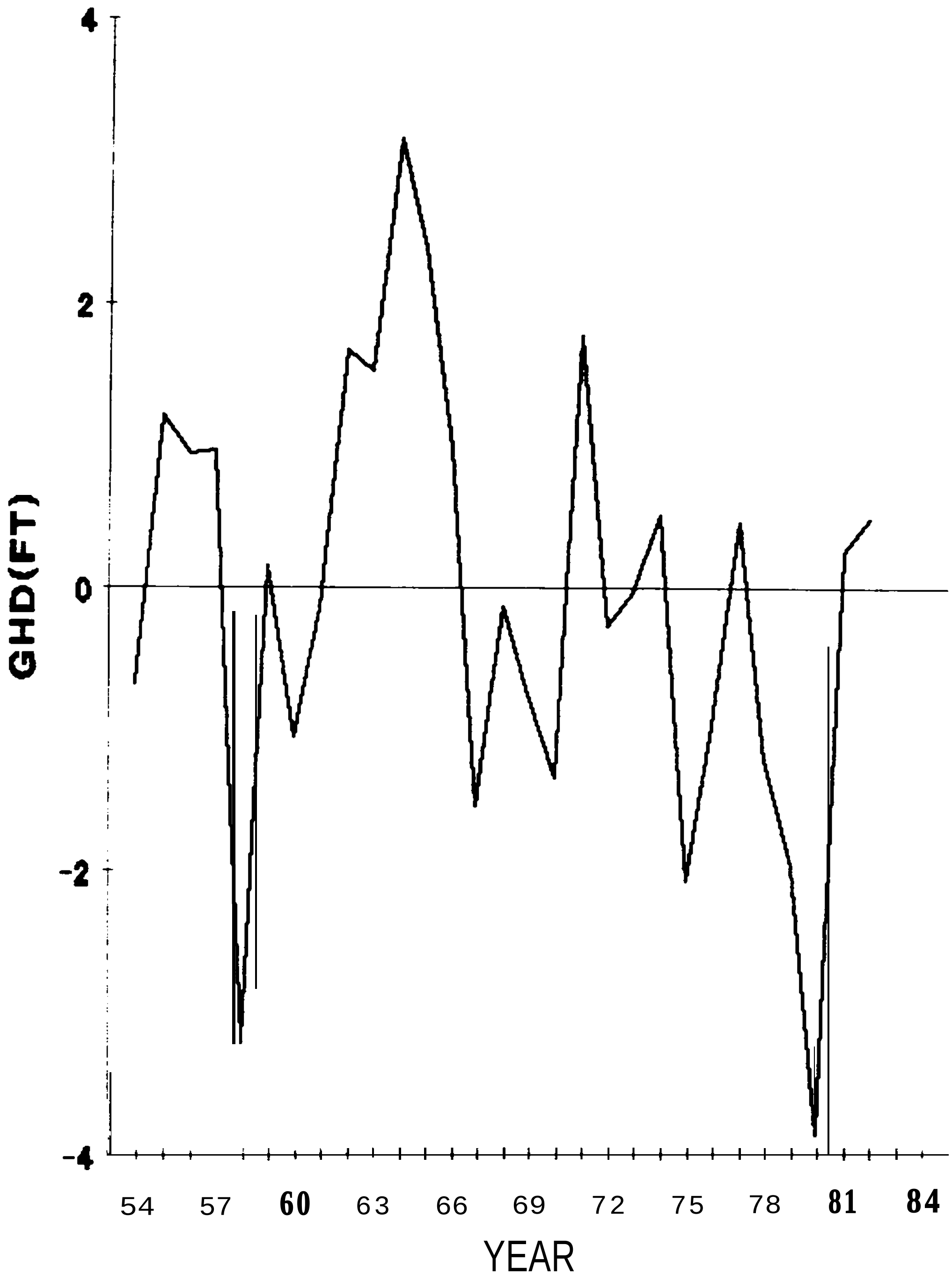


Figure 1. The difference in average flow in the main stem Flathead River between the spawning season and the incubation season for kokanee eggs. Gauge height measures flow in the river, and so average gauge height differ-mm (GHD) expresses the seasonal change in flow.

minimum flow of 3,500 cfs be maintained through the incubation period and the rest of the year. These flov recommendations were made to protect the invertebrate food supply and habitat required by all game fish species in the river, and to redress the adverse effects of peak pover generation on kokanee reproduction. These flows have been implemented by the Bureau of Reclamation since 1982. Their effectiveness in limiting kokanee egg and alevin mortality in the main stem Flathead River has been demonstrated by subsequent research (Clancey and Fraley 1986). In 1984 pre-emergent survival in the main stem vas 87 percent, approaching that found in McDonald Creek, a tributary of the Middle Fork where flow is not affected by discharge from Hungry Horse Dam.

Stabilization of the discharge from Hungry Horse Dam was implemented in 1982 to reduce losses in kokanee reproductive success in the Flathead River. It vas thought that the increased fry production from the river would improve recruitment. and contribute toward realization of MDFVP's management goals for kokanee in the Flathead system. After escapement to the river system increased from 1983 to 1985 one recovery scenario suggested that the main stem spavning run could increase to 150,000 fish by the late 1990's (Fraley et al. 1986).

Loss of Main Stem Spawning

We considered both the positive and negative effects of Hungry Horse Dam operations in ascribing losses incurred by river spawning kokanee. There are no quantitative surveys of kokanee spawning in the main stem Flathead or South Fork before Hungry Horse Dam was built. As mentioned above (Stefanich 1953 and 1954). we know only that substantial runs existed. We believe that dam operations from the 1954 to 1967 were generally favorable to kokanee reproduction, and that escapements increased during that period. Losses caused by the operations of Hungry Horse Dam are limited to the difference betveen main stem escapements before Hungry Horse Dam was built and escapements in the 1980's after hydroelectric operations had reduced the population.

Early escapement surveys, records of spawn-taking operations conducted by hatchery personnel, and quantitative spawner surveys from 1979 to 1985 all indicate that most of the spawning in the main stem Flathead River has occurred at areas influenced by groundwater springs. Between 1979 and 1984, redd counts at 19 spring-influenced main stem areas comprised an average of 59 percent of the total spawning in the main stem (Table 2). Eleven of these areas are heavily spring-influenced, where egg incubation and fry emergence is not impacted by fluctuating river flows. Escapement at these 11 areas averaged 35 percent of spawning in the river between 1979 and 1984. Kokanee are attracted to these areas by the thermal and chemical characteristics of spring discharge. Increases in main stem spawning caused by favorable dam operations developed primarily at non-spring areas on the upper

Table 2. Kokanee escapement (redd counts) in spring-influenced spavning areas on the main stem Flathead River, 1979 - 1984.

Area	River km	1979	1980	1981	1982	1983	1984
Brenneman's Slough	37.0	425	I.36	341	180	278	155
Reserve Drive	48.3	22	0	0	60	0	71
Gooderich Bayou	50.5	10	0	0	0	2	0
Pressentine Side Channel	52.4	55	13	830	0	154	65
Kokanee Bend	60.8	250	0	375	0	197	0
Taylors	66.0	0	0	11	0	36	0
Hvy. 40 Bridge	66.5	20	0	160	67	123	115
Colunbia Falls Slough	67.6	380	231	146	0	25	60
Anaconda Bar	68.5	100	0	288	0	260	890
Total Spring Influenced		1262	380	2151	307	1075	3.356
% of Main Stem Spawning		45	81.4	27.4	24	15.7	18.1

main stem. It is reasonable to assume, then, that at least 35 percent of the escapement in the early 1970's, vhen approximately 300.000 kokanee migrated into the river system, returned to these heavily spring-influenced areas. The loss attributable to unfavorable hydro operations, which began in 1975. can be estimated by the difference betveen escapement to spring-influenced areas in the early 1970's (35 percent x 300,000 = 105,000 fish) and total main stem escapement in the early 1980's (11.000 fish). The loss in main stem spavning vas. thus, approximately 94,000 fish.

Flathead Lake

Kerr Dam, located 7 km dovnstream of the natural outlet of Flathead Lake, vas completed in 1938. Montana Pover Company began operating the first 56,000 kv turbine in 1939. Tvo more turbines have been added since then, the second in 1949 and the third in 1954. so that total generating capacity is 180,000 kv. Prior to impoundment by Kerr Dam, the vater level in Flathead Lake vas near 2,882 feet from September to mid April. Spring run-off filled the lake to about 2,893 feet in May and June. The operation of the dam changed the lake level regime markedly. The operating license requires that full pool be held from June 10 to Labor Day, to facilitate recreational boating on the lake. Dravdovn begins in mid September. vith the minimum pool level of 2,883 feet reached sometime in March. Flood control constraints require that the lake be drafted to minimum pool by April 15. The license further requires that, in the event of a flood, water be spilled at the dam to prevent the lake level from exceeding 2,893 feet. A sill at the mouth of the lake restricts outflov at minimum pool to 5,200 cfs.

Two turbines at Kerr Dam generate baseload pover. The output of the third turbine is varied to meet the daily fluctuations in pover demand. Remote control of this third turbine from MPC's operations center in Butte allows instantaneous regulation of output to meet demand. Demand is high from 8:00 to 10:00 a.m. and 5:00 to 9:00 p.m. each day, in addition to the seasonal peak in December and January. The lake level is influenced by operations at Hungry Horse Dam, as well as those at Kerr Dam.

Kerr Dam operations have influenced the spavning ofkokanee along the shore of Flathead Lake since the dam was completed. Historical records indicate that the kokanee population was thriving by the early 1930's vith hundreds of thousands of fish spavning along the lakeshore and in the river system. Before the dam was completed, fall lake levels were near 2,883 feet. Kokanee were evidently spavning successfully in the shallow vater zone belov this elevation. After impoundment, fall lake levels were about ten feet higher. Though we have no record of spawning surveys until 1951, kokanee spavning shifted to the shallow water zone below the higher lake level successfully. The trend tovard smaller size at maturity, which lasted from the late 1930's to the mid 1950's. indicates that the abundance of kokanee vas increasing during this period, because kokanee growth rate is assumed to be density dependent.

Completion of Kerr Dam, and the nev lake level regime, changed the slope and substrate composition along the shoreline. Because the lake vas held near full pool from June through September erosive processes began to change the high shoreline. Beach profiles vere steepened and eroded material redistributed dovnslope. Finer grained material is eroded faster by vave processes, leaving a relatively coarse-grained beach in the vave zone. Before the construction of the dam, the shoreline vould have reached an equilibrium vith the vave dynamics of natural lake levels. The lake level vould have been lov during most of the year, in particular at the times of strong fall and vinter storms. A broad, coarse-grained beach formed over the entire area of the elevation change. The vegetated shoreline above high vater would have remained relatively stable.

After the dam vas built, vith the lake level held higher for a longer period in the fall, nev erosive processes began. Deeper water along the shoreline allowed larger vaves to impact the beach. The shoreline retreated, and the sediments were transported dovnslope over the previous beach. The upper beach profile steepened. Shores of resistant bedrock vould have changed very little over short time periods, whereas beaches developed on glacial till vould respond very quickly. Uave energy tends to be concentrated on headlands, moving sediment into the bays. Refraction of waves along a linear shoreline causes longshore transport of sediment. Piers and docks interrupt this longshore transport, and material accumulates on the upcurrent side of these structures.

Aerial photographs taken at irregular intervals before and since the dam was built shov major changes in the shoreline of Flathead Lake. Erosive forces have almost completely removed the vooded delta that existed at the mouth of the Flathead River. The photographs of the mouth of Svan River, Woods Bay, and Skidoo Bay shov modification of beach profiles and increased sediment mobility in the 20 years after the dam was completed. Substrate analysis by MDFWP in 1983 and 1984 shoved a highly dynamic beach system in Skidoo Bay. Dramatic shifts in the size composition of the substrate as the lake vas drafted and again as the lake refilled suggest that waves continue to move the substrate up and down the beach (Woessner, Brick and Moore 1985).

Kokanee spawning sites on the lakeshore are characterized by high groundvater discharge and pebble/gravel substrate that is neither too large for the fish to excavate redds nor too fine to inhibit water exchange over the incubating eggs. Erosion can obliterate redds by scouring substrate in the wave zone. or increase embeddedness by depositing fine-grained material downslope (Decker-Hess and Graham 1982). Deposition of gravel may prevent kokanee from building redds belov the groundvater table, reducing the attractiveness of some spavning areas and the survival of eggs in others. Spavning runs persisted along the Flathead Lake shoreline until the 1960's. so ve assume that changes in substrate composition did not affect spavning success.

Kokanee spavning along the shore of Flathead Lake represents a small and declining proportion (2 - 4 percent) of the total spavning escapement in the system (Table 3). Our study has shovn that egg mortality in the zone above minimum pool exceeds 95 percent, except in a limited number of sites vhere active groundvater seeps keep redds vetted through the incubation period. Though eyed kokanee eggs stay alive in even damp gravel for long periods, the alevins die immediately after they hatch unless they can reach the lake. So, kokanee fry also incubate and emerge successfully from redds built close to the minimum pool elevation, where the duration of exposure is short. Experiments have shown kokanee alevins capable of moving short distances through coarse substrate at the time of emergence (Beattie et al. 1985). Where groundwater seeps facilitate such movements along the lakeshore these alevins could reach the lake from redds above the lake level.

The number of redds below minimum pool has varied for the last six years, comprising from 5 percent to 40 percent of lakeshore spawning. Recruitment from these deep redds is largely responsible for maintaining the remnant lakeshore run. The quality of spawning habitat below minimum pool varies. Where clean gravel/pebble substrate exists and groundvater flux and dissolved oxygen are high, we estimated egg to fry survival to range from 20 percent to 30 percent (Decker-Hess and Clancey 1984, Beattie et al. 1985). At other areas low groundwater dissolved oxygen restricted survival to belov one percent.

Loss of Lakeshore Spawning

The marked decline the lakeshore spavning can be attributed primarily to changes in the operation of Kerr Dam which caused the lake to be drafted earlier in the fall and held at minimum pool for longer periods in the vinter and spring. The majority of kokanee spawn in October and November in shallow vater less than 12 feet (3.5 m) deep. Since dravdovn begins in September, the lake level during spawning is usually betveen one and tvo feet below full pool (2,892 to 2,891 ft elevation). All redds in the zone above minimum pool (2,883 to 2,892 ft) are subject to exposure during dravdovn, with the duration of exposure decreasing with elevation. Unless eggs in exposed redds are vetted continually by groundwater, runoff, or the adjacent lake, they die very quickly after exposure (Fraley and Graham 1982. Decker-Hess and Clancey 1984). Even if conditions favor egg survival in exposed redds. the hatched fry cannot reach the lake successfully

Table 3. Redd counts at Flathead Lake shore spawning areas from 1981 to 1987.

Area	Redd Count						
	1981	1982	1983	1984	1985	1986	1987
Wood's Bay	57	188	76	176	112	24	3
Yellow Bay	152	197	79	0	0	5	0
Blue Bay	45	55	45	30	38	0	0
Talking Water Cr.	12	4	33	45	164	61	4
North Buswells	0	0	15	115	71	39	0
Dee Creek	0	16	0	0	0	0	0
Gravel Bay	37	238	187	326	21	33	0
Doc Richards Bay	181	87	52	101	34	0	0
Pineglen	45*	85	0	90	207	65	0
Skidoo Bay	103	126	200	169	351	I.56	4
Big Arm Bay	0	0	0	13	0	0	0
Crescent Bay	5	31	19	18	99	18	0
Lakeside Bay	0	2	2	0	0	0	0
Hatchery	15*	10"	12*	50*	N/A	0	0
Somers Bay	0	0	28	1	59	3	0
TOTAL	652	1039	748	1134	1156	339	11

* Estimated Counts

unless the redd is very close to elevation of the lake at the time of emergence (Beattie and Clancey 1985). Until the late 1960's. slover drafting of the lake in the fall and shorter duration at minimum pool allowed successful incubation and emergence from redds belov 2,885 ft. Above this elevation egg mortality vas alvays high. A large enough proportion of lakeshore spavning must have occurred belov 2,885 ft to perpetuate the lakeshore spavning population.

The change in Kerr Dam operations that brought about the demise of the lakeshore run is shovnby examining the length of time the lake was held belov 2,885 ft during the incubation period (Table 4). These figures shov that conditions for incubating eggs were highly unfavorable from 1946 to 1958, then favorable until 1972, and groving increasingly unfavorable through the mid 1980's. From 1959 to 1972. there vere eleven years when the lake was held five or fever days belov 2,884 ft. Since then there have only been five favorable years. The unfavorable years from 1946 to 1958 vere at least partially compensated for by hatchery plants during that period.

From one to three million hatchery-produced fry were planted annually into Flathead Lake from the mid 1930's to 1957 (Table 1). Assuming tvo to five percent survival to adulthood, these plants could have substantially increased adult year class strength during that period. But a creel survey documented an extensive snag fishery on lakeshore spawners which harvested an estimated 68,000 in 1963 (Robbins and Worlund. 1966). Assuming that anglers harvested 50 percent of the spavners we may estimate that the total return exceeded 135,000 fish.

The 1963 adult year class vas recruited from fry emerging in 1960. assuming that most of the spavners were four years old. Only 130,000 hatchery fry vere planted in Flathead Lake in 1960. Kerr Dam operations vere favorable for lakeshore spavning in water year 1959 (October 1959 to September 1960) because the lake vas drafted belov 2,885 feet for only 16 days (Table 4). So ve assume that the 1963 spavning run resulted primarily from successful natural reproduction. Spavning surveys in the early 1950's (Stefanich 1953 and 1954) and interviews with residents (Decker-Hess and Clancey 1984) corroborate our belief that strong spawning runs to the Flathead Lake shore persisted until the late 1960's.

Based on the 1963 snagging harvest, ve know that the historic lakeshore spawning run numbered between 68.000 and 136,000 fish. Between 1981 and 1985, lakeshore escapement did not exceed 3,000 fish. The loss has been at least 65,000 adult kokanee, but could have been as many as 133,000 fish. This loss estimate is conservative. Robbins and Worlund (1966) did not differentiate the fall harvest of the shoreline snag fishery from the later harvest of immature kokanee that might have occurred in early 1964. We assumed that 50 percent of the fishing effort from October, 1963 through April, 1984 targeted shoreline spawners.

Table 4. Dravdovn duration belov 2,884 ft and 2,885 ft from 1928 - 1984 in Flathead Lake (from Decker-Hess and Clancey, 1984).

Year	<2,884	<2,885
1928	61	61
1929	181	181
1930	196	200
1931	211	212
1932	195	200
1933	144	178
1934	124	173
1935	208	212
1936	203	205
1937	212	212
1938	108	110
1939	57	149
1940	85	112
1941	54	84
1942	66	90
1943	51	66
1944	56	91
1945	48	63
1946	22	47
1947	22	50
1948	54	72
1949	60	81
1950	55	74
1951	19	41
1952	42	57
1953	39	58
1954	29	48
1955	28	65
1956	0	0
1957	47	59
1958	43	56
1959	0	16
1960	0	0
1961	0	0
1962	34	50
1963	0	20
1964	11	39
1965	0	0
1966	21	50
1967	5	32
1968	0	20
1969	0	8
1970	0	45
1971	0	31
1972	0	0
1973	32	46
1974	0	0
1975	45	60
1976	0	20
1977	37	69
1978	32	74
1979	64	87
1980	71	89
1981	0	48
1982	5	67
1983	0	62
1984	18	85

There is some evidence that the late-vinter ice or boat fishery did not become popular until the late 1970's. Therefore, the fall snag fishery could have harvested more than 68,000 fish, and the total lakeshore spawning run could have been larger.

We based our loss estimate on a single adult year class, but the size of spavners in 1963 vas substantially greater than in most years between 1950 and 1970 (Hanzel 1985). Because kokanee length varies inversely with year class strength (density dependence), ve may postulate that adult kokanee vere more abundant for most of that 20-year period than they vere in1963. Though it is clear that abundance fluctuated videly during that period, the average abundance of lakeshore spavners may have exceeded that found in 1963.

In 1962, the lakeshore snag fishery harvested 148,000 fish (Robbins and Worlund 1966). of which approximately 50,000 may have survived from 1959 hatchery plants. Depending on vhat proportion of the run was taken in the snag fishery, an estimate of total, naturally-produced spavners vould range from 90,00 to 180,000 fish.

Given the high variability in spavning run strength, and the paucity of quantitative historic data, ve can state that historic loss has been at least 65,000 spavners. The arguments just presented lead us to believe that this is a conservative estimate. Evidence has been presented here linking decline in lakeshore-and river-spavning kokanee to the effects of the operations of Kerr and Hungry Horse dams. We cannot, hovever, exclude the possibility that other environmental changes have also influenced spawning habitat quality and reproductive success. Sedimentation of some main stem river spawning areas has increased, largely because grazing stock reduce bank stability. Irrigation withdrawals reduce the flow in some tributaries. The rate of sediment accumulation exceeds the rate at which it is flushed out, and embeddedness increases. These effects have been observed at tvo main stem tributaries, Spring Creek and Brenneman's Slough.

Homesite and agricultural development along the shore of Flathead Lake may also have increased sediment input and influenced groundwater quality at shoreline spawning areas. We do not have the historic data to show that fine sediments have accumulated to detrimental levels at these areas, or even that embeddedness has increased over the last 2C years. Deposits of fine sediment do not generally limit egg survival at any of the lakeshore spawning areas that are still used by kokanee. Assays of groundwater quality at these spawning areas have not shown contaminant levels that are detrimental to developing fish eggs, though sewage leaches into groundvater along much of the lakeshore.

MDFWP studies support the contention that the influence of domestic and agricultural development has been relatively minor, compared to the impacts of fluctuating lake level and river flov on kokanee reproduction.

Changes in the Trophic Ecology of Plathead Lake

In the six years since studies of the impacts of hydroelectric dam operations on the Flathead kokanee fishery began. changes in the trophic ecology of Flathead Lake have added a nev dimension to the problems of maintaining the fishery, and mitigating losses incurred by hydroelectric operations in the system. These changes in part stem from the establishment of opossum shrimp (*Mysis relicta*) in the lake, and their competition vith kokanee for zooplankton food. Other factors, including interspecific competition and predation, may also be reducing the survival of kokanee in the lake.

Escapement surveys conducted in 1986 and 1987 documented a marked decline in the abundance of spavning kokanee in the Flathead system. In 1986, the kokanee spavning escapement to the Flathead River. its tributaries, the Swan River, and the Flathead Lake shoreline declined to the lowest number in seven years of study (methods for estimating spavning escapement are presented in previously published reports - Clancey and Fraley 1985. Decker-Hess and Graham 1982). The total number of spawners in the system was estimated to be 24,000 fish. This total included 21,500 spawners in McDonald Creek, 200 in the South Fork, 950 in the main stem Flathead River (Table 5). 250 in the Whitefish River, 200 in the Svan River, and 925 along the Flathead Lake shore.

In 1987 spawning escapement declined markedly again. In all spawning areas in the Flathead Lake/River system the numbers of spawners were the lowest on record. Surveys of McDonald Creek, the South Fork, the main stem Flathead, Whitefish River, Swan River, and the lakeshore shoved a total escapement of less than 600 fish.

The figures for 1986 and 1987 are minimum estimates of escapement because only the principal spavning areas in the main stem river and along the lakeshore vere surveyed. Previous study has shown that survey of twelve sites in the main stem river and 22 sites along the lakeshore provides a reliable index of spawning escapement (Decker-Hess and McMullin 1983, Clancey and Fraley 1986).

The decline in adult year class strength in 1986 and 1987 has cast uncertainty on the future of the kokanee fishery. More pertinent to this discussion, the decline in survival of wild fry has prompted further evaluation of a mitigation plan that relies on enhancing the production of kokanee fry in the Flathead River.

The folloving discussion outlines the history and rationale behind the introduction of mysid shrimp into the Flathead system,

Table 5. Redd counts for the 12 main stem Flathead River spawning areas 1979 - 1987.

Area Description	Area Number	Nunber of Redds								
		1979	1980	1981	1982	1983	1984	1985[b]	1986	1987
Brenneman's Slough	1	425	136	341	180	278	155	I.54	27	0
Fairview	17	359	0	118	0	0	550	35	0	0
Pressentine Side Channel	20-21	55	13	830	0	154	660	94	114	0
Bucks	25	290	5	363	0	124	22	33	0	0
Hoemer	27	150	0	494	0	368	140	81	4	0
Kokanee Bend	29-30	275	0	469	22	300	99	2	1	0
Columbia Falls Bridge	32	--[a]	--[a]	735	0	199	137	125	0	0
Spring above Taylors	34	20	0	160	67	123	115	40	1	0
Columbia Falls Slough	36	330	231	0	0	0	0	0	0	0
Mouth of Slough and upstream bank	35-37	150	0	641	0	1,327	510	60	84	0
Anaconda Bar Spring	38	100	0	288	0	260	890	77	19	0
House of Mystery	39	--[a]	--[a]	1,083	560	1,852	1,218	1,600	107	17
Total, I.2 areas		2,154	385	5,522	829	4,985	4,496	2,301	357	17
Total, 45 areas		2,802	467	7,853	1,528	6,680	7,440	--	--	--
% Total		77	82	70	54	73	60	--	--	--

a/ Areanotchecked.
b/ Minimum counts due to 300% of normal flows.

the impacts of similar introductions in other large lake systems, and the reasons vhy a substantial portion of the final tvo years of this study has been devoted to study of the interaction in Flathead Lake.

In an attempt to emulate the successful introduction of M. relicta into Kootenai Lake, B.C., vhere a trophy kokanee fishery vas produced in the early 1960's (Northcote 1978). MDFWP fisheries management staff transplanted opossum shrimp into 12 lakes in northvestern Montana, from 1968 to 1975. Mysis became established in six of these lakes, including Svan Lake and Uhitefish Lake in the Flathead drainage. By the early 1980's the Flathead Lake shrimp population had been seeded by dovnstream drift from these tvo tributary lakes. First collected in 1981 (Leathe and Graham 1982). mysids have increased rapidly to their present average abundance of over 100/m^2. Fisheries management agencies in several vestern states, including Washington, Idaho, Colorado, and California, carried out similar programs to introduce Mysis into lakes supporting kokanee fisheries.

Unfortunately, the success of the Kootenai Lake experiment vas not duplicated in any other system. Except in uniquely shaped lake basins, the diel vertical migration of mysid shrimp into deep vater makes them unavailable to feeding kokanee. The shrimp feed largely on the same macacrozooplankton upon which kokanee and other planktivorous fish depend. The videly duplicated result is that the availability of cladoceran zooplankton, such as Daphnia spp. and Bosmina spp., is reduced or eliminated, and that pelagic planktivorous fish populations decline (Rieman and Bovler 1980, Morgan et al. 1980). The evidence linking an increase in fish mortality to the decline in their preferred prey is admittedly circumstantial. Evidence from study of the Lake Pend Oreille fishery pointed to increased mortality in young-of-the-year fish related to the low availability of cladoceran prey in the early summer. The specific factors causing poor survival of older fish have not been identified, though predation and interspecific competition are thought to contribute.

The changes in the trophic structure of lakes in which M. relicta has become established vary widely. Lake basin morphology, primary and secondary productivity, and composition of the fish community react in different vays to the introduction of successful planktivore. Mysid populations peak at varying densities in different lakes, in some cases maintaining high and stable numbers, and in others fluctuating videly in abundance. Kokanee salmon persist in some lakes, in some cases reaching smaller size at maturity, and in others at lover abundance. In some lakes kokanee fisheries disappeared. It is not possible to predict the outcome of the interaction between mysid shrimp and kokanee in Flathead Lake at our current state of knovledge.

In the last two years, the focus of BPA-funded study of the Flathead kokanee fishery has been partially redirected from identifying the impacts of hydroelectric operations on reproductive success. We have looked at the kokanee/mysid shrimp interaction in its early stages, in hopes of directing efforts to mitigate hydroelectric impacts more effectively. The mandate of federal and private power marketing entities is to redress the losses in fish and wildlife productivity caused by their operations. It is in the interest of these entities to fund biologically sound mitigation programs that will be effective in perpetuating viable fish and vildlife populations over the long term. However. it is not their role to assume responsibility for biologically complex problems, such as the effects of the introduction of mysid shrimp into lake systems, even though such problems may bear directly on the success of mitigation efforts. It is to the advantage of all parties involved to develop mitigation schemes that are effective in the face of such biological complexity, if possible. During the last tvo years study of the Flathead kokanee fishery. ve have sought to identify and predict the outcome of the kokanee/mysid shrimp interaction, and to test whether the wild kokanee production can be successfully supplemented by artificial means. In particular, ve have looked for changes in the growth and survival of juvenile kokanee, and tested whether hatchery-produced, late-released kokanee exhibit better survival than wild fry.

STUDY OF THE KOKANEE - MYSID SHRIMP INTERACTION IN FLATHEAD LAKE

Description of the Study Area

Flathead Lake is the largest natural freshvater lake in the western United States. covering 510 km^2 in northvestern Montana. The lake's mean depth is 32.5 m, and its maximum depth is 113.0 m. The North, Middle, and South forks of the Flathead River, the Swan River, the Whitefish River and the Stillwater River comprise the Flathead vatershed, which drains 18,400 km^2 (Figure 2). The Lake becomes thermally stratified during the summer. and is mixed at other seasons, except vhen it freezes over. It's hydraulic retention time is short, about 2.2 years (Stanford et al. 1983). The lake basin was formed by glacial scouring of underlying soft sedimentary rock. Glacial moraines deposited at the terminus of the last ice advance define the lakes southern boundaries, and raised the lake level at one time until an outlet was cut southvestvard from what is nov Big Arm. The present outlet was cut to bedrock through the terminal moraine at the south end of the lake. The northern shoreline of the lake has been modified by the deposition of sediments carried principally during spring runoff by the Flathead River. Otherwise the main lake basin, excluding Big Arm and South Bay. is steep sided. A broad mid-lake bar, from 20 to 50 m deep, runs north-south 2 km off the western shore from Pt. Conrad to Indian Point.

Flathead Lake is classified oligomesotrophic. Agricultural and urban development in the basin contribute substantially to the natural nutrient load. Studies of primary productivity and nutrient dynamics have raised concerns, in particular, about the increasing phosphate load from sewage (Henry and Stanford 1983). However. both phosphate and nitrate may synergistically limit primary productivity in the lake during the spring and summer. Periodic blooms of the blue-green alga Anabaena floss-aquae have signaled the changing trophic status of Flathead Lake.

Of the eleven game fish species living in Flathead Lake, four are native: vestslope cutthroat trout (Salmo clarki), bull trout (Salvelinus confluentus), mountain whitefish (Prosopium williamsoni), and the pygmy whitefish (P. coulteri). The four introduced game fish species are lake trout (Salvelinus namaycush), rainbov trout (Salmo gairdneri), lake vhitefish (Coregonus clupeaformis), and kokanee. or lacustrine sockeye, salmon (Oncorhynchus nerka). With the exception of yellow perch (Perca flavescens), all the common non-game fish species are native. They include the northern squawfish (Ptychocheilus oregonensis), peamouth (Mylocheilus caurinus), longnose sucker (Catostomus catostomus), largescale sucker (C. macrocheilus). redside shiner (Richardsonius balteatus), and the slimy sculpin (Cottus cognatus).

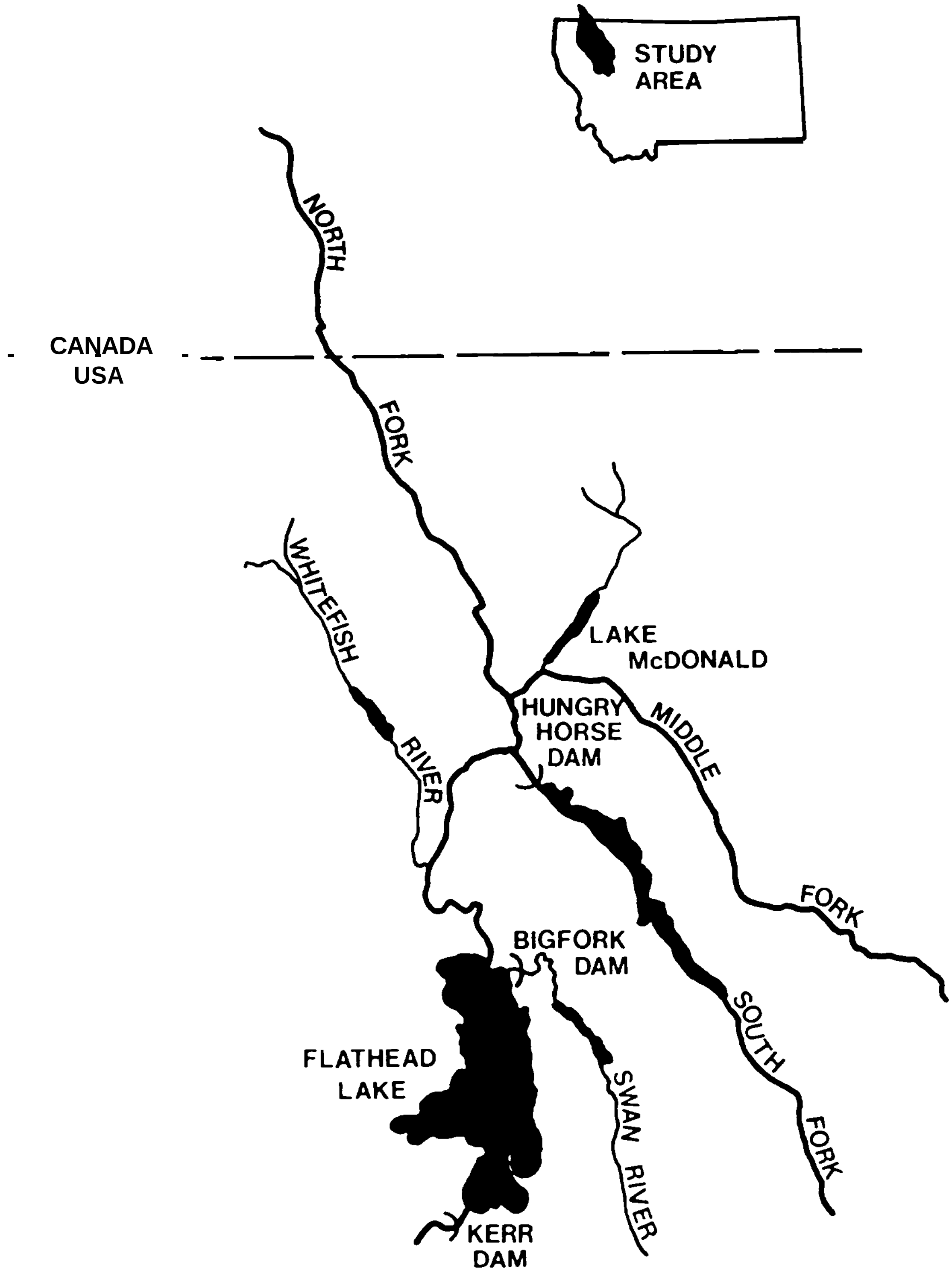


Figure 2. Map of the Flathead River drainage showing the location of hydxelectric projects.

METHODS

Fry Production Estimates

Estimates of the abundance of outmigrating kokanee fry vere made at the mouth of McDonald Creek and at the Sportsman's Bridge, near the mouth of the Flathead River. From the first veek of April until the last veek of June three l-m drift nets vere suspended from the bridge at the mouth of McDonald Creek at three points across the stream and at varying depths. The drift nets were circular in cross section, 1.5 m long, constructed of l/16" nylon mesh, vith a liner of l-mm nylon mesh. A detachable cod end of perforated 4" PVC pipe, lined vith l-mm mesh, vas fixed to the net vith hose clamps. The drift nets vere set for about 24 hours, then they were retrieved and the catch counted and released. The average catch per net was expanded to included the entire cross section of the stream and the seven day sampling period. Drift net sampling at the Sportsman's Bridge began the second veek of April and continued through the month of June. Three nets vere set midstream, at depths ranging from 0.5 to 2.0 m for 24 hours. Previous sampling had shown that over 90 percent of the migrating fry were in the surface 2.0 m of the river (Beattie and Clancey 1987). Fraley and Graham (1982) described the methods for expanding drift net sample data into estimates of total emigrating fry.

Zooplanktom Sampling

From April, 1986 until October, 1987 six stations on Flathead Lake were sampled to determine the species composition and abundance of cladoceran and copepod crustacean zooplankton. Each sample consisted of duplicate 30-m hauls of a 0.5-m Wisconsin plankton net, made of 80-micron Nitex (Research Nets Inc., Kent, WA). The net vas retrieved at a standard rate of 0.40 m/sec vith an electric winch. Samples vere preserved in 95 percent ethyl alcohol. We discontinued using formalin to preserve zooplankton samples because of the its toxicity, which is aggravated vith the chronic exposures typical of plankton vork. The six stations (Figure 3) were sampled biveekly from May 1 to October 15, and monthly for the rest of the year.

Standard techniques vere used to measure the density of the following genera: Daphnia Bosmina, Cyclops, Epischura, and Diaptomus. One-ml subsamples of the diluted rav sample vere transferred to a Sedgvick-Rafter counting chamber. Macrozooplankton vere identified and counted under 40X magnification. The sample vas diluted so that about SO organisms could be counted in the chamber. The larger species Epischura and Leptodora vere enumerated separately by examining the entire sample under a stereoscope. The resulting counts vere divided by the volume of vater sampled to estimate density. The plankton net was assumed to be 100 percent efficient vhen calculating the density of each zooplankton species.

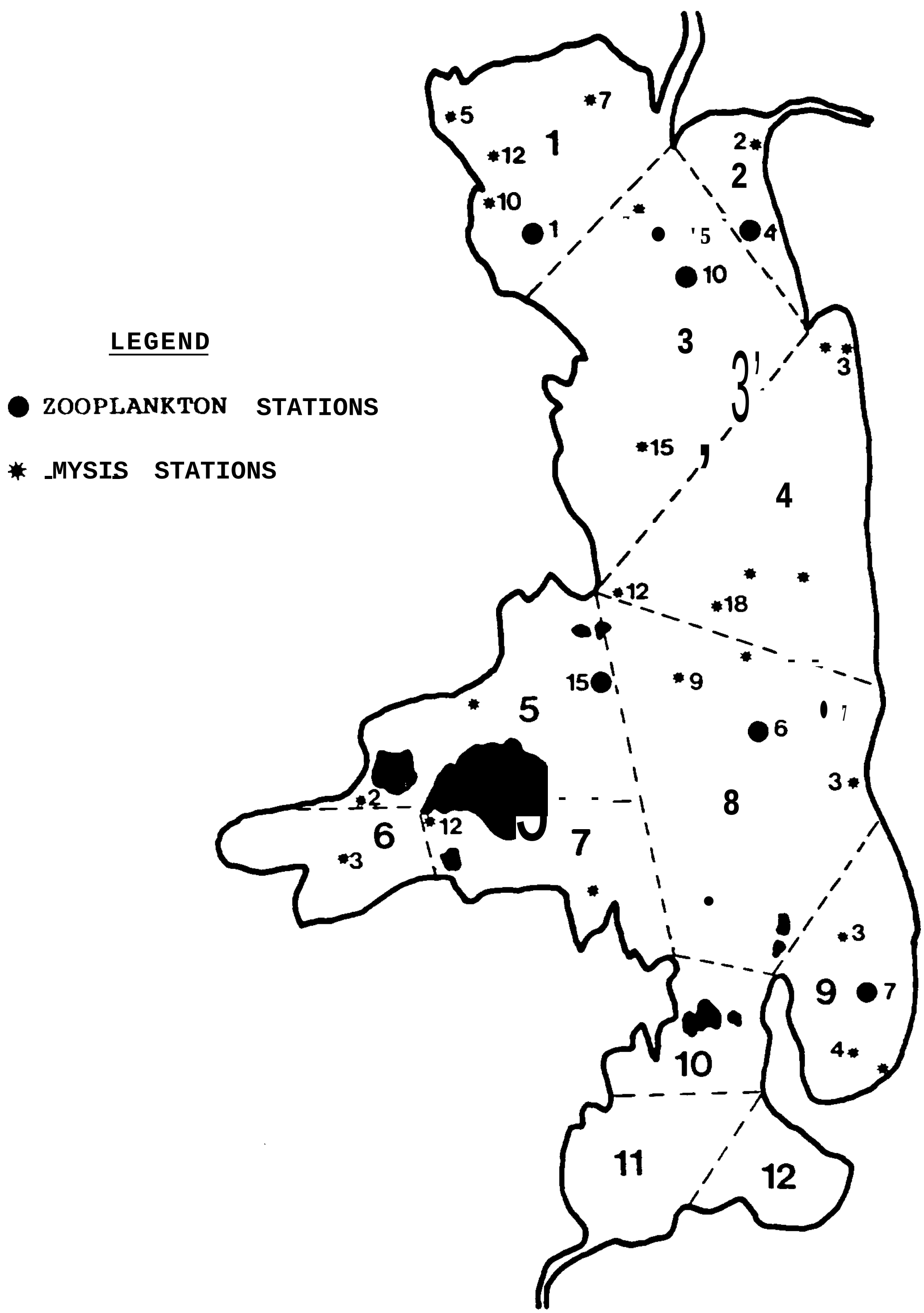


Figure 3. The locationof zooplankton and mysid shrimp sampling stations on Flathead lake. Un-numbered stationswere chosen randomly for the fall mysid estimate.

Mysid Shrimp Sampling

In 1986, mysid shrimp were sampled at the six zooplankton stations on Flathead Lake at monthly intervals from May to September. In 1987 the sampling frequency was reduced to an early summer sample at nine stations in June, and a fall sample at 25 stations in September (Figure 3). We made duplicate hauls of a 1.0-m Wisconsin plankton net, constructed of 500-micron Nitex. through the entire water column. The electric winch pulled the net at 0.40 m/sec. Sampling vas done at least two hours after sunset, as close to nev moon as feasible. The diel migration of mysids is knovn to be regulated by ambient light intensity. Sampling at new moon ensures that their vertical migration off the lakebed has begun. The samples vere preserved in 95 percent ethyl alcohol and counted under a stereo microscope.

Monthly sampling in 1986 vas designed to detect changes in the distribution of mysids and to generate some information on the life span of adult shrimp. The reduced sampling effort in1987 vas intended to test vhether predation was affecting the year class strength of shrimp. More sampling stations were included in the fall to randomly sample habitat of varying depth in the lake, and reduce the confidence limits about the lakevide average density. The trend in mysid abundance is developed from successive fall samples. Three depth strata vere sampled: from 0 to 40 m, which represents 45 percent of the lake; 40 to 75 m, which represents 30 percent of the lake, and greater than 75 m, which represents the remaining 25 percent of the lake. The randomly chosen stations were assigned proportionately among the depth strata. Stations were located using a Lovrance Model X-16 depth sounder.

Fish Sampling

We used a variety of net gear to sample kokanee and lake vhitefish. In May and early June, age Ot kokanee and lake whitefish were found in 2 to 5 ❑ of water along the shoreline of the lake. We sampled them by towing paired l-m drift nets made of l/8 in nylon mesh at approximately 1.5 m/sec. For the remainder of the sampling season, we sampled juvenile fish with midvater travls. In 1986, we used a 2-m square rigid-frame trawl, constructed of l-1/4 in mesh, vith the cod end of l/4 in mesh. This small trawl could be towed at 1.5 m/sec. In 1987, we used a 4-m box trawl (Research Nets, Kent, WA), constructed of panels of 1-l/2 in and l-1/4 in mesh, with a l/4 in mesh cod end and a detachable screened bucket. This trawl was opened with a pair of 2 ft by 4 ft otter boards attached to the mouth of the net by 40-ft three-point legs. In front of the boards, a 200-ft bridle of l/4 in wire was attached to the main 3/8 in towing vire. This larger trawl was toved at 1.0 m/sec. The depth of the tow vas measured by a Benthos time/depth recorder. Fish samples were preserved on ice for up to eight hours before processing.

Aggregations of fish were located before trawling using hydroacoustic gear. We used a Biosonics Model 105 portable sounder, a single-beam 420 Khz transducer, and a Biosonics Model 115 portable chart recorder operating off 12 volt DC battery power. Search transects were run at about 3 m/sec. The sounder was configured as follows: TVG 40 log R, 5 pings/sec, pulse width 0.4 to 0.8 m sec, receiver gain +12 dB. The recording threshold of the chart recorder was usually set between 0.03 to 0.08 volts. This setting excluded scattering from all but the most dense layers of seston. but allowed us to detect fish as small as 30 mm in length. The Love (1971) equation was used to estimate the target strength of various size classes of fish:

$$TS\ (dB) = 19.1 \log(\text{length}) - 0.9 \log(\text{Khz}) - 62$$

Trawling was most efficient at night and in late summer, because fish were more densely aggregated after the lake stratified.

Gill nets were more efficient than the trawl in capturing larger kokanee and whitefish. We set l/2-in and l-in mesh monofilament and nylon gill nets, 16 ft by 100 ft and 10 ft by 100 ft, respectively, in midwater in the vicinity of schools of fish. Because of the relatively low density of kokanee in Flathead Lake during 1986 and 1987, blind gill net sets, i.e. in suitable habitat where we had not previously located schools, were not successful. Nets set overnight in the thermocline captured kokanee and lake whitefish as small as 120 mm.

Age. Growth and Diet Analyses

We took standard length, weight, scales, otoliths, and stomach samples from all the fish we captured. Sagittae were stored dry in gelatin capsules after removing surrounding tissue. Stomach contents were extruded from the guts and preserved in 95 percent ethyl alcohol. Planktonic stomach contents were subsampled, identified and counted in the same manner as plankton samples, except where the stomach contained less than 200 organisms. In this case, and where stomachs contained larger macro-invertebrates, the entire contents vere identified and counted. Night-time trawl samples yielded the best quality stomach samples of kokanee, as the fish vere captured and preserved soon after the evening feeding period. Gill nets set late in the evening and picked early the next morning also yielded satisfactory samples. Digestion of the stomach contents vas not so great a problem in lake whitefish, which tend to feed on larger invertebrates. The proportions of each zooplankton species comprising each stomach were calculated. The samples were grouped by calendar month and by fish age to develop mean percent composition figures. A crude index of selection for each food species within the monthly groups vas calculated by dividing the mean frequency of each species in the stomach samples by its frequency in the water column at the nearest zooplankton sampling station.

To prepare otoliths for microscopic examination, ve embedded them in Spurr's medium (Pelco, Tustin. CA) in silicon rubber molds, and hardened this epoxy resin overnight at 60° C. The resulting chip could be marked, handled, and ground vithout damaging the otoliths. We ground a saggittal cross section of the embedded otolith to depth of the sulcus on 400 grit emery paper, then switched to 1500 grit paper for the final grinding and polishing. We examined the preparation at frequent intervals under the microscope, until the correct cross section vas reached. The thin section vas adhered to a glass slide vith a drop of immersion oil, and examined vith transmitted light under a 100x oil immersion objective. The image vas projected onto a Lenco PMM-925 black and vhite high resolution monitor through a Dage MTI Model 66 video camera equipped vith a high resolution Newvicon phototube. The camera vas equipped vith automatic control of gain and blackness. Mounting this camera on a trinocular head on the microscope, focused through a projection lens, made the final magnification approximately 2500 diameters.

The image of the dorsal radius of the otolith was measured to the nearest millimeter. Incremental grovth along the dorsal axis of the otolith vas consistently the most regular and simple to interpret. Beginning at the outside edge of the otolith, ve measured the radius of successive daily growth increments to the outside edge of the dark discontinuous zones. Increment radii were measured as far as possible tovard the focus of the otolith, usually to a radius corresponding to the initiation of spring growth. The technique allowed consistent measurement of 110 increments.

A distinct change in the increment pattern vas observed vhen hatchery fry vere moved to rearing pens. Stress from transport apparently induced a check in increment deposition, and the change in water temperature affected the vidth of subsequent increments. This pattern discontinuity enabled us to identify hatchery-reared fry in samples of fish captured in trawl sampling of Flathead Lake in the summer and fall of 1987.

The relationship betveen the fish length and otolith radius vas established by simple linear regression. Simple linear models (Y = a t bx) fit the 0+ kokanee data adequately, though exponential models ($y = e^{a+bx}$) or multiplicative models ($y = ax^b$) were better fits of the combined age classes. For the Ot kokanee, the linear model was used to back-calculate the length of the fish at each incremental radius of the otolith. This back-calculation gives a growth history of each fish. The slope of a secondary regression of estimated fish length on date approximates the growth rate of the fish. The validity of this otolith-based model of growth can then be checked by comparing back-calculated fish length to the true length of sampled fish. The residuals from this comparison (true length - calculated length) can be plotted to determine if systematic errors in the model exist. For example, other studies have found that large fish have relatively small otoliths (E. Brothers, pers. comm.), vhich leads to underestimating their grovth rate after back-calculating their length based on otolith radius. The statistical validity of the fish size:otolith radius relationship is crucial to the interpretation of grovth rates by this method.

Pen Rearing

In cooperation vith MDFWP hatchery staff, kokanee fry from Murray Springs and Somers Hatcheries were raised in floating pens at Somers before their release into Flathead Lake. The 12 ft by 12 ft frames were constructed of 1-1/2" aluminum tubing. Each frame was supported by four floats, made of styrene-filled tires (Topper Industries, Vancouver WA.), bracketed to the corner vertical member of the frame. Each pen, made of l/8-in delta nylon netting (Research Nets, Kent, WA), was 12 x 10 ft square and 20 ft deep (Figure 4). A veighted steel frame was attached to the outside corners of the bottom of each pen to maintain its shape. The pens were secured on the leeward side of a T-shaped floating dock, vhich was anchored in 35 ft of vater, about 100 yd offshore. The frames held the top 18 inches of each pen above the water, to retain the fish in stormy veather. The pens vere covered vith l-in plastic netting to exclude predators.

We fed the kokanee fry #3 Biodiet Starter (Bioproducts Inc., Warenton, OR) using Sweeney Model AF3-B automatic fish feeders (Sweeney Enterprises, Boerne, Texas). We cut back on the recommended daily ration of four percent live body veight per day, eventually setting the feeders to deliver 30 seconds of feed six times during daylight hours. During rainy veather the moist, fine-grained Biodiet food tended to clump and clog the automatic feeder, making it necessary to hand feed.

We raised two groups of 400.000 kokanee fry in the pens. The first group vas transported by truck from the Murray Springs Hatchery in Libby, MT on May 4 and 5, 1987. This first group vas held until June 4, 1987. The second group vas moved from the Somers Hatchery indoor raceways on June 9, 1987. We had planned to hold this group until early July, but the sudden onset of bacterial gill disease forced us to release them June 23, 1987.

Both groups of fry were marked by feeding them a measured dose of T-50 oxytetracycline mixed into Biodiet feed. The first group received the drug for six days just prior to release, and the second group for four days just prior to moving them to the pens.

Ten fish were removed weekly from each pen to track their growth rate. These samples were preserved in 95 percent ethanol to avoid the deterioration of otoliths that occurs in acidic preservatives. Standard length and weight were measured after 30 days in preservative. To determine the effect of the preservative on body size, ve folloved the length and weight of 25 individually

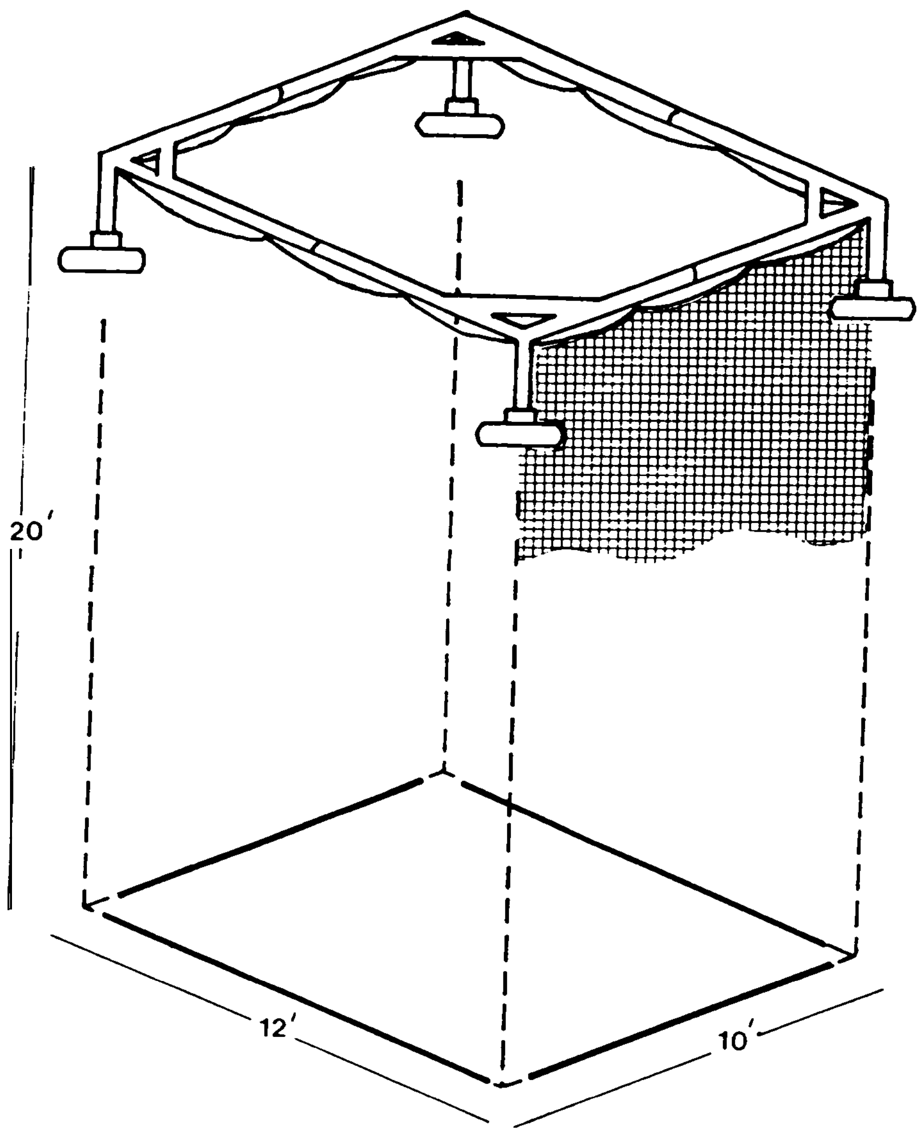


Figure 4. Schematic of the floating net pens used for rearinq juvenile kokanee in Flathead Lake.

marked fry taken at the beginning of the pen rearing experiment. The length and veight of preserved fry stabilized after 30 days in ethanol, after declining an average of 3.5 percent (S.D. = 1.7 percent) in length and 38.8 percent (S.D. 4.7 percent) in veight. Shrinkage in preservative varies vith the size, i.e. surface area of the fish. A previous trial vith smaller fry shoved that they lost only 9.5 percent of their body veight after 30 days in ethanol.

Water temperature, at the surface and at the bottom of the pens. vas recorded by a Taylor multiprobe recording thermograph. The pens vere not treated vith anti-fouling compound so they required periodic cleaning vith stiff brushes to reduce algal growth.

Data Reduction and Analysis

All data vere entered into dBase III+ files on IBM-PC compatible microcomputers. Analyses were done vith the Statgraphics (STSC, Inc., Rockville, MD) statistical package, and graphics prepared vith Chartmaster (Decision Resources, Westport, CT).

RESULTS

McDonald Creek Fry Production

We estimate that 9.8 million fry emigrated from McDonald Creek in 1986. These fry were the progeny of 122.500 adult fish that spavned in the fall of 1985. Assuming that the adult sex ratio was 50:50 males/females, and that each female produced 500 eggs (Beattie and Clancey 1987), the egg-to-fry survival rate vas 32.3 percent. The 1986 emigration began in early April and was finished by mid June, peaking in mid May (Figure 5).

In 1987, the total fry emigration from McDonald Creek vas estimated to be 3.7 million fish. The number of adult spavners in McDonald Creek in the fall of 1986 vas 21,500. Making the same assumptions as above, the egg-to-fry survival rate was 68.8 percent. The 1987 emigration occurred earlier than in 1986, lasting from mid February to the end of May.

Fry survival rates were similar to those found earlier (Fraley and McMullin 1983) in McDonald Creek. From a strong 1981 spavning escapement of 103,000 kokanee, fry survival was 22 percent in the spring of 1982. In 1983 fry survival was 68 percent, after a veaker spavning escapement of 31,000 adults. The variation suggests that redd superimposition, as well as environmental factors, affects egg to fry survival.

Zooplankton Abundance

The abundance of five of the seven principal macrozooplankton species in Flathead Lake declined in 1986 and 1987. in comparison to five previous years. Standing crops of cladocerans have changed most markedly. Two species, Daphnia longiremis and Leptodora kindtii have disappeared. Peak density has declined, and the summer pulse appeared later for Daphnia thorata and Bosmina longirostris. We believe that increased grazing pressure from the opossum shrimp, Mysis relicta, is responsible for the observed change in the zooplankton community.

Daphnia thorata, the most important food item for kokanee in Flathead Lake (Leathe and Graham 1982). has decreased from a peak density of 4.77/liter in 1983 to a peak of O.9/liter in 1987 (Figure 6). Until 1987, D. thorata was present in samples collected in April or May (Table 6). In 1987, D. thorata first appeared in samples taken in mid June. The percent of total zooplankton comprised by D. thorata has decreased from seasonal highs of 25 to 30 percent in previous years to a high of 12 percent in 1987. Mean density and percent composition at peak density have declined significantly between 1983 and 1987 (density $p < .01$, percent composition $p < .01$, see Appendix Table C).

Daphnia longiremis was alvays less abundant in our samples than D. thorata because it prefers colder, deeper water. The

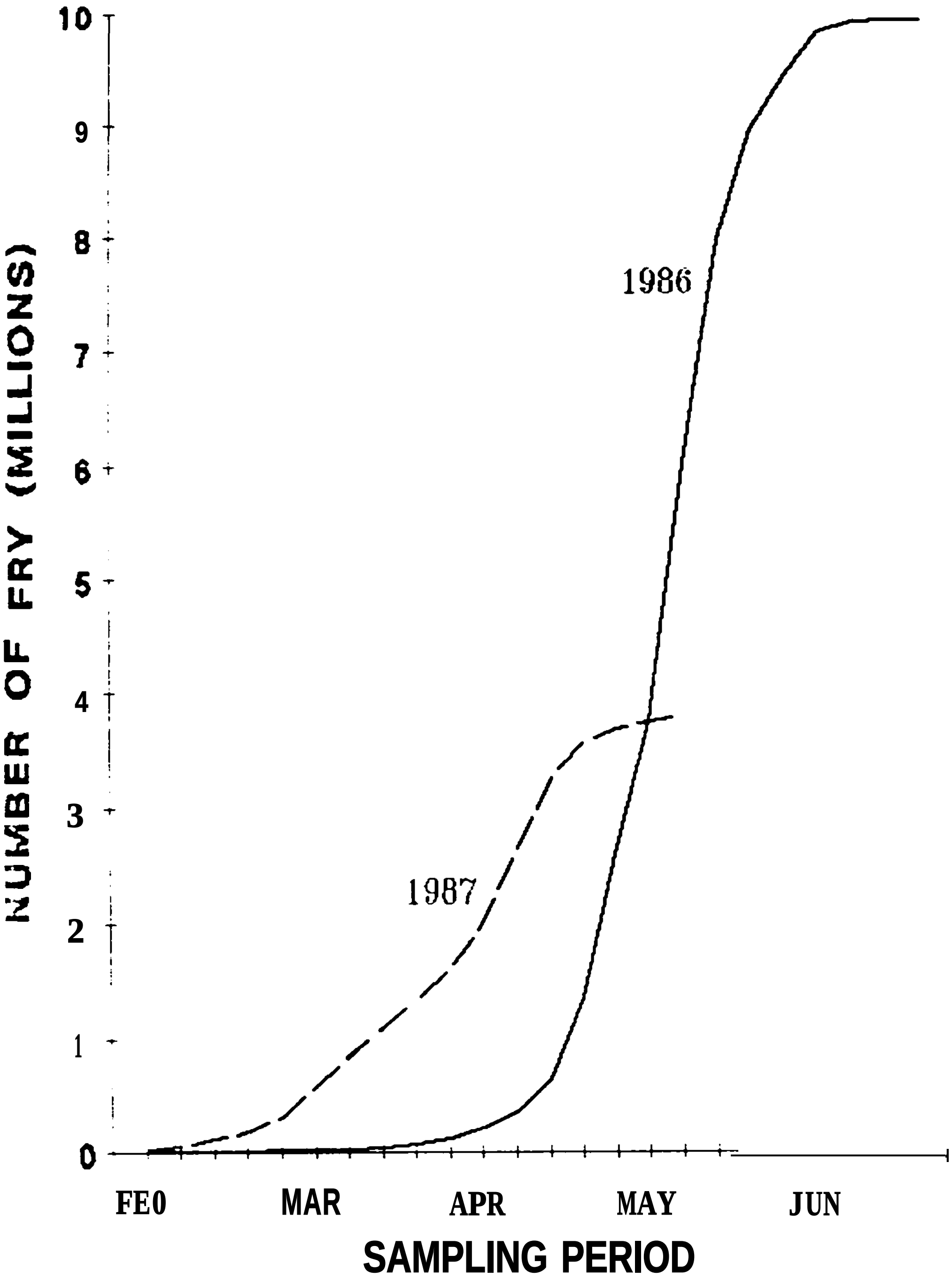


Figure 5. The cumulative number of kokanee fry outmigrating from McDonald Creek in **1986** and **1987.**

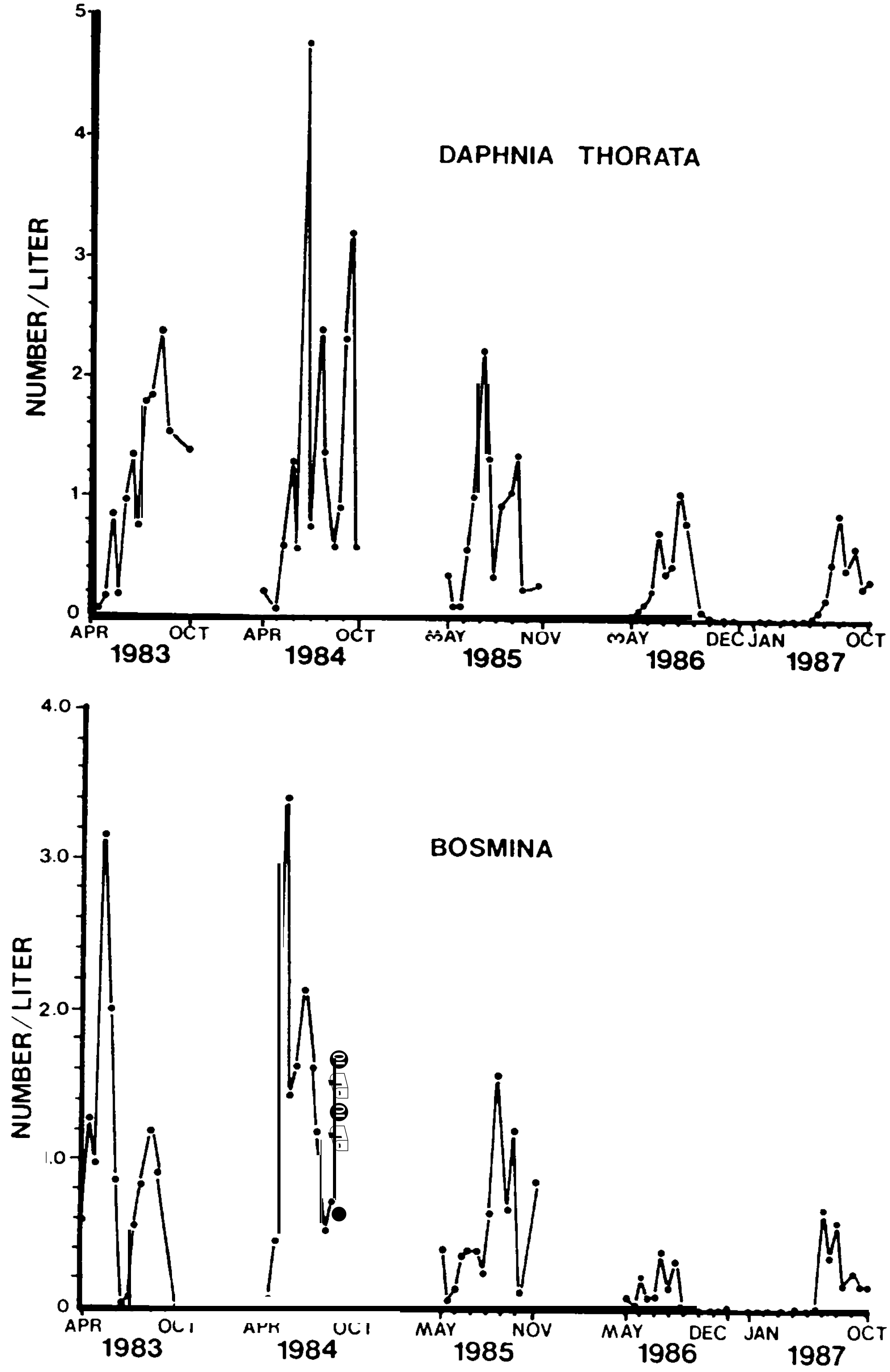


Figure 6 The abundance of Daphnia thorata and Bosmina longirostris at Station 2-4 on Flathead Lake from 1983 - 1987.

abundance of D. longiremis declined markedly in 1986, and this species vas not present in 1987 samples (Figure 7). The date of first appearance of D. longiremis vas delayed at least three and a half months from 1985 to 1986 (Table 6). and it vas present in only tvo samples in 1986.

The peak density of Bosmina longirostris exceeded 3.0/liter in 1984, then declined significantly (p <.0l) to 0.4/liter 1986 and 0.7/liter in 1987 (Figure 6). The spring increase in Bosmina density has also been delayed about one month (Table 6). Percent composition at peak density has also declined significantly (p <.0l) from 15 to 20 percent in the early 1980's to 8 percent in 1987.

From 1983 to 1987, Leptodora kindtii declined in density and percent of total zooplankton until it's disappearance from samples in 1987 (Figure 7). The date of first capture vas delayed from early June (Leathe and Graham 1982) to early September in 1986.

Copepod species have also been impacted by Mysis, though not as severely as the cladocerans. Diaptomus ashlandi is present all year in Flathead Lake. Generally, it makes up a major percentage of the zooplankton in Flathead Lake in the vinter. then decreases in relative abundance as the summer progresses. It vas less abundant in the summers of 1986 and 1987. The peak density in previous years had ranged from 13.3 to 26.3/liter. but in 1987 the peak was 4.5/liter (p <.02) (Figure 8). The percent of total zooplankton comprised by Diaptomus remained relatively constant until 1987 when it decreased markedly (p <.01).

The abundant Cyclops bicuspidatus has varied widely since 1983, but has not shovn a declining trend (Figure 9). It vas least abundant in 1985 when the density exceeded l.0/liter only in May and November and it comprised under 10 percent of total zooplankton most summers. In other years Cyclops made up 15 to 25 percent of the total zooplankton. The density and seasonal distribution of Epischura nevadensis, the largest copepod in Flathead Lake, has not changed markedly since 1984, though it vas four times as abundant in 1983 (Figure 8).

Peak total zooplankton abundance has decreased from 1983 to 1987 (p <.01, Figure 9). While the density peaked at 33.1/liter in 1983, it reached only 6.6/liter in 1987.

The average density of all zooplankton species vas not statistically different at northern and southern stations on Flathead Lake (Mann-Whitney test statistics, Appendix Table C). Leathe and Graham (1982) concluded that the zooplankton species distribution was homogenous throughout Flathead Lake. However, in May and June of 1987, there were marked differences in cladoceran abundance betveen station l-l and station 5-12. D. thorata was present in April samples at station l-l, but did not appear at other stations until mid-June (Figure 10). This species also

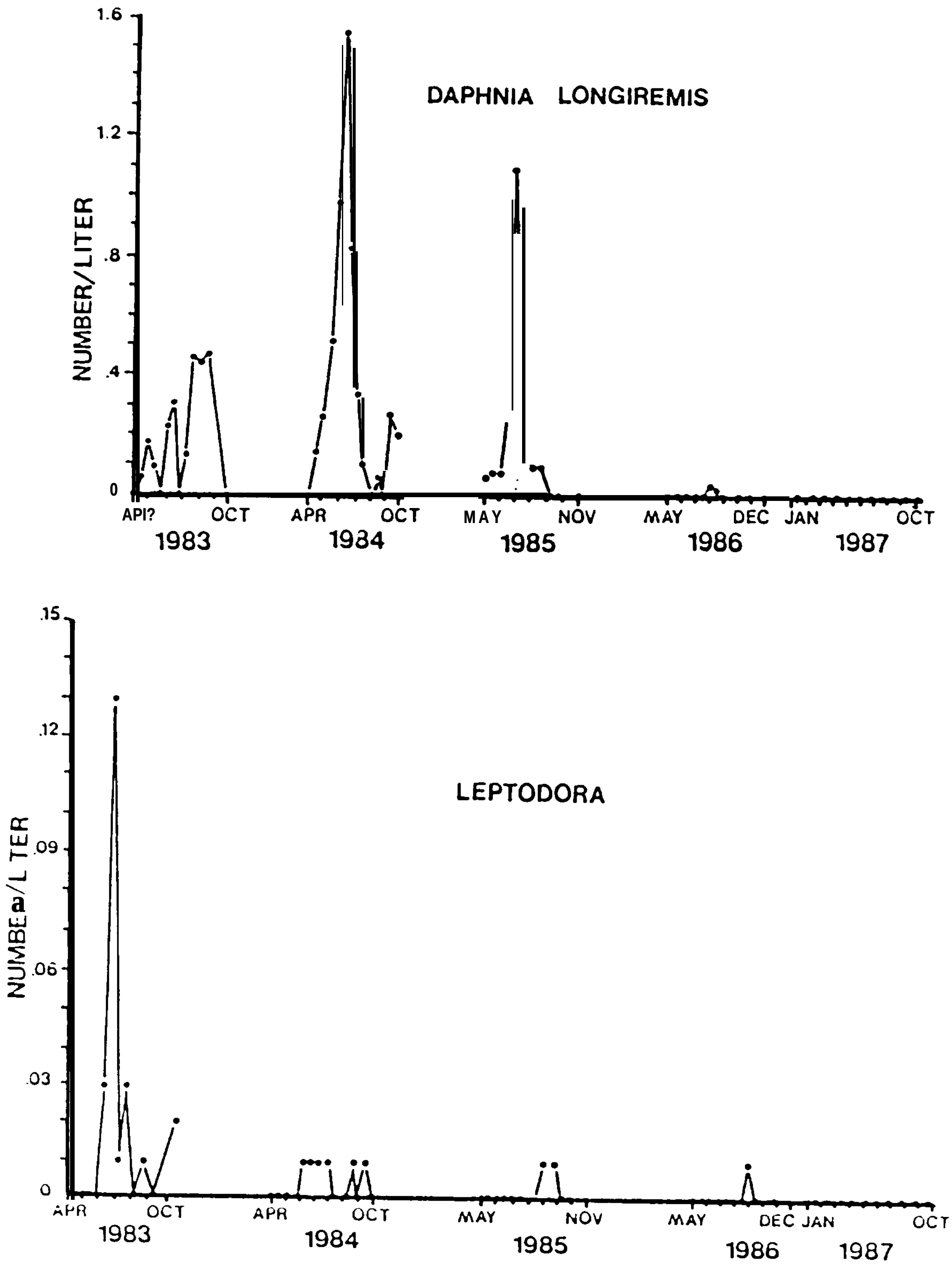


Figure 7. The abundance of *Daphnia longiremis* and *Leptodora kindtii* at Station 2-4 on Flathead Lake from 1983 to 1987.

Table 6. Date of first capture of zooplankton species at station 2 in Flathead Lake, 1983-1987.

	1983	1984	1985	1986	1987
D. thorata	4-06*	4-16*	5-01*	5-23*	6-18
D. longiremis	4-20	5-01	5-01*	8-18	None
Bosmina	4-06*	4-16*	5-01*	5-23*	5-18
Leptodora	6-17	6-14	8-22	9-02	None
Diaptomus	4-06*	4-16*	5-01*	5-23*	4-20*
Cyclops	4-06*	4-16*	5-01*	5-23*	4-20*
Epischura	6-02	6-14	6-11	5-23*	5-18

*Denotes the first sample taken after April 1 of any given year.

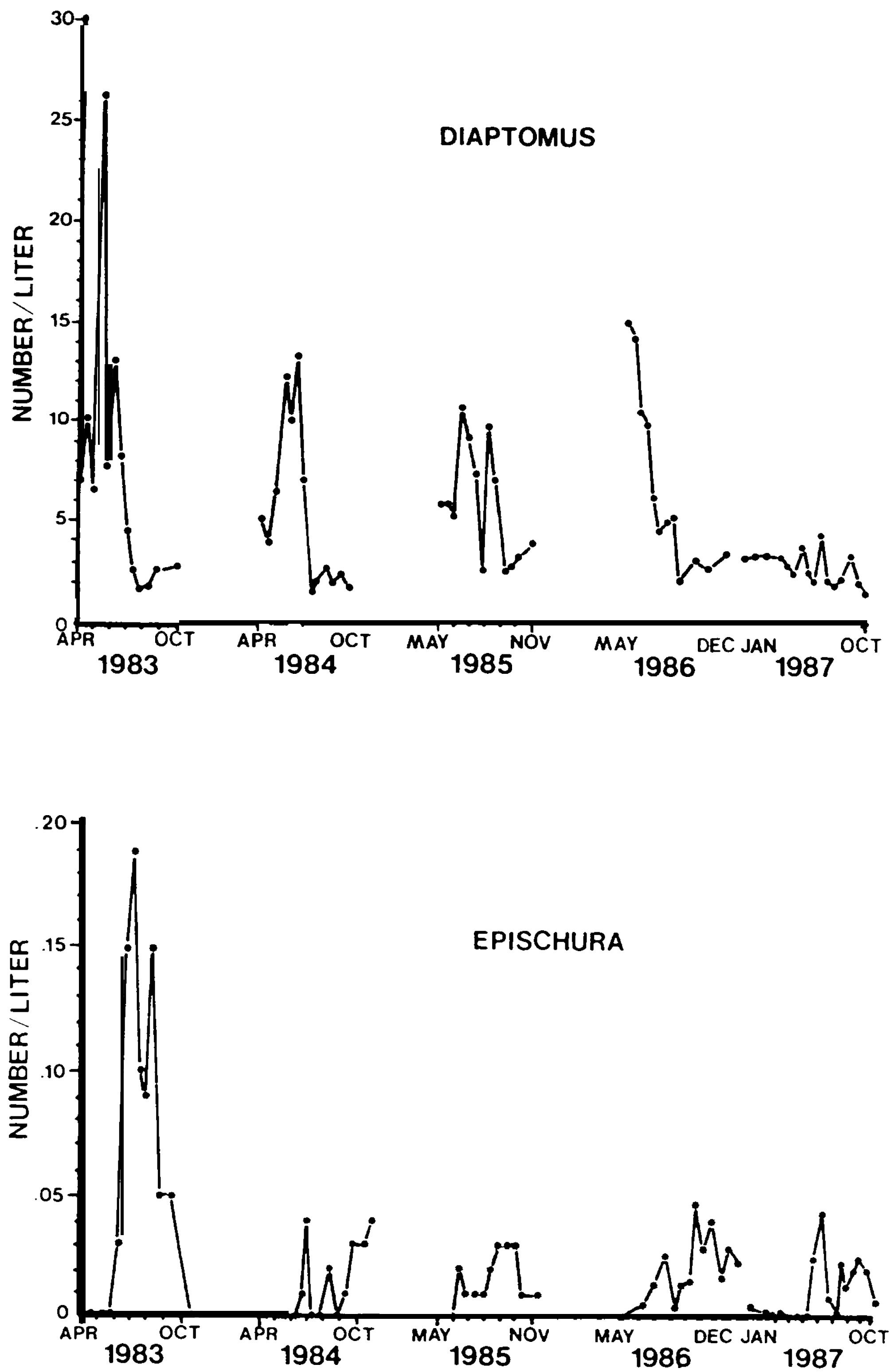
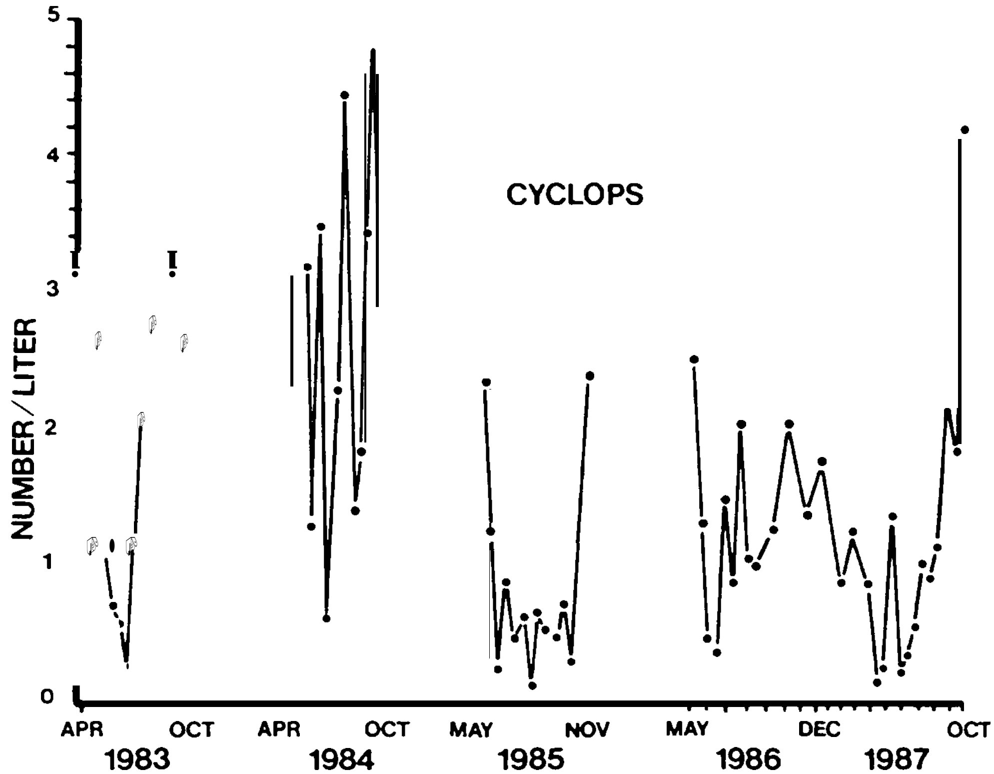


Figure 8. The abundance of Epischura nevadensis and Diaptomus ashlandii at Station 2-4 on Flathead Lake from 1983-1987.



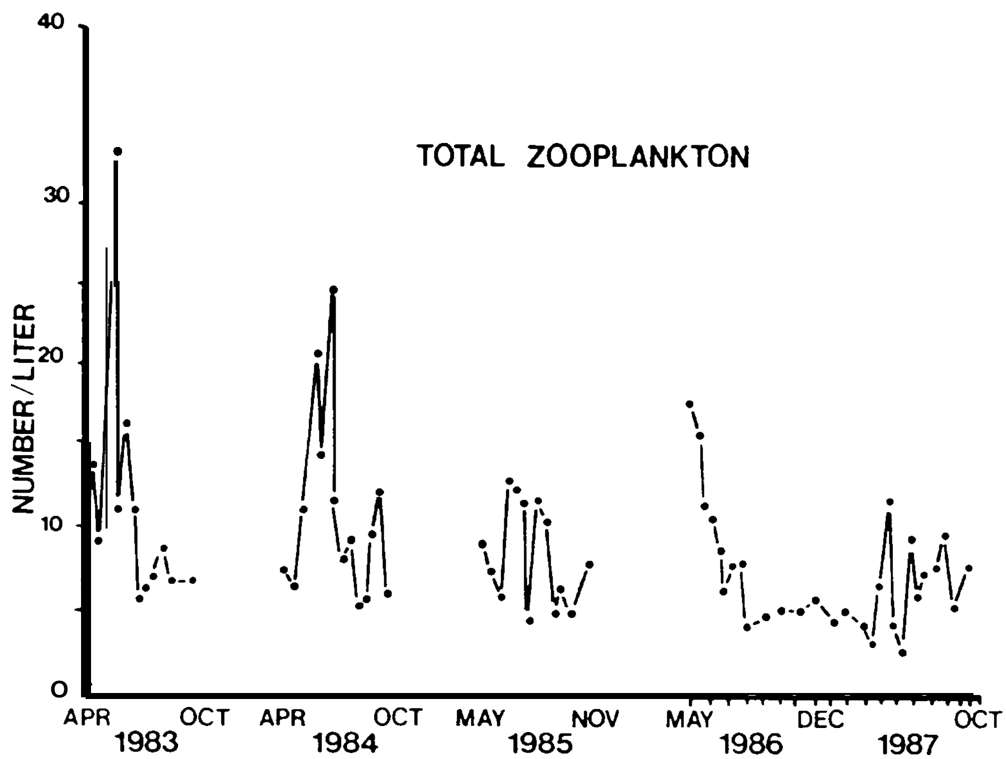


Figure 9. The abundance of *Cyclops bicuspidatus* and total zooplankton abundance at Station 2 on Flathead Lake from 1983 to 1987.

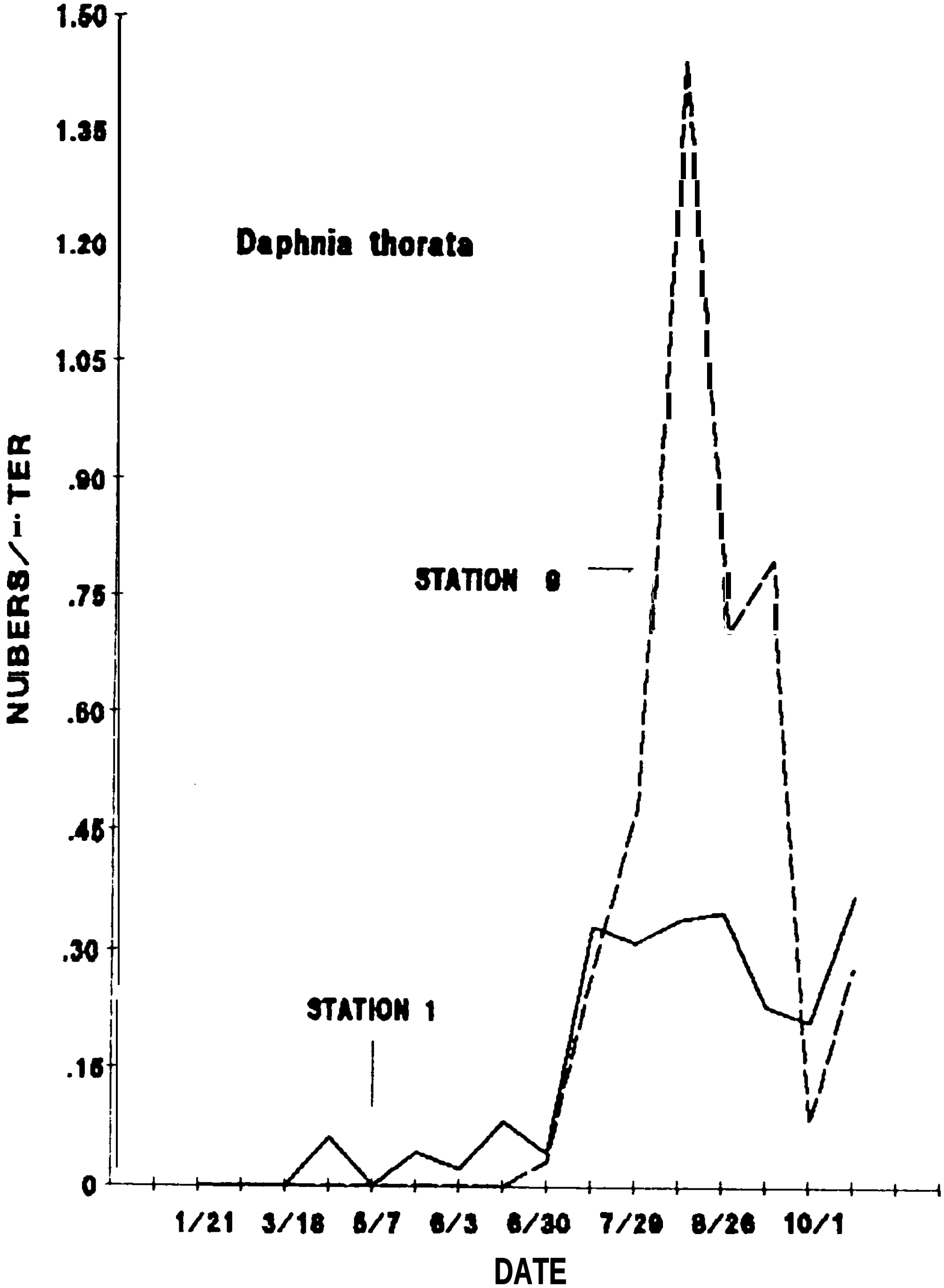


Figure 10. The difference in the abundance of Daphnia thorata at Station 1 (north lake) and Station 9 (south lake) in Flathead Lake in 1987.

reached peak density at station l-l earlier in the summer. This variation in spring cladoceran distribution may influence the distribution and survival of juvenile planktivorous fish.

Mysid Shrimp Abundance

The mean abundance of mysid shrimp in Flathead Lake in September, 1987 vas $108/m^2$. This figure is lover than that obtained in September, 1986 ($130/m^2$), but the two estimates are not significantly different because of high sampling variance. In 1986, mysid density ranged from $8/m^2$ to $275/m^2$ across six stations (Beattie and Clancey 1987). In 1987 vhen ve sampled 25 stations, density ranged from $0/m^2$ to $552/m^2$ (Figure 11). We conclude that mysid abundance is still increasing in Flathead Lake, though not as rapidly as it did from 1982 to 1985.

Spatial variation in mysid distribution is great in Flathead Lake. Abundance at stations in the southern part of the lake vas greater than at northern stations. Density exceeded $l00/m^2$ only at stations deeper than 40.0 m. but there is no clear relationship between abundance and station depth when all 25 stations are considered. Density was less than $15/m^2$ at all stations shallower than 25 m. Various environmental factors influence the distribution of mysid shrimp. including dissolved oxygen, light intensity, temperature, and prey availability (Beeton and Bowers 1982). In Flathead Lake their vertical migration at night stops below the thermocline. where water temperature exceeds 15°C (C. Spencer, University of Montana, pers. comm.)

In September 1986, we found that about 10 percent of the mysid population were juveniles (less than 10 mm long). In samples collected in September 1987 this figure had increased to 24 percent. Either juvenile mysids vere groving more slowly. or gravid females released their young later in the summer of 1987. In the Great Lakes, release of juveniles occurs through the summer (Carpenter et al. 1974). Monthly sampling in 1986 shoved that average mysid density did not change from May to September. Unless juvenile mysid mortality vas very high, these data vould suggest that large numbers of juveniles were not released after June.

We assume that, in Flathead Lake, mysids become sexually mature at the end of their first season in the lake (Bukantis 1985), but ve have not confirmed their life cycle or growth rates. Age at reproductive maturity varies among mysid populations and may be dependent on the trophic status of the lake, the density of mysids. and the abundance of planktivorous competitors (Morgan 1980).

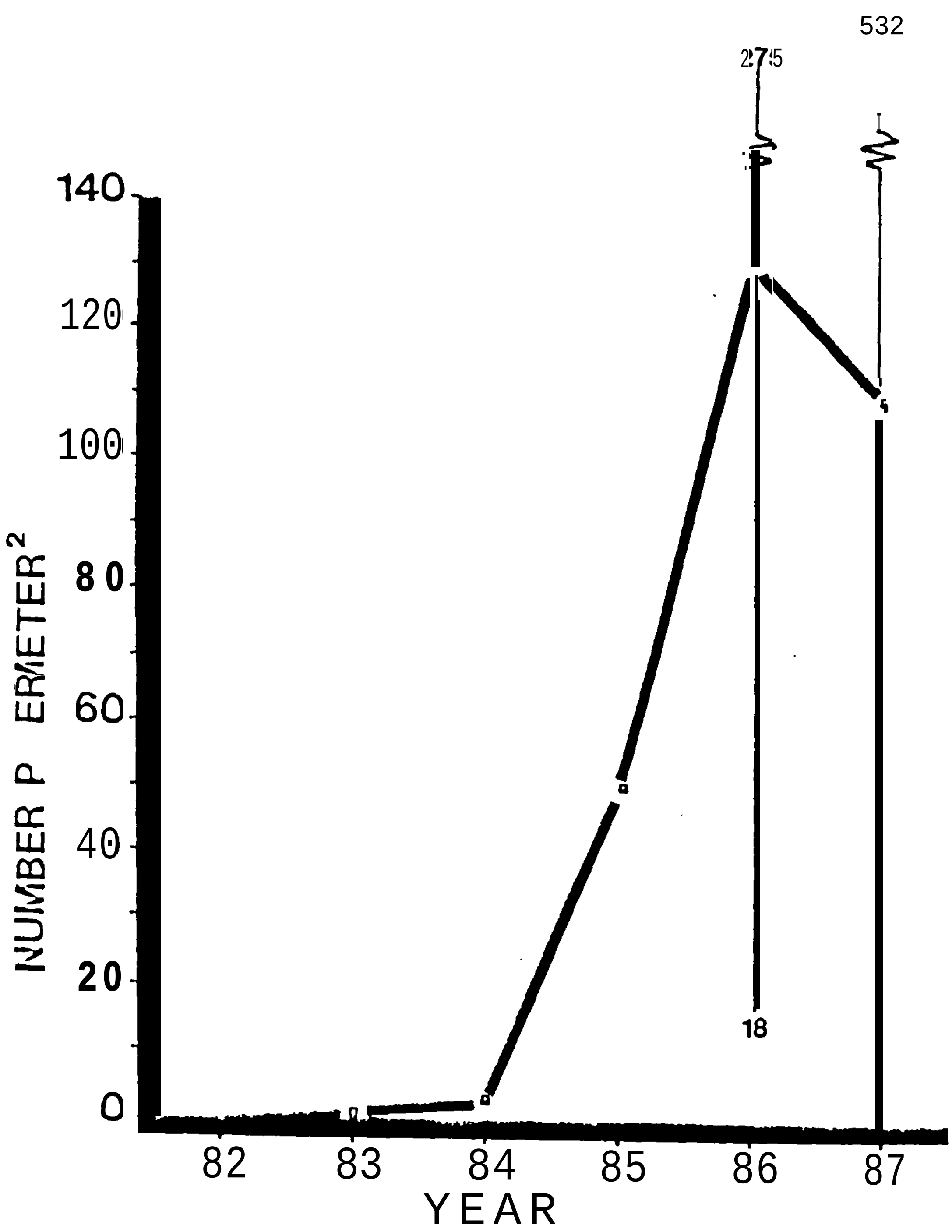


Figure 11. The increase in the average density of *Mysis relicta* in Flathead Lake, from 1982 to 1987. The range of densities measured in 1986 and 1387 are shown.

Kokanee Food Habits

YOUNG-OF-THE-YEAR KOKANEE

In 1986, we examined the diet of 30 young-of-the-year (age 0+) kokanee collected in August, September, and October vith the mid-water trawl. In August, their diet consisted of only tvo species. D. thorata comprised an average of 86.4 percent of the total diet, and Qischura nevadensis the remaining 13.6 percent (see Appendix Table A for diet summary by sample and sample locations). In September, D. thorata (89.6 percent) and Epischura (10.4 percent) still dominated their diet (Figure 12). In October, D. thorata and Qischura made up, respectively, 60.3 percent and 27.4 percent of their diets, though Bosmina (6.6 percent) and insects (6.5 percent) were found in some individuals. Throughout the summer and fall seasons Ot kokanee selected strongly for Epischura and D. thorata, when these species made up less than 1 percent and 2 to 11 percent, respectively, of the zooplankton available.

In May, 1987, the zooplankton diet of Ot kokanee vas dominated by Cyclops (69.1 percent) and Diaptomus (13.7 percent), vith Bosmina (0.7 percent), D. thorata (0.6 percent), and Epischura (0.4 percent) found less frequently. Dipteran insects (17.2 percent) and other insects (10.8 percent) contributed significantly to the diet of these fish. Their diet reflected strong selection for Cyclops and Bosmina. June diet was more diverse, made up of Epischura (42.4 percent), Cyclops (22.2 percent), D. thorata (19.5 percent), Diaptomus (11.7 percent), and Bosmina (4.2 percent). With Daphnia abundance beginning to increase in the epilimnion in July, the fry selected strongly for this preferred food. Insects were not found in these samples (Appendix B).

In July, D. thorata (46.1 percent), Epischura (31.4 percent), and Bosmina (21.9 percent) made up the bulk of their diet, vith Diaptomus and Cyclops contributing less than 0.1 percent and 0.5 percent respectively. Dipterans and other insects were found in two samples. Their summer food habits became less diverse than in previous months, with D. thorata making up 94.4 percent of July diet. Epischura (3.6 percent) were found in most of these samples in low numbers, while Cyclops (1.4 percent) and Bosmina (0.6 percent) vere found less frequently. Dipterans vere found in only a single sample. This trend continued into September vith samples still dominated by D. thorata (99.1 percent) and Esischura (0.7 percent). Cyclops (0.1 percent) and Bosmina (0.1 percent) were found infrequently. One stomach contained a small number of dipterans. The yearling fishes' strong selection for D. thorata was apparent all through the summer. but their selection for Epischura weakened after July, as this copepod species declined in abundance.

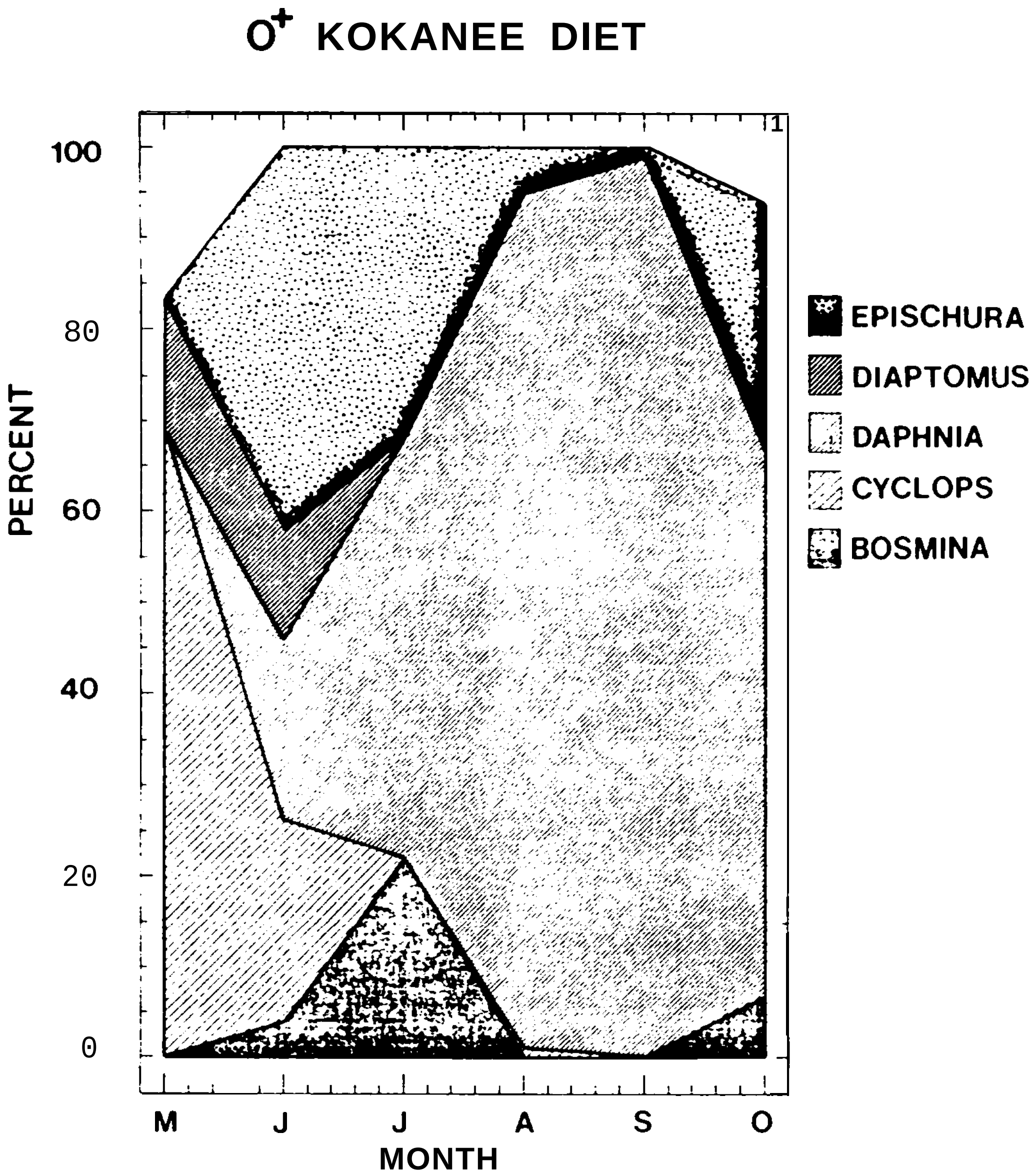


Figure 12. The zooplankton diet of underyearling (age 0+) kokanee in Flathead Lake from May to October 1986 - 1987.

YEARLING KOKANEE DIET

In 1986, ve examined 56 yearling kokanee stomachs. In June their diet vas composed of 39.8 percent D. thorata, 34.6 percent Epischura, 22.9 percent Bosmina, 1.9 percent Diaptomus, and less than 0.1 percent Cyclops (Figure 13). The June samples shov very strong selection for Daphnia, Epischura. and Bosmina. The diet of yearling fish collected in July vas similarly diverse. D. thorata made up 60.2 percent of their food, copepod nauplii 32.5 percent, and Cyclops 3.6 percent. Epischura and Bosmina contributed less than 0.1 percent each. These July samples shoved the only consistent utilization of nauplii by any age class of kokanee in the tvo years of this study. Four August samples shoved that D. thorata dominated their diet (95.0 percent). Diaptomus and copepod nauplii made up 0.2 percent and 1.3 percent, respectively, and Cyclops, Epischura, and Bosmina each contributed less than 0.1 percent, though Epischura vas found in fourteen of the 34 fish sampled. July and August samples again show strong selection for D. thorata. but the other components of their diet were eaten at lover frequency than their availability in the water column.

Collection of 1+ kokanee in 1987 began in mid June. The most common food was Epischura (72.1 percent), but their diet was diverse. It included 8.9 percent Diaptomus, 3.4 percent D. thorata and 1.7 percent Cyclops. Dipterans made up 6.9 percent of the total diet, and other insects contributed 1.2 percent. Insects were found in only four stomachs. This diet reflects strongly selective feeding on D. thorata, Bosmina, and Epischura. Both the cladocerans were at very low density in June. In July diet was still diverse, including D. thorata (83.7 percent), Epischura (15.0 percent), Cyclops (0.4 percent), Diaptomus (0.3 percent), and Bosmina (0.4 percent). Copepod nauplii were found in one stomach, and insects were found in six stomachs.

A limited sample collected in August shoved exclusively D. thorata in stomachs. September samples from these same tvo stations shoved a continuing lack of diversity in diet, with D. thorata comprising 92.3 percent of the diet. Epischura (7.7 percent) was found in tvo samples, and Cyclops (0.1 percent) in a single sample. As seen in the Ot kokanee samples, these 1+ fish preyed almost exclusively upon D. thorata through the summer, even though it comprised less than 5 percent of the available zooplankton in the epilimnion.

ADULT KOKANEE DIET

Because of the similarity of the food habits of the two older year classes of kokanee, collections of 2t and 3t fish were analyzed together. In November, 1985, stomachs contained 58.7 percent Epischura 30.5 percent D. thorata, and 10.7 percent Diaptomus (Figure 14). Cyclops were found in only two stomachs

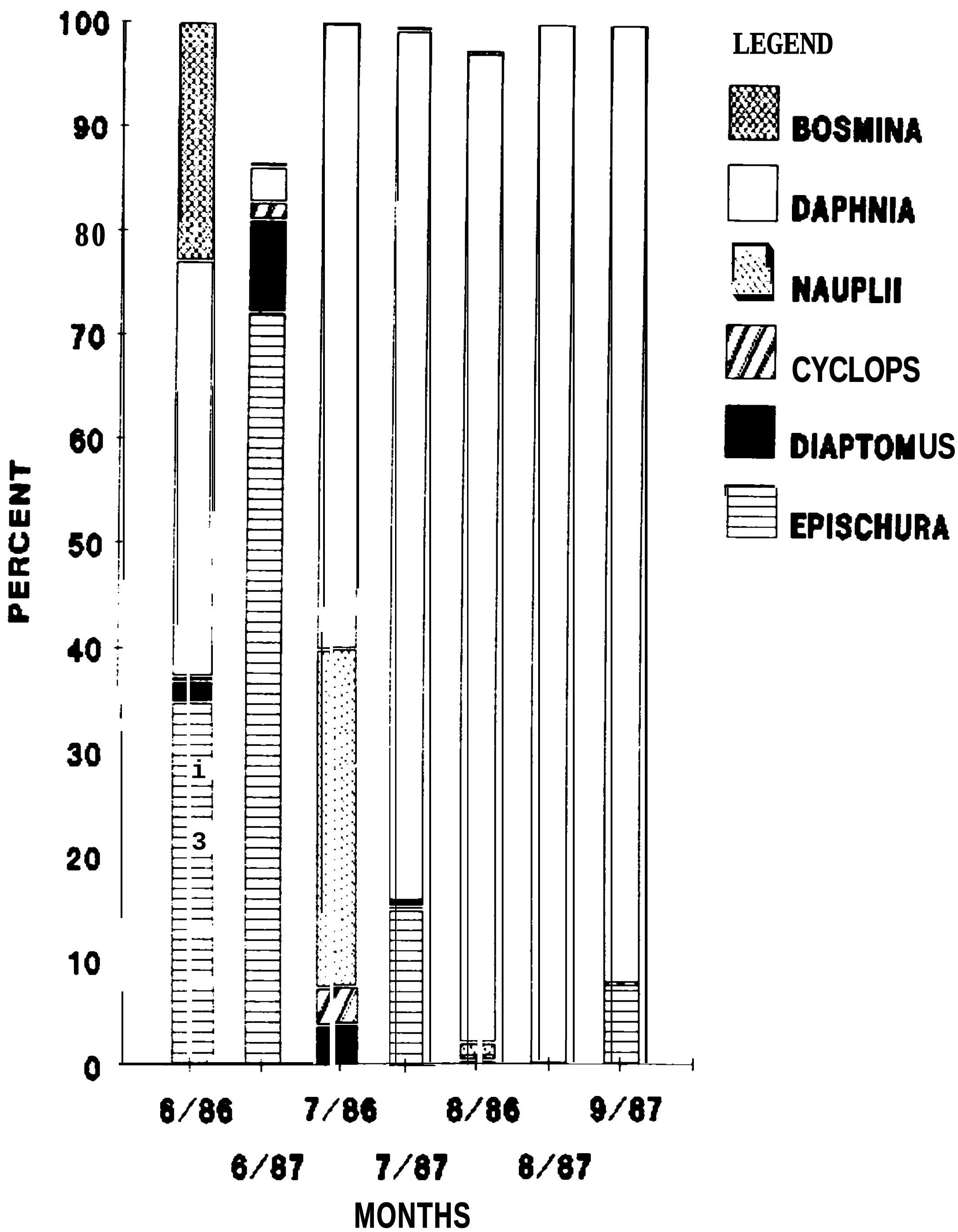


Figure 13. The zooplankton diet of yearling (age 1+) kokanee in Flathead Lake frun June to September, 1986-1987

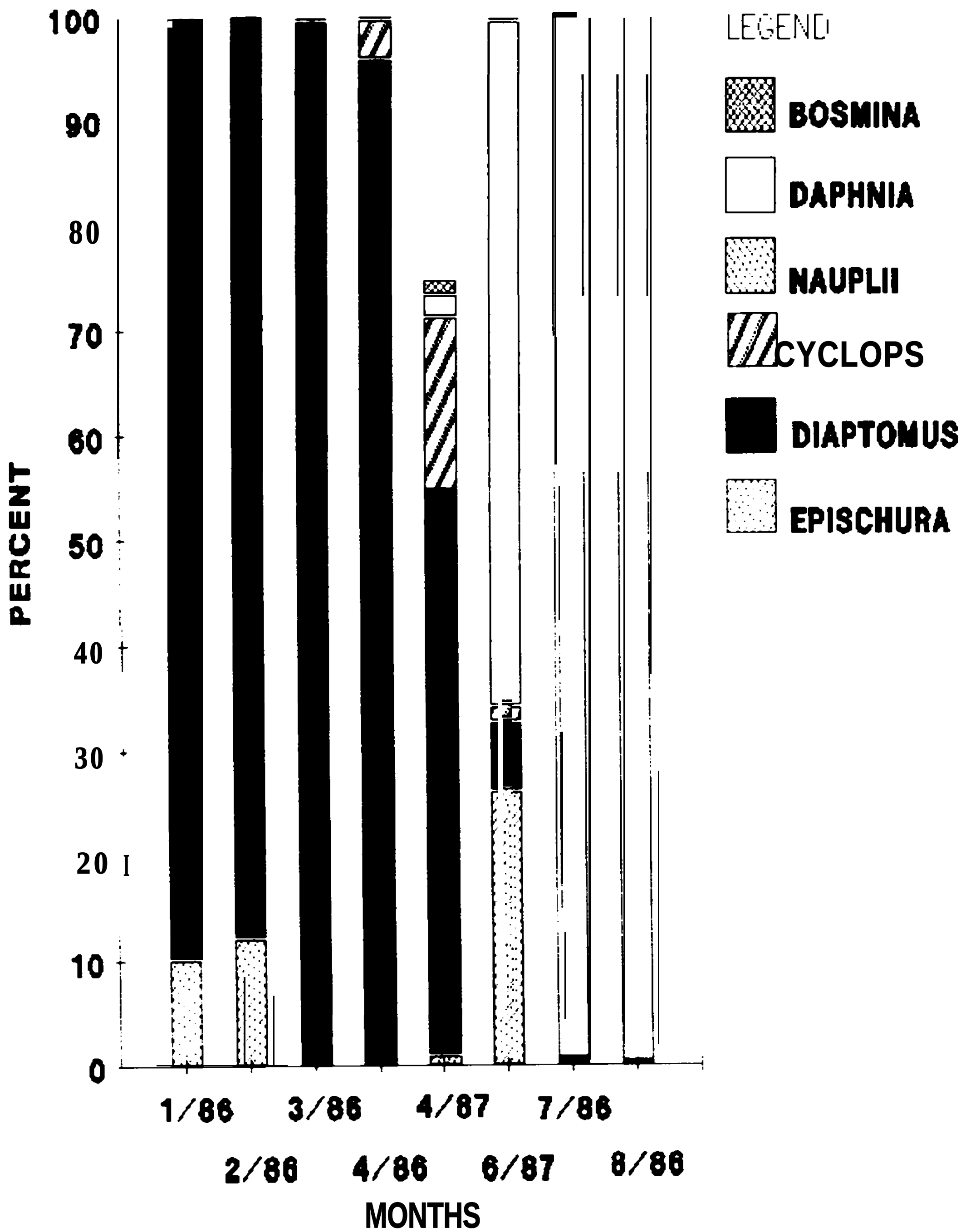


Figure 14. **The zooplankton diet of adult kokanee (age 2 and 3+) in Flathead Lake from January to August, 1986 - 1987.**

and comprised only 0.1 percent of the total diet. These samples vere all taken from sexually immature fish.

A number of samples vere collected during the vinter ice fishery in 1986. Samples taken in January contained 88.7 percent Diaptomus, and 10.1 percent Qischura. D. thorata (1.2 percent) were found in six stomachs, and Cyclops (0.1 percent) in four samples. February diet vas also dominated by Diaptomus (87.7 percent) and Qischura (12.2 percent). Cyclops (0.2 percent) was present in seven stomachs. and D. thorata (<0.1 percent) in two stomachs. Juvenile mysid shrimp were found in six of these samples, making up as much as 77.4 percent of individual stomach contents. The vinter samples through February all shoved strong selection for Epischura and D. thorata. In March Diaptomus comprised 99.4 percent of the-diet. Cyclops (0.4 percent) and Epischura (0.2 percent) were found in only five and four samples respectively.

In April, diet vas dominated by Diaptomus (96.0 percent) and Cyclops (3.9 percent). D. thorata (0.1 percent) were found in only one fish. Dipteran pupae and other insects were each found in one fish and comprised less than 0.1 percent of the total food.

Summer samples in 1986 included fish collected at four stations on four dates in July, and at two stations on four dates in August. These samples included fish taken in the lake fishery and gill net samples. The July diet consisted primarily of D. thorata (99.2 percent), of which 14.5 percent vas juvenile Daphnia. Epischura were found in nine stomachs (0.2 percent), Diaptomus in five stomachs (0.3 percent). Cyclops and Bosmina were found less frequently and each comprised less than 0.1 percent of the diet. Analysis of the August samples shoved very similar results, with D. thorata making up 99.2 percent of the diet, and Epischura contributing 0.2 percent. Diaptomus, Cyclops, d Bosmina were found less frequently, contributing 0.1 percent, <0.1 percent, and 0.4 percent respectively. Insects and ❑ ysid shrimp were not found in any summer stomach samples. July and August samples demonstrate again the strong selection for D. thorata, but not for Qischura, as was seen earlier in the year. Both these zooplankton species were increasingly abundant in July and August.

The sampling of adult kokanee in 1987 was limited by their lov density in the lake, and our decision to focus effort on juvenile year classes. A few three-year-old fish vere collected in April with the 2 ❑ mid-water travl south of the Flathead River delta (station 3-11). Zooplankton diet consisted of 53.9 percent Diaptomus, 16.4 percent Cyclops, 2.2 percent D. thorata, 1.5 percent Bosmina, and 1.0 percent Epischura. However, dipteran insects comprised most of the stomach contents of two fish. These samples did provide another example of kokanee able to locate and feed on sparsely distributed patches of D. thorata vhen this species was belov detectable density at the nearby station where we monitored zooplankton density. In June, their diet consisted entirely of zooplankton. D. thorata made up 65.4 percent of the total, Epischura 26.2 percent, Diaptomus 6.6 percent, Cyclops 1.4 percent, and Bosmina 0.3 percent. The dominance of D. thorata in these samples again demonstrates the strong preference kokanee exhibit for these relatively large, slov-swimming cladocerans. In mid June the density of D. thorata vas less than O.l/liter, and they comprised only 1.1 percent of the total zooplankton in the water column.

Lake Whitefish Food Habits

JUVENILE LAKE WHITEFISH

Lake vhitefish less than 140 mm in length were considered, for the purposes of this analysis, to be juvenile fish, i.e. either underyearlings (age Ot) or yearlings (age l+). The folloving discussion summarizes samples collected in 1986 and 1987 (a more detailed description of all the samples is found in Appendix D and E).

In May, the diet of juvenile whitefish consisted of zooplankton (71 percent) and dipteran pupae (29 percent) (Figure 15). The principle zooplankton prey species included Diaptomus (41 percent), Bosmina (37 percent), and Daphnia thorata (20 percent). Fish were selecting highly for the two cladoceran species, which were present at very low density in the water column. June samples contained dipteran larvae (82 percent), zooplankton (18 percent), and pelecypod clams (7 percent). Zooplankton found in the stomachs included Cyclops and Epischura, in addition to the three species mentioned above.

Zooplankton, primarily Daphnia thorata. comprised 86 percent of the food of juvenile whitefish in July, and about 50 percent in August. Dipteran larvae were still an important component in August, making up 40 percent of the diet in 1986, and 12 percent in 1987. August stomach samples also contained mysid shrimp (7 percent in 1986, 26 percent in 1987). Most of the shrimp eaten (67 percent) were adults.

ADULT LAKE WHITEFISH

In April and May, the diet of adult vhitefish was made up primarily of dipteran larvae and clams (Figure 16). During these months their diet was considerably more diverse in 1986 than in 1987, including more significant numbers of zooplankton, mysid shrimp, and gastropods (Appendix D).

Summer utilization of dipteran larvae by adult whitefish declined from about 30 percent in June, to 1 percent in July and August of 1987. They were a more significant part (12 percent) of the diet in August of 1986. Pelycypod clams were also more important in June (29 to 42 percent) than later in the summer (4 to 8 percent). Mysid shrimp were a more important portion of

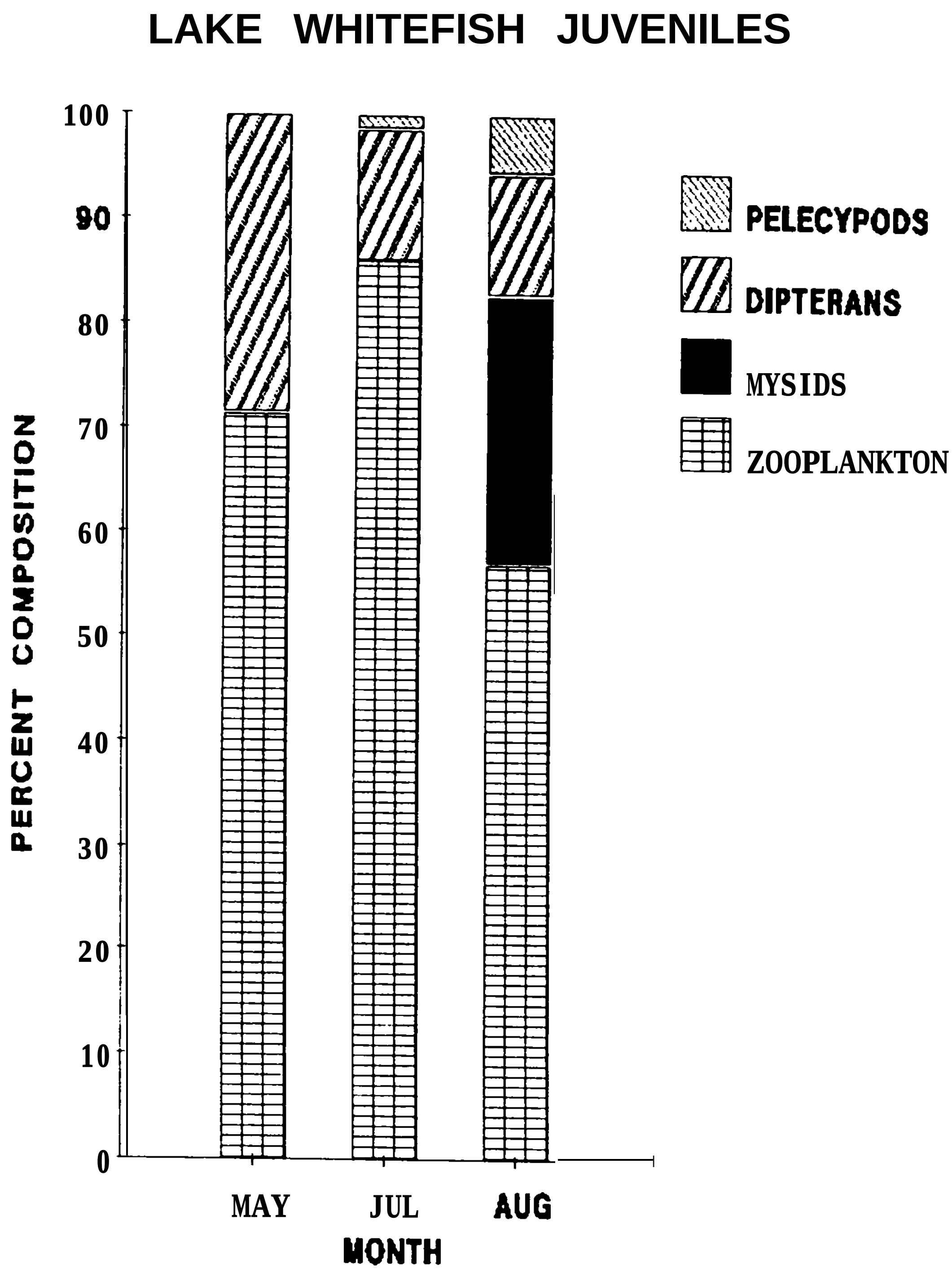


Figure 15. The diet of juvenile lake whitefi(under 140 mm in length) in Flathead Lake in 1987.

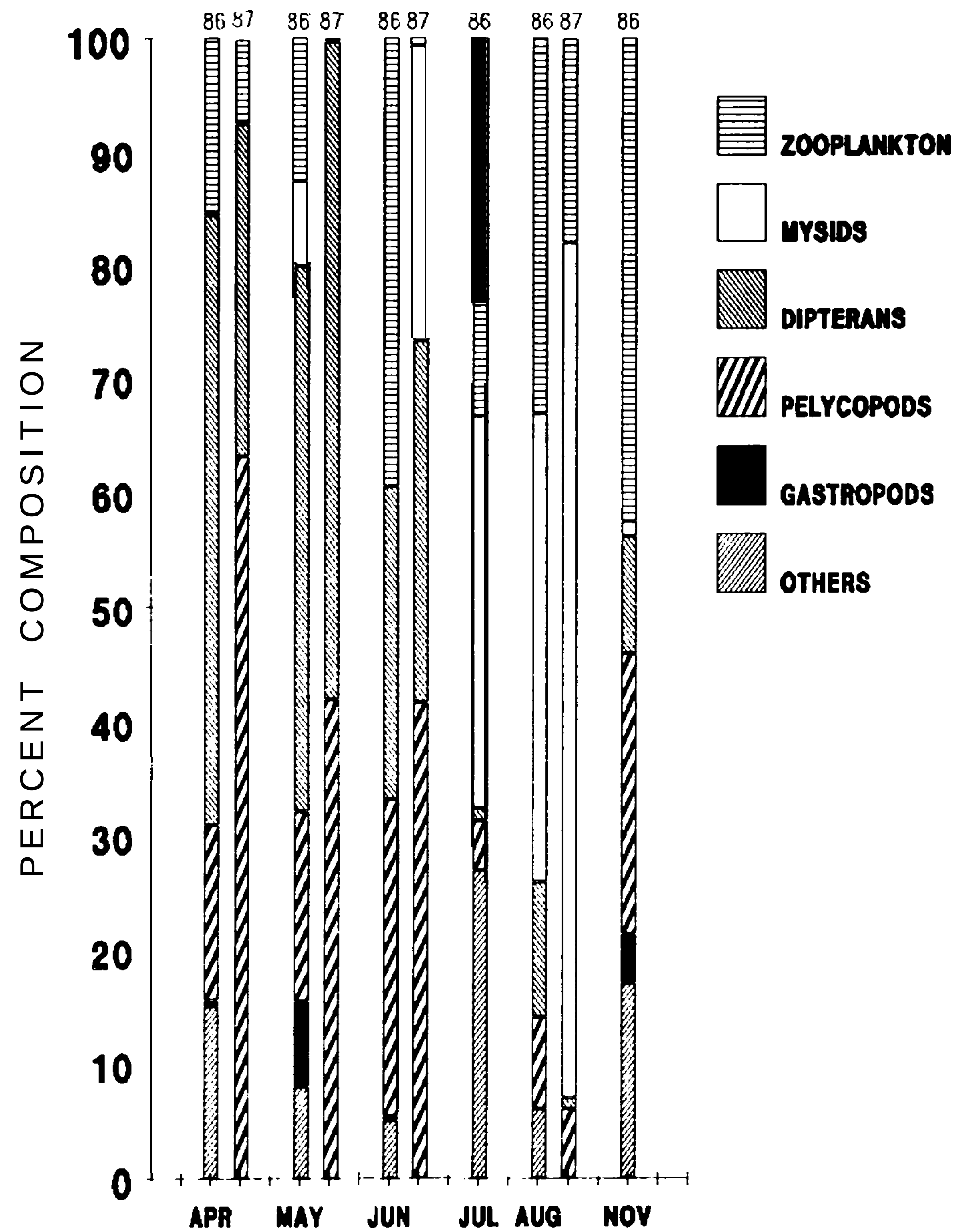


Figure 16. The diet of adult lake whitefish (over 140 mm) in Flathead Lake in 1986 and 1987.

their diet in the summer of 1987 than in 1986. In June and August of 1987, they comprised 26 percent and 75 percent, respectively, of the diet of adult whitefish. Zooplankton. on the other hand, made up a smaller part of their summer diet in 1987 (1 to 18 percent) than in 1986 (35 to 40 percent).

The increasing abundance of mysid shrimp in Flathead Lake accounts for their increased importance in the diet of lake vhitefish. An average of 246 shrimp vere found in individual whitefish stomachs. If the observed shift from zooplankton to mysid shrimp continues, the grovth rate of lake vhitefish could increase.

Nine adult whitefish sampled in November contained primarily zooplankton (43 percent), clams (24 percent), dipterans (10 percent), and snails (4 percent). The limited importance of snails in the diet of adult vhitefish in 1986 and 1987 contrasts with a previous study (Leathe and Graham 1982). vhich found them to be a major component of the diet in spring and summer.

We found limited use of the cladoceran Chydorus by adult vhitefish. though this species never appeared in regular zooplankton samples. In 1986, ten percent of the adult vhitefish stomachs contained fish. The only identifiable forage fish were yellow perch, averaging 31 mm in length. As many as 31 perch were found in individual stomachs.

Kokanee Growth Rate

1986

The size of outmigrant kokanee fry serves as a baseline from vhich ve assessed fish growth rate by measuring the size of juvenile fish captured on successively later dates in 1986 and 1987. In 1986, samples of outmigrant fry from McDonald Creek, Beaver Creek, Brenneman's Slough, and at the Sportsman's Bridge varied in length from 22 mm to 44 mm (Table 7). Since more than 90 percent of the total fry production emigrates from McDonald Creek, the average size of these fish represents a valid baseline for the growth of fish entering Flathead Lake. In 1986, the average size of McDonald Creek outmigrants vas 25.3 mm. The mean length of outmigrants increased over successive monthly samples, taken between mid March and mid June of 1986. Though length at emergence is not knovn to vary greatly, some fry reside in McDonald Creek for several weeks. The larger size of these resident fry would contribute to the increasing size of outmigrants. By contrast, the mean size of fry sampled at the Sportsman's Bridge did not increase consistently between April and June. The overall mean size of the Sportsman's Bridge samples was not significantly larger than that of McDonald Creek fish. This finding supports the contention that most fry migrate quickly down the river into Flathead Lake (Fraley and Graham 1982).

Table 7. Size of outmigrant kokanee fry collected in the Flathead River system in 1986.

Location	Date	Mean	Length (mm) Minimum	Maximum
Beaver Creek	3-12	25.4	23.0	27.0
Brenneman's Slough	3-6 4-25	29.9	25.0	44.0
McDonald Creek	4-16 5-13 6-12 6-24	25.3	23.0	33.0
Sportsmen's Bridge	4-15 5-7 6-4	24.8	23.0	35.0

Trawl samples of Ot kokanee collected at various locations in Flathead Lake suggest that their average length had increased to 69.4 mm by the end of August, and to 78.5 mm by the middle of October (Figure 17). These mean lengths are derived from small numbers of kokanee fry. The range of sizes found in each of these small samples makes it difficult to express confidence in the increment in mean size as a measure of average grovth rate. The data does suggest that rapid grovth persists into late October, in spite of falling vater temperature and decline in the availability of preferred cladoceran prey.

The mean length of yearling kokanee sampled in June 1986 vas 128.1 mm. Mean length had increased to 133.5 mm by mid July, and to 166.1 mm by the end of August (Figure 18). A few samples collected as late as November 7, 1986, ranged in length from 165 to 197 mm.

1987

In 1987. McDonald Creek outmigrants averaged 28.5 mm, and ranged from 24 to 39 mm in length. Mean length had increased to 36.5 mm in mid May, to 64.3 mm by mid August, and to 70.1 mm by mid September, 1987 (Figure 18). These 1987 data are derived from a more successful sampling effort than was achieved in 1986. Fry length varies widely, ranging from 50 mm to 90 mm in mid August, and from 51 to 100 mm in mid September.

Yearling kokanee collected in June, 1987, averaged 131.0 mm in length. Combined samples from the first two weeks of July averaged only 131.4 mm, an insignificant increase. By early September, average length had increased to 153.2 mm, but the length of individual fish ranged from 127 to 191 mm.

Growth of Pen-Reared Kokanee Fry

The average length of the first group of 400,000 pen-reared fry that were transferred from the Murray Springs Hatchery to Flathead Lake on May 4-5, 1987. increased 27 percent from 44.6 mm (S.E. 0.1 mm) on May 5 to 56.8 mm (S.E. 0.9 mm) on June 4, 1987, when they were released from the pens (Figure 19). Their mean weight increased 141 percent from 0.427 g (S.E. 0.019 g) to 1.029 g (S.E. 0.071 g), or about 4.5 percent per day. Their average condition (weight x 10^5/length^3) improved from 0.48 to 0.54. The average length of this group of fry did not increase significantly between the last two samplings on May 30 and June 5.

The second group of 400,000 fry were transferred from the Somers Hatchery to the floating pens on June 9. 1987. An outbreak of bacterial gill disease forced us to release this group on June 23, 1987, after mortality increased dramatically. The onset of gill disease was associated with water temperature exceeding 60° F after June 15, 1987 (Figure 20). Over the 15-day period these fish were held in the pens, neither their length nor weight

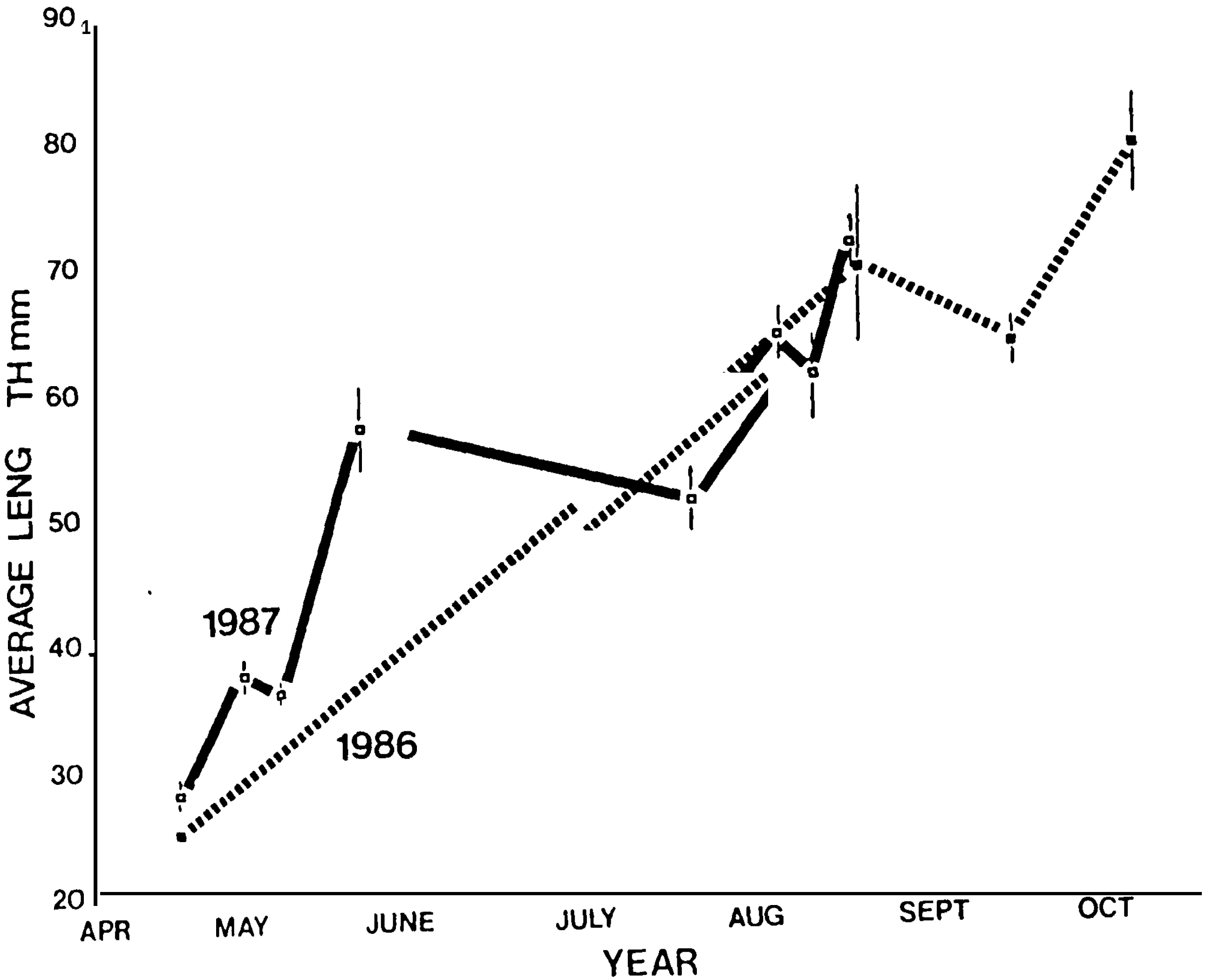


Figure 17. The increase in mean length of underyearling (age 0+) kokanee collected in Flathead Lake in 1986 and 1987. Standard errors are shown as vertical bars.

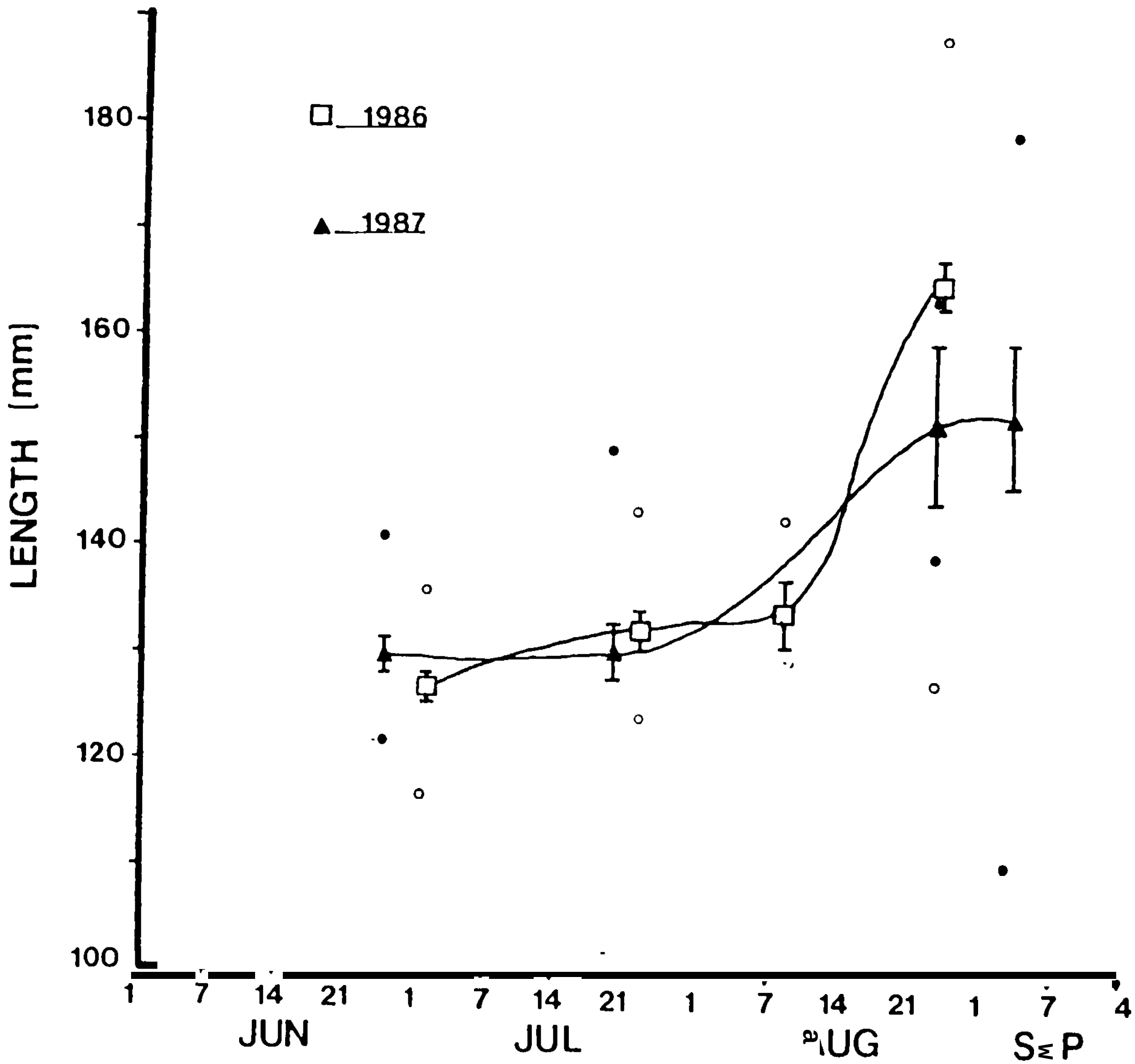


Figure 18. The increase in mean length of yearling (age I+) kokanee collected in Flathead Lake in 1986 and 1987. The standard error (vertical bars) and range of length (points) are shown.

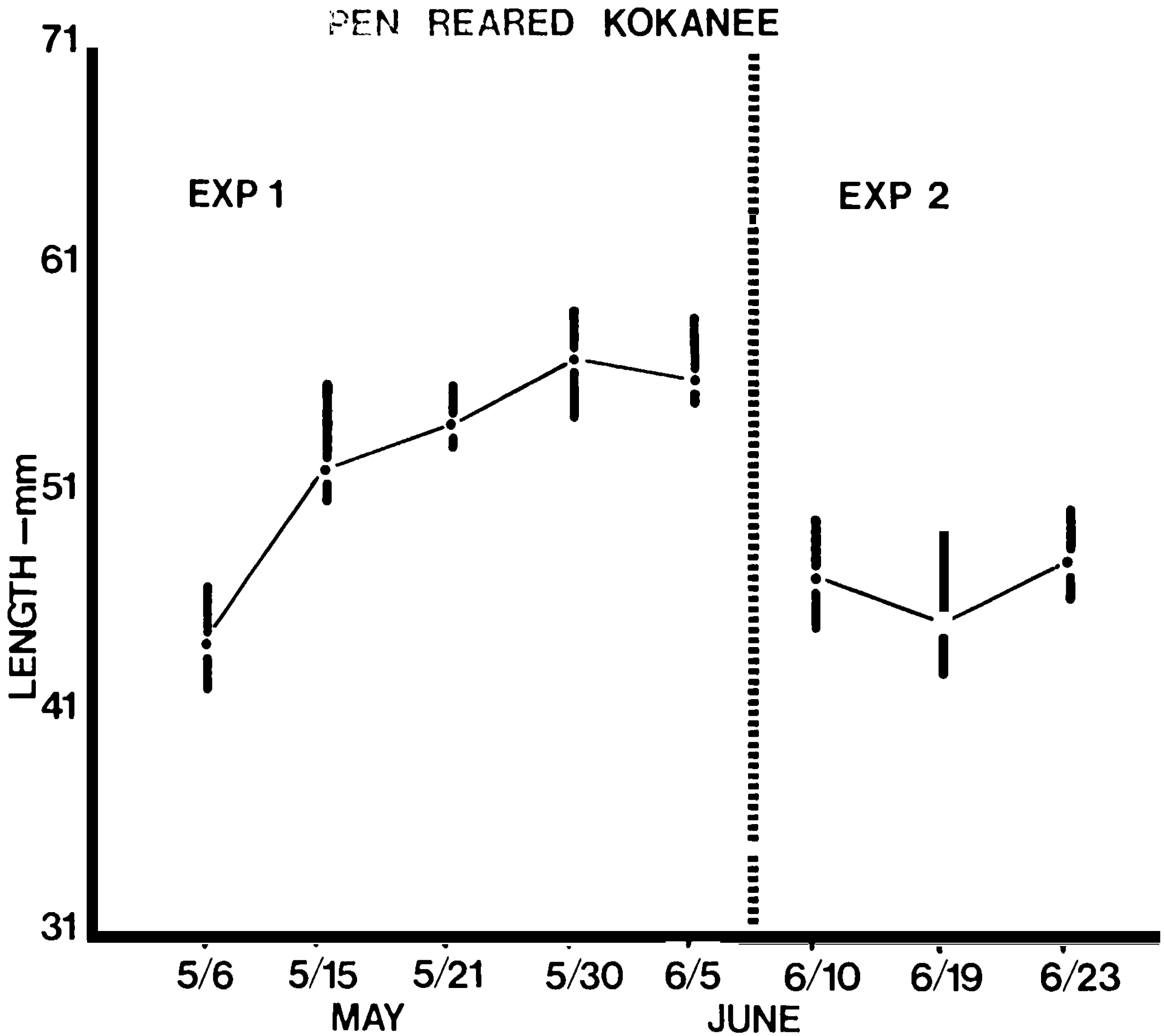


Figure 19. The growth of pen-reared kokanee fry in Flathead Lake. Mean lengths and standard errors measured at 7 day intervals, am shown for two rearing experiments.

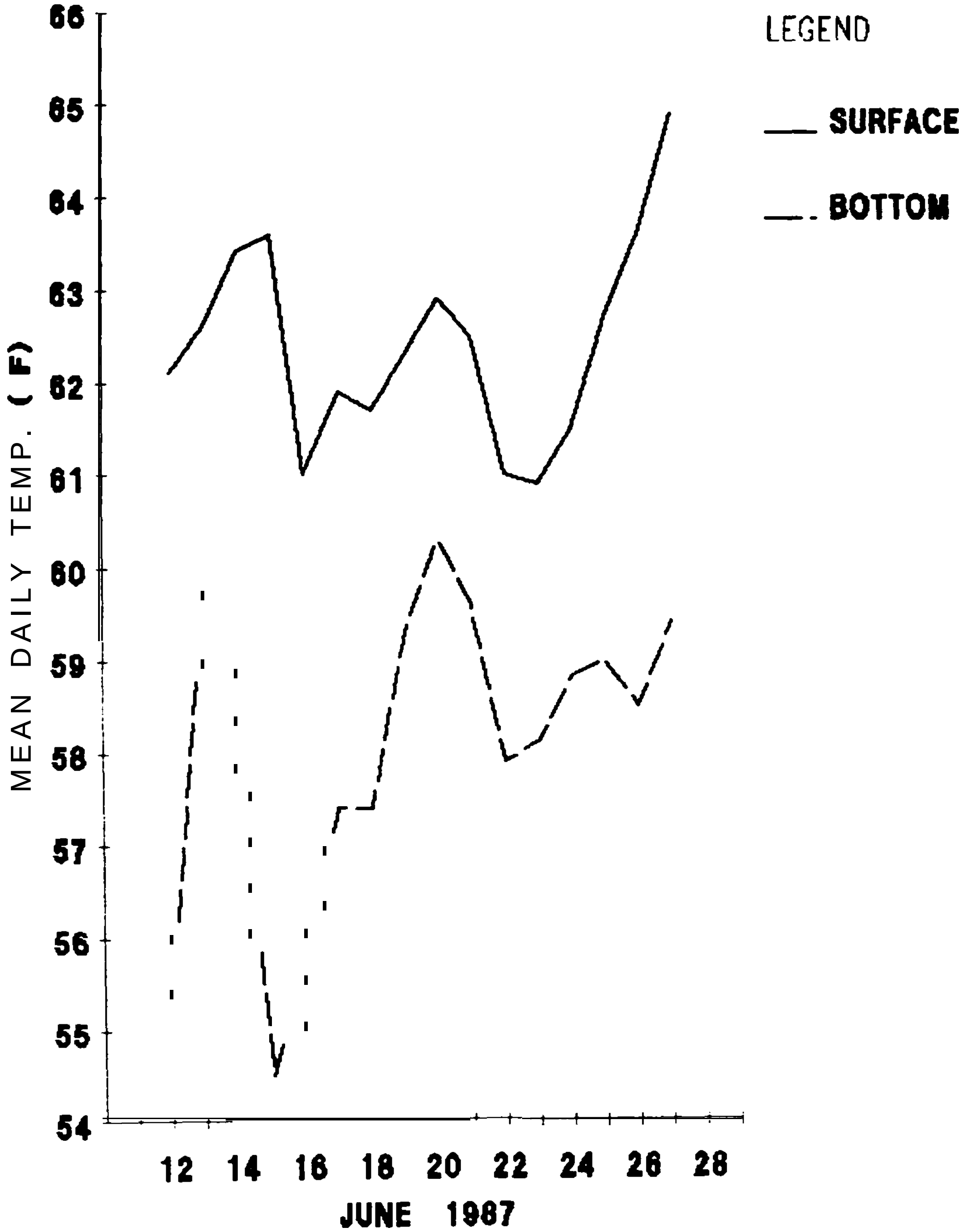


Figure 20. Water temperature at the surface and at 6 m depth at the pen-rearing site on Flathead Lake.

increased significantly. Their mean length on June 9 was 47.7 mm (S.E. 0.9 mm).

FRY SURVIVAL - 1987

The total number of fry entering Flathead Lake in late spring and early summer of 1987 vas estimated to be at least 4.8 million. This figure includes 3.7 million from McDonald Creek, 0.8 million released from the pen-rearing experiment. and 0.1 million released directly from Somers Hatchery. Approximately 19 percent of the total year class was artificially produced.

Of the 34 otolith samples we examined microscopically, six (18 percent) shoved pattern discontinuities that identify them as pen-reared fish. In another three samples, pattern changes occurred on dates close to the times of transfer from hatchery to pens and of release from the pens. The total proportion of hatchery fish in the sample could be as high as 26 percent. These data indicate that hatchery-raised fry survived at least as vell as, and possibly at an increased rate, compared to wild fry. This conclusion is based on a very small sample of fish.

The identity of these recaptured fish could not be confirmed by the presence of a tetracycline mark on skeletal structures, except in one positive and three doubtful cases. The failure of the pen-reared fish to retain the tetracycline mark was probably related to the fish being exposed to constant sunlight (ultraviolet), while being fed the drug. Ultraviolet light has been shown to prevent the binding of oxytetracycline to the organic calcium matrix of the skeleton (Trojner 1973). By contrast, the mark was clearly present in a sample of kokanee held inside the Somers Hatchery vhile being fed the drug. The mark was still readable on a small sample of pen-reared fish at the time of release, though it vas not distinct. Other studies that have held kokanee fry indoors while being fed tetracycline have recovered clearly marked fish, vhere the characteristic fluorescence is visible on external bony structures, after several months (Ed. Bovles, Idaho Fish and Game, pers. comm.)

In many other lakes morphologically similar to Flathead Lake, kokanee of all age classes condense into well-defined mid-vater layers in the pelagic zone at night (Rieman and Bovler 1980. Marino et al. 1987, Parkinson 1986). Our sampling effort, and that of previous studies of Flathead Lake (Leathe and Graham 1982, Hanzel 1983) was successful only in the shallov north end of the lake, and at nearshore stations in the north half of the lake. We never collected 0+ kokanee in the pelagic zone of the lake, though adult (2+ and 3t)kokanee are present there. We must assume that young-of-the-year kokanee are distributed differently than adults in the summer, and that a very large proportion of the 0+ population is occupying a relatively small area of the lake.

Growth Rates of 0+ Kokanee Derived from Otolith Analysis

We verified that increments observed on kokanee otoliths were laid dovn daily by examining the otoliths of pen-reared fish. When these fish vere transferred from Murray Springs Hatchery to the pens. the change in environment left an obvious discontinuity in the increment pattern on their otoliths. Thirty-one days after this transfer, the fish vere released into the lake. Increment counts (n = 20) from the edge back to the discontinuity vere distributed about a m'edian of 31, ranging from 28 to 33. Other studies corroborate this assumption that, in freshvater salmonids, otolith increments are deposited daily (Nelson and Geen 1986, Rice et al. 1985).

Using simple linear regression, ve derived the folloving relationships betveen the dorsal radii of otoliths and the standard length of kokanee. Linear models fit the combined age 0+ and age l+ fish data adequately. Yearling fish data were included to improve the back-calculated lengths of large Ot fish, fev of which vere included in the sample. For 1986 the otolith radius/fish length relationship vas:

length (Y) = -12.619 t .082 radius (X)

For this model (Figure 21) the correlation coefficient vas .965, indicating that otolith radius explained over 93 percent of the variation in fish length. Similar analysis produced the following relationship for kokanee collected in 1987:

length (Y) = -4.796 t .067 radius (x)

The correlation coefficient for this model (Figure 22) vas .960, indicating that 92 percent of the variation in fish length vas explained by otolith radius.

We used the slopes of back-calculated grovth curves as measures of grovth rate. The 1986 sample vas comprised of 29 fish, and the 1987 sample of 32 fish. The mean value of the slope of the growth curve for the 1986 sample was 0.405 (S.E. 0.011). which was significantly (p = .05) higher than 0.334 (S-E. 0.009) the mean value for the the 1987 sample. The distributions of the slopes in each sample are markedly different (Figure 23). These results indicate that fry grew at a faster rate in the summer of 1986. than in 1987.

The true length of Ot kokanee, at the time of capture, was only weakly correlated (r = 0.62) to their otolith-derived growth rate (Figure 24). This was not due to failure of the otolith radius/fish length model to predict the terminal length of fish, and thus to produce spurious growth rate estimates. The differences betveen true terminal length and predicted terminal length were distributed approximately normally, vith about

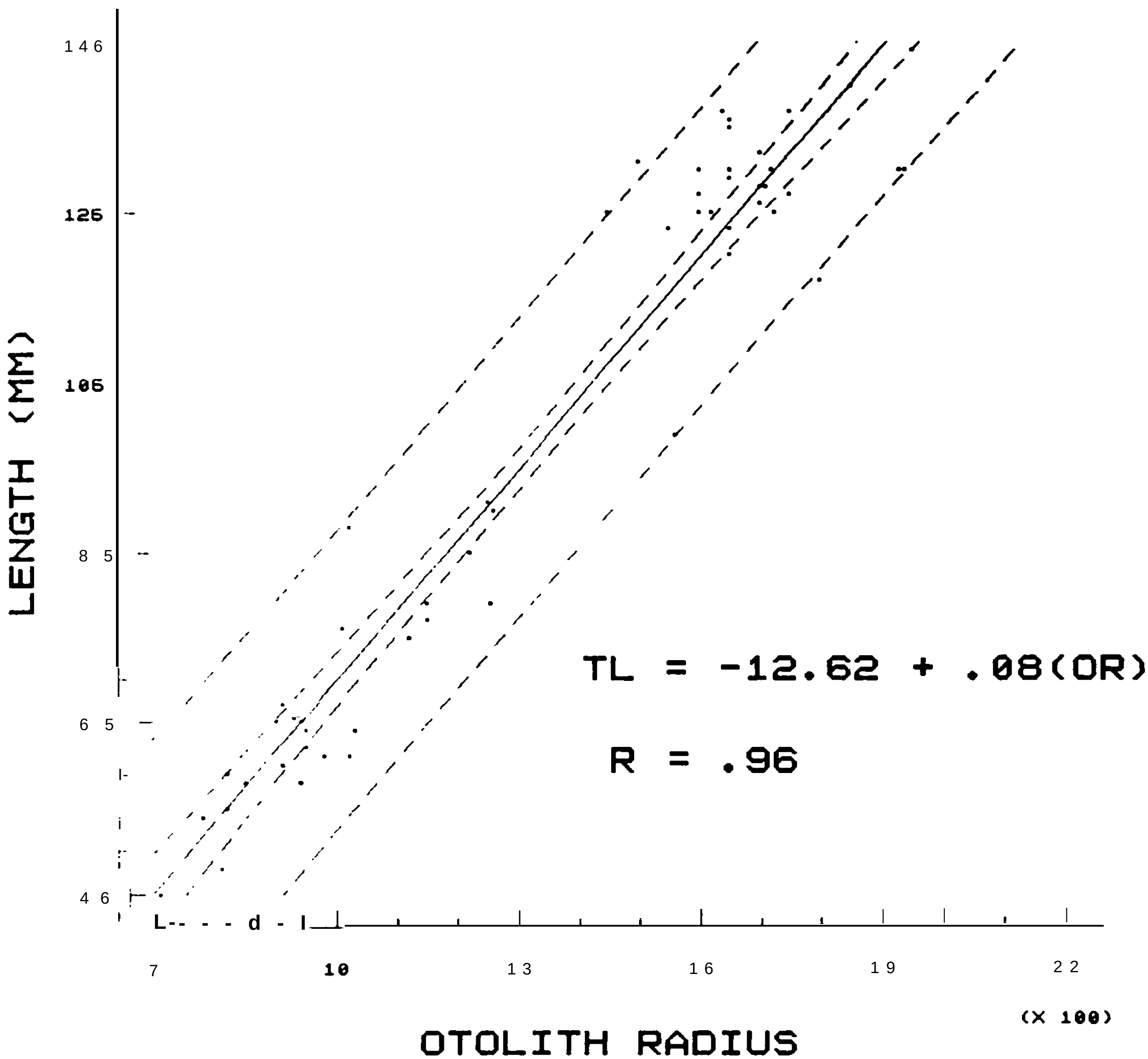


Figure 21. The linear regression model expressing the relatianship between dorsal otolith radius and standard length for juvenile kokanee in Flathead Lake in 1986.

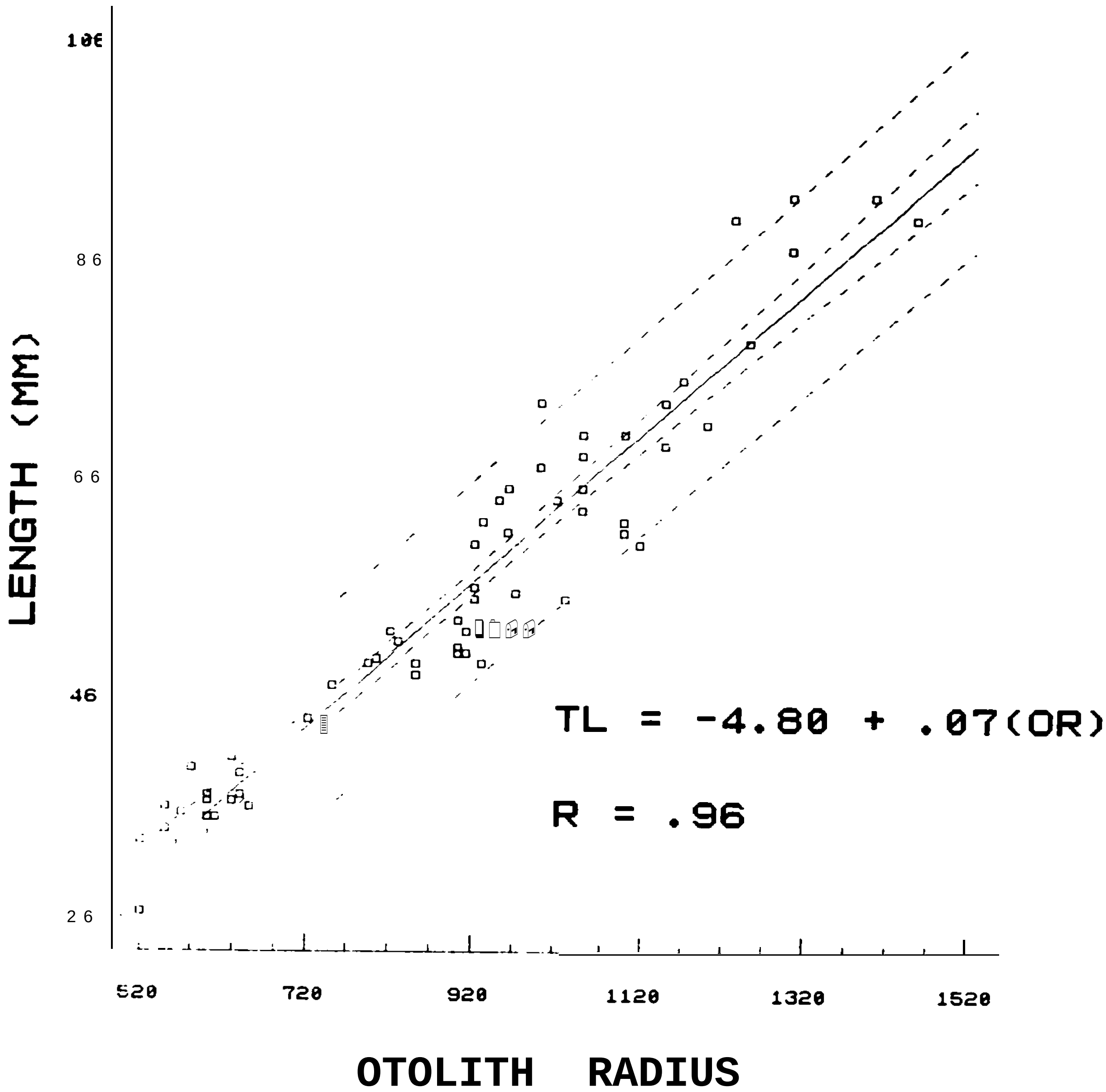


Figure 22. The linear regression model expressing the relationship between dorsal otmlith radius and standard length of juvenile kokanee in Flathead Lake in 1987.

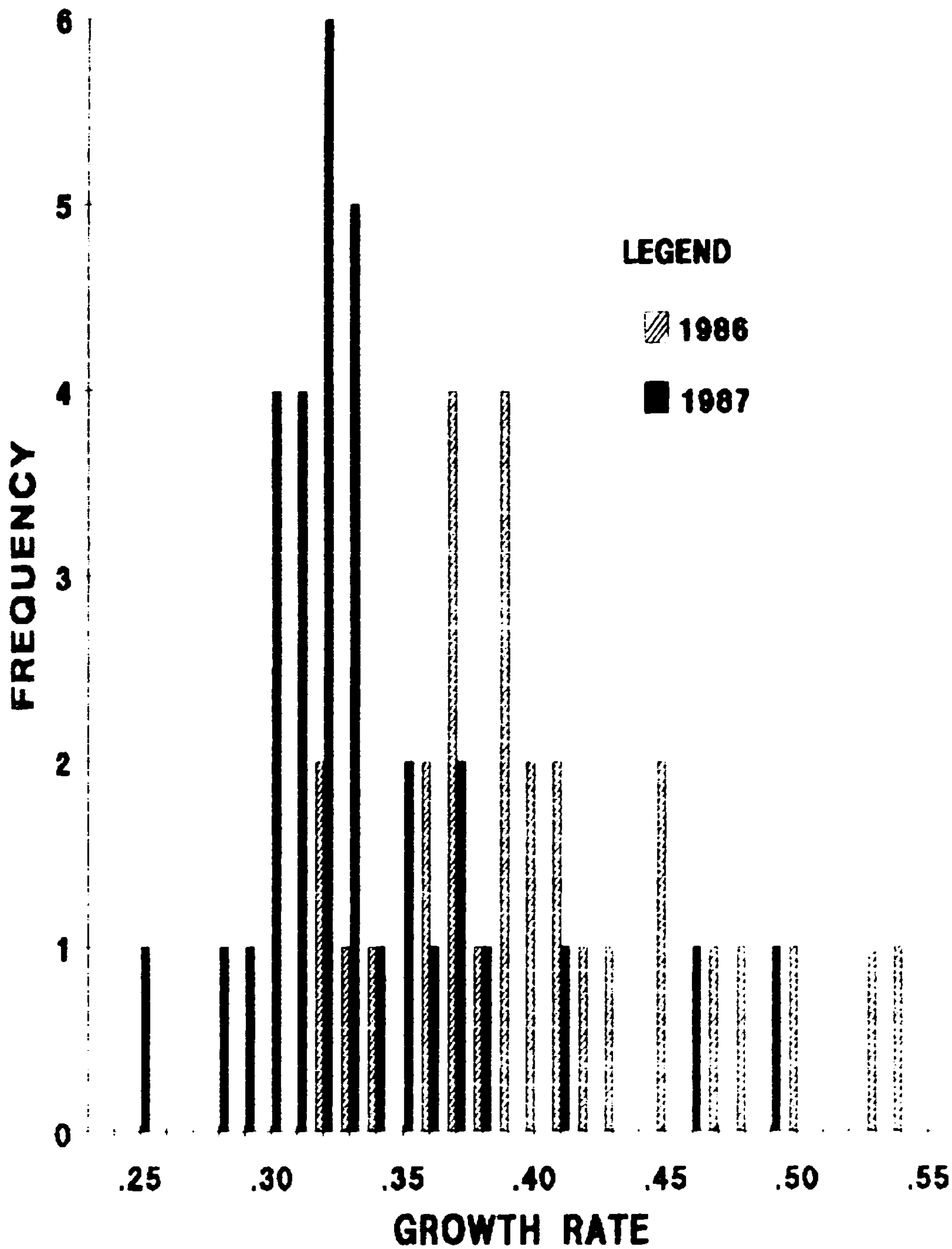


Figure 23. The distribution of the growth rates of underyearling kokanee in Flathead Lake, in 1986 and 1987.

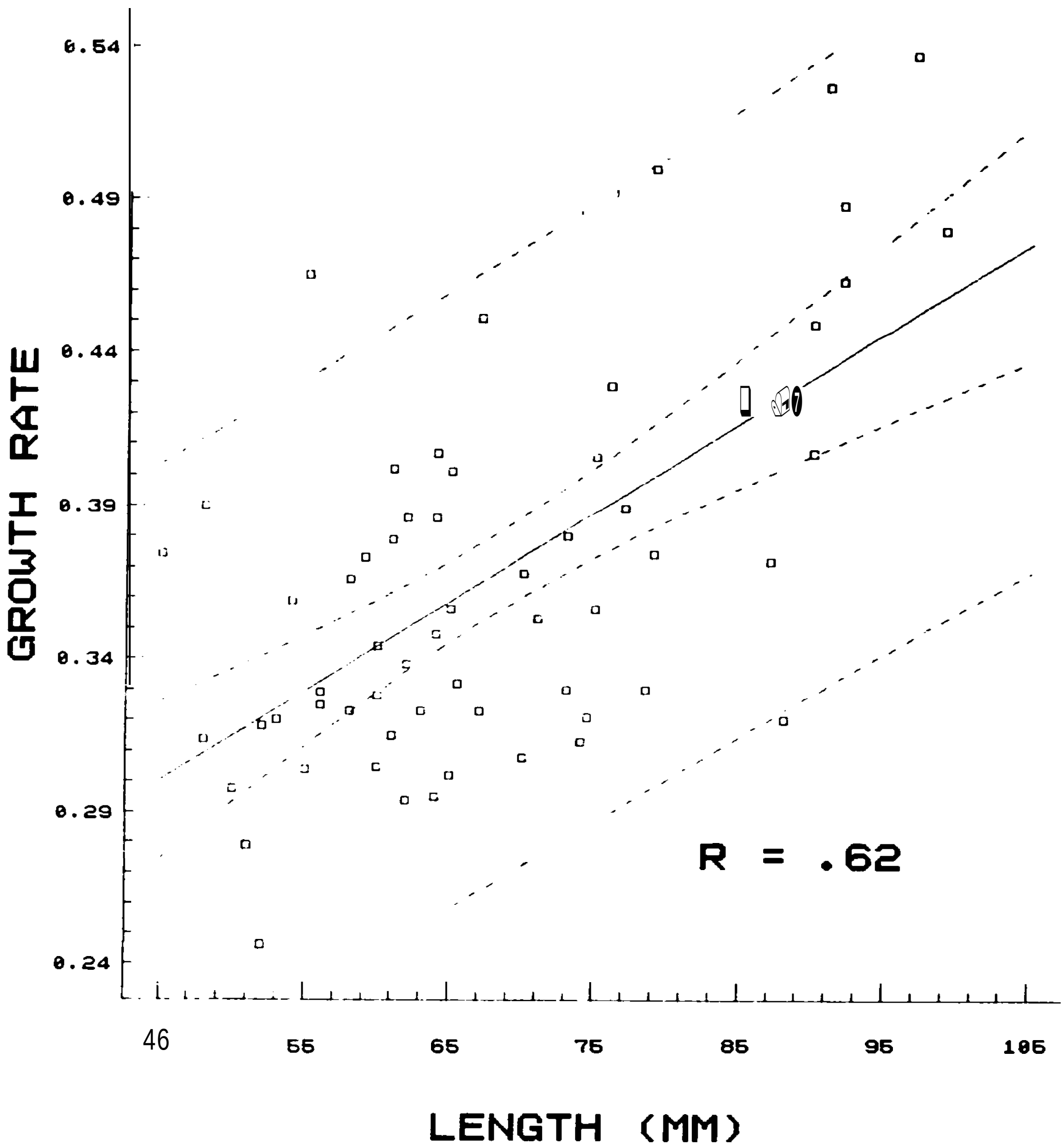


Figure 24. The relationship between growth rate, measured by otolith analysis, and length at capture of underyearling kokanee in Flathead Lake in 1986 and 1987.

90 percent of the errors falling vithin ± 10 percent of true length (Figure 25). The magnitude of these "residuals" vas not related to true fish length. The measured lengths of the fry used in the 1986 grovth analysis were not different in terms of mean, median, range, or distribution than those used for the 1987 analysis. The absence, then, of systematic error in the otolith radius/fish length model validates it utility in measuring grovth rate.

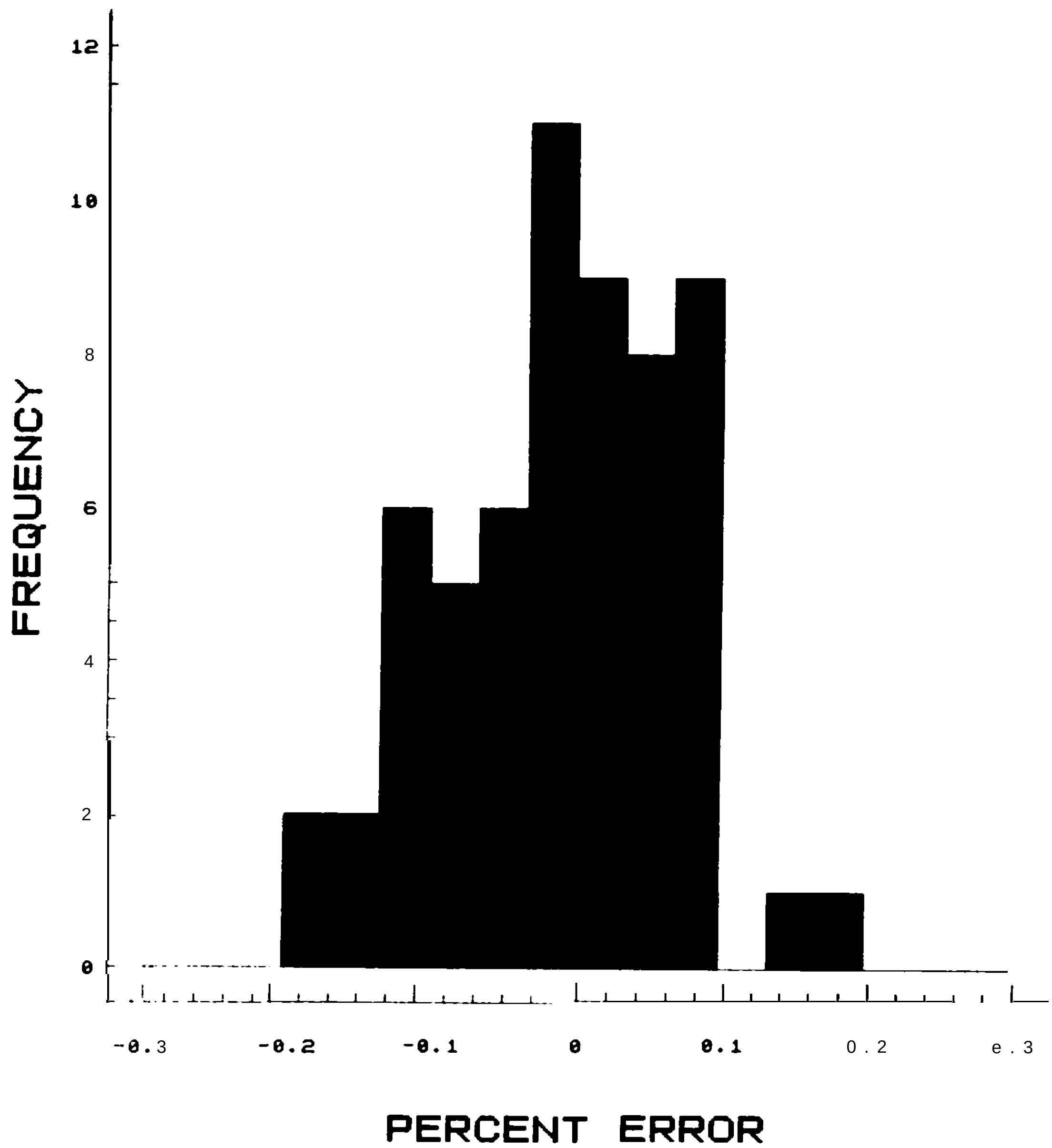


Figure 25, The distribution of the errors incurred in back-calculating the growth history of juvenile kokaneefrom otolith radius, Error is expressed as a percent of measured length at capture.

DISCUSSION

Survival of Adult Kokanee

The marked decline in the kokanee spavning escapement in 1986 and 1987 indicates that natural mortality has increased during their four-year life in Flathead Lake. Several factors may have contributed to the decline, but ve have not yet identified specific biological mechanisms. It is clear, hovever, that neither low fry production nor fishing harvest vere responsible for the decline. Estimates of the number of fry hatched in McDonald Creek in 1983 and 1984 were 12.4 and 13.1 million, respectively. These figures represent the majority of total fry produced in the system. A similar number of outmigrating fry (12.0 million) matured in the lake to produce the successful 1985 adult year class, which numbered at least 335,000 four year old fish. High fishing mortality has contributed to lov spavning escapement in recent history, notably in 1982 vhen about 90 percent of the 3+ fish vere taken by fishermen. Fishing mortality on the 3tyear class exceeded 70 percentin1986, but this fails to explain the dramatic decline in total 3t year class strength that year. Between 1981 and 1985 the number of 3+ fish in the lake, including fishing harvest and escapement, varied betveen 228,000 to 466.000. In 1986 this figure dropped to 82,500 (Table 8). After the vinter ice fishery in 1986, very fev kokanee vere caught either in the summer fishery in Flathead Lake or the fall fishery in the Flathead River. We must assume that the mortality "bottleneck" experienced by the 1986 and 1987 year classes occurred at some time in their juvenile life history.

Interspecific and intraspecific competition, and predation are the primary factors contributing to the mortality of juvenile and adult fish in lakes. In severalvell-documented cases in other lakes, the establishment of mysid shrimp (Mysis relicta) has been folloved by the decline of kokanee fisheries. In both Lake Tahoe (Morgan et al. 1979) and Lake Pend Oreille (Rieman and Bowler 1980) mysid grazing pressure reduced the abundance of cladoceran zooplankton, which make up most of the diet of all age classes of kokanee during the groving season. Circumstantial evidence pointed to the decreased availability of preferred food as a factor contributing to increased mortality. It vas thought that these conditions affected young-of-the-year fish most dramatically. However, the decline of the Pend Oreille kokanee fishery, i.e. the decline in adult fish abundance, probably began in the early 1970's - before the rapid increase in mysid shrimp was observed and presumably before any major changes in the zooplankton community were effected (Figure 26). If mysid-induced changes in the food chain can be assumed to have affected juvenile fish survival in the late 1960's and early 1970's in Lake Pend Oreille, such changes occurred at very lov mysid abundance. The documented decline in cladoceran abundance occurred as mysid density exceeded 1,000/m^2. These data suggest that kokanee are

Table 8. Escapement, harvest and fishing mortality on age III+ kokanee in the Flathead system.

Year	Escapement	Harvest Winter[a]	Harvest Summer[b]	Harvest Fall[c]	Harvest Total	Total III+ Year class	Percent Harvest
1979	60,289[d]						
1980	40,144[d]	5,000	17.250	11,348	33,598	73,792	.46
1981	134,714	53,530	118,600[e]	155,032[f]	327,162	461,876	.71
1982	33,277	115,490	82,925	25,916	224,331	257.608	.87
1983	54,239	51,780	94,375	4,365	150,520	204,759	.74
1984	107,414	45,210	194,703	10,756	250,669	358,083	.70
1985	165,447	50,810	126,293	15,575	192.678	358,125	.54
1986	21,441	44.980	30,429	2,363	77,772	99,213	.78
1987	1.956	4,700	1,000	133	5,833	7,789	.75

a/ Age compositian of kokanee harvested in winter compiled from tagging studies and winter creel survey.

b/ The 1985 creel survey is considered to be the most accurate summer harvest estimate. Statevide creel survey indicates little variation inharvest from 1982 to 1985, so we used the 1985 figure as an estimate for those years. Age composition of summer harvest from Hanzel (1986).

c/ For fall harvest percent age composition used McDonald Creek spawner percent age composition except for 1982.

d/ Minimum estimate.

e/ Because Graham and Fredenberg's (1982) estimate is considered too high, ve used 50 percent of their summer harvest figure.

f/ Includes 10,000 fishcaught in the lake.

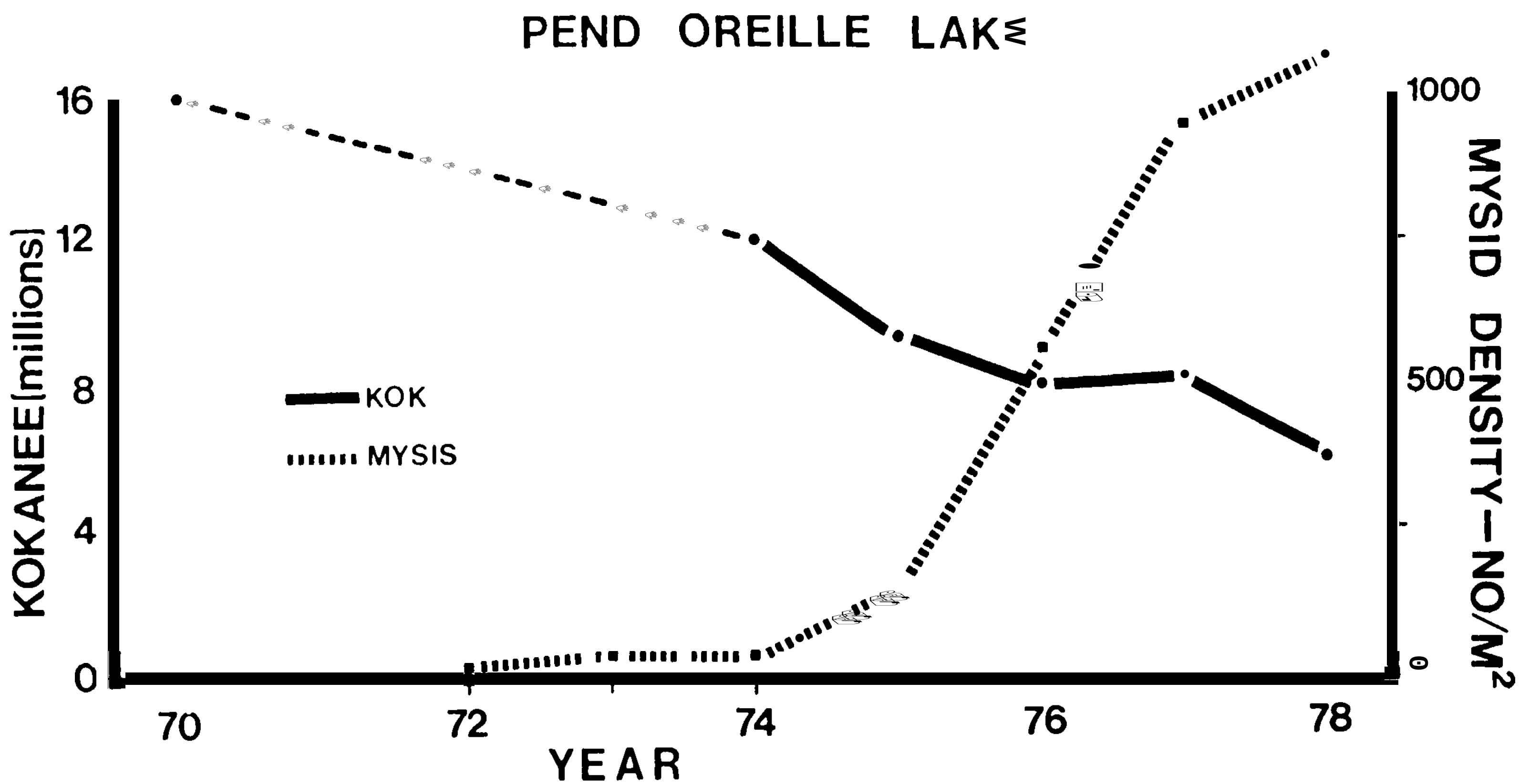


Figure 26. The coincident increase in the abundance of Mysis relicta and decrease in the abundance of kokanee in Pend Oreille Lake, Idaho, between 1972 and 1978.

susceptible to increased mortality when relatively small changes in their food supply occur.

The decline in the Flathead kokanee fishery appears to be folloving a similar scenario to that in Lake Pend Oreille. Though mysid shrimp were present in Flathead Lake in the late 1970's. having been introduced 'naturally" by drifting down from Svan Lake, Whitefish Lake, and Ashley Lake, they vere not collected until 1981 (Leathe and Graham 19821. Mysid density increased exponentially for the next three years. Marked changes in the zooplankton community vere not observed until 1986, though a declining trend in peak cladoceran density, Daphnia thorata in particular, and a delay in their summer pulse vas evident a year earlier. These rather subtle changes in the food chain may have been responsible for increased mortality of juvenile kokanee, which entered Flathead Lake in 1983 and 1984, though it seems that such a dramatic decline in fish survival vould require more overt changes in food availability. More detailed results of our study of changes in the zooplankton community and their effects on kokanee diet, grovth, and survival are discussed later in this report.

Other factors are certainly relevant to the decline in kokanee abundance in Flathead Lake. Subtle changes in the food chain may have greater effect on kokanee, given their coexistence with several other planktivorous species, including lake vhitefish, mountain vhitefish, pygmy whitefish. peamouth, redside shiner, yellow perch. and juvenile lake and bull trout. Interspecific competition vould intensify under any regime of reduced zooplankton food availability. Predation by lake trout and bull trout has alvays constituted a significant part of natural mortality. Even if this part remains constant, its significance magnifies as the total adult year class strength declines. We have no estimates of the abundance of lake and bull trout in Flathead Lake. According to sportsmen, lake trout fishing has improved in the last three years. Juvenile lake and bull trout prey extensively on mysid shrimp. Given the increasing abundance of shrimp, we might expect strong year classes of these predators to impact kokanee. The continued presence of kokanee in lake trout stomach samples testifies to their ability to utilize a prey species at low density. Without estimates of the abundance of predatory fish, however. it is purely speculative to assume that their impact has been the primary cause of the decline in kokanee.

There is no evidence that parasitism or disease are affecting the health of kokanee in Flathead Lake. Surviving adult fish, including spawners, appear to be in good condition. The size of spawners has increased over the last tvo years, as ve would expect in a species whose growth is density dependent. We have not investigated the physiological condition of kokanee beyond a comparison of length and weight. A small sample of adult kokanee were assayed for accumulations of pesticides and other hydrocarbons in 1985 (Phillips et al. 1987). The only remarkable result of these tests vas high PCB residues, from 0.l to 0.4 ppm in vhole body assays. These levels are not knovn to affect fish health directly.

A complete discussion of the factors limiting kokanee abundance must also consider factors that limit spavning success. As discussed in the introduction to this report, pre-emergent mortality in the main stem vas very high through the 1970's and early 1980's. until discharge vindovs vere imposed on the operation of Hungry Horse Dam during the spavning and incubation period (Fraley and Graham 1982. Clancey and Fraley 1985). Pre-emergent mortality is still very high along the Flathead Lake shoreline, because of dravdovn associated with the operation of Kerr Dam (Decker-Hess and McMullin 1983, Decker-Hess and Clancey 1984). Reproductive potential in the Flathead system has been reduced at least 50 percent because of declines in spavning habitat quality and unrecovered losses of spavning runs to these areas. The loss of potential recruitment from main stem and lakeshore spavning has rendered the Flathead kokanee population more susceptible to overharvest and predation. The continued success of kokanee through the 1960's demonstrated its resilience to these factors vhen a diverse range of spawning stocks supported the kokanee fishery.

Change in the Zooplankton Community - The Effects of Increased Mysid Grazing Pressure

Declines in the abundance of cladoceran zooplankton, which have been attributed to the establishment of *Mysis relicta*. have resulted in reduced densities and poor condition of planktivorous fish in lakes throughout the Holarctic region (Langeland 1987, Rieman and Falter 1981, Rieman 1979, Morgan et al. 1978). Increased grazing pressure has resulted in the complete disappearance of some cladoceran species from lakes. Langeland (1987) documented the disappearance of five cladoceran species from Lake Stugusjoen, Norway. vithin six years of Mysis introduction. *Daphnia* spp. and *Bosmina* crashed in the pelagic zone of Lake Tahoe, California-Nevada, vithin six years of *Mysis* introduction. Both of these lakes also contained planktivorous fish. Cladoceran zooplankton have also declined after the establishment of *Mysis* in Pend Oreille Lake, Idaho, Twin Lakes, Colorado, and Kootenay Lake, British Columbia.

The establishment of *Mysis* in Flathead Lake in the early 1980's has resulted in severe declines of cladoceran zooplankton. Two cladoceran species, *Leptodora* and *D. longiremis* could not be found in the zooplankton assemblage of Flathead Lake in 1987, and density of *D. thorata* and Bosmina were significantly reduced from previous years. The abundance of the copepod *Diaptomus* was also apparently reduced by mysid grazing.

The summer pulse of *Daphnia thorata*, which accounted for 70 to 90 percent of the summer and fall diet of all kokanee in Flathead

Lake (Leathe and Graham 1982). has occurred successively later since 1985. At most sampling stations in 1987, D. thorata was not present in our samples until after the lake began to stratify (Figure 27). That was also the first year that it was not present in our first sample in the spring. Temporal displacement of cladocerans is characteristic of lakes in vhich M. relicta becomes established (Zyblut 1970, Bovler et al. 1979).

Our data suggest that, as in other systems, epilimnial species such as D. thorata bloom only after thermal stratification. Mysid shrimp graze the entire water column until varming surface water temperature restricts their vertical migration. When mysid grazing pressure is thus lessened in the surface layer, species that prefer the epilimnion can increase rapidly. For the last two years enough D. thorata have survived mysid predation to seed the epilimnion and initiate a pulse after stratification (Figure 27). Potter (1978) found densities of D. thorata in the range of 1.5-2.0/liter near the shoreline of Flathead Lake before the peak of spring runoff.

In Lake Pend Oreille, D. thorata were replaced as the dominant Daphnia by D. galeata mendotae, presumably because the latter has a pronounced helmet spike vhich discouraged Mysis predation (Rieman and Falter 1981). Although D. thorata was replaced as the dominant Daphnia, it is still part of the zooplankton assemblage of Pend Oreille. Wells (1970) reports that in Lake Michigan, three species of Daphnia coexist vith Mysis. All three are epilimnial inhabitants.

D. longiremis were present in only tvo samples collected in 1986, and were not present in any samples collected from Flathead Lake in 1987. Peak density in the summer of 1985 was lover than in previous years. Perhaps Mysis affected the population prior to development of the overwintering ephippial stage, reducing the number of first generation individuals in the spring of 1986. S i n c longiremis distribute in the hypolimnion, they were susceptible to mysid grazing throughout the year. Morgan et al. (1981) documented the demise of tvo hypolimnial Daphnia species in Lake Tahoe. Nero and Sprules (1986) rarely found cladocerans in the hypolimnion after stratification in lakes in Ontario where M. relicta is native.

Bosmina have also decreased significantly in Flathead Lake since the establishment of Mysis. As vas the case vith D. thorata, Bosmina did not appear in our samples until after lake stratification. Although they were rare in plankton samples, Bosmina were commonly found in Mysis guts by Lasenby and Furst (1981). Data from Cooper and Goldman (1980) suggest that Bosmina may be preferred by smaller Mysis, vhile larger Mysis prefer Daphnia. Zyblut (1970) concluded that the decrease of Bosmina in Kootenay Lake may have been due to an increase in Diaphanosoma. He speculates that increases in the productivity of Kootenay Lake reduced the size of phytoplankton particles, which favored

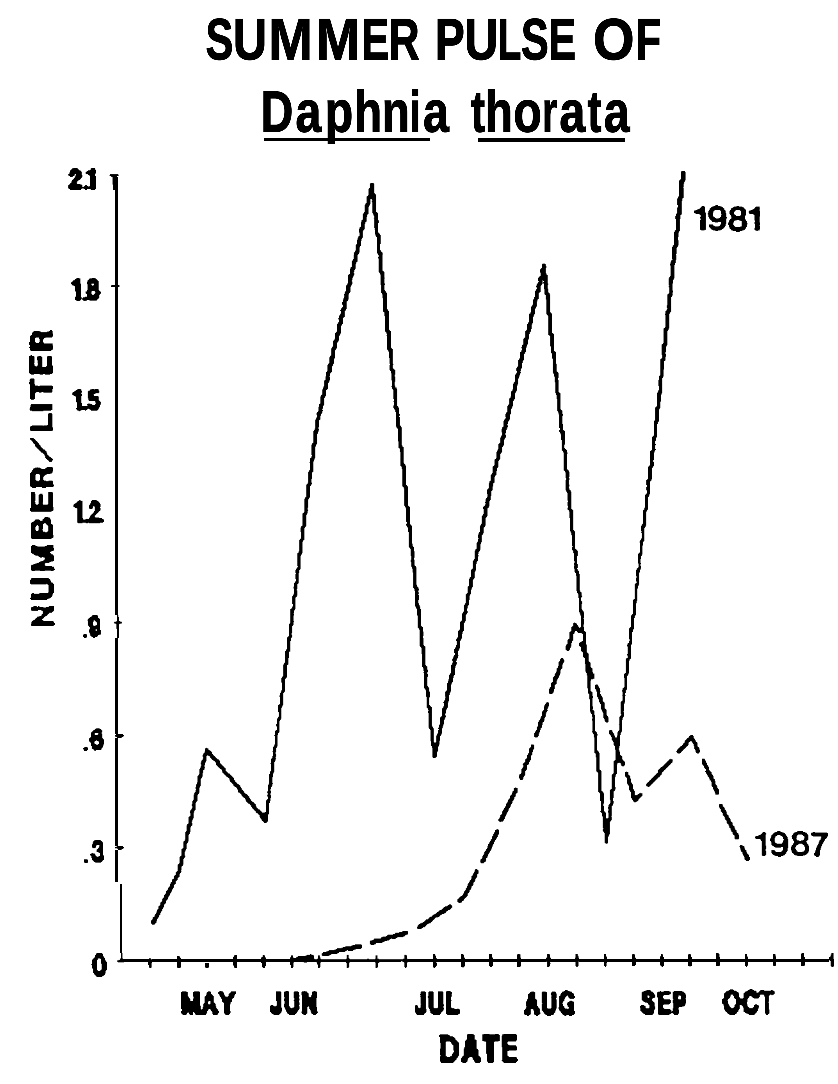


Figure **27. The temporal shift in production of Daphnia thorata** in Flathead Lake.

Diaphanosoma over Bosmina. We have no data to support such a theory in Flathead Lake. We believe the decrease of Bosmina in Flathead Lake is due to increased death rates from Mysis predation and the subsequent reduction of birth rates. Lake Tahoe was devoid of Bosmina by 1971 (Richards et al. 1975). but later was recolonized (Threlkeld 1981). One of the factors which led to recolonization vas reduced densities of Mysis.

Potter (1972) suspected that tvo forms of Bosmina existed in Flathead Lake - round and angular morphs. If that is the case, we may be seeing a phenomenon similar to that seen in Pend Oreille vith **Daphnia**. Perhaps one morph is less affected by Mysis impacts, and will exploit the void left by the reduction of other zooplankton. Since Bosmina persists throughout a greater portion of the lake than other cladocerans in summer and vinter (Potter 1978), it may be able to take advantage of areas of the lake vhere Mysis density is lov and rebuild it's population, as it did in Lake Tahoe.

The large, predacious cladoceran Leptodora also disappeared from Flathead Lake plankton samples in 1987. Though it never comprised a large percentage of the total plankton, it was an important food item for kokanee when it became available from June through November (Leathe and Graham 1982. Potter 1978). Bowler et al. (1979) found D. thorata disappeared from Lake Pend Oreille, vhich contains Mysis and Leptodora, but not from Priest Lake, Idaho, vhich contains **Mysis**, but not Leptodora. Our results contradict these findings, in that D. thorata is still present in Flathead Lake, while Leptodora, if present, are at undetectable levels.

Diagomus appeared to be maintaining it's population in Flathead Lake until 1987, when it peaked at 4.5/liter in mid July. Previously, Diaptomus density peaked in late May or early June, at over l0/liter. Langeland (1987) found that Diaptomus declined in Lake Stugusjoen after Mysis establishment. Mysis did not graze heavily on Diaptomus in Lake Tahoe (Folt et al. 1982. Rybock 1978) but it did decline in Donner and Fallen Leaf lakes, though it is not known if those declines were due to mysid grazing. Kokanee in Flathead Lake rely on Diaptomus as a vinter food supply {Leathe and Graham 1982). Potter (1978) states that Diaptomus is present in a variety of life stages at any one time, insuring that a portion of the population grows and reproduces.

Cooper and Goldman (1980) found Mysis to prefer Cyclops and Epischura over Diaptomus. However, Langeland (1987) found no changes in the Cyclops population of Lake Stugusjoen, and Cyclops appears to have been unaffected by **Mysis** in Flathead Lake. Our assertion that Cyclops is unaffected in Flathead Lake is based on the large fluctuations their population has gone through since 1983. In 1987, the density of Cyclops increased late in the year as it had in years before Mysis invaded Flathead Lake. The relatively low density of Cyclops in 1985 followed tvo successive vinters of total ice cover on Flathead Lake.

The reaction of Epischura to the Mysis situation in Flathead Lake is similar to that in other lakes vhere they co-exist. In Lake Tahoe, Mysis positively selected for Epischura, and they maintained a stable population after the impacts of Mysis had been felt (Folt et al.1982, Cooper and Goldman 1980, Rybock 1978, and Richards et al. 1975). This preference for Epischura decreased as other prey species became abundant. In Flathead Lake, Epischura density has remained vithin the range observed before Mysis vere present, and their temporal distribution has remained unaltered (Leathe and Graham 1982, Potter 1978).

Total zooplankton density decreased significantly in 1987 compared to previous years. Decreases in density of all species except Cyclops and Epischura are responsible for this decline. Diaptomus density vas strongly correlated ($r=0.98$. $p<.001$) to total zooplankton density by Decker-Hess and Clancey (1984). so the large reduction in total zooplankton is largely due to the reduced Diaptomus densities in 1986 and 1987.

Kokanee Diet: Response to Change in Food Availability

Changes in the availability of cladoceran zooplankton in the spring and early summer have not radically altered the diet of kokanee in Flathead Lake. Their characteristic shift from copepods to cladocerans occurs relatively late, because mysid grazing pressure delays the pulse of production of D. thorata until later in the summer, vhen thermal stratification isolates Daphnia in the epilimnion from the shrimp. Late summer mysid samples confirm that they largely avoid the surface waters as the epilimnion warms above 15°C (C. Spencer, pers. comm.). D. thorata is also less available in the fall and early vinter. as their abundance falls rapidly following destratification. D. longiremis and Leptodora are no longer present in the zooplankton community, and so they do not contribute to the diet of kokanee.

Previous study of the food habits of Ot kokanee in Flathead Lake (Leathe and Graham 1982) suggested that about mid May their diet shifted from copepods (e.g. Cyclops) to the increasingly abundant cladoceran Daphnia thorata. Because of the grazing pressure exerted by an increasing population of Mysis relicta, Daphnia and other cladocerans are much less abundant in the spring and early summer. Our 1987 zooplankton data show that D. thorata density did not bloom until mid to late July, though we found this species at very lov density in March at station l-l. The characteristic shift in diet, to the almost exclusive use of D. thorata did not occur until August, though it made up an increasing portion of their diet in June and July. In 1981, D. thorata made up about 70 percent of the diet of Ot kokanee in June (Leathe and Graham 1982). Their May diet was comprised mainly of the copepods Diaptomus and Cyclops. In June their diet diversified to include Epischura, Bosmina, and Daphnia. By July the principal components were Epischura, Bosmina. and Daphnia. The fry diversified their diet in May and June to include copepods and insects, vhen their preferred food vas unavailable. The behavioral trait of Epischura vhich renders them less susceptible or available to small salmon is not understood. Epischura is found at highest density in the upper 10 m of the vater column, vhere kokanee feed (Potter 1978, and Leathe and Graham 1982). Mysid shrimp vere not found in the diet of juvenile kokanee in 1986 or 1987, confirming the results from other research vhich suggests that the shrimp are either too large or unavailable to young fish.

The consequences of the change in food availability in the spring are unknovn. Eating smaller. more mobile copepods is likely to be energetically disadvantageous. If the lack of preferred food in the pelagic zone forces the Ot fish to remain onshore in search of insect larvae and other large prey, they could be more susceptible to predation.

Yearling and older kokanee diets changed less than Ot fish in comparison vith the previous study. In general yearling and older fish shifted to D. thorata earlier than did young-of-the-year. The preferred cladoceran made up the majority of yearling diet in July, and older fish diets in June. This is likely evidence of the greater mobility of older fish and the consequent ability to locate preferred food. There was a marked difference betveen the 1986 and 1987 diets of yearling fish in June, vith D. thorata and Bosmina comprising a much larger part of the diet in 1986. In the spring of 1987, yearlings were largely dependent on Epischura, perhaps in response to the reduced availability of cladocerans. In the spring of 1981 and 1982. Leptodora comprised from 20 to 40 percent of the diet of yearling and older fish (Leathe and Graham 1982), whereas this large cladoceran vas not found in any stomach sample in 1986 or 1987. Mysid shrimp comprised an insignificantly small portion of the diet of older kokanee sampled in 1986.

In 1986 and1987 ve were able to consistently collect O+ and 1+ kokanee in the northvest part of Flathead Lake. Zooplankton food, in particular D. thorata, is more abundant and is available earlier in the year in this shallov area. The limnologic conditions that foster earlier plankton pulses in this area are not fully understood. Nutrient-rich runoff from the Flathead River eddies into the northvest bays in May and June, but earlier thermal stratification and lov mysid abundance probably contribute more to early zooplankton availability. The advantages of residing in this area in the spring and early summer are obvious. Later in the summer, differences in cladoceran density betveen north and south lake stations are insignificant. Food availability does not explain our failure to find schools of juvenile fish at other locations in the pelagic zone.

Diet Overlap between Juvenile Kokanee and Lake Whitefish

Our data show that juvenile kokanee and lake vhitefish compete for the same zooplankton food species in the spring and summer. During May 1987, we found that young-of-the-year lake whitefish feed heavily on zooplankton primarily Diaptomus and Bosmina vith some D. thorata. From July through August, juvenile lake whitefish also feed heavily on zooplankton except there vas a dramatic shift to almost complete use of D. thorata concurrent with their increased availability in the water column. Some diet overlap occurs in the spring vhen both groups of fish feed on the copepod diaptomus. There is strong competition during the summer when both young-of-the-year lake vhitefish and kokanee salmon select heavily for the cladoceran D. thorata during the bloom of this species. Indices of diet overlap vere significantly high for kokanee and the three vhitefish species in Flathead Lake in 1981 (Leathe and Graham 1982). The impact of increased interspecific competition probably became more significant in 1986 and 1987. as the availability of preferred zooplankton prey declined.

Reckahn (1970) found that underyearling lake vhitefish in Lake Huron reside in shallov depths along the shoreline in early summer, move to the metalimnion during mid summer and fall then move to the hypolimnion as winter approaches. He also found that young-of-the-year whitefish feed heavily on planktonic organisms and then switch to a benthic diet by late fall. Our data shovs that young-of-the-year whitefish are primarily planktivorous from May through August. Although we did not sample whitefish through the winter, yearling (1+) whitefish fed exclusively on bottom or near bottom organisms namely dipteran larvae and clams by April.

We have not quantified the specific effects on young-of-the-year kokanee survival resulting from their coexistence in the same habitat as juvenile lake whitefish in the late spring and early summer in Flathead Lake. Nor have we collected any evidence that the combined grazing pressure of planktivorous fish reduces zooplankton standing stock significantly or thereby reduces secondary production. But the greater abundance of young lake whitefish, and the reduced availability of cladoceran zooplankton in May and June due to increasing mysid grazing pressure, probably combine to inhibit the growth and survival of juvenile kokanee.

Decline in Juvenile Kokanee Growth Rates

The majority of the 1986 sample was collected in late September and October, whereas the 1987 sample was collected in late August and early September. This vould suggest that by mid September of 1987 kokanee fry had reached the same size range that was reached a month later in 1986. However, the size of fry in the fall is a product not only of growth rate, but of when the fry entered the lake in the spring. The peak of the 1987 outmigration occurred more than a month earlier than in 1986. Their longer residence in the lake would partially explain the larger size of the fry in the fall of 1987. Epilimnial water temperatures at station l-l were varmer in 1986 than 1987 by about 2°C (Appendix E). It is probable that both vater temperature and food supply contributed to the faster grovth rates of fry in 1986.

The apparent decline in the summer grovth rate of age Ot kokanee betveen 1986 and 1987 in Flathead Lake can circumstantially be attributed to the continuing decline in their preferred cladoceran zooplankton food. Several studies have documented the relationship betveen ration size and fish grovth in experimental and natural environments. Water temperature, and therefore die1 migration behavior, co-regulates grovth rate under varying rations (Biette and Geen 1980). The growth rate of age Ot sockeye increased in coastal lakes in British Columbia vhen zooplankton food was increased by a lake fertilization experiment (Hyatt and Stockner 1985). But other factors, such as inter- and intraspecific competition, vere equally important in determining fish growth rate.

Decreased growth rate does not, however, explain the dramatic increase in mortality that has apparently already reduced kokanee abundance in Flathead Lake. Fish that grow slowly may be more susceptible to predation (Ponker 1971), and nutritionally compromised fish may be subject to disease. But no large scale die-offs of kokanee have been observed in Flathead Lake, which would suggest that outright starvation is not the central cause of increased mortality. It is important to recognize that the growth rates reported in this paper are those of fish that survived the early summer forage deficiency in the lake. Because of this possible size-selective mortality, the reported rates may not reflect the growth of fish that did not survive (Ricker 1975).

Yearling kokanee shoved a more dramatic decline in grovth rate than Ot fish, between 1986 and 1987. based on the increase in the size of fish sampled through those tvo summers. We do not have accurate estimates of yearling abundance, so the relative contribution of intraspecific competition (density dependence) is not known. Our data suggest that forage deficiency affects the grovth of older fish markedly. Even before the introduction of mysid shrimp, the growth of adult kokanee declined in their last two years. Age 3t and 4+ kokanee were not usually distinguishable based on size (Hanzel 1984). This suggests that food availability may always have limited kokanee growth rate in the oligotrophic Flathead system. The dramatic decline in food availability that has occurred in the last tvo years is, therefore. a likely cause of increased mortality.

RECOVERY ALTERNATIVES

The formulation of specific methods for recovering losses incurred by the Flathead kokanee fishery has been a principal objective of BPA-funded studies. Until very recently, enhancing the natural reproduction of kokanee by regulating dam operations and rehabilitating diverse spavning stocks throughout the system seemed to be attainable. Controlled discharge at Hungry Horse Dam, during the spavning and incubation season, vas implemented under this assumption. But the mysid shrimp/kokanee interaction, perhaps in concert vith other biologic factors, has introduced uncertainty into these plans, by causing increased fry-to-adult mortality. Since the successful winter fishery in early 1986, no substantial sport harvest of kokanee has occurred. With the survival of naturally produced fish uncertain, HDFUP has considered large-scale supplementation vith hatchery-produced fish as a means of supporting the fishery. For the same reason, MDFWP must re-evaluate a mitigation plan vhich focused on enhancing vild fry production in the main stem Flathead River.

At this point several management alternatives are available to HDFUP. The principal objectives cannot be set until the future viability of the Flathead kokanee fishery is understood. Our intent here is to describe alternative management plans applicable vhen this understanding is gained. Implementation of one of these alternatives wi11 be pursued vhen the outcome of the biological changes ongoing in Flathead Lake is better understood.

It is important to clarify the distinction betveen past losses in kokanee production that are at least in part attributable to the construction and operation of hydropover facilities, and recent or ongoing declines in survival related to change in the trophic ecology of Flathead Lake. Federal or private power marketing entities, or their ratepayers, are not responsible for mitigating losses that are related to biological changes in the lake system. HDFWP is responsible, in turn, to develop mitigation plans vhich are biologically sound and effective, and are vise expenditures of mitigation funds.

Alternative I

The most optimistic scenario suggests that the high kokanee mortality seen in the last two years is anomalous, that vild fry survival wi11 improve in the future, and that the fishery can be perpetuated based on this vild production. This scenario would require that the mysid shrimp population not increase beyond current levels, and that the competitive interaction between shrimp and kokanee vould result, at worst, in slightly increased fry mortality and slightly decreased fish growth rates.

OBJECTIVE: Maintenance of a kokanee fishery in Flathead Lake and in the Flathead River, based completely on naturally produced fish. Long-term effects of competition with mysid shrimp are assumed to be limited. The objectives of mitigation will be to: a) protect spavning in the main stem Flathead River, b) enhance the diversity and productivity of main stem spawning areas, c) enhance the productivity of spavning in other tributary streams, and d) enhance spavning success at tvo lakeshore spavning areas. In combination, these objectives replace 60,000 spavning kokanee lost from lakeshore spavning areas, and 94,000 spavning kokanee lost from main stem Flathead River spavning areas. They increase main stem river spavning escapement to 25 percent, and escapement to other tributaries to 10 percent, of system total escapement.

IMPLEMENTATION

Protection of main stem spawning success -- Maintaining a year-round minimum flov of 3,500 cfs, and stabilizing the discharge from Hungry Horse Dam, so that main stem Flathead River flov is held betveen 3,500 and 4,500 cfs during the spavning season (October 15 to December 15) has been shovn to reduce redd devatering and improve egg-to-fry survival to over 50 percent (Clancey and Fraley 1985). This discharge regime has been implemented since the fall of 1982 on an experimental basis, through an agreement reached betveen the Bureau of Reclamation and MDFWP. This measure creates and protects the habitat required for increased kokanee production in the main stem river.

Enhance Spawning in other Tributary Streams -- Traditionally strong kokanee spawning runs into Spring Creek and Swan River suggest that these tributaries hold the highest potential for improving the diversity of stocks contributing to the fishery. Spring Creek requires extensive streambed and bank rehabilitation, and removal of barriers to migration. A proposal to initiate this work (Spratt 1986) was made to the Montana State Water Quality Board. Funding of the first phase is authorized. Spring Creek is unaffected by upstream hydroelectric operations. The native cutthroat trout in this stream has been displaced by introduced eastern brook trout. Planned rehabilitation would make the lover reaches suitable for kokanee spavning and fry production.

Improving the fish passage structure at Bigfork Dam would improve the potential for kokanee reproduction in the Svan Lake/River system. The fish ladder requires modification so that it will attract upstream migrant kokanee, allow passage of all game fish species, including cutthroat trout, bull trout, and rainbov trout at the wide range of flovs encountered in the spring and fall (see Alternative IV). Kokanee are known to pass the dam at high flov and move onto spawning grounds in Svan Lake. A substantial number of Ot and lt kokanee move downstream in the spring and contribute to the fishery in the lake (Rumsey 1986). Attempts to improve spawning habitat below Bigfork Dam have been unsuccessful. Gravel placed belov the dam was quickly displaced during the spring freshet. But improving the passage structure would make available extensive spawning habitat in Swan River and along the shore of Svan Lake. A naturally-reproducing kokanee population exists in Svan Lake, but adult fish are smaller, and therefore less attractive to fishermen, than fish that mature in Flathead Lake. This Swan Lake population has coexisted vith mysid shrimp, since the introduction of ***M. relicta*** in the early 1970's. Increasing the number of kokanee migrating up from Flathead Lake to the Svan system to spawn. vould utilize Svan Lake as a rearing area, and increase the Svan contribution to the Flathead Lake fishery.

MANAGEMENT AND MONITORING SUPPORT

MDFWP fisheries management staff vould commit substantial effort tovard conservative harvest regulation, and monitoring of escapement and fry production at the enhancement sites. Harvest regulation vould require estimating yearling and 2t kokanee abundance in Flathead Lake annually, so that as those fish are recruited to the fishery, harvest can be regulated and spavning escapement optimized.

We would enlist the cooperation of private citizens who ovn the stream banks adjacent to tributary spavning areas to assist in rehabilitating riparian vegetation, limiting the effects of grazing on stream banks, and maintaining the quality of spawning habitat.

Lakeshore spavning site development would be planned and undertaken in cooperation with the Confederated Salish and Kootenai Tribes, who manage the lake fisheries in cooperation with MDFWP and regulate any shoreline development belov the high vater mark (2893 feet) vithin the boundaries of the reservation.

Alternative II

The kokanee fishery might also be maintained by a combination of vild fish production and hatchery supplementation. This assumes that approximately half of 300.000 adults required to sustain a fishery would result from vild reproduction. Assuming that the survival of hatchery-produced fry is at least double that of wild fish survival, the remaining half of each adult year class would be produced from hatchery plants. It is thought that if hatchery fish are released in mid to late July, at the time vhen zooplankton food production is most available, their survival would be optimized. Depending on fry-to-adult survival rates, three to five million kokanee fingerlings would need to be raised for late release. This plan would necessitate construction of new hatchery facilities capable of raising fish to the desired late release date.

OBJECTIVE: To maintain the Flathead kokanee fishery based partially on naturally-recruited fish and supplemented by plants of hatchery-produced fry (Management scenario 2). Hatchery plants of fry released in mid summer are intended to make up for the reduced survival of wild fry caused by competition with mysid shrimp. Target adult year class strength vi11 be 250.000 to 300.000, allowing sport harvest to exceed 150,000, and total spawning escapement to approach 100,000 fish.

IMPLEMENTATION

Wild recruitment -- The maintenance of productive spavning areas in the main stem Flathead River, the Middle Fork (McDonald Creek), and the South Fork wi11 supply the natural recruitment stipulated under this alternative. Stable flows in the main stem Flathead River wi11 be continued during the spavning season (October 15 to December 15). We propose that flow conditions during spavning be adjusted each year to benefit the number of main stem spavners. When main stem escapement exceeds 5,000 kokanee, the 3,500 to 4,500 cfs flow vindov wi11 be imposed on main stem Flathead River flov (gauged at Columbia Falls). Discharge from Hungry Horse Dam could be regulated to meet this vindov.

In years vhen main stem escapement is belov 5,000 kokanee, Flathead River flov need only be maintained above 3,500 cfs. This minimum flow should be maintained year-round for the benefit of other game fish species and their invertebrate food supply. This scheme precludes regulating unnecessarily, when stable flows are not required to enhance kokanee reproduction.

Natural reproduction will also be enhanced in the Swan River/Lake system, by improving fish passage at Bigfork Dam as described in Alternative I. The lover Swan River and Svan Lake could support a spavning run of 5,000 to 10.000 kokanee from Flathead Lake. Improved diversity of naturally-reproducing fish vould result. Planting imprintedkokanee fry in the Swan River would stimulate the enhancement of this run.

Hatchery Supplementation -- If late-released kokanee fingerlings achieve five percent fry-to-adult survival, releasing three million fish into the lake each year vould provide 150,000 adults to the fishery. Hatchery facilities would need to be expanded to accommodate these production goals. Tvo alternate plans to improve hatchery facilities are currently being considered by MDFWP. One plan outlines remodeling the Somers Hatchery facility, which was built in 1905. The vater supply vould be improved by purchasing the land surrounding the source spring, drilling a deep well, and re-plumbing the supply system. Incubation and rearing facilities would be upgraded to enable the production of the stated number of fry. It is likely that a spawning run returning to the adjacent bay. composed of fry imprinted on the spring water supplying the hatchery, would supply 50 percent of the eggs required to perpetuate the planting program. Approximately 3,000 females vould need to return to the hatchery to provide 1.5 million eggs. The second plan involves construction of a new hatchery. MDFWP ovns property slated for this purpose on Rose Creek, a small tributary of the main stem Flathead River. A high quality, high volume vater supply has already been developed at the site. That facility could be designed specifically to meet the needs of the Flathead fishery.

MANAGEMENT SUPPORT

Alternative II requires intensive management and monitoring study to succeed. The same yearly estimation of yearling and age 2t kokanee abundance vould be required to establish appropriate harvest limits in advance. Creel surveys vould be carried out to check harvest rates. Spavner surveys in the river system vould monitor escapement. The enhanced survival of late-release hatchery fish vould need to be verified by identifying their recapture rate in travl samples taken during the abundance estimation. Because the trophic ecology of Flathead Lake is dynamic, and at present changing rapidly under the influences of the establishment of M. relicta close monitoring of the grovth and survival rates of all age classes of kokanee is varranted. Reducing predation pressure on kokanee by liberalizing the sport harvest of lake trout is not considered to be an effective management tool.

Should vild fry production continue to be subject to very high mortality, as it has apparently been in 1987, it is not thought feasible to sustain a kokanee fishery based on purely artificial production. The costs of such a large hatchery operation, and the difficulty in collecting a sufficient number of eggs from various other kokanee populations in this area, would prohibit maintenance of the fishery by this means.

Alternative III

The remaining alternatives consider emphasizing the management of other fish species in the Flathead system. The trophy lake trout and bull trout fisheries in the lake are already increasing in popularity. There is renewed interest in enhancing native species fisheries, such as vestslope cutthroat and bull trout. It is important to recognize the difficulty in replacing the kokanee fishery. In terms of biomass, or number of fish, no other species now present in the system, vith the possible exception of lake whitefish, will support a harvest like that of a viable kokanee population.

OBJECTIVE: Monitor the lake trout and bull trout fisheries in Flathead Lake.

Increasingly abundant mysid shrimp are a major part of the diet of juvenile lake trout, and so it is possible that recruitment of lake trout will increase in the future. But this species is knovn to rely heavily on kokanee during its adult life (age 4t and older). Research vould need to examine whether the lake trout shifts its diet in the face of declining kokanee abundance and vhether the condition of trophy fish (above 20 pounds) is maintained. The lake trout fishery has been exceptionally successful for the last tvo years. Bull trout populations are thought to be stable in the system, based on escapement counts and juvenile fish density in rearing tributaries. Bull trout support popular seasonal fisheries during their spavning migrations and lesser, but significant, effort during summer and vinter fishing on the lake. Bull trout also feed on mysid shrimp, and the adults feed on a more diverse assemblage of fish than do lake trout. Research effort to measure bull trout and lake trout abundance in Flathead Lake would assist management efforts to regulate harvest.

OBJECTIVE: Enhance the vestslope cutthroat fishery in Flathead Lake.

There is evidence that cutthroat fishing vas formerly more productive in Flathead Lake. Competition with introduced species such as kokanee and lake vhitefish. predation by lake trout, bull trout, and other piscivores, and the reduction in spavning and rearing habitat caused by construction of Hungry Horse and Bigfork dams nov limit the cutthroat fishery. Their extended stream residence as juveniles (one to four years in tributaries to the Flathead system) complicates artificial supplementation, because rearing cutthroat to a size vhere they survive well after planting directly into Flathead Lake is expensive. Hovever. there is potential to improve habitat and productivity in rearing tributaries, re-open the Swan drainage to spawners and dovnstream migrants, and attempt hatchery supplementation on a limited scale.

OBJECTIVE: Promote the lake whitefish fishery as an alternative to the kokanee.

Lake vhitefish support productive and popular sport fisheries in other parts of the U.S. This species has not attracted much interest from the fishing public in the Flathead system, perhaps because of the the consistent availability of kokanee in past years. Recent surveys indicate that lake whitefish are very abundant in Flathead Lake, and that considerable sport harvest could be supported. Public education could work tovard increasing interest in this species.

OBJECTIVE: Control and reduce the mysid shrimp population in Flathead Lake by introducing an exotic fish predator. Biological control has not been adequately researched, and is wholly untried (Martinez and Bergerson, in press). Fisheries managers are understandably reluctant to introduce exotic species into cold vater systems in Montana, because their interaction with existing fisheries is so unpredictable. In theory, introduction of a mysid predator, i.e. a benthic-feeding, nongame species, could control the mysid population and reduce their competitive effect on planktivorous fish.

IMPLEMENTATION

Re-design and re-construct the fish passage structure at Bigfork Dam, to facilitate the upstream migration of cutthroat trout and bull trout, and reduce the entrainment of dovnstream-migrating juvenile of both species into the diversion canal supplying the powerhouse. Pacific Power and Light Company (PP&L) has initiated re-design of the existing fish ladder. Though legal responsibility for mitigating the effects of dam construction and hydropover operations in the Svan River lie solely vith PP&L, enhancing adfluvial fish production in the Svan has been proposed as a vehicle for redressing losses of habitat and fish production incurred when Hungry Horse Dam isolated the South Fork of the Flathead River (Zubik and Fraley 1987).

MANAGEMENT SUPPORT

Evaluating fish passage upstream and downstream at Bigfork Dam before and after the ladder is reconstructed is necessary to evaluate the success of the project. The potential for improving spawning and rearing habitat in tributaries of the Svan River also should be investigated. Introduced eastern brook trout have displaced native cutthroat trout in many streams, which raises the possibility of rehabilitating those sites. The use of imprinted fry plants to reestablish runs in rehabilitated streams could be evaluated.

The public is demanding a more aggressive fisheries management stance tovard the Swan system. Conservative fishing regulations aimed at improving trout fishing in Swan River will go into effect in 1988. Re-opening the Svan drainage has the highest potential of any mitigative project to enhance native fisheries, re-establish the integrity of the Svan-Flathead system, and redress some of the losses incurred by hydroelectric development in the system.

CONCLUSIONS

Our study of the Flathead Lake zooplankton community indicates that the mysid shrimp population is continuing to increase. Therefore, it is likely that reduced abundance and temporal displacement of cladoceran zooplankton production, upon which kokanee and other planktivorous fish species feed, will persist. Daphnia thorata will not be removed from the zooplankton community, because thermal stratification offers it a refuge from mysid predation.

Though further work is needed to identify the age classes of kokanee at which mortality occurs, the measured declines in grovth rate suggest that both underyearling and yearling kokanee are affected by the change in food availability. The decline in fry-to-adult survival from 2.5 percent to less than 0.1 percent, that occurred betveen 1985 and 1987 (before major changes in the food base were observed), suggests that other factors such as interspecific competition and predation are also affecting kokanee survival.

The future viability of the Flathead kokanee fishery wi11 depend, at least partially, on the success of the hatchery supplementation program. Research wi11 focus on evaluating the survival of hatchery-produced fry that wi11 be released in mid summer, when zooplankton food availability is optimum. Fry-to-yearling survival rate will also be measured. Survival estimates will decide whether a kokanee fishery can be perpetuated artificially in Flathead Lake.

A recovery plan for Flathead kokanee vould redress losses incurred by hydroelectric operations in the system in addition to the biological constraints outlined above. If the mysid shrimp population is unstable, wild propagation of a kokanee fishery may be possible. Flov regulation in the main stem Flathead River, and other means of enhancing wild reproduction in tributaries and in the lake, vould be logical ways to rehabilitate the kokanee fishery. If competition with mysid shrimp, and other biologic factors, compromise the survival of naturally-produced fish, artificial supplementation vith hatchery-produced fish may perpetuate the fishery. If a kokanee fishery is not viable in Flathead Lake, the emphasis of management and research will shift to other fish species. For example, it may be possible to promote the harvest of lake whitefish and enhance the opportunities to fish for vestslope cutthroat and lake trout. Uncertainty over the future viability of kokanee dictates that the objectives and methods of a recovery plan remain flexible.

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APPENDIX A

Biological data relevant to the study of mysid shrimp and kokanee on Flathead Lake.

Appendix Al. Food habits of Flathead Lake kokanee in 1986, summarized by sample date. (Zooplanktonexpressedaspercent of total number of zooplankton, insects as percent of total number of organisms in stomach.)

Young-of-the-year kokanee

Month	Stations Sampled	N	Epischura	Diaptomus	Cyclops	Copepod Nauplii	Daphnia thorata	Bosmina	Dipterans	Other Insects
					0+					
August	l-12	5	13.62	0	0	0	86.38	0		
September	l-5 l-5	17	10.4	.02	.02	0	91.07	0		
October	4-1 1-1 2-2 9-7 1-12 l-5	8	27.35	0	0	0	60.26	6.56		
					I+					
June	1-10	12	34.7	2.0	.5	0	39.8	23		
July	4-l	10	.2	3.5	3.6	32.4	60.2	.1		
August	l-5 1-12	34	.4	.2	.06	1.3	95.01	.05		
					II+/III+					
January	9-l	20	10.1	88.7	.1	0	1.1	0		
February	9-l	40	12.1	87.7	.2	0	.03	0		
March	9-l	20	.2	99.4	.4	0	0	0		
April	8-l	16	0	96.0	3.85	0	1.7	0		
July	4-l 4-5	16	.28	.30	.04	0	99.23	.09		
August	8-17 4-5 8-4	38	.2	.1	.03	0	99.3	.44		

AppendixA2. Food habits of Flathead bake kokanee in 1987, summarized by sample date. (Zooplanktcn expressed as percent of total number of zooplankton, insects as percent of total number of organisms in stomach.)

Young-of-the-year kokanee

Month	Station Sampled	N	*Epischura*	*Diaptomus*	Cyclops	Copepod Nauplii	*Daphnia thorata*	*Bosmina*	Dipterans	Other Insects
					0+					
May	2-2	13	.4	13.8	69.1	0	.6	.7	17.2	10.8
	l-5									
June	l-5	3	42.4	11.7	22.2	0	19.5	4.2	0	0
July	l-5	7	31.4	.09	.5	0	46.1	21.90	.8	.2
	8-2									
August	l-5	14	3.6	0	1.4	0	94.4	.7	.006	0
September	l-5	14	.7	0	.1	0	99.1	.05	.007	0
	4-17									
					I+					
June	l-5	15	72.1	8.9	1.6	0	3.4	.6	6.9	1.2
July	l-5	17	14.9	.3	.4	.07	8.4	.4	.2	.08
	l-11									
	4-l									
	4-3									
August	l-l	3	0	0	0	0	100	0	0	0
	l-5									
September	l-l	13	7.7	0	.03	0	92.3	0	0	0
	l-5									
					II+/III+					
April	3-11	4	1.0	53.9	16.4	0	2.2	1.5	0	0
June	?	15	26.2	6.6	1.4	0	65.4	.3	0	0

Appendix A3. Comparison of average density at three northern and three southern sampling stations for macrozooplankton species in Flathead Lake. The Mann-Whitney test statistic (z) compares the average rank of the two samples, and computes the probability (p) that the difference betveen the medians of the samples is as great or higher. Only Epischura appears to have different north and south lake abundance.

		1986	1987
D. thorata	z =	-.7815	-.6519
	p =	.4344	.5144
D. longiremis	z =	-.4019	
	p =	.6877	
Bosmina	z =	-.1357	.0654
	p =	.8920	.9478
Leptodora	z =	-.8350	
	p =	.4036	
Diaptomus	z =	.2027	-.4094
	p =	.8393	.6822
Cyclops	z =	.0788	-.3535
	p =	.9371	.7236
Epischura	z =	-1.968	-1.901
	p =	.0491[a]	.0572[a]

[a] Denotes significantly different average density.

Appendix A4. The percent composition of the major food items found in lake whitefish stomachs during 1986 and 1987.

1986

Size Group	Month	N	Stations (N)	Zooplankton	Mysids	Dipterans	Pelycopods	Gastropods
Juveniles	June	5	1-5 (1)	17.5	0	82.3	0	0
≤140 mm			2-8 (4)					
	July	0						
	August	7	1-5 (7)	43.9	6.6	39.8	6.0	0
	September	2	1-5 (2)	0	100.0	0	0	0
Adults	April	13	1-8 (1)	15.4	0.3	53.5	15.4	0.5
>140 mm			5-6 (8)					
			8-1 (4)					
	May	13	1-7 (2)	14.6	7.6	47.8	16.7	7.4
			2-10 (5)					
			3-10 (6)					
	June	13	1-1 (4)	40.0	0	27.5	27.8	0.4
			1-5 (1)					
			1-10 (1)					
			4-1 (2)					
			2-8 (5)					
	July	5	3-19 (3)	33.3	34.4	1.1	4.3	0
			4-5 (2)					
	August	25	1-1 (2)	34.8	41.0	12.0	8.0	0
			1-5 (3)					
			1-12 (2)					
			3-11 (9)					
			4-1 (4)					
			8-17 (5)					
	September	0						
	October	0						
	November		1-12 (6)	43.2	1.3	10.4	24.5	4.4
			5-8 (2)					
			9-5 (1)					

Appendix A4. (Continued).

			1987				
Size Group	Month	N	Stations (N)	Zooplankton	Mysids	Dipterans	Pelycopods
Juveniles <140 mm	May	10	2-11 (10)	71.4	0	28.6	0
	June	1	9-5 (1)	0	3.4	96.6	0
	July	9	1-5 (7)	86.0	0	12.5	1.5
			8-2 (2)				
	August	8	1-5 (6)	56.8	25.9	11.7	5.7
			3-9 (1)				
			3-10 (1)				
Adults <140 mm	April	15	1-12 (8)	7.1	0.2	29.4	63.2
			2-6 (1)				
			2-10 (1)				
			3-11 (5)				
	May	14	1-5 (13)	0.3	0	57.7	42.0
			5-9 (1)				
	June	12	1-5 (7)	0.7	26.1	31.6	41.7
			1-9 (2)				
			4-5 (2)				
			9-5 (1)				
	July	0					
	August	11	1-1 (1)	18.0	75.0	1.0	6.0
			1-5 (3)				
			3-10 (3)				
			3-15 (1)				
			3-16 (1)				
			4-9 (1)				
			7-2 (1)				

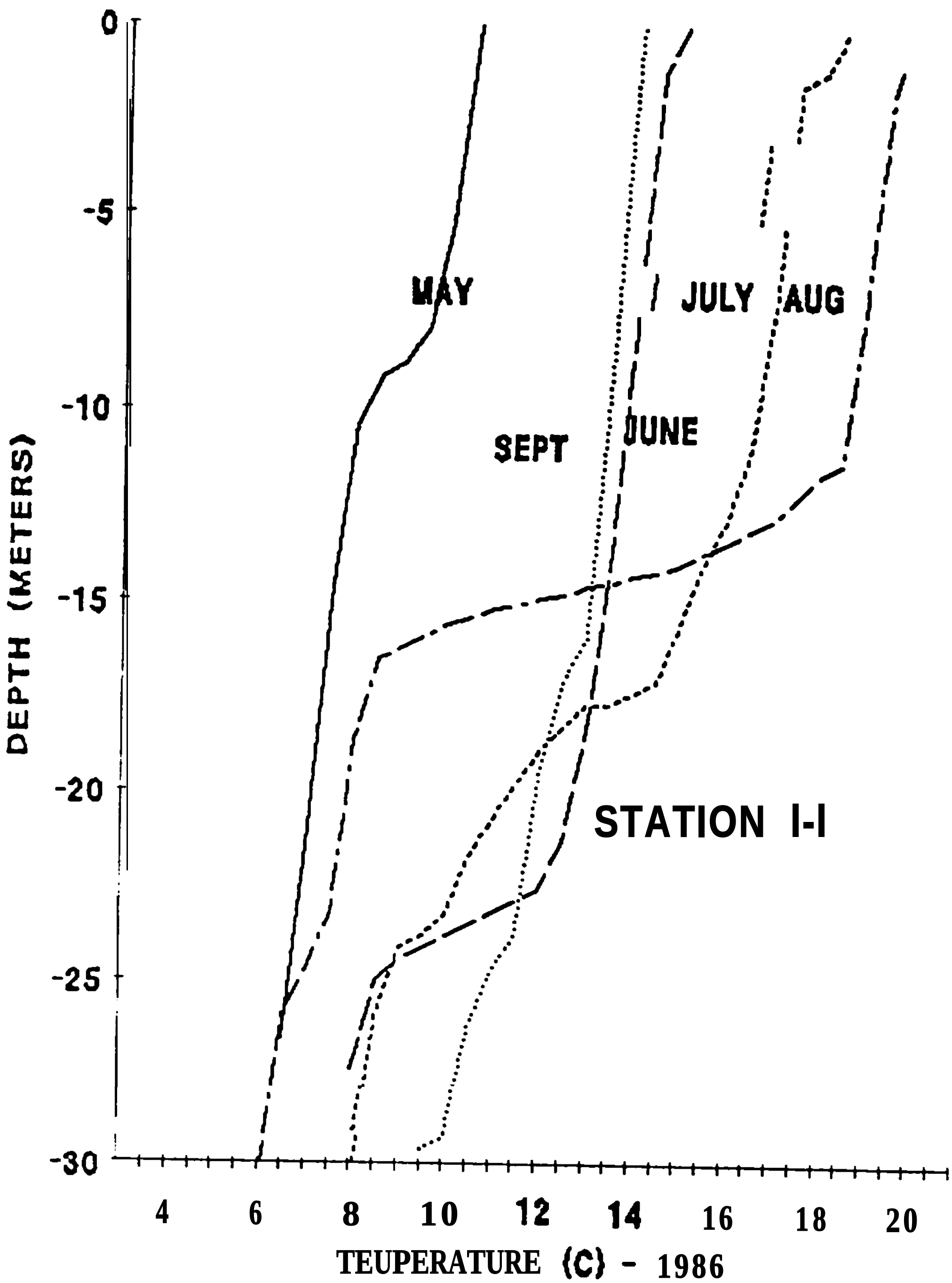

Figure 1. Temperature profiles at Station I on Flathead Lake in 1986.

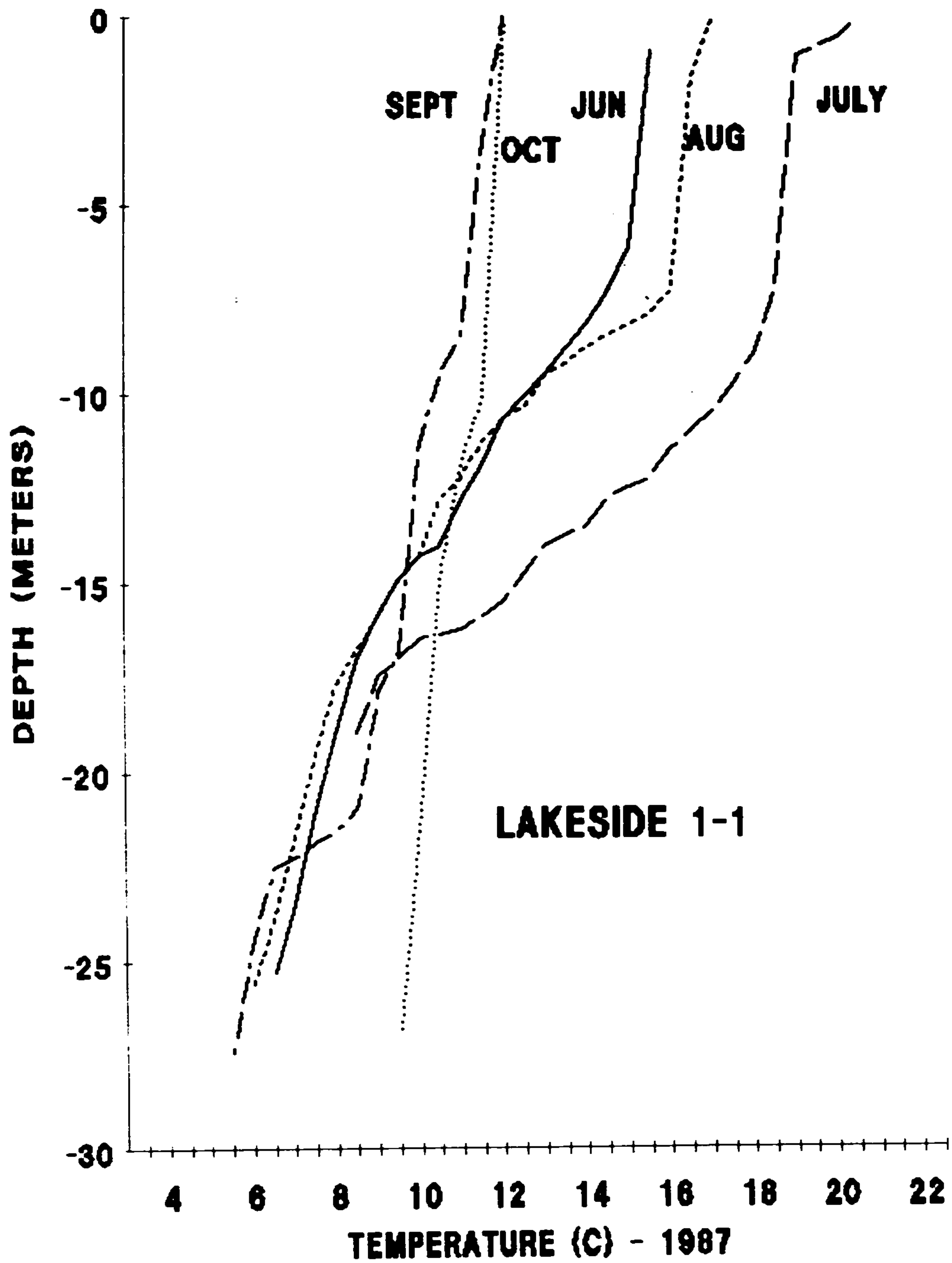

Figure 2. Temperature profiles at Station 1 on Flathead Lake in 1987

APPENDIX B

A bibliography of all research published by the Montana Department of Fish, Wildlife and Parks and its subcontractors on the effects of hydroelectric operations on the fisheries of the Flathead system.

Appendix B: Progress reports. final reports, and articles in scientific journals that summarize study of the effects of hydroelectric operations on the kokanee fishery in the Flathead system.

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