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Quantification of Libby Reservoir Levels Needed to Maintain or Enhance Reservoir Fisheries

Annual Report 1984

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Quantification of Libby Reservoir Levels Needed to Maintain or Enhance Reservoir Fisheries

Annual Report FY 1984

by;

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EXECUTIVE SUMMARY

We are evaluating the potential impacts of Libby Reservoir operation on the fishery in Libby Reservoir. The sampling program has been tested and modified to provide data for developing an understanding of how reservoir operation impacts the reservoir fishery. This sampling program was reviewed by other reservoir researchers and found to be adequate. Temperature appears to be an important variable influenced by reservoir operation which regulates fish and fish food production and distribution.

Horizontal distributions of salmo spp. showed seasonal movements towards near-shore zones when temperatures allowed and apparent concentrations in upper-reservoir areas during the spring and fall. Sampling fish macro-habitat preferences within the reservoir proved to be difficult, but limited sampling showed little preference exhibited for any specific cover or substrate types. Juvenile salmo spp. were found in both near-shore and limnetic zones with smaller (<120 mm) juveniles found only in near-shore zones and larger (120 to 200 mm) juveniles found in the limnetic zone. Kokanee were distributed primarily in the limnetic zone, except during the spring and fall when kokanee were captured in near-shore zones. The fall distribution of kokanee in near-shore zones was believed related to pre-spawning movements of adults seeking spawning areas. We are unsure of the reasons for spring movements into near-shore zones, but believe it may represent a food seeking response. Nongame species, particularly peamouth, appeared to move into near-shore zones as water temperatures warmed during the spring, remained in near-shore zones during the summer, and moved out of near-shore zones in the fall, Vertical distributions of salmo spp. and kokanee appeared to be regulated by temperature, but thermal maximums were occassionally challenged, probably in order to feed.

Purse seine population estimates for salmo spp. showed moderate precision for limnetic zones and poor precision when expanded to include near-shore zones. Spring estimates were positively biased because of non-random sampling to test the purse seine's effectiveness. An estimated 2.5 million kokanee (+8%) were present during August, 1984 based on hydroacoustic sampling. The presence of a single (1983) year class simplified estimation.

Kokanee grew rapidly and averaged 185 mm after their first summer in the reservoir. Their growth slowed during the winter and averaged only 5 mm from November through April, but increased again in May to average 15 mm per month through the summer. Approximately 30 to 40 percent of the male kokanee and 4 percent of the female kokanee were determined to be ripe (based on August 1984 samples) and probably spawned during the fall of 1984. These fish spawned at age I, after spending only two growing seasons in Libby Reservoir.

A total of 901 adult and 5,597 juvenile salmo spp. were tagged during 1983 and 1984. Returns to date have been 11 and 0.3 percent for tagged adults and juveniles, respectively. Movement of both juvenile and adult trout within the reservoir and between the reservoir and its tributaries appeared to be independent of tagging location. A possible down-reservoir trend was noted.

A total of 354 (+3) adult cutthroat trout ascended Young Creek to spawn. The maximum estimated spawning mortality was 25 to 30 percent. At least nine percent of the adult cutthroat trout which spawned during 1984 were repeat spawners from 1983 based on tag returns.

Surveys of tributaries indicated six tributaries contained at least one reach with excellent spawning habitat. One of these streams, Barron Creek, is known to be unavailable to spawning adults because of an impassable barrier located within the drawdown zone.

Zooplankton, particularly Daphnia spp. and Leptodora spp., and terrestrial insects dominated the stomach contents of salmo spp. during the summer of 1983. Kokanee ate Daphnia spp. almost exclusively. These fish species seemed to select for the larger Daphnia spp. present in the reservoir. Zooplankton densities peaked during the spring with two lesser peaks evident; one in the fall and one in mid-winter. Daphnia spp. densities usually made up 20 to 30 percent of total zooplankton densities. Length distributions of Daphnia spp. illustrated that length composition changed seasonally with more large Daphnia spp. found during the fall. Zooplankters were concentrated in the upper 12 m of the water column during the day with higher densities of Daphnia spp. generally found within the euphotic zone.

Density and biomass of benthic macroinvertebrates were obviously a function of how frequently the reservoir bed was wetted with the highest densities and biomasses observed in permanently wetted portions.

Abundance of macroinvertebrates on the reservoir's surface was similar, although patchy, in near-shore and limnetic zones. Diptera adults made up a significant portion of the total densities of macroinvertebrates observed during the spring with terrestrials making up a progressively larger percentage of the total as summer progressed.

Strategies for developing predictive models to describe relationships between reservoir operation and the reservoir fishery will concentrate on development of conceptual models first and then attempt to develop quantitative models using thermal predictive models, trophic transfer models, and population simulation models

ACKNOWLEDGEMENTS

We would like to extend a heartfelt thanks to Paul Hamlin, Mark Schafer, and Mark Sweeney, our competent field people, for a job well done in the field and in the laboratory, and for the help in preparing this report. Temporary field people which also contributed to the success of our effort included Bob Calamusso, Nick Hetrick, Mary Ellen Mueller, and Ron Rhew. Beth Morgan did much of the laboratory analyses. Patrick Graham, Special Projects Bureau Cheif, and Steve McMullin, Project Coordinator, helped develop the study proposal and plan the study. Personnel from the Kootenai National Forest including Gary Altman and Don Godtel and their staffs helped with many aspects of the study under the direction of John Lloyd, Fisheries Biologist. Fish and Wildlife Branch (Ministry of Environment, British Columbia, Canada) personnel, particularly Al Martin and Gerry Oliver, helped by providing background information, technical assistance, and lending a hand with field work. The U.S. Army Corps of Engineers, Libby Project provided background and current data on reservoir operation. The office staff in Kalispell provided technical and administrative support, particularly Alice Martin. The fisheries staff of region one, particularly Jim Vashro, Regional Fisheries Manager, and Joe Huston provided technical assistance and background information. Janice Pisano and Jean Blair typed the draft and final copies of this report.

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INTRODUCTION

Libby Dam was constructed on the Kootenai (spelled Kootenay in Canada) River as part of an international Columbia River Treaty between the United States and Canada to provide hydroelectric power and flood protection for the Kootenai and Columbia River basins (Columbia River Treaty 1961). Construction began in 1966, impoundment was first achieved on 21 March 1972, and a full pool elevation of 2,459 feet was first reached in July 1974.

In 1980, Congress passed the Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501) which created the Northwest Power Planning Council (Council) and directed it to "promptly develop and adopt. . . a program to protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat, on the Columbia River and its tributaries." The following recommendations by the Montana Fish, Wildlife and Power Ad Hoc Committee (compiled by Graham et al. 1982) were adopted by the Council as part of that program:

1) Except in years of extreme runoff (definedastwentieth percentile or higher flow) drawdown for power purposes shall not exceed 90 to 110 feet at Libby Reservoir [804(b) (1)];

2) Bonneville Power shall fund research to develop operating procedures for establishment of reservoir levels necessary to maintain or enhance fisheries [804(b)(3)]; and

3) The U.S. Army Corps of Engineers (USACOE) shall develop operating procedures for Libby Dam to ensure that sufficient flows are provided to protect the resident fish in the Kootenai River and Lake Koocanusa (Libby Reservoir) and that in the event of a conflict between maintaining the minimum flows [804(a)(f)] and maintaining reservoir levels [804(b)(l)], the USACOE shall consult with Montana Department of Fish, Wildlife and Parks (MDFWP) to determine which requirement shall be preferred (Northwest Power Planning Council 1982).

This study was initiated May 1983 to determine how operations of Libby Dam impact the Libby Reservoir fishery and suggest ways to lessen those impacts. The first year of the study was spent testing and selecting methodologies for collecting data and using these data to design a sampling strategy. We have finalized our study objectives to provide the following:

1) Quantify available reservoir habitat.

2) Determine the abundance, growth, and distribution of fish within the reservoir and potential recruitment of salmonids from Libby Reservoir tributaries within the U.S..

3) Determine the abundance and availability of food organisms for fish in the reservoir.

4) Quantify fish use of available food items.

5) Develop relationships between reservoir drawdown and reservoir habitat for fish and fish food organisms.

6) Estimate impacts of reservoir operation on the reservoir fishery.

Operation of Libby Dam for flood control and generation of hydroelectric power results in an annual drawdown and refill of Libby Reservoir. The USACOE operates Libby Reservoir to reach a full pool in July, begins drafting the reservoir in the fall, reaches a minimum pool elevation in late March, and begins refilling the reservoir in the spring. These annual fluctuations of Libby Reservoir water levels constantly change the amount and guality of reservoir habitat available to fish and fish food organisms. This annual expansion and reduction of living space probably results in increased competition for limited resources necessary for survival (i.e. food, preferred habitat). Coupled with this increased competition is the potential for lowered food production caused by the reduction in the water's surface area which receives sunlight energy, the reduced availability of nutrients from littoral sources, and the contraction of the reservoir's water surface away from productive terrestrial food sources.

We hypothesize that reservoir operation may affect the reservoir fishery by:

1) controlling the amount of reservoir surface area which collects incoming solar energy and terrestrial insects;

2) controlling the guantity and quality of habitats available to zooplankton (volume of water), benthic invertebrates (wetted reservoir bed), and fish;

3) exposing barriers to upstream migrating adults located within the fluctuation zone of spawning tributaries resulting in the loss of spawning habitat to spring spawners:

4) flushing phytoplankton, zcoplankton, and fish out of the reservoir through Libby Dam;

5) dewatering burbot spawning areas after spawning occurs;

6) eliminating "littoral" zone vegetation: and

7) modifying the thermal regime within the reservoir.

DESCRIPTION OF STUDY AREA

Libby Reservoir is located in northwest Montana (Figure 1). A detailed description of the drainage basin was presented by Bonde and Bush (1975) and Woods (1982). We described the physical environment and biotic community in our first annual report (Shepard and McMullin 1984). A maximum drawdown of 27.1 m (reservoir elevation of 2370.3 feet) was reached on 15 April 1984. The reservoir reached a full pool elevation of 2459 feet on 30 July 1984 and drafting below this full pool level began on 22 August 1984 resulting in the reservoir being held at full pool for only 23 days (Figure 2). The reservoir was held at full pool for a much shorter time during 1984 than any previous year the reservoir was filled (Table 1).

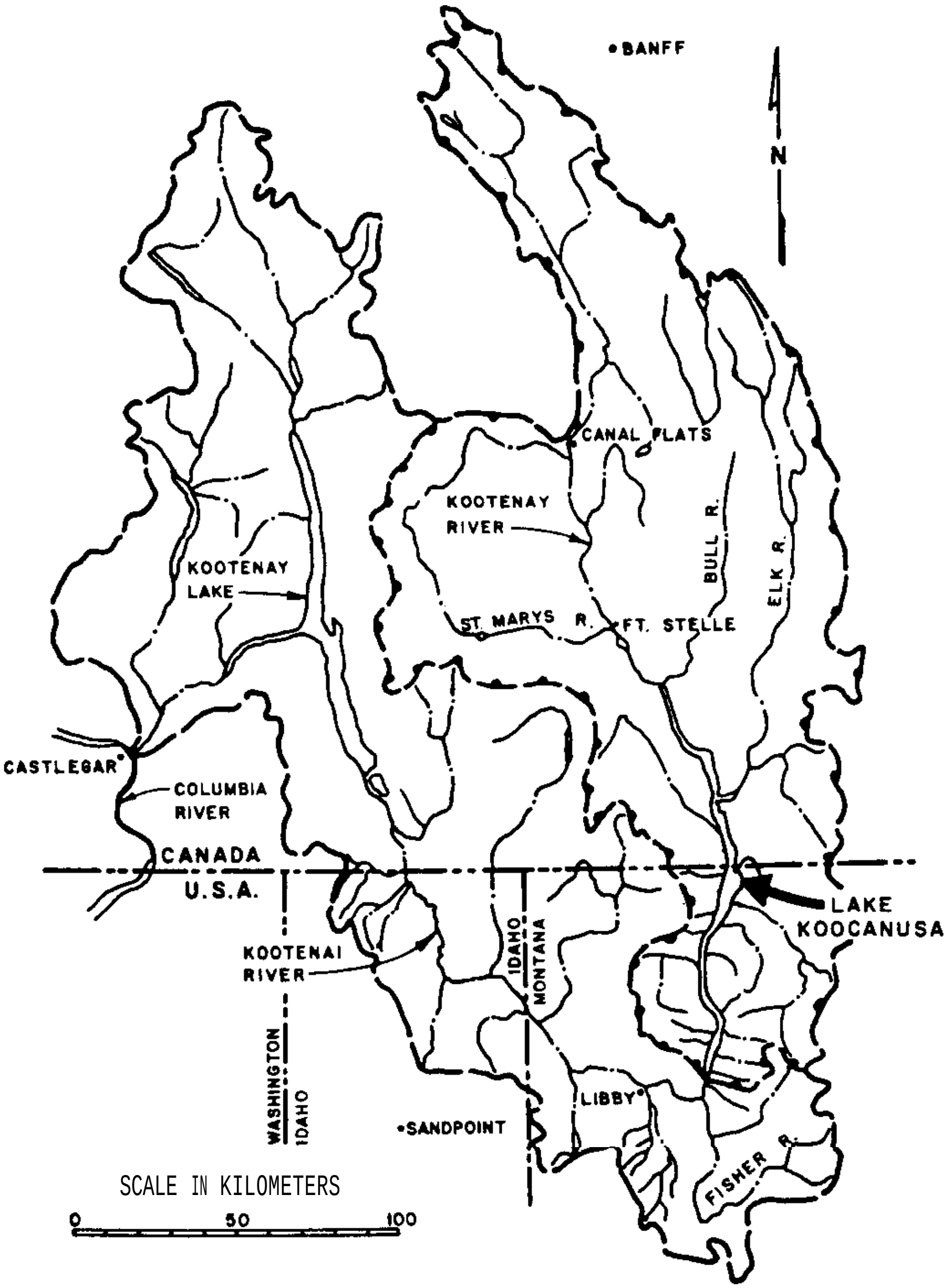


FIGURE 1. Map of the Kootenai River Basin showing the location of Libby Reservoir (Lake Koocanusa) (from Woods and Falter 1982).

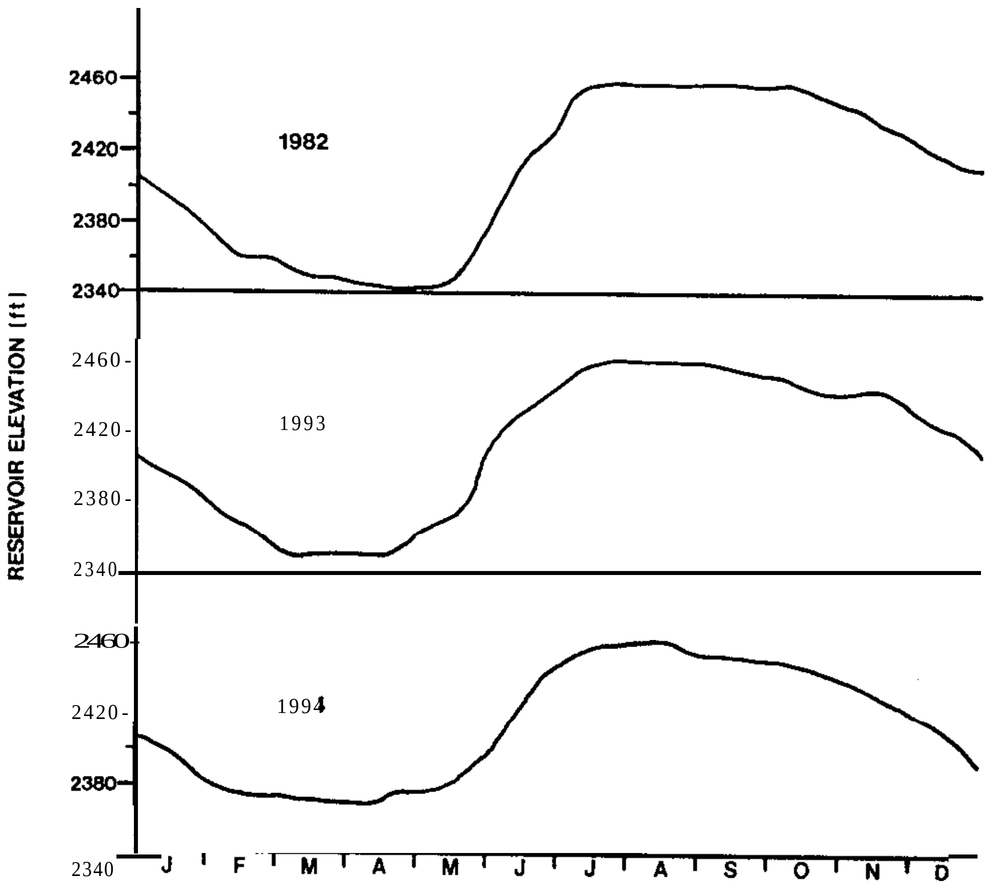


Figure 2. Monthly changes in water surface elevations of Libby Reservoir during 1982 to 1984

Table 1. Lake-fill time (yrs.), hydraulic-residence tine (yrs.1, maximum drawdown number of days held at full pool, and maximum reservoir elevation for Libby Reservoir by year from 1972 through 1984.

	Lake-fill time (yrs)	Monthly			Hydraulic-residence (yrs)	monthly			Maximum drawdown		No. days at full	Max. pool elevation
Year	annual	mean	min.	max.	annual				ft.	m.	pool	(ft.)
1972	0.14	0.17	0.04	0.52	0.14	0.14	0.02	0.37				
1973	0.22	0.40	0.10	0.88	0.33	0.49	0.11	1.29	230	70.3		
1974	0.28	0.61	0.09	1.28	0.29	0.33	0.13	0.67	153	46.6		
1975	0.37	0.63	0.11	1.13	0.41	0.78	0.10	2.66	172	52.4	0	2454
1976	0.38	0.71	0.13	1.54	0.38	0.55	0.13	1.56	152	46.2	61	2459
1977	0.64	0.93	0.26	1.64	0.50	0.59	0.24	1.42	100	30.5	0	2414
1978	0.43	0.75	0.18	1.33	0.48	0.63	0.24	1.28	129	39.3	44	2459
1979	0.66	1.08	0.22	1.78	0.62	0.97	0.22	2.08	95	28.9	0	2451
1980	0.52	0.94	0.17	1.47	0.58	0.78	0.29	2.07	106	32.3	65	2459
1981	0.33	0.89	0.12	1.77	0.41	0.59	0.23	1.29	110	33.5	58	2459
1982	0.46	0.84	0.11	1.53	0.46	0.49	0.24	0.89	117	35.7	61	2459
1983	0.50	0.81	0.13	1.96	0.51	0.61	0.22	1.57	111	33.8	54	2459
1984[a/]		0.88	0.16	1.54		0.91	0.26	1.53	89	27.1	23	2459
Average (Post 1974)									119		52.3	

a/ Through October

METHODS

Metric units are used throughout this report except for reservoir elevation, reservoir volume, reservoir area, and stream discharge which are reported in feet above mean sea level, acre-feet, acres, and cubic feet per second (cfs), respectively. We are using this convention because these are the units used by water managers.

SEASONS

We stratified the year into four seasons based on reservoir operation:

1) Winter (January through March) - when the reservoir is evacuated for flood control and power production;

2) Spring (April through June) - when the reservoir is refilled;

3) Summer (July through September) - when the reservoir is held at full pool: and

4) Fall (October through December) - when drafting of the reservoir begins for power production.

RESERVOIR HABITAT

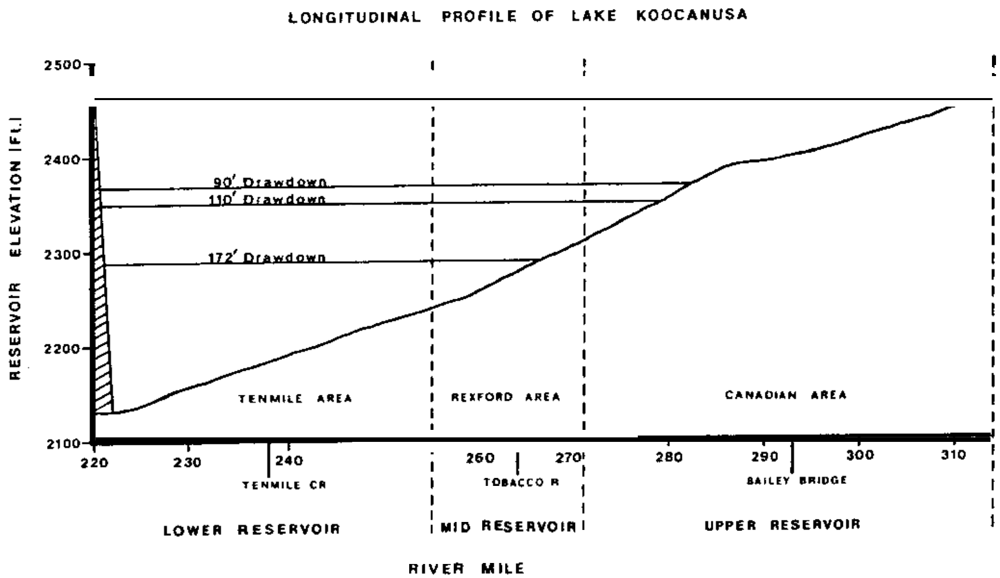
Stratification

The reservoir was segregated into three geographic areas based on reservoir morphometry, effects of reservoir drawdown, and political boundaries (Figure 3). Within each of these geographic areas we placed permanent sample buoys (the USGS maintains a sample buoy near Tenmile Creek which we used) where water quality and zooplankton sampling were conducted (Figure 4).

In addition to these permanent buoys, eight to 12 transects were established between recognizable landmarks in each of the three geographic areas. These transects were subdivided into east, west, and mid-reservoir stations for random sampling.

We have adopted the term “near-shore” zone because a true littoral zone does not develop in a fluctuating reservoir environment. We have defined the near-shore zone to be that portion of the reservoir within 100 m of the shoreline. Tnat portion of the reservoir not included in the “near-shore” zone was designated as the limnetic zone.

Vertical layers of the water column were defined using measurements of light penetration, water temperature (°C),



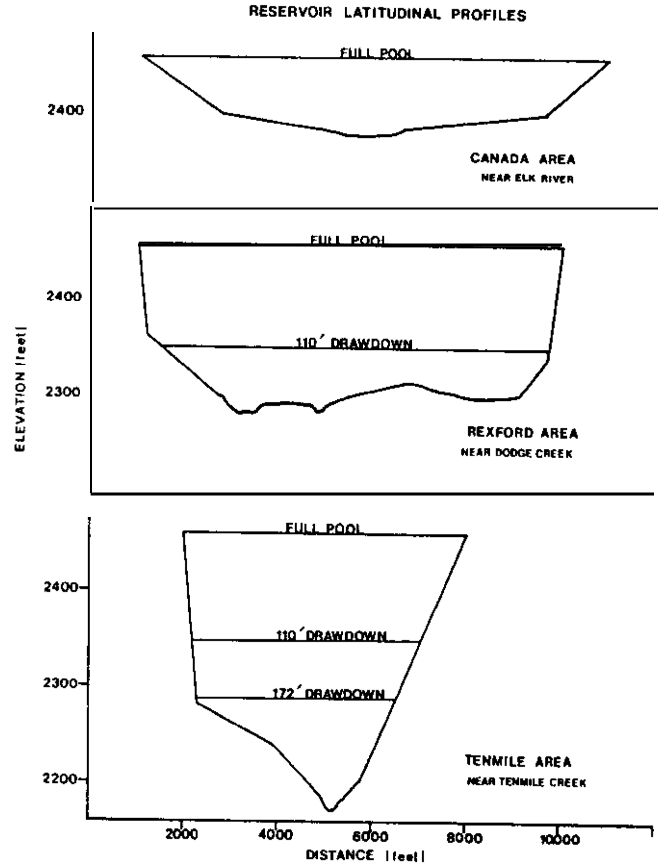


Figure 3. Longitudinal and latitudinal profiles of Libby Reservoir showing important reference pool elevations.

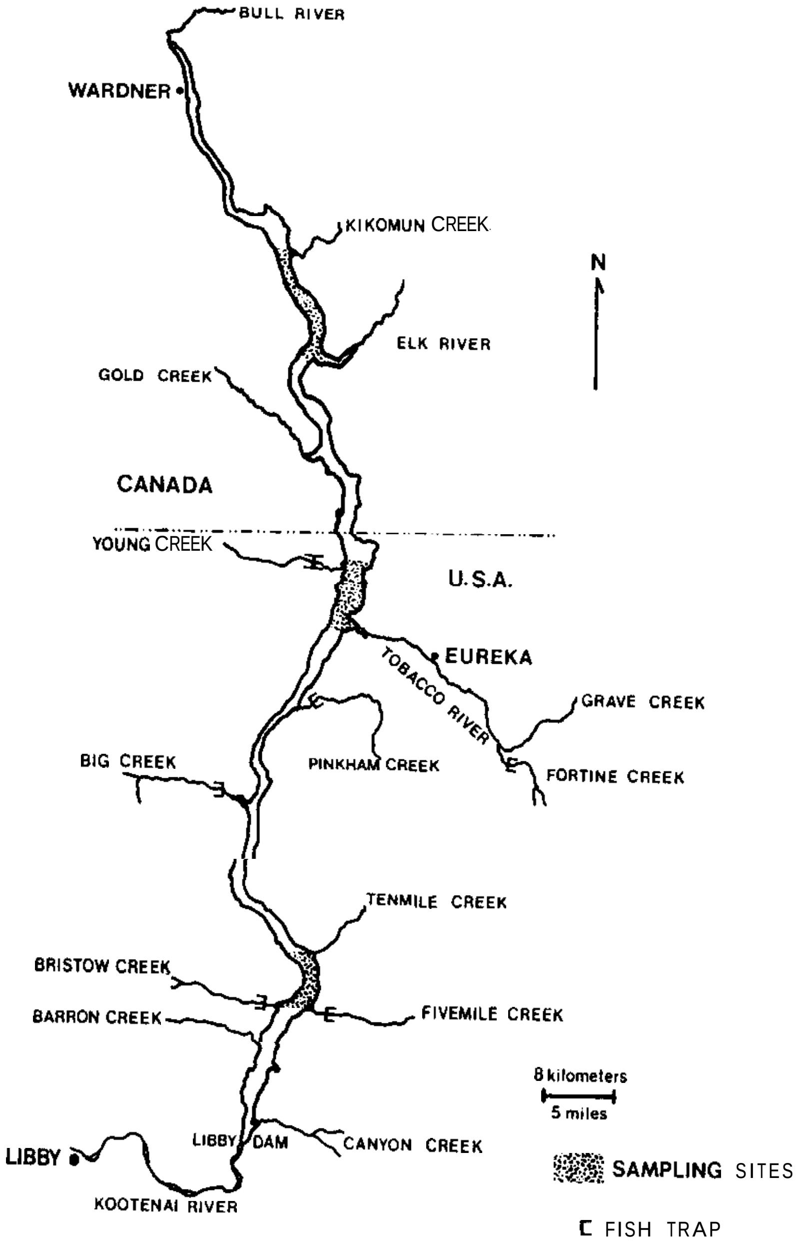


Figure 4. Map of Libby Reservoir showing sample sites and location of fish traps.

dissolved oxygen (mg.liter^{-1}), pH, and conductivity (umohs.cm^{-1}). Temperature, dissolved oxygen, pH, and conductivity profiles were measured with a Martek Mark V digital water quality analyzer and light intensity (foot candles) profiles were measured with a Protomatic photometer at permanent buoys. The above measurements were made biweekly from May through October and monthly from November through April. During the winter of 1983-84 measurements could not be made in the Canada area from December through June because of ice and dewatering of this upper portion of the reservoir. The Rexford area was ice-covered during much of December 1983.

Depth integrated measurements were taken at the surface, at one meter, then at every two meters down to 15 m, at every three meters down to 60 m, and at every five meters down to 95 m or the bottom. Sampling was done according to methods used by the United States Geological Survey (USGS) which also uses Martek Mark V meters (Greeson et al. 1977). Calibrations were done in the laboratory following the manufacturer's instructions prior to and following field measurements. Accuracy reported by the manufacturer were: temperature $\pm 0.1^{\circ}$C, dissolved oxygen ± 0.03ppm, conductivity ± 10.0 umhos.cm^{-1}, and pH ± 0.1 unit. Incident light was recorded above the water's surface and at one meter intervals to a depth of 30 m or at the point at which light intensity was one percent or less of surface light, defined as the lower boundary of the euphotic zone (Greeson et al. 1977).

Isopleths of temperature, pH, dissolved oxygen, and conductivity by sample station across time and by date across sample stations were plotted using the USGS program STAMPEDE.

Quantity of Available Reservoir Habitat

Contour maps of the area impounded by Libby Dam (U.S. Army Corps of Engineers, Seattle District, File Number E53-l-154, Sheets l-37, 1 inch = 400 feet, 10-foot contour interval, 1972; and British Columbia Ministry of Environment, Map Production, Surveys and Mapping Branch, Drawings M-249-C, Sheets l-63, 1 inch=200 feet, 5-foot contour interval, 1969) will be digitized using a Bausch and Lomb digitizer (Model-7048, Huston Instruments) connected to a Discovery computer. Each 10-foot contour interval will be entered by geographic reservoir area. U.S. Army Corps of Engineers digitized data for the above maps will be used to proof our data entry and edit computer data files of digitized data. Water surface area, water volume, wetted reservoir bed area, and shoreline length will be calculated using a program (GEOSCAN) developed by MDFWP (Lonner and Paxton, in prep.).

Reservoir Habitat Mapping

During March 1984 when the reservoir elevation was 2372 (ft) or 87 feet (26.5 m) below full pool, visual surveys were conducted covering approximately 39.6 km of shoreline in the Tenmile area and approximately 33.4 km in the Rexford area. We mapped the dewatered reservoir bed (from full pool elevation down to the 2380 foot contour) and component maps were drawn identifying substrate size classes and physical cover types (Table 2). Densities of cover types were expressed as the number of cover items per 100 m of shoreline (for trees and logs) or per 100 m^2 of reservoir bed (for stumps).

Tributary stream Surveys

All tributaries to Libby Reservoir within the United States were evaluated for their potential fish production. All tributaries were identified on USGS quad sheets (scale 1:24,000) and ranked according to stream order. First order headwater segments of tributaries were assumed to have little fish production potential and no further evaluations were conducted on these small, steep headwater tributary segments. Tributary streams were broken into relatively homogeneous reaches based on channel gradient, valley characteristics, and relative flow contribution. This resulted in 110 reaches in 64 named tributaries.

Each reach was surveyed. Surveys consisted of either a cursory field exam (if the reach was found to have limited fish production potential) or a complete stream survey in a one kilometer long section representative of the reach using a modification of methods presented by MDFWP (1983) (Appendix A). Environmental variables sampled included:

a) streambed composition:
b) flood signs:
c) average depth;
d) maximum depth;
e) channel width:
f) wetted width;
g) debris accumulation and stability;
h) instream and overhead cover (percent);
i) D_{90} measurement;
j) compaction and imbeddedness of streambed;
k) composition of habitat types (pools,. riffles, runs, pocketwaters, side channels): and
l) surface area of suitable spawning material in the streambed.

Measurements or visual estimates of the above variables were made at thirty randomly selected transects within each survey section. Suitable spawning habitat was defined as areas of the streambed larger than 0.5 m^2 predominated by material between 2 and

Table 2. Substrate size classes and physical cover types used for mapping the drawdown zone in Libby Reservoir.

Substrate Size Classes	Size Class
Sand and silt	<2.0 ml
Gravel	2.0 to 64 mm
Cobble	64 to 256 mm
Boulder	>256 mm
Bedrock	
smooth	
Irregular	

Physical Cover Types	Abundance Expressed As
Trees	Number per 100 m of shoreline
Stumps	Number per 100 m^2 of reservoir bed
Complex rock structure	
Manmade	
None	

64 mm in diameter. The total area of suitable spawning habitat in each one kilometer section surveyed was measured. All potential barriers, sediment sources, and other unusual landtype features observed within the survey section were noted.

Enhancement of Reservoir Habitat

One impact resulting from a fluctuating reservoir environment is the loss of terrestrial vegetation in the fluctuation zone and the lack of littoral zone development due to water level fluctuations (Ploskey 1982). Potential effects attributed to the loss of near-shore vegetation in Libby Reservoir include the reduction in numbers of redside shiners because of a reduction in suitable spawning substrates (Huston et al. 1984), increased sedimentation caused by fluctuating water levels washing exposed banks, and a reduction in the ability to cycle nutrients through vegetation. We wanted to determine the potential of revegetating the fluctuation zone in Libby Reservoir. Revegetation of the fluctuation zone was shown to be a viable alternative in other reservoirs (Brouha and von Geldern 1979; personal communication, Del Skeesick, U.S. Forest Service, Portland, Oregon).

Bristow Creek bay and Tobacco River bay were selected as sample sites (Figure 4). Unrooted willow (salix spp.) and red-osier dogwood (cornus sericea) slips were planted in sandy soil in four 0.9 by 1.8 m plots at elevations of approximately 2454 (ft), 2449, 2444, and 2439 (or depths of approximately 5, 10, 15, and 20 feet below full pool) in April 1984. Willow slips were treated in a Rootone solution for approximately two hours prior to planting. The sources for willow cuttings were an area near Stone Hill, east of the reservoir, and a bottom along Dodge Creek (elevations of 3000 and 2750, respectively) for the Tobacco bay site: and a low elevation bottom along Libby Creek (elevation of 2360 feet) for the Bristow bay site. No dogwood was planted in the Bristow bay site. Twenty-four groups of two or three sprigs were planted in each plot.

Sedge (carex rostrata sod was collected from a small lake bed near Young Creek. In May 1984, three pieces of sod were planted in each of four plots at both sites, similar to the sample design described above.

Survival was evaluated in June 1984 prior to innundation by Libby Reservoir. We assumed willow sprigs were alive if they exhibited leaf or shoot growth and sedge survival was based on the presence of green healthy leaves. Survival will be assessed again during the spring of 1985.

FISH ABUNDANCE, GROWTH, AND DISTRIBUTION

Libby Reservoir presently supports 17 species of fish (Table 3). We selected westslope cutthroat trout, rainbow trout, hybrids between rainbow and cutthroat trout, kokanee, and burbot as our target gamefish species. Northern squawfish, peamouth, and redside shiners were selected as our target nongame fish species. Information on distribution, relative abundance, and growth were collected for all fish species within Libby Reservoir, but our effort concentrated on target species with an emphasis on gamefish species. Abbreviations used throughout this report for the various fish species are as follows: rainbow trout (RB), westslope cutthroat trout (WCT), hybrids between rainbow and cutthroat trout (HB or WCTXRB), members of the genus Salmo spp. (SALMO), kokanee (KOK), bull trout (DV), mountain whitefish (MWF), burbot (LING), peamouth (PM), northern squawfish (NSQ), redside shiners (RSS), largescale suckers (CSU), longnose suckers (FSU), and yellow perch (YP).

We found it was extremely difficult to distinquish between rainbow trout, cutthroat trout, and hybrids between these two species using external morphological characteristics. We based cur identifications on scale size, presence or absence of basibranchial teeth, spotting pattern, and presence or absence of the red “slash” on each side of the jaw along the dentary.

Fish Abundance Trends

Near-Shore Zone

Seasonal and annual changes in fish abundance in near-shore zones were assessed using floating and sinking horizontal gill nets. These nets were 38.1 m long and 1.8 m deep and consisted of five equal panels of 19, 25, 32, 38, and 51 mm mesh. A floating gill net set consisted of two floating nets tied end-to-end creating a 76.2 m long net. Sinking nets were set singly. All nets were set perpendicular from shore. Catches were reported as the number of fish per single net.

From July 1983 to June 1984 one to seven double floating and two sinking gill nets were set monthly in each area. No sampling was conducted in the Rexford area in December or in the Canada area from December through June due to the presence of surface ice or dewatering (Canada area). We decided to switch to a seasonal, rather than monthly, sampling schedule beginning in August 1984. Our reason for this change was to allow for a more concentrated effort and resulting larger sample sizes. Water temperature and reservoir operation defined the seasons as follows:

1) Winter - reservoir elevation falling and reservoir temperature profile homothermous with surface water temperatures below 7.5 ^{0}C.

Table 3. Present relative abundance (A=abundant, C=common, R=rare) and abundance trend from 1975 to 1982 (I=increasing, S=stable, D=decreasing) of fish species present in Libby Reservoir.

Comon Name [a]	Scientific name[a]	Relative abundance	Abundance trend
Gamefish species			
Westslope cutthroat trout	Salmo clarki lewisi[b]	A	S[c]
Rainbow trout	Salmo gairdneri	A	I
Bull trout	Salvenlinus confluentus	C	S
Brook trout	Salvenlinus fontinalis	R	S
Lake trout	Salvenlinus namaycush	R	S
Kokanee salmon	Oncorhvnerka	C	I[d]
Mountain whitefish	Prosopium williamsoni	C	D
Burbot	Lota lota	C	I
Largemouth bass	Micropterus salmoides	R	S
White sturgeon	Acipenser transmontanus	R	D[e]
Nongame fish species			
Pumpkinseed	Lepomis gibbosus	R	S
Yellow perch	Perca flavescens	R	I[e]
Redside shiner	Richardsoniusibalteaus	C	D[g]
Peamouth	Mylocheiluscaurinus	A	I
Northern squawfish	Ptychocheilus oregonensis	A	S
Largescale sucker	Catostomus macrocheilus	A	S
Longnose sucker	Catostomus catostomus	C	D

[a] From American Fisheries Society (1980).
[b] We adopted the subspecies classification of Behnke (1979).
[c] Population is supplemented with releases of hatchery origin fish.
[d] Kokanee salmon abundance has increased dramatically recently due to an unauthorized release of salmon believed to originate from the Kcotenay Trout Hatchery, B.C.
[e] Five white sturgeon were relocated from below Libby Dam to the reservoir. At least one of these fish moved up river out of the reservoir and two were reported caught by anglers.
[f] Increasing trend for yellow perch based on first occurrence in recent gill net catches.
[g] Decreasing abundance of redside shiners was based on gill net catches which capture only larger (>100 mm) individuals.

2) Spring - reservoir elevation and surface water temperature rising with surface water temperatures between 9 and 13°C.

3) Sumner - reservoir elevation near full pool and stable with surface water temperatures above 17°C.

4) Fall - reservoir elevation and surface water temperature falling with surface water temperatures between 9 and 13°C.

Examination of gill net catch data found that the data followed a negative binomial distribution. For comparing significance of changes in fish abundance we can use the log (X+1) transformation recommended by Green (1979). Examination of probability plotting of preliminary data adjusted to normal variates using the log (X+1) transformation resulted in a nearly straight line indicating normality is a reasonable assumption. We can detect a difference of approximately 30 percent at an 80 percent level of significance by setting approximately 20 floating nets overnight per area per season. Moyle and Lound (1960) supported Moyle's (1949) contention that an 80 percent probability is as high a statistical accuracy that can be achieved in practicle fish population sampling using passive-fishing nets in lakes. Sinking gill nets were used to observe the vertical distribution of fish within near-shore zones.

Annual trends in fish abundance have been assessed since 1975 by MDFWP. Spring sampling in the Rexford area with sinking gill nets has been used to sample the relative abundance of suckers, mountain whitefish, bull trout, and burbot (Huston et al. 1984). Fall sampling in the Rexford and Tenmile (termed Cripple Horse by Huston et al. 1984) areas with floating gill nets has been used to sample the relative abundance of rainbow trout, cutthroat trout, hybrids between the two preceding species, redside shiners, northern squawfish, and peamouth (Huston et al. 1984). We continued this annual sampling following criteria described by Huston et al. (1984). Spring sampling was conducted in 1975, 1976, 1978, 1980, 1982, and 1984. Fall sampling was conducted in all years from 1975 through 1984 except 1977 and 1981. Prior to 1983 very few hybrids between rainbow and cutthroat trout were indentified although they were probably present in the samples. Investigators during this period made an effort to classify all Salmo spp. as either rainbow or cutthroat trout using external morphologic characteristics and the presence or absence of basibranchial teeth.

Limnetic Zone

Vertical gill nets were used to assess the relative abundance of fish species in the limnetic zone of each area. Replicate overnight sets of four 45.7 m deep by 3.7 m wide vertical nets similar to those described by Horak and Tanner (1964) of mesh sizes 19, 25, 32, and 38 mm were made monthly in each area. These nets were marked at one meter depth intervals. We did not make replicate sets in Canada or in Rexford during August because our sampling buoys were missing. Nat catches were reported as the number of fish per night from eight nets. When only a single bank of four nets were set, we doubled the catch for comparative purposes.

Al83 m long by 9.1 m deep purse seine with a mesh size of 19 mm was fished during daylight hours in the spring (March through May) and fall (October and November) and during the late evening and night in the summer (July). During the spring and summer we sampled only in areas where hydroacoustic soundings indicated the presence of fish because we were evaluating the purse seine's effectiveness. Consequently, catches during these times were positively biased.

Vertical Distribution

Vertical distribution of fish was assessed using vertical gill nets and hydroacoustic surveys. As vertical nets were retrieved fish were removed and depth of capture was recorded along with species, length, weight, sex, and state of maturity. Scale samples were taken to determine age.

Hydroacoustic sampling was done across three permanently established transects around the permanent buoys. These sonar transects were sampled with a Honda SiTex depth recorder (Model HE-356A) once during the day and once at night on a monthly basis in conjunction with vertical gill net sampling.

Population Estimates

Purse Seine Estimate Salmo spp.

The purse seine described previously was used to estimate numbers of Salmo spp. in the spring and fall using an area-density estimator (Everhart et al. 1975):

$$\hat{N} = \frac{A}{a} \sum_{i=1}^{a} N_i$$

Where: $\hat{N}$ = estimated number of Salmo spp.
A = total surface area of the reservoir
a = area sampled by the purse seine (0.267 ha)
N_i = number of Salmo spp. captured in the i^{th} purse seine haul.

The estimated variance is:

$$\hat{V}(\hat{N}) = \frac{A^2 - aA}{a} \qquad \frac{a \sum_{i=}^{a} N_i - \sum_{i=}^{a} N_i^{\;2}}{a(a-1)}$$

Assumptions used with this estimator include the following:

1) All the *Salmo* spp. were distributed in the upper 6.0 m of the water column. When surface water temperatures drop below 12.5°C, vertical nets captured *Salmo* spp. only in the upper 5.0 m. If any *Salmo* spp. were below 6.0 m the estimate would be negatively biased.

2) The purse seine captured all *Salmo* spp. in the 0.267 ha area and 6.0 m depth sampled by each purse seine haul. Purse seines have been found to be one of the most efficient and least selective gears for sampling salmonids in limnetic zones (Hartt 1975). If any *Salmo* spp. escaped the purse seine the estimate would be negatively biased.

3) The total surface area of the reservoir was known. Area-capacity tables were available for the reservoir (USACOE, 1980).

4) *Salmo* spp. were distributed uniformly throughout the limnetic zone of the reservoir, or if their distribution was not uniform, the sampling distribution was proportional to the density of fish in different parts of the reservoir.

In the spring 39 hauls were completed, primarily in the Rexford area, and in the fall 68 hauls were completed throughout the reservoir. Spring estimates were positively biased because areas sampled with the purse seine were selected based on hydroacoustic location of fish. Fall sampling was done randomly.

We made an effort to expand the estimates for *Salmo* spp. in the limnetic zone to estimate numbers in near-shore zones using a correction factor based on relative catches in limnetic versus near-shore floating gill nets. Use of this correction factor was necessary because densities of *salmo* spp. were higher in near-shore zones than in limnetic zones. We used the following estimator for near shore zones, defined here as the portion of the reservoir shallower than 12.2 m (the shallowest depth we could sample safely with the purse seine):

$$\hat{N}_C = (CF)S\bar{x}$$

Where: $\hat{N}_C$ = estimate of *Salmo* spp. in near-shore zones corrected using relative gill net catches:

CF= correction factor derived from relative limnetic versus near-shore floating gill net catches:

s= number of sample units in near-shore zone (hectares of near-shore zone divided by 0.267 ha);

$\bar{x}$ = mean number of Salmo spp. captured in purse seine hauls.

The standard deviation associated with the above estimate is:

$$\sqrt{\hat{V}(\hat{N}c)} = (CF) \sqrt{s^2 \hat{V}(\hat{\bar{X}})}$$

where: $\hat{V}(\hat{\bar{X}})$ = variance of mean catch of Salmo spp. in purse seine hauls.

Hydroacoustic Estimate of Kokanee

The number of kokanee (1983 year class) was estimated using hydroacoustic sampling during moonless nights in August, 1984. The kokanee population in Libby Reservoir was predominated by this 1983 year class (more than 99%). Hanzel (1984) found that the most reliable hydroacoustic estimates of kokanee abundance in Flathead Lake, Montana were made during moonless nights in August when kokanee were evenly distributed 12.2 m to 36.6 m below the surface. He attributed this distribution to the thermal stratification of the lake and the inability of kokanee to visually school because of darkness.

A Honda Sitex depth recorder (Model HE-356A) with a transducer beam angle of 10° was used. Tnirty-eight transects covering 76 km throughout the reservoir were surveyed (Appendix B). All targets within each 10 m depth interval were counted. Using vertical gill net catch data we assigned a proportion of the targets as kokanee within each 10 m depth interval. We followed methods presented by Thorne (1983), but were unable to accurately calibrate cone width in the field. We assumed the cone width was consistent with the 10° beam angle because we observed few kokanee above the 10 m depth contour (the depth zone at which side lobes may influence hydro-acoustic target strengths). Since we were dealing with a population composed almost exclusively of a single year class (and length class) of kokanee, the problems normally associated with variable target strengths and field calibration of the gear were minimal and would not impair our ability to estimate densities of kokanee. We computed the number of kokanee per 1,000 m^3 for each depth interval and then converted these number per volume estimates to number per area estimates using methods described by Hanzel (1984).

After computing the density of the 1983 year class of kokanee, an estimate of the population was computed using population expansion statistics (Snedecor and Cochran 1967):

$$\hat{N}_i = A_i \bar{Y}_i$$

Where: $\hat{N}_i$ = estimated number of 1983 year class kokanee in reservoir area i.

A_i = surface area of geographic reservoir area i (based on reservoir elevation of 2,430 feet). The reservoir was full (2,459 foot elevation) during sampling, but we ignored the upper 10 m (30 feet).

$\bar{Y}i$ = mean density of 1983 year class kokanee in geographic area i.

The standard deviation was estimated by:

$$\sqrt{\hat{V}ar\ (\hat{N}_i)} = \frac{A_i \sqrt{\hat{V}ar\ (Y_i)}}{\sqrt{ai}}$$

Where a_i = surface area sampled in geographic reservoir area i. We used the width of the sonar beam at 30 m depth of 5.0 m to calculate sampled areas.

Separate estimates were calculated for each area and then summed across areas to obtain a total estimate. We stratified the reservoir into four areas:

1) Tenmile area - from the dam up to Parsnip Creek;

2) Peck Gulch area - from Parsnip Creek up to the reservoir bridge;

3) Rexford area - from the Reservoir Bridge up to the U.S.-Canada Border; and

4) Canada area - from the U.S.-Canada Border to the head of the reservoir.

The following assumptions were made:

1) All kokanee were distributed below the 10 m depth contour. We knew a few kokanee were found less than 10 m deep, but the hydroacoustic gear discrimination at the 0 to 10 m depth interval was too poor to identify targets. The presence of kokanee above the 10 m depth contour would negatively bias our estimate.

2) We could apportion hydroacoustic targets into kokanee and non-kokanee using vertical gill net catches.

3) We were sampling a 5.0 m wide area. Cone width actually varied between 1.75 m at the 10 m depth contour to 10.5 m at the 60 m depth contour.

Reservoir Macro-Habitat Preference

We segregated the near-shore zone of the reservoir using habitat mapping information collected on cover types, substrate types, and reservoir bed gradient within the 1984 drawdown portion of the reservoir bed (between elevation contours 2459 and 2380). We returned to these areas during the summer and fall, when the reservoir was near full pool, and sampled these areas using boat mounted electrofishing gear and diver observation. Water clarity was so poor that divers could not observe fish. Electrofishing data were standardized as catch per unit effort of electrofishing time.

Relative abundance of the various fish species between limnetic and near-shore zones were compared from gill net data. Vertical distributions of fish were compared to thermal profiles and vertical distribution of zooplankton.

Growth

Fish captured during all sampling were measured (total maximum length) and weighed. Scale samples were collected according to methods described by Huston et al. (1984). Ages were assigned based on interpreting annulus formation on scales (Jearld 1983). We estimated growth based on average size of each age and migration class for cutthroat trout, rainbow trout, and hybrids captured in April 1984. We also followed the growth of the 1983 year class of kokanee from November 1983 through September 1984.

Movement

Fish movement within the Libby Reservoir drainage was assessed using tag return information and by trapping several tributaries. All gamefish captured during purse seine, electrofishing, and stream trap sampling were tagged with either a Floy anchor-type tag for fish longer than 250 mm, OK with a Floy dangler-type tag for fish 250 mm or smaller. We were unable to tag all kokanee because of the large number of fish handled. We adipose clipped kokanee in the spring of 1984 and flag tagged kokanee larger than 250 mm with color coded tags during the fall of 1984.

Tags were recovered by voluntary angler compliance and by our fish sampling effort.

An upstream and downstream wolf-type trap was operated in Young Creek (Huston et al. 1984) from 4 April through 15 October 1984 (Figure 4). This trap was operated continuously from 15 April through 28 July, and was checked intermittently from then on. Downstream box traps were placed in Bristow (11 June through 23 July), Big (19 June through 25 July), Fivemile (18 June through 23 July), Pinkham (26 June through 25 July), and Fortine (18 July through 17 August) creeks (Figure 4). Trap operators often angled above traps to capture spent adults moving back down to the reservoir.

Food Habits

Stomachs from a representative number of all fish species captured in gill nets during 1983 and 1984 were collected and emptied into labeled plastic vials with preservative (Table 4). Laboratory analyses have been completed for August 1983 samples. Numbers and weights of each taxonomic group of food items in each stomach were recorded. Subsampling was used when analyzing zooplankton and other abundant small food items. Wet weights of all food categories but zooplankton were measured to the nearest 0.01 g after removing excess water by blotting with a paper towel.

Dry weights and wet weights of zooplankters ingested by fish were estimated using length-weight regressions (Bottrell et al. 1976) and length-weight tables (Cummins et al. 1969). Length-weight regressions estimated dry weights (Table 5). Dry weights were converted to wet weights using a multiplication factor of 10. Bottrell et al. (1976) showed that this muliplication factor was applicable for wet weights between 10 and 300 ug, the range of sizes we found occurred most frequently in the zooplankton of Libby Reservoir. Cummins et al. (1969) developed tabled values to estimate wet and dry weights of Leptodora spp. by one millimeter length classes.

The majority of the zooplankters ingested by fish were fragmented and we used identifiable body parts to count the number of each genus within each stomach. We were forced to estimate lengths of Bosmina spp., Diaptomus spp., Epischura spp., and Cyclops spp. as being 0.3, 0.7,1.2, and 0.5 mm, reapectively on average lengths found in the zooplankton population at the time food habits information was collected. All dry weights were converted to wet weights. Leptodra spp. were seldom found in plankton samples, yet were found in several stomachs. We assumed an average length of 6.0 mm for all Leptodora spp. and used this length to enter length-weight tables developed by Cummins et al. (1969) to estimate the wet weights of Leptodora Body lengths of Daphnia spp. were estimated using measurements of the post-abdominal claw following methods presented by Leathe and Graham (1981) (Figure 5).

Table 4. Number of stomachs collected for food habits analyses from three areas of libby Reservoir during 1983-84

	SPECIES															
	RB		WCT		RB x WCT											
Season	<330	>330	<330	>330	<330	>330	DV	KOK	MWF	Ling	RSS	NSQ	CSU	FSU	YP	PM
Tenmile																
Sumner/1983	1	16	0	2	0	3	0	0	5	0	4	4	6	3	0	4
Fall/1983	7	10	4	4	2	11	1	2	11	2	1	5	0	0	0	5
Winter/1984	11	10	4	11	4	6	4	8	2	4	0	4	5	2	0	5
Spring/1984		10	5		10	4	5	15	1	0	6	5	5	5	0	5
Fall/l984	14	12	6	7	6	8	15	9	4	4	0	6	5	4	2	5
Rexford																
Sumner/1983	4	40	11	10	5	4	0	0	2	0	5	5	4	2	0	5
Fall/1983	8	lo	2	6	3	9	3	1	5	0	2	4	0	0	1	5
Winter/1984	9	10	13	7	11	10	3	25	10	1	0	5	5	2	0	5
Spring/1984	5	11	1	6	2	11	13	10	8	4	6	5	5	6	5	5
Fall/1984	11	11	7	10	11	3	25	11	6	0	0	5	5	0	1	5
Canada			2													
Sumner/1983	0	6	10	0	0	0	0	1	4	0	4	5	5	1	0	5
fall/1983	8	9		6	13	8	3	2	10	0	1	6	0	0	0	6
Winter/l984	frozen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spring/1984	dewatered		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fall/1984	12	10	9	4	10	4	3	11	14	1	0	5	5	1	0	6

Table 5. Regression equations used to estimate dry weights (mg) of zooplankters from length data (from Bottrell et al. 1976). Equation: $LnW = Lna + bLnL$

where: Ln = natural log;
W = wet weight (mg)
L = length in mm.

Genus	Lna	b ± 95% C.I.	Source
Daphnia spp.	1.468	2.8292 ± 0.0723	Pooled data (Daphnia spp. without eggs, enbryos)
Bosmina spp.	3.0896	3.0395 ± 0.2123	Pooled data
Cyclops spp.	1.9526	2.3990 ± 0.0854	Pooled data for all copepoda
Epischura spp.	1.9526	2.3990 ± 0.0854	Pooled data for all Copepoda
Diaptomus spp.	1.9526	2.3990 ± 0.0854	Pooled data for all Copepoda

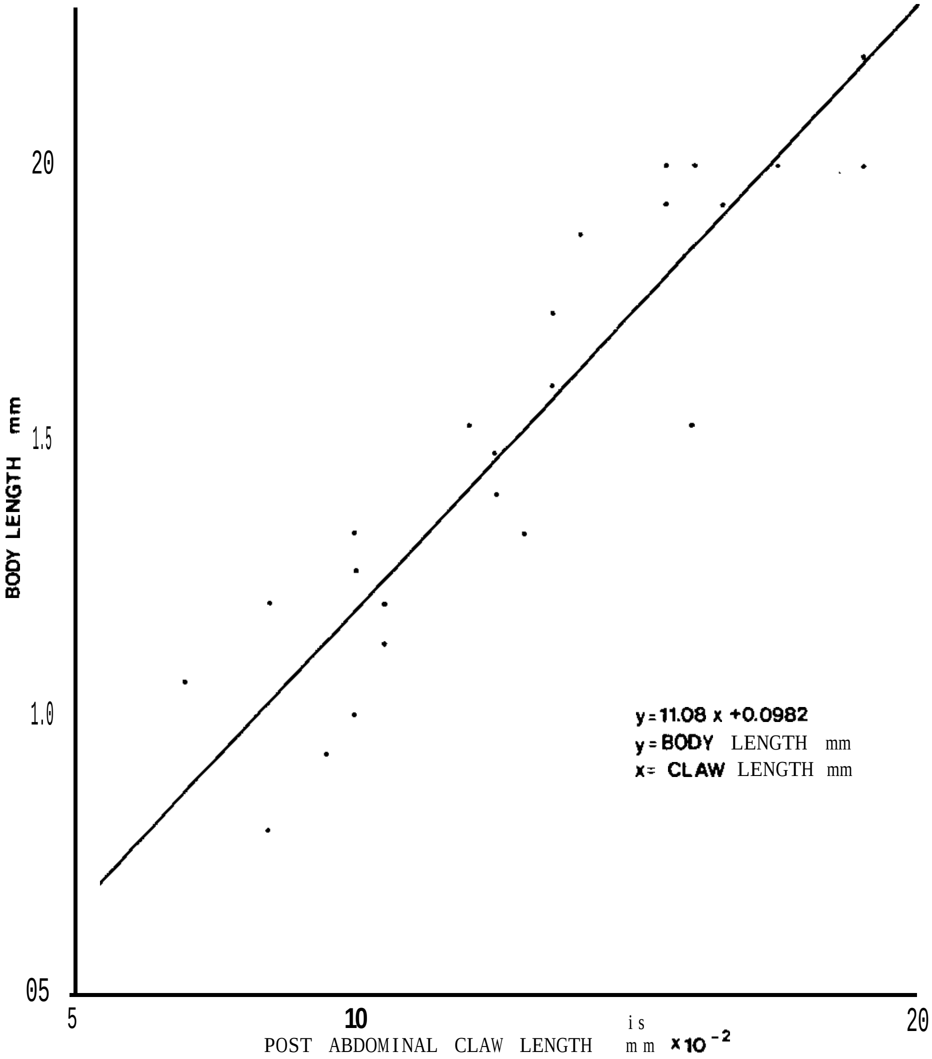


figure 5. Relationship between *Daphnis* spp. body lengths and post-abdominal claw lengths measured from a sample collected from Libby Reservoir during August, 1983.

An index of relative importance (IRI) was calculated to estimate the importance of a particular food item in the diet (George and Hadley 1979). The IRI is the arithmetic mean of the nunber, frequency of occurrence, and weight of a food item, expressed as percentages, in the diet. IRI values range from zero to 100, with a value of 100 indicating exclusive use of a food item in the diet. To calculate IRI's for insect parts, algae, and debris we used only frequency of occurrence and weight data.

ABUNDANCE AND AVAILABILITY OF FISH FOOD ORGANISMS

Zooplankton

stanaing crop

Two 30.0 m (or the entire water column when water depth was less than 30 m) vertical tows were made bi-weekly during May through October and monthly from November through April in each geographic area of the reservoir. A 0.3 m diameter Wisconsin-type plankton net was used for all tows. One tow was made at the permanent sampling buoy and one tow was made at a randanly selected point on an established transect in each area. In June, 1984 we added one additional random tow in each area for a total of three tows per sampling trip per area. Bottrell et al. (1976) stated that variances associated with replicate samples were relatively small. A few replicate tows made in Libby Reservoir indicated the same small sampling variance existed between replicates, therefore, no further replicate sampling was conducted.

A plankton trap similar to that described by Schindler (1969) was used to sample zooplankton monthly at permanent sample buoys in each geographic area. The trap sampled a 28.1 liter volume of water and a sample series consisted of nine discrete samples collected at depths of 30, 25, 20, 15, 12, 9, 6, and 3 m and immediately below the water's surface.

All zooplankton samples were preserved in a solution of water, methyl alcohol, formalin and acetic acid. Vertical tow samples were diluted in the laboratory to a concentration in which five milliliter subsamples contained approximately 80 to 100 organisms. Schindler trap samples were concentrated to 25 ml. Counting cells were fabricated out of Lexan plastic (glued to a glass slide) in which a continuous 5 ml channel had been cut. Five individual 5.0 ml subsamples were counted and averaged to estimate densities (number per liter) of zooplankters classified to genus. Carapace lengths of individual planters from one randomly selected 5.0 ml subsample were measured. Carapace length data were segregated into 0.5 mm length groups for each genus and averaged within each length group by genus. Biomass of zooplankters will be estimated using the length-weight relationships described previously in the "Food Habits" section. Biomass estimates have not yet been completed.

Densities of zooplankton by genus estimated from vertical tow samples and plankton trap samples were compared to evaluate the efficiency of vertical tows. Schindler (1969) and Bottrell et al. (1976) considered the plexiglass plankton trap to be one of the most efficient zooplankton sampling devices.

Vertical Distribution

Vertical distribution of zooplankters was assessed using plankton trap data described above.

Benthos

Three replicate samples were collected seasonally from three elevational strata in each area using a Peterson benthic dredge. The three elevation strata were classified as frequently dewatered (between full pool and the 2,369 foot contour), occasionally dewatered (between the 2,369 and 2,287 foot contours), and permanently wetted (below the 2,287 foot contour). Benthos samples were collected in October 1983, March 1984, and June 1984.

Benthos samples were wet sieved in the field using 5.6, 0.85, and 0.52 mm sieves. The material retained on the 0.52 mm sieve was preserved and returned to the laboratory where all macroinvertebrates were picked from the sample and identified to order or class (Diptera and Oligocheatea). The number and total blotted wet weight of each order (class) were counted (measured) and densities were expressed as nunber per square meter and grams per square meter of reservoir bed by elevational strata and geographic area.

Surface Macroinvertebrates

Macroinvertebrates upon the surface of the reservoir were sampled using a net made of 3.17 mm mesh ace bobbin netting tapered to 1.59 mm mesh netting tapered back to a collar. The mouth of the net was held open by a rectangular frame measuring 1.0 m wide by 0.3 m high. A removeable plexiglass bucket with a panel of 80 micron Nitex netting was attached to the collar at the cod end of the net. The net sampled a 1.0 m wide swath of the reservoir's surface.

Two sites were sampled biweekly in each reservoir area from May through October, and monthly from November through April. In June, 1984 we added one additional random tow in each area for a total of three tows per sampling trip per area. Sample sites were selected randomly using established transects as beginning points for the tows. Surface tows were made by towing the net along the water's surface for 10 minutes at a fixed rpm which corresponded to a speed of 1.0 m per second. Each 10 minute tow covered approximately 600 square meters. At each sample site one tow was made within 100 m of shore (near-shore zone) and one was made beyond 100 m (limnetic zone).

All macroinvertebrates were removed from the bucket and from within the net at the end of each tow and placed in a labeled vial with preservative. All macroinvertebrates collected in each sample were identified to order and counted at the laboratory. Blotted wet weights were measured (in grams) by order. Densities of surface macroinvertebrates were expressed as number per hectare and grams per hectare. Paired difference tests (Snedecor and Cochran 1967) were conducted to determine if significant differences existed for total number of macroinvertebrates per hectare and number of Diptera per hectare between near-shore and limnetic samples.

RELATIONSHIP BETWEEN RESERVOIR OPERATION AND RESERVOIR HABITAT

Once we have established what types of reservoir habitats are important for producing fish food organisms and habitats used by fish, we will be able to use our computer map data base with GEOSCAN to estimate amounts of available habitats at 10 foot contour intervals.

IMPACT OF RESERVOIR OPERATION ON FISHERY

Our ability to predict impacts of reservoir operation on the reservoir fishery will depend on several factors. First, our predictions will be most reliable for the range of conditions we encounter during the course of the study. It will be difficult to reliably predict operational impacts on the reservoir fishery unless we encounter the full range of potential operations during the study. One way we will be able to predict operational impacts will be through the use of predictive models. Secondly, there may be a time lag before reservoir operation effects are observed in fishery data. Thirdly, on the positive side, we are collecting information on all important trophic variables above primary producers and will be able to use these data to suggest the best approach for predicting operational impacts.

Fish food organisms

Zooplankton standing crop is a function of reservoir volume, primary productivity, thermal regime, flushing rates, and predation. Reservoir operation dictates reservoir volume and flushing rates, and influences primary productivity, thermal regime and possibly predator efficiency.

Production of benthic macroinertebrates was related to the frequency the reservoir bed was wetted. The portion of the reservoir bed between full pool and the 2,369 foot elevation contour has been dewatered annually since the reservoir was impounded in 1972. The portion of reservoir bed between the 2,349 and 2,287 foot contours has been dewatered seven out of the last 12 years and was dewatered last in 1983 (Table 1). The reservoir bed below 2,287 has not been dewatered since full pool was reached in 1974.

The density of macroinvertebrates on the reservoir's surface will be related to the surface area of the reservoir.

Fish

MDFWP subcontracted with the USGS to explore relationships between reservoir operation and relative abundance, condition, and first year reservoir growth of fish in Libby reservoir using data collected from 1974 through 1982.

Fish distribution was used to indicate habitat preference and thermal preference.

Modeling

Four major types of models have been identified through a literature review as having potential to predict impacts of reservoir operation on the reservoir fishery. A thermal model developed by Adams (1974) predicts the thermal regime of a reservoir using inflow volumes and temperatures, mixing coefficients, outflow volumes and depths, and reservoir morphometry. An advantage of this model is that it could be used to hold environmental variables constant and investigate only operational effects. A fish food availability versus fish utilization model (Ploskey and Jenkins 1982) has potential for transferring impacts of reservoir operation on fish food organisms through trophic pathways to predict impacts on fish. Habitat suitability models (for example: Hickman and Raleigh 1982) may be used to identify thermal and chemical preferences. Lastly, we may incorporate a population simulation model (Serchuck et al. 1980) to follow effects of several years of reservoir operation on a single target species.

RESULTS

In this annual report little interpretation of results is attempted. Instead, results are summarized and presented in graphs and tables. Detailed summaries are presented in Appendices C through K.

RESERVOIR HABITAT

Stratification

Surface areas of each geographic area within the reservoir are impacted differently as reservoir elevation changes (Figure 6). Storage volumes are affected similiarly. Relative changes are largest at the upper area (Canada) and smallest at the lower area (Tenmile. Shoreline lengths and wetted reservoir bed areas will be computed using GEOSCAN and will be available once contour data has been entered into a computer map data base. We plan to have this data base entered into the computer by spring of 1985 and edited by fall of 1985.

Euphotic zone depths averaged 12.0, 9.5, and 11.4 m during the period August 1983 to October 1984 in the Tenmile, Rexford, and Canada areas, respectively (Figure 7). The overall average euphotic zone depth for this period was 11.0 m. Typical seasonal profiles for temperature, pH, and dissolved oxygen (Figure 8 and Appendix C) illustrated that pH and dissolved oxygen levels found in Libby Reservoir were generally near the optimum required for cutthroat and rainbow trout (Raleigh et al. 1984; Hickman and Raleigh 1982). Optimum conductivity levels have not been evaluated for these species.

Vertical layering within the water column was based on a combination of euphotic zone depth and temperature profile data because levels of other physical-chemical parameters were near optimum levels reported for salmonids. The reservoir was homothermous from October-November through March-April in the Tenmile and Rexford areas. The Rexford area was ice covered in December and the Canada area was ice covered from December through February when reservoir levels dropped enough to dewater most of that area. Isopleths of temperatures illustrated the amount of habitat available providing optimum temperatures (Figure 9). Optimum temperatures derived from the literature for rainbow trout were 12 to 18OC (Raleigh et al. 1984); and 11 to 16°C for cutthroat trout (Hickman and Raleigh 1982).

The near-shore zone was defined as the portion of the reservoir within 100 m of shore. The limnetic zone was considered to be the remaining mid-water portion of the reservoir. The areas and volumes of these two areas will be estimated using the GEOSCAN computer program and a computer map data base.

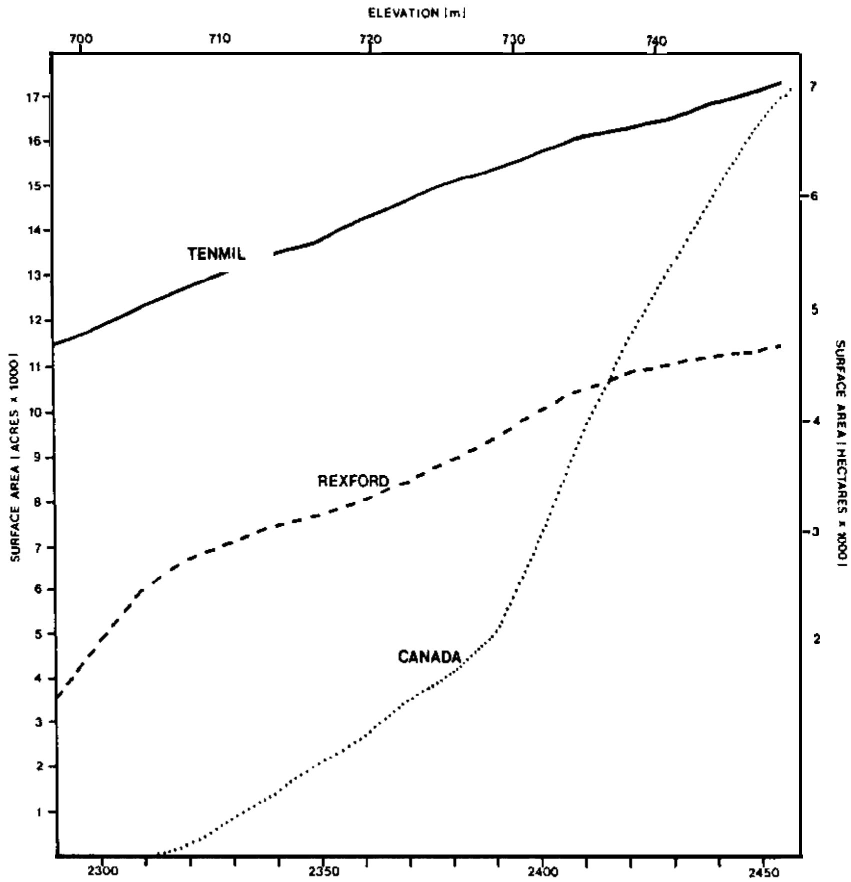


Figure 6. Relationships between changes in Libby Reservoir elevations and surface area of each geographic area within the reservoir.

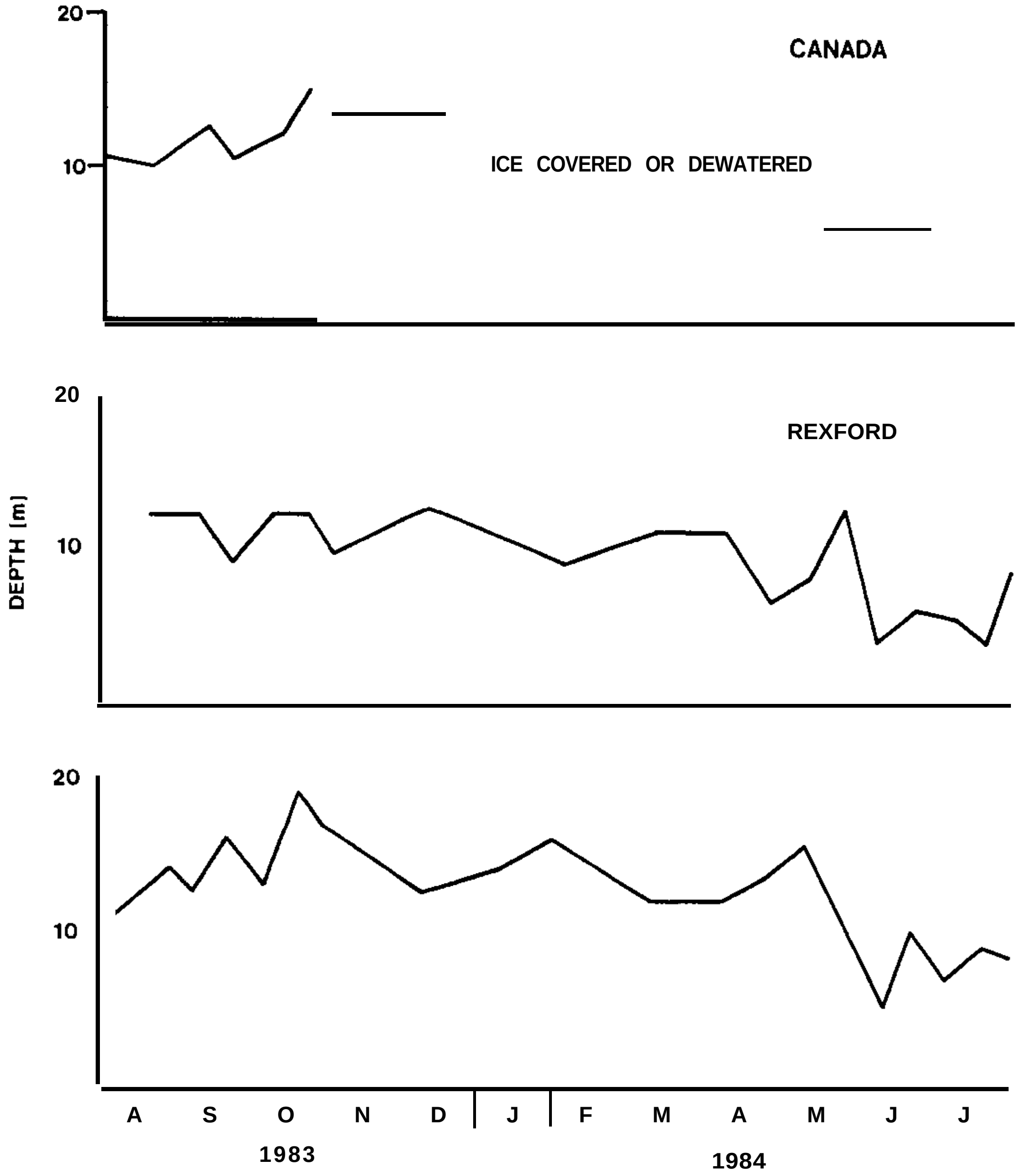


Figure 7. Euphotic zone depths measures in three areas of Libby Reservoir from August, 1983 through July, 1984

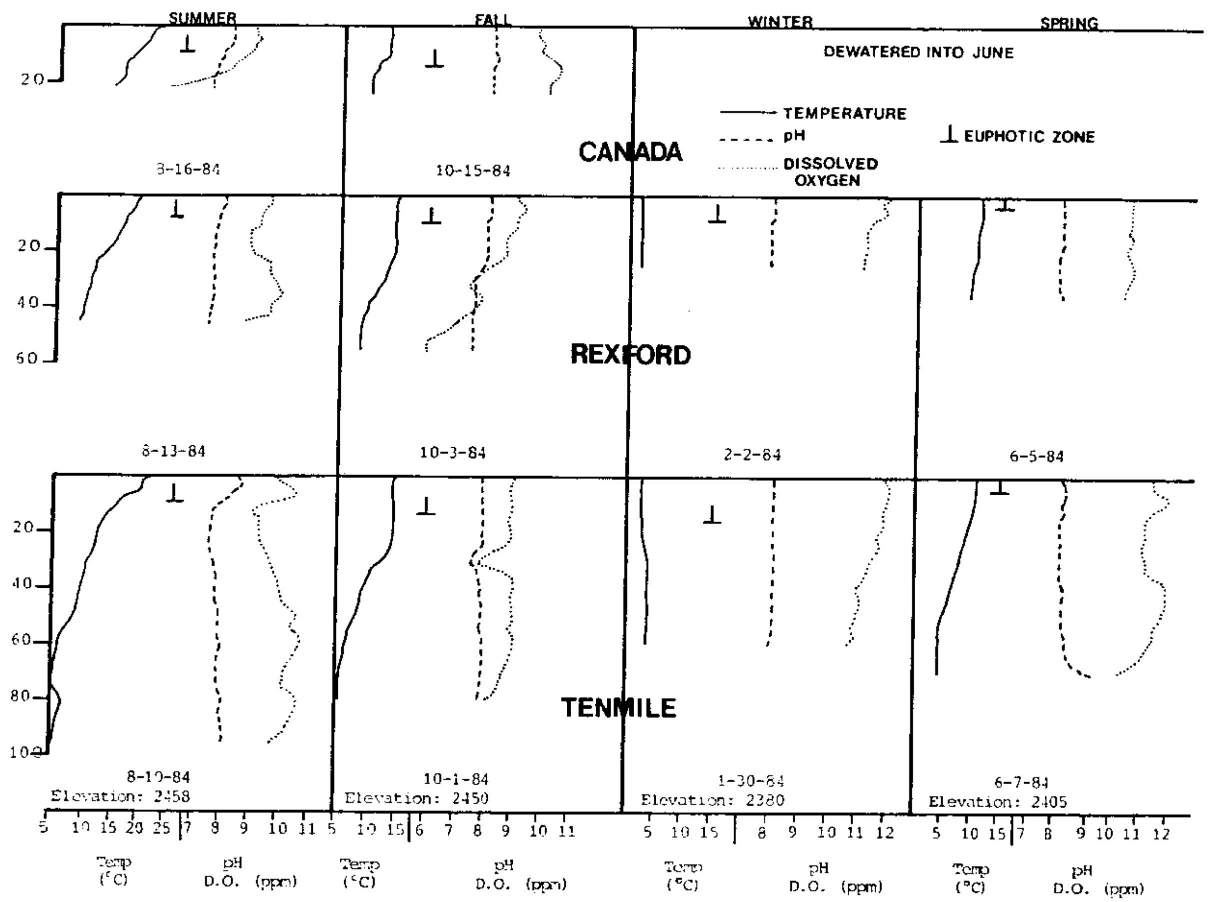


Figure 8. Typical seasonal temperature, pH, and dissolved oxygen profiles and euphotic zone depths measured in three areas of Libby Reservoir during 1984.

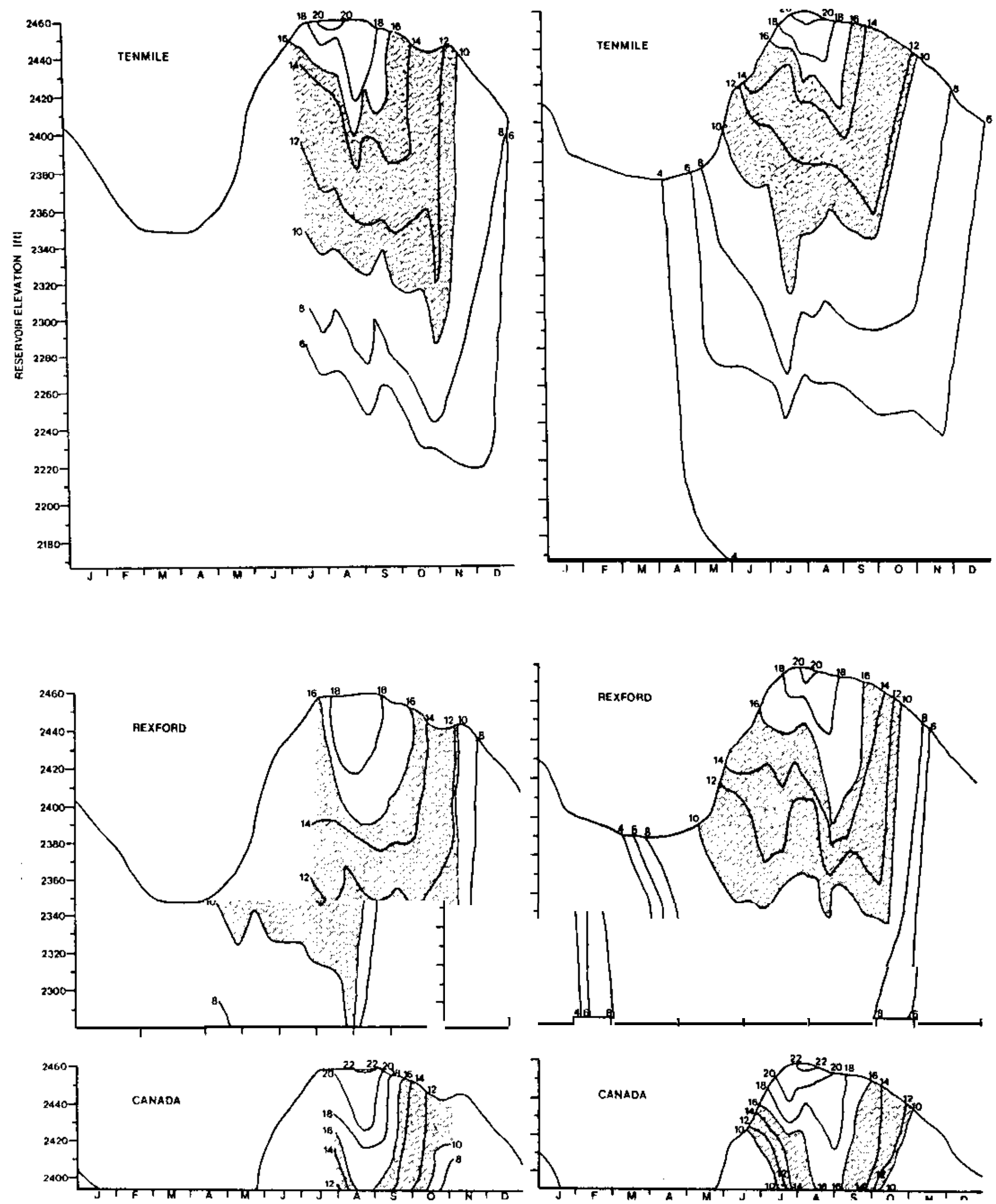


Figure 9. Temperature isopleths measured in three areas of Libby Reservoir during 1983 and 1984. Numbers are degrees Celsius and shaded areas represent optimum temperatures preferres by cutthroat trout (Hickman and Raleigh 1982).

Reservoir Habitat Mapping

Cover and substrate types were mapped (for example, Figure 10).

Enhancement of Reservoir Habitat

All of the sedge sod plants survived into June 1984 in both areas (Table 6). The willow sprigs planted in the Bristow Bay site survived well with green willow sprigs surviving at a higher rate (94% survival) than red willow sprigs (64% survival). Red willow and dogwood sprigs planted in the Tobacco Bay site did not have as high a survival rate (40% and 35%, respectively).

Spawning Habitat in Tribotary Streams

Stream reaches were ranked based on the amount of suitable spawning habitat they contained (Table 7). Barron, Bristow, Dodge, Young, Pinkham, and Fivemile creeks had at least one reach with excellent spawning potential (Appendix D). Barron Creek was unavailable to spawning adult Salmo spp. because of an impassable barrier located within the drawdown zone. Big, Cripple Horse, and Canyon creeks had at least one reach with good spawning potential. The Tobacco River drainage was not included in this analysis because habitat survey information summaries have not been completed.

Kokanee spawning habitat is known to be excellent in Kikomun and Norbury creeks, tributaries located in Canada. The only known spawning habitat used by significant numbers of kokanee within the U.S. is located in the Tobacco River from the reservoir up to the town of Eureka. We assume kokanee have attempted to spawn along shoreline areas, but believe no fry are produced from these shoreline areas because of dewatering and freezing of incubating embryos.

FISH ABUNDANCE, GROWTH, AND DISTRIBUTION

Fish Abundance

Near-shore Zone

Catches of fish in floating and sinking horizontal gill nets in near-shore zones illustrated the seasonal abundance of fish within the near-shore zone (Figures 11 and 12 and Appendix E). Salmo spp. were captured more frequently during the spring in near-shore net sets than during any other season. This spring abundance was probably related to pre-spawning movements of adults homing to spawning tributaries and a food-seeking response to the increased availability of emerging dipterans. Salmo spp. were infrequently

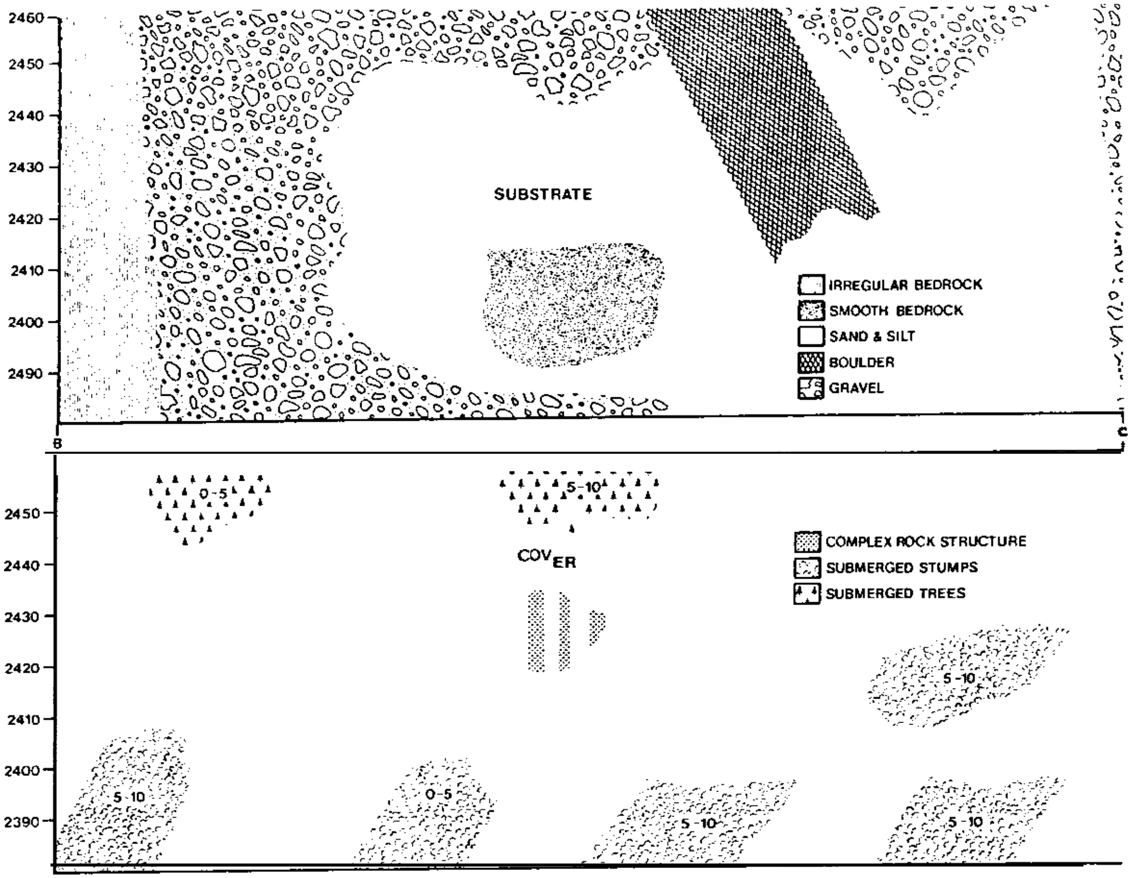


Figure 10. Habitat maps of an area of dewatered reservoir bed (elevation contours 2459 feet down to 2380 feet) showing substrate types (top) and cover types (bottom) available. Numbers in the cover type map represent cover densities (see "Methods" text for explaination).

Table 6. Survival of planted willow, sedge, and red ozier dogwood from planting in May, 1984 to June. 1984 prior to inundation by Libby Reservoir.

Area Species	Plot[a/]	Date Planted	 Inventoried	Number Planted	Number (%) Of Survivors
Bristow Bay					
Red willow	5	04/06/84	06/14/84	24	11 (46)
	10	"	"	24	15 (62)
	15	"	"	24	17 (71)
	20	"	"	24	19 (79)
Green willow	5	"	"	24	23 (96)
	10	"	"	24	22 (92)
	15	"	"	24	23 (96)
	20	"	"	24	23 (96)
Sedge	5 A	05/02/84	06/16/84	3	3 (100)
	5 B	"	"	3	3 (100)
	10 A	"	"	3	3 (100)
	10 B	"	"	3	3 (100)
	15 A	"	"	3	3 (100)
	15 B	"	"	3	3 (100)
	20 A	"	"	3	3 (100)
	20 B	"	"	3	3 (100)
Tobacco Bay					
Red Willow	5 A	04/05/84	06/23/84	24	16 (67)
	5 B	"	"	24	7 (29)
	10 A	"	"	24	8 (33)
	10 B	"	"	24	9 (37)
	15 A	"	"	24	10 (42)
	15 B	"	"	24	7 (29)
	20 A	"	"	24	8 (33)
	20 B	"	"	24	13 (54)
Dogwood	5 A	"	"	24	18 (75)
	5 B	"	"	24	8 (33)
	10 A	"	"	24	12 (50)
	10 B	"	"	24	2 (8)
	15 A	"	"	24	11 (46)
	15 B	"	"	24	5 (21)
	20 A	"	"	24	8 (33)
	20 B	"	"	24	4 (17)
Sedge	5 A	05/02/84	"	3	3 (100)
	5 B	"	"	3	3 (100)
	10 A	"	"	3	3 (100)
	10 B	"	"	3	3 (100)
	15 A	"	"	3	3 (100)
	15 B	"	"	3	3 (100)
	20 A	"	"	3	3 (100)
	20 B	"	"	3	3 (100)

a/ Number indicates approximate depth at full pool (ft.) and letter indicates replicate.

Table 7. Criteria for ranking spawning potential based on area of the streambed per kilomter of stream length which contained suitable spawning habitat[a].

Rank	Square meters of suitable spawning habitat[a] per kilometer of stream length
Excellent	> 200
Good	> 100 < 200
Moderate	> 50 < 100
Poor	< 50

[a] For an explanation of suitable spawning habitat see the "Methods" section.

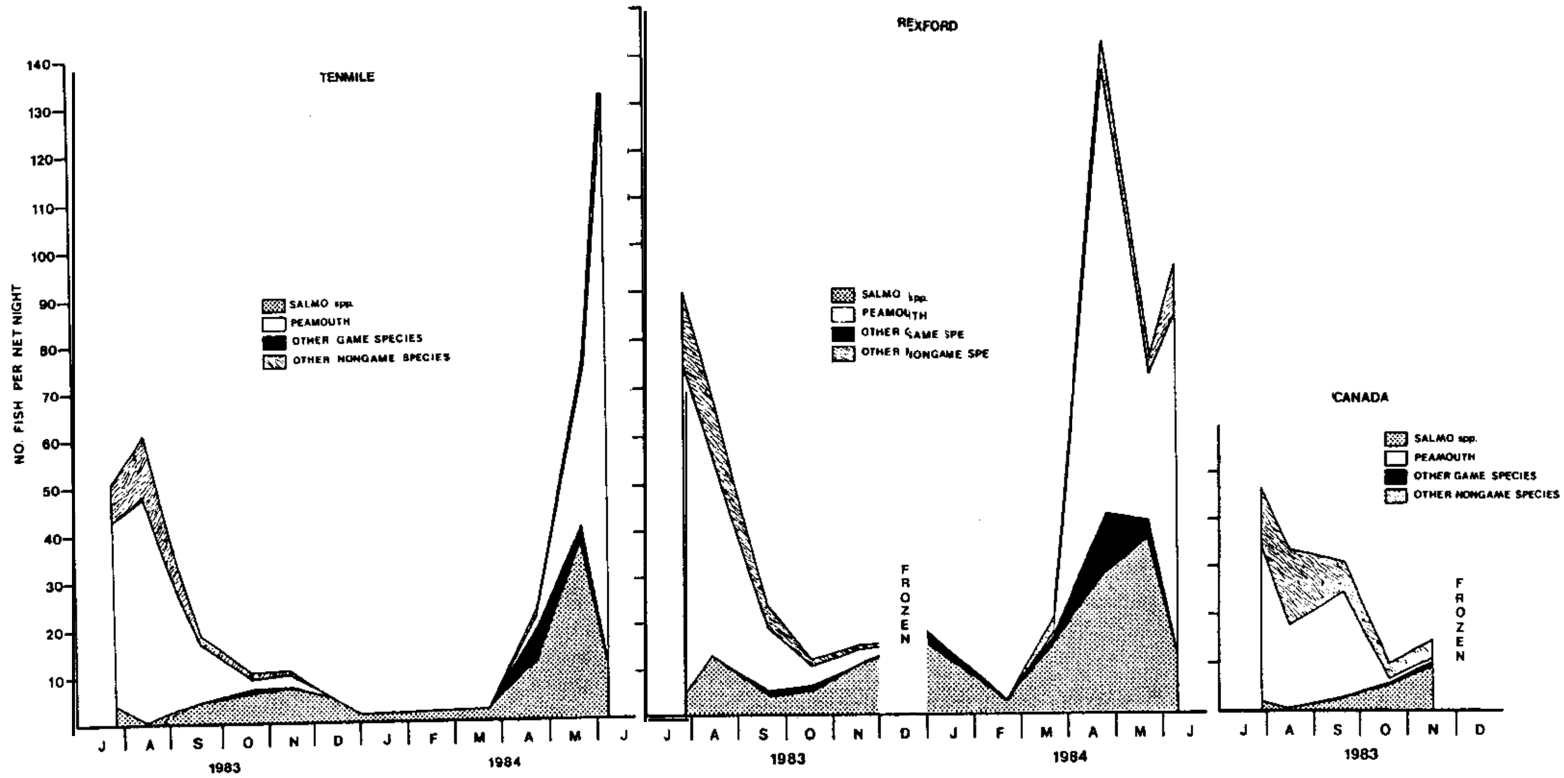


Figure 11. Monthly catches of fish (number of fish per net night) in floating gill nets set in near-shore zones of three areas of Libby Reservoir during 1983 and 1984.

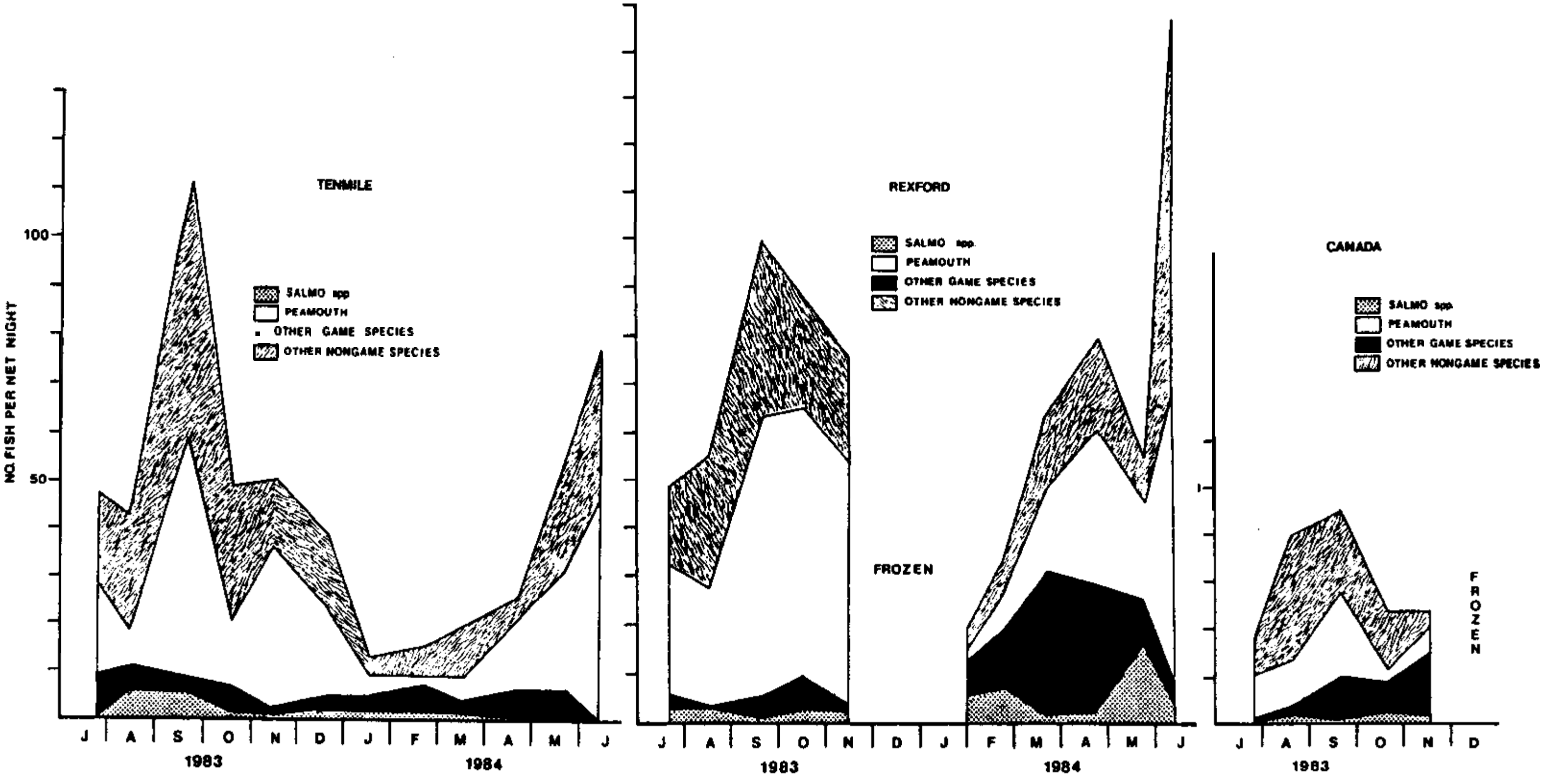


Figure 12. Monthly catches of fish (number of fish per net night) in sinking gill nets set in near-shore zones of three areas of Libby Reservoir during 1983 and 1984.

caught in near-shore gill nets set in the Tenmile and Canada areas during the summer, but surprisingly high numbers were captured in the Rexford area. We would expect that the high surface water temperatures observed during August would force trout into deeper cooler water. The night of our August sampling in the Rexford area was extremely windy and surface temperatures were near 16°C allowing trout to move into near-shore zones. Other gamefish most frequently captured in near-shore zones included kokanee and bull trout which were caught at high rates during spring 1984 (Appendix E).

Peamouth were the most abundant species in gill net catches during the summer Peamouth appeared to move to the bottom of the near-shore zone as surface water temperatures fell during the fall, and then moved out to the limnetic zone during winter. They returned to near-shore Zones in the early spring as water temperatures increased. Redside shiners were also more frequently captured during summer months in near-shore zones (Appendix E). Northern squawfish and largescale suckers made up the bulk of "other nongame fish" category in both floating and sinking gill net catches.

Annual floating gill net sampling from 1975 through 1984 indicated Salmo spp. abundance is presently lower (1982 through 1984) relative to their abundance prior to 1980 (Figure 13 and Appendix F). Abundance of kokanee increased dramatically in 1982 relative to previous years. The kokanee captured in 1982 gill net sets were large (average length was 440 mm) pre-spawning (ripe) fish. Floating net catches of kokanee dropped sharply in 1983 because fish from the 1983 year class were too small to be captured by gill nets and the 1981 and 1982 year classes were extremely weak year classes. Catches of kokanee increased in 1984 and were comprised primarily of 1982 year class fish. Peamouth abundance has increased steadily through 1982 and appeared to be leveling off during recent years, while redside shiner abundance dropped markedly during the 1978 to 1980 period. Northern sguawfish abundance has fluctuated through the sampling period.

Spring sampling during the same time period with sinking gill nets provided no conclusive evidence of changes in bull trout or burbot abundance (Figure 13 and Appendix F). The catch of mountain whitefish during the period 1980 to 1984 was relatively lower than that observed prior to 1980. Largescale and longnose sucker catches have fluctuated annually with a high catch of the former and a low catch of the latter recorded in 1984.

Limnetic Zone

Vertical gill net catches were dominated by kokanee in the lower two areas of the reservoir (Tenmile and Rexford) (Figure 14). Nongame species dominated the catch in the upper (Canada) area.

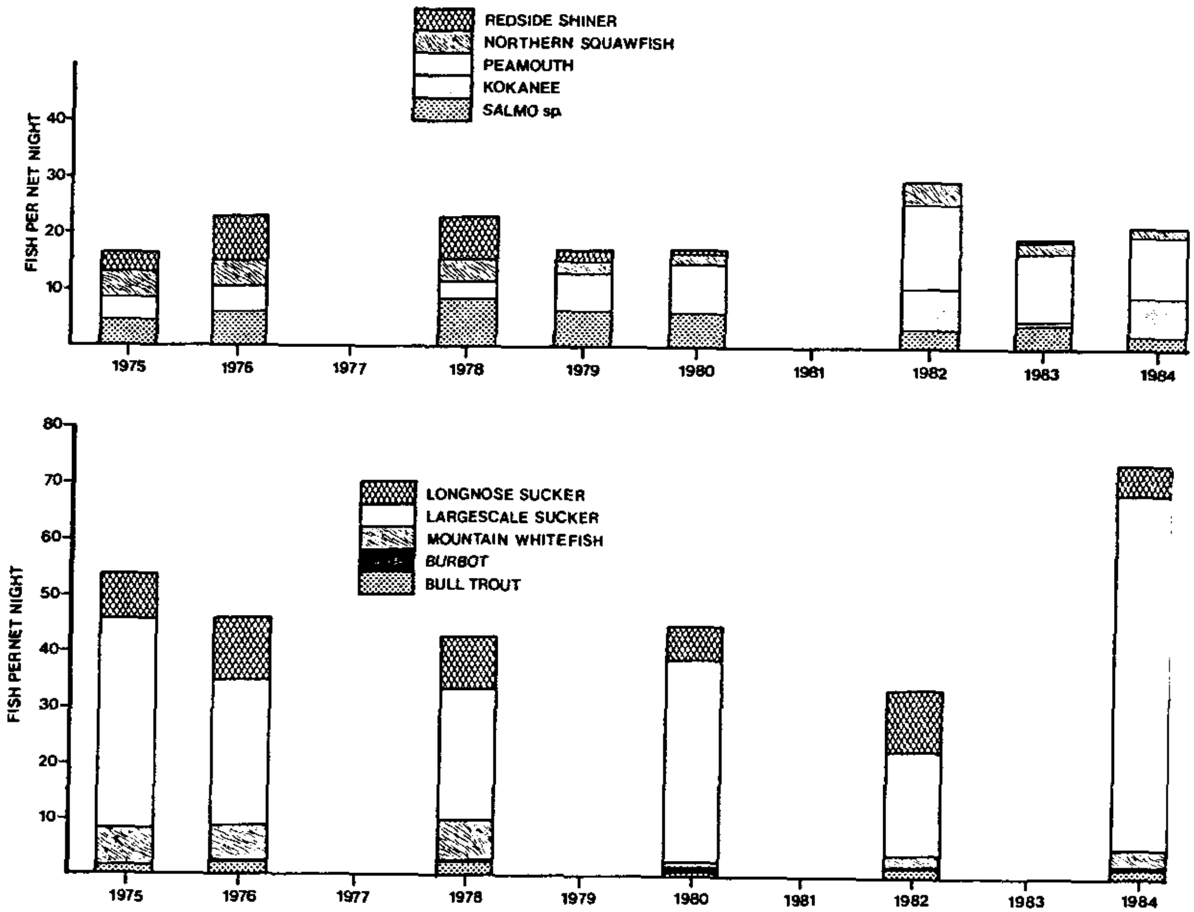


Figure 13. Annual catches of fish (number of fish per net night) in floating gill nets set during the fall (top) and sinking gill nets set during the spring (bottom) in Libby Reservoir from 1975 through 1984.

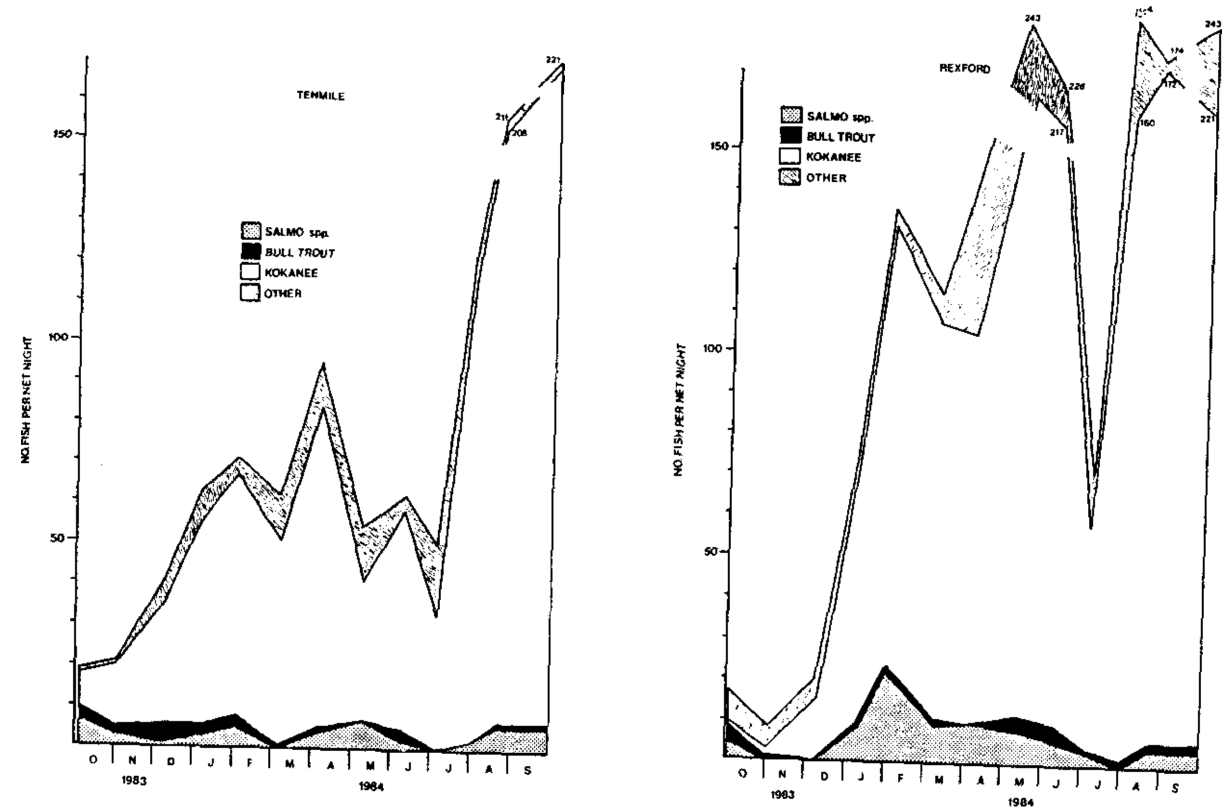


Figure 14. Monthly catches of fish (number of fish caught in eight vertical gill nets set overnight) in two areas of Libby Reservoir during 1983 and 1984.

Catches of Salmo spp. were highest in the Rexford area during the winter. Catches of Salmo spp. dropped from May through July before increasing in August. Catches of bull trout were consistent throughout the year. Peamouth dominated the "other" category during the winter and spring. Northern sguawfish, largescale suckers, and mountain whitefish were also included in the "other" category.

Kokanee also dominated the catch in purse seine hauls (Table 8). Largescale suckers were the next most abundant species in the catch followed by rainbow trout in the Tenmile and Rexford areas in the spring and summer and the Canada area in the fall. Catches of Salmo spp. were highest during the fall in the Canada area. Catches of the Salmo spp. were low, but second to kokanee, during the fall in the Tenmile area.

Vertical Distribution

Vertical gill net catches and Hydroacoustic surveys were used to describe vertical fish distribution and infer vertical habitat preferences. Vertical gill nets captured Salmo spp. in waters cooler than 18°C with cutthroat appearing to prefer slightly deeper and cooler waters (Figure 15 and Appendix G). Salmo spp. appeared to be distributed as high in the water column as temperature preferences permitted and generally preferred to be within 3.0 m of the water's surface when surface temperatures allowed. Rainbow trout were occassionally found deeper than other Salmo spp.

Kokanee were distributed throughout the upper 45 m of the water column, but appeared to prefer temperatures cooler than 17°C (Appendix G). Peamouth were captured in deep water (generally deeper than 15 m) throughout the winter and moved up towards the surface in the spring as water temperatures warmed. Peamouth were found near the surface during the summer once water temperatures rose above 10°C. Bull trout seemed to select areas cooler than 14°C and exhibited an apparent preference for water 10 to 12°C.

Hydroacoustic surveys showed that targets (fish) were sparsely distributed across sample transects during daylight and were densely distributed across transects during hours of darkness (Figure 16). Vertical distribution from the surface down to five meters was difficult to decipher from hydroacoustic charts because of near surface interference. Fish distribution below 5 meters on hydroacoustic charts generally corresponded to catches in vertical gill nets set in conjunction with hydroacoustic surveys.

Table 8. Mean catch (standard error) of fish by area in purse seine hauls conducted in Libby Reservoir during 1984.

Area	Season	n[a]	RB[b]	WCT	HB	SALMO	KOK	MWF	CSU	PM
			Mean Catch (SE)							
TENMILE										
	Spring		4.0	0.5	0.5	5.0	331.5	1.0	0.5	—
		2	(2.0)	(0.5)	(0.5)	(3.0)	(14.5)	(—)	(0.5)	(—)
	Summer[c]		1.0	0.6	0.4	2.0	35.0	0.4	0.2	4.2
		5	(0.6)	(0.4)	(0.4)	(0.7)	(33.5)	(0.4)	(0.2)	(1.1)
	Fall		0.1	0.1	—	0.2	24.7	—	—	—
		19	(0.1)	(0.1)	(—)	(0.2)	(6.0)	(—)	(—)	(—)
REXFORD										
	spring		3.0	1.7	1.3	6.0	120.3	3.0	9.4	1.6
		37	(0.6)	(0.4)	(0.3)	(1.0)	(55.3)	(0.6)	(3.6)	(1.3)
	Summer[c]		0.5	0.7	—	1.2	7.8	0.2	0.2	2.8
		6	(0.3)	(0.3)	(—)	(0.6)	(5.0)	(0.2)	(0.2)	(2.2)
	Fall		0.2	0.04		0.4	20.6	0.1	—	--
		27	(0.1)	(0.04)	(E,	(0.1)	(2.7)	(0.1)	(—)	(—)
CANADA										
	Fall		1.1	0.3	0.4	1.9	7.7	—	6.4	—
		22	(0.3)	(0.2)	(0.2)	(0.4)	(1.9)	(—)	(3.8)	(—)

a/ n=number of hauls
b/ Abbreviations were described in the "Methods" section.
c/ Summer sampling was done during the evening and night all other sampling was done during the day

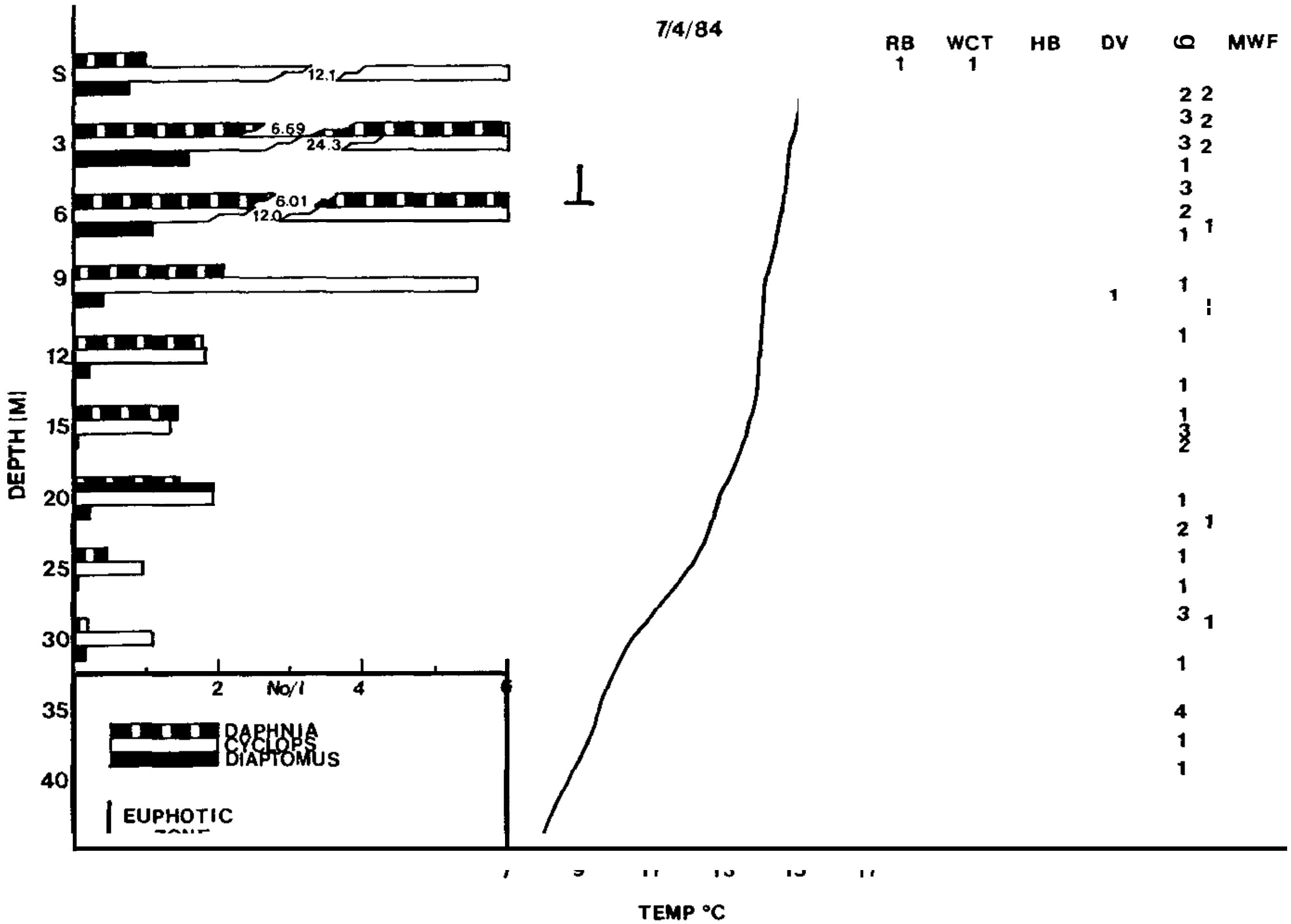
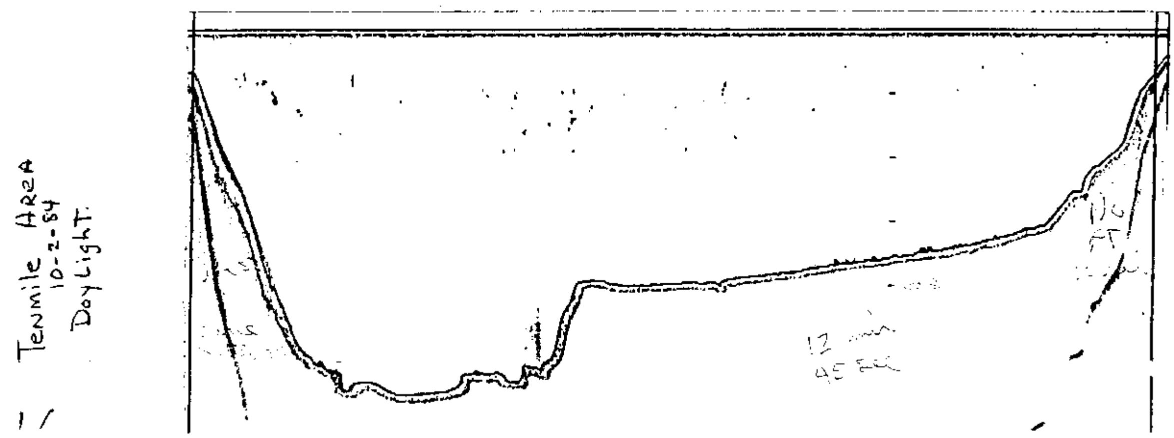


Figure 15. Typical seasonal vertical distributions of fish and zooplankton compared to temperature profile and euphotic zone depth in the Rexford area of Libby Reservoir during 4 July 1984.



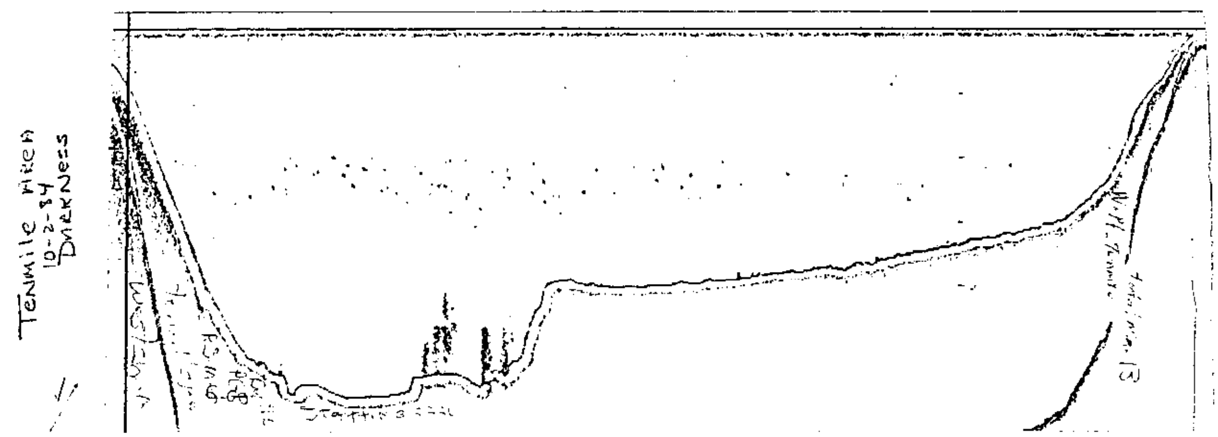


Figure 16. Hydroacoustic charts showing distribution of fish identified as targets during the day (1500 hours; top chart) and night (2230 hours; bottom chart) on 2 October 1984 in the Tenmile area of Libby Reservoir.

Population Estimates

Purse Seine Estimate of Salmo spp.

Estimates of salmo spp. populations within the limnetic zone were made using purse seine catches during the spring and fall (Table 9). Spring estimates were known to be high because we positively biased the results in actively seeking fish using hydro-acoustic sampling prior to purse seining to evaluate the effectiveness of the gear. We have no way of estimating the magnitude of our introduced bias.

Fall purse seine estimates were computed using two statistical designs, stratification by area and no stratification. Ninety-five percent confidence intervals around the two limnetic estimates overlapped, but the stratified point estimate was lower and had poorer precision. Fall estimates may be low. However, since spring estimates were known to be high and fish remaining in the reservoir in the fall survived through the summer fishery our fall estimates may be reasonable.

Near-shore gill nets captured 4.4 and 2.4 times as many Salmo spp. as limnetic sets in the spring and fall, respectively. These values were used as correction factors to expand limnetic purse seine catches for estimating numbers of Salmo spp. in near-shore zones. Using limnetic estimates to estimate Salmo spp. populations within near-shore zones resulted in poor levels of precision (Table 9).

Hydroacoustic Estimate of Kokanee

Hydroacoustic sampling data collected during August 1984 were statistically analyzed to estimate numbers of kokanee (1983 year class). We estimated there were slightly more than 2.5 million kokanee ($\pm$ 8%) in the reservoir at that time (Table 10). Using average weight data the above number represents approximately 400,000 kg of kokanee or 24.5 kg per hectare (21.8 lbs per acre). The highest densities of kokanee were found in the Tenmile and Rexford areas, while the Peck Gulch and Canada areas had significantly lower densities than either of the above two areas and Canada had significantly lower densities than Peck Gulch (Table 11).

Reservoir Macro-Habitat Preferences

Vertical and thermal habitats preferred by fish were described previously in the "Vertical Distribution" section. We attempted to describe our present understanding of area1 fish distribution during the year by using relative horizontal and vertical gill net, electrofishing, and purse seine catches of fish to infer where fish preferred to be during the course of a year. When using passive

Table 9. Estimated numbers of Salmo spp. derived from purse seine catches in Libby Reservoir during spring and fall, 1984.

Season	Geographic Area	Zone	Surface area(acres)	Estimate	95% CI[a] (%)
Spring	Total[b]	Limnetic	21,175	192,500[c]	± 39,949 (21)
	Total	Near-shore	5,521	220,836[c]	±424,181 (192)
		Total	26,696	413,336[c]	±464,130 (112)
Fall	Total	Limnetic	34,090	42,536	± 16,491 (39)
	Total	Near-shore	9,522	28,392	± 99,082 (349)
		Total	43,612	70,928	±115,573 (163)
	Tenmile	Limnetic	15,875	6,804	± 13,336 (196)
	Rexford	Limnetic	10,280	5,717	± 4,378 (76)
	Canada	Limnetic	8,300	23,795	± 6,661 (28)
	Total	Limnetic	34,455[d]	36,316	24,375 (67)

a/ 95% CI is the nine-five percent confidence interval.

b/ Total indicates estimate done for entire reservoir (No stratification).

c/ These estimates were high because of positive bias introduced by sampling.

d/ Total areas do not match because we had to interpolate between 10 foot contours on stratified estimate.

Table 10. Estimated numbers of 1983 year-class kokanee in Libby Reservoir expanded from hydroacoustic sampling during August, 1984.

Geographic Area	Total Surface Area[a/] ha	acres	Area Sampled ha	acres	Estimated Number	95% confidence Interval (%)
Tenmile	4,743.6	11,721.4	10.8	26.8	1,228,637	± 69,254 (6)
Reck Gulch	1,959.7	4,842.3	7.2	17.9	257,804	± 25,040 (10)
Rexford	4,466.3	11,036.l	10.8	26.7	1,059,356	±113,540 (11)
Canada	5.321.9	13.150.2	9.0	22.2	28,536	± 6,397(22)
TOTAL	16,591.5	40,750.0	37.8	93.6	2,574,333	+214,231 (8)

[a/] Total surface area based on a reservoir elevation of 740.7 m (2,430 ft.) (see Methods for explanation).

Table 11. Density of 1983 year-class kokanee in four areas of Libby Reservoir in August, 1984 determined from hydro-acoustic sampling and analysis of variance results and Duncan's new multiple range test results (OH 1977) illustrating where densities differ significantly.

Area	Density Number/acre	Density Number/ha	F-test[a]	Duncan's test[b]
Tenmile	104.8	259.0	144.6**[c]	
Rexford	96.0	237.2		
Reck Gulch	53.2	131.4		
Canada	2.2	5.4		

[a] Results from analysis of variance test comparing densities from all four areas.

[b] Duncan's new multiple rangetestata = 0.05 level. Solid line between connecting areas indicates no significant difference in kokanee density between areas.

[c] Significant at $p<0.001$ level.

sampling techniques such as gill nets, one must be careful about comparing seasonal abundance because of variable activity rates associated with changing water temperatures.

Salmo spp. appeared to prefer near-shore zones as long as temperatures in these zones were within tolerable limits. *Salmo* spp. catches in near-shore nets were highest in spring corresponding to the lowest catch in limnetic vertical nets suggesting they moved into near-shore zones during the spring. Reasons for this movement to near-shore zones were believed to be related to increased food availability in the form of emerging Diptera, a pre-spawning movement to begin searching for natal spawning tributaries, and increased metabolic activity in response to warming water temperatures. Water temperatures in near-shore zones were 9 to 11°C in the Rexford area and 6 to ll°C in the Tenmile area during May and June. During the summer, as water temperatures in near-shore zones warm, *Salmo* spp. moved offshore into deeper cooler water, but appeared to occassionally challenge their thermal habitat preference as indicated by our relatively high floating gill net catch in the Rexford area during August. The surface temperature in this area at that time was 18.6°C. *Salmo* spp. moved into near-shore zones during the fall and were found in both the limnetic and near-shore zones during the winter. We did see an increase in limnetic catches in vertical gill nets in the Rexford area which may indicate a movement to the upper end of the reservoir during the winter.

Electrofishing of near-shore zones containing various habitat types revealed no distinct trends in habitat preference exhibited by distributions of Salmo spp. (Table 12). We captured more large trout (>300 mm) and mountain whitefish during fall sampling than during spring sampling.

Electrofishing and purse seine catches of fish were used to describe the distribution of juvenile *Salmo* spp. in Libby Reservoir since juvenile trout were seldom captured in gill nets. Juvenile *Salmo* spp. were captured in both near-shore and limnetic zones: however, smaller juveniles (<120 mm) were captured exclusively in near-shore zones while larger juveniles (120 to 200 mm) were captured exclusively in limnetic zones. We speculate that territorial stream-rearing juveniles may visually key on physical habitat when they first enter the reservoir. This behavioral response to physical habitat forces these juveniles to inhabit near-shore zones. Dater, after these juveniles "learn" to seek the previously unfamiliar zooplankton food resources, they may move offshore into limnetic zones where food is abundant and predation is reduced.

Kokanee preferred limnetic zones throughout the year. Tne only seasons when kokanee were found in near-shore zones were in the early spring (April) and the fall. Spring use of near-shore zones may be related to increased availability of Diptera coupled

Table 12. Fish catch per hour of night electrofishing effort along the shoreline of Libby Reservoir shoreline areas were classified based on gradient (S=steep slope, M=mcderate slope, L=lcw or slight slope), substrate type (S=sand and silt, G=gravel, C=cobble, R=boulder, D-bedrock), cover class (O=none, l=little, 2=moderte 3=moderately abundant, 4=abundant), and cover type (R=rcck, D=debris) .

Area	Season	Length (m)	Habitat Type: Gradient	Substrate	Cover Class	Cover Type	Catch per Hour: Salmo	MWF	PM	RSS	CSU
Tenmile											
1	SUMlET	293	M	S	4	D	0	0	23.5	23.5	3.9
2	Summer	274	L	S	2	D	0	0	14.1	37.6	4.1
3	Summer	320	S	C	4	R	6.8	0	3.4	13.5	16.9
4	Summer	293	S	S,G,C	3	R,D	0	0	3.5	14.2	14.5
6	Summer	402	S	CJ	2	D,R	0	0	0	0	4.8
7	summer	329	M				0	0	4.3	4.3	0
	Summer	347	L	S	1	D	0	0	4 . 1	14.1	14.1
8	Summer	438					0	0	1.1	1.1	1.1
9	Summer	256	S	R,B	0		0	0	0	0	0
10	summer	375	S	GX	1	D	5.1	0	0	0	0
Rexford											
1	Summer	329	L	S,G,C	2	RJ'	0	0	0	0	0
2	Summer	384	M	S	1	D	10.0	6.1	0	30.0	10.0
2	Fall						3.1	6.3	0	6.3	9.5
4	summer	198	M	S	1	D	0	0	0	10.3	20.6
4	summer	320	L	S	4	D	0	0	0	1.9	35.6
	fall						6.1	10.0	0	0	0
5	summer	274	L	S	2	D	0	4.1	4.1	0	12.3
5	fall						9.2	64.6	0	0	0
6	summer	280	L	S	I	D	0	13.2	5.3	5.3	18.5
7a/	summer	192	S	R,B	3	R	0	0	0	0	0
8a/	summer	366	S	R,B	3	R	0	0	3.8	0	0

a/ Electrofished during the day

with lower densities of Daphina spp. Movement of kokanee into near-shore zones during the fall may have been related to a pre-spawning search for suitable spawning habitat.

Bull trout used limnetic and near-shore zones, but were seldom found near the surface. Peamouth and northern sguawfish mwed into near-shore zones during the spring. They remained near the surface in near-shore and limnetic zones during the summer, moved to deeper near-shore habitats during the fall, and out into the limnetic zone during the late fall and winter. Redside shiners were relatively abundant in near-shore zones during the spring and summer, but were seldom captured in either near-shore or limnetic gill nets during other seasons.

Growth

Growth of rainbow and cutthroat trout was evaluated using April 1984 samples of fish (Table 13). Empirical lengths at this time should closely represent annual growth since this is approximately when annulus formation occurs. Rainbow trout in the sample were predominated by fish which spent one (51%) and two (38%) years rearing in natal tributaries (migration class X_1, and X_2, respectively). Second year reservoir growth for these two migration classes was 78 and 66 mm, respectively, based on comparing two consecutive year classes. Rainbow from both migration classes reached approximately 420 mm by age V. Wild cutthroat trout were predominated by migration class two (66%) and three (24%) fish. Hatchery origin fish made up 37 percent of the total cutthroat trout sample. Second year reservoir growth was 81 and 64 mm for these two migration classes, respectively, based on comparing two consecutive year classes. Cutthroat from both migration classes reached approximately 380 mm by age V and 405 mm by age VI.

Monthly growth of the 1983 year-class of kokanee was followed from November 1983 through August 1984 (Figure 17). Kokanee average 185 mm in November, although vertical nets probably selected for larger individuals. Growth from November through the following April was slow and averaged only 5 mm. Weight increased by an average of 15 grams during that same time period. Beginning in May, growth increased rapidly and length increased by an average of 15 mm per month through September, while weights increased by 19 grams per month. Using August sampling we estimated that approximately 30 to 40 percent of the male kokanee and 5 percent of the female kokanee spawned during 1984 based on size of the gonads. These kokanee were age I and had spent only two growing seasons in Libby Reservoir. Growth then appeared to slow again and the loss of some larger members of the 1983 year class to the 1984 spawning resulted in a smaller average size in the remaining population.

Table 13. Average lengths of rainbow and cutthroat trout in April 1984 by age and migration class based on interpretation of scale samples taken from fish captured in Libby Reservoir (Number of fish in sample in parentheses).

Species Migration class	n(%)	Age II	III	IV	V	VI
Rainbow Trout						
X_0[a/]	8 (9)	332 (7)	430 (1)	---	---	---
X1	45(51)	320(22)	398(15)	420 (4)	421 (4)	- -
X2	33(38)	- -	323(11)	389(13)	419 (9)	---
X3	2 (2)	---	---	365 (2)	---	---
Average		323 (29)	369 (27)	393(19)	420(13)	- -
Cutthroat Trout						
XH	30	306(13)	372(10)	392 (7)	---	---
X_0	4 (8)	308 (1)	356 (3)	---	---	---
X1	1 (2)	283 (1)	---	---	---	---
X2	33(661	---	301(20)	382(10)	385 (2)	408 (1)
X3	12 (24)			315 (7)	379 (4)	406 (1)
Average		305(15)	328(33)	365(24)	381 (6)	407 (2)

a/ Subscripted X indicates age at which fish entered Libby Reservoir from tributaries. An "H" indicates a hatchery origin fish.

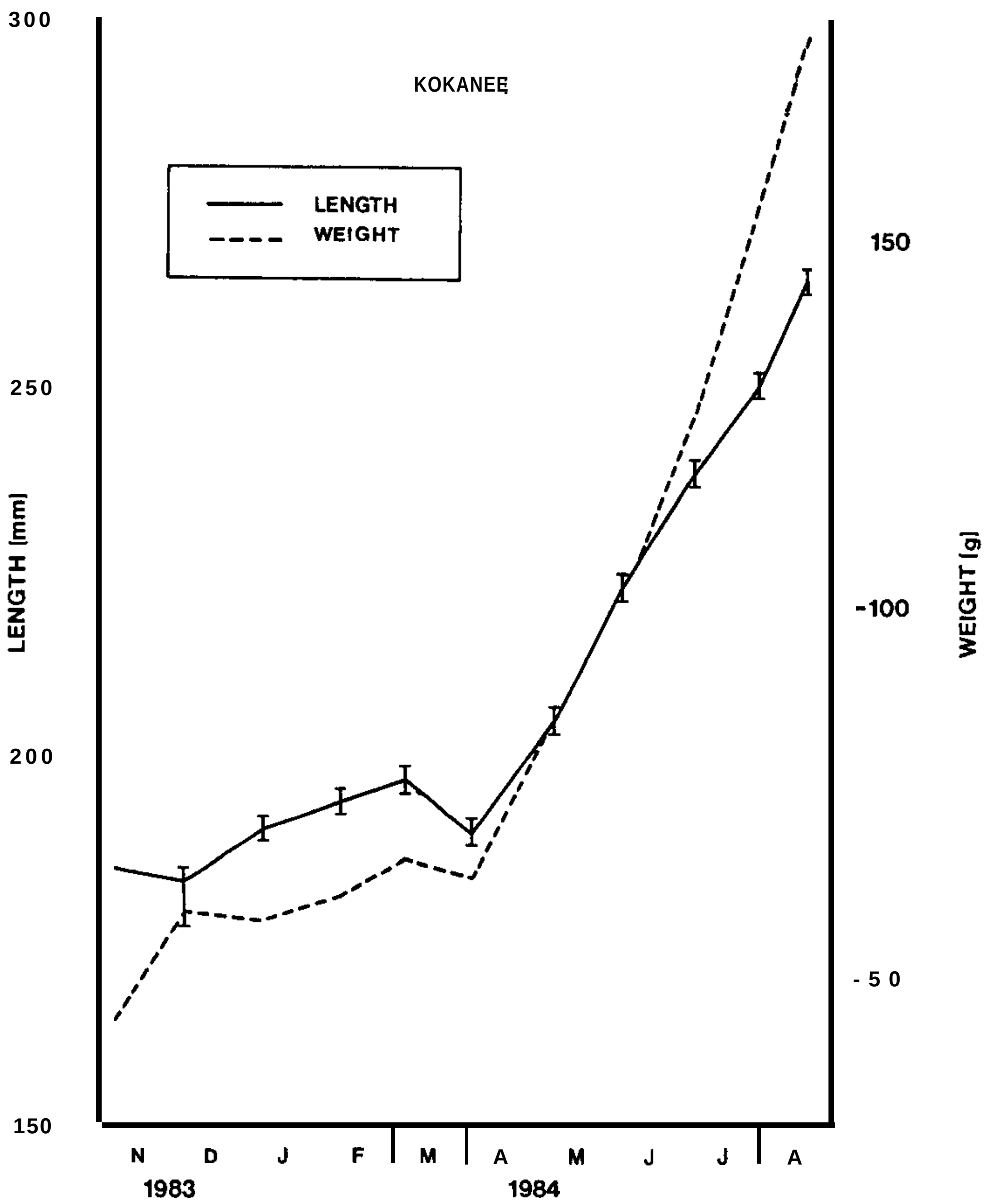


Figure 17. Monthly growth of the 1983 year class of kokanee in Libby Reservoir from November, 1983 through August, 1984. Vertical bars represent 95% confidence limits.

Movement

Tributaries

Youna Creek

An estimated 354 adult westslope cutthroat trout ascended Young Creek to spawn during 1984 (Pppendix H). The sex ratio of this spawning run was 1:2.4 (♂:♀). Spawning mortality was estimated to be between 25 to 30 parcent, although this must be considered a maximum estimate because we had a mink predation problem during our downstream trapping. We tagged a total of 227 adult cutthroat trout moving downstream through our trap. We cbserved that at least nine percent of the adults which spawned during 1984 were previous year spawners based on tag returns. This is a minimum estimate because an unknown amount of tag loss occurred. We captured one adult cutthroat (a ripe male 287 mm long) which we had tagged the previous year as a juvenile emigrating downstream (160 mm long). This fish grew 127 mm.

We trapped a total of 1,330 juvenile trout emigrating downstream in Young Creek (Appendix H). The majority of these juveniles were tagged (982) and emigrated from mid-May through mid-July. Two hundred fifty-six of these, particularly young-of-the-year (57%), emigrated later, primarily during October and November.

Bristow Creek

A total of 36 adult *Salmo* spp. were captured and tagged leaving Bristow Creek after spawning. The majority were cutthroat (55%) and hybrids (33%). Most of the adults left by the end of June (Appendix H). Approximately 40 percent of the adult cutthroat were determined to be of hatchery origin based on eroded dorsal fins. Sex ratios were 1:3 (♂:♀) for all Salmo spp. combined.

A total of 175 juveniles were trapped and tagged emigrating from Bristow Creek. The majority were identified as cutthroat (94%) and juvenile emigration appeared to end after 10 July, although the trap was operated through 23 July (Appendix H).

Big Creek

A total of 51 cutthroat trout (10 percent identified as hatchery origin), 4 rainbow trout, and 22 hybrid adults were captured moving out of Big Creek after spawning (Appendix H). Sixty-three of these fish were tagged. Most of these fish moved through the trap between 4 July and 20 July.

A total of 1,549 cutthroat trout, 24 rainbow trout, and 278 hybrid juveniles were trapped emigrating downstream in Big Creek (Appendix H). A total of 1,730 were tagged. Movement occurred throughout the trapping period, but was slowing when traps were removed on 25 July.

Fivemile Creek

Rainbow trout adults predominated the downstream catch of adult trout in Fivemile Creek (28 fish), followed by cutthroat (21) and hybrids (19). Downstream movement of adults was spread out over the trapping period (Appendix H). This delayed mwement may have been caused by fish holding abwe our trap because when streamflows dropped our trap was in a slow run. Approximately 38 percent of the adult cutthroat trout captured were hatchery origin fish, similar to Bristow Creek. Sex ratios for all three species were skewed more towards males than we found in other tributaries (WCT-1:0.6; RB-1:0.8; HB-1:1).

The majority of downstream migrating juvenile trout were identified as cutthroat trout (258) with very few rainbow trout (1) OK hybrids (8) trapped. Juveniles moved primarily in late June and early July (Appendix H). The absence of juvenile rainbow trout in our trap catch may reflect a problem in identification OK may indicate juvenile rainbow trout emigrate at smaller sizes (earlier ages) and were not vulnerable to our trap.

Pinkham Creek

The lower portion of Pinkham Creek channel has a high gradient and much of the streamflow flows subsurface. The downstream trap in Pinkham Creek was placed in a poor location because once streamflows receded the trap was left in a slackwater pool. Consequently, most of the adult fish held above the trap and had to be captured using angling. Therefore, we were unable to use catches of fish in the downstream trap to describe the timing of downstream movement. We captured and tagged 14 cutthroat trout, 12 hybrids, and five rainbow trout adults. A total of 55 iuvenile trout were captured The majority of these were identified-as cutthroat trout (91%). Forty-seven juveniles were tagged.

Fortine Creek

Only three adult and 85 juvenile Salmo spp. were captured in the downstream trap placed in Fortine Creek (Appendix H). We were unable to install the trap until 18 July because of the size of the stream and volumes of water discharged. Juvenile movement through the trap ended by 1 August. We also captured mountain whitefish, largescale suckers, redside shiners, northern squawfish, and eastern brook trout in the trap. Water temperatures in Fortine Creek were generally higher than other tributaries trapped during 1984.

Tag Returns

Movement within Libby Reservoir and between the reservoir and its tributaries was assessed using voluntary angler tag retunrs and tagged fish recovered by our sampling gear (Appendix H). Approximately 11 percent of the 901 tagged adult Salmo spp. were recaptured. The majority (95%) were returned by anglers. It appeared adults moved throughout the reservoir and tributary origin did not play a major role in reservoir distribution (Table 14). There may be a slight down-reservoir trend, but several fish moved up-reservoir.

Returns of the 5,597 dangler tags tags placed on juvenile Salmo spp. were extremely low (less than one percent). This low return could be related to one OK more of the following: small size of the tags making them difficult for anglers to notice; the small size of juveniles preventing them from making up a significant portion of angler's catch; OK tag loss. Using this limited information it appeared juveniles also moved throughout the reservoir (Table 14). Several were captured by anglers from the tributary in which they were tagged shortly after being tagged. It was interesting to note that both an adult and a juvenile were captured in the Kootenai River below Libby Dam.

Reservoir Food Habis

Food habits data have been summarized for gamefish collected during the summer of 1983 (Appendix I). IRI values showed that zooplankton, particularly Dapnia spp. and Leotodorg spp., and terrestrial insects made up the bulk of the diet of salmo spp. during the summer (Figure 18). Smaller (≤330 mm) Salmo spp. appeared to prefer zooplankton and Diptera adults, while larger (>330 mm) Salmo spp. seemed to exhibit a preference for Daphina spp. and terrestrial insects. Mountain whitefish ate zooplankton comprising all genera and Diptera adults and larvae. Kokanee ate Daghia spp. almost exclusively.

Gamefish, particularly trout and kokanee, seemed to select larger Daphnia spp. as indicated by comparing Daphnia spp. size compositions and average sizes in the diet with those sampled from the zooplankton population (Table 15).

ABUNDANCE AND AVAILABILITY OF FISH FOOD ORGANISMS

Zooplankton

Standing Crop

Our data indicated the 0.3 m plankton net was more efficient than the plankton trap (Table 16). This result conflicts with

Table 14. Smnmary Of tag return informaten obtained from 901 adult and 5,597 juvenile trout tagged in Libby Reservoir and its tributaries during 1983 and 1984.

Tagging Location	Reservoir (area)			Tributary (to area)			Kootenai	
	Tenmile	Rexford	Canada	Tenmile	Rexford	Canada	River	Unknown
ADULT:								
LIBBY RESERVOIR								
REXFORD area	14	9	3	2	1	1	--	8
Tenmile area	1	—	1				—	—
KOOTENAY RIVER								
Canada area	4	1	3	1	—	3	—	1
TENMILE AREA TRIBUTARIES								
Bristow Creek	1	—	—	—	—	—	—	—
Fivemile Creek	5	—	--	—	--	—	1	1
Big Creek	5	—	—	—	—	—	—	—
REXFORD AREA TRIBUTARIESS								
Pinkham Creek	2	—	—	—	—	—	1	—
Young Creek	10	13	1	3	—	1	—	7
Total adult (901)a/	42	23	8	6	1	5	2	17

104 (11.5%) returned: 99 by anglers and 5 in our nets.

Tagging Location	Tenmile	Rexford	Canada	Tenmile	Rexford	Canada	River	Unknown
JUVENILE								
TENMILE AREA TRIBUTARIES								
Big Creek	2	1	—	5	—	—	1	2
REXFORD AREA TRIBUTARIES								
Young Creek	2	1	2	—	--	1	—	—
TOTAL (5,597)a/	4	2	2	5	—	1	1	2

17 (0.3%) returned: 16 by anglers, 1 by our nets.

a/ Number of fish tagged.

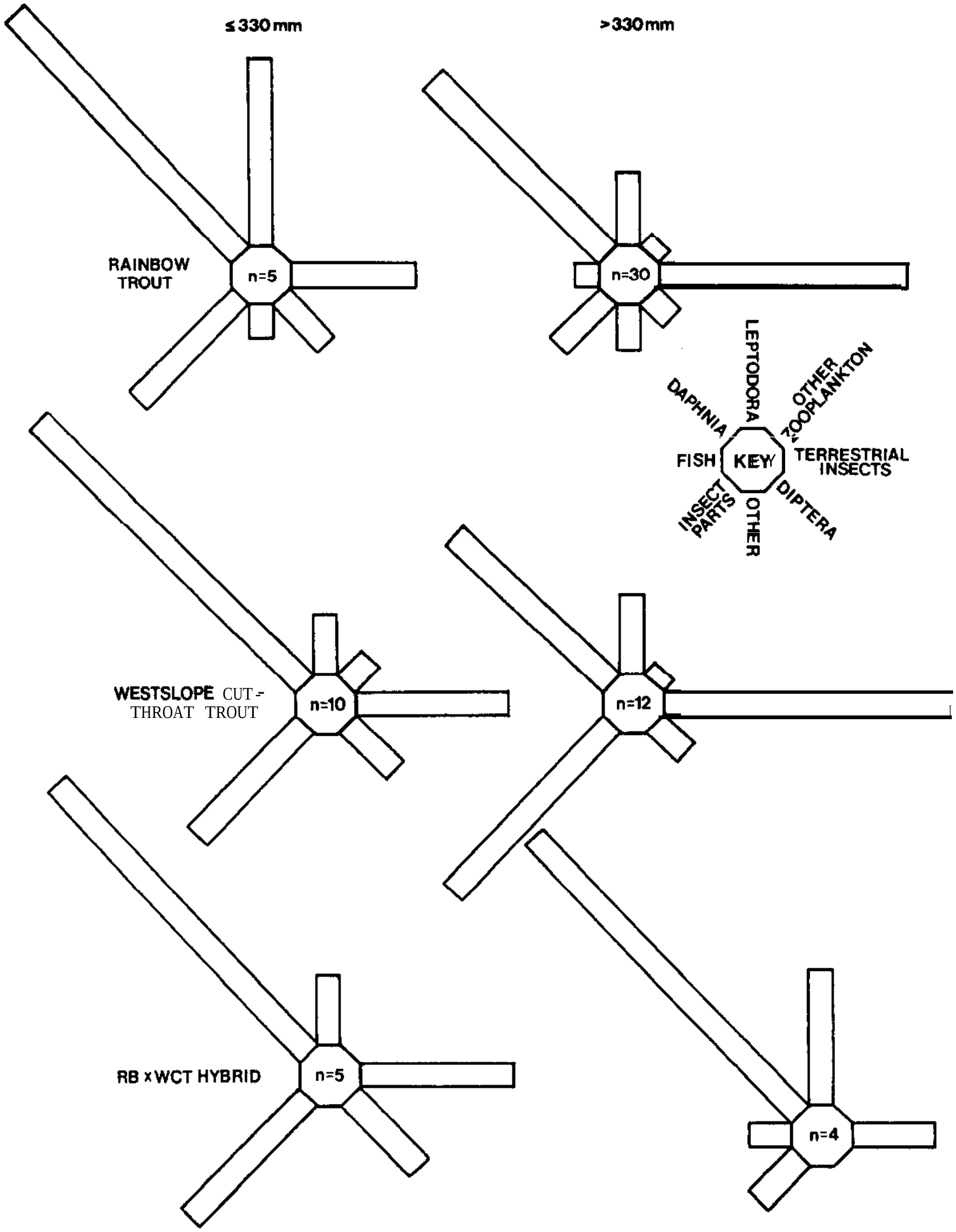


Figure 18. Indices of relative importance (IRI) for gamefish collected in Libby Reservoir (all three areas combined) during August, 1983.

Table 15. Size composition (%), mean lengths, and mean estimated weights of *Daphnia* spp. ingested by gamefish and available in the zooplankton population[a/] in Libby Reservoir during August, 1983.

	RB[b/]	WCT		HB	KOK		MWF	Available
Size class (mm)	≤330 mm	>330 mm	≤330 mm	>330 mm	all sizes	>330 mm	all sizes	Zooplankton
0.5 to 0.99	- -	---	---	---	---	- -	- - -	46
1.0 to 1.49	---	---	3	7	---	5	14	31
1.5 to 1.99	80	49	65	73	87	80	47	22
≥ 2.0	20	51	32	20	13	15	39	1
Mean length (mm)	1.89	2.05	1.94	1.91	1.85	1.89	1.74	1.16
Mean wet weight (µg)	262.8	330.8	283.0	270.8	247.4	262.8	208.4	66.0

a/ Available zooplankton as sampled by Wisconsin tows during August.

b/ Fish abbreviations were explained in the "Methods" section.

Table 16. sampling efficiency (percent) of Wisconsin net compared to a Schindler plankton trap for 30 m vertical tows in three areas of Libby Reservoir during 1983 and 1984. The Schindler plankton trap was assumed to be 100 percent efficient.

Month, Year	Daphnia			Bosmina			Cyclops			Diaptomus		
	Tenmile	Rexford	Canada	Tenmile	Rexford	Canada	Tenmile	Rexford	Canada	Tenmile	Rexford	Canada
September, 1983	129	369	—	216	—	—	276	409	—	286	514	—
November, 1983	109	176	—	—	—	—	148	195	—	266	331	—
December, 1983	300	151	—	—	200	—	246	265	—	303	127	—
January, 1984	219	298	—	—	125	—	250	303	—	265	391	—
February, 1984	209	176	—	—	119	—	353	176	—	432	182	—
March, 1984	1069	113	—	100	113	—	407	164	—	706	218	—
April, 1984	144	120	—	428	—	—	136	175	—	163	209	—
May, 1984	—	67	-	-	54	—	—	108	—	—	178	—
June, 1984	83	65	—	83	82	—	95	85	- -	121	126	—
July, 1984	112	100	109	135	111	119	88	126	140	45	119	134
August, 1984	78	35	—	32	55	- -	85	65	- -	96	73	—

results documented in the literature (Schindler 1969, Bottrell et al. 1976) and we cannot explain why it occurred. Regardless, it seemed reasonable for us to assume plankton net hauls represented zooplankton densities most accurately, and densities reported here were based on net tow data.

Zooplankton densities peaked during July in the Tenmile area (14.1 per liter), Mayinthe Rexfordarea (18.06 per liter), and in November in the Canada area (27.34 per liter) (Figure 19). Two lesser peaks occurred in both the Tenmile and Rexford areas, one higher peak during September and another lower one in January or February. Daphnia spp. generally comprised 20 to 30 percent of the numbers, while Cyclops spp. generally made up the largest percentage (Appendix J).. Bosmina spp. were most abundant during the summer and present in low numbers during the winter.

Length distributions of Daphnia spp. showed that larger Daphnia spp (>l.5 mm) were most abundant during the fall and absent during much of the winter (Figure 20). Area1 differences existed in length frequency distributions between the Tenmile and Rexford areas with few larger Daphnia spp. seen in the Rexford area during the spring and early summer. Daphnia spp. smaller than 0.5 mm were not seen in plankton samples during the late fall.

VerticalDistribution

Zooplankton densities were higher during the day above the 12 m depth contour than below it (Appendix G). Densities of zooplankers, particularly Daphnia spp., appeared to highest within the euphotic zone, and vertical kokanee distribution appeared to be related to vertical Daphnia spp. distribution (Figure 15 and Appendix G).

Benthos

Densities and biomass of Diptera larvae and Oligocheates were lowest in the frequently dewatered portions of the reservoir bed and highest in the permanently wetted portions in the Tenmile and Rexford areas (Table 17). The Rexford area had a higher density and biomass of Dipterans than the Tenmile area when comparisons were made within drawdown frequency strata.

Surface Macroinvertebrates

Comparison of near-shore versus limnetic surface tows found that although total mean densities of macroinvertebrates were often higher on the limnetic water surface, there was no significant difference between near-shore and limnetic catches (Table 18). The same result was found for the adult Dipteran component of the surface catch. Distribution of surface macroinvertebrates was found to be patchy, both spatially and temporally (Figure 21), but

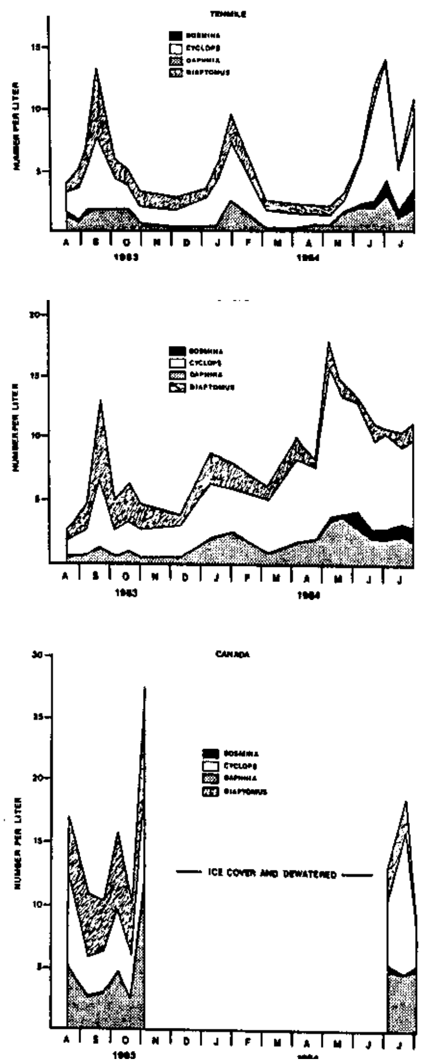


Figure 19. Densities (number per liter) of the four most abundant genera of Zooplankton in three areas of Lihhy Reservoir from August, 1983 through July, 1984 based on 30 m vertical tow samples.

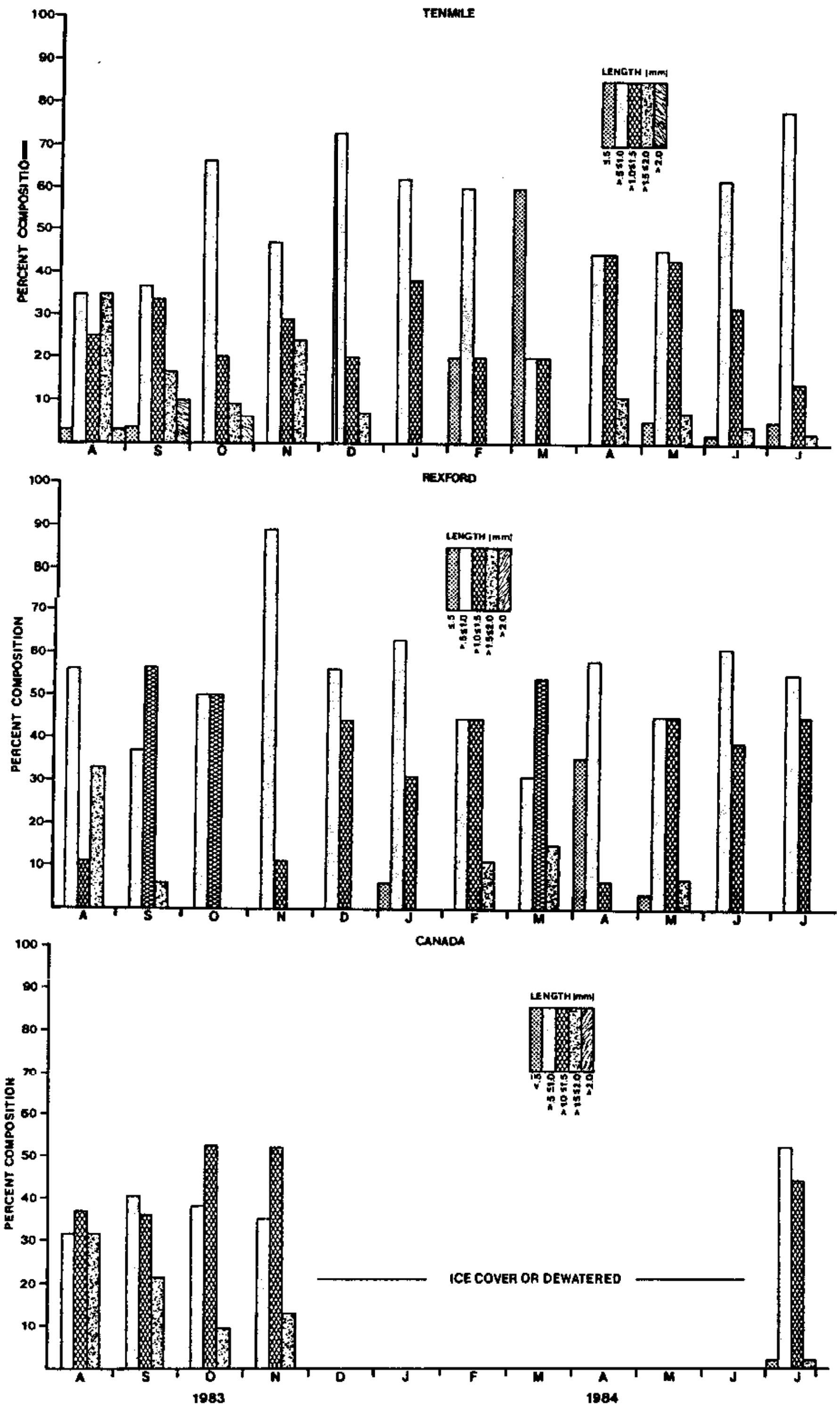


Figure 20. Length frequency distributions (by 0.5 m length classes) of Daphnia spp. captured in 30 m vertical tows in three areas of Libby Reservoir from August, 1983 through July, 1984.

Table 17. Estimated densities (number per m^2) and biomass (grams per m^2) of Diptera and Oligochaeta within the reservoir bed of Libby Reservoir in frequently dewatered, occasionally dewatered, and permanently wetted substrates (by area) during October 1983, March 1984, and June 1984.

	Frequently dewatered		Occassionally dewatered		Permanently wetted	
	Tenmile	Rexford	Tenmile	Rexford	Tenmile	Rexford
Number/m^2						
Diptera						
October, 1983	40	125	126	667	312	2,867
March, 1984	86	180	256	351	334	1,329
June, 1984	14	4	319	527	628	1,417
Average	47	103	234	515	425	1,871
Oligcchaeta						
October, 1983	4	4	7	183	50	301
March, 1984	4	0	110	149	52	272
June, 1984	0	0	305	455	158	689
Average	3	1	141	262	87	421
Grams/m^2						
Diptera						
October, 1983	0.153	0.328	0.328	2.443	2.252	10.901
March 1984	0.260	0.756	0.820	1.231	1.485	3.977
June, 1984	0.026	0.036	1.261	2.277	3.555	8.336
Average	0.146	0.373	0.803	1.984	2.431	7.738
Oligochaeta						
October, 1983	0.001	0.001	0.007	0.177	0.025	0.471
March, 1984	0.007	0	0.203	0.175	0.056	0.261
June, 1984	0	0	0.224	0.347	0.203	0.928
Average	0.003	<0.001	0.145	0.233	0.095	0.553

Table 18. Comparison of total catches of macroinvertebrates from the surface of Libby Reservoir (number per hectarc in limnetic versus near-shore zones during August, 1983 through July, 1984.

	Tenmile		Rexford		Canada	
	Near-shore	Limnetic	Near-shore	Limnetic	Near-shore	Limnetic
Number of samples	34	34	34	34	14	14
Total mean density (number/ha)	136	213	180	316	250	61
S.D.[a]	215	485	317	761	646	71
Mean difference	-77.2		-136		189	
Paired t-test	N.S.[b] p>o.20		N.S. p>0.l0		N.S. p>o.20	
Mean Dipteran density (number/ha)	58	74	138	270	81	17
S.D.	133	269	323	768	241	29
Mean difference	-16.1		-132		64	
Paired t-test	N.S. p>o.50		N.S. p>o.20		N.S. p>o.20	

a/ S.D. is standard deviation

b/ Paired difference best (Snedecor and Cochran 1967) showed no significant difference (N.S.) at level of probability indicated (p>value).

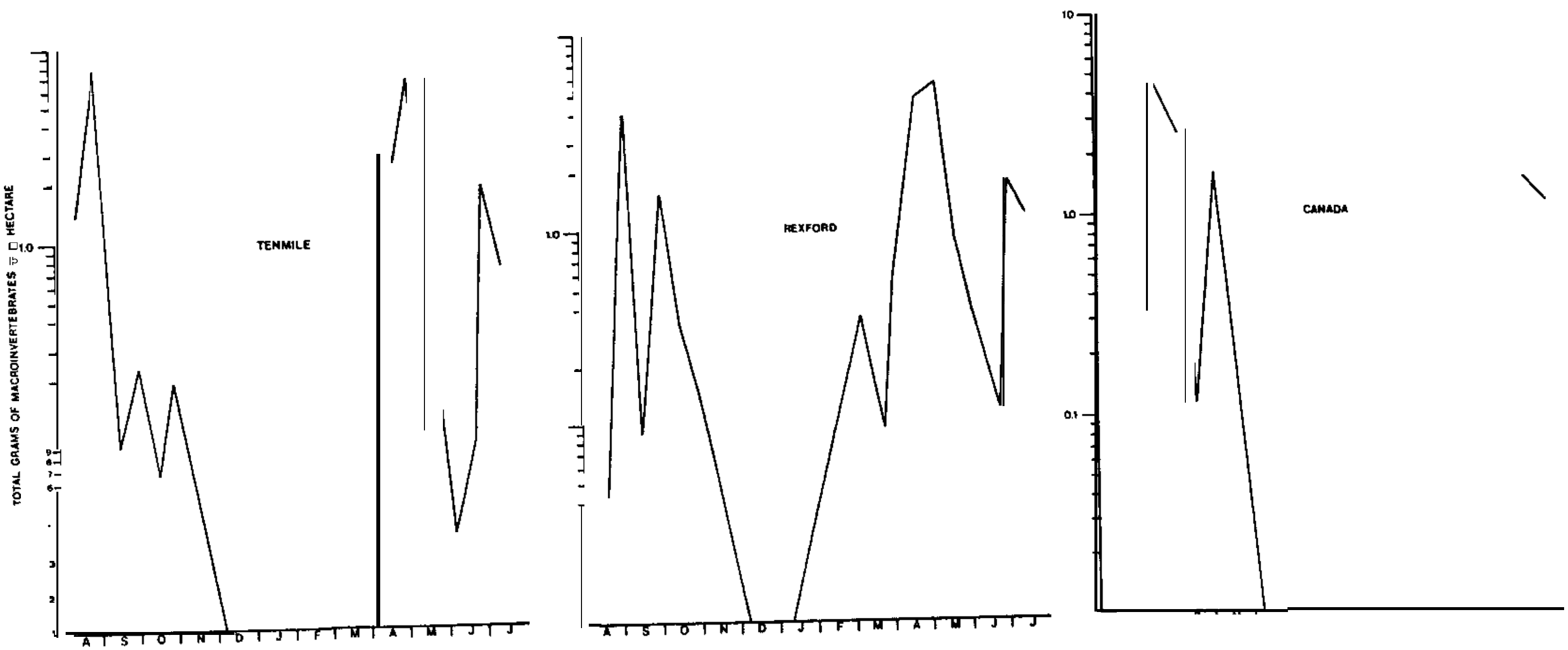


Figure 21. Estimated biomass (grams per hectare) of macroinvertebrates on the surface of three areas of Libby Reservoir during 1983 and 1984.

seasonal comparisons yielded useful information (Table 19). The aquatic component, primarly dipterans were most numerous in the spring catch in both the tenmile and Rexford areas, but the abundance of this aquatic component dropped during the summer. Surprisingly, winter densities in the Rexford area were as high as fall densities, but this resulted because March catches were relatively high while nothing was found in January and February samples. Biomasses of terrestrials were generally higher than aquatics during all seasons (Appendix K). In general, the orders Hymenopter and Homoptera were the most abundant terrestrials (Appendix K) .

RELATIONSHIPS BETWEEN RESERVOIR OPERATION AND RESERVOIR HABITAT

We will be using our computer map data base and the GEOSCAN program to estimate available habitat for fish and fish food organisms based on reservoir elevation. This program will allow us to estimate volumes of water by depth contour (and temperature contour), amount of near-shore habitat, etc.

IMPACTS OF RESERVOIR OPERATION ON THE FISHERY

We initially envisioned our study would focus primarily on the maximum annual drawdown, however, while that aspect of operation is important there may be other components of reservoir operation which also affect reservoir fisheries. The timing of refill and drawdown, the length of time the reservoir remains at full pool, the problems associated with an inability to refill, and the volumes of water discharged are all operational components which may influence the fishery. We began this study as a two phase project. Phase I (from 1 Way 1983 through 30 September 1986) was proposed for collection and interpretation of data and the development of a data base to evaluate potential operational regimes on the reservoir fishery; and Phase II (from 1 October 1986 through 30 September 1987) was proposed as an effort to cooperatively evaluate all study efforts on irmpacts of reservoir operation for establishing an operation plan that would protect or enhance reservoir fisheries while meeting other hard constraints (MDFWP 1983).

In developing a sampling regime for the study we wanted to ensure that our sampling effort collected all necessary data needed to model or predict impacts of, as yet, unknown reservoir operationalregimes. To that end we contacted a number of experts in the limnological and fishery modeling field including the USGS, Aquatic Ecosystems Analysts (former members of the Fish and Wildlife Service's Reservoir Research Group) and the Fish and Wildlife Service's Habitat Evaluation Procedures Group.

We eventually subcontracted with the USGS because: they have been measuring physical-chemistry parameters and primary production in Libby Reservoir since its formation; Woods and Falter (1982)

Table 19. Seasoml average densities (number per hectare) and biomass (grams per hectare) of terrestrial and aquatic macroinvertebrates captured on the surface of three areas of Libby Reservoir during August 1983 through July. 1984.

Season/Year	Tenmile N.S.	Tenmile L.	Tenmile Avg.	Rexford N.S.	Rexford L.	Rexford Avg.	Canada N.S.	Canada L.	Canada Avg.
Number per Hectare									
Summer/1983	(14 tows)			(10 tows)			(8 tows)		
Terrestrial	93	463	278	23	58	41	29	38	34
Aquatic	17	21	19	7	10	9	17	46	32
Total	110	484	297	30	68	50	46	84	66
Fall/1983	(16 tows)			(14 tows)			(10 tows)		
Terrestrial	18	22	20	19	64	42	483	43	263
Aquatic	10	10	10	9	19	14	100	10	55
Total	28	32	30	28	83	56	583	53	318
Winter/1984	(8 tows)			(12 tows)			(frozen)		
Terrestrial	--	--	--	47	49	48			
Aquatic	--	--	--	3	22	13			
Total	--	--	--	50	71	61			
Spring/1984	(28 tows)			(26 tows)			(dewatered)		
Terrestrial	58	49	53	16	11	14			
Aquatic	113	158	135	258	436	347			
Total	171	207	188	274	447	361			
Spring/1984	(18 tows)			(12 tows)					
Terrestrial	83	52	67	143	51	97	50	43	46
Aquatic	23	26	25	25	17	21	25	17	21
Total	106	78	92	168	68	118	75	60	67
Grams per hectare									
Summer/1983	(14 tows)			(10 tows)			(8 tows)		
Terrestrial	4.37	1.91	3.14	0.48	2.93	1.71	0.72	1.41	1.07
Aquatic	0.05	0.12	0.09	0.01	0.01	0.01	1.02	1.04	1.03
Total	4.42	2.03	3.23	0.49	2.94	1.72	1.74	2.45	2.10
Fall/1983	(16 tows)			(14 tows)			(10 tows)		
Terrestrial	0.06	0.20	0.13	0.15	0.90	0.53	1.26	2.51	1.88
Aquatic	0.05	0.01	0.03	--	--	--	0.31	0.05	.18
Total	0.11	0.21	0.16	0.15	0.90	0.53	1.57	2.56	2.06
Winter/1984	(8 tows)			(12 tows)			(frozen)		
Terrestrial	--	--	--	0.12	0.14	0.13			
Aquatic	--	--	--	0.01	0.03	0.02			
Total	--	--	--	0.13	0.17	0.15			
Spring/1984	(28 tows)			(12 tows)			(dewatered)		
Terrestrial	1.33	0.23	0.78	0.40	0.08	0.24			
Aquatic	0.47	0.60	0.54	0.71	1.48	1.10			
Total	1.80	0.83	1.32	1.11	1.56	1.34			
Summer/1984	(18 tows)			(12 tows)			(12 tows)		
Terrestrial	1.56	0.44	1.00	1.96	0.70	1.33	0.69	0.35	0.52
Aquatic	0.18	0.10	0.14	0.26	0.05	0.15	1.02	0.07	0.55
Total	1.14	0.54	1.14	2.22	0.75	1.48	1.71	0.42	1.07

developed an initial primary production model using Libby Reservoir information: and they maintain a District Office in Helena. The USGS had no one available with expertise in both modeling and fish population dynamics, consequently, they were able only to look at simple linear relationships between reservoir drawdown, fish growth and fish abundance (Appendix L). They found no significant correlations which was not surprising since the majority of past research has suggested multivariate control of fish abundance and growth. They developed a flow chart outlining a modeling strategy with our assistance (Appendix L). Gene Ploskey of Aguatic Ecosystem Analysts suggested we wait until the end of our data collection period, allowing the data to direct our modeling effort. He assured us that our sampling program was rigorous enough to cover the development of a trophic dynamics model, but cautioned that we may want to develop a conceptual model because our sampling period may not be long enough to develop a realistic trophic dynamics model (Appendix M). The following is a discussion of what variables and relationships we will be evaluating to predict the effects of reservoir operation on fish populations in Libby Reservoir.

fish food

Zooplankton

zooplankton production is dependent upon primary production which is dependent upon sunlight energy and nutrient availability. Woods and Falter (1982) developed a multiple regression to predict area1 primary productivity in Libby Reservoir. Three of the six variables selected in their multiple regression (euphotic extinction coefficient, stability of primary thermocline, and flushing rate) are controlled or influenced by reservoir operation.

The amount of useable habitat available to zooplankton also may limit zooplankton production. We will be documenting changes in zooplankton standing crops related to changes in reservoir volume within the upper 30 m of the water column. Thermal regimes and hydrodynamics within the reservoir also affect zooplankton production. We discuss thermal model predictions later under "Modeling". Flushing rates also have been shown to contribute significantly to zooplankton mortality rates (Ploskey 1983) and there is evidence for that happening in Libby Reservoir (personal communication John Irving, Argonne National Laboratory, Argonne, Illinois).

Lastly, predation upon zooplankton populations by fish in Libby Reservoir is probably the largest cause of zooplankton mortality. We need to investigate the effects of concentrating fish and their zooplankton prey by reducing pool volumes on both fish and zcoplankton populations.

Benthos

It was obvious from our data that reservoir operation negatively impacts benthic standing crops. We need to determine how fast recolonization occurs and if recolonized areas ever fully recover. Preliminary calculations indicated fish production could be increased by as much as 15 kg for every hectare of reservoir bed that changed from a frequently dewatered zone to an occassionally dewatered zone. This increase was based on the assumptions that all Diptera are eaten by fish, either in the larval or adult stage, and assumes a food conversion rate of 75 percent (Leidy and Jenkins 1979). We need to estimate generation times for Diptera to determine the production of Diptera within the reservoir. The relationships between temperature, depth, substrate type, and length of a single life cycle for Diptera will be used to make these estimtes. The above values will be obtained from the literature.

Surface Macroinvertebrates

While surface macroinvertbrates have been shown to be an important seasonal food item (McMullin 1979), their distribution was temporally patchy on the surface. Numbers of macroinvertebrates on the water's surface were often higher in the limnetic zone when compared to the near-shore zone. This result may be caused by the use of surface macroinvertebrates as food by trout which were found at a higher concentrations in near-shore zones. The direct relationship between surface macroinvertebrates and surface area of the reservoir is obvious. More surface area provides a higher probability an insect will land on the reservoir's surface. The aquatic adult component of the surface macroinvertebrate community during the spring probably provides an important food source for adult Salmo spp. prior to their spawning migration.

Fish

Distribution of Salmo spp., bull trout and kokanee appeared to be regulated, in part, by the thermal regime within the reservoir. Changes in operation which alter this thermal regime may impact fish production by regulating fish distribution. We have showen that the relative abundance of Salmo spp. were generally higher in near-shore zones compared to limnetic zones. Quantity of near-shore habitat may change differently than linmetic habitat with changing reservoir elevations. Salmo spp. were much more abundant in the upper geographic area (Canada), during the fall based on purse seine catches (Table 8). Early drafting of the reservoir would limit the amount of this upper-reservoir habitat.

Lower water elevations provide less water volume and concentrates fish. this concentrating effect during the spring may make gamefish more vulnerable to anglers. There has historically been a popular early spring fishery for salmo spp.. this aspect of reservoir operation may be desirable depending upon angler harvest throughout the year.

Water temperature affects fish growth rates. Reservoir operation influences thermal regimes within the reservoir. Fish growth is also regulated by food production and availability which reservoir operation has been shown to influence. Analyses of otolith samples will provide estimates of seasonal growth, allowing us to compare seasonal growth between years of varying operation.

It may be possible to evaluate operational effects on fish abundance by comparing annual trend and population estimate data to past reservoir operation. However, deep drawdowns and the initial "trophic surge" common in new reservoirs occurred simultaneously making it difficult to determine causative agents in the response of fish populations. Using fish growth and abundance information, we should be able to derive an index of fish production on an annual basis.

Estimating total and angler-harvest mortality rates for Salmo spp. between the spring and fall of successive years will enable us to estimate natural mortality rates. We assume natural mortality is influenced by reservoir operation. We also have estimates of spawning mortality, so we should be able to tie natural mortality directly to reservoir residence.

Modeling

The goal of this study is to provide decision makers with information describing impacts of various reservoir operational regimes on the reservoir fishery. To that end we will be developing a predictive model which will allow decision makers to understand trade-offs and opportunities provided by different reservoir operation regimes. We presently feel that a conceptual model will be a logical starting place, based on recommendations from Gene Ploskey (Aquatic Ecosystems Analysts, Fayetteville, Arkansas). After analyses of our data this spring, we will develop a compartmentalized conceptual model. If we find that our data suggests development of a trophic dynamics model is appropriate we will begin constructing a predictive model. We feel confident that some type of predictive model can be developed, but we may need to look at relative, rather than actual, values.

Natural variation within fish and fish food components will probably be high enough to limit confidence in values predicted by any model. Regardless of the type of model developed, the modeling effort will increase our understanding of how reservoir operation impacts a cold-water fishery and that information will be valuable in deciding how to best mesh reservoir operation and the maintenance of a reservoir fishery.

We plan to "filter out" much of the environmental variation by using a thermal predictive model (Adams 1974). Since temperature regulates or controls many functions of both fish and fish food organism, we plan to predict the thermal regimes within the reservoir using the above modle. This model will allow us to hold environmental variables (volume of inflow, temperature of inflowing waters, and solar radiation) constant, while evaluating impacts of operational variables (discharge volumes, timing of discharge, and depth of discharge) on the thermal regime within the reservoir. We can then use these predicted thermal regimes to predict fish distribution patterns, primary productivity (using Woods and Falter's (1982) model), zooplankton productivity (as an index related to primary productivity) and losses (based on generation times and flushing rates), and fish growth.

We can also use changes in reservoir surface area, reservoir bed area, reservoir volume by depth (temperature) contour interval, reservoir volume by zone (limnetic versus near-shore), and shoreline length estimated by the GEOSCAN program to guantify changes in habitat used by fish and fish food organisms. Using the GEOSCAN estimates in conjunction with the thermal prediction modle will enable us to predict operational effects.

RECOMMENDATIONS

1. Continue sampling as modified below:

    a) collect food habits data through August 1985, then switch to either cursory or pooled food habits analyses:

    b) investigate desirability of sampling macroinvertebrates on the reservoir's surface more frequently during the period April through October

    c) use seasonal rather than monthly horizontal gill netting to sample fish abundance;

    d) collect three zooplankton samples per area each sample trip;

    e) relate euphotic zone depth to secchi disk depth:

    f) sample for burbot larvae by towing an icthyoplankton net during March through June;

    g) electrofish representative tributary stream reaches to provide data for developing a model to predict potential of tributaries for producing trout;

    h) change seasonal criteria to represent thermal changes within Libby Reservoir; and

    i) conduct diurnal sampling of both fish and fish food organism distributions in at least one area of Libby Reservoir.

2. Conduct a creel census and economic survey of the recreational fishery.

3. Use log (x+1) and log (x) transformations on all fish and fish food data for statistically comparing annual abundance.

4. sample downstream losses of zooplankton and fish below Libby Dam.

5. Delay trophic dynamic model development until enough data has been collected. Use present information to develop a conceptual model.

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