Libby Reservoir Water Levels

...n or Enhance Reservoir Fisheries

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QUANTIFICATION OF LIBBY RESERVOIR WATER LEVELS NEEDED TO MAINTAIN OR ENHANCE RESERVOIR FISHERIES

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EXECUTIVE SUMMARY

The first six months of the fishery investigations in Libby Reservoir were aimed at developing suitable methodology for sampling physical-chemical limnology, fish food availability, fish food habits, and seasonal distribution and abundance of fish populations. Appropriate methods have been developed for all aspects with minor modification of original proposed methodologies. Purse seining has yet to be tested. Physical-chemical limnologic sampling could be reduced or subcontracted with the U.S. Geologic Survey to allow for more intensive sampling of fish food or fish distribution portions of the investigation. Final sample design will be determined during 1983-84.

Future directions of the study revolve around two central issues, the potential for flexibility in reservoir operation and determination of how reservoir operation affects fish populations. Simulated maximum drawdown levels during a 40-year period were controlled by power in seven out of eight years. Drawdowns were generally within 10 feet of the flood control rule curve, however. There may be more flexibility with regards to timing of refill and evacuation. This aspect needs to be evaluated further.

Production and availability of fish food, suitability of reservoir habitat, and accessibility of off-reservoir spawning and rearing habitat were identified as components of fish ecology which reservoir operation could potentially impact. Two models based on trophic dynamics and habitat suitabilities were suggested as a framework for exploring the relationship of reservoir operation on the fish community.

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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 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 (defined as twentieth 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 Corps of Engineers (COE) 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)(1)], the COE shall consult with MDFWP to determine which requirement shall be preferred (Northwest Power Planning Council 1982).

This study was initiated May, 1983 to meet the following objectives:

1) Quantify reservoir habitat by segregating the reservoir into geographic areas, shoreline versus pelagic zones, and vertically, based on physical and chemical attributes.

2) Assess use of available reservoir habitats by important fish species and document seasonal changes in habitat use based on reservoir operation. Determine the abundance and availability of fish food items in the reservoir including the distribution, abundance and composition of

the zooplankton community, the benthic community, surface insects and forage fish. Quantify the seasonal use of food items by important fish species.

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

4) Estimate impacts of various levels of drawdown on affected fish populations.

This report contains two major segments. The first segment presents methods used to collect information during the first six months of the study (May through October, 1983) and summarizes results of stream trapping. Since the primary goal of these first six months was to develop an appropriate sample design, the data collected represents limited information. The thrust of this portion of the report is to document suitable techniques for meeting the objectives. Results from June, 1983 to October, 1984 will be fully presented and discussed in next year's annual report.

Metric units are used throughout this report except for reservoir elevation, reservoir volume, reservoir area, and stream discharge which will be reported in feet above mean sea level, acre-feet, acres, and cubic feet·second^{-1} (cfs), respectively. We are using this convention because these are the units used by water managers.

The second segment of the report presents a prospectus which will: 1) describe the physical environment and biotic community of the reservoir and discuss the factors potentially controlling fish population levels; 2) explain present and proposed reservoir operation and how reservoir operation is controlled; 3) introduce ideas on what flexibility might exist in reservoir operation to benefit fish; 4) explore the possible relationships which may exist between reservoir operation and the biotic community; and 5) conceptualize how a model could be developed to meet study objectives.

STUDY AREA DESCRIPTION

The Kootenai River drains an area of 49,987 km^2 covering portions of British Columbia, Montana, and Idaho (Figure 1). A detailed description of the study area was presented by Bonde and Bush (1975) and Woods (1982).

PHYSICAL ENVIRONMENT

Kootenai River Drainage

Following impoundment of the Kootenai River by Libby Dam, approximately 145 km (90 mi.) of the river was transformed to a reservoir with annual vertical water level fluctuations of up to 52.4 m (172 ft.) (Figure 2). The length and depth of the reservoir changes dramatically with these fluctuations (Figure 3). At full pool, Libby Reservoir contains 5.869 million acre feet (7.16 km^3) of water with a surface area of 46,456 acres (18,801 ha) and a mean depth of 126 feet (38.5 m). At the maximum allowable drawdown (172 feet), reservoir volume is reduced by nearly 85 percent, surface area is reduced by 69 percent, and mean depth is reduced by 51 percent. At a drawdown of 90 feet (the upper drawdown limit recommended), reservoir volume is reduced by 55 percent, surface area is reduced by 42 percent, and mean depth is reduced by 22 percent.

Available Nutrients

Prior to impoundment of the Kootenai River by Libby Dam, nutrient loadings to the upper Kootenai River were large enough that Bonde and Bush (1975) predicted the reservoir had a high potential to become eutrophic. The source of much of the phosphorous input to the upper river was a fertilizer plant near Kimberley, British Columbia. Woods (1982) determined that based on daily areal primary productivity (range: 63.6 to 105.5 $mg \cdot C \cdot m^{-2}$). Libby Reservoir was at the lower end of the oligotrophic classification. He attributed this discrepancy between the oligotrophic rating based on areal primary productivity and the eutrophic rating based on nutrient inflows to the inability of nutrient loading models to account for physical and limnological processes which controlled the availability of nutrients to phytoplankton.

In 1975, a Pollution Control permit issued by the province of British Columbia was responsible for forcing Sullivan Mine (Cominco) to upgrade their effluents by recycling and treatment which was accomplished by 1979. This treatment of effluents eliminated the direct discharge of acid mine drainage (and associated heavy metals and fluoride) and significantly reduced phosphorous input (G.G. Oliver, Fish and Wildlife Branch, Ministry of Environment, Cranbrook, B.C., personal communication). Domestic sewage treatment in Cranbrook, B.C. was also upgraded to a spray irrigation project in 1977.

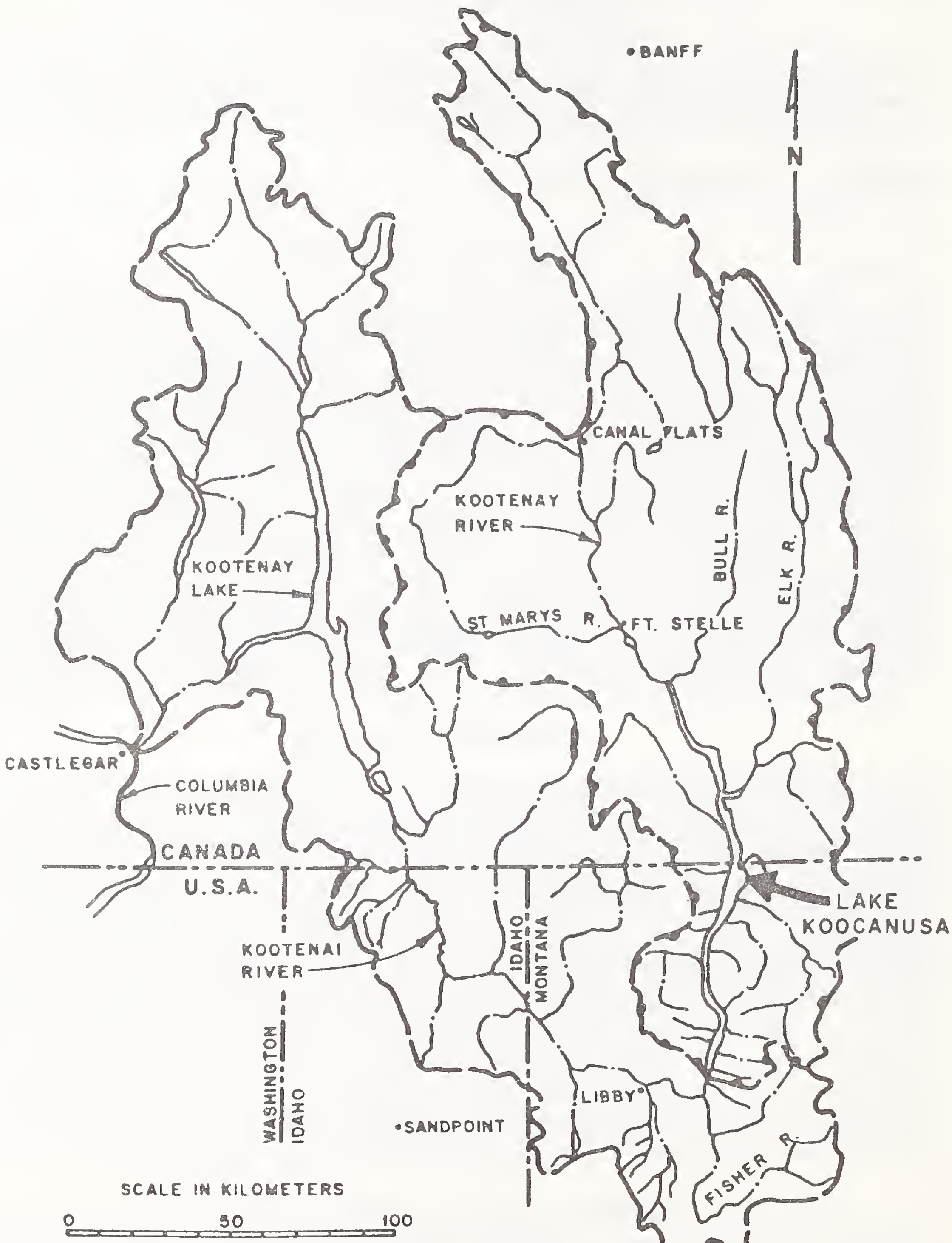
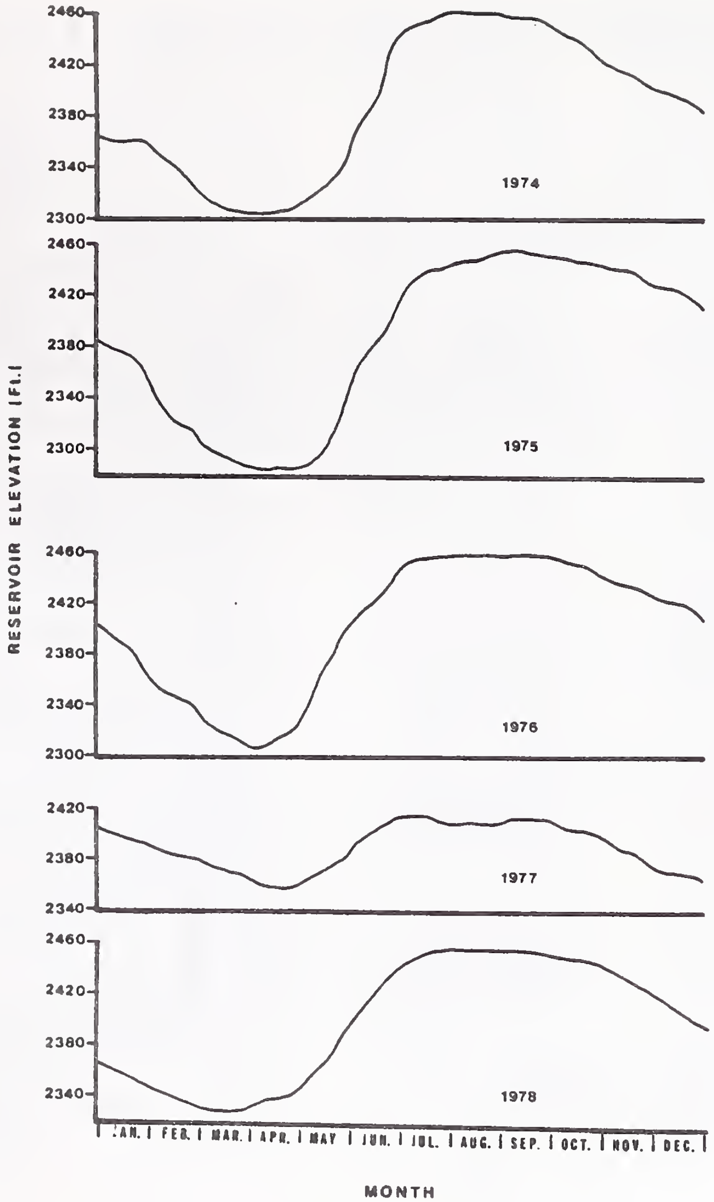


Figure 1. Kootenai (spelled Kootenay in Canada) River Drainage basin (from Woods 1982).



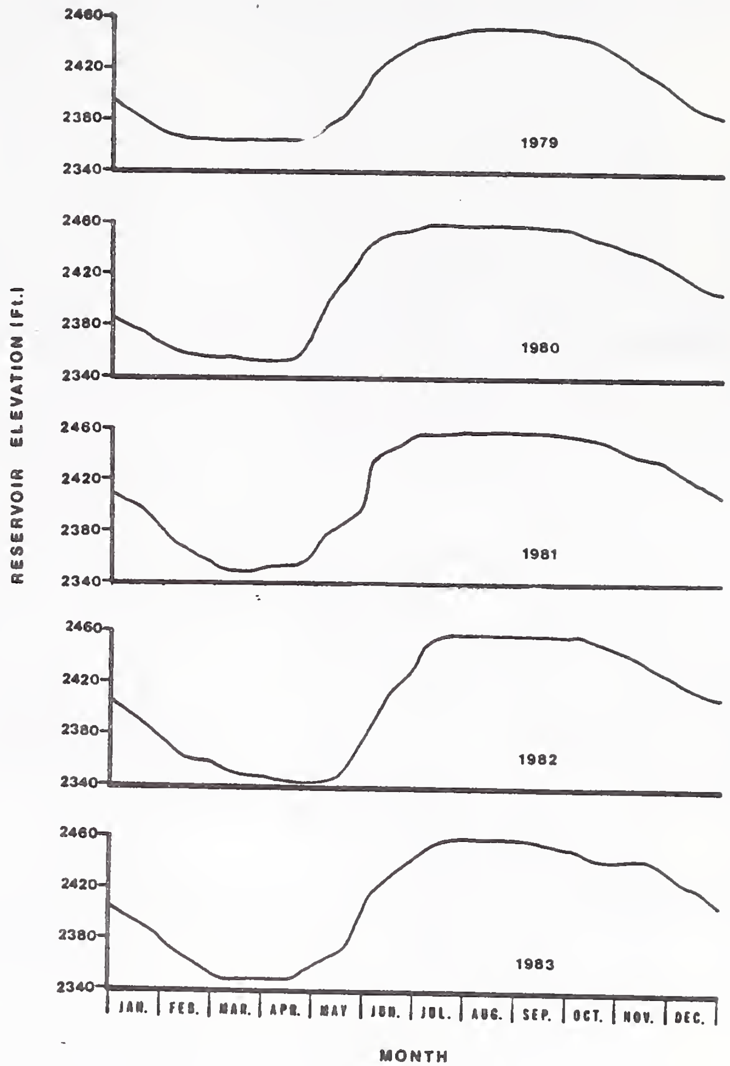


Figure 2. Monthly variations in water surface elevation of Libby Reservoir, 1974 to 1983.

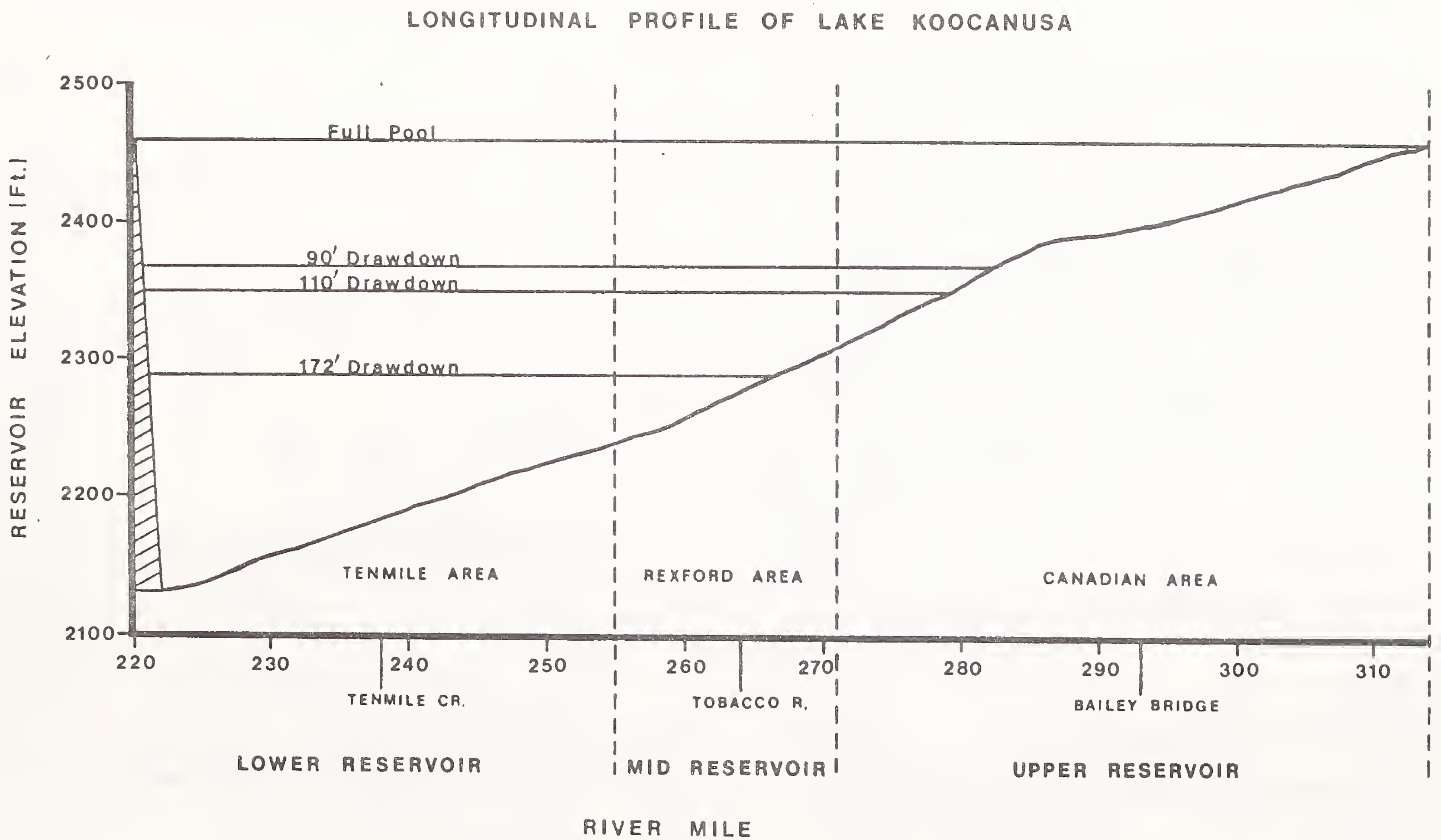


Figure 3. Longitudinal cross-sectional profiles of Libby Reservoir at water surface elevations of 2,459 feet (full pool), 2,369 feet, 2,349 feet, and 2,287 feet (maximum allowable drawdown).

BIOTIC COMMUNITY

Phytoplankton and Zooplankton

Primary productivity in Libby Reservoir was estimated by Woods (1979, 1981, 1982) and Woods and Falter (1982). Irving and Falter (1981) described the species composition, biomass, and spatial and temporal distribution of both the phytoplankton and zooplankton communities within Libby Reservoir during 1977. They found the phytoplankton community was dominated by Chrysophyta and Euglenophyta. The zooplankton community was dominated by *Daphnia* sp. in the upper portion of the reservoir within the United States and *Cyclops* and *Diaptomus* were most abundant in the lower reservoir. Phytoplankton and zooplankton densities peaked in early to mid-summer and were lowest in the winter.

Fish

Westslope cutthroat trout were selected by MDFWP biologists as the target species to manage in the reservoir. Reasons for this decision included: 1) the desirability of managing for a native fish species; 2) the availability of a Hungry Horse Reservoir stock of westslope cutthroat trout already adapted to a fluctuating reservoir environment; and 3) the belief that this species would be able to establish "wild" spawning runs in reservoir tributaries. Consequently, a program to enhance production of westslope cutthroat trout in tributaries to the reservoir was undertaken. The program included rehabilitation of tributaries consisting of one or more of the following: 1) removal of fish passage barriers; 2) chemical treatment to eliminate undesirable fish populations; and 3) imprint planting of cutthroat trout fry (May 1972, 1975, Huston and May 1975a).

As partial mitigation for Libby Dam, the Army Corps of Engineers constructed a westslope cutthroat trout hatchery (Murray Springs Hatchery near Eureka, Montana) which was completed in 1980. Cutthroat trout raised in the hatchery were first released into the reservoir in 1981. Management of the cutthroat trout fishery in the reservoir calls for annual releases of 300,000 yearlings and 500,000 fry into the reservoir.

The fish community in Libby Reservoir has been extensively monitored from impoundment through 1982 under a contract with the U.S. Army Corps of Engineers to: 1) monitor population trends of major fish species; 2) seasonally determine the vertical and horizontal distribution of major fish species in the forebay area; 3) collect data on angler harvest and movement of game fish; 4) determine growth rates and condition factors of major game fish species; and 5) determine food habits of rainbow and cutthroat trout (Huston and May 1975b, May and Huston 1976, 1977, 1978, 1980, 1981, McMullin 1979, May et al. 1979). A final report summarizing their work is presently being completed (Huston et al., in prep). The relative abundance of each species in the reservoir and trend of abundance procured from gill net and creel census sampling suggests the reservoir's fish community is still in a state of flux (Table 1).

The incidence of hybridization between rainbow and cutthroat trout has been steadily increasing since 1975 making it difficult to assess population trends for these species. Individual fish belonging to the rainbow-cutthroat species complex have been increasingly difficult to visually identify to species using external morphological characteristics. This continued hydridization threatens the genetic integrity of the stock of westslope cutthroat trout produced naturally in reservoir tributaries. Gill net catches and creel census data indicated abundance of rainbow trout was increasing or remaining relatively stable, while the abundance of cutthroat trout was declining (May and Huston 1981). Hatchery-raised cutthroat trout were believed to contribute as much as 50 percent to the reservoir's population of cutthroat trout in 1982 (Huston et al., in prep.).

Kokanee salmon abundance increased dramatically during recent years and a large spawning run was observed in 1982. The origin of this large year-class was probably an unauthorized release of kokanee fry from the Kootenay Trout Hatchery, upstream from the reservoir in British Columbia (Huston et al., in prep.) Age information indicated the 1982 spawning run was dominated by the 1980 year class. Mountain whitefish and redside shiner abundance has declined in recent years, while peamouth abundance has steadily increased. Theories for these causes of the changes in the fish community and implications of those changes will be explored in the prospectus segment of the report.

Table 1. 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.

Common 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	*Salvelinus confluentus*	C	S
Brook trout	*Salvelinus fontinalis*	R	S
Lake trout	*Salvelinus namaycush*	R	S
Kokanee salmon	*Oncorhynchus nerka*	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[f]
Nongame fish species			
Pumpkinseed	*Lepomis gibbosus*	R	S
Yellow perch	*Perca flavescens*	R	I[e]
Redside shiner	*Richardsoniusi balteaus*	C	D[g]
Peamouth	*Mylocheilus caurinus*	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 Kootenay Trout Hatchery, B.C.

e/ Increasing trend for yellow perch based on first occurrence in recent gill net catches.

f/ 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.

g/ Decreasing abundance of redside shiners was based on gill net catches which capture only larger (>100 mm) individuals.

METHODS

STUDY AREAS AND SAMPLE SITES

Libby Reservoir was segregated into three study areas (Tenmile, Rexford and Canada) based on reservoir morphometry and the effects of drawdown (Figures 4 and 5). Within each of these study areas, buoys were placed at a permanent sampling site for water quality and zooplankton sampling. Vertical gill net, horizontal gill net (floating and sinking), and benthic invertebrate sampling was conducted near these permanent buoys, except in the Canadian area which was too shallow for vertical gill nets. In addition to these permanent sample sites, random transects were plotted across the reservoir at visual landmarks for additional zooplankton sampling, purse seining and surface insect sampling.

RESERVOIR HABITAT

Morphometry, Cover and Substrate

A base map of reservoir elevation contours was digitized for storage in our computer. We will overlay various habitat component maps (i.e. cover types or substrate types) upon that base map. This system will allow us to evaluate the effects of water level elevation changes within the reservoir upon fish habitat. Additional maps have been ordered from the U.S. Army Corps of Engineers and British Columbia's Survey and Mapping Branch.

Reservoir morphometry will be assessed by digitizing contour maps of the reservoir area prior to impoundment (U.S. Army Corps of Engineers, Seattle District, District File Number (E53-1-154, Sheets 1-37, 1 inch = 400 feet, 10=foot contour interval, 1972 and British Columbia Ministry of Environment, Map Production, surveys and Mapping Branch, Drawing M-249-C, Sheets 1-63, 1 inch = 200 feet, 5-foot contour interval, 1969) using a Baush and Lomb digitizer (Model - 7048, Huston Instruments) connected to a Discovery computer (manufactured by Action Computer Enterprises). Each 10-foot contour interval will be digitized by geographic area (Tenmile, Rexford, and Canada). The area and volume of each 10-foot interval can then be computed using the program GEOSCAN developed by MDFWP (Lonner and Paxton, in prep.).

In April 1984, when the reservoir is expected to be at an elevation of 2,370 feet (89 feet below full pool), a visual survey of cover and substrate types will be done by boat. The surveyors will sketch locations of substrate types and cover types between the full pool level and present pool level onto base maps between 10-ft. contour intervals. Cover types will be submerged trees, stumps, complex rock structures, manmade or none. Substrate types will be irregular bedrock, smooth bedrock, boulder, cobble, gravel, sand and silt. These cover and substrate types will be digitized

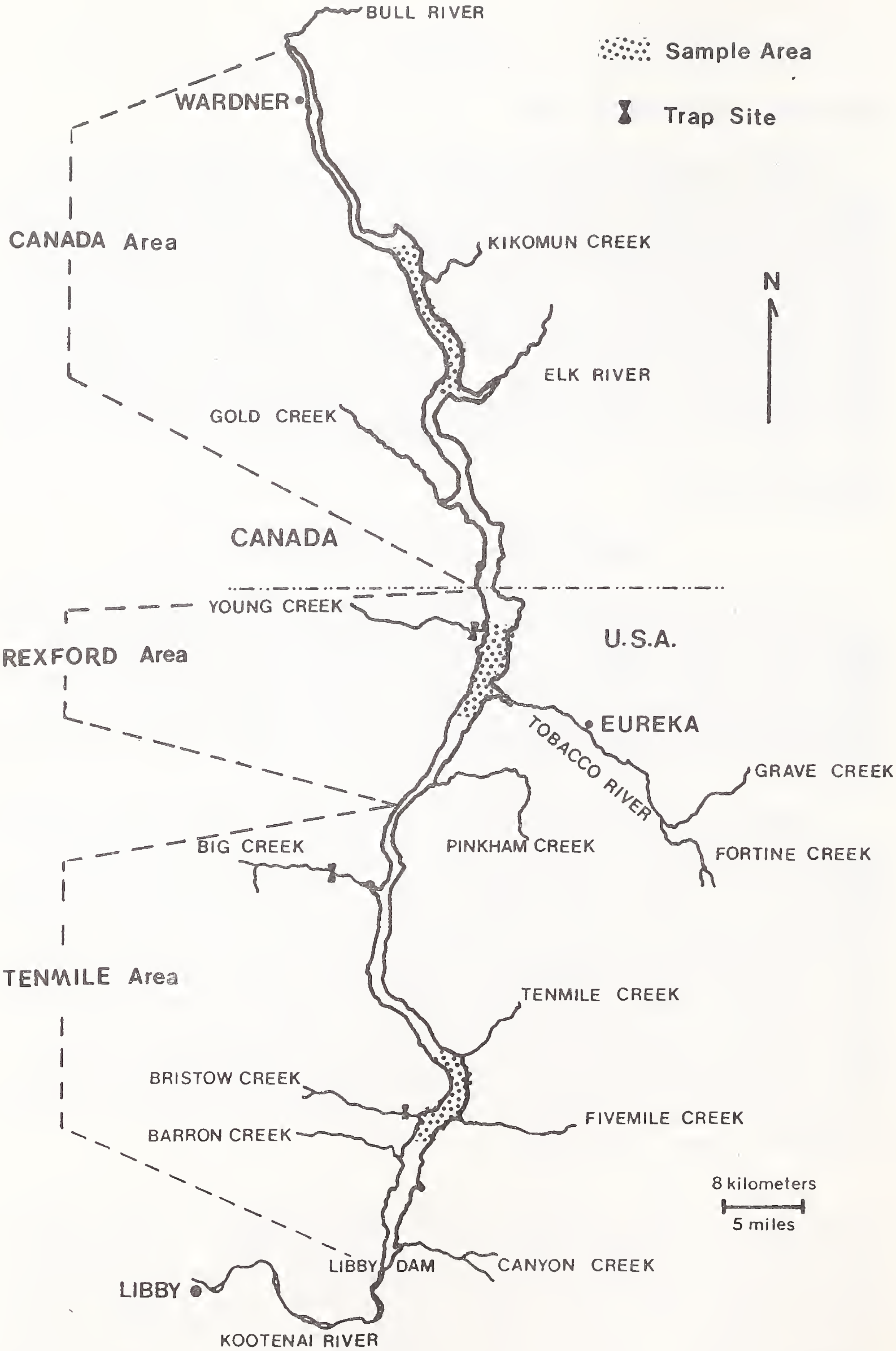


Figure 4. A map of Libby Reservoir showing important tributaries, geologic study areas, and downstream trapping sites.

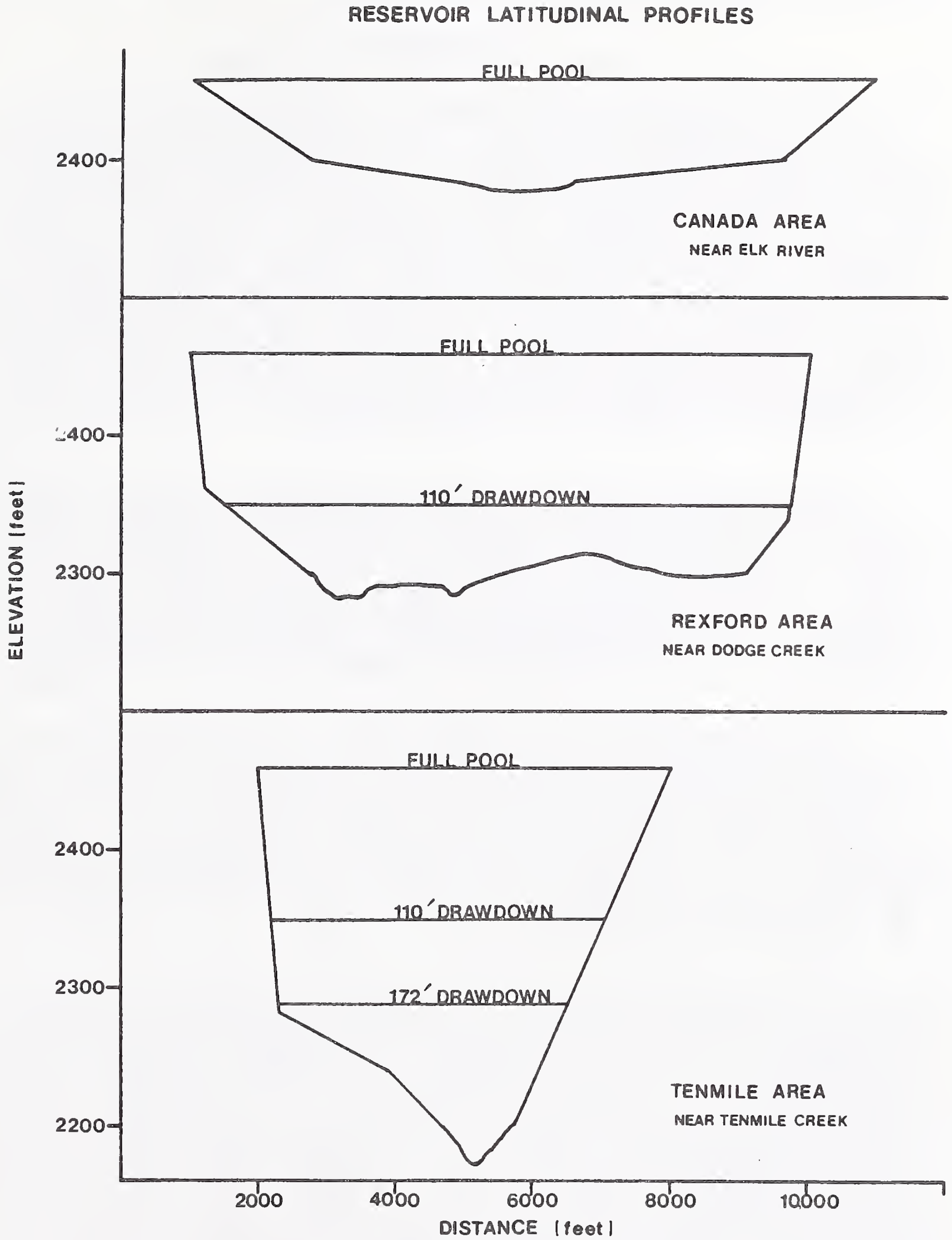


Figure 5. Typical cross-sectional profiles of Libby Reservoir across the Tenmile, Rexford, and Canada study areas.

over the contour map to form an overlay to assess habitat at various reservoir elevations and depths.

Physical-Chemical Limnology

Water temperature (^{o}C), dissolved oxygen ($mg \cdot liter^{-1}$), pH, and conductivity ($umhos \cdot cm^{-1}$) were measured with a Martek Mark V digital water quality analyzer at the permanent sampling buoys. Measurements were taken biweekly from May through October and will be taken monthly November through April. In addition to our sampling, the United States Geologic Survey (USGS) sampled monthly from May through October at three stations within the reservoir (for locations see Storm et al. 1982). Depth integrated measurements were recorded at the surface and one meter, then every two meters down to 15 m, every three meters down to 60 m, and every five meters down to 100 m or the bottom.

Sampling was done according to methods used by the USGS which also uses Martek Mark V meters (Greeson et al. 1977). This included calibration of the meter in the field following the manufacturer's instructions. When meter readings were in doubt, water samples were collected in the field and returned to the laboratory for analysis. Accuracy reported by the meter's manufacturer were: temperature $\pm 0.1^{o}C$, conductivity ± 10.0 $umhos \cdot cm^{-1}$, pH ± 0.1 unit.

Light penetration was measured in foot candles with a Protomatic photometer. Incident light was recorded above the water's surface and the amount of light was measured immediately below the water's surface and at one meter depths down to 30 m. The lower boundary of the euphotic zone has been defined as the depth at which light penetration is reduced to one percent of incidence (Greeson et al. 1977).

Several problems were encountered during measurements of physical-chemical profiles. Field calibration of the Martek meter requires a minimum of one hour at each sampling station. At ambient air temperatures below $0^{o}C$ field calibration was impossible and the conductivity probe would not function. All calibration had to be done in the laboratory prior to field sampling during cold weather and water samples were collected and returned to the laboratory to verify the meter's readings. We believe the time spent calibrating the Martek meter for dissolved oxygen, pH, and conductivity might be better spent in other aspects of the study. A review of past data (Storm et al. 1982) indicates the range of values for these constituents were within tolerance limits for fish species found within the reservoir. We plan to explore the feasibility of subcontracting with the USGS to intensify their sampling of the reservoir to provide these data.

FOOD AVAILABILITY

Zooplankton

Crustacean zooplankton was sampled from the upper 30 m of the water column. Irving and Falter (1981) stated that most of the zooplankton in Libby Reservoir was concentrated above 22.9 m during 1977 and 1978. Two 30 m vertical tows were made biweekly in each geographic area from mid-August through October, 1983 using a 153 micron mesh conical plankton net. Samples were collected using a net having a 0.3 m diameter orifice with the exception of the August samples which were collected using a 0.115 m diameter net. Samples in each area were taken at the permanent limnological buoy and at one randomly selected site each sampling trip. Samples were collected according to methods presented in Leathe and Graham (1982).

Vertical distribution of zooplankton was assessed using a 28.1-liter plexiglass Schindler plankton trap (Schindler 1969). A plankton trap sample series consisted of samples collected from the surface and every three meters down to 15 m, and then every five meters down to 30 m. Plankton trap sample series were conducted in the three areas at the permanent limnological buoys in September and October.

Zooplankton samples were preserved in a solution of methyl alcohol, formalin, and acetic acid. Samples were diluted in the laboratory to a concentration at which each five ml subsample contained approximately 80 to 100 organisms. Schindler trap samples were concentrated to 25 ml. Counting cells were fabricated out of lexan plastic (glued to glass) in which a continuous 5 ml channel had been cut. Five 5.0 ml subsamples were counted.

A variable power dissecting microscope set at 20X was used to count zooplankters. Zooplankters were classified to genus (*Epischura, Cyclops, Diaptomus, Daphnia, Leptodora, Bosmina*) and all juvenile copepods were identified as nauplii. We were unable to identify individual plankters to species with any degree of confidence because of an apparent wide variation in morphologic characteristics within species. Densities were expressed as numbers·liter^{-1}. One random 5.0 ml subsample was used to measure carapace length of each individual plankter by genus using a graduated field in one ocular of the microscope. Biomass of zooplankters will be estimated using length-weight relationships of Bottrell et al. (1976).

Surface Insects

Surface insects were sampled using a meter net towed along the water's surface. The net consisted of a one meter wide by 0.3 m high frame to which was attached a net consisting of 3.17 mm mesh ace bobbin netting tapered back to 1.59 mm mesh bobbin netting with a collar. A removable plexiglass bucket was attached to this collar. The bucket had a panel of 80 micron netting to filter the surface water and retain all insects.

Two randomly selected sites in each area were sampled biweekly, August through October. Two samples were collected at each sample site. Each sample was collected by towing the net at approximately 1.0 $m \cdot sec^{-1}$ for 10 minutes in a zig-zag pattern. One tow was made within 100 m of shore and one further than 100 m from shore.

All insects were preserved and individuals were identified to order and counted. Blotted wet weights of all individuals by order were measured in grams. Densities of insects were expressed as numbers and weight per hectare.

Temporal and areal distribution of insects on the reservoir's surface was patchy. There was no distinct relationship between numbers of insects captured and zone of the reservoir (near-shore versus open water). We may need to sample surface insects more intensively to adequately assess their abundance and availability as fish food.

Benthic Invertebrates

Benthos samples were collected for the fall season during October with a Peterson dredge from pre-selected sample transects in each area. Nine samples were collected from each area; three above elevation 2,370, three between 2,370 and 2,287, and three below 2,287. In the Canada area, only six samples were collected; three above elevation 2,370 and three from the permanently wetted river channel.

Benthos samples were sieved in the field by washing the sample through 5.6, 0.85 and 0.52 mm sieves with buckets of water. The material retained on the 0.52 mm sieve was collected and preserved. All macroinvertebrates were picked from the sample and identified to order or class (Diptera and Oligocheatea). Numbers and total blotted wet weights were determined and densities were expressed as $numbers \cdot m^{-2}$ and $grams \cdot m^{-2}$.

FISH DISTRIBUTION AND ABUNDANCE

Near-Shore Sampling with Horizontal Gill Nets

Standard Montana experimental floating and sinking gill nets were used to sample fish in near-shore areas. These nets are 38.1 m long and 1.8 m deep and consist of five equal length panels of 1.9, 2.5, 3.2, 3.8, and 5.1 cm mesh. Floating nets sampled from the surface down 1.8 m and sinking nets sampled from the bottom up 1.8 m. A floating net set consisted of two floating nets tied end to end (double floater) and fished perpendicular from shore. A sinking net consisted of a single sinking net fished perpendicular from shore. Five to seven double floaters and two sinkers were set in the evening and retrieved the next morning on a monthly basis in each area.

All fish were removed and species, length (mm), and weight (g) were recorded for each game fish and a representative subsample of approximately twenty of each species of nongame fish. Sex and state of maturity (ripe, spent, mature or immature) were recorded for game fish. Scale and/or otolith samples were taken from all game fish.

Species of cutthroat trout, rainbow trout, and their hybrids were identified using external morphological characteristics throughout this study. Frequent errors in identification are made when using this technique (Leary et al. 1983). We plan to verify species composition and identification using electrophoretic analysis during 1984-85.

Horizontal gill nets were found to be effective for sampling most fish species in near-shore habitats at night. We found only limited numbers of bull trout and burbot in our horizontal gill nets. We need to find a better technique for sampling these two important predators. Larger samples of predators would be useful in determining food habits of both species and the spawning period of burbot.

Vertical Distribution

Eight vertical gill nets were set monthly in two banks of four at permanent buoys in the Tenmile and Rexford areas (Figure 4). Nets were set in the evening and retrieved the next morning using methods described by Horak and Tanner (1964). The nets used were 3.7 m wide and 45.6 m deep and depths were marked in 1.0 m increments. Each bank of four nets included nets of mesh size 19, 25, 32, and 38 mm. Fish were removed as nets were retrieved and their depth of capture was recorded in addition to information described in the previous section.

Vertical gill nets were found to be effective for capturing fish from the pelagic zone of the reservoir at night. Vertical nets also provided insight into depth distribution of these pelagic fish species and gave us an indication of what fish species we observed as "targets" using hydroacoustic sampling.

Hydroacoustic sampling was conducted using a model HE-356A Honda Si-Tex Depth Recorder in conjunction with vertical netting. Three permanent transects were located in each area and hydroacoustic runs were made across these transects once monthly during the day and at night, beginning in October.

Hydroacoustic sampling was valuable when fish were distributed throughout the water column in pelagic zones of the reservoir. Hydroacoustic sampling could not identify "targets" (fish) located near the surface or near the bottom and seemed to be of limited use near shore. We plan to expand our hydroacoustic sampling to cover random transects in addition to the permanent transects. This random hydroacoustic sampling could be done in conjunction with surface insect tows and would provide information to validate the assumption that fish numbers and distributions in our sampling areas were representative of that geographic area.

Purse Seining

A 183 m long by 9.1 m deep purse seine was fished several days to test its efficiency. The seine was made up of two 76.2 m long panels of 19 mm mesh net with a 30.5 m long bunt of 9.5 mm mesh in the center. The small mesh size of the bunt contributed to slow pursing times which was believed to greatly reduce the seine's effectiveness. We are now modifying the seine by removing the bunt and replacing it with a 30.5 m long section of 19 mm mesh to reduce drag during pursing. Intensive purse seine sampling will be done during the spring and fall when cool surface water temperatures allow fish to concentrate near the water's surface where they are available to the seine.

FOOD HABITS

Food habits of the major fish species were assessed seasonally in all three areas. We collected stomachs from a representative number of each species of all game and nongame fish and two size classes of westslope cutthroat and rainbow trout ($<$330 mm and $\geq$330 mm).

Stomachs will be analyzed according to methods presented by McMullin (1979) and Leathe and Graham (1982). Preliminary analyses of coarsescale and longnose sucker stomachs collected during August found these stomachs contained unrecognizable vegetable and detrital matter. We discontinued collecting sucker stomachs, but will continue cursory field examination of sucker stomachs to ascertain whether they are consuming plankton or macroinvertebrates during any season.

AGE-GROWTH

Scale samples have been collected from all game fish captured in gill nets and downstream traps following methods of Shepard and Graham (1983). Ages will be determined after acetate impressions of scales have been prepared (Shepard and Graham 1983). Growth will be determined by following the average length of each year-class throughout the year and by back calculating growth to each annulus from scale samples collected in the spring and fall. Validation of aging techniques will be evaluated following methods described by Beamish and Fournier (1981) and Beamish and McFarlane (1983). Length-weight relationships will be established based on condition factor.

TRIBUTARY STREAMS

Stream Trapping

A Wolf Trap was operated in Young Creek from 6 June through 21 July and box traps were installed and operated in Big and Bristow creeks from mid-June to 21 July to monitor and tag downstream migrating juvenile and adult trout. Traps were checked twice daily and all fish were removed, anesthesized, measured and weighed. Species, length, weight and tag number and type were recorded for each fish by date. All fish longer than 250 mm were tagged with numbered anchor tags and fish 100 to 250 mm were tagged with numbered dangler tags. Scales were taken for age determination from fish in Big and Bristow creeks.

Habitat Surveys

Habitat surveys were conducted in the majority of the west side tributaries and several east side tributaries by reach according to methods presented in Graham et al. (1980a). Reaches were separated on USGS contour maps (1:24,000) using valley characteristics, channel gradient and amount of tributary inflow.

Westslope Cutthroat Trout Redd Surveys

Surveys of spawning tributaries were conducted to enumerate westslope cutthroat trout redds. All tributaries where spawning was observed in the past (May et al. 1979, Huston and May 1975b) and where spawning was believed possible, were surveyed with the exception of the upper Tobacco River drainage. Surveys were done in late June and early July. Abundant June precipitation kept streamflows high and made redds difficult to distinguish, therefore, redd numbers reported are a minimum count. Locations and number of redds were recorded.

DATA ANALYSIS

Reservoir Habitat

We will evaluate the amount of reservoir habitat available at various water surface elevations using a computer program called GEOSCAN (Lonner and Paxton, in prep.). This program will compute water surface area, reservoir bottom surface area, and water volume based on preselected near-shore and open-water habitats at various water surface elevations. We will have the capability to overlay cover types and substrate types to calculate areas of these habitat components at various water surface elevations. These computations will be done by geographic area.

Physical-Chemical Limnology

Isopleth diagrams of the reservoir will be generated using a USGS computer program called STAMPEDE (Woods and Falter 1982).

Depth integrated physical-chemical measurements will be correlated to depth distribution of zooplankton and fish to investigate what, if any, environment variables may be controlling the vertical distribution of zooplankton and fish.

Fish Food Availability

Analyses of zooplankton, surface insects, and benthic macroinvertebrates were based on density data. Biomass and numbers of each of these three major food categories will be determined on either an areal or volumetric basis. Food availability versus food utilization will be evaluated as a selectivity index using the odds ratio and its log (first introduced by Fleiss 1973, then modified by Gabriel 1978).

Fish Distribution and Seasonal Abundance

Fish distribution and abundance data were analyzed using catch per single net night by species. A Wilcoxon matched-pairs signed-ranks test will be used to determine if a significant difference exists between inner versus outer floating gill nets within each double floating set (Daniel 1978). We will be testing the distribution of net catches using Chi-squared goodness of fit test (Lund 1983). After determining how net catches are distributed, we will decide whether analyses of catches could best be done by transforming the data to normalize it, and then using normal statistics or using nonparametric techniques. We hope to be able to use normal statistics so that we can simultaneously evaluate difference between areas, seasons, and years. Correlation and regression analyses will be used to relate environmental and food abundance variables to fish distribution and abundance.

Food Habits

Food habits data will be summarized for each species by season and size class (when applicable) according to methods presented by Leathe and Graham (1982). Food selectivity will be evaluated using the odds ratio and its log (discussed previously). Diet overlap will be evaluated using either the Schoener index (Schoener 1970) or based on Chi-squared (Pearre 1982).

Migration Patterns of Game fish

Migration patterns of game fish will be assessed from tag return information collected during our sampling and from angler returns. Angler tag returns, especially voluntary tag returns, may bias fish movement data because the distribution of angler pressure is generally not uniform throughout the reservoir and voluntary tag returns are more likely near population centers. A creel census would allow for more complete recovery of angler caught tagged fish and reduce the bias inherent in voluntary angler returns. The program RTRN (Graham et al. 1980b) will be used to sort and analyze migration data.

Tributary Streams

All habitat data will be entered onto the Montana Interagency Stream Fishery Database (Holton et al. 1981). Tables and maps summarizing habitat and fish information for each tributary stream by reach will be prepared similar to those found in MDFWP (1983a, 1983b).

RESULTS AND DISCUSSION

Only stream trapping and spring spawning site surveys are reported in this document. All results from May 1983 to October 1984 will be presented in the 1985 annual report.

STREAM TRAPPING

An estimated 260 adult cutthroat trout immigrated to Young Creek to spawn in 1983 (Joe Huston, MDFWP, Kalispell, Montana, personal communication). From 6 June to 21 July, 1,612 juvenile fish (1,321 cutthroat trout, 288 hybrids and 3 rainbow trout) emigrated to the reservoir from Young Creek. Peak emigration occurred during the latter half of June (Figure 6). June rains seemed to prolong and spread out the emigration of juveniles. The majority of emigrating juveniles were between 120 and 220 mm in length and were age II and III.

A total of 935 juvenile emigrants (405 cutthroat trout, 519 hybrids, and 11 rainbow trout) were caught in the downstream trap set in Big Creek. Peak emigration occurred in late June, but the trap was put in on 17 June and may have missed a large segment of the emigration (Figure 7). Juvenile emigrants generally ranged between 120 and 170 mm in length and were age II and III. We also captured 31 post-spawning adult fish emigrating back to reservoir (17 cutthroat trout, 11 hybrids and 3 rainbow trout).

A total of 339 juvenile emigrants (177 cutthroat trout, 169 hybrids, and 3 rainbow trout) were caught in our downstream trap in Bristow Creek (Figure 8). Since the trap was not put in until 14 June, it was likely that we missed a portion of the emigration. Emigrants were captured primarily during June and their lengths ranged generally between 110 and 170 mm.

A total of 2,311 juvenile trout and 246 adult trout were tagged when passed through our downstream traps. To date, we have recovered eight juvenile tags and 17 adult tags from anglers. Most of these fish were recaptured in the reservoir.

WESTSLOPE CUTTHROAT TROUT REDD SURVEYS

A total of 311 redds were observed during surveys of Libby Reservoir tributaries (Table 2). Bristow, Big, Young, and Pinkham creeks were identified as the most heavily used spawning streams of those streams surveyed. Redd surveys can be used to locate spawning areas, but are of little value in documenting abundance of spring spawners because of the variable conditions during surveys. During 1983, late spring and early summer rains kept streamflows high. These high late flows caused silting in of redds constructed early (making identification difficult) and resulted in stream surveys being done during high flows reducing surveyor's efficiency. We do not plan to repeat spawning site surveys during 1984 in those streams surveyed during 1983.

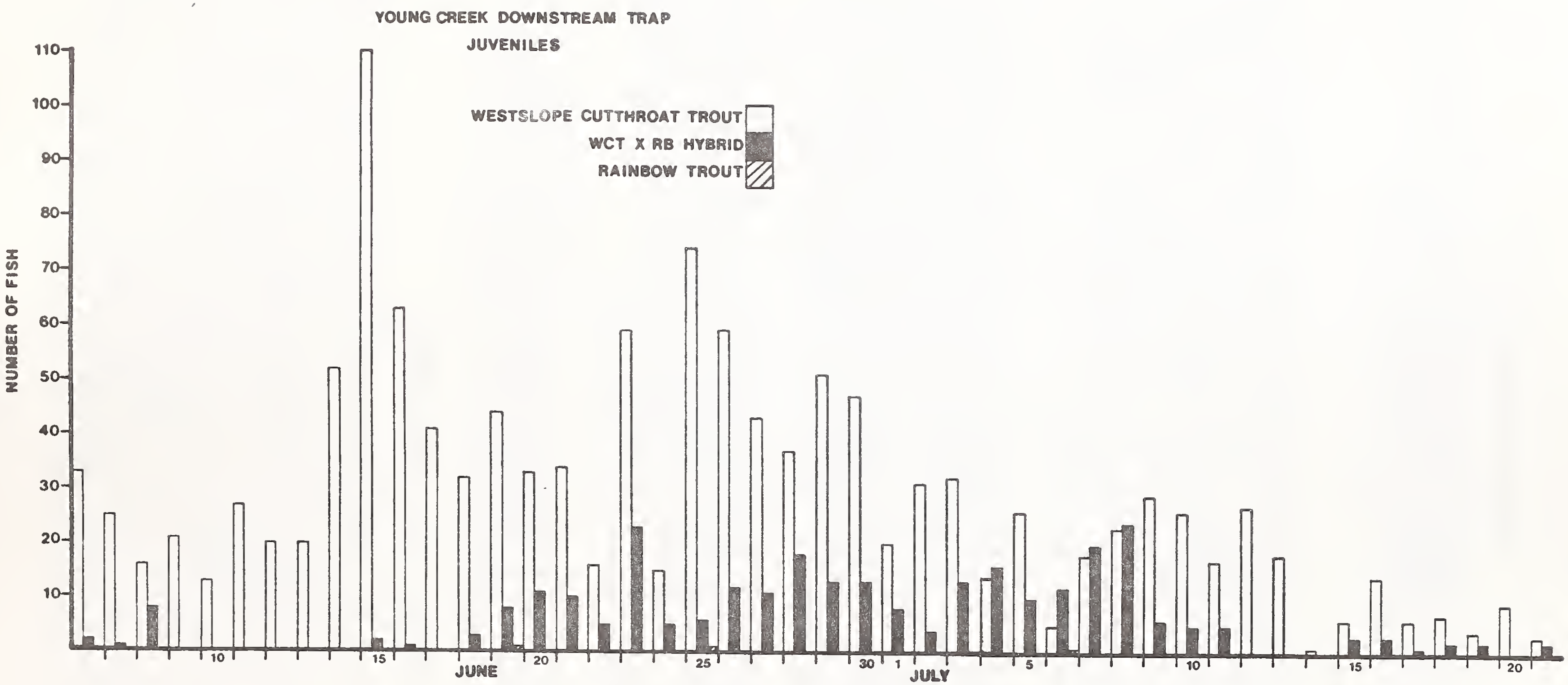


Figure 6. Number of juvenile fish (by species) passed daily through a downstream trap located in Young Creek, 6 June to 21 July, 1983.

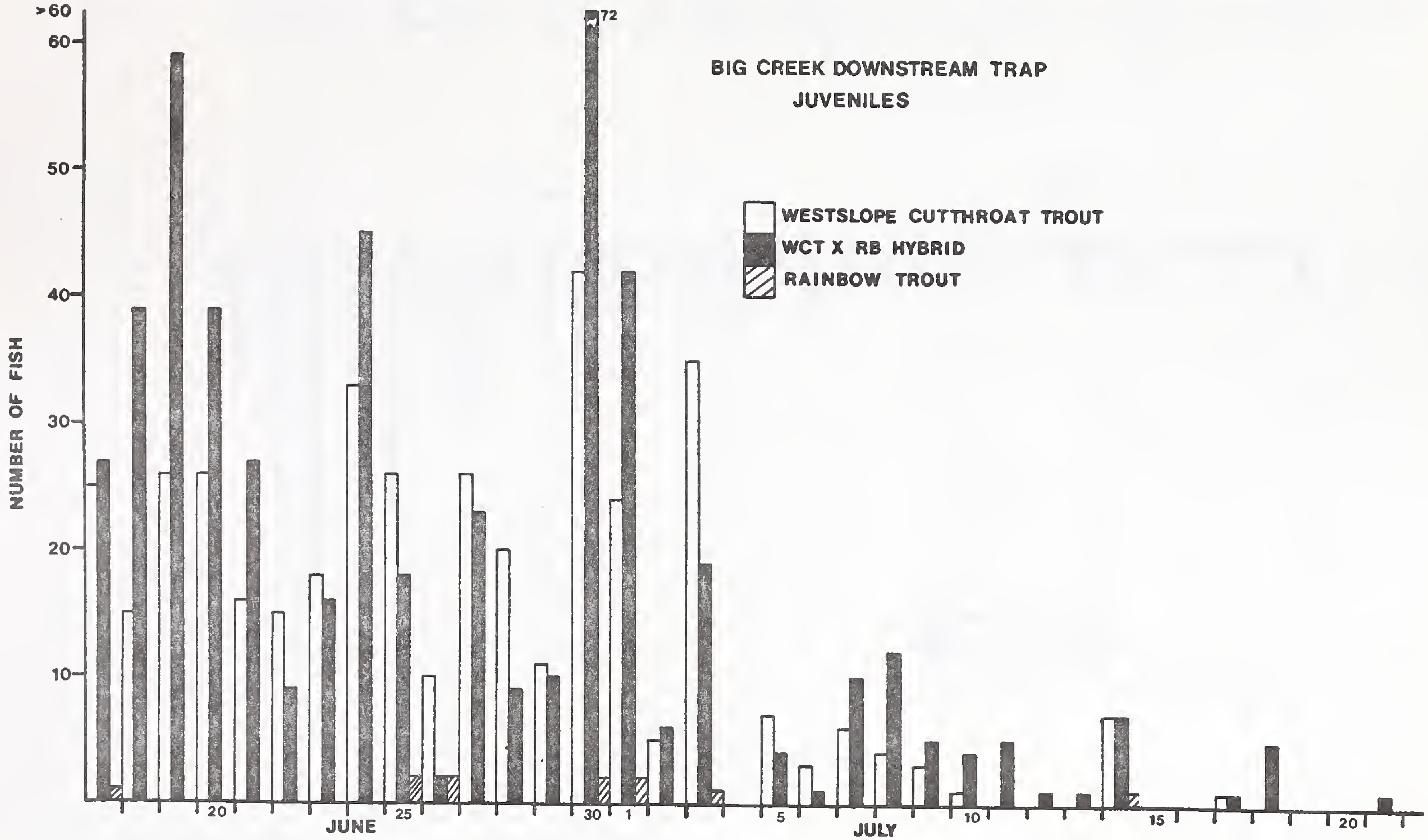


Figure 7. Number of juvenile fish (by species) passed daily through a downstream trap located in Big Creek, 17 June to 21 July, 1983.

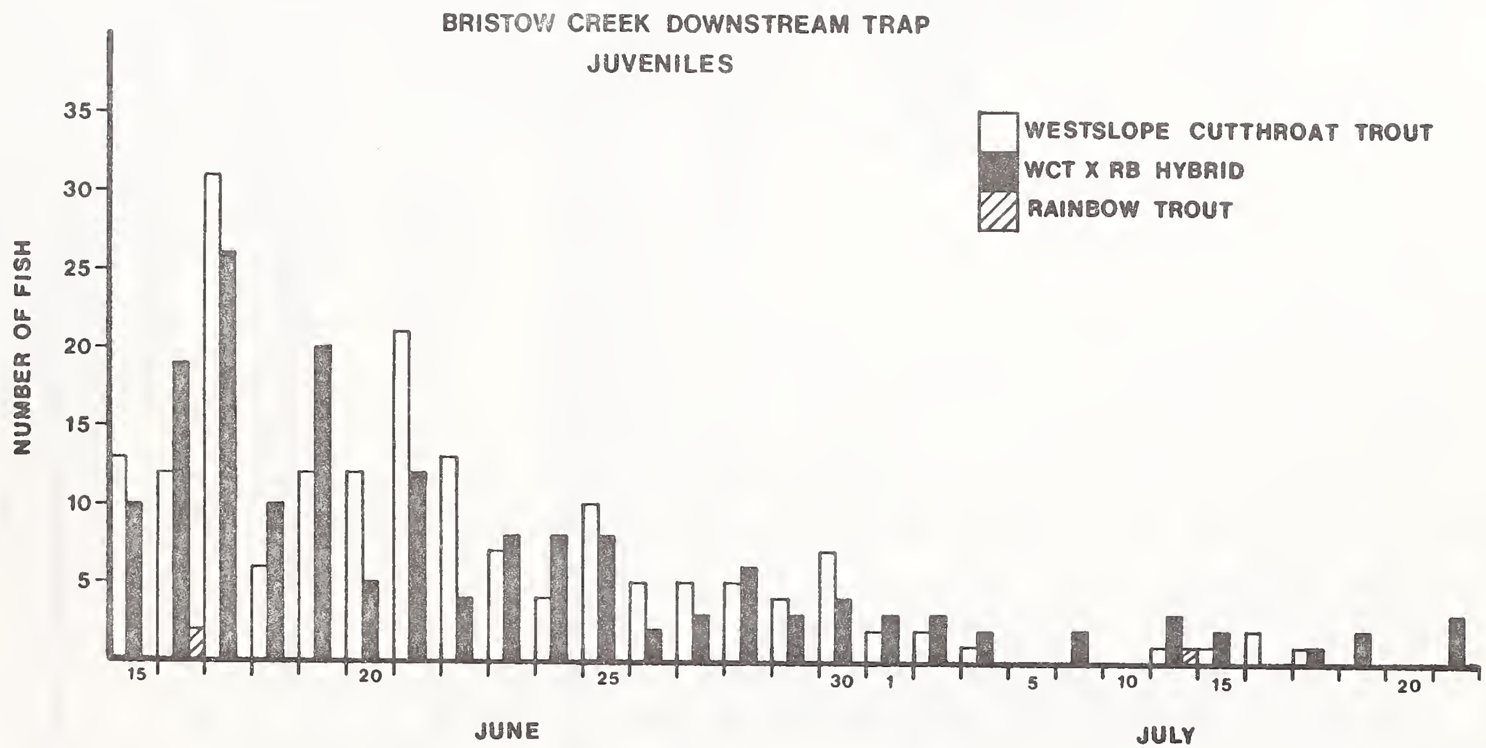


Figure 8. Number of juvenile fish (by species) passed daily through a downstream trap located in Bristow Creek, 14 June to 21 July, 1983.

Table 2. Number of cutthroat trout redds seen during spawning surveys conducted in tributaries to Libby Reservoir during 1983.

Creek	Area surveyed	Number of redds
Canyon	Mouth up to falls	8
Cripple Horse	Mouth up to cascade (Sec. 6)	1
Bristow	Mouth up to FDR	7
	FDR up to Sec. 8 bridge	46
	Sec. 8 bridge up to Camp Creek	14
		67
Big	South Fork (mainstem	22
	West branch of South Fork	52
	East branch of South Fork	15
	Steep Creek	4
		93
Fivemile	Mouth up to Sec. 14	7
Sullivan	FDR up to Falls	5
Pinkham	Mouth up to Camp 32	27
	Camp 32 up to falls	55
		82
Young	Mouth up to West Kootenai Road	2
	West Kootenai Road up above meadow	29
	From meadow up to bridge in Sec.	3
		34
Grave	Cursory Survey	1
Therriault	Cursory Survey	1
TOTAL		311

PROSPECTUS

In 1984, twelve years after impoundment, Libby Reservoir is still undergoing change, both biologically and politically. Biologically, nutrient and pollutant sources to the reservoir have been reduced as a result of pollution abatement efforts in the upper drainage within British Columbia, and the fish community supported by the reservoir has been changing due to natural and man-caused events. Politically, reservoir operation is being re-evaluated to comply with the Northwest Power Planning Council's recommended "water budget". This "water budget" was proposed to enhance survival of juvenile anadromous salmonids in the Columbia River by allowing fishery managers some control over flow releases from mid-Columbia and lower Snake River dams. Libby Reservoir, a large headwater storage reservoir, will likely be called upon to store water during the spring to provide water to downriver projects late in the spring after "water budget" flows have been released. Consequently, Libby Reservoir's operation will be re-evaluated and modified to include "water budget" releases in the Columbia River system operation. All aspects of reservoir operation will be re-examined including flood control criteria, power generation needs, and fish resource requirements. Drawdown limits and timing of drawdown and refill will result from this effort.

This re-evaluation provides an opportunity to examine past operating criteria and attempt to develop an operational plan which will ensure the maintenance or enhancement of resident fish resources within Libby Reservoir. The present study was developed, in concert with the above events, to recommend reservoir operation criteria which would best meet the needs of target fish populations in the reservoir. This prospectus explains what resources are available and how these resources could be managed to provide flood protection and hydroelectric power to citizens of the Pacific Northwest, while maintaining the important regional fishery that exists in Libby Reservoir.

BACKGROUND

Fish populations normally respond in a predictable manner after a lentic (reservoir) environment has been created by impounding a lotic (riverine) environment. Immediately after impoundment, fish populations generally increase and the fish community shifts from a community dominated by lotic species to one dominated by lentic species. Reasons for this response include the altering of a riverine environment which favors lotic species to a reservoir environment which favors lentic species, rapidly expanding habitat during reservoir filling, and an increase in nutrient sources and food supplies caused by flooding of terrestrial areas (Elder 1964, Neel 1967, Frey 1967). After several years, fish populations tend to decrease somewhat and stabilize at a lower level than that immediately following impoundment (Ellis 1937, Evans and Vanderpuye 1973). The reasons for this decline have been related to increased interspecific and intraspecific competition after the newly created habitat has been filled, the loss of terrestrial vegetation near shoreline areas caused by water level fluctuations and wave action, and loss of a portion of the food supply and nutrients (Ellis 1937).

The majority of research conducted on the effects of fluctuating water levels on reservoir fish populations has dealt with warm and coolwater fisheries (Ploskey 1982). Work done regarding coldwater fisheries has been conducted mostly in Scandinavian waters (Ploskey 1982). Aass (1960, cited in Ploskey 1982) stated the extent of water level fluctuations is the only factor that affects changes in the fish food fauna. He also believed trout catches declined in fluctuating impoundments, probably because of low benthos populations, and the harvest of chars frequently increased as a result of improved zooplankton production. This conclusion implies that planktivorous fish can do well in a fluctuating reservoir environment, while insectivores do not (Isom 1971, Miller and Paetz 1959). Reduction of benthos in fluctuating reservoirs has been related to desiccation, loss of vegetation as a substrate and food source, freezing and siltation (Kaster and Jocobi 1978, Benson and Audson 1975, Claflin 1968, Elder 1964, Fillion 1967, Kimsey 1958). Conversely, zooplankton populations seem to increase dramatically immediately following impoundment, remain relatively constant (even in fluctuating reservoirs), and any decline in zooplankton abundance after impoundment was attributed to a loss of productivity caused by leaching of nutrients from the recently flooded reservoir bottom (Kimsey 1958, Grimas 1961, Miller and Paetz 1959, Nilsson 1964).

The fishery in Libby Reservoir is unique to most western cold water reservoirs in that much of the sport fish production is from natural sources. Rainbow trout, bull trout, burbot, kokanee salmon, and some westslope cutthroat trout reproduce naturally to supply the reservoir's sport fishery. Westslope cutthroat trout populations are supplemented with annual releases of approximately 300,000 fingerlings and 500,000 fry from Murray Springs State Hatchery. The literature on cold water fisheries in large fluctuating reservoirs is limited, and what is available deals primarily with hatchery planted rainbow and brown trout (for example; Marrin and Erman 1982, Geer 1978).

Physical-Chemical Environment

The morphometry of Libby Reservoir was described earlier in this report. Nutrient loadings to the reservoir were high enough to place the reservoir in the eutrophic classification; however, average daily areal primary production values of 63.6 to 105.5 $mg \cdot C \cdot m^{-2}$ placed the reservoir at the lower end of the oligotrophic category (Woods 1982). Woods (1982) attributed this difference to the following limnological processes within Libby Reservoir which affected the availability of influent nutrients including:

1) stratified interflow or underflow of the Kootenay River during the annual filling phase preventing all the nutrients which enter the reservoir from being available for phytoplankton uptake;

2) absorption of phosphorous to suspended sediment particles and the subsequent deposition of this sediment on the reservoir bed; and

3) weak thermal structure in Libby Reservoir which circulates the phytoplankton out of the euphotic zone.

Biotic Community

The biotic community consists of successive trophic levels through which energy and nutrients flow to support biomass. The various levels are made up of primary producers, primary consumers, secondary consumers (primary carnivores), tertiary consumers (secondary carnivores), and so on with decomposers (or reducers) breaking down material and returning it to the nutrient pool (Pianka 1974). In Libby Reservoir, the primary producers are phytoplankton, primary consumers are zooplankton and benthic invertebrates, secondary consumers are zooplankton and fish, and tertiary consumers are fish.

Phytoplankton

Phytoplankton use light and nutrients to produce biomass. Phytoplankton in Libby Reservoir were dominated by the diatom genera (Bacillariophycae) Cyclotella, Fragilaria and Asterionella and the yellow algae (Chrysophyceae) Dinobryon (Irving and Falter 1981). Rawson (1956) reported that Asterionella and Dinobyron reported Cyclotella and Dinobyron, were typical of oligotrophic lakes.

Average phytoplankton densities in Libby Reservoir ranged from 53,000 to 1,480,000 cells·liter^{-1} and averaged 498,000 cells·liter^{-1} (Irving and Falter 1981). Rieman (1976) reported peak phytoplankton densities of 3,000,000 cells·liter^{-1} in Lake Pend Oreille, a large oligotrophic lake in Northern Idaho.

Zooplankton, Benthos and Adult Insects

Zooplankton, benthos and adult insects provide a link to transfer energy from primary sources of production (phytoplankton and terrestrial vegetation) to fish. Zooplankton and aquatic macroinvertebrates utilize autochthonous sources of energy, while terrestrial insects utilize allochthonous sources. The two major factors controlling autochthonous energy sources are sunlight energy (both temperature and light penetration) and nutrient availability.

Westslope cutthroat and rainbow trout ate *Daphnia* sp. almost exclusively during the winter of 1977, prior to the presence of kokanee salmon (McMullin 1979). Small rainbow trout and all cutthroat trout shifted to a diet of both terrestrial insects and zooplankton during the summer with aquatic dipterans being important during the spring while large (>330 mm) rainbow trout used fish extensively (McMullin 1979). Kokanee salmon are very efficient plankton predators (Rieman and Bowler 1980, Leathe and Graham 1982).

Fish

Game fish species in Libby Reservoir spawn primarily in tributaries during the fall, winter and spring, while nongame fish species spawn primarily in the reservoir during spring and summer (Table 3). Game fish species often rear as juveniles in tributaries, in contrast to nongame species which rear in the reservoir. Distribution of subadults and adults of both game and nongame species within the reservoir is variable and dependent upon thermal structure, thermal preference, and prey availability. Considerable overlap exists in food habits between many of the fish species (Table 3). This overlap could lead to serious competition if an efficient predator can crop the densities or alter the size composition of a shared prey item such that it becomes unavailable to other species. This possibility will be discussed later in this report.

We will now present more detailed life-history information for selected target species in Libby Reservoir. Our target game fish species include rainbow and cutthroat trout, kokanee salmon and burbot. A brief discussion of the probable reasons for the decline of mountain whitefish will also be included. Our target nongame species include peamouth, redside shiners and northern squawfish.

Before beginning life-history reviews, it is necessary to present information on the status of both the westslope cutthroat and rainbow trout stocks which presently inhabit Libby Reservoir. Both species were present in the Kootenai River prior to impoundment. Behnke (1979) described the westslope cutthroat trout (*Salmo clarki lewisi*) as a subspecies and documented three life-history patterns for this subspecies:

1) an adfluvial pattern where juveniles emigrate from natal tributaries to mature in a lake (or reservoir) before returning to their natal tributaries to spawn;

2) a fluvial pattern, where juveniles emigrate to a river from their natal tributaries to mature; and

3) a resident pattern, where juveniles remain in their natal tributaries throughout their life.

Table 3. General life history of the more common game and nongame fish in Libby Reservoir (data compiled from Scott and Crossman 1973, Brown 1971, and Carl et al. 1977).

Species	Spawning Timing	Spawning Location	Juvenile rearing Location	Juvenile rearing Length of time (yrs)	Subadult and adult lentic residence Distribution	Subadult and adult lentic residence Food habits	Age at maturity (yrs)
Gamefish							
Westslope cutthroat trout	Spring	Tribs.	Tribs.	1-3	Near the water's surface in both pelagic and near shore areas	Zooplankton, terrestrial and aquatic insects	3-4
Rainbow trout	Early spring	Tribs.	Tribs.	0-2	Near shore and near water's surface in pelagic areas	Zooplankton terrestrial and aquatic insects, fish c/	2-3
Bull trout	Fall	Tribs.	Tribs.	1-4	Dictated by prey and temperature	Fish	5-6
Kokanee salmon	Late fall	Tribs. or shoreline d/	Lake	-	Mostly pelagic	Zooplankton	2-4
Mountain Whitefish	Late fall	Large e/ tribs.	Large tribs.	0-1	Near the bottom, and along shoreline	benthos, zooplankton	2-3
Burbot	Winter to early spring	Tribs. or in lake f/	Lake g/	-	Deep waters of pelagic zone, may move into shore for food	fish, young feed on aquatic insects	3-4
Nongame fish							
Redside shiner	Summer	Lake shoreline h/ or tribs.	Lake	-	Schools near shore, moves into pelagic zone at night in summer	Aquatic insects plankton	2-3
Peamouth	Early summer	Lake shoreline	Lake	-	Schools along shore	Insects, zooplankton	3-4
Northern squawfish	Early summer	Lake shoreline or mouth of tribs.	Lake	-	everywhere	fish, young	5-6
Coarsescale sucker	Spring	Tribs. or shoals in lake	Lake	-	Near the bottom at depths <25 m	bottom material, (benthos, detritus, etc.)	4-5
Longnose sucker	Spring	Tribs. or shoals in lake	Lake	-	Near the bottom at all depths	bottom material (benthos, detritus, etc.)	4-5

a/ General distribution disregarding thermal constraints.
b/ A list of all food items most commonly used.
c/ Larger rainbow trout use fish.
d/ Kokanee salmon will spawn along lakeshores of gravel, rubble or fractured rock.
e/ Mountain whitefish generally spawn in large mainstem tributaries.
f/ Burbot have been reported to spawn over shoals, in deep water, and in shallow covers of lakes.
g/ Burbot young may rear up to a year in tributaries if spawning occurs there.

Since the formation of Libby Reservoir, cutthroat trout previously exhibiting a fluvial life-history pattern in the Kootenai River have shifted or been replaced by cutthroat with an adfluvial pattern. The remaining references to cutthroat trout refer to this adfluvial westslope cutthroat trout, unless otherwise specified.

The "enhancement" of tributaries to Libby Reservoir included releasing Hungry Horse Reservoir stock of fluvial and adfluvial westslope cutthroat trout. This stock was raised in the Jocko River State Hatchery until 1980, when Murray Springs State Hatchery began operating. In recent years, it was realized genetic diversity in this hatchery stock had been reduced (Allendorf and Phelps 1980). MDFWP biologists began collecting wild westslope cutthroat trout during 1983 to revitalize this hatchery stock.

There have been questions raised regarding the origin of rainbow trout in Libby Reservoir. These rainbow trout were believed to originate from one or more of the following sources: 1) they were originally native to the upper Kootenai River drainage; 2) they were offspring of early hatchery releases; 3) they were from recent releases out of British Columbia's Kootenay Trout Hatchery; or 4) they were from recent releases out of Montana's Jocko River Hatchery. Neither British Columbia's nor Montana's hatchery records showed any recent releases of rainbow trout into the Kootenai River drainage above Libby Dam. The hatchery stock in British Columbia's Kootenay Trout Hatchery originated from an inland stock, while Montana's hatchery stock originated from a coastal stock from California. Phelps and Allendorf (1980) conducted electrophoretic analyses on rainbow trout from Libby Reservoir, British Columbia's Kootenay Trout Hatchery, and Montana's Jocko River Hatchery. They found the rainbow trout from Libby Reservoir was a coastal type of rainbow trout, but this coastal type rainbow trout from Libby Reservoir was different enough from the coastal type stock raised in the Jocko River Hatchery to rule out recent releases from this hatchery as their source. They concluded the rainbow trout in Libby Reservoir probably were offspring from releases of hatchery rainbow trout within the drainage prior to 1950. Circumstantial evidence is available indicating there have been losses of rainbow trout from the Kootenay Trout Hatchery (Phelps and Allendorf 1981, Joe Huston, MDFWP, Kalispell, Montana, personal communication), although studies to date indicate these fish have not contributed significantly to the reservoir's rainbow trout population (Phelps and Allendorf 1980, 1981). Phelps and Allendorf (1981) also raised the possibility of a genetically discrete stock of rainbow trout using the Tobacco River drainage by showing a statistically significant difference at three gene loci between the Tobacco River rainbow trout and the rainbow trout collected from the reservoir.

Widespread hybridization between rainbow and cutthroat trout was occurring in Big Creek as early as 1977, as electrophoretic analyses from ten spawning adults collected during 1980 revealed nine were first generation hybrids (Phelps and Allendorf 1981). It is apparent that the integrity of the cutthroat trout stock will inevitably be lost, and the only "pure" cutthroat trout in the reservoir's future will be those released from Murray Springs Hatchery.

Rainbow and cutthroat trout spawn in tributaries to Libby Reservoir during spring (May and Huston 1980). Rainbow trout begin entering tributaries as early as mid-April and the last adults generally move into spawning tributaries by the end of May (May and Huston 1980). Adult cutthroat trout usually move into spawning tributaries later, from mid-May to mid-June (May and Huston 1980). In Big Creek, both rainbow and cutthroat trout ascend the stream during the same time period throughout May (May and Huston 1980). Both species select similar types of spawning areas (Reiser and Bjornn 1979, Shepard et al. 1984). Embryos have been reported to incubate in the streambed for four to eight weeks dependent upon stream water temperatures (Scott and Crossman 1973). After emerging, fry rear in tributary streams for two or three years (range: 1 to 3) in the case of cutthroat trout, and an average of one (range: 0-2) for rainbow trout, before emigrating to the reservoir (May and Huston 1980). While rearing in tributaries, juvenile cutthroat trout have been shown to prefer pool habitats, while rainbow trout are somewhat less selective (Shepard 1983). During stream residence both species have been found to eat mainly aquatic macroinvertebrates and terrestrial insects (Bisson 1978, Shepard et al. 1982).

A review of the literature found no information regarding habitats used by juvenile trout during their first year of reservoir residence. We suspect these juveniles may be especially vulnerable to predation because of their small size (100 to 200 mm). Juveniles in the reservoir feed primarily on adult insects and zooplankton.

Distribution of both species in the reservoir after their first year was related to thermal preference and feeding habits. Cutthroat trout preferred temperatures in the 15 to 18 ^{o}C range and avoided temperatures higher than 19 ^{o}C. Rainbow trout preferred temperatures in the 17 to 19 ^{o}C (McMullin 1979). Food habits were discussed previously and illustrated the dependence of both species on the zooplankter Daphnia in the winter. The distribution of cutthroat trout during the summer was bimodal with the highest concentrations in their preferred temperature range and a smaller concentration near the surface. This surface concentration was related to their preference for surface insects. Even when temperatures rose above 19^{o}C cutthroat trout continued to feed on surface insects (McMullin 1979).

Kokanee salmon were believed to be present in Libby Reservoir as a result of salmon drifting downstream from Kootenay Trout Hatchery; however, prior to 1979 kokanee salmon were considered rare. In 1979, kokanee salmon were frequently captured in gill nets (May and Huston 1981). We believe a large release of salmon from the Kootenay Trout Hatchery was the source of this strong year class. An estimated 26,000 adult salmon spawned in 1982 (Huston et al. in prep.) The kokanee salmon population in the reservoir is expanding rapidly, typical of a newly established population exploiting a "new" environment. Reports from Canada and our data indicate the salmon population has been extensively pioneering new spawning areas including Kikomun Creek, the Kootenay River near Skookumchuk Creek, Tobacco River, and Gold Creek, in addition to their original natal tributary, Norbury Creek (MDFWP files, Kalispell, Montana). At the present time we are unsure how much potential kokanee spawning habitat exists in the drainage to Libby Reservoir, but believe in-reservoir spawning attempts would be unsuccessful because of winter drawdowns.

Kokanee salmon adults prefer to spawn in medium-sized gravels in groundwater influenced areas (Fraley and Graham 1982). Spawning occurs during September and October in tributaries to Libby Reservoir (Joe Huston, MDFWP, personal communication). Embryos in other drainages were found to incubate for 15 to 20 weeks (Scott and Crossman 2973, Rieman and Bowler 1980), but kokanee embryos in Libby Reservoir tributaries may incubate longer (Joe Huston, MDFWP, Kalispell, Montana, personal communication). This longer incubation period may be related to colder water temperatures during incubation in Libby Reservoir tributaries. Fry move immediately down into the reservoir after emerging as was the case for Flathead Lake drainage kokanee (Fraley and Graham 1982).

After fry reach the reservoir they probably inhabit the pelagic area of the reservoir, similar to the fry distribution found in Lake Pend Oreille (Rieman and Bowler 1980). Kokanee salmon were distributed pelagically in both Pend Oreille and Flathead lakes. Vertical distribution was controlled by thermal stimuli (Rieman and Bowler 1980, Hanzel 1980). These authors found kokanee preferred temperatures below 10°C.

Kokanee salmon were considered by Rieman and Bowler (1980) to select prey following an optimal prey selection strategy described for other pelagic planktivores (Eggers 1977, Werner and Hall 1974). Sockeye salmon (and the freshwater kokanee salmon) can utilize zooplankters as small as 0.4 mm which inspired Koenigs (1983) to describe them as an "obligate" planktivore; meaning that kokanee salmon are obligated to feed on zooplankton because they are so well adapted for it. Further, Koenigs (1983), Rieman and Bowler (1980), and Rieman and Falter (1981) described the ability of kokanee and sockeye salmon to select the largest plankters, and progressively consume smaller plankters as the larger plankters disappear. The combination of the rapidly expanding population of kokanee salmon in Libby Reservoir and their ability to crop large-sized zooplankters could lead to serious competition for a winter zooplankton food resource between salmon and cutthroat and rainbow trout. Intense size-selective predation on the zooplankton population, particularly by kokanee salmon, may make much of the zooplankton's biomass unavailable as food for trout. Geer (1978) found trout in Joes Valley Reservoir, Utah were unable to feed on small zooplankton after the larger zooplankters had been cropped. The potential unavailability of zooplankton as a winter food resource for rainbow and cutthroat trout could reduce their growth and survival.

Burbot were present in the Kootenai River prior to impoundment, and their abundance has increased slightly in the reservoir (May and Huston 1981). A popular localized winter fishery exists in the Rexford area of the reservoir.

Adult burbot are known to spawn in the Kootenay River near Wardner, British Columbia (Al Martin, British Columbia Ministry of Environment, Fish and Wildlife Branch, Cranbrook, B.C., personal communication). They are believed to spawn in the Tobacco River, and are suspected to spawn within the reservoir. The literature suggests burbot spawning habitat is diverse and ranges from deep water to shoals and shelves to shallow coves of lakes, as well as in rivers and streams (Scott and Crossman 1973, Carl et al. 1977, Brown 1971). The young may remain in the river or stream, if spawning occurred there, for up to a year before moving down into a lake or reservoir (Eddy and Surber 1947).

Burbot grow rapidly during their first year (up to 210 mm) on a diet primarily of aquatic macroinvertebrates. They soon begin eating fish and continue their piscivorous habits throughout their life. Burbot inhabit the deep cool waters of lakes and reservoirs, but will move into shoreline areas to feed (Scott and Crossman 1973).

Mountain whitefish abundance in Libby Reservoir has declined from 1975, immediately after impoundment, to 1981 (May and Huston 1981). Three possible causes may have operated individually, or in concert, to reduce mountain whitefish abundance in the reservoir:

1) reduced recruitment due to inundation of important main river spawning habitat located in the Kootenay River below Wardner, British Columbia (G. Oliver, British Columbia Ministry of the Environment, Fish and Wildlife Branch, Cranbrook, B.C., personal communication);

2) difficulty in effectively switching from a diet of benthos to a diet of zooplankton and potential competition for similar food resources between mountain whitefish and peamouth (Scott and Crossman 1973, Daily 1971); and

3) the reduction of whitefish numbers from depensatory mortality through predation, meaning the density of predators is high enough to significantly reduce their prey population (especially if a single prey species is preferred and that species population has already been reduced by other environmental factors) in Libby Reservoir by two voracious predators that prefer mountain whitefish, bull

trout and burbot (Leathe and Graham 1982, Eddy and Surber 1947).

Peamouth were considered rare in the Kootenai River prior to impoundment, although following impoundment its abundance increased and it is presently one of the most abundant fish in the reservoir (Huston et al. in prep.). Peamouth spawn in May and June in shallow water near the shoreline of lakes (Scott and Crossman 1973, Brown 1971). Hatching occurs in one to two weeks (Brown 1971). Peamouth remain near shore in schools throughout their lives and consume aquatic and terrestrial insects and zooplankton, particularly Daphnia and Diaptomus (Scott and Crossman 1973, Brown 1971). Peamouth eat the same items as cutthroat and rainbow trout and mountain whitefish and a potential for competition may exist (Daily 1971).

Redside shiners were common in sloughs, backwaters and low velocity pools of the Kootenai River prior to impoundment (Huston et al. in prep.). Immediately following impoundment, shiner abundance increased through 1978, then began declining and is presently at a relatively low level (May and Huston 1981). Huston et al. (in prep.) believed the decline was related to the loss of flooded vegetation in shoreline areas by fluctuating reservoir levels. They thought the impact of the decline of the shiner population was most keenly felt by larger rainbow trout which preyed heavily on shiners (McMullin 1979). Redside shiners exhibited a seasonal distribution pattern in Paul and Pinantan Lakes where shiner schools moved into shoal areas in the spring, moved off shore in July, then moved back near the shore in August (Crossman 1959, Johannes and Larkin 1961). These authors also reported a diurnal dispersal of shiner schools off shore during the night to distribute throughout the lakes near the water's surface and then reschooling near the shoreline during the day. Redside shiners eat aquatic and terrestrial insects and zooplankton (Brown 1971).

Northern squawfish increased in abundance following impoundment from being "rare" in the Kootenai River to being "abundant" in Libby Reservoir (Huston et al. in prep.). These authors suggested the abundance of small northern squawfish in 1982 sampling may indicate the northern squawfish population will increase during the next few years.

Northern squawfish reach sexual maturity at age five or six in most Montana waters (Brown 1971). At maturity, females average 350 to 500 mm in length and produce approximately 6,000 to 27,000 eggs (Brown 1971, Patten and Rodman 1969). Spawning occurs in gravelly shallows which may be located along a lakeshore, at the mouths of tributary streams, or a short distance upstream in a tributary stream (Brown 1971). Lake dwelling forms appear to spawn in tributary streams only when suitable gravel shallows were not available within lakes. Eggs are adhesive, demersal and small (1.0 mm in diameter). These eggs are deposited at random over gravel beds and hatching occurs approximately one week after deposition at water temperatures of 17°C. Squawfish are slow-growing, long-lived fish.

Northern squawfish young inhabit shoreline areas during the summer and move offshore into deeper waters during fall and winter. Adults generally remain offshore in deep water although they frequently move into shoreline areas when foraging.

Young squawfish (25 to 100 mm in length) feed primarily on insects. As they grow larger, fish become increasingly important as a prey item, and larger squawfish feed almost exclusively on fish. Squawfish will consume salmon and trout, beginning when they reach a size of 100 mm in the case of sockeye salmon (Ricker 1941). Squawfish have been considered a significant predator on young salmon and trout (Hall 1979, Brown 1971). Brown (1971) also noted that squawfish may compete with salmon and trout for food.

RESERVOIR OPERATION

Operation of Libby Dam is dictated by a combination of factors including flood control, generation of hydroelectric power, recreational constraints for the reservoir, and down-river constraints for both the Kootenai River and Kootenay Lake, British Columbia. Evacuation of water from the reservoir during the fall and winter provides hydroelectric power as well as storage space to contain run-off. Provided the water supply is adequate and forecasts of that supply accurate, the reservoir is normally filled by the end of July and remains at full pool until after Labor Day for recreation and anticipated power needs. Downriver constraints include minimum discharge and maximum tailwater fluctuation limitations. A minimum discharge of 4,000 cfs is recommended below Libby Dam, but 3,000 cfs is allowed when required for refill. Emergency low discharges of 2,000 cfs are allowed for short time periods. Maximum tailwater fluctuations of one foot per half hour and six feet per day are permitted from October through April, and one foot per hour and four feet per day from May through September. During the summer season (May through 15 September) the project is operated to maintain river flows below 8,000 cfs during the weekends whenever feasible. The International Joint Commission's (IJC) 1938 Order requires that water elevations in Kootenay Lake, British Columbia (downriver from Libby Dam) be lower than 1,744.0 feet on 1 February, 1,742.4 feet on 1 March and 1,739.32 feet on 1 April to provide storage for spring runoff. Once water levels in Kootenay Lake fall to an elevation of 1,743.32 after spring run-off, the lake may remain at that level until 31 August when the water level may be raised to an elevation of 1,745.32. The reason for these controls on Kootenay Lake water levels is that Kootenay Lake has a restricted outlet which can pass only a limited amount of water (Table 4). Kootenay Lake is drawn down to 1,739.32 by 1 April to provide; 1) flood protection for lakeshore residents and downriver areas, 2) storage for power generation, and 3) drainage for agricultural lands adjacent to Kootenay Lake.

Table 4. Approach channel capacity (cfs) of channel[a] above Corra Linn Dam related to water level elevations.

Elevation (ft)	Channel capacity (cfs)
1,738.0	14,000.0
1,741.0	26,000.0
1,744.0	39,500.0
1,747.0	55,600.0
1,751.0	81,700.0
1,755.0	112,000.0

a/ Grohman Narrows.

Libby Reservoir provides flood control storage for three key areas:

1) Bonner's Ferry, Idaho;
2) Kootenay Lake, British Columbia; and
3) The lower Columbia River.

Flood stages and/or flood flows for these key areas are shown below:

1) a river stage of 31 feet (elevation of 1,731 and estimated discharge of 57,000 cfs) at the USGS gauge at Bonner's Ferry, Idaho;

2) no firm elevation at Kootenay Lake, B.C., but lake elevations higher than 1,747.0 begin flooding lakeshore property; and

3) a river discharge of 450,000 cfs on the Columbia River at the Dalles Dam.

The regulation of flows in the interest of the lower Columbia River generally provides adequate flood protection for the lower Kootenai River (U.S. Army Corps of Engineers 1972).

Operating rule curves are developed for each project in the system every year based on water management plans. Water forecasts are used to determine operation from January through April. These forecasts are provided the first week of each month. For Columbia River Treaty projects, including Libby Reservoir, Assured Operating Plans are prepared five years in advance followed by Detailed Operating Plans which are prepared prior to the runoff season during the year covered by the plan. Two guideline documents describe flood control and hydroelectric operation plan preparation (U.S. Army Corps of Engineers 1972, Columbia River Treaty Committee 1983).

Operating rule curves are developed by using a series of curves which are fixed for each project based on historic water supply, project storage, and runoff forecasts. These fixed curves are:

1) mandatory rule curve (MRC) or flood control curve;

2) a group of four critical rule curves (CRC1 through CRC4) which controls the maximum allowable drawdown based on a four year critical low water period (August, 1928 through February, 1932), and at the end of that time storage capacity has been depleted (i.e. the reservoirs would be emptied);

3) an assured refill curve (ARC) which depicts the maximum allowable drawdown to ensure refill if the second lowest historical runoff should occur (January through July, 1931);

4) a variable refill curve (VRC) which limits the drawdown to ensure the reservoir would refill with 95 percent assurance based on water supply forecasts; and

5) a lower limits energy control curve (LLECC) which limits drawdown levels in January through March to ensure the system will be able to meet firm power loads prior to spring runoff (Table 5).

The operational rule curve is adjusted to these five curves based on fixed criteria (Figure 9).

The MRC for Libby Reservoir is consistent from August through December to provide storage to ensure meeting Kootenay Lake lake elevation constraints. After December, the MRC is adjusted at the beginning of each month (until April) based on water supply forecasts (Figure 10). The CRC's, ARC, and LLECC are fixed curves (Figure 11). The VRC begins to operate in January, after the first water supply forecast has been made, and is adjusted monthly based on water supply forecasts.

FACTORS CONTROLLING FISH POPULATIONS IN LIBBY RESERVOIR

Fish populations generally are controlled by some limiting factors which keep the population below a certain level. This factor or factors usually operate on a particular life-stage. We theorize that fish populations in Libby Reservoir may be limited by one or more of the following:

1) amount of useable habitat (escape cover may be an important habitat component for fish subject to predation);

2) recruitment of fish to the reservoir from in-reservoir and off-reservoir spawning and rearing areas;

Table 5. Months of the year each type of rule curve is used to determine reservoir operation (from Columbia River Treaty Committee 1983).

		Months												
		A	S	O	N	D	J	F	M	A	M	J	J	
1.	Critical Rule Curve	C	C	C	C	C	C	C	C	C	C	C	C	This curve is developed for each reservoir by the Critical Period Regulation Study and will be used as an operating guide in the 30-Year System Regulation Studies.
2.	Assured Refill Curve	A	A	A	A	A	A	A	A	A	A	A	A	This curve is the same for each water condition in the 30-Year System Regulation Studies. The values may be the same as the CRC in the first 4 or 5 months.
3.	Variable Refill Curve						V	V	V	V	V	V	V	This curve is defined in paragraph 8(b) and will vary with the water condition. There will be 30 different curves used in the 30-Year System Regulation Studies.
4.	Mandatory Refill Curve	U	U	U	U	U	U	U	U	U	U	U	U	This curve is a function of requirements such as flood control, bank protection, etc., and will generally vary with each of the 30 water conditions.
5.	Lower Limits Energy Content Curve						L	L	L					This curve serves as a limit on the potential total system and project draft to protect the system's capability to meet loads until the start of the spring freshet.
6.	Operating Rule Curve The Operating Rule Curve for each of the 30 water conditions will limit reservoir operation in respect to secondary generation. Reservoirs will be drafted below Operating Rule Curves if necessary for firm load requirements in accordance with paragraph 9c.	O	O	O	O	O	O	O	O	O	O	O	O	The monthly values for this curve are derived from the first five curves based on the following criteria: C or A whichever is higher, except that after 1 January, V will be used if it is below the higher of C or A. In all cases, if U is lower than the value thus determined, U will be used. In no case shall it be lower than the Limiting Rule Curve (L).

NOTE: The same steps as above for 30-Year System Regulation Studies are used in actual operation except that the Variable Refill Curve beginning January is developed each month from actual inflow volume forecasts.

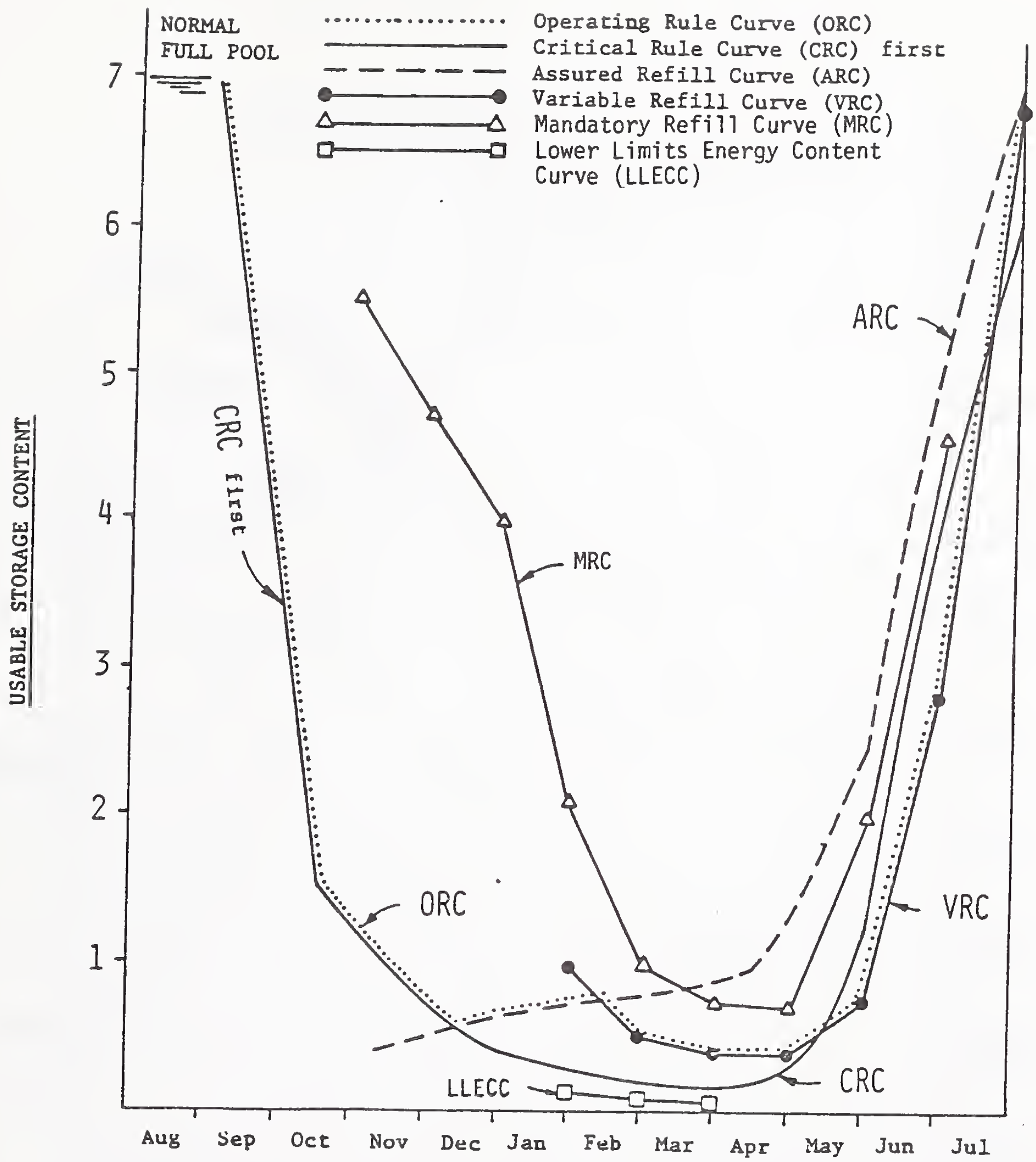


Figure 9. Hypothetical rule curves illustrating how an operational rule curve (ORC) is formed for Columbia River flood control-hydroelectric projects (modified from Columbia River Treaty Committee 1983).

Note: 1. In the studies the Operating Rule Curve (ORC) is defined by the higher of the first Critical Rule Curve (CRC) and Assured Refill Curve (ARC) through December 31. After January 1, it is defined by the higher of the CRC or ARC. Then it is defined by the VRC. In no case shall it be higher than the Mandatory Refill Curve (MRC) nor lower than the Lower Limits Energy Content Curve (LLECC).

2. In the studies, the MRC defines the maximum allowable elevations and is determined from independent simulated flood control regulations.

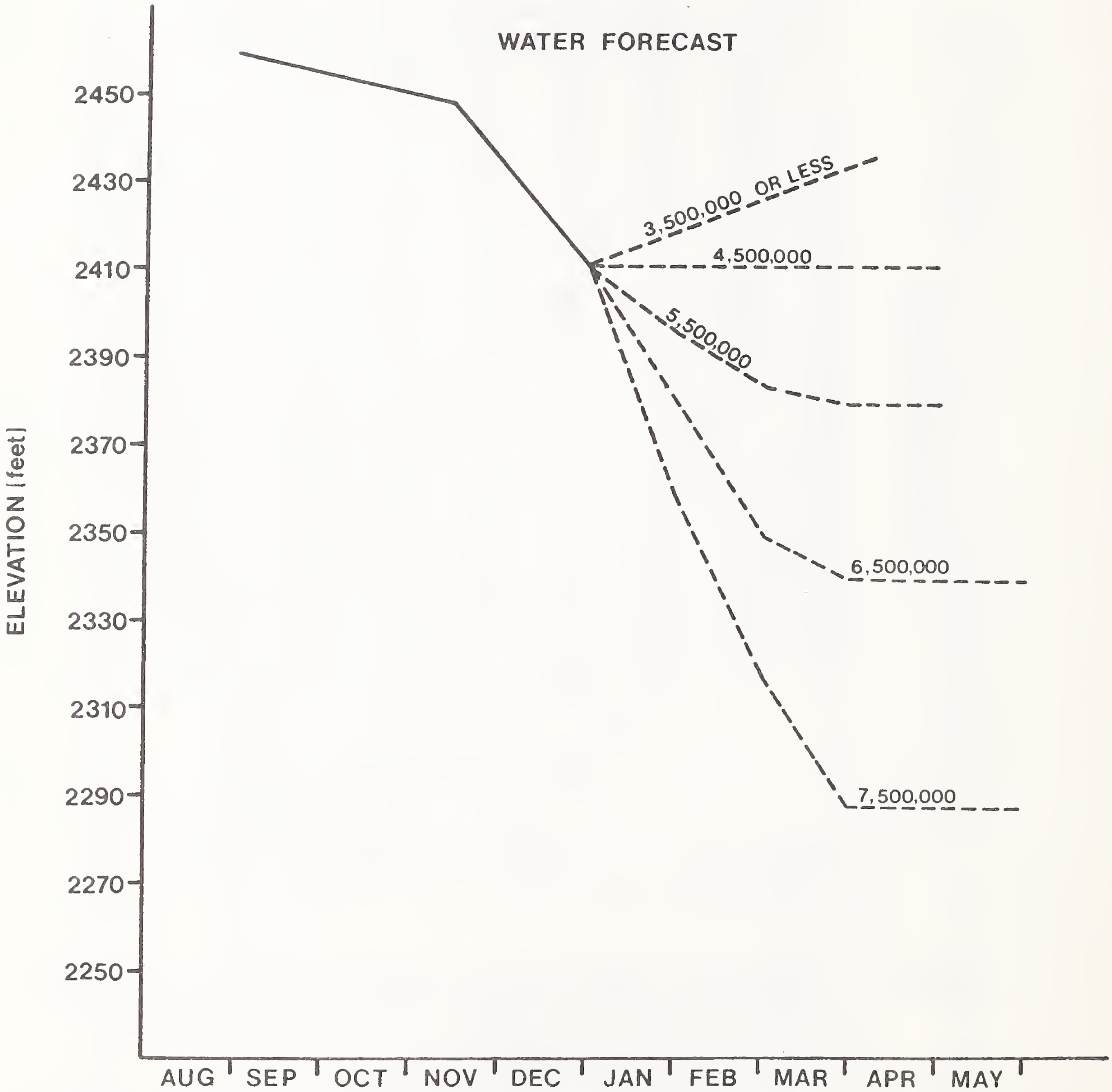


Figure 10. Mandatory rule curve (MRC) for Libby Reservoir to provide flood control storage. Dashed lines represent different curves based on water supply forecasts.

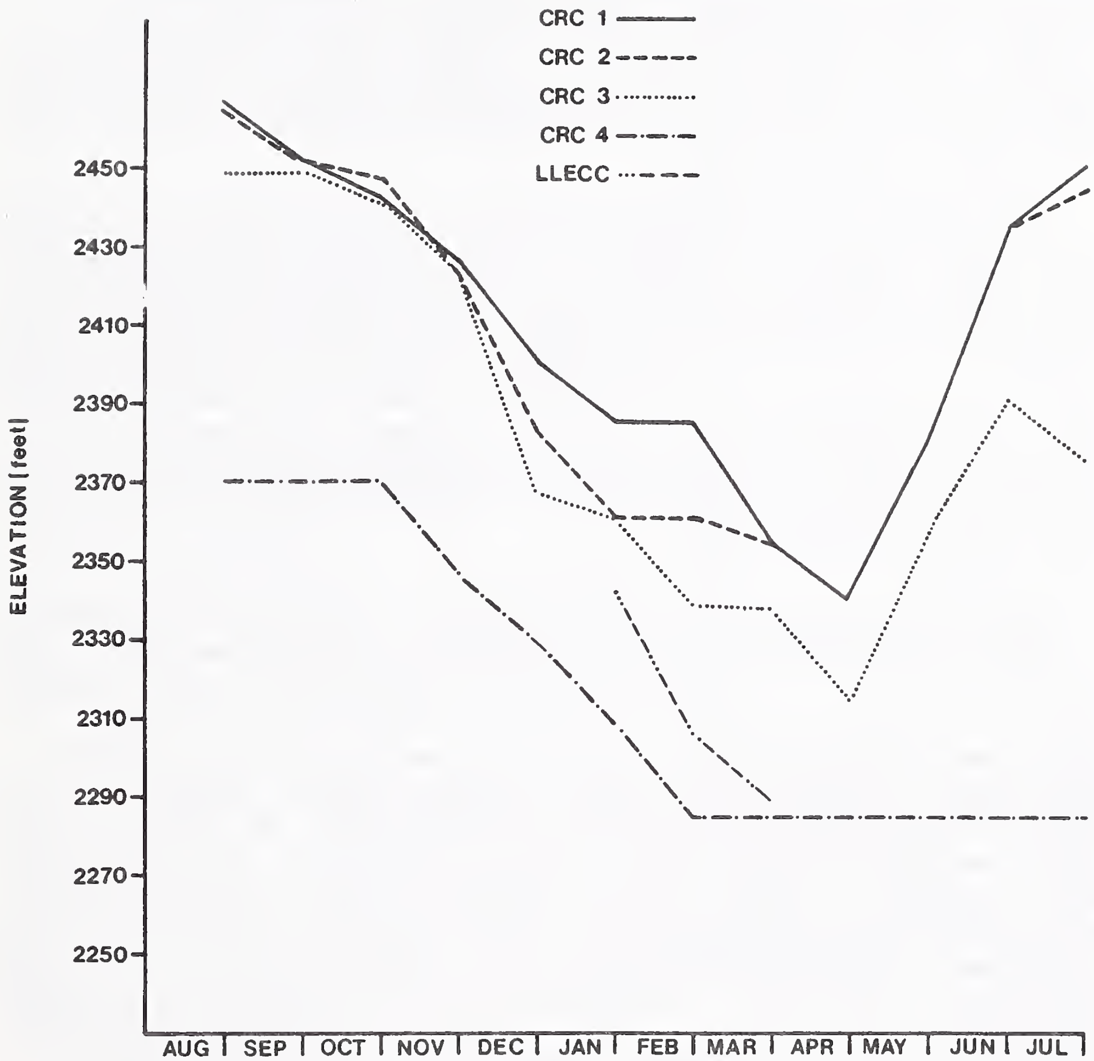


Figure 11. Critical rule curves (CRC1-CRC4) and lower limits energy control curve (LLECC) for Libby Reservoir.

3) amount, quality and availability of food resources;

4) mortality of fish in the reservoir from predation, harvest and natural sources (other than predation).

Recruitment to the reservoir's fish population depends on number of adult spawners, accessibility to spawning grounds, quantity and quality of spawning habitat, survival of embryos to emergent fry, and (for those species which rear as juveniles in tributaries) survival of juveniles until emigration from tributaries into the reservoir.

The factors influencing juvenile survival in tributaries and within the reservoir would be similar, so only juvenile survival within the reservoir will be described. Juvenile survival within the reservoir depends upon being able to find food without being eaten by a predator. Once a fish grows to a certain minimum size, predation is significantly reduced as a mortality factor (Parker 1971). The density of various size classes of predator dictates the probability of encounter and subsequent ingestion for useable size classes of prey. Escape cover can also improve the ability of prey to avoid predators.

The amount, quality and availability of food affects the rate of growth and survival of fish within the reservoir. These food resources must be in areas accessible to the fish, and of sufficient quality and quantity that the energy gained by eating the food is equal to or greater than the energy spent to capture it. Mortality by predation was discussed previously. Mortality due to angler harvest is dependent upon accessibility of fish to anglers, inherent catchability of the species, and amount of angling pressure. Natural mortality is that mortality due to disease, parasites and old age. Normally, natural mortality occurs only when an individual in the population has been under stressful environmental conditions (starvation, crowding, etc.). The amount of useable habitat is the volume or area of habitat containing the suitable habitat components required including suitable temperatures. Quality of habitat relates to condition nearest optimum for the age-class and species of interest.

Operation of Libby Reservoir can affect fish populations within the reservoir in a number of ways. Spring spawning species may be unable to access important spawning tributaries because of low reservoir elevation in the spring. Low spring reservoir elevations are known to expose a natural rock falls barrier (at an elevation of approximately 2,425 feet) in Barron Creek. If the reservoir inundated this barrier, spawners could utilize the Barron Creek drainage for spawning. Reservoir operation was believed to reduce an important rainbow trout forage species, the redside shiner, by eliminating an important component of their spawning habitat in the form of flooded vegetation (Huston et al. in prep). At the same time, an undesirable nongame species, peamouth, which utilizes habitats similar to redside shiners has increased in abundance. Unfortunately, this species is rarely eaten by rainbow trout, so an important prey species was lost with no known replacement. Huston et al. (in prep.) related the loss of redside shiner to reduced numbers of large rainbow trout.

We speculate that the lack of near-shore cover may limit the survival of juvenile trout when they first enter the reservoir by exposing them to predation. Little is presently known about juvenile trout habitat preference and distribution during their first year of reservoir residence. Deep seasonal drawdowns may expose juvenile fish to abnormally high predation rates by concentrating fish into a smaller space and allowing predators such as bull trout, burbot and northern squawfish better access to prey (McCammon and von Geldern 1979). Finally, thermal regimes within the reservoir influence fish distribution and may limit useable space. We are unsure at this time how operation affects the overall thermal structure of the reservoir.

Bonneville Power Administration (BPA) is responsible for reviewing our recommended operational guidelines to improve the fishery in Libby Reservoir. BPA would need to determine what impacts any change in reservoir operation to benefit fish would have on power production, and decide whether the proposed operational changes are feasible. The U.S. Army Corps of Engineers would then review any operational changes recommended by BPA and decide whether or not to implement them.

Potential operational changes which may benefit the fishery are: 1) limit annual drawdown to provide more winter habitat and food production, 2) refill the reservoir faster during the spring to provide access into spawning tributaries and fill the pool earlier to allow fish a longer growing season, and 3) delay the drawdown of the reservoir in the fall to provide a longer growing season. The latter two changes would also provide a longer recreation season for the reservoir.

PREDICTING BENEFITS TO THE RESERVOIR FISHERY

Our goal is to develop a set of reservoir operating rule curves based on habitat and food requirements for fish within the reservoir. To do this will require developing models which predict effects of reservoir operation on specific habitat types used by fish, as well as food resources used by those fish. These models will not only have to be species specific, but will also need to consider important life-stages of targeted fish species.

Review of the pertinent literature by ourselves and United States Geologic Survey cooperators has indicated three approaches are probably most suitable for our needs. One is a trophic dynamics approach where energy flows are modeled (Kitchell et al. 1974, Adams et al. 1983, Taylor et al. 1980, Chen and Orlob 1973, Ploskey and Jenkins 1982). Another approach models habitat availability and suitability for each species of interest by life-stage (McConnell et al. 1982, Aggus and Bivin 1982). Habitat suitability criteria for most game fish and several nongame fish species have been developed by the U. S. Fish and Wildlife Service, Habitat Evaluation Procedures Group, Fort Collins, Colorado (for example: Hickman and Raleigh 1982). However, little definitive data has been collected to develop habitat suitability curves for preferred reservoir habitats. The predictive capability of regression equations used in these models can vary depending upon specific habitat availability and environmental conditions (Aggus and Bivin 1982). Finally, population simulation models can be used to simulate population growth for an individual species (Serchuck et al. 1980).

Kitchell et al. (1974) stated that to produce a model for investigating the complex interactions operating on a fish population in natural conditions we must consider the total system including food availability, predation, fishing pressure, and environmental variables. They further warned that any model must include a significant portion of the important mechanisms operating to control a population or it will have little hope of simulating responses to a complex environment. It is then the duty of the modeler to determine what factors are important mechanisms influencing the population of interest and concentrate on those mechanisms. Since our goal is to recommend reservoir water level operational criteria which will benefit the fishery, we will concentrate on environmental variables influenced by water level fluctuation; however, we cannot ignore other important variables which collectively control fish production such as spawning and rearing habitat. We plan to strive for as simple a model as possible. To reach this end will require testing of variable combinations to select the best model, and then validation of the model using field data. We plan to develop the model using existing data (and models) and then fine tune the model with information collected during the first three years of the study (1983-1986) to provide information where gaps presently exist. Validation of the model will be done during the final year of the study (1986-1987).

The model we are proposing to develop will have a food component based on energy flow through successive trophic levels to fish and a habitat component based on habitat availability and habitat preferences of species by life-stage. We will rely on a model to be developed by the USGS for predicting the effects of reservoir operation on the zooplankton community and thermal structure of the reservoir. We will use their model outputs as input variables in our model to estimate effects of reservoir operation on the relative abundance of targeted fish species under various operational scenarios. We are presently investigating the feasibility of adapting models developed by Kitchell et al. (1974) and Ploskey and Jenkins (1982) as a method of partioning available food resources to meet food requirements of reservoir fish.

The habitat model will rely on data collected on habitat used by targeted fish populations in the reservoir, data collected on quantity and quality of available habitat within the reservoir, and a review of habitat preference information for target fish species. Another important component of the habitat portion of the model will be predicted thermal structure of the reservoir developed by the USGS. This habitat model will use area and volume of habitat segregated into classes based on preferences of targeted fish species by life-stage to determine relative quality and quantity of available habitat under various reservoir operational scenarios. The final product will be a single model created by linking the food availability versus use model to the habitat availability versus preference model. This linked model will use reservoir operation to describe the relative abundance of fish (by species) the reservoir could support under various schemes of operation. This model could be used to determine which life-stages were impacted, what type of reservoir operation impacts a particular species the least, and what environmental variables are most critical to fish populations.

RECOMMENDATIONS

1) Continue sampling the reservoir and its tributaries following procedures presented in the work plan with the following modifications:

   a) subcontract all physical-chemical sampling to the USGS (We should continue measuring temperature profiles and light penetration);

   b) use length-weight relationships to determine zooplankton biomass;

   c) standardize sample times for collection of surface insects to mid-afternoon;

   d) conduct a diurnal sampling program for surface insects, zooplankton and vertical fish distribution;

2) Initiate a pilot study to investigate the feasability of re-establishing several species of vegetation (willow, redosier dogwood, and sedge) in the upper portion of the drawdown zone (elevation 2,439 to 2,459).

3) Sample icthyoplankton from February through May to collect burbot fry in an attempt to establish where spawning occurs.

4) Investigate the advantages and disadvantages of sampling fish with horizontal gill nets (floaters and sinkers) seasonally using a more intensive effort, rather than monthly.

5) Electrofish shoreline zones of the reservoir during May and July in an attempt to locate juvenile salmonids.

6) Snorkel shoreline zones of the reservoir during July in an attempt to locate juvenile salmonids and to observe the use of structural cover by salmonids.

7) Investigate the feasibility of doing a movement and habitat use study of juvenile trout within the reservoir using radio telementry.

8) Conduct a creel census in 1985-86 to estimate angler harvest, collect harvested fish tags for movement and growth information and collect stomachs for food analysis from predators not sampled frequently in gill nets (bull trout and burbot).

9) Do electrophoretic analyses on a random sample of westslope cutthroat, rainbow, and cutthroat-rainbow trout hybrids to determine the amount of hybridization within this complex and the genetic origin of these fish.

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WATER CODES

Barron Creek	1-11-0200-01
Big Creek	1-11-0420-01
Bristow Creek	1-11-0640-01
Canyon Creek	1-11-0920-10
Cripple Horse Creek	1-11-1520-01
East Branch of South Fork Big Creek	1-11-1960-01
Fivemile Creek	1-11-2340-01
Grave Creek	1-11-2720-01
Pinkham Creek	1-11-5140-01
South Fork Big Creek	1-11-6220-01
Steep Creek	1-11-6520-01
Sullivan Creek	1-11-6620-01
Ten Mile Creek	1-11-6800-01
Therriault Creek	1-11-6860-01
Tobacco River	1-11-6920-01
Young Creek	1-11-7780-01
Lake Koocanusa (Libby Reservoir)	1-11-8690-05

DOE/BP — 296
September 1984